UNIVERSITY OF SOUTHAMPTON

FACULTY OF HUMANITIES

Web Science

Online Cultural Heritage: Facilitating Complex Query Making through Tangible User Interfaces

by

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ABSTRACT

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ONLINE CULTURAL HERITAGE: FACILITATING COMPLEX QUERY MAKING THROUGH TANGIBLE USER INTERFACES

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This thesis presents a novel approach to reduce the complexity and overload of information in Cultural Heritage (CH) on the Web through the use of a Tangible User Interface (TUI). It discusses how the Web and its technologies such as the Semantic Web have changed the interoperability and reach that knowledge, data and information can have. These technologies have allowed to link knowledge across CH organisations and helped to reduce uncertainty about the information used to create it. Nevertheless, it is cumbersome for a vast majority of online users to find relevant content, due to the overload of information available and the complexity of its nature. This research argues that this is because two main factors. The first factor is the dependency of Graphical User Interfaces on the Web that hinder complex exploration and technologic engagement for general users. The second factor identifies a requirement for CH organisations to become part of an Online Cultural Heritage ecosystem engaged through an interactive system on the Web. As a result, CH organisations do not have a meaningful system for their users to explore their content. This research addresses these problems by [1] developing an understanding on how CH knowledge is integrated across different organisations and different ways in which users engage and manipulate it and, [2] exploring how a TUI can facilitate the production of complex queries that enables the user to engage with the conceptual and technical information used to describe the knowledge about OCH collections.

Chapter One presents an outline of the research problem, aims and objectives. It discusses the new challenges that CH organisation face when engaging with their users on the Web.

Chapter Two presents a literature review of the current state of CH organisations, their information and knowledge and how they relate on the Web. Chapter Three argues that on the Web, CH organisations are conceptually and contextually integrated into a single entity that can be called Online Cultural Heritage (OCH). CH studies do not to consider that on the Web, visitors are no longer limited to a particular type of CH organisation (e.g. library, museum), nor to a particular collection held by that organisation. In addition, this chapter gives a brief introduction to Europeana as example of how information is shared across organisations on the Web, as it will be used as main case study later on. After describing the roles that data and information have on the production of knowledge, Chapter Three continues by presenting a literature review that highlights how users transform data into knowledge and their different needs of information when approaching information sources. It further identifies how users engage with Europeana's information and the interfaces used to do it. Therefore, Chapter Four addresses the relevance that user interfaces have on accessing information, data or knowledge on the Web and particularly OCH. It explains how TUIs can boost performance by providing the required thought structure through physical activities and the use of constructivism as theoretical approach. It introduces interaction design principles (such as Token and Constraint (TAC) and OnObject) where physical affordances are used to convey information to users, thus reducing the complexity of an interactive system.

Chapter Five presents the research framework general plan. It introduces the a-priori and a-posteriori phases of the research, where the first one focuses on understanding users' behaviours when querying Europeana and OCH, and Chapter Six will fully discuss Europeana as a case study. The research framework is fully described in Chapter 7 for the a priori section present the a-priori phase as a user centred design experiment where participants express their query behaviours. The test users included people with particular knowledge about cultural heritage objects (e.g. historians, archaeologists) analysing how they convert data into knowledge according to their different levels of need of information. The evaluated results are further used to contextualise the role of the interactive prototype to be designed. Such design process is presented in the following Chapter Eight. This chapter presents the integrated interaction design methodology adapted for the development of the TUI prototype. It presents the evaluation results for both experiments. It concentrates in Usability and UX evaluations to understand the engagement that users have with OCH information through the TUI. Such methods identify emotions and sense of helplessness related to the interactive process. It integrates a usability test to reveal users' procedural task results that highlight the strengths and weaknesses of the system, which alter users' engagement with the information.

Chapter Nine concludes by reviewing the results obtained and highlighting the challenges posed, benefits that the Web and its particular technologies offer to CH organisations, and the need for the adoption of interactive systems such as these, that eases question making processes and allow users to explore complex datasets in a meaningful way, while it also describes future work that can be carried out.

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Figures and Tables

DECLARATION OF AUTHORSHIP

I, Javier Pereda declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

ONLINE CULTURAL HERITAGE: FACILITATING COMPLEX QUERY MAKING THROUGH TANGIBLE USER INTERFACES

I confirm that:

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Chapter 1: Introduction: aims, objectives and research questions

The purpose of this research is to explore ways in which Tangible User Interfaces (TUI) can help users to produce complex queries of cultural heritage (CH) information on the Web. Despite that this research focuses primarily in CH, the research framework developed for this research can also help understanding the role of TUIs and querying in other disciplines outside of the CH sector.

Independently of how CH organisations share their knowledge on the Web, they will have to offer users a User Interface (UI) to interact with this information. The way in which people use these UIs is a central topic of this research. Although there is a wide range of interaction paradigms such as Transparent Computing, Ubiquitous Computing and The Internet of Things, the vast majority of interactions with information on the Web take place through Graphical User Interfaces (GUI). This research developed a methodological and theoretical framework that leads to the construction of tools and interfaces to expedite the access and exploration of Online Cultural Heritage (OCH) information by producing complex queries. This framework is based on the use of Tangible User Interfaces (TUI) as the main interaction paradigm.

Although the work around TUIs is still on its infancy, there is a growing body of literature that suggests that TUIs can fill many of the interaction and engagement gaps commonly produced by GUIs. GUIs produce a division or add thinking processes between the users and the task they want to perform, while TUIs offer the opportunity to engage directly with the task. Engaging with OCH information such as that contained in a digital collection of paintings made by Picasso, requires relating complex sets of concepts such as information on the creator of the content, what constitutes a painting, who Picasso was, creation dates and what organisations hold the information, amongst many others. This is a very challenging task since users have to keep all these sets of data and information in their mind. When working with GUIs, users commonly have to divert that attention into the tasks required to interact with the system. Alternatively, it has been suggested that TUIs reduce that gap allowing users to use their cognitive senses to operate the system, thus offering the opportunity to focus their attention in the task at hand instead of the interface.

Based on such aforementioned benefits, this thesis aims to explore how TUIs can facilitate the query-making process by embracing the complexity and concepts used to describe OCH collections on the Web, the goals of this research are:

1. To define what Cultural Heritage is and its role in the Web.

2. To outline the different technologies and models that Cultural Heritage organisations use to generate the OCH information networks.

3. To generate a common ground based on Ackoff's Data Information Knowledge and Wisdom (DIKW) model, regarding the definition of key concepts such as 'data' and 'information', and to understand how users implement them in order to produce 'knowledge'. This common ground is also used to comprehend the 'information life-cycle' process of the different CH organisations and how it relates to the OCH ecosystem.

4. To understand how User Interfaces (UI) are used to query the knowledge held by CH organisations.

5. To produce a research framework that incorporates Human Computer Interaction (HCI) and problem-solving methods informed by User Centred Design (UCD), looking to integrate in a holistic way the full complexity of OCH elements through queries.

6. Derived from such research framework, to create a TUI to explore how users can engage with OCH by producing complex queries that embrace the diverse conceptual elements that describe the collections.

7. To provide an understanding of the demographic profiling of OCH users, participant screening used for the experimental methodology, and the evaluation that informs the final prototype design process.

8. To provide a critical evaluation of the TUI prototype and point out the particular benefits and limitations of the use of TUIs in the querying process of OCH knowledge.

In order to delve into the full complexity that this task entails, this thesis introduce, uses and combines a variety of concepts and approaches from fields such as Cultural Heritage, Museum Studies, Human Computer Interaction, Semantic Web, Pedagogy, Human Information Interaction, Visual Communication, and Web Science. This introductory first chapter aims to explain how Online Cultural Heritage (OCH) is constructed as an ecosystem of the wide range of CH organisations such as Museums, Libraries and Archives, as well as the technologies required to make it work. As expected, many CH organisations work in different ways. ***Chapter 2*** will address these internal and external differences when sharing and providing access to their content either online or offline.

Due to the young state of the Web and digital technologies, there is still not a consensus or specific definition of the different ways in which CH organisations reach their audiences. Definitions such as online or digital museum, as well as online or digital library fail to encompass the trans-organisational and trans-conceptual reach that OCH manages to achieve. The access provided to OCH in this research, will embrace the whole range of CH organisations through a wide range of technologies such as the Semantic Web and interactive systems. To engage with this content, or with any content on the Web for that matter, people fully depend on user interfaces to access it. These interfaces can enhance or hinder the different experiences that people might look for when engaging with CH. OCH engagement takes place through the making use of the information. Moreover, the transfer of knowledge remains a central part for the majority of CH organisations, particularly the public ones. That said, educational activities are not limited to that single pedagogic experience. They can also be linked to the wide range of experiences that CH visitors want to have, such as social, entertainment and delight experiences.

User Interfaces engage with this connected information in different ways and at different levels. OCH interfaces need to convey the complexity and extent of exploring content across the different domains. This complexity, fuelled through the use of ontologies, can aid users that are exploring or querying such content to reduce the uncertainty of the results of their searches. These experiences can take place through traditional Web technologies, commonly used by CH organizations on the Web, such as websites and rendered multimedia objects on a Web browser. But there are other sets of important information, such as metadata, which are hidden behind the browser. This metadata provides an extra layer of intelligence that offers a better or deeper understanding of what is presented on the Web by describing particular relationships or describing the background of what is being presented.

Despite the aforementioned, the sets of information which are hidden behind the browser or behind the interaction tools, become an essential part of the OCH ecosystem. In order to make sense of these sets, specific concepts such as ‘data’, ‘information’, ‘knowledge’ and their difference needs to be defined and explored in detail. By connecting different sets of ‘data’ and ‘information’, users are able to engage with knowledge. On the one hand, users can engage with OCH in a wide variety of ways, such as querying directly the ‘data’ through, for instance, statistical analysis of coordinates or natural language processing to produce a categorisation of articles. On the other, users can also engage with the ‘information’ produced from the result of processing or organising such ‘data’. The engagement with OCH depends in the way users interact with the different sets of ‘data’ or ‘information’ provided. To understand these relationships, ***Chapter 3*** introduces Ackoff’s (Ackoff, 1989) DIKW model, which is used to produce a common ground of what is meant when discussing ‘data’, ‘information’ and ‘knowledge’. Many different organisations and disciplines use some of these terms interchangeably despite them having different meanings.

OCH organisations are different from what can be considered ‘*on the Web’* (online presence), *offline-digital* (e.g. intranet libraries) and ‘*four-walled’* (physical museum) versions, due to the fact that in OCH the access to both, ‘data’ and ‘information’ are essential to produce any kind of engagement with the ‘knowledge’ through a User interface. Although the majority of CH organisations offer access to ‘information’, access to ‘data’ can also lead to the production of ‘knowledge’. Ackoff’s DIKW model indicates a linear progression from data, to information, to knowledge and to wisdom. If ‘knowledge’ is to be produced, ‘data’ and ‘information’ has to be offered in a meaningful way, thus can be regarded as a ‘coupled element’, where ‘data’ and ‘information’ have to work together in order to create ‘knowledge’. But different organisations work and refer to ‘data’ or ‘information’ in different ways as it is discussed in Chapter 2. To help contextualising how users might engage with these elements, the Ackoff’s model is also used to understand and contextualise the different kind of interactions (e.g. querying) that might take place in CH organisations when working with ‘data’ and ‘information’ through the information life cycle. In addition, the DIKW model is also used to identify or classify the role that the content and the organisation providing it are playing in the OCH ecosystem. For instance, while some museums can provide data, other organisations can provide the data model to add meaning to such data.

Taking into account the central role that ‘information’ (as a coupled element) plays in OCH, it is important to understand how is it that CH organisations work with it (e.g. sharing or producing information). In this sense, there are different ISO certified models designed to work with CH organisations such as the OAIS model and standardised information processes that can be divided into three main stages: information production, sharing and engagement. Within their own organisational boundaries, CH organisations will deal with their information in a way that is meaningful for them. For example, museums might follow a different model instead of OAIS, or might decide to model their data under event-oriented ontologies such as CIDOC CRM. Moreover, libraries might decide to implement object-oriented ontologies such as Dublin Core. Europeana (which is the case study for this research), for instance, provides a method and recommendations to other organisations in terms of the information production process. In addition, Europeana can help incorporating the data through repositories and sharing the information. Finally, Europeana also provides interfaces and interaction systems designed by a community to offer access to that information and data. Within this, an Application Programing Interface (API) that facilitates the development of interactive tools to engage with the content is offered. Europeana, as the majority of OCH organisations, fit within this tripartite information lifecycle (data, information and knowledge). The decisions of how the organisation will work within the lifecycle are based on their particular needs and budgets. Therefore, the people involved in specific stages of information, will have precise needs that the interactive tools have to cover in order to add meaning to the information that is being dealt with so a specific knowledge can be obtained from it.

In this research, the term OCH was created to refer to and encompass the ecosystem of 'data' and 'information' with the capability to add 'meaning' and to produce 'knowledge', and the different relationships that these create with the CH organisations, communities and technologies. This sets a theoretical foundation and scope of what OCH encompass as a Web socio-technical system. The knowledge complexity behind OCH is made available in the form of computer languages (machine and human readable), such as XML or RDF-XML, with different CH organisations using different interactive tools to work with them. Under this premise, this research starts from the theoretical understanding that while supported by Semantic Web technologies, 'OCH knowledge', is a term where 'data', 'information' are always together and 'meaning' is conveyed through the data models in knowledge-bases.

Europeana has been chosen as a case study because it presents an example of the OCH ecosystem as defined in this research. Digitised collections are very recent and expensive to produce and to share in a homogeneous way. The vast majority of European cultural heritage is not digitised. According to Europeana (2016b), barely 10% of collections have been digitised, which in total represent around 300 million objects. However, not all these digitised objects are accessible, or even available online. The OCH ecosystem requires the embracement of new technologies, dealing with copyright and developing novel methods for the digital economy. Europeana provides the best resource to find objects in a collection, since they reference 12% of the available digitised collections. If users search for content and fail to find what they are looking for, that might hinder their experience with OCH. Europeana offers a large amount of re-usable objects with a wide variety of structured conceptual elements that ease the development of interaction tools for experimentation.

To produce 'knowledge', an interface has to provide tools for users to add 'meaning' to the 'information' or 'data'. Therefore, UIs play an essential role in such processes. Engaging with OCH knowledge through querying is a challenging task for users, due to the number of concepts and mental relationships produced by the 'data'. Constructivist approaches can help users to manage overwhelming emotions related to information overload as part of the engagement with the information process. TUIs have a constructivist nature where users can physically and visually segment specific sets of information and isolate each thinking task, thus boosting the performance through multi-sensory activities. In the case of TUIs, these can help managing such complex information, and aid users to focus on the main task at hand (i.e. understanding the information), instead of concentrating on learning or operating a UI, which commonly incurs in a mental effort that creates a division between the user and the content. With TUIs, users can focus directly on concepts, which are materialised as physical objects. The tools to engage or query CH content have different user requirements depending on what stage of the information life cycle they are required for. Therefore, this same chapter presents the different interaction tools commonly used in the CH sector and present the different interaction protocols currently used. In addition, at the end of Chapter 3, the literature review focuses on the Engagement with Information life cycle stage and discuses previous work developed for Europeana. By studying the different interaction tools, this thesis aims to provide an overview of the landscape of the common perspectives and paradigms commonly implemented in the CH sector.

Taking the above into account, ***Chapter 4*** explores how User Interfaces are designed, detailing the different principles that can help adding meaning to the information. As said, within the information lifecycle in OCH, this research focuses primarily on the engagement with information. This stage takes place when the information is given to people to produce knowledge or even more data. The engagement with information can take place in different ways, such as querying, exploration or visualisation. While exploration and visualisation are good ways of obtaining knowledge and organising information, querying can be considered one of the most powerful engagement approaches. Accessing knowledge through visualisation tools, means that the user will have to follow pre-defined pathways and methods set by the designers, especially as a first-time approach, as it happens with many users. Nevertheless, different querying or expressing that particular need of information has to take place if any meaningful information is to be retrieved from a system. Once that information is retrieved, it can be further organised and visualised or queried again.

The process of querying can be complicated, and in addition, users can produce questions in different ways. This is because people begin their queries from different knowledge levels or information needs. The differences in the need of information will set up the context of how the questions are asked, and the different behaviours and preferences that influence how queries are developed. In this process, there is an initial visceral level where the first engagement with information occurs. Alternatively, there is a formalised level of need of information where queries become more formalised and specialised. This research aims to facilitate querying by implementing the required complexity commonly attached to specialised levels to users who arrive on a visceral state through TUIs. As discussed in Chapter 3, while the learner advances further through the levels of need of information, there will be higher implications than when accessing information in a lower level such as a leisure activity, which can be classified as a visceral or conscious level. Important factors such as the need of information, digital literacy, and background can affect how users will move across the DIKW model aided by an interactive system. These factors will help in setting a foundation of general user behaviours that can range from navigators to explorers, depending on how structured their searches for information on the Web. Most importantly, there are levels of technical and conceptual complexities in OCH, that hinders how general users engage with knowledge. The TUI prototype designed in this research aimed to reduce such steep learning curves commonly attached to querying databases (or knowledge-bases) or searching on the Web. In addition, the benefits of TUIs become more evident when constructivist-learning processes associated to this type of interface, motivates users to explore, reducing negative behaviours such as fear or information overload.

The research framework and design methodology of such prototype is set in ***Chapter 5***, where all the pedagogic and HCI principles explored in previous chapters come together, building a methodological framework for the construction of the TUI. This framework consists of a combination of different methodologies including visual and HCI design, User

Centred Design, and an evaluation based on the TUI performance and the engagement and user experience.

The first step in building this framework took place before the interaction design process (A-Priori), and it's presented in Chapter 7. This process was carried out to identify users' behaviours and needs, which provided an understanding of what their specific requirements from possible tools. These tools have to offer users the opportunity to engage in the DIKW model process and transfer between the different states of need of information (data/information/knowledge). Chapter 3 discusses the different behaviours that people might follow when interacting with information in the engagement stage. To place these behaviours into context, it was necessary to define the specific groups for evaluation. Based on a survey ran by the European Commission (European Commission, 2013), it was noted that the vast majority of OCH users are commonly going to start their explorations form a visceral state, where they do not have enough information to produce an informed query. They commonly search for articles (53%), information about events (44%) and listening to music (42%). User Centred Design (UCD) helps in the identification of those behaviours when using a particular tool and their specific need of information.

Integrating UCD in the design methodology can help obtaining the users' input before the final prototype evaluation takes place, which helps in the identification of their requirements. Interaction design methodologies in HCI and SA&D focus on the tool and usually exclude the input of end users and other human factors (such as information needs) until the final prototype is designed. The interaction design methodology (A-Posteriori) is presented in Chapter 8. By combining the a-priori and a-posteriori sections of the research framework aimed to provide firstly, an understanding of how the organisations use and manipulate knowledge with their tools (such as CMS, ontologies, etc., Chapters 2 and 3); and secondly, how users are currently engaging with this content and to define the current problem in OCH, which is the lack of engagement from general users. In addition to that, Visual Design methodologies were used looking to solve this problem of engagement, instead of solely focusing on the performance of a tool. Interaction design principles such as natural mapping and the communication of the affordances of the tool were aided by Visual Design methodologies, such as Prototyping or Articulation which was used to provide a faceted system that integrated the different affordances throughout the TUI. After exploring different interactive systems developed in Europeana hackathons, it can be said that these tools do not aim to solve a problem, but to produce high performance tools for Europeana.

This is a common issue in HCI; human factors (again, such as the different information needs) are commonly neglected or placed in a lower level than that of the usability and performance evaluations of a system. This is also reflected in the development methodologies commonly used in the HCI community. Nevertheless, it is important to mention that this kind of hackathons are usually created to invite people to produce tools and/or designs for a specific approach, such as the use of Europeana's API. The interaction design methodology (A-Posteriori) in this research, looks to address these issues by extending the SA&D/HCI methodology with a problem solving procedural method created by Munari (2004) (Munari, 2004). Through this method, the interaction design process starts with and understanding provided by the a-priori phase of the research framework, which informs the interaction design method what is required for users to engage with OCH, instead of how information can be used within a particular technology.

The benefit of blending the methodologies proposed in this research, is that technologic applications as well as human factors are addressed in the problem-solving process. Although HCI methods already consider some human factors, there is no regard of the tools as part of the human experiences, since traditional HCI methods work based on metaphors (as in GUIs). That being said, to facilitate the engagement with OCH knowledge, designers have to consider all inputs of human experiences, such as embodied cognition, and not just the ones based on software. The TUI literature review in Chapter 4 identifies how different UIs work and the design principles to be implemented under a TUI context. Therefore, this research implements a HCI/TUI, as well as a Graphical Design/TUI methodology, where the integration of both includes the production of real world and UI objects. Once the TUI and interface tools are built, they can then be evaluated as an object, tool and system. These tools were constructed taking into account a prior UCD experiment. Users express their agencies and needs through this experiment that is further evaluated and provides the foundation for the design of the object tools and the interactive system. In a later stage, an evaluation takes place where the full capabilities of a design prototype are tested. To evaluate the original question of how can users produce complex queries in OCH, this research also includes User Experience (UX) to measure and define Engagement through the experiences and affective responses of the users. In addition, Usability testing informs the performance of the tool and places in context the instrumental evaluation.

Chapter 6 introduces Europeana as the case study and describe the way in which the diverse data and information sets are organised to produce knowledge and the way in which they can be explored and queried. To implement the a-priori process in the case study (Chapter 7), it was required to understand what particular sets of data and information were available, and how they could be facilitated to users in a meaningful way. These exercises are commonly carried out through 'think aloud' exercises where, for instance building a query, users may say the specific action that they are performing in that moment, meanwhile the observer makes annotations of such actions. There are many real-world factors such as physical space, presence, and motor skills that are not reflected in GUI observation methods. The UX/UCD experiment in the a-priori phase, implemented stickers in the exercise that depicted possible tools and interactions that users could implement while building a query. This way, in a similar way as a TUI, they can offload the mental process involved when constructing a query to the particular item and shuffle it if necessary (until fixed to the paper). In addition, following this TUI-UCD participatory approach, while constructing the query in this way, the user builds a visual trail or 'roadmaps' of the actions and terms used to build that query, that can be traced back when needed. The sticker-tools are a reflection of the different data fields and operators that can be implemented through Europeana's API. Participants provided information on what specific tools from that API were the most meaningful for them, thus providing information for the analysis phase before the design of the final prototype takes place.

Based on European and Europeana's demographics there is a higher chance that the majority of end users will approach the OCH from a visceral or conscious level. Although the interaction design process (a-posteriori) did not consider a particular digital age group as a target, this research considered the inclusion of a wide range of digital generations that might engage with the system. The UX/UCD experiment that took place before the interaction design of the prototype included participants from the CH sector (such as archaeologists and historians). This type of participant informed the design process in the experiment as basic users, since the vast majority do not work with Semantic Web, nor perform complex queries on the Web. Nevertheless, they do have the conceptual understanding of the different CH organisations that build OCH. The participants from the CH sector were selected because they are likely to be more acquainted than non-CH participants, with the different queries that could be performed under Europeana's' API. As a result, the final prototype includes the behavioural and conceptual processes depicted by the CH participants that helped them to produce meaning from querying. The UX/UCD evaluation of the a-priori phase, informs how different queries and data elements can be transformed into tools. Therefore, the final prototype implements the different interactive design principles (covered in Chapter 4), a TUI querying system and pedagogic design, accomplishing an easy use while integrating the complexity that comes with querying multiple concepts and linking them together.

Chapter 7 provides a short presentation of the final prototype, while ***Chapter 8*** provides a detailed description of the design evaluation of the prototype, the frameworks used, and the results obtained. Finally, ***Chapter 9*** offers a conclusion and a reflection regarding future work and possible implementations.

The interactive prototype presented users with the opportunity to query OCH information from Europeana's collections, and it allowed them to explore and query OCH content beyond a single organisation. In terms of evaluating the TUI, it was observed and recorded that users learned quickly how to use the system and were able to produce complex queries through it. This was possible due to the fact that the system eliminated the technologic complexity, and enabled the users to work directly with the OCH concepts instead of having to focus on the technology required to query it. Although there is certainly a novelty effect commonly attached to TUIs, the system still managed to motivate users to explore further. Moreover, it also invited them to test different results by modifying some of the terms of their queries, testing the different parameters of the query facets or components. All users showed excitement regarding the opportunity to retrieve content from across CH organisations in this way. Most importantly, it was confirmed that they were motivated and interested in the possibility of producing complex queries through a UI. It was also observed based on the responses from the participants and the observations, that users strongly praised the simplicity of the system, while acknowledging the complexity behind the information reached behind. The final prototype was tested with both CH and non-CH participants. There were no meaningful differences in the usability and experience results when working with the interface. CH and non-CH participants differed in the way they conceptualised particular elements of the ontology, such as defining fictional characters as if they were real people.

Although in this case the TUI was designed using off the shelf computer equipment and keeping costs low to promote its adoption, designers have to consider that this is a fundamental difference with GUIs. While GUIs are constrained to a computer monitor or screen display and commonly depend on the mouse and keyboard, they can be found in the majority of homes with a personal computer. In contrast, TUIs commonly require some level of construction or set-up. This can be mitigated by adopting a solution as the one presented in this research, where all the materials are easy to access.

In terms of the technologies used, the TUI was built following W3C recommendations such as standard HTML, CSS and JavaScript languages. This had as a goal the desire to produce tools that can be adopted and extended. In the case of the TUI created in this research, it also has the convenience that once the system has been set up, with technologies such as the use of visual markers, the prototype allows other people that do not work with HCI or TUIs to produce paper based tools and test their hypotheses and experiment with them. It is acknowledged that some general users might be reluctant to engage in DIY activities. However, there are growing communities that are more than willing to do so.

The final evaluations of the system were considerably positive with 100% task completion rates and fast first-time learning curves. However, there are still areas in which more research and work has to be done, such as implementing searches by colour or image size. In addition, there are other protocols such as IIIF, which are used to manipulate high-resolution images. This could enhance the different experiences and levels of querying complexity that can be achieved when interacting with the TUI prototype.

There has been a large investment in the CH sector to enhance their digital collections, and OCH datasets are becoming larger, richer and more meaningful. Nevertheless, although the Web and Semantic Web technologies have dramatically increased the quality of the knowledge online and particularly in OCH, it can be argued that general users have not yet been fully benefited from it. Regardless, of whatever context, on the Web, all users must engage with it through a user interface. This research presents how interfaces, and particularly TUIs can help users to produce complex queries that helps them to engage with complex sets of information. In addition, this research presents an understanding of how users might engage an attempt to make sense of data models in OCH such as Europeana's.

The results of this research show that TUIs can ease the elaboration of complex and more meaningful queries in OCH collections which are described in the data models. Furthermore, using TUIs for exploring data enables users to engage and focus directly on the data. By removing technological factors such as the use of complex query languages and technical factors such as the understanding of the diverse properties of a data model, users can become more open and willing to explore, and experiment on their own. The interface enabled users to work with OCH content, and produce complex queries, thus producing relationships among diverse concepts logical elements through Europeana collections.

1.1 Why we need a new way to study and understand cultural heritage and the Web

Cultural Heritage organisations follow their own particular management strategies. On one hand museum management is very different to the management of libraries or archives. On the other the way visitors behave in these organisations is different as well. Furthermore, different CH organisations will organise their information in different ways thus changing the approach in which visitors ask and navigate it in search for knowledge. Web technologies allow for these organisations to integrate and assimilate their data in a single space. This presents a new challenge that has not seen before. CH visitors have now the opportunity to query information from a wide range of CH organisations in a single key press. For this reason, it is important for CH groups to understand how their visitors might engage with the content they are providing.

1.1.1 Challenges in the Engagement of Information

The way in which visitors approach particular CH organisations will depend on the frequency they have visited that particular place. It will also depend on the reason of why they have the need to access it. These needs are essential when studying user engagement and usability due to the fact that users that are looking for information for a university exam will have a higher level of stress to the ones looking for Mediterranean cook books. These different information needs provide the context where activities (information seeking) will take place. In the case of this research, the information space is the Web. Therefore, it is important to consider that the Web as an information access point, the different levels of information needs from the wide range of CH organisations will be combined. From a traditional perspective, an art gallery or museum never had to worry about users getting stressed for not finding information about a particular topic due to the fact that these places are commonly perceived for engagement and enjoyment, as opposed to a library predominantly perceived as an information seeking place. Nevertheless, engagement and enjoyment as well as the ease to find information can enhance learning experiences. Therefore, on a first layer of engagement, on the Web, CH organisations have the challenge of integrating their different information methodologies as well as the tools to allow visitors to engage with them in their different levels of information need. On a second layer, CH relies on providing a pedagogic service to their visitors. On the Web, these pedagogic elements might cross management and administrative boundaries commonly set by their offline counterparts. This is to say that museums will have to take into consideration the way in which libraries communicate knowledge as well as archives and galleries. On the Web CH visitors navigate from an independent space such as their homes or a ubiquitous mobile phone in the attempt to gain knowledge.

1.1.2 Building the Theory Behind Online Cultural Heritage (OCH)

Museums have as one of their main objectives to communicate and educate their communities which are the ones commonly funding them. This is the case of many public museums and libraries. Their incursion on the Web has been slow and there is still much research to be carried out to improve Web experience. Among many challenges one of the main issues has been the technological disruption that the Web has produced in many industries including the CH sector. Therefore, it is important to understand these unique changes to allow an interdisciplinary understanding of the challenges that CH is facing. For this reason, this research has indicated two main tracks of how CH is established on the Web. The first track refers to [1] Cultural Heritage on the Web where its organisations use the Web generally as a media communication channel. This includes the use of social media, marketing, video and other Web technologies to communicate their current events and activities that do not necessarily relate or are essential to pedagogic objectives. The second track concentrates on the pedagogic and educational aspect of CH. This research refers to it as [2] the Online Cultural Heritage. This is the space where any CH organisation uses technology on the Web to produce the engagement with their content. It is important to mention that both tracks do not necessarily need to be separate from each other. Both tracks are used to enhance visitor engagement and experience from the Web to the physical location and vice versa.

1.1.3 New Problems and Complexity of Information and its User Interfaces

Online Cultural Heritage (OCH) as a central topic of this research aims for a pedagogic engagement with CH content through a wide variety of Web and digital technologies such as multimedia, data modelling and the Semantic Web that have arguably enhanced the quality of the information that describes CH collections. This research discusses the pathway that information will follow under the CH and OCH scope thus describing current issues with the engagement with information. It can be suggested that all digital content has to be accessed through a user interface. Nevertheless, not all user interfaces are suitable to engage with OCH content due to its complexity and extent. This generates not only interactive and usability issues but also engagement issues. This research proposes the use of Tangible User Interfaces as the pathway to engage with such content by producing more meaningful queries. Although there is still very little evidence on distribution issues of TUIs and their use on the Web, there is research that suggests that they can ease mental tasks when interacting with the computer thus allowing users to focus on the activity instead of focusing their attention on the interface tools.

1.2 Research Questions

Once the foundation of OCH is set, this research argues that there is a lack of engagement tools to interact with their content, such as systems that enable the productions queries that embrace the complexity behind OCH (Semantic Web). One of the most common ways for users to explore this information is by querying. Nevertheless, querying OCH knowledge and information requires a combination of both technical and conceptual elements of engagement. This is an issue not limited to the CH sector but it is arguably an issue that can be adopted across different Information technology industries. This thesis argues that this is an issue with User Interaction (UI). The Web is predominantly based on Graphical User Interfaces (GUI), where depictions of tools are presented to users thus expecting users to learn their affordances merely by visual means. This issue relates to tables and haptic devices where arguably, interaction is neither meaningful nor natural for users. TUIs embrace natural human behaviour to communicate tool affordances to users. This raises the questions of: [1] how can TUIs facilitate the production of complex queries in OCH content? [2] Is it also possible to assist users in the process of question making? [3] What are the implications of the different states of need of information whilst interacting with OCH TUIs?

1.3 Looking for solutions: Exploring and Managing Information with Interfaces

Many CH organisations are looking for ways to engage with their audiences thus providing user empowerment opportunities in pedagogic activities. Based on the relevance that educational activities have on the CH sector, and the way interactions happen on the Web, the CH sector encourages such empowerment through constructivist activities that allow users to become independent learners outside of the physical boundaries that commonly limit CH organisations. The OCH channels these opportunities into a single environment on the Web. This environment is the interface where users ask questions to the vast defined knowledge provided by the wide range of CH organisations. Nevertheless, the vast majority of such interfaces on the Web are based on GUI platforms, thus overlooking many of the benefits that TUIs offer to learning and engagement with information. There is a wide range of interactive systems in the CH sector designed to input, manage and engage with the information. This thesis argues that since these interfaces are predominantly based on GUI paradigms, there are still many novel technologies that can facilitate the engagement with OCH knowledge, particularly on the Web. Large sets of OCH information are currently structured and made publicly available, thus integrating collections from across the CH sector. Despite this, it seems that general users are not fully embracing these benefits, since they have to query this information by typing complex syntax queries or through cumbersome GUI interactive systems.

1.3.1 Europeana as Case Study: Reducing Complexity to Facilitate Information Exploration Through TUIs

There are many CH organisations sharing their data online. Most of them have structured their information under a data model that can be machine readable (XML/RDF) as well as human readable. This way, computers can know what is being described and assist humans to analyse the information. There are many organisations using these data models such as The British Museum, The British Library and many other CH organisations across the world. Moreover, there are organisations gathering the data from those organisations and further integrate the information. Europeana is an organisation that acts as a portal for a wide range of CH organisations. The reason of choosing this particular organisation is due to its cross-domain reach. Europeana gathers data from over 600 organisations across Europe including galleries, libraries and archives. Exploring concepts under this portal should allow users to develop complex questions that place them in an international and interdisciplinary environment. Prior research indicates that when working under a single CH organisation such as a museum, visitors will bound themselves to a question making process limited by the organisation itself. Using Europeana as a case study allows expanding conceptual boundaries thus allowing a wider grasp of OCH complexity.

Europeana has already made a substantial investment trying to understand how users might engage with their content and query their information. They have encouraged appropriation and re-usage of their content through hackathons, research and collaborative hubs. Nevertheless, the interface as a centric point for information engagement or access needs to be studied beyond its usage as a simple tool. To date it is difficult to find evidence of Web based TUIs, even more so in CH or OCH. The vast majority of Europeana's interfaces have been based on GUIs. Arguably, there is a key contribution to be made in the area where TUIs can not only help users to grasp information complexity but facilitate engagement and improve usability performance for Web based interactive systems that can empower users. OCH is only a small space in the Web universe, nevertheless it promotes engagement and independent learning that can act as examples for other industries and organisations outside cultural heritage.

There is a wide range of standards for the CH sector based on the use of computer based access and manipulation of records. Standards such as the Open Archival Information System (OAIS), were also designed to preserve the information of diverse communities in the CH sector. This includes the preservation of digital documentation, such as storing the files in a CD ROM or hard drive, as well as providing a knowledgebase of terms which the communities that deal with such digital documentation can understand it and use it (Lakshmi and Jindal, 2004:143). Such efforts in the integration of knowledge have expanded the role that the diverse computer based technologies play in the documentation process and preservation of CH organisation. The Archive & Records Association (2016) and Riley (2010), produced a comprehensive list of how these metadata standards are used in the CH sector. These metadata standards were classified as Archival Metadata Structure (e.g. ISDF, ISDIAH), Metadata Structure Standards (e.g. Dublin Core ISO 15836, Spectrum) and Metadata Content Standards (e.g. RDA, DCMI, MARC 21), among many others. In addition, Interoperability Protocols such as The Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) from the Open Archives Initiative (OAI) where data is harvested from different providers so other organisations can use it.

Based on the role that interoperability protocols among others, play in the integration of documentation of libraries and archives, along with other CH organisations, it needs to be considered that libraries are not just in the role of acquiring and preserving texts. They are institutions that collect graphic and audio documents as well. This creates a very close relationship with museums. Many of them share the same information. For example, some illustrations by Leonardo Da Vinci are allocated in the *Servicio de Dibujos y Estampas* of Spain's National Library as well as in *Museo Nacional del Prado.* Both institutions show very similar items and describe them in a very similar way; but what keeps them separate is the way and format used to catalogue such objects. Those relationships become more evident when digital libraries are placed on the Web. Libraries are adopting and developing technologies to enhance their *information quality*. Starting from early technology adoptions such as the microfilm, new electronic resources in libraries have become more dependants on these types technology. As a result, their field is quickly accommodating a broad new range of terms that encompass electronic and/or digital descriptions of their resources (Diez, 2013:57). For instance, 'Digital collections', 'repositories' and 'open archives' are now very common terms when libraries and the Web are involved and present the main point of access to knowledge.

1.3.2 Accessing information on the Web: Online Libraries (OL)

On the Web, libraries present theses, books, and monographs among a wide variety of documents that are meant to meet specific visitor requirements. In order to meet such requirements, information quality problems need to be solved. Information quality factors can be organised as information as a product or information as a process. On one hand information as a product identifies factors such as overload and ambiguity. Information needs to be refined to remove an overload through prioritization and hierarchical structuration. Ambiguity is addressed by adding glossaries and richer communication media. Factors such as incompleteness, inconsistency or inadequate formats also affects information as a product. Moreover, information as a process identifies factors such as reliability, access and distortion (Lesca et al., 2010:Section: 4.1). Under OCH scope, OLs have to be particularly aware of these factors. Online visitors will engage with information provided by diverse organisations and individuals that will affect the understanding of what a particular thing is and how its described. It is through the use of data models and ontologies that such distortion can be ameliorated. That is why it has been argued that libraries have been shifting from "information as a product to information as a process" (Zeitlyn et al., 1999:12). This is to say that libraries are focusing not only on how the information is delivered but also in the process of how people learn. Arguably, one of the main differences of accessing a library on the Web is that the exploratory process to find information is more dynamic and immediate. For instance, hypertext allows documents to be virtually infinite, offering access to primary, secondary and tertiary sources. Beside text, visitors can also explore digital images, videos and 3D graphics among others. For this reason, libraries are focusing on providing the environments through which visitors can explore and browse their collections.

As the Web changes, so are the services provided by libraries. Web 1.0 provided a channel only to obtain information and consume it; it was unidirectional. When the evolved to the Web or Web 2.0, libraries realised the importance of taking into account the information of their users and communities. Libraries started incorporating information such as comments, ratings and most importantly, gave users the opportunity to *tag* content and add value to the content (Diez, 2013:67). It was then that users were capable of creating their profiles and personalising their catalogues for the first time. As part of the services provided by what can be referred as Libraries 2.0, a library on the Social Web (Web 2.0) bibliographic services were linked with social technologies allowing users to build communities around their tags or research interests such as Refworks or Mendeley. Furthermore, with Web 2.0, users can annotate, comment and highlight digital content. In this change, what made the difference was that libraries started to re-utilise social information. All the information such as tags that were produced by users, were becoming increasingly important. For example, folksonomies were created by terms produced by a user community. In this manner, there are a wide variety of technologic changes that has promoted a transformation in the querying process of library users. Many CH organisations are now using Semantic Web technologies to enhance the communication between their content and the users. Through Semantic Web approaches, libraries can take advantage of natural language to produce better results, reasoning and especially, link them to other institutions.

Technology has changed how visitors interact with museums, libraries and archives. It has also changed the skills required to work in those institutions. But it has to be considered that these institutions are in the knowledge industry. Museums are primarily concerned with material culture and libraries with texts and other media. However, once their object of study is digitised, it breaks the *four-walls* that binds the institution that holds it, allowing collaboration between other organisations, even outside their line of study. As previously mentioned, museums and libraries are no longer separate when it comes to information. There is now a thin line that differentiates museums and libraries invisible to the end user. Even though different CH organisations approach the Web in different ways and for different purposes, it can be said that many Web technologies have offered the opportunity to unify and homogenize their information on the Web. When performing questions about CH objects on the Web, the answers users receive can be provided by a wide variety of institutions and even other users. Users are still capable of selecting information specifically from a desired institution, if the information is provided. Users learn about the artefact that is physically hosted in a *four-walled* institution through its digital depiction that is linked to information from different groups and organisations. When those searches are performed, the institution that provides the information is also invisible to the end user. What the end user sees then, is the final result, the information that he or she is looking for. For this reason, restricting the perception of CH just to the online museum or online library might prove counterintuitive when performing searches about CH on the Web.

1.4 Conclusion

Technology has changed how visitors engage with CH organisations. This engagement takes place in diverse ways in the different CH organisations. While museums are primarily concerned with material culture and libraries with text and other media, some of their content is similar and is just managed in a different way. Once any given object becomes digital, it is no longer bounded by the particular paradigm of the organisation that holds it. On the Web, end users do not commonly make distinctions between the different CH organisations when they search for information. As a result, the differences between the different CH organisations become less visible. There are still many different standards and information procedures that the specific organisations will follow, but for the end user this is not visible. The end user will engage with a post-processed and curated set of information provided by a wide range of organisations and individuals. This is the reason why on this research the term Online Cultural Heritage was produced.

The engagement with the digital collections on the Web will take place through an interface that offers the interactive tools to engage with the information that describes them (e.g. query systems, SPARQL endpoints). This information is no longer bounded by a specific organisation, thus opening new questions of how is it that users engage with museum content from a library perspective. The generation of Web 2.0 opened the opportunity for people who do not necessarily work inside the CH sector, to provide information about the collections as well. This has challenged the hierarchical structure of CH organisations and has virtually become normal on the Web. The technologic and information management tools adopted these social information inputs in the way of folksonomies, among others. In OCH information about re-use, such as copyright, user generated content attaches extra knowledge that enhances the description of what is being presented.

Content held by museums is no longer restricted by the internal rules of that organisation. The same can be said about the other CH organisations. For this reason, it is necessary to identify the information reach of the current CH technologies. When users search on the Web, queries can be produced across a wide range of domains and particular perspectives of information management could hinder users' engagement with the information. To engage with OCH knowledge, users have to be offered the opportunity to query cross-domains and in their own terms.

Chapter 2: Understanding Cultural Heritage and the Web

Online Cultural Heritage (OCH) and how its defined departs from the way in which Cultural Heritage (CH) organisations work on the Web. CH organisations work in particular ways and have their own particular workflows such as the OAIS reference model, which are used in CH organisations to standardise the processes, and technologies in which these organisations revolve around the information they work with. This chapter presents the current state of how CH organisations work with their information and the technologies and common practices used.

Traditionally, many of the CH organisations differ in the way in which their internal policies or in the internal processes that take place when they manage the information about their collections. Although there are attempts to standardise these workflows and reference models, as expected, there are still many conceptual differences between the different CH organisations, for example libraries and museums. This has also created specific requirements for their members and communities. For example, the way in which collections are described will differ between a library and a museum, even when they both describe the same object (such as a painting or a book). Many of the technologies used to catalogue the CH information, will carry many of the paradigms embedded within those organisations. For example, the different data models and ontologies used such as Dublin Core or CIDOC CRM, will describe a specific record from a different perspective. Dublin Core will describe it starting from the object itself, while CIDOC CRM tend to start from an event where a specific object took part. This is further discussed in Chapter 3. Although, common visitors or users will not engage directly through the specific paradigms behind each data model or ontological perspective behind each type of CH organisation, there are still specific behaviours and experiences that visitors seek when visiting a particular museum, library or CH organisation. Many CH organisations will have shared experiences that are commonly pursued by visitors, such as entertainment or aesthetic activities in an exhibition. But there are particular experiences that occur differently such as learning or pedagogic experiences (e.g. looking for academic texts in a library, or searching for the documentation of a specific collection artefact in a museum). On the Web, the vast majority of users do not make the distinction between the different CH organisations. Many CH organisations are losing audience numbers on the Web because they fail to integrate themselves to the OCH ecosystem.

This chapter has the main objective of presenting the current state of how CH organisations work and the particular interactive tools on which they depend. In addition, it also introduces how CH organisations and their audiences merge on the Web, generating a new space where users try to carry a set of usual experiences and behaviours from one CH organisation to another. This is to say that, in the Web, the user will not make the distinction between, for instance, information that comes from a library or a museum. Finally, this chapter explains common technologies and paradigms that lay out a general consensus of the tools used in different CH organisations.

2.1 Defining Cultural Heritage, Institutions and Their Information

UNESCO among other institutions has an active role in preserving cultural heritage, dividing it into two main areas: Tangible and Intangible Cultural Heritage (ICCROM et al., 2013). Concurrently, in the attempt of protecting and managing cultural heritage, it has been divided into three main types: [1] Built Environment, [2] Natural Environment and [3] Artefacts (Grattan, 2006).

Figure 1. The Heritage Sector as defined by Grattan (2006)

As a result, several disciplines and organisations have been created and put in charge of managing those areas of cultural heritage. For example, buildings, man-made landmarks and cities are considered part of Built Environment and are currently studied by disciplines such as Archaeology, Architecture and Urban Planning among others. Natural Environment includes national parks and natural objects, commonly studied by Geologists, Biologists and Natural Preservation specialists. Finally, artefacts such as books, crafts and archaeological artefacts fall into the areas of Archaeology, Design, Librarians and Museums among many others.

What these groups, disciplines and areas have in common is that they intersect in Cultural Heritage. These groups and institutions have been interested in the answers that can such tangible and intangible heritage can offer to their research. Furthermore, they are also interested on how they can communicate such knowledge to society. In this process institutions have catalogued, documented and produced research around heritage. Later on, with the use of computers, that information started to become digital. The attempt to preserve the documented heritage for posterity also promoted the digitisation of many tangible and intangible heritage things. Those datasets were commonly aimed for the same organisations and not for general public. Even today, many of the information contained in these organisations is not meant to be used by general audiences. For example, museums will acquire artefacts and produce knowledge about such artefacts, but they usually show a small percentage of that knowledge and artefacts (curation) to the public (Grattan, 2006:10). Nowadays, digitally documented heritage can and is shared on the Web and a wider number of groups and individuals can access use it. As a result, there has been a wide set of technologies that attempt to facilitate the digital engagement with those datasets. But engagement with information through interactive systems is still not yet completely understood. By understanding how users interact with information and particularly OCH information through interactive systems, it can explain CH organisations how to integrate and deliver their knowledge in ways that are meaningful to their users and communities.

There is extensive work on how information can be distributed and accessed by users through interactive systems. Such is the case of content management systems (CMS) and conceptual reference models (CRM) that provide access to OCH data in a linked data format (Orr, 2003, Doyle, 2003, de Boer et al., 2012, Diez, 2013:139, Isaac, 2013). When information has been stored in an information system, it is still necessary to allow users to perform questions in it. For this, there are querying languages such as SQL, SPARQL, Gellish English and XQuery among others (Allemang and Hendler, 2011). Nevertheless, these languages require specialised skills and knowledge about the content in the information system. The existing approaches to solve this problem have been through the use of interactive querying systems that do not require such technical skills. These systems have commonly followed approaches largely through [1] graphical user interfaces (GUI) and recently through [2] tangible user interfaces (TUI). The work with GUIs has successfully developed querying systems that can explore linked data of different organisations including CH. Nevertheless, the arguments against GUIs is that they are usually complicated and difficult to use and disconnected from natural human environments depicting the tool and environment that people are meant to work with (Ishii and Ullmer, 1997, Ullmer and Ishii, 2000). By contrast, many TUIs have been proven to be beneficial for learning an exploring knowledge by exploiting sensory-motor and bodily patterns (Piaget and Cook, 1952, Anderson, 2003, Zaman et al., 2012). In the same way, TUIs present the opportunity to ameliorate interaction complexity (Bakker et al., 2012, Ishii and Ullmer, 1997). For this reason, TUIs have successfully proven to be intuitive and easy to use and show a lot of potential to ease interaction engagement with OCH knowledge. Nevertheless, they have not yet been tested with linked data especially on the Web and much less with CH. Most importantly, TUIs present the opportunity to enrich and ease interaction by implementing the same skills that people have learnt by interacting with the real world (Ishii and Ullmer, 1997). There are still hybrid interaction methods such as Augmented Reality (AR) that merge physical reality by projecting digital information on to physical objects, or spaces where the whole interactive environment is replaced completely as in the case of Virtual Reality (VR). Nevertheless, it can be said that such interaction paradigms despite having a level of connectivity to real human environments, they still require an interface in between that communicates the affordances of how to interact with the objects or manipulate the data (e.g. VR viewer, AR phone/camera). That being said, the way in which TUIs and physical objects communicate their affordances and the way in which they promote embodied cognition, has also dragged the attention of the AR community, thus producing a merge of AR and TUIs called Tangible AR (Zhou et al., 2008, Lee et al., 2004a). Although it has been acknowledged that AR can help extending the physical properties of the TUIs (McPherson and Radkowski, 2016), AR manipulation (and VR) still remains on a digital level, lacking the positive effect behind direct manipulation and embodied cognition. Finally, TUIs can promote social interaction, where many users can see and interact at the same time, whicle GUIs, AR and VR can only be used by a single user who hold the interface viewer or peripheral (e.g mouse).

It is under this premise that it can be argued that TUIs can produce a more approachable environment for many levels of users to engage with OCH knowledge. Based on these advantages offered by TUIs, this research aims to explore through their use [1] how OCH knowledge can be queried without a specialist perspective, aided by embodied interaction, [2] how TUIs systems can be used to provide a more accessible interaction paradigm to different OCH knowledge and areas to a wide audience, and [3] how the process of how these audiences produce the conceptual relationship between the physical objects and the information to be queried. However, before describing how this can be done, it is important to identify the different leading groups and organisations that produce, share and use this knowledge. In addition to that, it is also crucial to understand the process through which knowledge is produced, shared and used. This will be covered in Chapter 2. There are a wide variety of institutions and organisations that encompass and embrace cultural heritage such as libraries, museums and archives among others. Many of them have fully adopted the

Web and its technologies, while others are still in the process of becoming digital and/or online entities. However, it can be argued that although these organisations and institutions can be perceived as independent, when they become integrated in a single information space on the Web, they can shorten their differences, becoming unified as a single entity. Europeana is a good illustration where queries can be performed across a wide range of CH organisations and the results are unified in a single space. Moreover, when users perform Web searches in spaces such as Wikipedia or Google, users look for a particular set of information regardless of who owns the information or the particular artefact. For this reason, is important to distinguish first how different CH institutions and organisations produce, share and use knowledge so can they be integrated in a (tangible) querying system.

2.2 Museums

2.2.1 Definition of the Museum

Museums are spaces where objects and their information is stored and presented to various audiences. The American Museum Association defines a museum as “either a public or private organisation” –which- “owns, protects and uses tangible objects and exhibits them during certain time periods” (Kotler and Kotler, 2001:32). In the case of the UK, they are also expected to hold collections and empower people to get inspiration and learn (Trevelyan, 2008). Visitors commonly attend these places to see the artefacts presented, thus receiving information related to such objects. Such information is transformed into a learning experience. This is one of the reasons why museums exist: to disseminate knowledge, as well as to preserve it. Museums play a very important role in the cultural development of the community. For instance, several governments have identified the importance that museums play in the development of culture in their population, and therefore defining museums as research and education spaces (España, 2004) and in other cases, identified the relevance that museums play in the development of culture and national identity of their population (México, 1988), thus making them spaces of education. Public museums around the world have been in charge of educating generations through their collections. In the case of private museums, although they are independently regulated and their priority objectives might be different, they acknowledge the potential of pedagogic content in their exhibitions as well.

2.2.2 Museum Information and Complexity

Museums disseminate and preserve knowledge through material culture and present it to visitors through exhibitions. They have a responsibility towards the communities of whom they hold the objects thus playing an important role in their cultural development (ICOM, 2013, Trevelyan, 2008). Museums are also in charge of storing and cataloguing information related to the artefacts. That information has now become an intrinsic part of the museums. Many times, information about artefacts can be as important as the artefact itself. If a museum does not have any information about the meaning, status or significance about an object, they will not be able to present it to an audience, since it will become impossible to communicate anything truthful about it (Lord and Dexter, 2010: 89). Within the museum context, objects are commonly attached to information sets that help visitors contextualise and understand what is it that they are looking at. Dealing with information that describes collections' artefacts is a very complex task. As a result, a whole industry sector was developed around information management. In the case of museums, they created departments in charge of information management. For example, the UK and many European countries, curators have commonly carried out documentation tasks. Now, this job has become so complex that museums created registry managing posts to manage the information provided by the curators (Lord and Dexter, 2010: 89). This highlights the complexity of information and the relevance that it has to the CH community. Although there is a general perception that museums are storehouses of objects, they have also become powerhouses of information as well (Orna and Pettitt, 1998: 33) and have a responsibility to distribute such information (Orna and Pettitt, 1998, Lord and Dexter, 2010, Jones-Garmil, 1997).

2.2.3 Technology in the Museum

Several technologies have been implemented to ease the information management tasks in the museum sector, such is the case of databases, digital reproductions (3D, photo, etc.) and information retrieval systems that have extended the capabilities of how information is used and managed. Vast sets of information are now being stored in digital form (e.g. discs, hard drives, servers). From a holistic perspective, museum collections are becoming digital libraries of information catalogued in the same manner as the original objects. In the same way that digital libraries show digital information originally contained in a physical book, the digital information media held by the museum represents or depicts the original physical collection's artefact. With the creation of the Web and ubiquitous technology, museums can now share information, not only with specialists, but also with any person in the world. This is why museums can be identified as powerhouses of information; this means that museums became the source or a well-respected group that provides the information to a community. Therefore, digital information on the Web as well as in the *four-walled* museum can become more important than the object described.

Museums and Online Museums (OM) distribute information with different complexity levels depending on its use and end user. In the four-walled museum, the artefact acts as a trigger for visitors to engage with information and visitors can obtain information by engaging with it. The artefact becomes a channel were visitors can gather information from. In OMs there is no artefact to trigger that engagement. The engagement is produced through digital information. This is due to the fact that on the Web, users are not able to access the physical object but digital depictions (e.g. images, 3D models) as digital information. On the Web, visitors have to navigate through information to access OM objects. Arguably, this is then when visitors can gain knowledge or a desired experience in OCH. An example of this is when a visitor attempts to find information about any object on the Web. They would start by typing a 'search keyword' on a search engine (e.g. Google, Yahoo). This will return a list of websites that may contain information about such object/s. The primary stage is merely interacting with the information retrieved from different data sources online (e.g. Google, Wikipedia search). Users will then find information about that object and they may or may not compare different websites to see which one might contain more information; and ideally these websites will include visual representations of the object. It is at this second stage that the online visitor will link the previous information with the visual representation(s) of the object. When visitors combine all the digital information presented about the object, they can gain new knowledge and share it.

2.2.4 Accessing Information on the Web: Online Museums (OM)

Current research propounds the view of the OM as an extension or as an experience that is always linked to the *four-walled* museum. Liu (2009) inquired the role of OMs as the counterpart of the museum. Barton's (2005) research about the integration of museums and libraries on the Web took a perspective where the OMs replicates the museum's objects, collections and displays to reach new audiences. Schweibenz (1998) in one of the earliest papers that define OMs and Virtual Museums, indicated that museums could use the internet as a communication tool to connect online users to a "real museum experience". Many of these definitions have been produced based on a particular understanding of the technology and social behaviours around the CH sector and the Web. Nevertheless, interaction and information technologies have changed, thus calling for new definitions and approaches into how CH is understood when placed on the Web. For example, it can be argued that the OM has to be studied separately. This is because many times, the information presented may not be related to the traditional museum or organization. This is to say that the OM is not necessarily linked to a *four-walled* museum; it is the space on the Web where a user can access CH information. For example, the British Museum can openly share a database of any given collection. This database will contain information and perhaps images or digital reproductions of such objects within the database content. Anywhere in the world, people can access it and produce exploratory systems where any visitor can query the information within it. These interactive systems can work through a website, web app, mobile app, or even electronic components with Internet access. The designed application can be developed as standalone, completely unlinked to the British Museum identity, which provided the information in the first place. Moreover, users might not have any interest to visit the British Museum after all. It is merely the engagement with the object or information through its many digital forms that they want to engage with. The foregoing discussion implies that OMs operates under a different paradigm thus requires to be studied considering it as a standalone museum system. The OM has been regarded as an additional tool that might extend the experience of a particular exhibit or museum visit. Previous research has studied whether online content should be presented before or after a particular exhibit, presenting digital information to potential visitors of the *four-walled* museum (Franciolli et al., 2010). But as mentioned before, there is little literature that considers these activities to be completely unlinked to the museum or the CH organisation that holds the objects and their information. On logical grounds, there is no compelling reason to argue that the OM has the advantage and capability of being scalable in terms, not only of experience and information, but also of accessibility. In addition, OM information is not limited to a single institution, organisation or source. OMs have the potential to include many sources of information related to a single topic or object and become a source for the

OCH ecosystem. They can share and consume information from other OMs and organisations in OCH. Nevertheless, it is important to understand how many traditional aspects of the *four-walled* museum are present in OMs and OCH when developing theoretical and methodological frameworks of how users/visitors might engage with OM/OCH information.

2.3 Libraries and Archives

2.3.1 Library Information and Complexity

Libraries have the purpose of acquiring, preserving and exhibit books and documents and to provide the space for those books and documents to be read (Diez, 2013:35). When libraries organise their collections, they produce extra sets of information (e.g. categories, collections). Such information is dealt and managed by archivists and/or documentarists. Libraries hold primarily texts in the form of books. Nevertheless, there are other sets of information that are produced as part of administrative and managerial processes that commonly are not shared to general users. This kind of information sets and the processes in which they are used are commonly carried out internally and can become part of the archives; this is the case of the cataloguing process. Libraries among other CH organisations offer the opportunity for a wide range of online and offline social activity that might take part internally or externally within the organisation. It has been described that libraries are spaces where visitors will gather around the documents as well as the social aspect (Vårheim, 2007). It has also been stated that visitors might gather based on the information they collect and consume (Fisher et al., 1979). This becomes more evident when discussing social tagging, folksonomies and specialty driven research groups. The information created in these processes can be deemed valuable. Nevertheless, it can be argued that is difficult to identify the value on the different sets of information. For example, internal library groups such as administrative and managerial groups can be created around information that can benefit their particular group or area of work. Marketing departments in libraries have the need to identify their market environments. This includes defining if what is being distributed is a service or a product, understanding the main distribution technologies, information trends, demographics and even usability among others. Obtaining these sets of information were not devised to enhance the library as a learning space but to enhance profitability in the organisation. Nevertheless, library practitioners should not disregard that some of this information might prove beneficial for learning or that it might contain relevant information for other group searching for knowledge. For example, information trends are relevant for marketing and pedagogic aspects as well. Visitors searching for business information depend on the timeliness and reliability due to the fact the this type of information is more valuable when is current and up-to-the-minute (Diamond and Oppenheim, 2005). Identifying different sets of information for different functions is a very extensive and complex task. Most of these information sets and processes are not easily identified, such as specialist user requirements. These are born from the result of external un-established processes such as research and/or creativity. Nevertheless, this information is produced and introduced into new information cycles and activities by documentarists (Diez, 2013:37). Regardless of how or where this extra information is produced and used, it is important to note that there is a requirement beyond just cataloguing books in a space. Nevertheless, this information and knowledge complexity can be mitigated with Semantic Web frameworks that provide the opportunity to integrate them across communities and enterprises and has to be considered when working with OCH. That is the reason why there are so many information specialist jobs in library organisations; especially with scientific publications where the specialty is not only in reference to archival or documentarists processes, but about the specialty of the topic (Diez, 2013:38) or area.

2.3.2 Library Technology

With the amount of information that has been produced by librarians, archivists and documentarists, libraries are trying to make their information more accessible. Moreover, digital scanning of books has promoted libraries to be expanded on a digital environment, thus accelerating the growth of digital collections. As a result, owning digital collections opened a wide variety of services and promoted collaboration with other institutions. Many of the new documents are created digitally. When discussing digital documents, there can be a distinct difference between documents that are ***born digital*** and the documents that are ***digitized***, that as previously mentioned are created by producing electronic reproductions of the original object. In this sense, there have been many technologies that have re-shaped how libraries manage their collections. It was during the 1960s when the term automated library was used (Diez, 2013). During this time, only large libraries such as

Washington's Library of Congress and some major university libraries were able to purchase computers, which were commonly placed in the computer labs (Diez, 2013). By the 1980s UNESCO started distributing an information system called CDS/ISIS, based on the Integrated Set of Information Systems (ISIS) and releasing its first commercial package by 1986 (Diez, 2013). Information technologies became deeply linked with libraries and archive systems. Furthermore, the electronic library was created where technologies were used with the aim to unify working criteria and standardise their services. As a result, there were standards created such as the International Standard Bibliographic Description (Galeffi, 2014) and Machine Readable Cataloguing System (Library of Congress, 2014a), focused on sharing and distributing catalogues more efficiently and allowed collective catalogues to be created. In the attempt to ease the process to input data into the computer when producing a catalogue, studies in the early 1960s were carried out to produce prints from catalogues in machine-readable form. These studies were proposed as a proposed format for a standardised machine-readable catalogue in 1965. This standardisation project was later on called the Machine-Readable Cataloguing project or MARC, which collected 50,000 records by 1968. MARC managed to integrate data from maps, books and serials into one single format. MARC was later called LC MARC until it became an ISO international standard with the name of USMARC (Wedgeworth, 1993:541). USMARC is currently called MARC 21.

There is a wide range of standards for the CH sector based on the use of computer based access and manipulation of records. Standards such as the Open Archival Information System (OAIS), were also designed to preserve the information of diverse communities in the CH sector. This includes the preservation of digital documentation, such as storing the files in a CD ROM or hard drive, as well as providing a knowledgebase of terms which the communities that deal with such digital documentation can understand it and use it (Lakshmi and Jindal, 2004:143). Such efforts in the integration of knowledge have expanded the role that the diverse computer based technologies play in the documentation process and preservation of CH organisation. The Archive & Records Association (2016) and Riley (2010), produced a comprehensive list of how these metadata standards are used in the CH sector. These metadata standards were classified as Archival Metadata Structure (e.g. ISDF, ISDIAH), Metadata Structure Standards (e.g. Dublin Core ISO 15836, Spectrum) and Metadata Content Standards (e.g. RDA, DCMI, MARC 21), among many others. In addition, Interoperability Protocols such as The Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) from the Open Archives Initiative (OAI) where data is harvested from different providers so other organisations can use it.

Based on the role that interoperability protocols among others, play in the integration of documentation of libraries and archives, along with other CH organisations, it needs to be considered that libraries are not just in the role of acquiring and preserving texts. They are institutions that collect graphic and audio documents as well. This creates a very close relationship with museums. Many of them share the same information. For example, some illustrations by Leonardo Da Vinci are allocated in the *Servicio de Dibujos y Estampas* of Spain's National Library as well as in *Museo Nacional del Prado.* Both institutions show very similar items and describe them in a very similar way; but what keeps them separate is the way and format used to catalogue such objects. Those relationships become more evident when digital libraries are placed on the Web. Libraries are adopting and developing technologies to enhance their *information quality*. Starting from early technology adoptions such as the microfilm, new electronic resources in libraries have become more dependants on these types technology. As a result, their field is quickly accommodating a broad new range of terms that encompass electronic and/or digital descriptions of their resources (Diez, 2013:57). For instance, 'Digital collections', 'repositories' and 'open archives' are now very common terms when libraries and the Web are involved and present the main point of access to knowledge.

2.3.3 Accessing information on the Web: Online Libraries (OL)

On the Web, libraries present theses, books, and monographs among a wide variety of documents that are meant to meet specific visitor requirements. In order to meet such requirements, information quality problems need to be solved. Information quality factors can be organised as information as a product or information as a process. On one hand information as a product identifies factors such as overload and ambiguity. Information needs to be refined to remove an overload through prioritization and hierarchical structuration. Ambiguity is addressed by adding glossaries and richer communication media. Factors such as incompleteness, inconsistency or inadequate formats also affects information as a product. Moreover, information as a process identifies factors such as reliability, access and distortion (Lesca et al., 2010:Section: 4.1). Under OCH scope, OLs have to be particularly aware of these factors. Online visitors will engage with information provided by diverse organisations and individuals that will affect the understanding of what a particular thing is and how its described. It is through the use of data models and ontologies that such distortion can be ameliorated. That is why it has been argued that libraries have been shifting from “information as a product to information as a process” (Zeitlyn et al., 1999:12). This is to say that libraries are focusing not only on how the information is delivered but also in the process of how people learn. Arguably, one of the main differences of accessing a library on the Web is that the exploratory process to find information is more dynamic and immediate. For instance, hypertext allows documents to be virtually infinite, offering access to primary, secondary and tertiary sources. Beside text, visitors can also explore digital images, videos and 3D graphics among others. For this reason, libraries are focusing on providing the environments through which visitors can explore and browse their collections.

As the Web changes, so are the services provided by libraries. Web 1.0 provided a channel only to obtain information and consume it; it was unidirectional. When the evolved to the Web or Web 2.0, libraries realised the importance of taking into account the information of their users and communities. Libraries started incorporating information such as comments, ratings and most importantly, gave users the opportunity to *tag* content and add value to the content (Diez, 2013:67). It was then that users were capable of creating their profiles and personalising their catalogues for the first time. As part of the services provided by what can be referred as Libraries 2.0, a library on the Social Web (Web 2.0) bibliographic services were linked with social technologies allowing users to build communities around their tags or research interests such as Refworks or Mendeley. Furthermore, with Web 2.0, users can annotate, comment and highlight digital content. In this change, what made the difference was that libraries started to re-utilise social information. All the information such as tags that were produced by users, were becoming increasingly important. For example, folksonomies were created by terms produced by a user community. In this manner, there are a wide variety of technologic changes that has promoted a transformation in the querying process of library users. Many CH organisations are now using Semantic Web technologies to enhance the communication between their content and the users. Through Semantic Web approaches, libraries can take advantage of natural language to produce better results, reasoning and especially, link them to other institutions.

Technology has changed how visitors engage with museums, libraries and archives. It has also changed the skills required to work in those institutions. But it has to be considered that these institutions are in the knowledge industry. Museums are primarily concerned with material culture and libraries with texts and other media. However, once their object of study is digitised, it breaks the *four-walls* that binds the institution that holds it, allowing collaboration between other organisations, even outside their line of study. As previously mentioned, museums and libraries are no longer separate when it comes to information. There is now a thin line that differentiates museums and libraries invisible to the end user. Even though different CH organisations approach the Web in different ways and for different purposes, it can be said that many Web technologies have offered the opportunity to unify and homogenize their information on the Web. When performing questions about CH objects on the Web, the answers users receive can be provided by a wide variety of institutions and even other users. Users are still capable of selecting information specifically from a desired institution, if the information is provided. Users learn about the artefact that is physically hosted in a *four-walled* institution through its digital depiction that is linked to information from different groups and organisations. When those searches are performed, the institution that provides the information is also invisible to the end user. What the end user sees then, is the final result, the information that he or she is looking for. For this reason, restricting the perception of CH just to the online museum or online library might prove counterintuitive when performing searches about CH on the Web.

2.4 Conclusion

Technology has changed how visitors engage with CH organisations. This engagement takes place in diverse ways in the different CH organisations. While museums are primarily concerned with material culture and libraries with text and other media, some of their content is similar and is just managed in a different way. Once any given object becomes digital, it is no longer bounded by the particular paradigm of the organisation that holds it. On the Web, end users do not commonly make distinctions between the different CH organisations when they search for information. As a result, the differences between the different CH organisations become less visible. There are still many different standards and information procedures that the specific organisations will follow, but for the end user this is not visible. The end user will engage with a post-processed and curated set of information provided by a wide range of organisations and individuals. This is the reason why on this research the term Online Cultural Heritage was produced.

The engagement with the digital collections on the Web will take place through an interface that offers the interactive tools to engage with the information that describes them. This information is no longer bounded by a specific organisation, thus opening new questions of how is it that users engage with museum content from a library perspective. The generation of Web 2.0 opened the opportunity for people who do not necessarily work inside the CH sector, to provide information about the collections as well. This has challenged the hierarchical structure of CH organisations and has virtually become normal on the Web. The technologic and information management tools adopted these social information inputs in the way of folksonomies, among others. In OCH information about re-use, such as copyright, user generated content attaches extra knowledge that enhances the description of what is being presented.

Chapter 3: Understanding Online Cultural Heritage

The previous chapter aimed to produce a general understanding of the content that is commonly expected from CH organisations such as museums and libraries. Producing digital versions of their collections undergoes through curatorial and digitisation processes where information is attached to describe them. Each organisation specialises in a particular range of objects and collections. For example, museums and artefacts, galleries and paintings and libraries and texts. As a result, such specialisation has created a level of standardisation and patterns in the way information about collections is managed and processed. Such patterns and processes affect the kind of information that is presented to their audiences.

On the Web, CH organisations have commonly delivered this content through websites. This delivery of information has usually been delivered in a linear fashion. Users have been presented with information, that in many cases just replicated the content from exhibits and from a single organisation, which commonly were the ones who held the original object. Nowadays, the Web enables users to gather information from across the diverse CH sector. To explore information on the Web, users must engage with a user interface (UI) to gather any kind of information. UIs are an intrinsic part of the information access on the Web, because they can enhance on hinder completely how users access, and explore information on the Web.

CH organisations play an essential role in providing information to the OCH ecosystem through the use of Semantic Web technologies. Semantic Web technologies allow CH organisations to produce and use information across domains, reduce its uncertainty and enhance its quality. Moreover, this information is now accessible and readable by both, computers and humans. CH organisations embed many of their field specialisations through ontologies and data models that structure the information. It is this way, that CH organisations facilitate the re-use and access to the information that describes their collections. For example, Europeana provides access to the information through an API that facilitates the development of UIs to interact with such content. Europeana as a transnational and trans-domain organisation will gather information from across Europe and diverse CH organisations and provide enable a conceptual framework through the Europeana Data Model (EDM). On one hand, the EDM provides the structure elements such as data fields, concepts and domains. On the other, specific sets of data such as catalogue numbers, collections, authors and materials will be incorporated and contextualised to describe the collections.

It is still unclear how users might engage with a homogenised source of OCH information commonly tied to specific domain paradigms. This research looks into how users can produce queries that make use of conceptual elements (e.g. data model – dc:Creator), as well as information and data about specific collections (e.g. authors - Picasso, dates - medieval), in a way that conveys users' mental complexity. There are also different levels of complexity when user engage with a data model, and the information attached to it. It is important to understand if users are to engage with data or information or both when they try to produce a query. Due to the interdisciplinary nature of this research, this chapter will address the differences primarily between data and information, to produce the 'theory expansion' that clarifies their roles in OCH, and their use within an interactive system.

This chapter will finish by presenting how TUIs can be used to query and explore information. It will analyse a series of TUIs designed to query and explore sets of information and in some cases, data, and discuss how these interactive systems can benefit users aiming to query OCH. It will also analyse different interfaces developed through Europeana's hackathons. Many of the interfaces developed in these hackathons provide examples of how Europeana's API can be implemented with Web technologies. This research aims to facilitate such empowerment by querying through a TUI that embraces such Web technologies. Nevertheless, it is important to understand what elements of the repository are users meant to be engaging with: data, information or both.

3.1 From Cultural Heritage to Online Cultural Heritage

Museums and libraries use the Web to link their information with other organisations and to expand their knowledge. They also use the Web to enhance marketing and commercial strategies. This can produce the impression that just having a Web presence implies that the organisation also carries out their role as CH organisation. CH organisations in the OCH ecosystem have to contribute to the knowledge. If the organisation does not provide information that enables online visitors to extract, explore or query, they are taking a passive role of being just 'on the Web'. From this concept, two main definitions can be derived: ***CH organisations on the Web*** (e.g. museum/library on the Web), which do not contribute to the knowledge in OCH and ***Web/Online CH organisation*** (e.g. online library/museum), which becomes an active actor within the OCH ecosystem by providing re-usable information or even data. This research focuses on OCH organisations, that many times fall outside of the CH sector (e.g. universities, design agencies, media) and their roles with the information in OCH.

This section will focus on highlighting the role of OCH organisations and the different ways that their users can relate or interact with the information. For example, OCH users can query information through playful activities, serendipitous discovery or formal queries related to their professional research work. Traditionally, these activities commonly took place by engaging directly with the artefact, object or the original source of information (e.g. book). The engagement with the physical object also communicated information (e.g. smells, textures) that might not be registered on a catalogue or database. Nevertheless, CH organisations are looking for ways to communicate such tangible knowledge through digital means (e.g. AR, RTI). These previous examples, present a small sample of what can be considered information that can be relevant for users. The OCH ecosystem that enables the transfer of cross-domain information to a wide range of users from diverse disciplines.

This chapter will produce the theoretical expansion of what is meant by information and data, in an interdisciplinary context. This will help understanding how deep in the data model or repository users can engage. This is followed by a section that discusses the different stages of how users relate to this information: production, sharing and engagement. This research focuses primarily on engagement (with information), where such engagement if facilitated through a querying system. This section will also discuss different behaviours when querying and information seeking. Finally, the chapter presents an analysis of different interactive systems used to query OCH, and TUIs used to query and explore information.

3.2 Reshaping the OCH Technology to Engage with Information

To understand how technology is used to work with information in the CH sector, it is necessary to clarify who and how is using that information. On one hand, museums generate content to self-manage their collections such as databases, where the use is commonly internal. On the other hand, they produce content for a wide variety of audiences such as general public and researchers. In the case of libraries, they organise and classify knowledge based on specific visitor/user needs. Libraries classify their information (e.g. author, year, topic) so books can be easily found in a building or in a catalogue. Nevertheless, Fandino (2008) and Kelly (2008), argued that classification on its own does not completely fulfil users' needs due to its limited scope. Librarians require to further organise classified information to enhance the quality of information retrieval. These examples show that there are different kinds of information that can be presented in different ways and with diverse levels of specialty. Alternatively, museums and libraries can also share information about specific social events or a list of opening times. Although that information can be relevant to the museum or library, it might not be relevant to interact with a collection and much less to obtain knowledge about it. Therefore, it is important to define what set of information and in what form needs to be provided to the user/visitor so they can gain new knowledge.

In the context of making sense of the information, there might be different levels of information (or data) that might fall outside the scope of what users or organisations might need. For example, libraries have defined metadata typologies that include descriptive, administrative, structural and even preservation data, such as the Machine Readable Cataloguing (MARC), or Dublin Core (DCMI) (Diez, 2013:101, Jones et al., 2006:87, Morales del Castillo, 2011:30). These metadata structures and schemas are not limited just to libraries. Other organisations are also using and creating their own schemas, such as SPECTRUM and CDWA in the case of museums and ISAD, ISAAR and EAD for archives. The metadata enables them to standardise and reduce uncertainty about the information and data used to describe their collections, as well as describing organisations and administrative areas, which can be useful for internal use but not necessarily for general users. That being said, the producers of information need to be aware of the different ways that information can be used. Museums need to review the information they require to perform a particular task and the department can be in charge of it. For instance, the marketing department might not be the most appropriate group to provide information for the development of Geographic Information Systems content of archaeological data. In this case, it archaeologists can be the best option to obtain such information. Orna et al. (1998:69) defined the process to obtain adequate information to perform a specific task by different areas in the museum:

1. Identify what information the museum holds.
2. Identify who needs what information, and what of that information is not currently held by the museum.
3. Identify projects designed to enable easy access to the required information.

Since different groups in the museum structure will require different types of information, it is necessary to produce a common ground in regard of what information is valuable, for the museum as an organisation, and for each individual group. What might seem valuable for one department might not seem important for another.

To present an understanding of the landscape of how Orna's information workflow can fit within a traditional museum structure, it can be arranged based on their function as presented by Lord et al. (2010): [1] Administrative, [2] Assets and [3] Activities. In addition, libraries are also organised based on how they deal with their information. Although this is not an exhaustive list, it can be said that libraries have a similar structure to museums: [1] and administrative body, [2] a department that focuses on technical aspect of documents (Technical Services) and [3] a department that specialises on the use of the objects or the information (Consultation) (Fagan and Keach, 2009:11, Khan, 1996). Despite that many CH organisations have these very well defines organisational structures, on the Web, these structures are less evident. On the Web, accessing information about an artefact, is commonly structured and defined by Ontologies, data models and several metadata elements that lay out the pathway for visitors to find specific topics (Barton, 2005). The organisational difference between museums and libraries seems to rely on the way they structure the information (metadata). In OCH, information is unified in a single space, veiling organisational paradigms set up by institutions and organisations. CH groups and Universities are among others the primary members of the OCH network that help how this information can relate to other sectors. It is therefore, important for them how is the information they work with related to those other members of the Web as part of the OCH ecosystem.

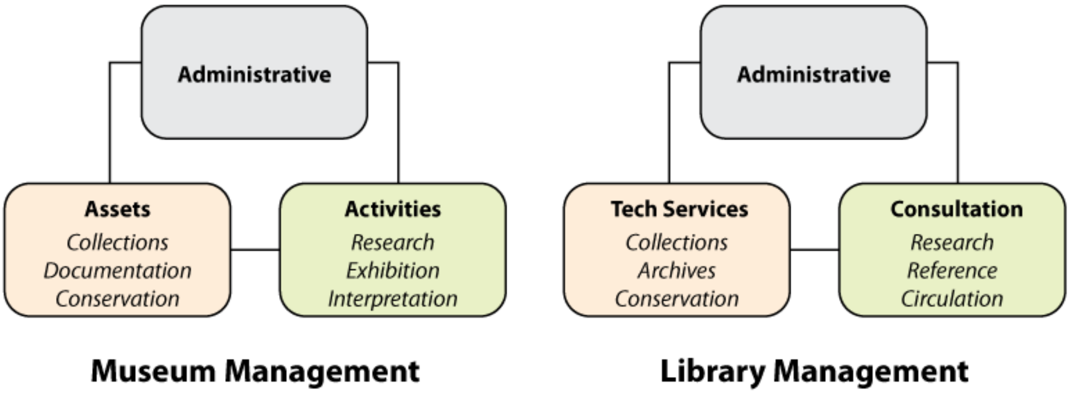


Figure 2. Traditional structure of museums (Lord and Dexter, 2010:40) and libraries management.

Due to the fact that on the Web many of the information can be re-used or repurposed for other activities, can complicate the process of identifying how a particular group or museum-sector can use it. For example, a marketing study that identifies a specific target group of visitors can be valuable to the Administrative department, and it might provide also valuable information to the Activities department because it could identify specific user groups for their interactive content. Moreover, the Assets department can also use this information to enhance the usability of their management information system used to document their artefacts. These prior examples, will require a particular set of technologies (e.g. databases, CMS) and techniques (e.g. taxonomy, nomenclature) to work with such information. In many cases, the people and organisations involved with such tasks will have to share information between them. For this, they require to produce a *theoretical common ground*, an agreed understanding of different terminologies and jargon. For this, terms can be agreed within a specific context or departmental function, thus helping to integrate concepts. This is known as 'Theory Expansion'. Alternatively, through 'Theory Extension', information can be just extended by adding extra definitions or descriptions to a concept (Repko, 2012:286). It will allow further understanding of a particular thing but will not integrate its understanding to alternative views, disciplines or groups.

The following section will present a foundation of OCH concepts taking a *theoretical expansion* method to produce a *common ground.* This has the purpose of providing the theoretical background into how information can be used within the OCH context. Terms such as data or information visualisation, meta-data, and data become blurred when introducing other disciplines such as Computer Science or Design within the CH sector. This following section will also aim to clarify such disparity of definitions, thus produce a new understanding and guideline of how different actors relate to information in the OCH ecosystem.

3.3 Producing a Common Ground: Defining the Key Concepts Related to Information in OCH

Museums and libraries share a direct connection with culture, due to the fact that they are 'keepers' of material culture, the knowledge associated with it, and they have the role of institutions for cultural access and research (Grattan, 2006:5). Museums and libraries are expected to produce research and share knowledge with the community that collectively funds them. They are also expected to encourage people to explore and learn through their collections, and therefore is necessary for them to communicate knowledge efficiently with their audiences (Grattan, 2006, Trevelyan, 2008). The information contained in the museums, libraries and their online versions might extend from physical collections to anecdotal recollections and social conversations produced by the community and researchers. This section will provide an understanding of the role of CH organisations as providers of information, under the premise that they are organisations for learning. That said, due to the fact that museums and libraries and other CH organisations are educational institutions, their role in the OCH ecosystem should not be any different. It was previously discussed that there are different motivations and expectations that visitors have when they approach CH organisations. Nevertheless, gaining new knowledge is still one of the main reasons why users navigate through OCH (or visit CH orgs.). For this reason, to understand how this ***knowledge*** can be obtained, it is necessary to identify what ***information*** is and how it needs to be given to the audience, and in which ***data***-form. Finally, it was previously discussed that knowledge producers such as museums and libraries need to be aware of how their information is going to be used. This research will not attempt to give an extended analysis of the epistemology or etymology of these concepts, but rather to provide the *theoretical common ground* to contextualise such terms in an interdisciplinary environment.

3.3.1 The Data, Information, Knowledge and Wisdom Model: Knowledge Construction

This thesis has emphasised that one of the main roles of museums and libraries and other CH organisations is to disseminate **knowledge**. For example, when museums attempt to make a connection between their collections and their visitors, this connection is commonly carried out through the data and information that museums have about that particular artefact in the collection. Such data and information contains the knowledge about that particular thing. Moreover, some specific types of libraries, such as academic libraries, will focus primarily on performing as learning spaces and as knowledge centres (but actually referred as information centres) (Closet-Crane, 2011:9). This can be seen as an indicator of how important knowledge is for CH and why it needs to be studied. Therefore, it might prove beneficial to understand what **knowledge** is and how is constructed. From a general perspective based the following definitions, it can be said that:

a) **Wisdom** is the skills or knowledge obtained through a specific time or period. (OED, 2013). Commonly refers to a particular set of knowledge from a specific body or time.

b) **Knowledge** is a set of facts, information or skills obtained by interacting with the world, a practical or theoretical understanding of a subject (OED, 2013).

c) **Information** is a set or collection of data (facts) about a specific thing (OED, 2013). Sharing information is accomplished through a communication process. This communication process involves the transformation of data into information and how it is presented and or organised so other human beings (and even computers) can make sense or interpretations of it (Koohang et al., 2008:53).

d) **Data** is derived from the Latin word datum, which stands for something that is conceded as a basis of an inference or a piece of information (OED, 2013). Data are unprocessed representations of reality (Koohang et al., 2008:51). Moreover, data is factual and commonly used for performing tasks that might be limited to the affordances of its data system (interpretation).

Ackoff (1989) produced the Data-Information-Knowledge-Wisdom (DIKW) model to define such terms (Figure 3). This model suggests that the DIKW elements are structured as a sequence with hierarchical levels. Nevertheless, Ackoff certainly indicated a direct relationship between these terms; one has to feed each other in order for them to evolve to the further level. In addition, it has been argued the relationship between the items in the DIKW occurs through a communication process (Nürnberger and Wenzel, 2011) that might be affected by noise and data quality. This noise or lack of data quality could be produced by ignoring how information is going to be used and why. There are three main issue levels that can affect the effectiveness of communication or transition between the DIKW elements: technical, semantic and influential (Nürnberger and Wenzel, 2011). In addition, according to Ackoff, by understanding the particular element that is being engaged with, the person is able to transition through the DIKW model. This is to say, that it is by making the **data meaningful**, enables the transition to **information**, and further on to **knowledge** and **wisdom**. This perspective has been challenged since it has been claimed that in order to transition a practical application ('a productive use'), followed by an analytic phase of the use of information ('know how') (Kakabadse et al., 2003). Under this perspective, there is a process of realisation and action/reflection that takes place between **information** and **wisdom**, which is currently not present in Ackoff's model.

In this thesis, the DIKW will be used to understand how people can query diverse sets of data and information that construct OCH knowledge (bases). In addition, it can help as a guideline to create the necessary common ground and clarify how people might interact with the diverse elements of the DIKW model in the diverse activities carried out by diverse members of the CH sector.

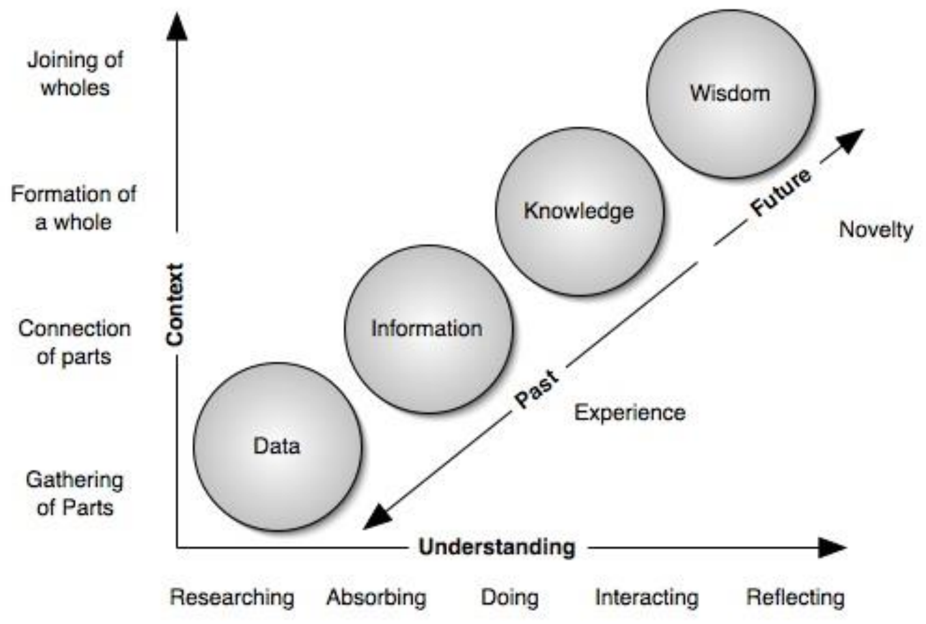


Figure 3. Ackoff's DIKW Model

These are Ackoff’s interpretations (Ackoff, 1989):

1. **Data** has no further meaning. Its contents need to be contextualised. It simply exists and has no meaning beyond its existence.

An Excel spread sheet contains numbers, annotations and/or measurements, which represent some data, which without any context is useless. In the case of museums, nomenclatures and ‘specialist’ jargon might also fall into this category. If such data is presented without context, references or background, it might be meaningless to an audience. In OCH, data is the minimum part of a metadata object. For example, dcCreator as a Dublin Core metadata element describes an entity or person who is responsible for producing or creating the resource in a database. But standing by itself it cannot be expected for visitors to know what that term means or represents.

2. **Information** is produced once **meaning** is given to the **data**, thus giving context to it. It is meant to answer essential questions such as who, what, when and where.

Once **data** is contextualised, the user can begin to make sense (add **meaning**) to what the **data** means. This way that **information** is built up by usable **data**. In the case of OCH, many technologies help providing such meaning or context to the **data** used to describe a collection. For example, dcCreator, when provided in context with an ontology or RDF Triple, it contains an URI (Uniform Resource Identifier); a unique identifier on the Web that defines what that thing is. For example, dcCreator has the URI http://purl.org/dc/elements/1.1/creator where it can be defined what the object is. Once, the element has been identified, it can be linked to values, and attributes. For example dcCreator:Pablo Picasso provides two different **data** elements that when coupled (or tripled, in the case of RDF) together contextualizes the **data** to the user (or the computer), thus transforming it into **information**.

3. **Knowledge** is **information** collected and connected in order to become useful. By nature, **knowledge** is deterministic since it is meant to solve the "how?" of a specific topic or situation.

Computers can support the process of producing **knowledge** by linking and adding meaning to sets of **information**, as well as providing the tools to engage with large sets of **knowledge** (e.g. data visualisation tools). User Interfaces (UI) play an essential role in OCH since the large sets of **knowledge** held behind the collections is currently structured behind ontologies and data models that link large sets of triples of **information** that help contextualising the **data**. Concepts such as **knowledge** bases, refer to the inferencing process of relating two or more concepts together (Hackley, 1999), which the foundation of RDF Triples.

In the case of OCH, the **information** and **data** used to describe the collections is extensive, thus users rely on these UIs to make sense and negotiate through the diverse **information** sets to obtain the **knowledge** they are looking for. This is precisely where TUIs excel as UIs. TUIs can help users make sense of complex sets of information. This can prove extremely beneficial to produce complex negotiations (e.g. query, navigate) on the **information**. For example, dcCreator:Pablo Picasso can provide **information** to generate or engage with the **knowledge**. The user is able to identify: [1] a producer/creator of a particular object, [2] the name of the particular author and [3] the joint of the two **data/information** elements together that enables the user to **understand** what is being described.

4. **Wisdom** becomes then the transformation of **knowledge** into something that is able to be used within a context or for a particular purpose.

It has been mentioned all across the DIKW definitions, the role of **meaning** to enable the transition between them. **Wisdom** requires a mental understanding, which could be said it only refers to humans. It is possible to save OCH **knowledge** through diverse **information** and **data**-sets, but it is unlikely that computers will enable the storage and distribution of **wisdom**. What OCH offers, is an ecosystem of **knowledge** by enabling the sense-making process of **information**, and by definition **data.** Computers and humans alike can produce the reasoning of the **information** and **data** used to describe collections, and store and distribute that **knowledge** on the Web (knowledge bases).

Based on Ackoff's definitions, the OCH ecosystem can enable access to a **knowledge** repository that contains **information** that describes the collections through diverse **data**-sets. In this scenario, the **data** is always coupled with more **data** to produce **information** as in the case of data models and Ontologies (RDF Triples). Organisations in the OCH ecosystem have the capability to provide access to the ***knowledge**-base* (as in database), of structured data. Nevertheless, users will have to engage directly with the **information** and the **data** and until they make sense of it, they will merge it into **knowledge** (See Figure 4). This process takes place in a similar way when knowledge graphs and knowledge bases are produced. The computer will make sense through a reasoning process and produce the set of **knowledge**. Alternatively, users can also make also be aided by the computer to produce such reasoning as well. Users can produce query syntaxes that implement such **data** elements and provide an **information** query retrieval that will aim to solve a question of a particular **knowledge** gap. In addition, it is possible to access only **data** or **information** if required, and produce more **information**.

It is under this premise that the use of **data** and **information** in OCH technology can help providing understanding of its provenance and sustainability, thus enabling the production of more useful **knowledge** which users can generate **wisdom**. OCH offers the opportunity to interconnect with other museums, libraries and institutions. Ontology systems offer the interoperability and cross-reference for the information provided about a specific object or dataset. The analysis of how **data, knowledge** and **information** are used with the technology on different contexts in the CH organisations also enable understanding different sustaining and disruptive technologies that affect the current OCH sector and CH organisations. One of the main objectives of this research is to facilitate the engagement with **data** and **information** held in the OCH ecosystem. By providing engaging experiences with that **data** and **information**, the visitor should be in a better learning position thus gaining **knowledge**.

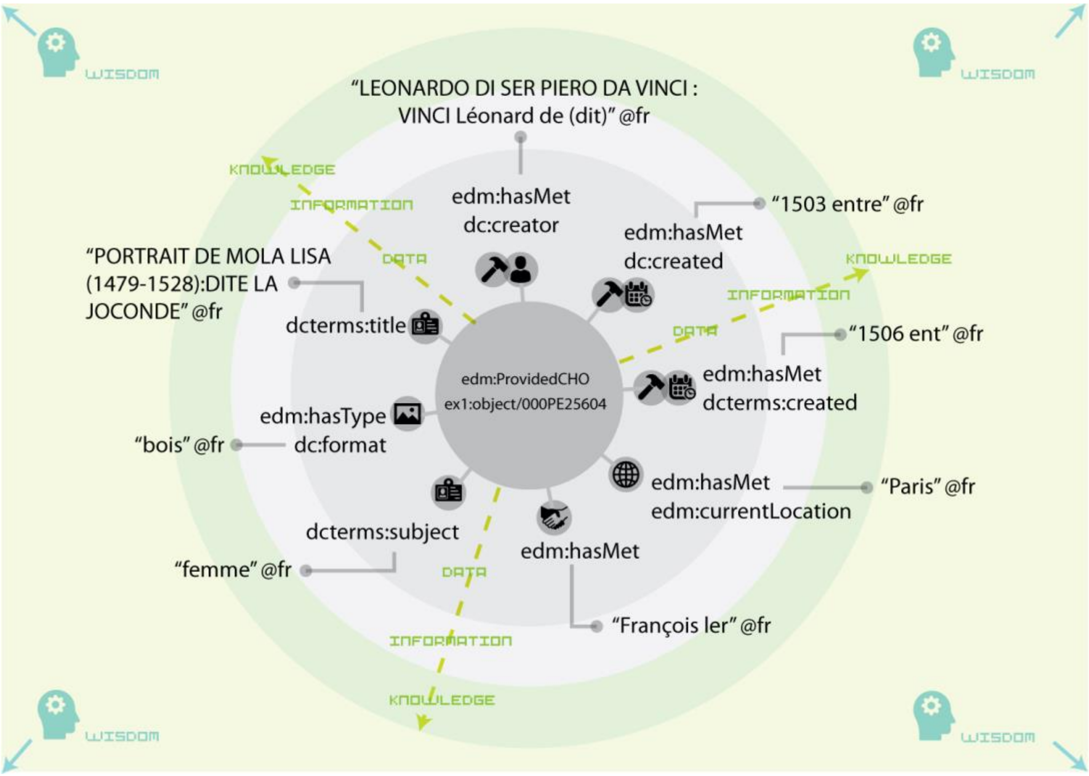


Figure 4. Europeana Data Model

Although Ackoff's DIKW model has been widely accepted across groups working with databases, information and data mining (Kwiatkowska et al., 2009:356), there are alternative approaches which add that **data** has to be contextualised in order to become valuable for the community (Stair and Reynolds, 2011:6). It is argued that **data**, regardless of its form (raw data or interpreted data) will always have to be contextualised, ordered and processed in order for it to become information (Fayyad et al., 1996, Zhang and Galletta, 2006, Davenport and Prusak, 1997). This makes **raw data** an oxymoron since all **data** has to be contextualised and interpreted (Gitelman, 2013:43).

Regardless of particular definitions of the terms, it is important to note that there is also value on **data** itself. An information production process can also be initiated from **raw data**. UK's Open Government Data originally released in comma separated values has provided **data** for a wide range of communities, allowing them to arrange the **data** and 'narrate' alternative stories of that **data** (OGD, 2014, Berners-Lee, 2009). In CH and particularly in Digital Humanities, users might benefit from accessing data warehouses where they can perform analysis on the **data** through a wide range of interfaces (Kratochvil, 2013:338.4)**.** These interfaces will vary depending on the end user. On one hand, users such as researchers might take control of the data provided by the organisations and carry out a wide variety of tasks such as spatial, time, and even speech analysis (Library of Congress, 2014b, Open Layers, 2014, Williford et al., 2012). On the other, CH organisations can also make use of the **data** to produce their own interactive **information** and use within their organisation (Zimmermann et al., 2003, JSTOR, 2014, Knoblock et al., 2013, Sherrin and Wallis, 2012). Offering the opportunity to work directly with **data** allows for more **information** to be produced (Stair and Reynolds, 2011). From a utopian perspective, CH organisations should provide access to both, **data** and **information,** enabling users to navigate back to the original **data**. Nevertheless, for pragmatic reasons, it can be said that **data** and **information** will be presented together if any production of **knowledge** is to take place, especially through their digital content. Different groups in OCH have the capability to use the **data** and connect it to other **data.** That **data** can be further processed and transformed into **information**, which can be linked to other sets of **information** and **data** as well. It is here where the output of this new constructed **information** can be used to learn something and produce **knowledge**. This knowledge can eventually connect to other knowledge systems. It is through **understanding** that the transition between the DIKW elements is carried out (Bellinger et al., 2004).

Museums and libraries exist as source, mediators and holders of **knowledge**, and considering how visitors interact with DIKW elements can help to identify how to offer access to their digital content (Grattan, 2006:5, Poole, 2013, Trevelyan, 2008). **Information** is the element that allows CH institutions to share **knowledge**. For this reason, it was important to clarify the role that **information** plays under the umbrella of OCH. It was previously mentioned that establishing what information is relevant for different groups in the CH sector could help identifying who is meant to be interacting with it. Nevertheless, the terms **DIKW** might not have the same definition within different groups in OCH. Therefore, it was relevant to produce a **common ground** of what is meant by these terms in the context of this research.

3.4 Information and its Users

Different CH sectors such as museums and libraries will require different sets of data and information in order to provide the specific knowledge they want to convey. This research aims to focus on the different ways in which knowledge in CH sector can be transferred through online means. Moreover, this research addresses data and information as a synergic relationship where one cannot exist without the other, especially when the main objective is the transfer of knowledge. One of the main objectives of this research then, is to find ways to make information meaningful to the user so he/she can appropriate it and transform it into knowledge.

Three main 'layers' or 'levels' of user-information relationships in CH have been identified in this research: [1] information production, [2] information sharing and (Couture et al.) [3]engagement with information.

3.4.1 Information Production

The amount of information produced every day and data stored has been increasing exponentially due to the fact that many CH organisations are currently undertaking heavy digitisation processes of their collections. For example, the British Museum adds approximately 2,000 digital images every week to their online collection database (British Museum, 2014). Furthermore, digitisation services along with the curatorial process have been commonly led by the CH sector due to the ownership of artefacts and the attempt to preserve material culture. Digitised objects become digital information that users and visitors can engage with. But as previously mentioned, there is also information that is ***born digital***. This is to say, information will be produced as part of research process as well as part of tasks aimed to preserve the original artefacts (Dow, 2009:10). It was also mentioned that with Web 2.0, many users are becoming producers of information by sharing their knowledge through the Web. This was somehow expected and it was anticipated that 'users' were going to become producers of knowledge (Jones-Garmil, 1997:179). There are many current cases where academic groups seek the 'crowd intelligence'. Such is the case of *folksonomies* (produced by users) in the use of categorisation and organisation of information is becoming more common. Chapter one presented how Web 2.0 and social technologies were becoming more relevant in CH. It was also discussed that Semantic and Linked data technologies can assist to provide meaning by increasing the amount and easiness to find data related to a specific 'item', and the structure to make inferences about them. Ontologies can provide a shared vocabulary to be used by people and machines thus unifying the language and promoting Web standards. The Web as a *social-machine* allows users to produce knowledge and connect it in ways that were never done before, especially in the case of linked data. The CH sector has taken leadership in content production, but it needs to be aware of the roles as information producers they might have under the OCH ecosystem as a socio-technical system.

3.4.2 Information Sharing

It is at this stage that information is shared between people and organisations in the form of **data**. Some of the most important factors when sharing information are not only access to the data, but also to create relationships between different sources. Access to most of the information available related to a specific object (e.g. ultra-high-resolution images), should be provided not only to staff members, but also to external parties that might benefit from it (such as independent developers). Arguably, OCH organisations are part of a network where sharing information becomes an intrinsic part of enhancing the quality of information. For instance, if every CH organisation uses or creates a different data model, it will become difficult to share content among them or to agree with different terms. CH organisations can provide the structure and tools for users to make use of this data, thus providing a shared vocabulary that increases collaboration across disciplines.

A relevant aspect of information sharing and exteriorising specific sets of information, lays in deciding what is relevant for a wide variety of visitors. Libraries have typologies of metadata that assist sharing the information according to their use or function. It has been indicated that museums need to allow visitor to exchange thoughts in order for them to expand their knowledge and ideas (Addis et al., 2005). The objective of OCH visitors may vary from academic purposes to merely recreational. For this reason, it is important to provide the appropriate tools and information access so they can achieve the objectives that persuaded them to visit a specific OCH site.

In the case of information sharing among CH groups, to connect or communicate between each other might not be an easy task. To ease this problem, there has been a movement such as the Dublin Core Metadata Initiative to harmonise data across these different CH groups. CH organisations can benefit from using this type of data approach as a standard to promote ways of facilitating the engagement with their content. Although there are other 'standard' data models such as EDM and CIDOC, the groups involved with those models have been working in their integration, promoting cross-community collaboration (DCMI, 2013). By providing this kind of platform, different organisations in and out CH can connect and share their information more successfully. This provides better opportunities for users to produce an understanding of the information presented. These same groups have identified how RDF metadata can be used to integrate collections from a wide variety of CH organisations. Therefore, they have encouraged the development of tools for the access and repurpose of CH digital content. For instance, Europeana alone has been running hackathons since 2011 and produced over 50 different community developed applications to explore their data (Europeana, 2014).

Sharing information in a structured way (e.g. as done when using a data model) allows gathering data and information, where users can add their meaning, thus making it useful and re-usable. Reuse information can include different implementations that might go beyond the original purpose for what it was designed. Organisations such as IIIF (IIIF, 2014) are capable of providing high quality image and content visualisation tools for different organisations and individuals based on a common shared vocabulary that can be applied across different fields. The stage of information sharing focuses on novel ways of interacting with data, it analyses different methods of data distribution and how it reaches audiences through different socio-technical pathways (e.g. websites, apps, APIs, documentation).

3.4.3 Engagement with Information

In order for data and information to be accessible, it needs to be produced and input into a system, but it also has to be shared. Once information reaches the users, it requires to be presented in a way that is meaningful. From that, the user can appropriate such information and produce knowledge from it. The OCH ecosystem is built upon a combination of a wide range of technologies such as user interfaces, scripting languages and visualisation tools among others. Moreover, there are protocols, standards, access and information management approaches that set the way CH and OCH works. Once end users attempt to engage with OCH, the will do it through a user interface. In other words, the main pathway for users to engage with information is the user interface designed by this wide range of communities that integrate such tools and technologies. On one hand, Human Computer Interaction (HCI) studies how these interactions might happen and how they can be improved. On the other, Engagement Studies focuses on how users will interact with such interfaces or coding languages in order to make the experience more meaningful. As it will be seen later, these studies include different areas that help to define how this happens.

There might be several reasons why a visitor might visit OCH sites. The Web is a new technology and therefore, there is the need for more research to identify the main motivations to visit a specific sector in the OCH ecosystem. Nevertheless, entertainment, sociability, learning, aesthetic, commemoration and delight have been usually identified as the main experiences that visitors look for when visiting the *four-walled* museum (Kotler and Kotler, 2001). There might be some indication that OCH is attempting to provide the same experiences. As mentioned before, this research argues that the main objective of OCH is to provide knowledge to their audiences. Therefore, those *four-walled* museum experiences might even be considered secondary objectives resulting from information interaction. In OCH, there is a new opportunity to expand and combine such experiences. For example, in a *four-walled* museum, sociability might be limited to the physical location of the display. In OCH, sociability has a wider reach since the Web has no geographic boundaries. Moreover, sociability can be mixed with learning and entertainment where online visitors can be empowered by learning from different communities around the world. This will also raise many exciting opportunities when designing content for such wider audiences. Many factors such as ethnicity, digital literacy, Web access, privacy and copyright, and information standards will play a crucial role when promoting engagement with OCH. These factors are part of the context where the engagement with information happens and it is “the particular set of circumstances from which a need for information arises” (McCreadie and Rice, 1999). In order for this to happen it will be an important milestone to identify what would be the best interaction methods for online visitors. This can be achieved through HCI, User Experience (UX) and Human Information Interaction (HII). It is also important to understand how to curate information and content to be distributed through different specialty levels, thus providing the most appropriate content and information. This can be accomplished through Museum Studies, Information Management and HII.

Most of CH organisations go through the information process of production, sharing and engagement. Information production can be viewed as a process where information flows towards the organisations and groups that will share the information in a later stage. Many of the sharing and engagement might include external processes (such as analysis) commonly performed by end users and groups outside of the organisation that shared the information. Sharing of information can be both, external and internal thus connecting production and engagement. Engagement occurs when users use a computer or digital technology to access the CH organisations. The engagement phase on the Web should allow users to achieve their specific needs. These different stages of information have the objective of providing the tools for users to learn and ideally share that new knowledge with other people. Moreover, it also needs to be considered the opportunity for researchers to engage directly with data. Researchers and specialists are capable of accessing metadata directly and perform different kind of analysis. Through these analyses, more information can be produced. Tim Berners-Lee (2010) presented how by opening data with Linked Data standards allowed other individuals and organisations to produce information and knowledge by linking data (mashups) from different organisations such as the produced by the U.K. government.

3.5 OCH Users. First Engagement with Information

As previously mentioned, an objective of this research is to provide a wider understanding of the engagement that visitors might have with OCH. To do this, it is proposed to define the different audiences, motivations and purposes of such users. Users' motivations to visit or explore OCH are extensive. They can vary from looking to answer specific questions to a serendipitous activity. Nevertheless, the usual pursuit is the gain of knowledge. It has been proposed that even serendipitous activity can fill in gaps in the user's knowledge and/or reduce uncertainty about a specific topic (Belkin, 1980). In this pursue, the user will proceed to negotiate by interacting with a system (e.g. typing a question in Google). This negotiation is a communication process between the user and the system (Taylor, 1967: 18). Arguably, the system should adapt to the user information need and not to be oriented by the way in which information is catalogued or implemented (Diamond and Oppenheim, 2005:14, Taylor, 1967). This is to say that the system is meant to help the user making meaning of the information, instead of 'forcing' a particular path on the user. Users are in need to express and feel their agency in an interactive space and to see the technology as an extension of themselves, rather than merely a tool over which they may or may not have control (McCarthy and Wright, 2005a: 268). As in the case of Human Information Interaction and Human Computer Interaction, the CH sector has commonly focused on providing a straight line when telling a story or presenting a display. On the Web, hypertext allows users to navigate through information in different ways and provide the opportunity to explore potential alternative information paths. An interactive system should encourage that independence of flow. Therefore, it is important to incorporate such perspective into a system that can explore the complexity of OCH information.

A proposed strategy to define how users might develop their learning paths will be by understanding the level of information ***needs*** when accessing OCH. There are different levels of information need that shape the way in which information is explored, and they also condition the processes by which the user will approach OCH. These level needs and objectives have to be contextualised in order to understand the different type of users according to how they approach OCH by asking questions. The context where the activity happens might modify the information need and therefore the ways in which the questions are asked (McCreadie and Rice, 1999). For instance, a scheme defined by Taylor (1967) identified different levels of need when searching for information. He indicates that when a user is searching for information, they will base their preference of an information need based on a [1] visceral, [2] conscious, [3] formalised and [4] compromised level.

The ***visceral*** level constitutes an unexpressed need for information. Many information seekers will arrive to an information place such as a library or museum merely out of curiosity, with no specific learning objective in mind (Kotler and Kotler, 2001:134). Visitors arriving in a visceral state might have different reactions when navigating through the information presented. On one hand, visceral visitors under a leisure activity might end up making simpler and routine decisions (Kotler and Kotler, 2001:143). On the other, visitors with a more specific information need might have negative reactions such as anxiety (Case, 2002:100) when arriving in a visceral state. At a ***conscious*** level, users have identified their need for information beforehand. There is an understanding of a specific information need but do not have enough information to make a specific query. When visitors go to information places looking for information there will be a difference between arriving in a visceral and a conscious level. Arguably, information can be given and identified by a system before it has been asked for or formulated as a question, assisting visitors to transfer from the visceral to the conscious level. Nevertheless, it is important to mention that not all CH visitors will look, at least in their purpose visit, to make that level transfer. Marketing studies have shown that people make particular decisions when looking for information based on the impact their decisions will have on their lives (Kotler and Keller, 2009:163). When visitors arrive as part of a leisure activity their decisions will have a *lower implication* compared to visitors looking for specific set of information as part of a university or school coursework. These *high implication* choices are made as a result of among others, a personal or social risk of making a –wrong- decision. When under a *high implication* choice, visitors will differ from the prior ones due to the fact that they will be looking to transfer from a visceral or conscious level to a formalised one (Kotler and Kotler, 2001:143). After the conscious level, visitors will be able to formulate a question to either a system or another person. This is the ***formalised*** level. Therefore, presenting information for *high* or *low implication* visitors might have different psychological results. *High implication* visitors will attempt to explore various information sources and evaluate them, thus increasing their focus towards the learning activity (Kotler and Kotler, 2001:144). Finally, once visitors have enough information, they reach a ***compromised*** level where the question is asked based on the terms and qualifications of a specific group or database. Under a compromised level, visitors know what information is required to solve a particular question or problem (Raber, 2003:110). Arguably, a learning environment has to consider such levels of needs. Users will access information as a navigational strategy upon the system; for this reason the system should work towards 'sense making' instead of retrieving a specific set of information. Nevertheless, designing interactions for several level needs might prove complicated. Therefore, scalability and/or adaptability of the system might prove beneficial.

Moreover, providing flexibility in a system should allow users to exchange from the different information *need levels*. By providing different modes of interaction and engagement, users may be able to switch between the different levels of need. In this sense, the system could provide the engagement pathway for different levels of speciality. In the case of this research, these ideas will be incorporated in the design of the experiments built to test ways in which user engagement with OCH can be facilitated. This approach relates to the Psychology of Everyday Actions (Norman, 2002:47) where the actions to achieve a goal are studied in order to understand how people (users) might behave. This will be further explained in the next chapter where we discuss user interfaces and the interaction design methodologies. However, before this, it is essential to provide the state of the art identifying the different perspectives and technologies that have been used previously to share and engage with information on the Web, and especially in the CH sector.

3.5.1 Information Stages in OCH context: Production, Sharing and Engagement with Information

Previous research has looked into how information can be explored through a wide variety of interactive methods and system designs. As mentioned, there are some factors that shape how knowledge is engaged and managed. On one hand, there are the information management elements that influence how *information (and data)* will be created, stored and distributed. For example, the Semantic Web, linked databases, and information systems play a role in how information is created, distributed and queried. On the other hand, the interactive systems provide the tools to make those sets of *information* accessible and usable by a wide range of people.

To make information accessible, there has been a development of Content Management Systems (CMS) to allow non-technical people to manage data stored in a system. Moreover, there are data querying systems to provide access to a wider range of people so they can ask questions about the data contained in a system. These form part of Information Technology (IT) studies, aiming to understand the different ways on how information can be managed and used by people. Such work focuses on the use of information and exploration of knowledge systems such as OCH and the interaction design perspectives. In order to understand how information can be used in an efficient way, it is appropriate to explore the work that has been done in these areas.

The previous section identified specific processes in OCH. Arguably, most of the groups in the CH sector will have to go through the production, share and engagement stages of information. These stages might vary in name or by who is meant to take charge of it. CH groups such as museums and libraries have studied how this process takes place in their organisation. Present understanding on how different CH organisations work has not reached a specific standard, especially since digital preservation cannot be a one stop shop type of solution. Nevertheless, there are models that can be used to compare how this process of information production, sharing and engagement takes place. For instance, the

Open Archival Information System (OAIS) reference model has commonly being used by different CH groups as a model for preserving information, thus making it accessible to users (Jones et al., 2006:78, Diez, 2013:115, Branin, 2005:8). Even though there is not a standard archival model for CH institutions, previous work indicates that this is the most commonly used. It will serve for the purpose for this example to identify the different stages of information in CH institutions. The OAIS model incorporates a preservation planning process where the information is produced and consumed. Preservation planning is possible due to an administrative process where (information) producers follow a set of rules and agreements, sends a submission information package (SIP). Further on, the SIP is enhanced with descriptive information. This should potentially make information usable (data management) and available (archival storage) to users. By this stage the SIP has been transformed into an archival information package (AIP). Finally, users query and access the information. It is here where the AIP is transformed into a dissemination information package (DIP) that is delivered to them.

Another way of looking the stages of information is to compare it from different organisations. As mentioned before, most CH groups are very likely to go under this same process. The museum digitisation process is very similar to the OAIS model, and is still compatible under the aforementioned stages of information. Figure 5 presents a comparison between the OAIS model, a museum model and how it fits within the three stages of information. The lower section of Figure 5 identifies that museums will still have to go through a digitisation, management and presentation process (White et al., 2004), and it can be argued that it is fully compatible with the OAIS model. Both models contain information where an ***ingest/acquisition*** process occurs. Next, there is a requirement to store and share that information in a meaningful manner. Further on, there is the area of information sharing. The ***database*** is produced ensuring that the information is usable (***data management***) and accessible (***archival storage***). Finally, engagement with information is where the information is ***presented*** and ***accessed*** by users.

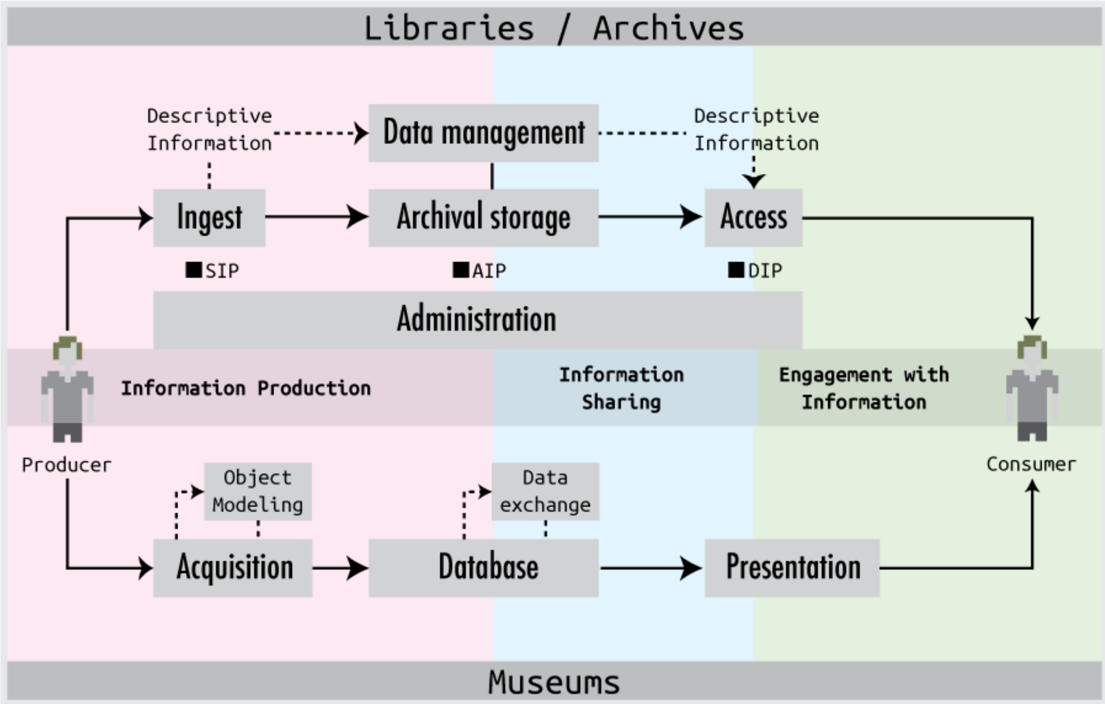


Figure 5. OAIS and Information Process

Consumers or users will use interactive systems when accessing information. As part of the OCH ecosystem, several CH sectors provide the structure of the information for it to be distributed. Many CH organisations, groups and researchers have paved the way for users around the world to gain knowledge from OCH digital content. Nevertheless, the way OCH knowledge is presented, is still far from being an optimal knowledge tool. The next sections will focus on these systems and the technologies that *engage with information*.

3.6 Current State of Engagement with Information

To investigate how information can be explored through interactive methods and systems, there are some factors such as information management and interaction design elements that need to be considered. Information Management focuses on how information will be created, stored and distributed. Moreover, this information follow physical and logical constraints established by the originating institutions or groups that produced the data and described it to produce information (e.g. ontologies, linked databases and information systems). Further on, that information is then made approachable and usable by a wide range of people through interactive systems.

3.6.1 Content Management Systems and the Semantic Web

Content Management Systems (CMS) can be used to manage, index, search and obtain information about a specific set of information. Moreover, a CMS will assist organisations in their three stages of information: collection (information production), management (information sharing) and publishing (engagement with information) (Boiko, 2005:83). Moreover, a Conceptual Reference Model (CRM) can help providing “definitions and a formal structure for describing implicit and explicit concepts and relationships within a system” (Lazarinis et al., 2011:94). CRMs include the different ontological representations, descriptions and relationships that allow making relationships between the data. These ontologies can be either domain specific (domain ontology) or they can also be more generic (upper ontology) thus being able to describe generic and universal objects across a wider range of domain fields (Lim et al., 2011:8). In the case of the CH sector, they have been used to store and classify information about collections and/or enhance interoperability thus enhancing navigation, visualisation, and content presentation as in the case of (digital) libraries and museums (Morales del Castillo, 2011:80). For example, CIDOC is a CRM that provides the ontology to integrate knowledge across the diverse organisations (domain ontology) in CH (CIDOC, 2013). For example, the British Museum has produced a linked database of their collection (British Museum, 2014) organised under the CIDOC CRM. The British Museum among other organisations has followed this path to allow developers to produce applications where visitors can explore their collections. To access such information on the Web, there is a wide range of intelligent applications such as search engines that might not provide results that match consistently; the applications used to navigate the information can be “only as smart as the data that is available to it” (Allemang and Hendler, 2011:3). Furthermore, a Semantic Web approach allows producing an infrastructure to distribute such organised information through a Resource Description Framework (RDF). Building CRMs with RDF enable organisations to further increase knowledge integration and interoperability across a wide range of organisations using same technologies (W3C, 2014). Most importantly applications using Semantic Web technologies can truly be ‘smart’ applications; with the use of RDF, users and applications can retrieve the data they need

(Allemang and Hendler, 2011:4). This is to say that humans and machines can now read and find information on the Web through the use of RDF, and the ontologies behind them reduce the chance of misinterpreting information. To find information on the Semantic Web, queries for this system have to be performed through SPARQL. SPARQL allows users to perform explicit questions to the database and produce results that can integrate and link resources from external linked databases.

Although SPARQL and the Semantic Web in combination constitute one of the most powerful tools to explore information, their implementation and use require high level of understanding not only of technology, but also of the querying language to perform a question and navigate through the information. There is a wide range of languages to query data such as XQUERY, SQL, COQL and Gellish English among others. Nevertheless, SPARQL has been the attempt from W3C to standardise an RDF query language (Allemang and Hendler, 2011:55). Therefore, many organisations that use Semantic Web or CRMs provide a SPARQL endpoint or any other entry point such as the Open Archive Initiative for Metadata Harvesting (OAI-PMH) that offers direct through a 'Repository Explorer' (OAI, 2014). The benefits of providing access to the (meta)data through a Semantic Web approach, allow users to cross-query sets of data, integrating the results in a single space (Martinez and Isaksen, 2010). Nevertheless, querying **data** is still far from being a tool or a system that can be used by a general audience. Even if a SPARQL endpoint was a query language easy to implement, it will still be difficult for general users to query the data. This is because SPARQL (another query languages) work as a *Tell-and-Ask* system (Allemang and Hendler, 2011:63). The system requires users to *tell* a fact or facts so it can retrieve the answer they are looking for. This might conflict and produce stress in users that arrive on a **visceral/conscious** level of need of information, since they do not possess any knowledge to *tell* something to the system even if they knew SPARQL. Many of the research has commonly focused on querying based on the specific language through *command driven* inputs such as SPARQL, where applications can be built to enhance users' capabilities on the information retrieved (Allemang and Hendler, 2011:52). Arguably, information retrieval applications can provide users with the tools from a visceral to a compromised level of information need to explore information on the Web and especially in OCH.

3.6.2 Information Retrieval Systems: Querying for Knowledge

Information retrieval is the process of finding information on a wide range of resources and dates back to the 1950s (Shen, 2007:1). This process is commonly carried out through searches (queries) based on the metadata or text such as a Web search engine (Google Search). One of the main objectives behind a CMS and CRM is to provide users ease of access to an organised set of information. Moreover, on the Web, embedding Semantic Web technologies also allows computers to assist finding and retrieving extra sets of information. Information retrieval experts have been studying the different ways in which users can retrieve information and how they might learn from those searches (Boiko, 2005:165, Davenport and Prusak, 1997:84).

When users attempt to retrieve information, thus communicating with a (database) system, they can be assisted through a wide range of tools included in an interface. Research centres such as MIT, UIUC, IBM and Carnegie Mellon among others have provided approaches using Human Computer Interaction (HCI), visual communication, User Experience (UE), information studies and digital humanities. Their main perspective have been to prioritise the study of interfaces (interactive systems) where users can have an intuitive control (Rücker et al., 2011:12, Ingwersen, 1992:7). Information retrieval systems can take a wide range of approaches to enhance how users will explore the information in any given data systems. For instance rich-prospect browsing gives users an initial view of all items of a given collection aided with some tools to manipulate and visually organise those items (e.g. zooming, renaming, annotating) (Rücker et al., 2011:162). This approach provides users with a general understanding of what sort of objects are contained in a collection. Data visualisation systems are information (data) retrieval systems where information is mapped to visuals. They encourage users to explore enhancing engagement with the data (Murray, 2013:3). Information Retrieval Systems present a different view from what command driven queries have to offer since as any programing language, it is difficult for a general user to learn and utilise them. From an Exploratory Search approach, users mix querying and browsing strategies to enrich the process of selecting useful information (Marchionini, 2006). All these information retrieval system approaches attempt to enhance the way users query and deal with the information. Visualisation and design methods enhance the transition between the information system and the user. Nevertheless, research in this area has been limited to users using graphic user interfaces (GUI). Our research acknowledges the paradigm and potential that the information retrieval and its different methods have to offer to information exploration in OCH. Nevertheless, we believe that such methods can be also delivered through Tangible User Interfaces (TUI) where users can take control of the system, and not being distracted from the original task (Hornecker and Buur, 2006, Dourish, 2004:27).

3.7 Stages of Information and Europeana

Europeana as an organisation exists only within the Web. It does not own any physical collection of artefacts, books or even the data itself. Europeana offers CH organisations the opportunity to engage with their information. This is to say that the CH organisations share what they have and Europeana ensures that the information and data is findable and usable by more people and organisations. This is the reason why CH organisations have to know their role within the OCH ecosystem. The information process will still include the information production and sharing processes under the control of the CH organisation holder. Nevertheless, the engagement with information is completely given away to Europeana. The information sharing process between CH organisations and Europeana will ensure that information can be further integrated or extended to further CH-Europeana datasets. In this stage, Europeana becomes the facilitator for CH organisations to become a stronger collaborator in the OCH ecosystem. This is to say that when collaborating with Europeana, CH organisations can choose different tiers of collaboration ranging from a very basic share of metadata, so it can show on Europeana's search engine to a full share of high resolution files for free re-use (Europeana, 2015b). The minimum requirement for CH organisations is to provide metadata that fits Europeana's data model and with a minimum set of ten elements to describe the collections (Europeana, 2015a). These ten elements should describe the title, topics, user generated content, CH organisation that provides the data and the link to the object, among others. This information sharing process requires CH organisations to fit within a particular standard to enhance collaboration and data quality. In this case the CH organisation becomes part of the OCH ecosystem as an entity that collaborates with data through Europeana. Once the information has been assimilated, the engagement with information although facilitated by Europeana through it's API, it will be outside of their control, especially if the CH organisation allows for their objects to be re-used (Figure 6).

Figure 6. Europeana Publishing Tiers

Although CH organisations are commonly the primary holders of the artefacts, they might not be the sole owners of the data that describes a particular object. On the Web, data is more democratic and organisations and individuals could describe objects in OCH. A wide range of records originated from two or more institutions can also describe a single object. By showcasing, and integrating the data through a distribution platform, can offer the opportunity to increase the quality and amount of information that describes the collection. Moreover, once the data quality as a information sharing process has been agreed within the ecosystem, the process of engagement with information can also be promoted. By providing access to external communities such as designers and developers, experiment and produce interfaces for a wide range of applications where the CH organisations' content is displayed. The process of engagement with information in OCH is highly important, since it cannot be expected from CH organisations to be the experts in HCI, UX or HII. It can be argued that CH organisation should focus on the quality of information and providing content. By sharing their content, CH organisations can then take advantage of a being included in the interfaces being developed and learn about a wide rang of interactive perspectives that can be used to engage with their collections.

3.7.1 Engagement with Europeana

Once information has been structured and shared, designers and developers can produce interactive systems to engage with it. These interfaces will present the specific perspectives and methodologies of the people behind the development of the system. Beyond the commercial parameters of the data, CH organisations will partially loose control of how this information is interacted with. The information production stage helps reducing the uncertainty of the knowledge about the collection when shared in a latter stage. This information requires to be presented to end users in a way that is meaningful for them. In this case, developers will focus on providing that engagement with information stage by whatever interaction method they think will perform the task of making information meaningful. Although this task can be carried out in isolation from any CH organisation, it can be suggested that as part of a design methodology, the development process requires an understanding of how users might engage with the information. CH organisations commonly carry studies of their visitors when engaging with their collection. Nevertheless, they do not know how these same visitors behave when interacting with their own computers at home. Alternatively, interaction designers have better understanding of such behaviours. The engagement with information stage in OCH requires an understanding of the digital, online and real world to fully grasp the complexity of how users might interact in OCH.

3.7.2 Querying and Integrating Data with Europeana

As said before, one of the main roles of Europeana is to act as a portal for distribution of OCH knowledge. Distribution of OCH knowledge is carried out on the Web through a wide range of interaction paradigms. By allowing user interfaces to connect to the data on the Web, users can access it ubiquitously. Users are no longer limited to a particular location when accessing the content. The user interface will be in charge of providing the access to the data previously integrated by Europeana. To add meaning to the information, the interactive system can provide the context when users interact with it. The engagement with information in OCH extends beyond the presentation of information to a user. This process includes many of the potential tools form production of information process. When users interact with the linked data content, there is still the possibility to annotate, and expand the reach of where is the information going to be retrieved from. In this sense, CMSs behave in a similar way once the information has been introduced and staff members require to review or explore the records in their system. Pragmatically, end users will not have enough knowledge about the topic to know exactly what to look for. For this reason, it has been common that interfaces of CH organisations on the Web provide pre-designed pathways to explore a particular collection. Nevertheless, that will restrict users to a specific collection with no opportunity to expand their topic or reach of the search. When exploring through Europeana, there is a larger range of topics and over 2,000 different organisations to search across from. This means that when users search OCH data through Europeana they will be querying across a wide range of domains and topics. Moreover, to produce a more specific query, users must introduce keywords about that specific topic, for example, specifying the Renaissance or the Byzantine era as a time-space range. In addition, users must know the particular data field in the ontology that describes what they are looking for. To facilitate this, Europeana has further integrated the ontological fields through an API that includes them within a single *term* as. For example, ontology terms for locations edmPlace, edmPlaceLabel, edmCurrentLocation can be integrated within a single *Where* data field. It is important to mention that although the data fields of the ontology have been simplified to single terms, it does not reduce its complexity. The main query reach will still retrieve data from all the expanded ontology terms. In addition, the original ontology term can still be used independently for a more specific term search if desired. Chapter 6.2 will further discuss in detail the different API fields and ontology fields offered by Europeana.

Interaction designers are facing new challenges to offer end users the opportunity to integrate OCH knowledge. New interaction and Web technologies can aid in such task though the integration of interaction paradigms that promote sense making and pedagogic activities such as TUIs and the inclusion of Web technologies such as Linked Data and APIs. To do this, Europeana has invited a wide range of communities to produce such interactions and test their API.

3.7.3 Previous and Current Interfaces for Europeana

Europeana has promoted the production of interactive systems with their API through hackathons, where designers and developers are invited and expected to produce something during a short amount of time. Although these interfaces might not be aimed to solve conceptual interaction factors, they provide examples of how current Web technology can be used. In addition, many of these hackathon prototypes are further developed into Web services used by companies, organisations and individuals. The vast majority of interfaces showcased by Europeana have been developed directly as a database search tool (Table 1). This is understandable due to the complexity of representing text in abstract forms. The list presented in Table 1 is a selection of interfaces tagged by Europeana as 'API Implementation' and 'Discovery'. These interfaces are meant to act as the first encounter with the data for users. There are other interfaces that are not listed that fit better within a data visualisation tool than a knowledge discovery or query tool. The process of data visualisation can be considered as a post-query process. Many of these tools, also offer a visualisation tool once the query has been performed such as OMNIA, Culture Collage and DPLA. Nevertheless, it can be argued that under the data visualisation process there is already a level of direction imposed to the users. As part of the engagement with information, this research focuses on the process that users require to make sense of the information that they are looking instead of forcing them under a pre-designed pathway.

Searching as a database is commonly implemented through search boxes. Users are expected to know what to type in that box. In some cases, such as in OMNIA, Culture Grid and EOD among others, the interface provides a drop-down menu to select what data field is the keyword going to be assigned to. In other cases, the interfaces such as DHO and Wandora, offers several fields or facets for users to input different data fields with independent keywords. In addition, searching from text can be one of the most straightforward methods for querying. Attempting to materialise abstract concepts might prove confusing for users. Text input might prove to be a straightforward method to describe what is meant to be searched. Nevertheless, there is still a remaining gap to contextualise such text input. Multiple facet queries seem to provide the contextual support. Nevertheless, these terms are commonly offered as lists. It can be argued that offering a list of topics or eras might help users to put in context what is in the record. Nevertheless, interfaces such as DHO, OMNIA and Wandora which use multiple facet queries, do not allow combinations of terms. The queries are commonly re- compressed into a single keyword query (Figure 7).

Many of the interfaces under the database field search group seem to follow design processes similar to library catalogue search interfaces. They commonly present a text search box, followed by a drop-down menu to attach the data field. In other cases, the main search is focused primarily on the menu search option. Nevertheless, these approaches might prove difficult to produce further combinations or more complex keyword relationships.

Database Field Search	Embedr, WUD, Unbubble, Culture Collage, DPLA/Europeana, Kringla, Biglioteca Digital Hispanica, Culture Grid, Europeana Open Culture, VuFind, Royal Museum Central Africa, Related Items Widget, PIONIER Network Digital Libraries Federation, Open Pics App, National Library of Ireland, EOD, DISMARC, Hispana, Europeana Remix, European Local Austria, ECLAP, ATHENA	Single Query Box
	Europeana Aggregation Landscape, Wandora, DHO, Biblioteca Virtual Ignacio Larramendi, OMNIA	Multiple facet / query
	Serendipomatic, EEXCESS, E-Explore, Mashificator, CH Context Widget	Text to query
Content Exploration	Culture Pics, CultureCam, Inventing Europe, European Cloud	Visual exploration (Search)
	Linked TV	Video exploration
	EEXCESS, E-Explore	Visualisation through plugin
	Museums.EU, CARARE Map	Map exploration

Table 1. Europeana API Interfaces for Discovery and API implementation (Europeana, 2016a)

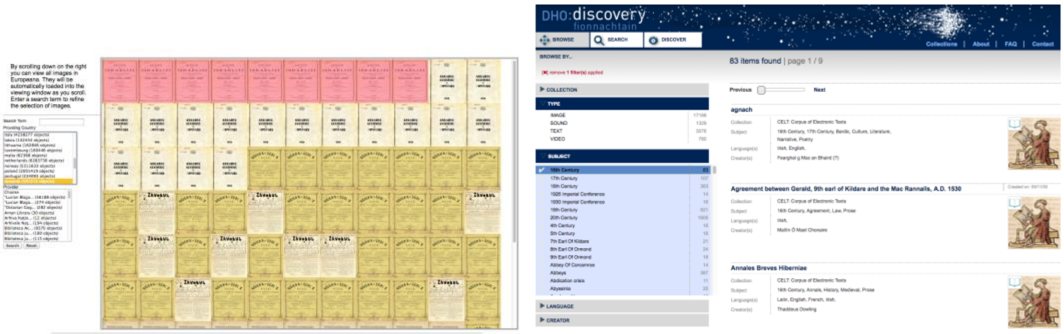


Figure 7. OMNIA (left) (OMNIA, 2015) and DHO (right) (DHO, 2015) interfaces.

Other alternatives to eliminate the specific keyword search have been through extending the purpose of the text. For example, EEXCESS (EEXCESS, 2013) developed plugins that aid referencing when typing. When users type in a word processor such as Google Docs, they can option-click the specific word and the plugins will search across Europeana definitions, images or any links. It acts in a similar way to the definition finder in Microsoft Word, with the difference of including Europeana resources. This same company has developed a similar plugin for other online text processing tools such as Wordpress.

Alternatively, under a similar text sentences searching tool, there are interfaces that will search using larger sets of texts that can go up to 2000 words, to search for Europeana content. The input text is sent to a Web service such as Zemanta or Yahoo! Term Extractor where the text is automatically structured by a wide range of categories, concepts and relevance, among others. Once the text has been structured, it will select the 5 most relevant texts and use them as the main keywords to search in Europeana (Ottevanger, 2010). The retrieved results are further displayed in a 'carrousel gallery'. It can be argued that this process of serendipitous searching employed by interfaces such as Serendipomatic and The Mashificator, shows how computers have the ability to analyse and catalogue text. It also shows how to connect different API services together to automate a series of responses to take advantage of OCH structured data such as Europeana's. Nevertheless, these examples remain under the same principle of single keyword query search. In the case of the 'serendipitous search', despite using 5 keywords, they are treated individually as 5 independent searches and not as a query statement that compose a 5-keyword query.

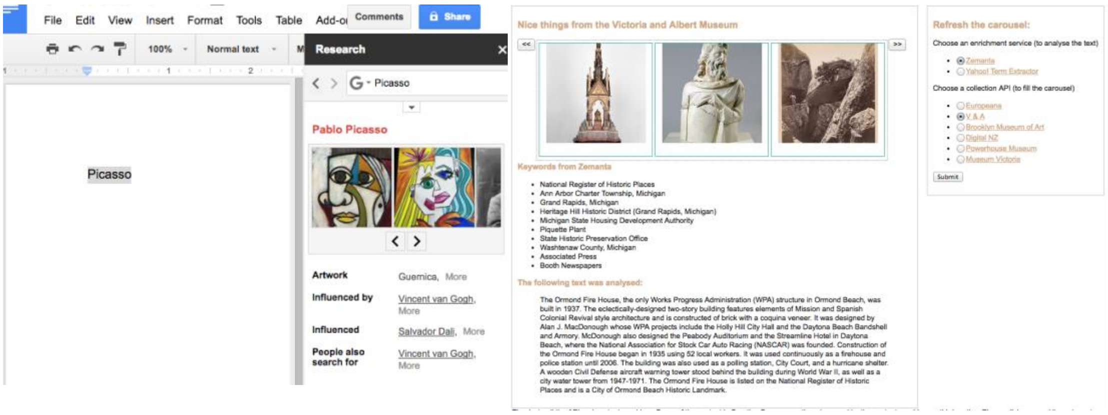


Figure 8. EEXCESS (EEXCESS, 2013) Plugin on Google Docs (left) and The Mashificator (Ottevanger, 2010) (right).

Arguably, it might be difficult to break the use of text as the main paradigm for search. When communicating with a computer, such as making queries, the code used to search has to be commonly translated to some sort of textual input. These texts are then categorised and placed into context to perform a semantic search.

Other alternatives for searching without text can include searching from a map, or by image. Examples such as CARARE show the benefits of the Geodata embedded in the metadata of the collections, where precedence of the collection or the location where it was found can be displayed (Figure 9, left). Navigating through maps appears to be complicated if users want to select a specific object. To do this, the interface still presents the single keyword query box-search as in the prior examples.

Another alternative to search was by retrieving objects that look similar. In this case, the system can use an algorithm to find similar shaped images. Other image search interfaces work with image capture. For example, CultureCam can take a picture with a webcam and use it to find similar content within Europeana's content (CultureCam, 2015). Alternatively, Europeana has also implemented a search by colour through their API (Europeana, 2013). To search by colour, the CSS or HEX colour code can be attached as a parameter of the query through the API and images that have similar colours will be retrieved. Searching by image parameters has specific benefits where users do not have to focus on technical or specific data to explore collections. Despite the benefits that these visualisations and query tools can bring to users, they are still limited to non-specific content and do not allow users to produce complex relationships of data.

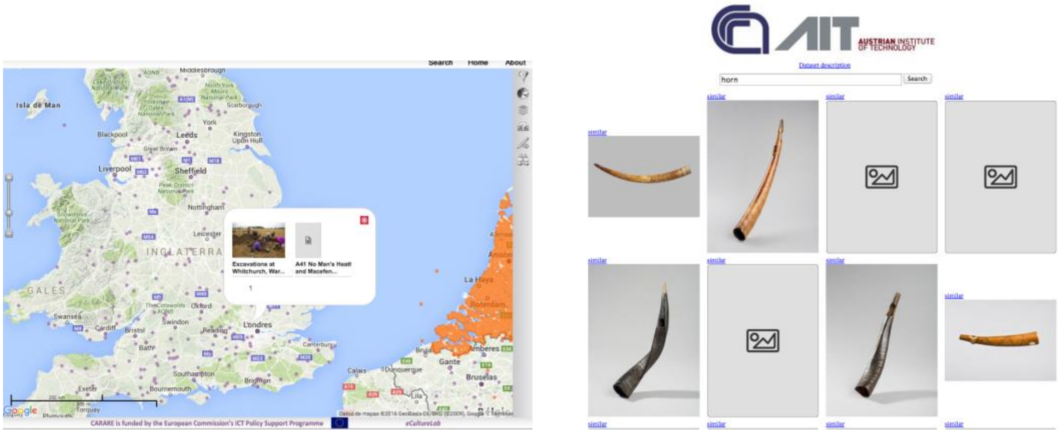


Figure 9. CARARE map search (CARARE, 2014) (left) and AIT similar image search (Austrian Institute of Technology, 2016) (right)

The current examples and approaches taken by a wide range of communities to develop engagement interfaces with Europeana content seem to have limit themselves to the single keyword query. The aforementioned examples provide a general landscape of potential benefits when for users to engage with the data. Nevertheless, it can be said that these interactive systems have been developed from a technical perspective where they manage to solve a technical issue. Despite this, the human factor still remains, where the meaning of the information has to be facilitated for users to have a learning experience. Users could benefit from an interactive system where the technical and conceptual complexity of Europeana’s content can be alleviated. In addition, none of the interfaces reviewed attempt to break the GUI paradigm. There is still a missing cognitive element that can help users to conceptualise and work directly with the metadata directly. TUIs can help with that transition and help users organise those complex metadata relationships and produce complex queries.

3.8 The role of user interfaces as the gateway to OCH: Research Questions

The TUI paradigm offer users better cognitive understanding of how a system (e.g. information retrieval system) works through roles such as exploration, constraints, affordances and learning by doing, among others (Hornecker and Buur, 2006, Bakker et al., 2012, Shaer and Hornecker, 2010, Dourish, 2004). When designing for tangible interaction, there are some opportunities to make physical objects interact with a computer. There are sensors and actuators that respond to proximity, manipulation or even to the natural elements. Such is the case of radio frequency identification (RFID) or Bluetooth low energy (BLE) where microchips can store information very similarly to barcodes and transfer information wirelessly to a device. Physical drawings can also communicate with an interactive system. The computer vision approach uses graphics commonly in black and white called markers. These markers can be recognised by a system through a webcam thus translating the structure of the drawing (marker) to information as well (Figure 10). It is through this OnObject method that everyday objects can be embedded with interactivity. OnObject approaches can break spatial boundary constraints that interactive systems such as touchscreen systems or any other screen based approach lack, thus allowing users to focus their attention on their embodied cognition (Chung, 2010:15).

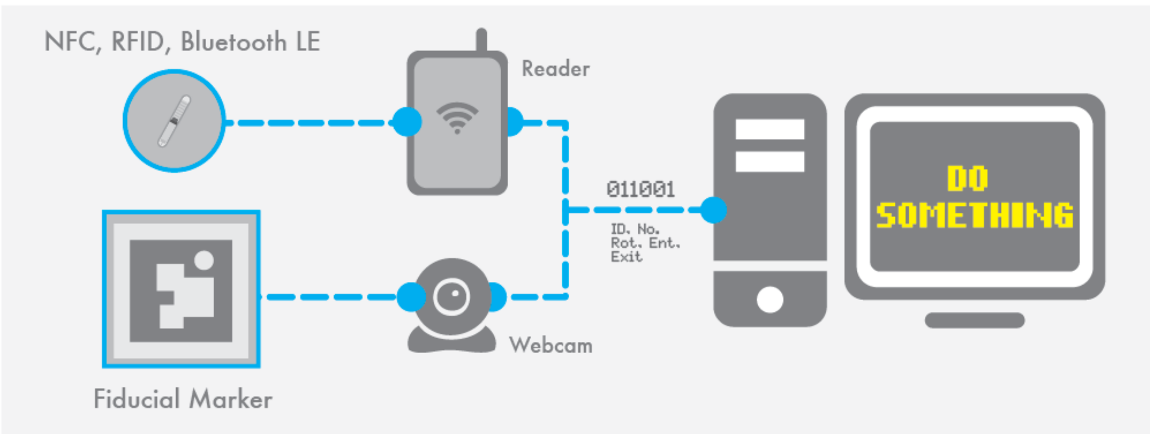


Figure 10. Sensors and Markers

A TUI approach can be used to develop information retrieval systems where physical objects query and organise information. TUI systems allow specific objects to represent particular sections of the information system. For example, in the paper 'Physical Query Interface for Tangible Augmented Tagging and Interaction' (Seo and Lee, 2013), the system developed uses Augmented Reality (AR)(another marker based interaction), to produce SPARQL queries where users can retrieve a pamphlet of a particular car model. It has been mentioned that even though the use of markers OnObject interaction in TUI systems can provide extendibility, they are commonly used only as tokens to abstract information (Chung, 2010:11), thus unlinking them from real world experiences that enhance cognitive perception. Nevertheless, Seo and Lee's project presents an alternative solution by linking the physical tools using AR and RFID with the visual elements of the interface (e.g. tags) and visual results of the query (e.g. car 3D render) (Figure 11). Users will place predesigned tags on a table that contains an RFID reader to perform the queries. Each RFID tag can be attached with different query variables that are translated into a SPARQL query on the system. There are manipulation tools (e.g. rotate, move) where the result (cars) of the query is rendered through AR. This way, users can examine and select the desired result for further use. By using RFIDs, the system can store users' selected results, providing the extendibility required by tokens in OnObject interaction.

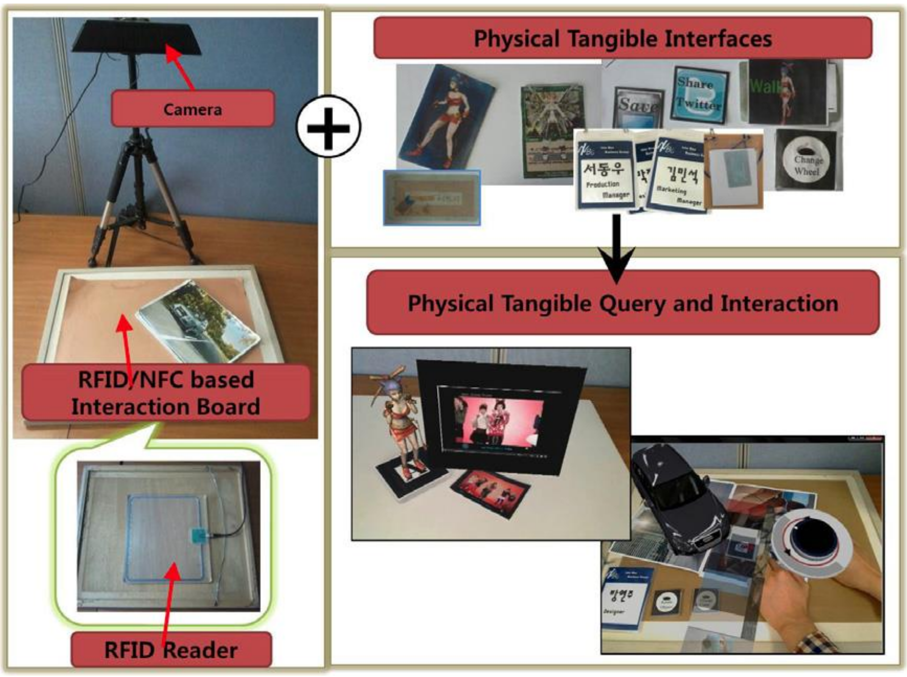


Figure 11. System Overview of Tangible Query. (Seo and Lee, 2013)

Being able to re-write the information on RFIDs has also allowed offering context-aware and self-adaptation in the system. Seo and Lee's interface presents four different interaction sections where different activities can be contextualised according to the user. These interactive sections are: identification, service, control and data (Figure 12). Each one of those sections is meant to interact with the information in a different way. The identification interface provides the context stored in the RFID. For example, the system can make the distinction between a 'Marketing Manager' and a 'Production Manager' noticing role differences. This might prove beneficial when attempting to adapt querying processes through the wide range of levels of need of information. It is this way that users can access the service interface and perform their query on the interface by combining the different tags. However, since the queries happen through the combination of the different interfaces or sections, the authors argue that to design all the different interactions for each section or interface can be very cumbersome. To solve this, they implemented a filter tool, which compiles the data from the different interfaces and presents the final result to the user. This is to say that the service interface will show a variety services available to the each of the identified users. In the same fashion, the control interface also provides an adaptive set of tools to manipulate the results on the data interface section. For instance, the identified user is presented with an augmented 3D model, which can be manipulated through the control tools. Finally, the data interface displays the information of the changes made. This system successfully adapts to the different user requirements and present the query results according to those different user levels. Moreover, it also successfully allows users to produce SPARQL queries without actually having to produce or type any command query.

Figure 12. Four sets of tools for the interface (Seo and Lee, 2013).

Another interesting system is Tangible Atoms. This is a project developed by a French company called Tangible Display (Tangible Display, 2013). The interface introduces the complexity of mineralogy to a general audience. Users learn by making combinations of different atoms, retrieving the minerals that are composed by the combination selected. They also created a professional version that provides more information about the collected item. The project blended several methods for TUIs such as tokens and tabletop interaction supported by a video display. Combining several interaction methods should allow users to obtain pedagogic benefits from tangible interaction thus providing an *adaptive* level of complexity when using visual displays.

Figure 13. Tangible Atoms

When working with information it might become difficult to make sense of everything that is retrieved in a query. Tangible User Interfaces (TUIs) can help making sense of complex sets of information. The ***token + constrain*** approach uses physical elements to produce direct affordances on how data is manipulated (Shaer et al., 2004, Ullmer et al., 2003). The project 'Tangible Query Interfaces: Physically Constrained Tokens for Manipulating Database Queries' (Ullmer et al., 2003) allows user to explore information about real state. Users are provided with "nine parameter" wheels used to represent the fields in the database. They are combined with a query rack to represent correlations in the active query. They have successfully implemented physical constrains as part of the parameters of manipulation of data through a token + constrain approach. The authors argue that TUIs can make a direct mapping between the information and the physical object implemented in the system. One of the downsides of this type of interface is that its scalability is limited to real world physical rules. This might limit a wide variety of operations that can be applied to the data.

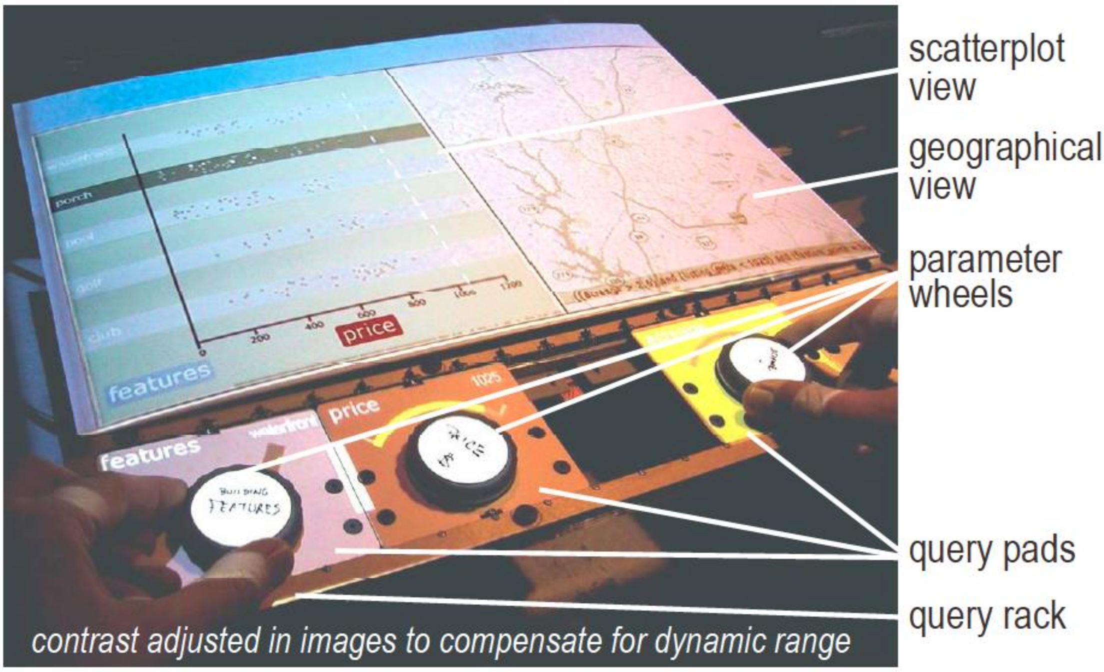


Figure 14. Parameter wheels and visualisation (Ullmer, et al. 2003)

Regardless of the success of the previous systems, there are valuable lessons to be learn from their development. Among the common problems identified in these systems is that they require high level of computer knowledge to build them, so adaptation might be difficult to carry out. They are not distributable and therefore limited to be used on location. Nevertheless, they also help dealing with vast amounts of information and they also allow queries on semantic databases through physical objects.

Providing objects that represent the structure of the data and how it can be navigated can also help users to understand what sort of questions they can ask (Camarata et al., 2002). Camarata et al. (2002) produced a system where users can navigate information about historic facts of the Pioneer Square district in downtown Seattle. It provides four cubes that represent: who, what, where and when respectively. By placing the cubes on an ‘interactive area’, users choose specific information about the particular theme printed on the face of the cube (Figure 15). The information gets displayed on a screen and is further navigated by moving the particular cube on the interactive area. Moving the cube forward changes the information about the chosen topic. By presenting this particular method in the museum where the information is held, visitors are able to intuitively navigate the information (Camarata et al., 2002). Arguably, it successfully provides an introduction to what sort of information can be found in the museum. Nevertheless, there is no real ‘freedom of navigation’ due to the fact the users follow pre-designed paths devised by the designers. Therefore, although the information retrieval method provides an intuitive interaction method, it is constrained to a limited set of information. Beyond the interaction success of the interface, there is an extendibility factor to consider. An interface such as this one cannot be extended, whereas OnObject interaction methods can provide an alternative approach to further experiment with this type of interactions.

Figure 15. Navigation Cubes (Camarata et al., 2002).

In the case of these projects the beneficial elements of these systems present a positive interaction paradigm. For instance, producing a system that adapts to the user level can help to include different types of users according to their knowledge and/or needs. In addition, providing an interface that can produce queries without the user knowing a query language or the content of the database, can promote the exploration of museum collections databases. Finally, allowing the user to make direct mapping between objects and the data can improve the pedagogic capabilities of an information retrieval system.

Physical objects can aid users in organising their thoughts when dealing with multiple concepts at the same time. The constructivist approach of TUIs can aid by letting users pace themselves and isolate specific sections or phases of any given task. One of the limitations of physical objects, is that is difficult to adapt them to dynamic data. While digital information or displays are dynamic and can be easily updated, physical objects are bound to real world rules. Alternatively, mini-displays embedded as part of a physical object can help transforming these. In this sense, a specific physical object can re-adapt and present more extensive sets of information while maintaining its physical properties that benefit tangible interaction. CubeQuery (Langner et al., 2014) makes use of this approach by performing database queries of a music library with Sifteo Cubes. Sifteo Cubes are mini displays attached to sensors that can be triggered by actions such as proximity, motion and touch among others as part of a user input. This way, CubeQuery takes advantage of the physical actions. The interactive system uses the cubes and a table display combined to produce the output display. Each one of the cubes represents a specific parameter, which allows users to facet their searches. This is to say that users can select a cube, fix a specific data type (e.g. title or artist), isolating those particular data types and values. When an extra cube is used, it will produce another independent facet that can have its own parameters. Users can combine as many cubes or facets as required and the display table will show the results of the query. Users can also implement boolean operators such as AND or OR. Boolean operators were implemented according to the relative position of the prior cube. Horizontal alignment cubes construct facets joint by ANDs, while vertical aligned cubes construct ORs. When all properties and elements are constructed, the interface displays the album’s thumbnails. When any facet or parameter is changed, the display auto updates itself. Arguably, this automatic response, can help promoting direct manipulation where the physical objects have an immediate response with the digital content. This can help easing the communication between the interactive system and the user.

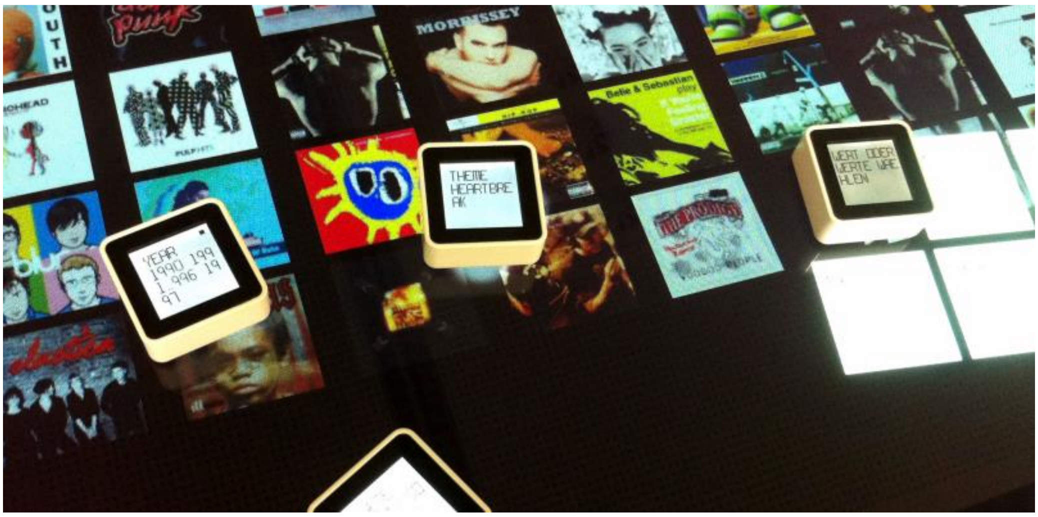


Figure 16. CubeQuery Interactive System (Langner et al., 2014).

Evidently integrating the digital display to the physical object can bring many benefits to make the objects more adaptive to the interactive environment. Moreover, they can allow objects to contain larger sets of information beyond the common interactive affordances. In this case, the adaptive display allows each object to adapt to a particular faceted search section of a query. Arguably, faceted searching could promote the required segmentation of a query, thus easing the mental effort required to combine multiple parameters. It can be said that for users who are not familiarised with specific datasets or sets of knowledge, it can be very difficult to relate multiple concepts on the first encounter. Moreover, it is also difficult for them to grasp the extent of a specific knowledge system held in a database. Faceted searches can help alleviating such complexity and help deconstructing it aided by the physical objects. Stackables (Isenberg et al., 2012), is a TUI that produces such faceted searches by stacking boxes with a mobile phone acting as a mini displays and an Arduino to process the actions. The system searches across a database of over 1500 books. It implements boxes that will depict a particular dataset facet. The boxes also have two spinning wheels to change the facets or values of the facets (Figure 17). By stacking the boxes, users can produce the combination, thus isolating each individual element of their question. Once the final query is produced, the results are displayed on a screen. Stackables and CubeQuery have managed to easily segment faceted queries by including the display as part of the interactive object. Nevertheless, this requires a more difficult setup in both of these scenarios. Despite Sifteo's SDK or Arduino's ease to produce prototypes, these approaches require larger investments from end users. In addition, there is still a large set of electronics to connect that low digital literacy users cannot be expected to build. Nevertheless, these examples present many benefits of the integration of physical objects with adaptive displays to extend their affordances.

Figure 17. Stackables Interface (Isenberg et al., 2012)

Many of the TUI examples previously showcased have managed to take advantage of the benefits of the physical and digital world. They show how TUIs can help to understand complex datasets and to expand queries beyond a single keyword. Nevertheless, these examples have been performed under specific datasets with a limited range such as book or musical library. It can be argued that such approaches can enhance the engagement with those specific datasets. Nevertheless, it can be said that OCH data encompasses a large number of data fields and values and there is still the question of how a TUI can adapt to larger sets of data that include the wide range of CH organisations.

Many organisations including the ones in the CH sector such as libraries and museums revolve around information and managing such information, which includes providing visitors and users the tools to navigate it (Keene et al., 2008:2, Carpenter, 2010:27). Therefore, CH organisations and groups have focused their attention in producing systems that can assist them and their visitors to deal with the complexity of the information hosted across and in their own organisations. CH organisations have used a wide range of approaches from areas such as information management (e.g. CMS, CRM), to make information accessible to users. On the Web, information can be linked through Semantic Web approaches (e.g. RDF, Ontologies) thus connecting it to a wide range of internal and external groups and organisations. This can result in an information overload that might hinder many experiences (e.g. learning) and information processes (e.g. sharing) on a wide range of users (Davenport and Prusak, 1997:48, Diez, 2013:19, Marchionini, 2008). User interfaces can provide insights about the content and the structure contained across the information systems in CH and OCH (Rücker et al., 2011:42). User interfaces such as information retrieval systems are deeply related to human cognition that enhances users' learning capabilities (Alwi and McKay, 2011, Ingwersen, 1992:41). Therefore, previous studies suggest that TUIs can offer a more meaningful cognitive experience where interaction with a system and it's learning capabilities can be enhanced (Bakker et al., 2012, Vissers and Geerts, 2014, Dourish, 2004, Marchionini, 2006). Nevertheless, implementing TUIs across for a wide range of users might prove to be complicated, especially if they are meant to be distributed across the Web. OnObject interaction and the use of computer vision approaches (e.g. markers) might present a higher potential of distribution.

3.9 Conclusion

When users engage with OCH information, the term 'information' encompasses 'data' attached with 'meaning' to produce 'knowledge'. That 'information' can be re-used and re-purposed through a user interface. Users depend on these interfaces to access any set of information on the Web. In the particular case of OCH, general users will have to engage with complex sets of metadata that incorporates 'information' from different domains inside and outside the CH sector.

Information goes through a life cycle in the CH sector. The engagement with information is different in each one of the information stages (production, sharing and engagement). This thesis focuses primarily on the last stage: the engagement with information. This stage is particularly relevant, because it is where the 'information' is externalised to end-users. This information is commonly accessed through interfaces, such as information retrieval systems. These interfaces allow users to explore, query and discover the information held within an information system add meaning and produce information relationships which turns it into knowledge. To query Semantic Web data, languages such as SPARQL are used. Nevertheless, Semantic Web query languages are too complicated to use by non-technical experts. For this reason, Europeana has provided an API access to facilitate the development of tools to engage with their content. Nevertheless, all the interfaces produced to engage with Europeana through their hackathons fail to break the GUI paradigm. These interfaces have managed to offer a direct engagement with the 'data' and the 'information'. However, the main problem still remains that in many cases the interfaces fail to offer 'meaning' to the users so they can engage through the different conceptual elements of Europeana.

Querying information is an area, that is greatly based on GUIs. Many of the hackathon prototypes analysed still require users to focus on the interactive tools instead of the information. This chapter also presented a state of the art of TUIs to explore information. The examples of TUIs provided in the literature review facilitate faceted searches that can be beneficial to segment different conceptual elements in OCH. The use of physical objects provides a conceptual reference of how the tools implemented in an interface can be used, and can provide information of how to relate the different information elements to be explored. Although these TUIs are highly based on lab settings, they offer useful examples of the use of cognitive interaction with information. Furthermore, these examples show how faceted searches facilitate a constructivist search activity when exploring the information. In addition, negative behaviours related to information overload can be alleviated if users have the opportunity to segment their thoughts and re-structure them. This is a great advantage because when people search for information on the Web, it is very unlikely that they will use multiple terms or multiple concepts in their queries, especially users on the lower levels of need of information such as visceral or conscious. Faceted searches within a TUI activity can offer the cognitive structure to organise the different concepts and produce a more complex query.

This chapter focused on how user interfaces can be used to query OCH and the state of the art of TUIs to query data. The next chapter presents the theoretical framework in which user interfaces are based on and built from a GUI and TUI perspective. The chapter discusses the different interaction paradigms and how they can fit in the context of empowering users to produce more meaningful interaction engagement with OCH. The examples already presented pave the way of possible opportunities of interaction, and the next chapter will present the different theoretical frameworks in which those interactions will take place.

Chapter 4: User Interfaces

User interfaces play an essential role in the engagement with information in OCH because they are always necessary to access any kind of digital information. In addition, the user interface is the tool through which the 'information' becomes useful to the user. The process in which users will add meaning will be affected by the different behaviours (such as searching for leisure or for research purposes; see 'needs of information' in Chapter 3) when asking the interactive system about a particular topic. In this case, the interactive system needs to communicate to the user the different transactions that can be performed on the system, as well as the different conceptual elements that can be queried. This research focuses on understanding how to facilitate the engagement with OCH information by producing complex queries. This is a process that takes place when OCH information is made available to end-users. Chapter 2 presented different paradigms and processes that are embedded into the interfaces used to deal with the information in the different stages of the information life cycle, which were explored in Chapter 3. There is a predominant use of GUIs on the interactive systems used to engage with the information in the CH sector, as well as in OCH. This is because is easier to develop and distribute interfaces that only interact on the screen due to facility to change or repurpose them through coding. Since GUIs work with representations of tools that are always attached to the WIMP (window, icon, menu and pointing device) paradigm, and every house with a computer will have a monitor, keyboard and mouse, the only requirement to change that application is to change that representation of tools. In the case of TUIs, to change the interactive properties of the system, the physical and digital interactions have to be changed. This means that TUIs are inherently affixed to the particular task that they were created for. This is to say, that TUIs are difficult to use in a different task for what they were designed for. In the same way that a Phillips screwdriver is designed for a particular type of screw, TUIs are designed for a particular task. But in the same way as the Phillips screwdriver will inform its user what type of screw it can be used on, based on the human cognitive perception, TUIs can also inform users about the particular affordances of the tools. By combining both perspectives, a physical tool and a visual display such as a tabletop display, can offer the flexibility for the TUI tools to be re adapted to alternative tasks.

This chapter introduce those GUI and TUI paradigms. The chapter aims to present a landscape of the different interactive methods so to determine the particular interaction principles can be implemented in a prototype to explore information. It will focus on introducing the different terminology of the paradigms and principles used to convey the affordances of the interaction tools. The chapter also introduces the term *pyfo* coined by Shaer et al. (2004), which describes the physical 'objects' used as tools as part of the interactive system. When working with CH objects, the term can be confused with the *pyfo*.

The chapter finishes by placing the aforementioned principles within the information exploration context in OCH. There are particular benefits associated with the principles used in TUIs such as making sense of what the tools are meant to do through embodied cognition and reducing the sense of helplessness through constructivist processes where users can structure their thoughts aided by the *pyfos.*

Previous chapters focused on the different stages of information in the OCH ecosystem. Nevertheless, there is a long-standing question of how users are actually using such information. It was previously mentioned that an interface is necessary to use and access such information. It is due to the nature of digital content that interfaces become a central part of gaining knowledge on the Web, especially in OCH. Although there are a number of studies related to HCI focusing how user interfaces might help in pedagogic activities, most of the literature has focused on GUIs. There are a number of aspects that require research when working with TUIs. This chapter focuses on understanding TUIs and why they are relevant to cultural heritage. Moreover, different elements that compose a TUI may have a specific benefit when using it. By studying and understanding those affordances, we can produce a methodology for designing the experiments that will aid users to enrich the quality of their queries in OCH.

In the same way that there are different users, experiences and levels of information needs, there are also different ways of interaction with systems (e.g. haptic, tangible, biometric). Moreover, there is a wide range of technologies and opportunities that make interfaces relevant to OCH such as tangible interaction and embodied cognition as part of an interactive system. Bearing in mind the previous points, this research believes that TUIs can offer a more positive engagement as a knowledge transfer tool over GUIs when working with OCH.

As noted in the prior chapter, one of the primordial reasons why users might access to OCH is to gain knowledge. By interacting with information provided by OCH, users can engage with that knowledge, thus producing different experiences. Added to this, it was also mentioned that users would not be looking only for a particular experience, but also for a

need to answer his/her question (knowledge gaining). Therefore, members of the OCH ecosystem require providing the environment for learning; this is to say an experience that can solve users questions. Based on the different levels of information needs that cause users to ask a question in different ways, OCH systems should also address those questions according to their particular level.

4.1 Introduction to User Interfaces: history and types of interaction

Computing has become part of people's everyday life. People use computers as tools for many activities through the day, from the time they wake up by using an electronic clock with an alarm to turning off the television with a remote control before going to sleep. In order for these tools to be used, interfaces have to be implemented so people or users can communicate with that particular computer and perform a task. An interface is the connection between a user and a (computer) system. An interface, allows a tool to be used and manipulated, in other words, to be interacted with (Dix et al., 2004:128). Historically in the computer world, an interface became another type of machine-tool that allowed the operator to manipulate and use the data or set of instructions stored in the processors (Rogers et al., 2011:7). The operator commonly did this through a set of dials and switches that were relatively straightforward to manipulate. Many of these machines and/or tools had (and still have) in common the necessity to make them human accessible. In the same way that a hammer uses an ergonomic design that allows the striking action to be enhanced, the computer systems used switches to enable those internal registers to be manipulated by a human physical action. Anthropologically, many of these interfaces have evolved from a natural design produced having in mind the human body (e.g. pressing, pulling). The ability to create designs that humans can identify as a natural process became an important factor in later periods of the computer world.

In the late 1970s and the beginning of the 1980s there was an attempt to make computers more accessible to the common user. The invention of the monitor helped with this. Computer scientists and software designers were able to use pixels to depict the tools that were previously used (e.g. *internal registers*). Human cognition played an essential role in this process (Shneiderman and Plaisant, 2004, Norman, 2002). Visual display combined with a keyboard and mouse input was implemented to interact with computers. For the first time, there was research focused on graphical user interfaces (GUI). Nevertheless, it was until the 1990s that computing spread with the possibility of being *personal*. The term *personal* implies a high level of adaptation or *personalisation* that computing systems and applications are meant to fulfil. But in order to provide such levels of personalisation, the user needs have the tools to manipulate the system without having profound computing knowledge. For this reason, users' tasks were simplified through direct manipulation by offering visual representations of real world objects that can be used to perform tasks, and watch the computer react immediately (Shneiderman and Plaisant, 2004). Direct manipulation allows users to learn computing tasks easily. It prevents from making errors and encourages exploration, among many other advantages. Direct manipulation uses *real world metaphors* to recall from prior human experience tools that might represent a specific task. Apple computers became popular due to their operating systems that provided GUIs with *direct manipulation*; later on, it was adopted by other systems. *Direct manipulation* and *real-world metaphors* play an essential role when facilitating interaction with a computer. Implementing human experience into the UI, systems can become more approachable. For the first time, the users were empowered by allowing them to explore new ways of learning, working and socialising.

Despite this, for many years the general perception of human-computer interfaces has been limited to using a mouse and a keyboard. It was all based on working with windows, icons, menus and pointers (WIMP). These interfaces were designed to work on a desktop in a visual way through a desktop (screen), creating a paradigm of how users were supposed to interact with computers (Rogers et al., 2011: 60). Since most of these interactions occur on a screen, they have been linked to the visual connection with the WIMP/GUI. These technological changes have produced new human-computer interaction paradigms such as:

Ubiquitous computing (ubicomp) focuses on integrating or blending the interfaces to our everyday life. By blending with people's environment, they become invisible interfaces (Dix et al., 2004:717).

Pervasive computing evolved from *ubiquitous computing* under the conception of allowing users to interact with such systems at any time and place. Nevertheless, it refers to the everyday tools of our lives such as mobile phones (Dix et al., 2004:181, Shneiderman and Plaisant, 2004:25).

Even though it is common to see the terms pervasive and ubiquitous computing used interchangeably, they mean different things. It is through ubiquitous computing that we are trying to get rid of pervasive devices and blend them into a single one, such as the smartphone that integrates different technologies into a single device.

Wearable computing embeds interactive systems into clothing, which are part of the users' environment. It is an evolution of the ubiquitous and pervasive computing area (Blythe et al., 2004:162, Shneiderman and Plaisant, 2004:610).

Tangible User Interfaces is an area where interaction happens in a physical environment. It transforms the digital world into a physical environment. For example, Augmented reality superimposes digital information over physical objects (Shneiderman and Plaisant, 2004:215, Dix et al., 2004:723).

Attentive environments and transparent computing utilises users' biometrics as a trigger for interaction, i.e. gestures and expressions. Emotions and physical movements are interpreted by a computer, which triggers an interaction that the user is looking for (Aghajan et al., 2009:50).

The Workaday World focuses on everyday work environment related artefacts and how people relate or interact with them. It attempts to understand and use the relationship of technology and information (Moran and Anderson, 1990, Sengers et al., 2006).

The Internet of Things (IoT) focuses on embedding objects with information. These 'smart objects' can interconnect and interact with other objects and users (Amores et al.).

These different paradigms present forms of how interaction designers think about their users and the way the system might relate to them (Rogers et al., 2011). However, this does not mean that a system has to be limited or based merely on one of these paradigms. A system should provide the pathway for a goal to be achieved through a set of tasks to achieve that goal (Dix et al., 2004:323). From our particular research approach, the main user goal is the acquisition of knowledge from a wide range of OCH sources. An interface informs users with a particular set of operations that can be performed on the system. Added to this, such operations can be adapted according to the levels of information need of the users. For example, an interaction based on a *formalised need* might require fine tuning tools unlike a *visceral need* user where his/her interaction might be more superficial (e.g. a tourist might do a visceral need question regarding an archaeological site, while a specialist will most likely perform a formalised one). Having considered information retrieval systems as an interactive approach, this study contends that TUIs can provide a more meaningful pathway for exploring and acquiring knowledge in OCH.

This next section introduces particular approaches of how TUIs can be used to promote interaction processes with a system through approaches that embrace human cognition. Even though TUIs have received very little attention in the literature compared to traditional or GUIs, there is yet a growing corpus of research that presents a positive pathway promoting their use.

4.2 Tangible User Interfaces

From the perspective of User Interface (UI) design, there have been different approaches to study how interactivity might happen and how it can be facilitated. HCI focuses on task completion or achieving particular user goals based on different interaction methods (Dix et al., 2004:5). It has been argued that commonly TUIs are task oriented, limiting the extendibility and adaptability to further tasks than the ones that they were designed for (Chung, 2010:13, Rogers et al., 2007, Bossy, 2013, Cuendet and Dillenbourg, 2013). Moreover, the physicality that TUIs have to offer complicates distribution and adaptation for applications beyond their original design. Nevertheless, they have shown to be particular beneficial for easing interaction problems, not only with GUIs, but also with non-graspable systems (e.g. haptic, multi-user systems). In the Web context, little attention has been paid to explain how Web-distributed TUI users behave when setting their own systems at home. The current or most popular method of communication on the Web has always primarily been through GUIs. This has created a paradigm of how we are supposed to work on the Web. However, many technologies are being incorporated to the Web that breaks the GUI barrier. The IoT is an example that shows how physical objects can produce interactive responses and interact between users and other objects. TUIs certainly provide a new and promising paradigm where interaction can be facilitated through human cognition. The CH environment is surrounded by a significant proportion of material (physical) culture. One of the main issues with the OCH is the disconnection to that original physical object displayed in the museums and libraries. Transferring the physical properties of the *four-walled* museum or library through TUIs, can help narrowing the bridge in between the OCH and the traditional CH sector. Moreover, from a pedagogic perspective, constructivist theory has promoted the idea of best learning by interacting with the learning material or 'learning by doing'. This next section presents those particular interactive benefits that assist users with interactive design principles and how those particular approaches might ease the interaction between OCH and users through TUIs.

4.2.1 Design Principles (Human Computer Interaction) in TUI Context

Different technologies have allowed interaction designers to focus on factors that go beyond the efficiency of a system. Currently, there is a wider concern to understand hedonic elements that are meant to increase the usability and engagement with a system. Rogers et al, (2011) indicate that interaction designers are also concerned about systems that can be: enjoyable, fun, entertaining, helpful, motivating, aesthetically pleasing and emotionally fulfilling, among others. There are some design principles that can promote such emotions such as: visibility, feedback, and constraints (Norman, 2002).

Visibility

When a system is designed, it will include specific elements that engage directly with the user. For this reason, the tools used need to communicate visually to the user what is he/she supposed to do with it. Don Norman (2002) refers to this as "natural signals". Users relate their intended action and the actual use of a tool as well as the difference between those tools through cognition and intellect. From a Psychology approach, there is a constant visual communication between users (people) and objects (e.g. interactive systems) that allows them to understand how they are meant to use things (Norman, 2002:8, Shneiderman and Plaisant, 2004:214).

Feedback

In the real world, every action produces a reaction. If a glass is dropped, it is expected to fall. If it hits the ground, then is anticipated to bounce or break. From human experience, we expect those reactions to happen. Nevertheless, if such reactions do not occur, it produces a reasoning conflict on the user. Feedback consists of letting the user know that an action has happened or is taking place (Rogers et al., 2011: 21). The essence of feedback is providing information about their actions, status and perhaps even reason of why errors might happened (Shneiderman and Plaisant, 2004). There are several ways how this might be presented, such as *haptic,* audio and visual responses.

Mapping

Mapping occurs when we relate two or more things. It is related to the feedback or reaction that occurs as a result of manipulating an object. Through natural mapping, people can understand straight away the meaning of the tools implemented. This can be applied by using physical analogies and cultural standard (Norman, 2002: 23). Natural mappings are represented by biological or cultural paradigms. This is to say that if for instance, a person wants to increase the heat intensity of an oven or a thermostat, there is a common convention that implies that more intensity (e.g. adding value -with a knob-) means more heat (Figure 18 Left). This mapping occurs under a representative dimension or scale of additive (or subtractive) value. Nevertheless, not all mappings work on a dimension where value is added or subtracted. For example aesthetic values cannot be measured in more or less (e.g. more aesthetic, less creative). In this case, the dimension of an object has to be substituted for another object or dimension to produce such mapping (Norman, 2002:23, Erlandson, 2010:100). Changing the HUE of the TV or activating the city drive on a car does not represent a change in a dimensional value since there is no such thing as more or less HUE or more or less city drive. To enable mapping, the dimension has to be substituted for other objects or dimensions instead (Erlandson, 2010:100, Carroll, 1991:28). Substitutive dimensions replace the additive dimension and allow our brain to replace those values (Figure 18 Right). This being said, representing mappings on additive dimension commonly work under sequential processes, while substitutive dimensions work by replacing the state of the dimension (Carroll, 1991:28). Natural mappings are deeply influenced by life and cultural experience. Many widely recognised symbols can affect the efficacy of the mapping process. For example there are symbols such as the play on music devices that are widely recognised. Arguably, interacting with objects can be simplified when they provide good visibility of the possible actions by taking advantage of natural mappings. Nevertheless, when using natural mappings, designers need to be aware of individual cultural or semantic differences that are not shared globally since it might lead to errors or frustration when the system is used (Erlandson, 2010:103).

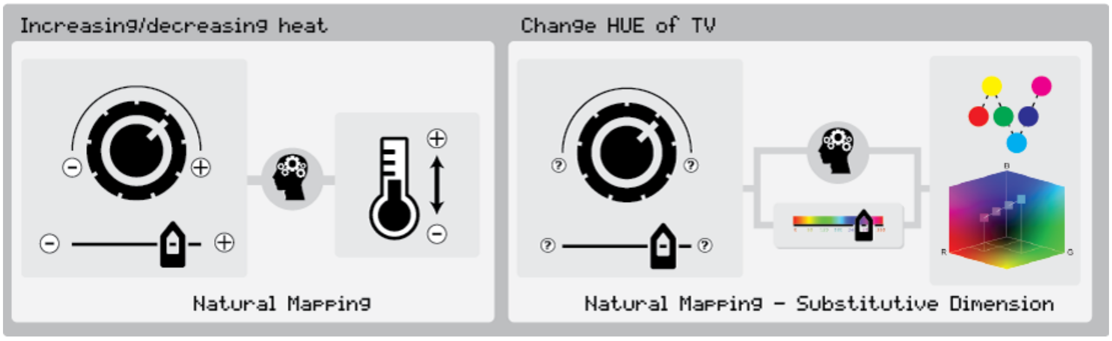


Figure 18. Natural mappings.

Affordances

It is easier for users to interact with interactive interfaces when the tools implemented communicate what they are capable of doing. The term *affordance* refers to the perception of how a tool might be used. They indicate how the tool is supposed to be used. This is an essential part of the visual communication process between tools and users. A user should be able to know what to do just by looking at the object (Norman, 2002: 9). Complex tools might require some sort of instructions such as manuals or labels. Nevertheless, simple tools or objects should be able to work on their own. If a simple tool needs to be explained, this generally means that the design is failing.

Moreover, when implementing tools in a system, they should invite users to use them. There are several factors that affect how affordances are communicated to users. In this sense, it is argued that TUIs provide a positive environment to show the real and perceived affordances of the tools (Shaer and Hornecker, 2010: 63). In the TUI world, affordances are no longer related only to the action they represent. The affordances in TUIs also include perspectives from Ergonomics that study how people might handle the objects differently depending on their material, colour, shape, etc.

Pyfos – Token and Constrains Paradigm (TAC)

Pyfo is the name given to objects that take part in the interaction of TUIs. This term was designed to encompass how objects are constructed and capable of describing their different affordances. In this case, a Pyfo can contain or be built by other pyfos (Shaer et al., 2004). Graspable pyfos are commonly presented as ***tokens***. They usually represent specific interactions or sets of information. Tokens are directly related to their physical representation that might help identifying their interactive affordances, while their ergonomics might present how it is supposed to be manipulated. These affordances of objects are also delimited by another pyfo called ***constraints***. In TUIs, physical *constraints* impede many of the actions that can be physically performed. Moreover, *constrains* are considered as an *affordance*. Constrains can be implemented as part of a sequence of actions that need to be performed in order to carry out a specific task or action (Shaer and Hornecker, 2010). These two pyfos create the TAC (Token and Constraints) paradigm where a *token* is related to one or more *constraints.* The pyfos in the TAC paradigm help relating digital information and interaction with physical objects. Moreover, *mapping* elements will also assist in communicating the affordances of the objects when combined with the TAC paradigm (Ullmer et al., 2003).

Physical Objects (Embodiment)

Many people find difficult to explain something or to convey a message. They can use metaphors or analogies as communication tools. For this reason the use of metaphors has been thoroughly used in interaction design. By integrating knowledge that we are acquainted with, *metaphors* can be used to describe conceptual models based on objects or activities (Rogers et al., 2011: 55). As said before, the use of metaphors in interaction design has to be used for the purpose of *mapping* concepts and not to replace the physical object that is represented in the interactive system. In the case of TUIs and embodied interaction, the objects support that cognitive process since physical objects help linking the abstract and the concrete (Bakker et al., 2012). By integrating embodiment and metaphors, interactive processes can be promoted and facilitated. Metaphors help understanding the digital meaning of the object linking real world actions with actions performed on the interface. Moreover, embodiment spatial awareness linked to sensory-motor interactions, relate the space to the task that is performed (Hurtienne and Israel, 2007). By taking advantage of sensorimotor knowledge and experience, interaction can be facilitated. From the time we are born, we start interacting with the world and building a set or classifications of how we interact with objects and give them different levels of meaning; thus becoming part of our human language. Because of this, we agree with Shaer and Hornecker (2010) in that it is of high relevance to investigate and find how human behaviour can be integrated into interactive systems so they can become part of our everyday life. By embodying interaction, users can expand their *perceptual intelligence* or *conceptual inference.* This is to say that embodied interaction can ease epistemic activities, thus making them more comprehensible.

Within HCI, TUIs present an interactive paradigm where a wider range of opportunities can be exploited. An example of this is the capability of different levels of digital inclusion to be applied into interactive interfaces. Nevertheless, it has to be considered that there is a wide range of paradigms to explore, from which the most appropriate methods for the OM can be identified.

4.3 The Benefits that TUIs can bring to OCH

Recently, many CH organisations have been focusing on how different audiences gain knowledge through their content (Hooper-Greenhill, 2004). It has been argued that learners need to engage actively with educational content. This has commonly been done through hands-on activities and participatory displays and exhibitions. Many of these approaches are deeply linked to constructivist learning. Constructivist learning allows learners to construct meaning through activities that engage both, mid and body (Henriques, 1990). User-learners are looking for spaces within CH where they can be able to learn in their own terms (Kelly, 2006). Nevertheless, it seems that many CH organisations have not successfully provide such environment, especially online. Many CH organisations such as museums are failing to provide learners an environment where they can produce their own narrative thus making them feel scared to do so (Roberts et al., 1997:140). CH organisations are looking on how to widen their audiences (Kawashima, 2006, Travers et al., 2006) and empowering their visitors by allowing them to appropriate their content and in their own terms (Keene et al., 2008). For this, the Web can enhance learning experiences. In OCH learning environments are placed outside of CH traditional environments. Participatory environments in OCH can facilitate dialogue between CH organisations and their audiences. In OCH, users should be provided with tools that they can be able to adopt as their own so they can use them in their own way (Liu, 2009). Many of the literature criticises the use of technology in CH since they have been merely copies of what is being presented through the texts (Franckel et al., 2010). Arguably, OCH is a space for exploring knowledge through a wide variety of interfaces, especially through TUIs that can provide deeper engagement and better learning curve (Sylla et al., 2012, Xie, 2008). Moreover, TUIs can promote further exploration of OCH data collections by allowing users to use their intuitive skills (Wakkary et al., 2009).

4.3.1 TUIs and Data Exploration: A Constructivist Approach

There is a deep connection in between TUIs as tools for engagement due to the benefits to metacognitive processes provided by embodied interaction. Moreover, it has also been noted that physical objects play a big role in constructivist learning (Papert, 1993, Sylla et al., 2012). Therefore, it can be said that TUIs as physical tools have a big role to play in constructivist environments. If users are to explore data from OCH, the tools need to reflect such learning environments where they can construct and produce meaning. When exploring OCH knowledge, it is very difficult to scope what information is in there in order to ask a question. When visitors walk into libraries looking for books, they require information about where a particular book might be and how to find it. If such information is not accessible to the visitors, they will have to search *helplessly* around the library hoping to find the particular book they are looking for. In a very similar manner, looking into the OCH *black box* might be getting empty result queries. It has been proposed that uses can make sense of what is contained by providing some navigational categories such as: content, structure, context, features, limitations, connections, trends, anomalies, navigation, reminders, processes, reassurance and reduced helplessness(Rücker et al., 2011:41). Such factors can be integrated into an interface that assists users to explore the data. Moreover, TUIs can boost performance by providing the required thought structure through a wide range of physical activities (Mayes and de Freitas, 2004). CH organisations need to provide tools that can provide through their affordances the information of how to explore their content and what they might be able to find. Moreover, they can use XML to add an invisible intelligence layer to describe objects and offer users to the opportunity to contribute to a vocabulary of tags (Rücker et al., 2011:36). These vocabularies of tags can be further implemented in information systems as part of a navigational strategy. Previous research has indicated that presenting too much information can cause anxiety and dysfunction, as well as presenting to little information (Case, 2002:100). It is very common for student to experience anxiety when they visit a library for the first time due to information overload (Mellon, 1986, Case, 2002:118). Sometimes, users might also avoid knowing what information is available to reduce anxiety as well (Maslow, 1963:122). Anxiety and stress is more likely to be produced in activities where users cannot leave the activities such as students. Moreover, it was noted that in libraries, students were threatened by the size, not knowing how or where to begin a search and their knowledge about where to find things (Mellon, 1986). Many CH organisation such a libraries are facing this problem where technology has added another level of complexity. The exploratory system should assist users to provide that ***reduced helplessness*** in order for them to engage and keep on engaging with OCH content. On first glance, users can determine what collections they are exploring, how big the collection is but more specifically if what they are exploring or browsing can help answering their question. User-learners will attempt to separate what they "need to know" from what they "would like to know"; they undergo through a filtering and omitting process of the information presented (Case, 2002:98). Computers are intermediaries to the information (Marchionini, 2008), computer interaction is not *natural* but TUIs can offer more *natural interactions* through its embodied interaction that promotes metacognitive processes through a constructivist approach.

4.4 Conclusion

When exploring OCH information, users can feel overwhelmed with the amount of information and concepts to deal with. To engage with information, the UIs will require the user to understand how the interface works, make sense of the information that can be retrieved, and make the connections between the different concepts in OCH. The vast majority of GUIs work with representations or metaphors of the tools. TUIs provide direct manipulation where the affordances are provided through real world metaphors. Users will apply their prior knowledge of physical experiences in the real world, also known as sensory-motor skills and relate them to make sense of the different affordances of the interactive tools. This can help alleviate distractions from the task of querying OCH.

Beyond the interaction benefits, TUIs can also promote the conceptual engagement with the content in OCH. On one hand, epistemic actions can aid users to explore and experiment with different combinations of concepts. Particularly with first time users, it can alleviate the stress of engaging with the information for the first time, such as in the visceral and conscious state of need of information (discussed in Chapter 3). The process of 'learning by doing' invites users to explore different interactions where they learn particular patterns and processes in which their searches might be more meaningful for what they are looking for. Coupled with the constructivist perspective, users can still further isolate interaction and thinking patters through the different faceted searches. On the other hand, TUIs can aid users to visually structure their thoughts to process complex queries. Pragmatic actions in TUI environments can help users to make sense of the data fields and concepts used in a search.

Interacting with a computer is not natural for users. TUIs attempt to make that interaction more natural by grounding the different affordances of the tools on the different sensory-motor skills that users learned by experiencing the real world. This perceptual intelligence can communicate what a system is meant to do. To engage with OCH information, the system should provide the technical and conceptual tools to add meaning to the different layers of complexity behind OCH. The different research areas of computer interaction provide a wider understanding of the interaction that can take place beyond the screen, and the interaction principles describe the different processes in which affordances can be conveyed to users.

In order to select the specific interaction paradigms (such as TUIs, Ubicomp, etc.) and required principles to construct a OCH exploration tool, it is required to identify which of these are beneficial to a particular group. The next chapter will discuss the methods that can be followed for designing such TUIs.

Chapter 5: Research Framework

This chapter presents a research framework that describes the processes implemented in this research to produce a TUI to query Europeana data on the Web. The framework was produced from an interdisciplinary understanding that considers [1] the role of Design and Creative Industries (e.g. Graphic Design, Illustration) and [2] UI and HCI workflows (e.g. software design). The role of this framework is to provide an understanding of the methodological workflows commonly carried out in interaction design (software, UI) and the process in which they can be integrated to Design (problem solving) methods. Under this approach, Design approaches can help identifying further factors such as the hedonic or social properties of an interactive system, that are not usually considered within common interaction design methods. In addition, it also important to consider that there are many HCI/Interaction Design companies who work with a specific setting, process and understanding of how interaction processes should take place. Nevertheless, this interdisciplinary research framework aims to provide the structure and common ground towards a holistic understanding of how users might interact with OCH knowledge and how to integrate such understanding into an interaction design process in that considers the role of Creative Industries as well as HCI specialist views together.

5.1 Creating Pathways to Design and Evaluate Tangible User Interfaces for OCH

OCH users can vary from University academics who already have knowledge about what might be held within the collections, but do not know how to query and access such information, to teenagers who might just be looking to explore the collections as a leisure activity. While on one hand users will try to find information that is meaningful for them, there is also the need to engage with the information in a meaningful way. That said, to explore information on the Web, users will most likely begin their exploration by querying through services such as Google Search (Case, 2002, Kay et al., 2015, Rasmussen et al., 2010). In the case of OCH, producing such queries requires users to express what they want to find by producing complex combinations of concepts and logic embedded in the data model, ontology and knowledgebase. Users will begin to query from a particular perspective based on their different *Levels of Need of Information* presented (discussed in Chapter3). The research framework in this thesis includes a user centric method that informs the interaction design process how users might engage with de diverse elements of the knowledge-base in Europeana's OCH repository. While it has been acknowledged that users will need meaning to engage with or produce knowledge, the user centred design method can aid understanding users' *Need of Information* and their particular behaviours when engaging with the knowledge and integrate such understandings to the ineraciton design methodology

The interaction design methodology implemented has been produced from two main overarching methodologies: [1] the SA&D/HCI methodology produced by Zhang et al. (2004) (See Appendix A) which integrates human interaction procedures commonly linked to HCI and [2] a Problem Solving methodology (Munari, 2004). The fact that TUIs work 'in the real world', detaches them from common HCI methodologies, where Munari's problem solving process can enable an understanding of the hedonic properties of the interactive system. The production of this research framework should enable CH organisation to include such processes to their workflows while still enabling external or internal developers to follow the standard process established on their own discipline (e.g. HCI, software design). Finally, after the implementation of the interaction design method, the research framework introduces an evaluation process which will indicate the effectiveness of the system. While the system enables the querying production through OCH Europeana's data by producing complex combinations of concepts, such evaluation can showcase the diverse user experiences and usability factors that might affect the way in which users will produce their queries and generate complex combinations of data elements for further iterations.

5.1.1 Research Framework General Plan

This research framework can be viewed into two main overarching workflows: [1] interaction design a-priori methods and [2] a-posteriori methods. The first will aim to understand and contextualise how an interactive system or the particular interaction methods will be more suitable for the specific information engagement environment, such as working from home or within an installation in a museum, as well as the *Needs of Information* of the users. The second focuses on how the implementation of the a-priori findings within a interaction design methodology that incorporates HCI, Software Development practices as well as problem solving through Design. Such methodological integration should enable the merge of diverse disciplines (e.g. HCI, Graphic Design, Product Design) and industries (e.g. Software Development, IT services, Heritage Sector) to collaborate in an integrated workflow. The research framework followed these steps:

Querying in OCH Through a TUI

This thesis explored how to facilitate users with tools to query OCH data. The thesis originates from the idea that there is plenty of usable knowledge in OCH that remains unusable due to the lack of tools to query it (See Chapter 3).

A-priori. UX/UCD Experiment

The first stage (a-priori) implements a User Experience experiment from a user centred design approach (UX/UCD) to understand how user might attempt to query such data if they had the available tools to do so (see Chapter 6). For this, the experiment recruited participants from the CH sector. This way participants will have (some) knowledge of what is being contained in Europeana's repository, but might not know how to query it. Therefore, the experiment focuses on their understanding of how they will query from their own perspective. This experiment takes place similarly to a think aloud experiments, where users are given a set of queries with particular Boolean logic and data fields. This experiment is aided with a set of stickers that represent possible tools that could be implemented in the system to promote the use of space and the use of physical objects. Users behaviours (e.g. memorability, query construction), and the way stickers were used (e.g. sequence, most used, groupings) were annotated in a database and queried. This analysis provided a general understanding of how users might want to start and organise their queries, as well as the tools that they most likely require to query OCH data through Europeana.

A-posteriori. SA&D/HCI-M

Analysis and Design

This is followed by the integrated interaction design and problem-solving methodology (SA&D/HCI-M) a-posteriori in which users' behaviours are analysed and implemented in the Design phase of the SA&D/HCI methodology. The a-priori phase provides a wide range of settings of the particular data fields and logic operators and the way in which users will most likely use them (e.g. grouping, query construction), and are incorporated into the design of the pyfos.

Problem Solving

The Analysis and Design phases are extended through the Problem-Solving methodology (see Appendix 2) where holistic questions such as distribution, construction, materials and physical properties of the system are introduced as part of the Analysis and Design phases of the methodology. Although, TUIO has been introduced as one of the few standards towards the development of TUIs, this phase also questions the possible factors that might hinder the use of the interface. For this reason, this research framework introduced a DIY approach, which while it was not evaluated, it serves the purpose of providing a system and methodology that can be further implemented by a wide range of actors in the OCH ecosystem.

There are factors that might hinder TUIs adoption, such as the complexity to build the system or the compatibility of technologies that facilitate distribution. Although this research is not testing the distribution capabilities, it still acknowledges the requirements within the OCH ecosystem to preserve the openness and technologic standards in which OCH is built upon. For example, being an interface that works on the Web, the interface has to be distributed. This means that users will have to build the interactive system themselves. To encourage the adoption of the technology, the prototype in this research used off the shelf-technology and used paper-based pyfos. Munari's methodology considers the hedonic properties of using a paper-based object as a pyfo, as opposite of using wooden or plastic ones that can produce a sturdy sensation. The complexity behind TUIs has forced developers to commonly build and text this kind of systems in a lab-based environment.

Implementation

Once the interactive tools are designed, the system in finalised and tested in the Implementation phase. In this phase, the diverse physical properties and affordances (e.g. pyfos, Token and Constrain) are introduced.

Evaluation

The Evaluation phase takes place by presenting users with diverse queries to analyse users will be able to produce complex queries that implement a wide range of data fields through the system. In addition, the evaluation phase will explore users' querying process as a free exploratory tool. The evaluation process will inform about the strengths and weaknesses of the system. Evaluation methods commonly include Usability measurements, which indicate the performance of the tool. In addition, Use Experience (UX) will indicate the human responses such as experiential, hedonic and emotional responses toward the system. The scoring of the evaluation is carried out through Usability and Engagement methodologies where task completion rate and timing will be measured. In addition, participants are surveyed and catalogued based on their digital, interests and work backgrounds, among others, to further contextualise (see Appendix 4) Usability and Engagement patterns.

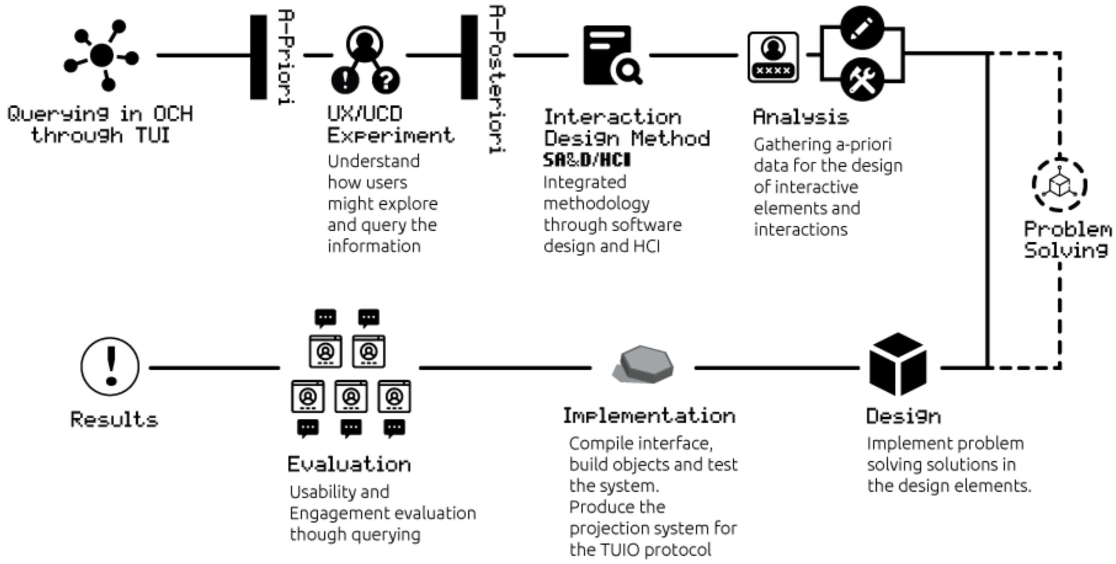


Figure 19. Research Framework Overview

5.2 Conclusion

Due to the late development of TUIs, there is yet no current standard methodology to develop them. The same can be said about its evaluation process. New trends such as UX are attempting to enhance the understanding of human behaviour in HCI evaluations. The reason for this is two-fold. Firstly, because the HCI community has paid more attention to the performance of the tools, commonly distributed as software, thus overlooking many important human factors such as emotional and multi-sensory experiences. In contrast, Design (e.g. Graphic and Product Design) focuses on the implementation and purpose of a specific design object, where in many cases, undertaking approaches such as Speculative Design within Critical Design practices (Malpass, 2017, Dunne, 1999), where the design of objects are hypothesised beyond their current paradigm. It will not only explore how the system can be used (HCI), but will also explore the possibility of the system becoming part of an everyday household, while considering the role that the function of objects has in relation to the space where they are used. Although Critical Design practices focus on more theoretical approaches, it serves as creative solution to present and merge such methodologies for the development of interactive tools to query OCH.

The extended methodology used in this thesis for the development of the TUI prototype, incorporates a combination of (a) software design and HCI methodology (SA&D/HCI), with

(b) a problem-solving methodology. The final procedural methodology follows standard software design methodologies, allowing the creation of tools (or pyfos in the case of TUIs) that can fully embrace human cognition thus facilitate the production of queries in OCH.

Chapter 6: Querying in OCH Through TUIs. Introducing Europeana as an OCH Case Study.

The previous chapter presented the research framework for this research. This research originates from the idea that there is a lack of tools that can empower users to produce complex queries that embrace the convolution behind Ontologies, data fields, Boolean logic and specialist knowledge, among others that build upon the OCH knowledgebase. OCH users are presented with the opportunity to engage with data, information within a knowledge base (e.g. Europeana or British Museum repositories). This chapter describes in depth how 'information' (data, meaning and information) is organised and structured through the Europeana Data Model (EDM) and the different ontological approaches in which the data model is constructed. Information such as 'who created a particular object', 'which CH organisation holds it', and 'its date of creation', are some of the sets of information used to structure the data model.

This chapter also investigates the capabilities of Europeana as a source of OCH information, as part of the analysis phase on the SA&D/HCI methodology. Its aim is to introduce what sets of 'information' will be required by the users. Based on the API data fields, this chapter presents the UCD experiment where users express their strategies of exploration through a wire-framing prototype (stickers experiment). The UCD experiment gathered people from CH with different digital literacy backgrounds. The results of the UCD are further analysed through summary statistics such as frequency count. In addition, the behaviours were coded based on spatial and enjoyment perception, among others. The UCD participatory design experiment provided an introduction to participants to the different data fields available in the API, and how users might like to use them. The experiment encouraged users to use operators, data fields, and spatial awareness to distribute those objects on a surface arranging in a cognitive way different query facets.

This chapter pays special attention to the way in which SPARQL queries relate to the API calls. Europeana's API allow users to query particular aggregated field and facets. Nevertheless, it is important to mention that users can still query particular data field elements from the data model such as dc:title, or dc:creator from the Dublin Core ontology. These data fields provide the semantic structure to contextualise the queries that users want to produce.

6.1 An Overview of Europeana as a Case Study

Europeana is an organisation that gathers information across Europe. It is estimated that only 10% of Europe's Cultural Heritage (CH) has been digitised. Nevertheless, not all of it is accessible or reusable. Europeana provides access to 12% of that available digitised heritage. This means that Europeana provides access to 0.012% of all Europe's digitised CH. This number might look small, but it represents millions of records in Linked Data format ready to be explored. However, to access this content, it requires the user to understand complex sets of information related to the collections held in Europeana and technologies that are not commonly accessible to the general public. For this reason, Europeana provides an API where developers can produce interfaces that ease the engagement process with its 'information'.

Chapter 3 described the information complexity within Online Cultural Heritage (OCH). Online Cultural Heritage (OCH) is built of information that describes a wide range of artefacts and knowledge across different CH groups and organisations. This can vary from particular archaeological findings to historic texts and paintings. Many of this information is now represented and depicted digitally through information systems and a wide range of interfaces that offer users the opportunity to explore what CH organisations have in their collections (e.g. information retrieval systems). Although OCH visitors might want to perform searches from an expert perspective such as researchers (formalised need of information), this research focuses in producing an interactive system for general users that would address question from a visceral level of need of information. This means that users will be looking for introductory sets of information and the opportunity to explore freely.

Many of the previous discussed research about how users navigate and engage with information has been commonly carried out where the information is being held (e.g. libraries, museums). Therefore, this presents a gap in the literature that aims to explain how these processes are carried out from users' houses and personal environments. This is particularly relevant since according to studies from Johnson et al., (2010) and a report of how the Web is being used in the UK from Great Britain's Department for Business (2009), there is an increase of people that are using the Web to search for information. When users search for information about CH, their search will commonly start from outside those CH organisations that provide the information and are commonly unaware of the different services in the OCH ecosystem that were used by the end user to finally reach their organisation's information (Kay et al., 2015, Rowlands et al., 2008).

CH organisations commonly contain their particular decision-making perspective which is reflected in the way the knowledge (information) is managed (Lippincott, 2005). When searching on the Web, users search across thousands of gigabits of indexed websites, which tends to clash against common approaches taken by CH organisations that fail to provide access to content beyond what is held within their boundaries. Nevertheless, Semantic Web technologies challenge such traditional organisational structure. OCH content is not tied to a particular organisation and it interoperability is merely tied to a particular data structure or ontology defined for a particular purpose. For example, the British Museum is deeply tied to CIDOC-CRM and shares a data structure particularly designed to manage museum collections among others (British Museum, 2015, British Museum, 2014, CIDOC, 2013). In contrast Europeana has gathered a wider range of data models including Dublin Core, SKOS and FOAF and produced their own data model called the Europeana Data Model (EDM). They needed to produce their own data model, because they needed to describe collections that did not commonly fitted the Dublin Core data model, which was designed with libraries in mind (Isaac, 2013, DCMI, 2013). These examples provide evidence of how Linked Data can join knowledge from organisations that not necessarily work together. Moreover, the way in which users are currently searching on the Web suggests that their queries are no longer tied to organisational boundaries (Kay et al., 2015, Blackwood, 2014).

There are two main factors that might affect users' engagement with OCH repositories: [1] The digital literacy required to query the content and [2] Information Overload. Many OCH organisations provide direct access to their Linked Data through a SPARQL Endpoint. The SPARQL Endpoint is a service that allows queries using the SPARQL language and retrieve the data in many machine readable formats, particularly RDF (W3C, 2011). Despite that there are other query languages, the vast majority are not considered user friendly (W3C, 2011, DuCharme, 2013:295). Users have to produce long and complex lines of code that they need to learn before even starting to ask the question. Furthermore, SPARQL queries have to be scripted in a *Tell-and-Ask* fashion. This means that users require to have prior knowledge of what is contained in the repository and what is it that they want to ask for before a query is typed into the system (Allemang and Hendler, 2011:63). This is not only an issue about the objects in the collection, but also about the data model itself. For example, if a user is looking for the painting "*Testa di Toro*" by Picasso that is held by Cultura Italia. The user will have to know at least one of the data fields to ask the query. For example:

Property	**Value**	**Resource (URI)**
Has title	Testa di Toro	http://purl.org/dc/terms/title
Was created by	Picasso	http://purl.org/dc/terms/creator
Is held by	Cultura Italia	http://purl.org/dc/terms/isPartOf

Table 2. Data Objects

In addition, a SPARQL query that lists the titles of objects that have been created by Pablo Picasso might look like this:

```
PREFIX dc: <http://purl.org/dc/elements/1.1/>

SELECT ?title

WHERE {

    ?objectInfo dc:title ?title .

    ?objectInfo dc:creator "Picasso, Pablo"  .

}
```

Figure 20. SPARQL Example of Search for Picasso Objects

Many of these Ontology elements have been integrated to Europeana's API to facilitate the use of data fields in the queries without knowing or using SPARQL. For example, the API data field 'title' will gather data from the Dublin Core data fields dc:title and dcterm:alternative. Nevertheless, despite the simplification of the syntax, users will still have to learn the diverse data fields (and query language) used in the API to call particular elements of the EDM. This research aims to explore how a TUI can facilitate the production of queries that embrace all these diverse data fields, logic and concepts.

It can be said that there are three main factors that increase the complexity of the engagement with information in OCH: The technologic complexity such as knowing SPARQL in order to produce queries, the technical complexity to produce different combination of SPARQL scripts and the conceptual complexity to relate the different data fields, concepts and topics when producing queries. For this reason, an UIs can promote better understanding and use of the complexity behind the information systems through innovative interactive tools (Sumner, 2005).

Information retrieval systems, discussed in Chapter 3, offer the tools to extract information (or knowledge) from this kind of repositories. Nevertheless, they still lack the intuitiveness and commonly place another layer in between the interface and the user. It was also discussed in Chapter 2 that organisations have been investigating how to promote such interactions and engagement with the information. That being said, many of the prototypes and applications limit themselves to the GUI paradigm. Only a few scenarios such as the ones presented in the literature review in Chapter 3 presented the benefits of using TUIs for repository or database (and knowledge base) exploration through queries. Nevertheless, there is still a lack of adoption of TUIs, which can be attributed to the novelty of the research field as well as the difficulty to construct and extend them for other tasks. In response to this, the research framework identifies these problems and extends the interaction design process by considering the construction and user adoption of the TUI. In addition, this problem-solving approach recognizes the need to provide a system that can be distributed across the Web. The distribution of TUIs on the Web can be promoted by providing the tools to build a system that can be further extended (e.g. printable, re-designable pyfos), and provide the way for users and organisations to extend the tools to perform questions on the system.

This research aimed to offer an interactive environment that promotes flow and encourages navigation through computer vision technology. Computer vision allows OnObject interaction by adding markers to physical objects or to produce objects (e.g. printed pyfos) that can be used as interactive elements. Through OnObject interaction, the system can use pyfos that represent a particular query or combination of data fields (e.g. where, creator, what) that can assist users in their navigational strategy. The Token and Constraints paradigm (TAC) can also help users in their information seeking process. The TAC paradigm can provide users with the tools to formulate complex questions by combining series of pyfos. Through the TAC paradigm, users can select different levels of complexity for their queries. For example, a query that involves a place (where) and an object (what) will involve two pyfos. To represent more complex or extended questions that can include, places, persons, objects and different dates, which can be represented through a sequence of pyfos with their corresponding affordances. Through natural mapping and embodied cognition, users can identify the different correlations between the objects. In this case the particular information elements that conform a query.

It was previously discussed that Europeana has carried out some research and hackathons to encourage interaction designers to produce tools to explore Europeana's repository (see Chapter 3). It was further discussed that all of them were fixed to GUIs. Despite of the innovative data visualisation approaches, most of the interfaces lack novel interaction approaches to query data or to grasp the conceptual complexity of OCH. For this reason, this was an identified research gap that needs to be addressed.

When searching through large sets of knowledge, users might feel (helplessly) lost. The TUI paradigm can also help to provide a higher state of flow to encourage users to explore. The use of OnObject interaction can help users to facet and join different data model elements and operators as part of their querying process. In addition, the physical affordances of the tools convey the different actions that can be performed in the system (e.g. using Boolean operators, navigating timeline, clearing results). Due to the type of information held in OCH, it might be expected that users will need to be exposed to whole sets of knowledge. Users will have to start their search for knowledge by querying a statement of what is it that they are looking for. For this reason, it can be argued that is common to offer users with form fields to input their search (Figure 22). Nevertheless, it has been found that the vast majority of users will need a lot of information about a few topics (Rasmussen et al., 2010). This is also reflected in the way users arrive to Europeana or to many of the individual organisations' websites. The vast majority of searches commonly originate from single entry form searches such as Wikipedia and Google (Blackwood, 2014, Rasmussen et al., 2010, Kay et al., 2015).

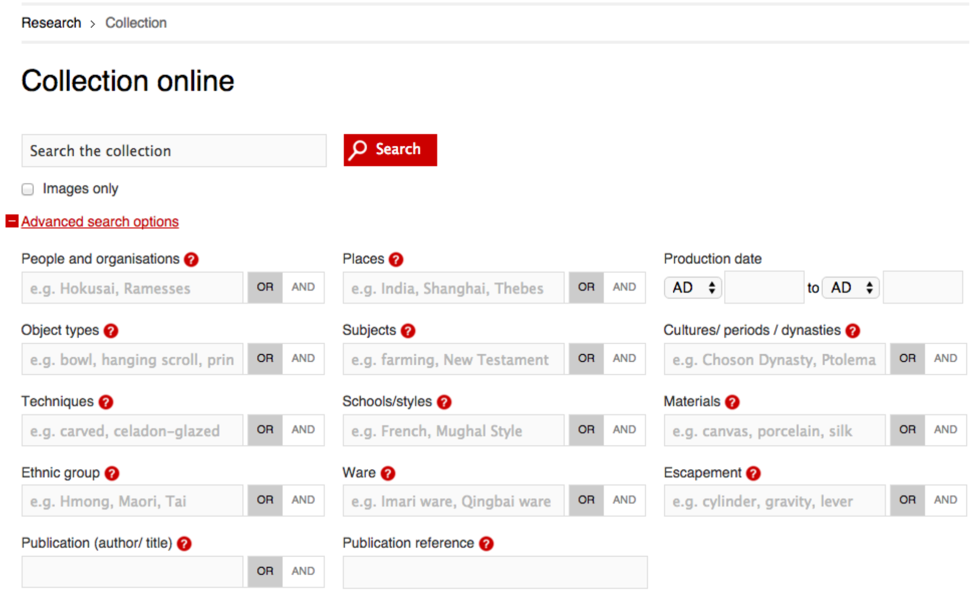


Figure 21. British Museum Search

Figure 22. Top: Europeana Portal Search Field

The above examples present the attempts from the British Museum and Europeana to provide access to their database through form fields (British Museum, 2014, Europeana, 2013). The fact that these groups are looking for novel ways to interact with their different knowledge elements (data/information) beyond traditional form fields, reflects on the lack of engagement that users have with these particular approaches (Europeana, 2014). Research by Blackwood (2014) and Rasmussen et al. (2010) who work for Europeana, indicates that the vast majority of users that access OCH are commonly re-directed from external links. Europeana among many other CH organisations are trying to figure out how to bring those users so they can use their services as a primary source. OCH as a social-machine should take advantage of being part of a network composed of communities with a wide range of skills. For example, many organisations have produced the Engagement with Information through Application Program Interfaces (API) to access their content. There is a wide range of services that can be provided through the use of APIs. For example, Google has developed around 57 different APIs to provide services that range from Youtube analytics to font management (Google, 2015a). In the same way, there are alternative APIs for Social Media (e.g. Pinterest, Facebook, Instagram), Marketplaces (e.g. Ebay, Forsquare) or to produce Mashups (Trendsmap, Poligraph). In addition, Europeana has also produced an API to allow access to their content. This API is also embedded to their search console (Figure 22 - Bottom), where users can also perform their queries (Europeana, 2013). Nevertheless, due to the fact that this is part of the API, it will return machine-friendly results such as results in JSON (Figure 23). There is still many information that will be difficult to make sense of, such as reading spatial parameters such as latitude or longitude (edmPlaceLatitude:[48.85341]) or *namespaces* and their descriptors (edmConcept:http://vocab.getty.edu/aat/300010797). Furthermore, users will also require being familiar with the data model structure and content in order for them to perform a meaningful query.

Figure 23. Europeana API Console

Europeana's API is a REST API where queries are performed very similarly to a browser accessing a page in a Web server using HTTP protocol (StackOverflow, 2014, Hunter, 2013). This is to say, that queries are performed under the principle of GET, POST, PUT, PATCH and

DELETE. This principle makes it easier to develop applications and access data from a wide range of data services such a Europeana because it can be implemented with a wide range of Web languages such as JavaScript, HTML and XML. In the case of Europeana, their data is stored under an Apache Solr instance that requires to extract data through a syntax called Apache Lucene (Europeana, 2013). This is to say that the HTTP GET request has to be performed under this syntax language. For example, a search that looks for anything that says Pablo Picasso might look like this:

http://www.europeana.eu/api/v2/search.json?wskey=xxxx&query="Pablo+Picasso"

Although this query might look simple, it can start becoming complicated to the user when more complex elements are included in the query. For example, a search that looks for things **made** by Picasso **located** in France might look like this:

http://www.europeana.eu/api/v2/search.json?wskey=xxxx&query=WHO%3Apicasso&qf=COUNTRY%3Afrance&start=1&rows=24&profile=standard

Therefore, as queries become more specific, the HTTP request becomes longer and more difficult to understand. But the underlying principle relies on users producing such HTTP request that will further return JSON data that can be rendered in a display such as a Web browser. Furthermore, since queries are performed under Apache Lucene, there is still a wide range of *Term Modifiers* and *Booleans* that can be annexed to the query (Apache Software Foundation, 2013). Apache Lucene Term Modifiers can work in a similar way to Google's Search Operators and Punctuation (Google, 2015b). Nevertheless, the complexity behind any modifier still requires users to learn them as well as the particular data model modifiers. Therefore, Europeana has integrated these elements in their API Console interface (Figure 22 – Bottom) thus allowing users to implement them in the HTTP request through the interface. This approach is still limited and is difficult to perform more complex queries. Moreover, it has been identified that there is a gap in the literature where there is no understanding of how users might relate the concepts of the knowledge stored. Moreover, Europeana has hosted several hackathons where they have developed around 152 interfaces, prototypes and query tools that use their API. Nevertheless, all of them have been designed as GUIs (Europeana, 2014, Europeana, 2016a).

6.2 From Data to Query. Querying with Europeana's API.

Building ontologies for CH organisations depend heavily on how the organisation might understand a particular topic. Ontologies provide the mental model for different people to talk about the same topic thus assimilate different points of view (Allemang and Hendler, 2011:15). Therefore, in CH some ontology models have been created to describe their particular collections. Ontologies turn into a central topic, due to the fact that it is through them that conceptual complexity is incorporated and latter deployed through Linked Data. In the case of Europeana, they have integrated a wide range of ontologies that describe particular elements held in the collections of the organisations they host (Table 3). Embracing these ontologies, allows the organisations to provide a wide-ranging description of what is being presented in the catalogue. As a result, some objects of the ontology can be used to describe a title and creator by using Dublin Core (dc:title, dc:creator). Subsequently, the creator of the artefact can show which other creators have influenced him/her, or any siblings by using FOAF to describe those relationships (foaf:knows). Each ontology will describe very specific relationships or terms that enable organisations to explain to a third party the different concepts that make a particular object. For this reason, Europeana has attempted to include and extend many of the ontologies to promote the aggregation of content to their data model. For example, Europeana can describe a place (edm:place) where an event occurred (edm:event). This place and event is related (dc:relation) to an object with a title (dc:title). For instance, the event of creating *Bullfight* by Picasso, took place (edm:happenedAt) Madrid, Spain.

Ontology Abbreviation	Name of Ontology	Description of the Ontology
DC/DC Terms	Dublin Core	Ontology aimed to describe library content.
ORE	Open Archives Institute	Ontology aimed on aggregated Web content.
FOAF	Friend of a Friend	Describes people and their social relationship in a Linked Data format.
SKOS	Simple Knowledge Organisation System	Designed to integrate vocabularies and provide context for them through thesauri and

		taxonomy based
RDAU	Resource Description & Access	Focuses on library content aiming on merging content into a library card like system.
CC	Creative Commons	Describes copyright information about the content.
EDM	Europeana Data Model	Provides an integration schema for other organisations to map their data in Europeana.

Table 3. Data Models Used in Europeana

Before the Web, or the Semantic Web, users had to ask their questions directly to the organisation that hosted the information. This is the reason why there is a large increase in the recent research literature that incorporates querying processes across diverse organisations such as the ones in the CH sector. According to Blackwood (2014) and Kay et al. (2015), the vast majority of people searching for CH information on the Web will start their queries in sites such as Google or Wikipedia. This suggests that users are aware or have a basic understanding of what is the purpose of a search box on a browser. Blackwood (2014) indicated that users like to search from a generic site that includes a broader set of results, such as browsing content or by faceted navigation. To this date, it is very unlikely that users will perform complex queries. Research by Spink and Zimmer (2008), Nielsen (2001), Jansen et al. (1998), Jansen and Spink (2006) and iProspect (2006, 2004), noted that the vast majority of people who use search services such as Google Search, will limit themselves in between one or two keywords, thus expecting the service to guess what they are looking for. Furthermore, if they cannot find what they are looking for, they will add more keywords to refine their search in the same search engine (iProspect, 2006). Research by Fry et al. (2008:267), indicated that many academic users know that Google Search will not give relevant results, but still kept on using it due to its simplicity. Users are very loyal to the search engine that they use, thus hope that by adding more terms the query will produce better returns, trying to adapt to that specific system, as reported by iProspect (2006, 2004). In addition, although according to Spink et al. (2008, 2001) and Wang et al. (2003) there is very little understanding of why Web searchers show this sense of loyalty to a search engine or why they will continue using such tool, research by Fallows (2005) indicated that majority of users will quickly produce the habit of using one or two search engines. For this reason, under the current user behaviour, it is very unlikely that they will provide an extensive and complex query since it is how they learned how to use the Web.

The Web has evolved and the use of Semantic Web content has become a more powerful tool to search and retrieve what users are actually looking for. For example, Google's attempt to attach meaning to users' queries has been through their Hummingbird Project. Users perform queries as if they were having a conversation, such as 'Who painted the *Mona Lisa?*' The algorithm will attempt to understand the meaning, thus increase the accuracy of the results. Hummingbird will attempt to contextualise the results based on a disambiguation of the words used (Sullivan, 2013). In addition, Google's Knowledge Graph can further segment the results returned and contextualise them better (Bradley, 2013). Nevertheless, regardless of how the disambiguation or meaning of the query is attached, it is the algorithms that attach the meaning instead of the user.

The ontologies try to describe the world to machines and other people. The concepts described in the ontologies will be tied to the particular social and scientific background of the people who created the ontology. It is very unlikely that general end users will be aware of the different ontologies or terminology used to query OCH information. While Hummingbird and Google Knowledge Graph partially automate this process, in OCH to produce an understanding of the linked information that encompass the knowledge, users need to grasp what is it that they are asking. In this case, Europeana's aggregated fields can help assimilate to some extent the complexity behind the different elements of the data model and still empower the user to understand what sort of information is being queried. In scenarios where users approach OCH knowledge and use a query system for the first time, these approaches can reduce the technical and technologic complexity behind dealing with extensive sets of data fields and new interaction systems. Despite that the organisational boundaries will fade in the OCH ecosystem, users will still embed their particular backgrounds into their querying processes. This is to say that librarians will embed their own particular behaviour when describing the particular record, as well as museum curators, and this has reflected in how users see and engage with the knowledge and information of each organisation (Trant, 2009, Robinson, 2012). OCH technologies provide the infrastructure to integrate the knowledge from the diverse CH organisations. Once a first layer of engagement by facilitating the technologies (e.g. SPARQL, Data Model) has been facilitated, a second layer of engagement takes place where users can conceptualise and make sense of the complexity of what is being described, particularly if the same item is described in a different way.

The ways in which collections are recorded and presented will affect how the different information is linked, especially considering the different ontologies available in the CH sector. For example, querying through different data models such as Dublin Core (DC) or CIDOC CRM has to be approached into different conceptual ways, because DC has focused on describing objects and CIDOC CRM to describe events. Although other data models such as EDM can still built on top and integrate them, users might still bring their own conceptual paradigms in their search. Due to the novelty of the Semantic Web and particularly its use within the CH sector, there is not yet a way for users to convey the conceptual complexity through their queries. By easing the technical and technologic complexity (1st layer of engagement, see next section) through the use of TUIs, users can focus on the conceptual elements (2nd layer of engagement), which will inform how users might understand and approach OCH information. It can be acknowledged that there will still be technical and technologic factors that will be assessed as part a standard tool performance analysis, but what remains central is how users can understand the complexity and extent of the collections within OCH, without limiting themselves to a single CH organisation. The diverse range of ontologies that structure the Semantic Web offer an unseized opportunity by general users to explore and query the knowledge in new ways. Nevertheless, the semantic information in OCH requires to be embraced in it whole complexity, and the vast majority of current tools that populate the Web are not fully empowering users to add meaning to their querying processes. When users query OCH knowledge, that engagement should focus primarily on the information and its content, and not on the tools or technical elements that structure the metadata. Nevertheless, the data models will still play an essential role behind how queries should be made or structured. Data models such as EDM or CIDOC CRM, will still differ in the way the knowledge is bein described, even though they might share many of their classes and properties.

In the case of the EDM, Europeana has developed their data model sharing many of the properties of CIDOC CRM and Dublin Core. Particular OCH specialists will be acquainted to a particular ontological approach, while for general users the use of the data fields has to be provided through an interface that acts as translator for them. The interface will add meaning to what and how queries are produced. Nevertheless, despite the integration process followed by Europeana, and the attempt to merge knowledge across OCH, users will still have to figure out how information is represented across the different data fields. The a-priori phase (UX/UCD Experiment) of the research framework devised three main factors to integrate EDM knowledge: [1] Identify the essential data fields and operators, [2] identify the particular query processes and how they translate within the API and [3] how these queries are constructed with the use of their API language and user's concept making process.

Europeana has attempted to integrate OCH content within few metadata parameters that can be approached either from an object or event centric approach. This is to say that the object centric approach will start from a particular described object (edm:ProvidedCHO), thus linking to all its particular features (classes) such as the creator of the object (dc:creator), the location where it was made (dcterms:created) or its title (dcterms:title). In this approach, EDM provides a set of classes to refine the knowledge about the object. These are: an Agent to describe a person or an organisation, an Event to describe when an event took place, a Place that describes a particular geographical entity, Timespan to describe dates and an entity Concept from SKOS to arrange the knowledge and provide a classification scheme (e.g. human, female). Alternatively, the event centric approach is aimed to describe objects that were used in events (Figure 24). This is particularly relevant when the objects had a particular role in historic events. For this, EDM focuses on three main properties: when was the object involved in the event (edm:wasPresentAt), where did the event took place (edm:happenedAt) and when did it happen (edm:occurredAt). Even though both approaches are fully supported, Europeana promotes the use of object centred approaches to enhance its compatibility and provide consistency for basic search functions (Isaac, 2013:17). This is where conceptual factors are to be considered. It can be said that museum users with CIDOC experience will approach exploration through a more event centred perspective while library people might have in mind a more object-oriented approach. Nevertheless, Europeana's logs and surveys indicate that the vast majority of their visitors will look for objects and particular artists and not events (Neil, 2013, Blackwood, 2014), thus suggesting that providing an object oriented approach, as suggested might offer a more effective pathway.

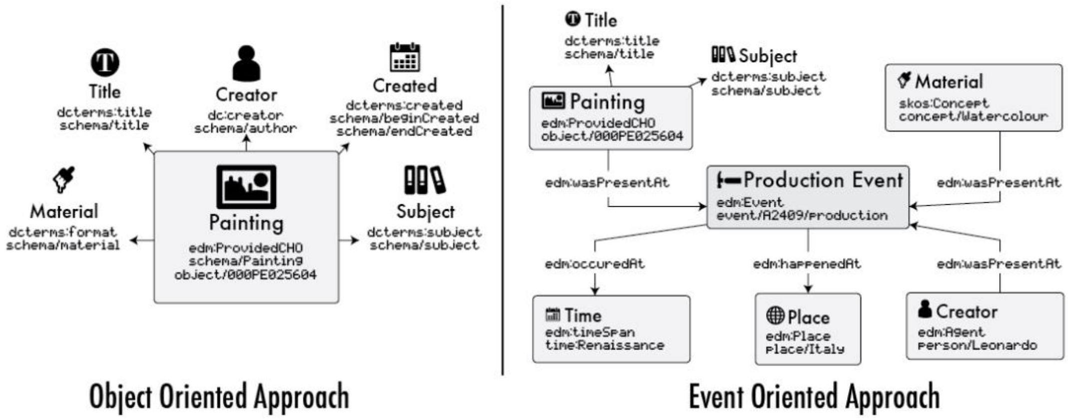


Figure 24. Object Oriented Vs. Event Oriented Approach (Isaac, 2013)

When working with an object-oriented approach, users should recognise particular properties such as creators, materials, places, subjects and title among others that will help describing the particular a particular thing. This can vary from archaeological artefacts to user generated content such as 3D files and even taxonomies. Users can either query through a SPARQL Endpoint or through an interface through their REST API. For this, there is a translation to Apache Lucene query language where the final query will be produced. The API can retrieve the data in JSON or on Open Search Specification. Nevertheless, working with JSON format can be a more direct option when working on JavaScript languages. To produce a query, it is necessary to insert a request with a particular syntax. The query syntax is the translation of the EDM and its ontologies into Apache Lucene syntax. Likewise, the API requests are the way into linking particular features (sets of information) that describe the object. The queries are commonly structured by two parameters: Query (query) where a specific syntax is used to call particular data fields of the EDM. The second one, is a Facet Filtering Query (qf), used to add a second variable to the query. These second option can be used to refine the question being made. For example, if a user wants to find images of London, the main query is London and the facet filtering retrieve records that indicate that their type is an image. Users can enter many different facets to refine their query as necessary. Moreover, the query can also specify particular ontological term that describes any of their query elements such as proxy_dc_title. Table 4 presents some of the data fields used in the API. These parameters can be used either for query or filtering query.

API Field Search	Description and data field(s)
who	Creator or contributor of a particular thing
where	Name of a a location
COUNTRY	Objects that come from an organisation in a particular country
YEAR	Dates
pl_wgs84_pos_lat pl_wgs84_pos_long	Latitude and longitude
timestamp_created timestamp_update	ISO 8601 format date for objects created or updated on a particular date.
TYPE	Looks for a particular object format (e.g. image, text, 3D)
language	Will select records described in a particular language
rights	Access objects with specific copyright. (e.g. CC-BY-SA, BY-NC)
UGC	Find content that is user generated
subject	Find objects by subject (e.g. female, body, war)
Title	Look for a title object

Table 4. Europeana General Field Terms (Europeana, 2013)

The data fields used on the API refer to a particular field in the data model. This means that users can also produce queries that call for those specific elements of the different ontologies used in the EDM, such as Dublin Core, SKOS or FOAF. For example:

API Field Search	EDM Field	Description
Cultural Heritage Objects Descriptions [edm:providedCHO**]**		

proxy_dc_date	dc:date	Date of creation of something
proxy_dc_creator	dc:creator	Person attributed with creation of thing
proxy_dc_subject	dc:subject	Topic of the resource
proxy_dc_title	dc:title	The name given to the resource
People, Individuals or Groups responsible for an action [edm:Agent**]**		
ag_foaf_name	foaf:name	Name of a person
ag_skos_prefLabel	skos:prefLabel	The preferred reference word
ag_edm_isRelatedTo	edm:isRelatedTo	The role of the agent in relation to a thing
ag_rdagr2_gender	rdaGr2:gender	Gender of the individual
Place or location [edm:Place**]**		
pl_skos_prefLabel	skos:prefLabel	Preferred reference word to name place
pl_dcterms_isPartOf	dcterms:isPartOf	The resource is included to something
pl_owl_sameAs	owl:sameAs	Links two different records as same
Time or duration of a record [edm:TimeSpan**]**		
ts_edm_begin	edm:begin	Date when event started
ts_dcterms_isPartOf	dcterms:isPartOf	Concept of where the event took place
Information about the Web representation of the record [edm:WebResource**]**		
wr_dc_rights	dc:rights	Copyright information about resource
wr_ebucore_height	ebucore:height	Digital height of resource
wr_edm_codecName	edm:codecName	Codec format used in video file
dc:source	wr_dc_source	Information where to find object
Table 5. API fields to query EDM fields (Europeana, 2013, DCMI, 2013)		

Users can use any of the given API search terms to call the specific term of the different data models. Nevertheless, although this can aid users to be more specific on their queries, it will also complicate the search process and will require to be more specific in the information input in the query. If users are to implement each individual term of the EDM, Dublin Core or any other ontology, they will have to be aware of them and the specific term used in the record to store the information.

Europeana provided a way to extend the reach of the queries of the API through aggregated fields. These aggregated fields are terms in the Apache Lucene syntax that will gather several fields of the data model and combine them together. Users can then decide to use these aggregated fields or any of the specific fields, such as the ones from Table 5. The aggregated fields can reduce the accuracy of the queries since it will be combining different terms, but it will help users to retrieve general records of the collections, which then can be further filtered when they carry on constructing their query.

Api Data Field	Description	Combined API fields from the EDM model (Table 5)
title	Title of the object	proxy_dc_title proxy_dcterms_alternative
who	Person or provider of the specific record	proxy_dc_creator proxy_dc_contributor ag_skos_prefLabel
what	Topic or lexical representation of a record	proxy_dc_type proxy_dc_subject proxy_dc_format cc_skos_prefLabel cc_skos_broaderLabel
when	Time related fields	ts_skos_prefLabel proxy_dc_coverage proxy_dcterms_created proxy_dcterms_temporal proxy_dc_date proxy_dc_subject

where	Fields used to describe a place	proxy_dc_coverage proxy_dcterms_spatial proxy_dc_subject pl_skos_prefLabel

Table 6. Aggregated Fields

Beside the terms used in the queries, Apache Lucene syntax used in the API calls can also use a wide range of operators. For example, to search objects dated ranged particular dates, a combination of two years is necessary. For this, the keyword TO is added to embed a range to it. For example, a query that will look for things dated between the years 1500 to 1600 will look like this:

… query=YEAR:[1500+TO+1600]

Using a range can help users to link different fields together, such as dates or alphabetical searches. Using operators can help users to extend the reach of their queries or to be more specific about the specific record that they want to retrieve. Nevertheless, by adding more operators and terms can also increase the mental complexity which will take a toll on the users. Some of the available operators are presented in the table below:

Type	Operator Syntax	Syntax Example
Boolean	AND, OR, NOT	WHERE:France+NOT+Germany
Range	TO	YEAR:[1500+TO+1600]
Date math.	NOW, DAY, WEEK, HOUR, YEAR	timestamp_created:[2003-01-01T00:00:00+TO+NOW-1DAY]

Table 7. Apache Lucene Operators in Europeana API

Through a combination of operators, math and data fields, users can combine and extract the particular data fields required for their query. There are over 100 different API data fields that have been translated from the EDM. For example dc:title becomes title. As a result, this extensive list of API data parameters has been produced to extend users' queries to any level. The examples provided before are instances of the translation from EDM to the API. Nevertheless, those API parameters, can provide an introduction for users to understand how the ontologies help shaping the knowledge and information behind EDM. Although users cannot perform a full semantic search as the ones carried out through an SPARQL Endpoint, they can engage with the specificity of the data fields backed up by the EDM. This traces back to the original question of how general users can add meaning to OCH information through their queries. The compilation of the different semantic properties of the EDM through the API properties can provide a way for users to understand how information is described across OCH. Users who arrive in a visceral or conscious state of need of information can benefit from such integration of information to empower a basic understanding of what is behind OCH but cannot grasp yet the whole complexity behind the semantic technologies that make OCH work. Nevertheless, the various API fields and operators can offer the mental structure to develop the precision and accuracy of what is being asked in a way that is still meaningful for them. There is a further list of data fields and operators that can be retrieved from Europeana's API documentation (Europeana, 2013).

Europeana as an OCH organisation presents a wide range of opportunities to evaluate how the querying process of OCH concepts can take place. They hold a wide range of data fields strongly supported by an ontology. There are billions of records that are ready to be queried through their API.

6.3 Conclusion

Europeana is an organisation which that has gathered billions of records across the wide range of CH sectors. In addition, they enable access to structured data through the API that allows designers to experiment with different ways of exploring, querying and visualising those digital collections. Despite that Europeana hold the largest digital collection of Europe in a single space, the vast majority of searches will originate from outside Europeana (e.g. Google). In addition, users are currently limiting themselves to a short amount of query elements, which commonly lack any logic operators and/or that aim to implement any kind of semantic or conceptual interpretation. Europeana provides access to a wide range of elements of the ontology through the API as well as the use of aggregated fields which combine a range of data fields. By using aggregated fields, users can originate their queries from a holistic approach, thus querying from larger concepts and further implement specific ontology fields if required.

When querying Europeana knowledge, users will be carrying out such process by using these technical elements, as well as their conceptual understanding of what is held in the collections and how they are organised or curated. The next section provides an understanding how these processes take place from a technical and a conceptual perspective (1^{st} and 2^{nd} layer of engagement). This research aims to produce a TUI that can facilitate users the tools to produce complex queries that embrace both layers of engagement, thus embracing the diverse information sets and the conceptual logic that comprises OCH knowledge.

Chapter 7: Methodology A-Priori. Developing a TUI to Query Europeana.

This chapter discusses in depth the methodology carried out in the development and design for the TUI to query Europeana. It begins by introducing the finalised interface and the way in which users engage through the technical and conceptual layers. While on one hand, the TUI facilitates the production of complex queries by using a data fields and logic operators, on the other, once that technical complexity has been reduced, it enables users to implement multiple concepts and elements in a single query.

This chapter will introduce the a-priori section methodology of the research framework where at first it was necessary to identify what the diverse type of users that query the Web and the specific behaviours in which they do it. The a priori methodology implements a User Centred Design (UCD) study which focuses primarily on the conceptual elements and the processes in which users organise their query strategies. This is followed by the analysis and discussion of the study, which discusses how such querying strategies are linked to Europeana's structured data.

7.1 Presentation of a Tangible User Interface to Query Europeana

The TUI prototype works by a combination of OnObject interactions and the TAC paradigm on an interactive table. Users place pyfos that represent a specific data field, grouped with Boolean logic. When placing the pyfo on the surface, the interface highlights its space and shows an input field where users can input text with a keyboard. In addition, there are two main display elements where one of them shows the number of results held by a particular organisation and the kind of object it is. Furthermore, the upper part of the display table will present the results with a thumbnail and title of the item.

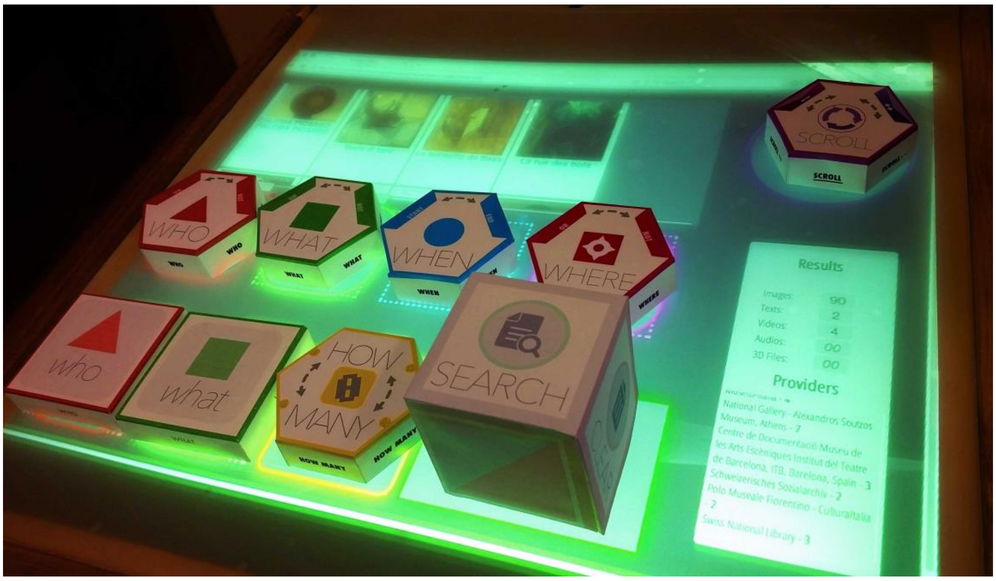


Figure 25. Table-top TUI prototype

One of the most common ways to query data with GUIs has been through input forms. Users have to type a specific question query element in a form field. Alternatively, visitors can use a SPARQL endpoint or API to type such query. These approaches will require users [1] to know what is it that they are looking for beforehand, [2] know the data structure, and [3] know the querying language required by the system. These present diverse technical complexities before the user even begins to contemplate the conceptual complexity stored within the data model. The TUI system facilitates the production of complex queries, through a first layer of engagement (Figure 27), where the technological approach is carried out. Users perform their questions by replacing syntax query sequences such as the Apache Lucene or SPARQL through the use of pyfos. For example, a pyfo can represent the WHO data field which encompasses dc:creator and other data fields that depict an author of a particular record. When the pyfo is placed on the table, the user can then type the particular creator such as ‘Picasso’ by using a keyboard. The two Boolean operators OR and NOT are each embedded to one face of the pyfo. This way, by rotating the pyfo to that side, users can activate it and attach it to the query. By repeating this process, each one of the pyfos can isolate a group of concepts and help users to produce their faceted queries (Figure 26). Even though users will still require to type the particular term (e.g. Picasso, Paris), the fiducial activates and embeds the syntax and operators of the query (Figure 27). These pyfos offer a combination of physical elements with their particular affordances where interactions with the computer will take place.

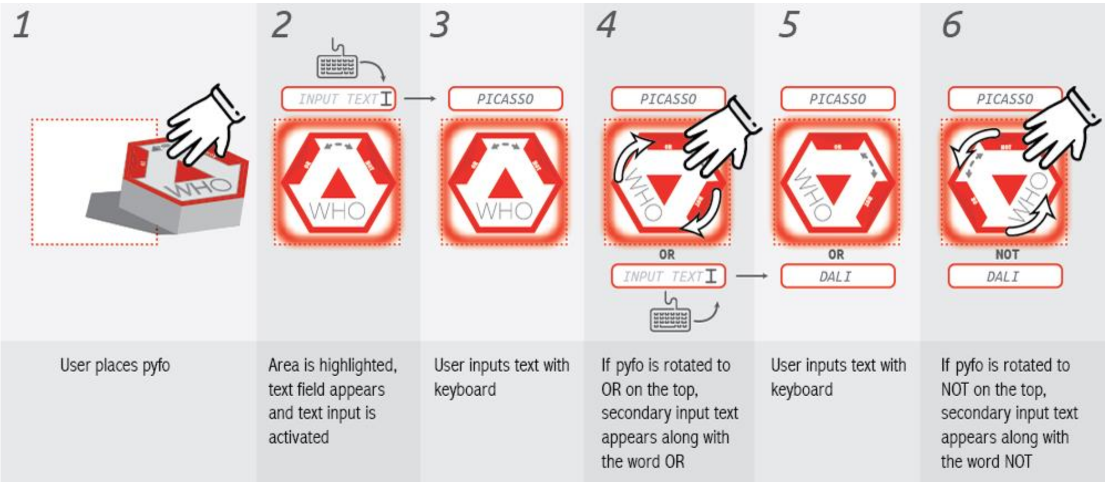


Figure 26. Example of how the pyfos are used

Once a physical object is associated with a particular computational interaction (e.g. pressing enter key, scrolling text) it can be further referred as a Pyfo or Token under the Token and Constrain paradigm (TAC). Pyfos are embedded with specific interactive actions to be performed in the interface. This process is carried out in a single stage, unlike GUI interfaces, where the user first needs to engage with a peripheral to activate the tool. This is also known as Direct Manipulation (see Chapter 4), where interactive processes can be simplified thus enabling users to focus on the exploratory tasks instead of dispersing their attention toward peripherals.

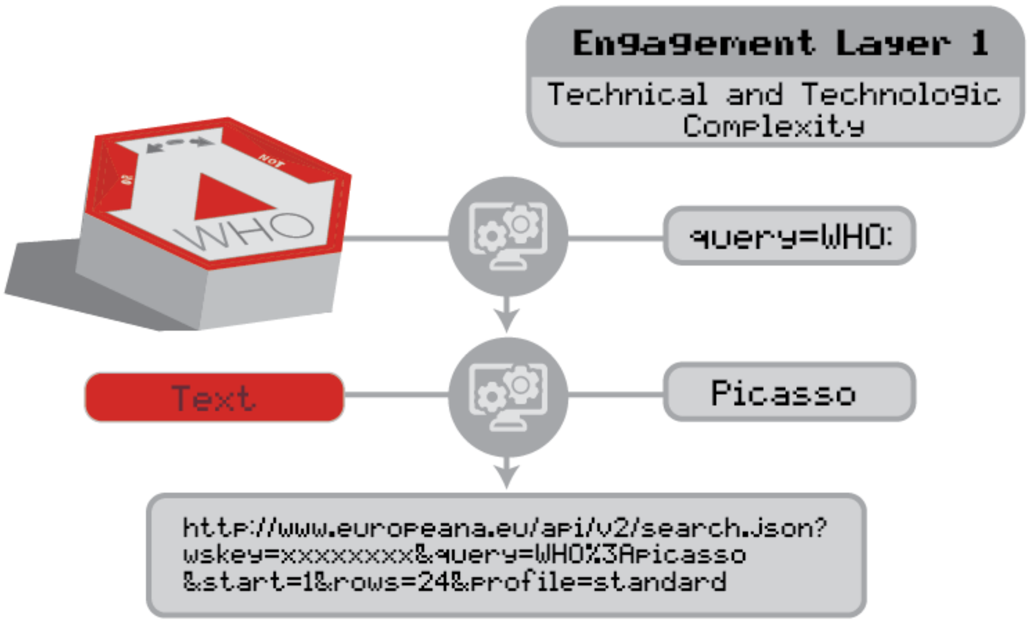


Figure 27. Engagement Layer 1 – Technical and Technologic Complexity

On a second layer or engagement or stage (Figure 28), users are encouraged to engage with the knowledge complexity through the combination and direct manipulation of diverse data and information elements with the aid of these physical tools. The use of Booleans and the combination of different fiducial elements present users with the opportunity to produce lengthy and complex queries. This is promoted through the affordances of the objects, their direct manipulation and embodied cognition. Moreover, as discussed on Chapter 4, Human Interaction paradigms such as Ubiquitous and Transparent Computing, the computer can become invisible behind an everyday object such as a table, thus removing associated stress elements related to interacting with a new interactive system. As a result, the prototype adopts these particular benefits provided by TUIs and provides an alternative way to query OCH information thus enabling users to produce complex queries and further explore content commonly difficult to engage due to its technologic complexity.

A primary research objective was to provide a way to query OCH information in a way that embraced such complexity. OCH is currently difficult to query for general users, due to that same complexity behind the data models and extent of the knowledge covered. In addition, due to de fact that general users are unaware of Semantic Web technologies, it will be very unlikely that they will understand the extent of how Linked Data can integrate the information and data from different organisations across the OCH. Providing users with the opportunity to navigate and explore to a metadata level can bring many benefits such as their capacity to expand the complexity and the specificity of their queries. By facilitating the conceptual understanding of the information structure and data fields, it can reduce the overwhelming feeling of information overload. Therefore, in the prototype, Pyfos have the role of alleviating the complexity and providing the conceptual structure for users.

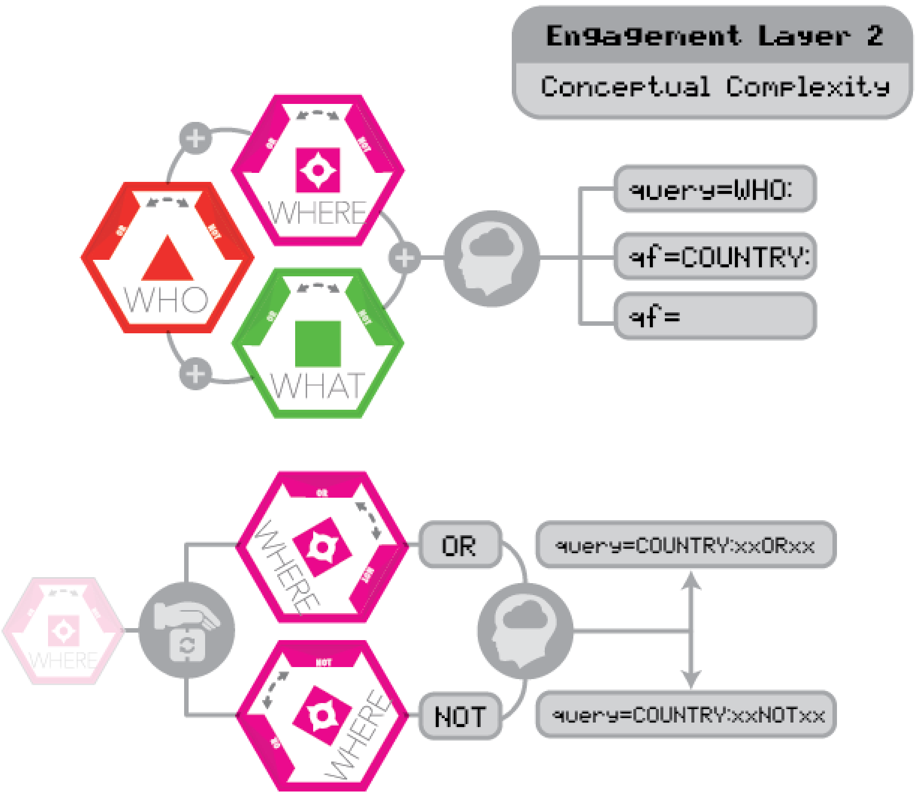


Figure 28. Engagement Layer 2 - Conceptual

The objective is to integrate the technologic and conceptual complexity within a single space where users from a wide range of digital literacy levels can perform queries that will make use of the benefits behind OCH. Therefore, it is of high relevance to provide a tool that assists users in understanding concepts and helps them to feedback those new understandings back to the interface to expand their queries. For this reason, eliminating the computer, thus presenting it as a TUI Tabletop system can be the way forward. When users place the tokens/pyfos on the surface, the display indicates that that particular object has been activated thus allowing users to input the text of that particular element. The main objective of performing actions on an interactive surface through physical objects, motivate users to explore the different functions of the system without producing stressful reactions. An interface should also invite users to produce what can be considered a mistake. From a constructivist perspective, users should learn by doing, thus encouraging them to make mistakes (Papert, 1993). In this case the term mistake is not viewed as a negative thing but a positive learning process that need to be embraced correctly so users will not get frustrated. By allowing users to eliminate technical errors such as clicking in incorrect places or misspelling query syntaxes, users can focus primarily on the different combinations that might or might not return some results. Since the objective of this research is to understand how to facilitate people to produce complex queries , it is of high relevance to understand how users might attempt to extract OCH knowledge before it is even displayed or further manipulated in a visualisation interface.

7.2 Research Framework. A-Priori Methodology

7.2.1 Understanding User Behaviour through UX/UCD Approach

The UX/UCD was carried out before designing the prototype to find out the way in which users currently search on the Web and how they might search OCH if they had the tools required to do so. Commonly, these kinds of assessments take place through think aloud exercises. As described by Ramey (2006), Xu et al. (2008), Ciocca et al. (2012), and Dix et al. (2004:343), observational approaches are common in HCI to gain insights of how people use a system. Beside think aloud observation, another way to obtain information is through a UX approaches such as wire-framing where participants are presented with rough sketches of common or possible interaction elements (Allen and Chudley, 2012). The benefits of wire framing are that the experiment in itself generates a visual track of annotations and actions that the observer can directly annotate to keep track.

Based on UX wire framing exercises, the UX/UCD experiment in this methodology uses stickers to offer pre-designed tools to provide the annotation of a particular action that is meant to take place. In this case, by providing different data fields to be wire framed on a surface, participants can embrace spatial cognition (Figure 29). These UX approaches have been usually carried out by providing Web browser depictions to users, which can restrict users' cognitive processes to go beyond the tools that they already know. The main objective of this UX/UCD experiment was to provide participants an opportunity to express their need of information and agency aided by wire framing tools. In addition, users can also segment and pace their thinking processes by distributing those tools on a surface.

UX/UCD experiments are commonly presented to participants through scenarios or tasks that emulate or trigger the action that should be carried out in the interface (Dix et al., 2004:200, Allen and Chudley, 2012). These scenarios take place through tasks that are given to the participants. For example, the data models behind OCH, such as EDM, can note the difference between things (what/ dc_subject) and people (who/dc_creator)(See Chapter 6). Therefore, users can communicate such concepts through their queries. As mentioned before, although participants who work within the CH sector have already been exposed to the way in which these organisations manage and catalogue their information, they do not necessarily know the specific fields of the data model, or even be aware that such ontology exists. For this reason, participants are presented with diverse tasks designed to trigger the use of conceptual elements. For example, participants can be asked to search for '*images of Picasso the painter (person) but not his paintings (Picassos)'*, or *'18th century Europeana objects from France'.* These queries aim to explore different ways in which users might begin to produce a query or explore the concepts on their own. To trigger participants' own cognitive processes, they are presented with these tasks under a minimal guided environment as defined by Piaget (2013, 1952). For this, participants are provided with a wide range of tools as stickers (see Appendix B for the categories), and asked to solve the query (Figure 29, also see Chapter 6). During this process, it was explained to participants that these tools can help them to produce their queries since they depict the possible actions that can take place either by engaging with the data model (e.g. selecting an aggregated field or implementing boolean logic), interacting with results (e.g. navigating through images), selecting particular areas of interest (e.g. exploring archaeological sites or touristic areas) and performing standard interaction and tangible interaction actions (e.g. touch, type, scroll).

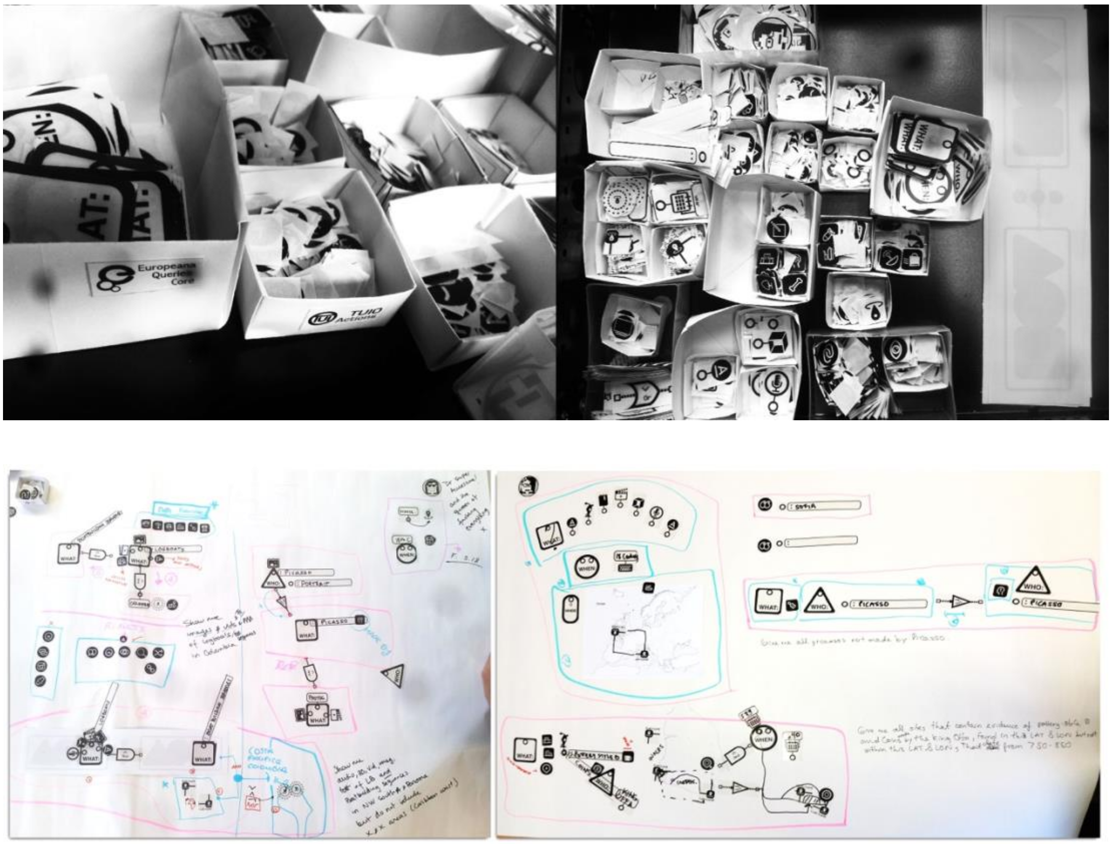


Figure 29. Sticker-Tools for UX/UCD Experiment placed on a surface

To obtain a deeper understanding of why certain groups of participants might behave in a particular way, a survey was carried out. This survey was designed to identify personal characteristics such as the digital generation, literacy level and their relation with different CH organisations. Appendix B presents the questions asked to participants. The survey depicted their current behaviours when searching the Web and provided a deeper understanding of their behaviour and actions in the UX/UCD experiment. Furthermore, a relational database was produced (Appendix B) to record the information from this experiment. This was done using Microsoft Access (Figure 30, also see Appendix A) and the final database contained the collected qualitative and quantitative data so it could be further analysed.

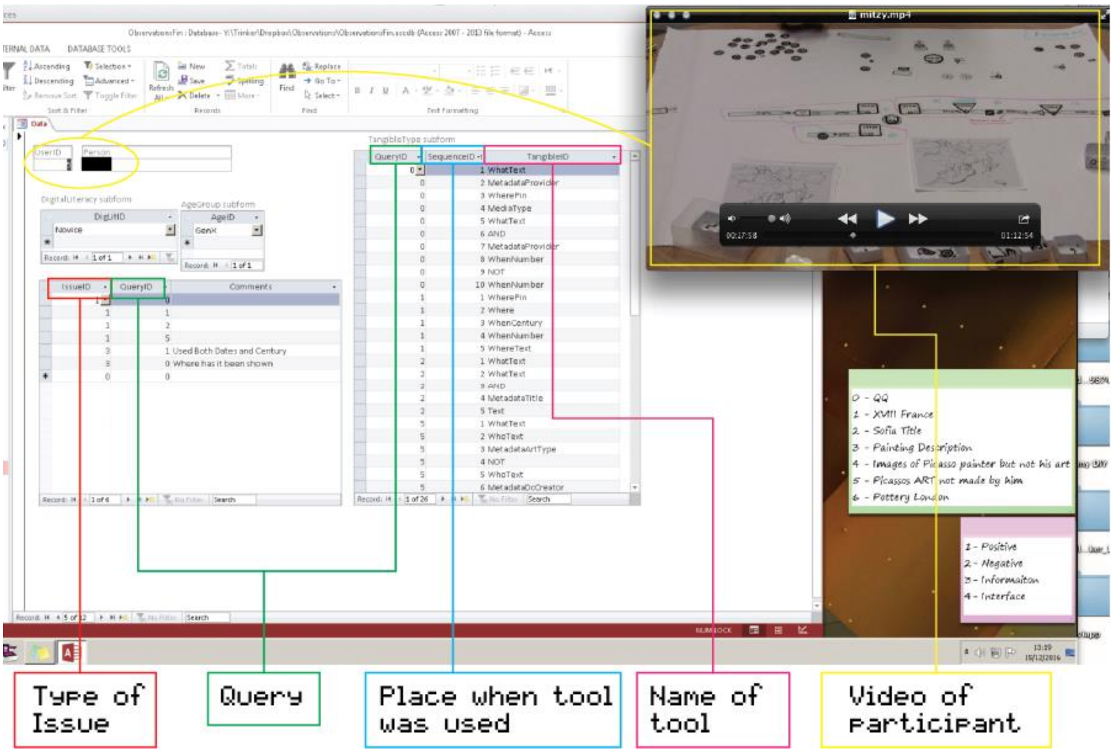


Figure 30. Annotation of participants actions

The qualitative and quantitative annotations of the UX/UCD experiment were analysed using descriptive statistics to explore how many items or tools do participants used per query, particularly from the 'open search query' that were asked to perform and how they arranged them. Every tool was given a name that relates to the different data fields or possible operations to be implemented on the final system. The different ways in which participants organised the tools they used, informed the design process regarding how they might query the data. This information is then translated to Project Selection & Planning Phase, as well as the Analysis phase where the final user, and their parameters are defined so they can be studied and implemented when developing an interactive system.

7.3 Building an Understanding of OCH Users

When users are offered the opportunity to engage with OCH, their queries will vary according to their background, age, and level of information need among many others. Due to the novelty of Linked Data and the Web, OCH engagement requires to be adopted over traditional CH perspectives where engagement is limited to a single organisation. Although diverse CH organisations have their own paradigms and work behaviours, these fragmentations have a tendency to disappear at least in the search behaviours from end users (Waibel and Erway, 2009, Kay et al., 2015, Greenhill and Wiebrands, 2012). CH organisations are slowly reacting to these novel search behaviours and attempting to integrate themselves to the OCH ecosystem (Trant, 2009, Marty, 2009, Marty, 2014). This is reflected in how CH organisations develop their search tools. In this respect, information-seeking processes have a tendency to remain on individual areas where the information is being queried. For example, research that explains how information is explored in libraries, rarely discusses how that information might be queried when it is being explored from a museum, despite that current research already discusses how they can converge with other CH organisations. Chapter 3 discussed the need of an interdisciplinary perception of the Cultural Heritage sector once it reaches the Web.

Semantic Web technologies facilitate the content integration from different domains and help homogenising the information. OCH user behaviours suggest that they require a search tool that integrates such content in a single space and that enables them to implement the diverse technologies and data elements to express their queries. Europeana's API manages to integrate a cross-domain OCH collections and provide the foundational conceptual structure to empower users to perform meaningful queries based on their own perspective. This perspective is heavily influenced by the state of information need in which they arrive to query OCH. Those specific behaviour patterns can be used to understand the specific user requirements when developing for querying OCH (McCreadie and Rice, 1999, Taylor, 1967). Concurrently, OCH tools need to provide some level of adaptation, since users' needs can change over time (Sumner, 2005). In the case of Europeana, users' requirements can complement the different states of need of information, thus help understanding the behaviours that users might follow when exploring OCH. Interactive interfaces have the role to provide access to the digital content, as well as inspiring users to do so.

To further understand these user needs, methods such as User Experience (UX) can aid on users' behavioural statistical information, digital literacy, context of interaction and habits among others, to produce personas and map them to particular product (O'Leary et al., 2015, Sward and Macarthur, 2007). UX personas can become helpful to identify user characteristics such as digital information and search literacy, gender, and age among others. This information can provide the guidance in a *scenario* or experiment. *Scenarios* is a common Marketing approach now adopted by UX to identify how key players (*personas*) such as users can affect the original perception of how a product can be used, or presented to an audience (Groucutt et al., 2004:248). These particular approaches can be used to identify what processes users follow to gather knowledge and for what particular use. Merging aforementioned approaches will help providing an understanding of what can become a meaningful way of querying and which particular terms and data fields might be used.

The first approach is to define personas. In this research personas assist identifying digital literacy, navigational strategies and common queries. Although Europeana primarily includes CH knowledge, it might also include data from sources outside the CH sector. In the case of digital literacy, Marketing has identified digital behaviours of a wide range of users of different generations. There are five main age groups that define their particular behaviours: Maturists (pre-1945), Baby Boomers (1945-1960), Generation X (1961-1980), Generation Y (1981-1995) and Generation Z (after - 1995). Although this classification varies within the literature, most of them round up to similar years (Tapscott, 2008, Jones and Shao, 2011). This classification also provides an understanding of how they use particular technologies. For example, Maturists commonly have problems with digital technologies, while Generation Y are more avid. For this reason, they have been further defined as Digital Immigrants and Digital Natives, where the Natives are born into an environment that commonly uses the technology becoming an everyday learning process (Figure 31). Nevertheless, despite that there is some influence on how generational backgrounds will use digital technologies, this research focuses on general users who arrive on a visceral or conscious state of need of information, who most likely will use the system for the first time. That being said, although there is some influence of how different generations use digital technologies, when it comes to learning new digital skills there is no concise evidence that links generations to digital literacy learning (Eshet-Alkalai and Chajut, 2010). The definition of digital natives was further extended with the Net Generation and the Generation Next. The Net Generation experienced a connective technology (Tapscott, 2008:18, Jones and Shao, 2011:5). This connectivity might not be perceived as today with examples as the programmable Web and video telecommunications but it started shaping the thinking processes of those particular generations. The Net Generation can be understood as a particular behaviour that users have adopted instead of the range of digitals skills that they might have.

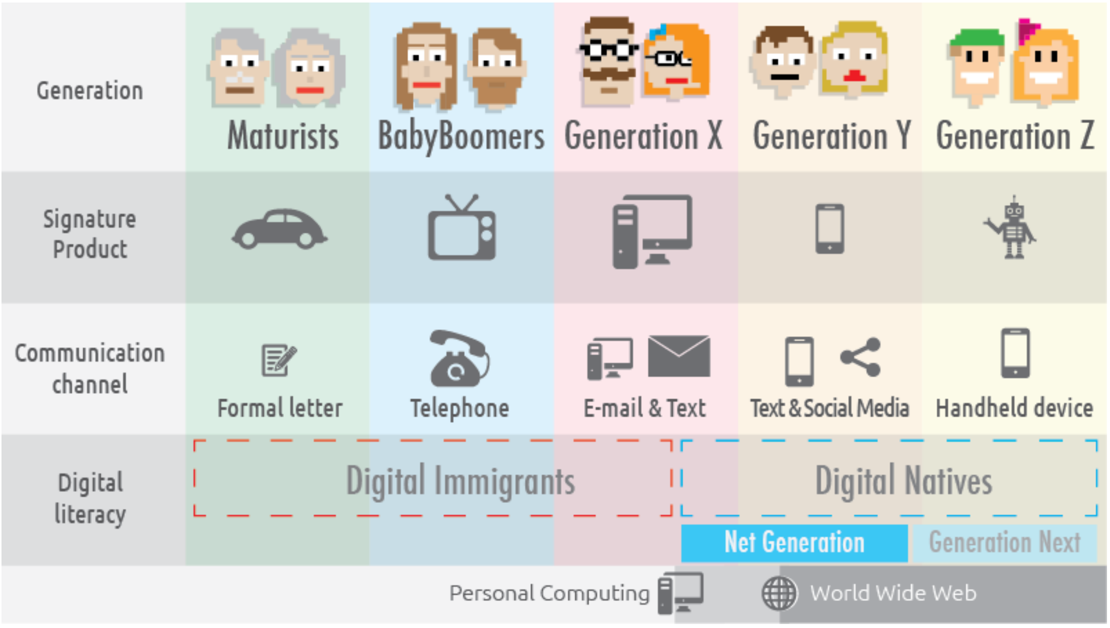


Figure 31. Digital Generations (Robertson Associates, 2013, Tapscott, 2008, Jones and Shao, 2011)

These definitions help Marketers and Designers to understand users' needs thus provide guidance to produce tools that adapt to a wide range of digital and information literacy. It is therefore important to understand that just producing tools is not enough. Prior research identified that even though students have had more access to technology, their information literacy did not really improved (Rowlands et al., 2008). Research by Jones and Shao (2011) and Ferri et al. (2008) identified three categories of how students engaged on the Web: [1] The Digital Mass who is the majority of users. They commonly just read content and rarely contribute. [2] The Neo-Analogical group spend less time on the Web but still manage to contribute. Lastly, [3] the Inter-Activated spend a lot of time on the Web and contribute frequently.

Pedagogic institutions are increasingly concerned in the way their new generation students engage with learning technologies. When developing information technologies, the tools should offer learning pathways that fit to the ways in which users like to approach information. According to Europeana's Personas Catalogue (Rasmussen et al., 2010), these information approaches are influenced by their IT skills, digital literacy, task knowledge, language qualifications and their search processes. User classification based on these parameters, can be divided into search literacy and search behaviours. White and Drucker (2007) identified Web search behaviours that represent two main classes of extreme users: Navigators that are very inconsistent searchers and Explorers that follow very consistent strategies when searching. While Navigators explore heavily all the different links and diverge into different areas, explorers will be more linear way of searching. Explorers will follow sequential processes, for this reason, they are very consistent and very likely to return to particular domains. These two categories represent the extreme spectrum of how people search. Therefore, it is important to keep in mind that the vast majority of users will fall between these two categories (White and Drucker, 2007). The second main category of Europeana's Personas Search Catalogue is based of factors such as IT skills, digital literacy, the knowledge about the particular topic they are looking for (Task Knowledge), and in the use of another secondary language(Rasmussen et al., 2010). Beyond IT skills and digital literacy, research by Eshet (2002), has indicated that users will also require prior understanding of how to work with a wide range of media formats, such as Print, Video or 3D among others. New Media Literacy appears to be increasingly relevant to CH where a fast pacing technology keeps on evolving and changing engagement with their content. Related to Human Information Interaction, Information Literacy refers to the complexity behind identifying false information or assessing the validity of the information (Eshet, 2002:5). Lateral literacy, which is deeply linked to the Navigator profile spectrum, refers to the mental flexibility to multi-task within their navigation strategy thus having the ability to join content from different sources or links (Eshet, 2002). This classification includes many approaches of how students will perform in fast developing technologies and present important characteristics of how people perform on the Web. Nevertheless, there is still a gap in understanding how these factors might shift when working with TUIs. Photo-visual literacy has been researched only from a GUI perspective, since it studies the user cognitive process when working with visual ant text elements such as icons and menus when exploring information.

It is very likely that the vast majority of people who search for Europeana's content will be digital natives. A survey from the European Commission (2013) showed that 30% of people use the Web for cultural purposes at least once a week. The vast majority of these people were digital natives between the ages of 15 - 24 (44%) and 25 – 39 (39%) age group.

Moreover, there were a 29% of people who never use the Web to search for cultural things. From this group, 36% were people over 55 years old, or people with less than 15 years of education (44%). This creates a contrast as well with the vast majority of users using the Web for cultural purposes that are people that are either still studying or have over twenty years of education. Despite this popularity with younger generations to search for CH content on the Web, according to Europeana, their vast majority of users are between 45 and 54 years old (Rasmussen et al., 2010:23). This contrast is due to the sample that answered Europeana's survey. This survey was conducted among CH professionals, such as teachers, curators and managers. The largest sample of respondents after 'others' who did not fitted within other profession description in the survey (37.7%), were managers/administrators (12.7%), librarian/information specialist (9.3%) and student of college/university (8.6%). In addition, the people surveyed indicated that they found out about Europeana from journals and links from other websites. This suggests that such contrast between both reports is due to the sample of who uses particular services. While the report from the European Commission sampled users without any restrictions, Europeana sampled their users who are most likely people who currently work in the CH sector.

Since the digital divide cannot be attributed to the generational gap, it is important to consider that once digital literacy factors are reduced or even eliminated, there are still search literacy factors that can be attributed to the second engagement layer. This is to say that despite the expertise of users, they will still have to learn the technical and conceptual elements behind OCH. For this reason, the sample selected is prioritised on their acquaintance to CH topics instead of their digital literacy. Digital literacy can be associated to the Usability measurements and performance of the final evaluation. The interaction design methdology explores how users might approach OCH information through UX/UCD approaches.

OCH organisation and particularly Europeana can benefit in providing tools that aid search behaviours as well as search literacy factors. Based on query reports by Europeana (Ceccarelli et al., 2011, Greenhalgh, 2015, Neil, 2013), some user behaviours such as searching starting from generic terms commonly using terms such that define places or authors. The most popular queries in Europeana searched for work by Leonardo Da Vinci in 2013 and Vincent Van Gogh in 2015. Also, users produced generic queries such as Paris or Japan and *aardewerk* (pottery in Dutch) or *woodwork* seemed to serve as introductory pathways to greater collections. Although in the 2013 report *plastic surgery* and *West Riding Lunatic* came up as most popular searches, this increase was attributed to the advertising that took place through Mashable and other social media networks. Nevertheless, both 2013 and 2015 Europeana reports indicated that those queries were carried out through a single keyword. Querying through single keywords seems to permeate throughout the Web. Even though users were already querying through Europeana, they did not manage to grasp the extent of how they can search across the different data fields. In addition, these behaviours can also suggest that users most likely will arrive under a visceral or conscious state of need of information.

Within the OCH ecosystem, sharing content through Mashable takes part of an advertising or marketing process that do not help users to gain knowledge. It can trigger a query in the search of knowledge, but if fails to provide the required engagement with the information. The promotion of particular collections, can aid users to arrive in a conscious state of need of information and aid in the query process. For example, the term '*West Riding Lunatic'* refers to a particular asylum in in Yorkshire, UK. Nevertheless, visitors never had a further engagement beyond the conscious level due to the lack of information tools. Users require to empower themselves to query from that particular starting point thus follow their own learning pathways. These reports provide an understanding of what and how users might start their querying process. Therefore, they provide a starting point of the tools that might be required to engage in a visceral or conscious state of need of information, where user will begin their engagement activity.

7.4 A-Priori. User Experience Design Process: Definition of User Needs Through User Centred Evaluations

The objective of the UX/User Centred Design experiment is to understand the behaviours that users will follow if offered the required tools to explore OCH information. Before designing any interactive tool, it is necessary to identify how these tools fit within the decision-making process when exploring information.

The main parameters for selecting participants were based primarily by their background. Participants that already work with CH are more likely to already have questions to make through Europeana's repositories. These participants are more likely to arrive in a visceral or conscious state of need of information, because they do not have any knowledge of Europeana's data fields. This can be supported by the query log reports and surveys from Europeana from 2013 and 2015 (Greenhalgh, 2015, Neil, 2013). In addition, although it is more likely that digital natives will approach these kind of systems, there was no concise evidence that suggested that a generational divide would make a difference in the digital literacy learning process (Eshet-Alkalai and Chajut, 2010).

Through UX/UCD approaches, users can inform the interaction design methodology the specific process in which they might carry out a particular task. Europeana query logs provide a starting point, which provide a general overview of common tasks that can be carried out by users. Digital literacy and generational groups should not play a major role in the UX/UCD approach due to two main factors: first, there is no relationship between age and learning new technologies, and second, the experiment should inform how any given technology can me implemented in their own terms and not the other way around. This is not to say that when a final prototype is produced users do not have to learn how to use the system. Users who approach the interactive system for the first time will still have to learn how to operate and negotiate through the tools to produce their queries. Nevertheless, this process can be alleviated through the use of TUIs. That being said, the affordances of the tools should communicate the way in which users can increase the accuracy and reach of their queries through the use the different data fields and operators available through Europeana's API. The UX/UCD approach will inform what will be the most meaningful pathway to communicate those affordances in the system.

In order for participants to focus on the query tools, they should already have some insight of what sort of content can be found within the CH boundaries. When Europeana attracted audiences through Mashable, those users had an idea of starting keywords to begin their query. Similarly, CH professionals such as historians or archaeologists should already have some knowledge about the content held in Europeana collections. In other words, CH specialists might know what they are looking for but do not know how to make an appropriate question.

7.4.1 Further Understanding of Users' Behaviours

To further understand user requirements, a survey among 21 CH professionals was carried out. The prior literature review portrayed a general landscape of how users explore information on the Web. It described how people used Europeana in particular. Nevertheless, the survey carried out in this research, was designed to provide a deeper understanding on the reasons why users decide to search through a particular approach. This sample is further sub-divided into a sub-sample of 12 participants who took part in the UX/UCD experiment. The original sample presents a general understanding of the Web searching behaviours by CH professionals, and the sub-sample will map those behaviours within the UX/UCD experiment.

The majority of the survey respondents (12) were from Generation Y and the remaining (9) from Generation X. The vas majority of respondents (18) indicated that they can visit the website of the main organisation they are working with for their research in order to gather information (Figure 32, also see Appendix B). In addition, the same number of respondents visits those organisations physically to gather information. It can be expected that CH practitioners will have deep connections with CH organisations, due to the fact that CH organisations are still the source of many of the specialist knowledge. The fact that the majority of the people surveyed can visit the website of the organisation for their research, indicate that the organisation provides enough information for the to carry out specialist research task. The vast majority of subjects (19) use the Web for their research but they will commonly start their searches through search engines such as Google Search (16) or Academic Search Engines such as Google Scholar (4). Only 1 person indicated that they use the organisation's website to start their searches (Figure 32).

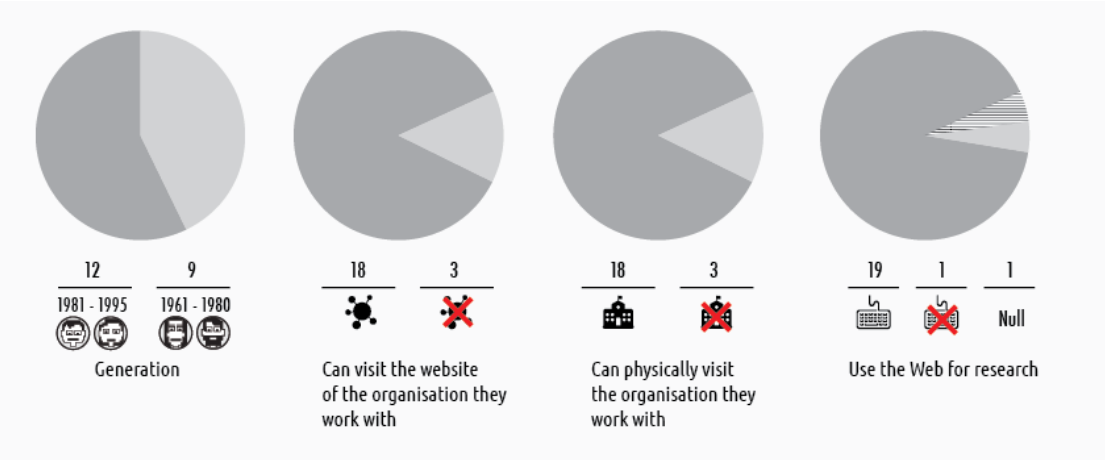


Figure 32. Participants Research on the Web

Despite that the majority of participants tend to visit the website of the organisation they work with, they will still start their searches on a Web Search Engine. This is arguably due to the ease to find and single out the required sets of information that they are looking for. Nevertheless, 7 respondents noted that when they search on the Web, one of the main problems is that the information is scattered through to many sources. Google as a search engine will gather information from all sources across the Web, thus there is no way of segmenting the results retrieved until the results return. The only option is either performing a search directly on a website (eg. www.britishmuseum.com: text) or by skimming the information retrieved after the search. That being said, it is very unlikely that users will add any extra operators to enrich their query, since only 6 users claimed to use Search Engine operators. The remaining participants either do not know them (8) or know them but don’t use them (7).

Participants seemed to be confident with their digital literacy, since the majority (17) considered themselves to be competent searchers (Table 8). Although it is acknowledged that there are different kinds of literacies, there seems to be a disregard for the search empowerment provided by search operators. By using the wide range of operators and data fields, user can produce more accurate queries, thus retrieving more meaningful results. Nevertheless, users are not implementing current search tools. In addition, Europeana has the opportunity to integrate results within a single space, thus reducing the lateral literacy requirement through a single complex query.

Do you use search operators and symbols when you perform queries on a search engine such as Google? (e.g. $, @, #, “”, intitle: , filetype:)	
I don't know them	8
I know about them, but don't use them	7
Yes, I use them	6
Your level of expertise when searching on the Web is…	
No Response	1
Competent	17
Expert	3

Table 8. Users expertise perceptions

The reason why the vast majority of users begin their searches through Google Search (16) or Academic Search Engines (4) seems to be due its ease of use. The majority of participant indicated that it’s either easy or extremely easy to use Search Engines and Academic Search Engines (Table 9). Despite that 6 participants indicated that they have access to their research topic through the website of a specialist, they still did not used it. Only 1 participant indicated that they would do so. The ease of use is a common occurrence that appears on the participants’ responses. Despite that the organisations’ website is seemed as a higher quality source of information than Google Search, participants still decide to begin their queries through a generic search. Alternatively, academic search engines seem to combine both ease and quality.

Users are depending on their lateral literacy skills to skim through the numerous results provided by the ambiguity of their queries. 10 participants claimed that the main problem they face when searching for information is that the information is scattered through too many sources. It can be acknowledged that users will still have to navigate through the query results. Nevertheless, if users manage to embed a certain ontological meaning to their queries, the navigational process can be reduced. In addition, such navigational processes can be carried out through data visualisation tools. Nevertheless, to visualise anything, a query to produce an original sample of data has to be produced. The UC/UCD experiment aims to understand how this original query can take place and what are the required tools.

Where do you commonly start your search in the Web?	
Academic Search Engine (e.g. Google Scholar, Web of Science)	4
Search Engine (e.g. Bing, Google)	16
The organisation's website (e.g. British Museum, National Library)	1
What are the main problems you face when searching for information?	
No Response	5
Information is scattered in too many sources	10
Lack of training or digital skills in using IT resources	1
Required material is not available	5

Ease of Search		Quality of Information	
Search Engine (e.g. Bing, Google)			
No Response	2	Fair	13
Difficult	2	High	2
Easy	8	Low	2
Extremely easy	5	Very high	1
Neither hard nor easy	4	Total	21
Academic Search Engines (e.g. Google Scholar, Web of Science)			
No Response	2	*No Response*	4
Difficult	2	Fair	2
Easy	11	High	10
Extremely easy	3	I don’t use it	1

I Don’t Use it	1	Very high	4
Neither hard nor easy	2		
The organisation’s website (e.g. British Museum, National Library)			
No Response	5	*No Response*	3
Difficult	3	Fair	6
Easy	7	High	7
Extremely easy	1	Very high	5
N/A - I don't use this resource	1		
Neither hard nor easy	4		

Table 9. Participants' Searching Patterns

7.4.2 Description of UX and User Centred Design Experiment

The main purpose of the UX/UCD experiment was to identify how users might produce queries if offered the necessary tools to do so. The experiment provided users with a set of interactive tools depicted as icons on stickers. These sticker-tools delineate actions that could be eventually performed on a query system. Among the different tools, the stickers represented the diverse data fields, operators, and visualisation actions (e.g. grouping or selecting) that could be implemented in the system. There were 150 different stickers designed that were further grouped by their type of affordance. There were three main categories: Europeana Queries, TUIO Actions and Professional Organisations (Table 10). Europeana Queries included the Core Queries that depicted tools that were thought to be fundamental to start a query. These included the basic API data fields such as *who, what, text input* and alternative ways of querying time such as using a calendar to depict *when* and map brackets for the *where*. Moreover, there were alternative Europeana elements to expand the queries, such as Booleans, Action Queries, Media Queries, as well as Geographic and Cultural elements. Furthermore, it was expected that user would attempt to express their need to arrange or organise their queries by performing particular actions such as grouping objects, zooming in or viewing the next retrieved image as part of a navigational strategy. Finally, a group of tools that depicted Professional Organisations was designed to allow users to explore content from a particular type of provider. This was designed to understand if users required querying an organisation in particular. Although these tools already contained particular meaning, they were not limited to that original purpose, the objective was to provide a visual and physical reference of a particular process that the participant followed when exploring information.

Europeana Queries Core	***Europeana Core Queries*** Who, what, start date, end date, lat, long, keyboard input, media type
Europeana Queries Booleans	***Europeana Boolean Queries*** AND, OR, NOT, TO
Europeana Queries User Actions	***Europeana User Action Queries*** Select text, quote text, share, like, unlike, explore further, comment
Europeana Queries Obj//Media	***Europeana Object/Media Queries*** User text (chat), pdf, image, audio, voice recording, video files, collections
Europeana Queries Geo//Cultural	***Europeana Geographical/Cultural Queries*** Forest, landscape, industrial, museum, gallery, footpath, path, geo-area
TUIO Actions	***TUIO Touch/Fiducial Actions*** Skip, touch, slide, swipe, scale, boolean touch,
Professions Organisations	***Professional Organisations*** Military, Science, Site, University, Archive, Excavation, Marketing, Office

Table 10. UX/User Centred Design Tools

Figure 33. Sticker-Tools for UX/UCD Experiment

Participants were asked to find a set of objects from 6 different queries. Furthermore, they were also offered the option of making a free query at the end. These queries were:

1. 18th century Europeana objects from France
2. List of objects that contain the name “Sofia” in their title.
3. List of objects which contains the word "painting" in its description
4. Find images of Picasso the painter (person) but not his painting (Picassos).
5. Find Picassos (paintings) that are not made by Picasso (person).
6. Pottery artefacts found in London

Participants were offered a printed map to place their queries directly on it if desired so. They were also provided to choose an avatar. These avatars had different designs based on gender and digital generation. They did not have any function on the querying process, they were used to identify faster the particular generations when analysing the results. When users were asked to perform any given query, they could either just grab the sticker tool or place it on the surface.

If the participant could not find a tool the tool they were looking for, they were prompted to ask so they could be pointed out to the specific tool. In addition, if the action they were trying to perform was not available, they were offered an alternative tool to depict the action that they wanted to do. When this happened, an annotation was made next to it so it could be further registered in context. Actions such as typing were carried out by using a marker and writing directly over the sticker-tool. Many of the text-input tools were designed with a field where participants could write on.

While participants were placing the stickers, they were showed how the query could be performed through Europeana's API using Postman, a Web application to send HTTP request to the API. Participants were also asked to fill up a survey that identified their digital literacy Web search perceptions. This survey served to contextualise the behaviours of the participants. Users were asked about their topic research and how likely were for them to use the Web to research about it.

The prior section identified how users tend to explore and learn in Web environments, but there is still no understanding of how users might approach Semantic Web querying especially in OCH. This experiment contributes to the understanding of how users conceptualise semantic querying and the particular tools that they might find meaningful for their searches. In this experiment it was important to make a distinction between conceptual, technical and technologic factors when coding user behaviours. Conceptual elements were indicated when the participant implemented their own particular perspective or way of thinking. Technical elements referred to searches made in a way that did not fit the data model. Technologic elements were denoted to be concepts where the technology is not able to support the query. It is important to indicate that some of the participant scenarios can have more than one case.

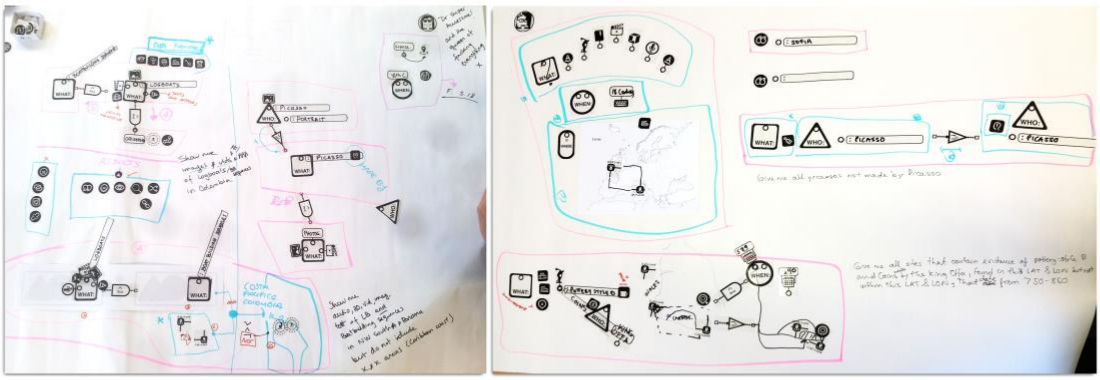


Figure 34. Participant 1 (left) and 10 (right) sticker placement

The experiment recruited 12 participants from different academic areas of CH such as Archaeology, History and Museum Studies. Although their search behaviours were prior discussed in the prior section, Appendix A presents the results separated by participants who took part in the UX/UCD experiment. Most of the survey results between both groups are very similar. Their search behaviours will be mapped as well in Appendix B with an extended table of participants' results of the experiment and search behaviours.

7.5 Participants and Results

To keep track of the combinations and annotations, participants were video recorded and the annotated coding was captured in MSAccess. Furthermore, the coding was placed in a database to perform the statistical analysis in SPSS. The coding was implemented in the database. For example, conceptual, technical and technologic annotations were scored in the UserIssues category (Table 11). When a participant [Users] places a tool [TangibleType], its order when it was placed [SequenceID] and the query [QueryID] is recorded as well. Therefore, all annotations and use of tools were recorded and particular thinking processes were annotated as well and further referenced to the participant and their digital generation and literacy perspective.

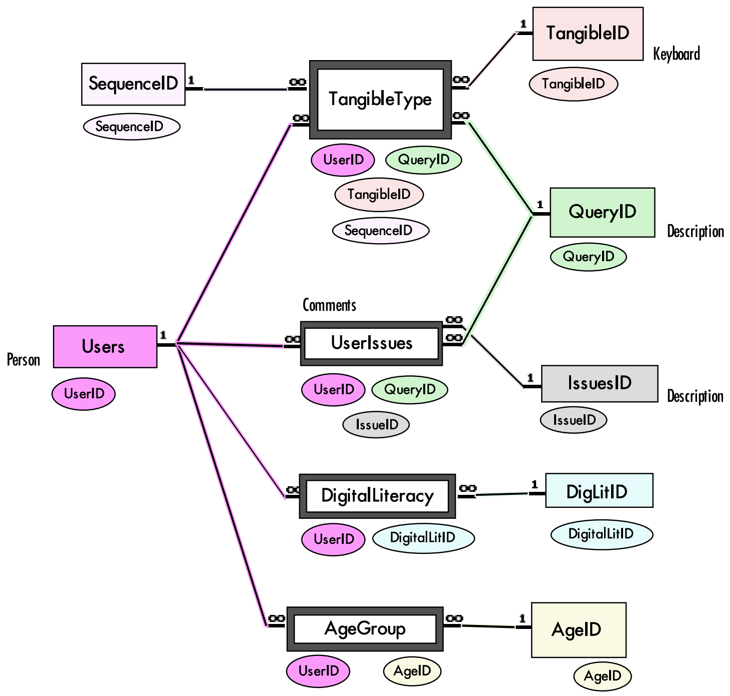


Table 11. Coding Scheme For the Database

The experiment showed that users were able to use multiple keywords, operators and data fields, despite that only 2 of 10 of them use operators in Search Engines. All participants were willing to explore and to produce complex queries aided by the diverse tools. These tools allowed participants to segment the different parts of the query, which also helped them to organise their thoughts and ideas of what they were searching. Users were not concerned about the how the data fields or ontological representation might describe what they were looking for. Only 2 participants knew what the Semantic Web is, and 6 had an idea of what it is. In addition, only 1 person knew about Europeana. Therefore, participants did not have any prior knowledge about the diverse Semantic Web technologies that enable OCH information. Despite this lack of knowledge, the tools presented in the experiment, enabled user to express their query needs in a way where the majority them, could be translated to SPARQL queries or API calls. For example, the question 5: *Find Picassos (paintings) that were not made by Picasso.* Figure 35 presents the different approaches of how participants attempted to resolve such query. Participants presented a tendency to segment their queries based on concepts with a specific keyword, such as what:painting. Then link linked the concept with NOT and the remaining conceptual element who:Picasso. The tools enabled participant to conceptualise the difference between things and people, in other words objects and creators. Although within the EDM, organisations as providers can also be identified within the who data field, this approach can enable users to produce a grasp of the different relationships of information in Europeana and produce queries that go beyond a single keyword.

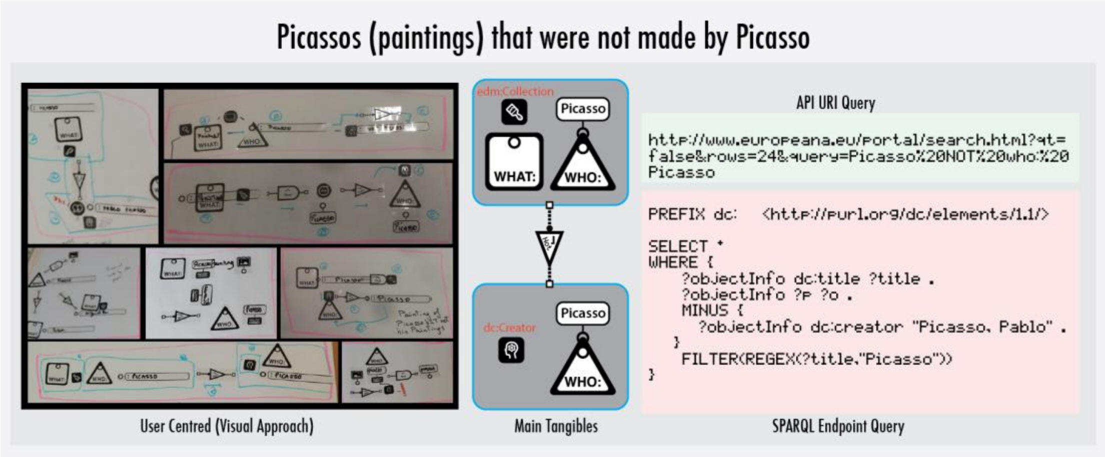


Figure 35. Participants approach to find Picassos not made by Picasso

To perform queries in Europeana, users are required to have the technical knowledge in order to produce queries tied with the specific data fields and operators. In addition, they are also required to conceptualise how they can refer to a particular collection or object from their own perspective in a way that matches the technical elements of the data model. The general overview of the participants indicates that they had no prior engagement with Europeana before the experiment, thus had no understanding of how information was structured in the data model. Nevertheless, the depiction of the data fields facilitated that communication to search for things. Furthermore, the possibility of placing such depictions or tools on a surface, allowed participants to segment their thinking processes when producing their queries. Participants had a tendency to organise their thought from larger concepts such as who or what. After selecting a primary field, they proceeded to delineate the required details. For example, queries 4 and 5 (Figure 36), required participants to make a distinction between Picasso the person (who) and a depiction or a Picasso as a thing (what). Participants segmented the statement of the query into different facets. On a first stage, participants began to make a distinction of the particular differentiation between the artwork and the person. Once that distinction was made, they contextualise that main data field through extended metadata details, such as a painting or a creator of a content. When the participant finished that segment of the query, it was commonly followed by a pause, where they used that moment to place a boolean to join the next facet of the query. In the case of queries 4 and 5 it was expected to have a NOT boolean, since they had to remove Picasso the person from the results. That being said, once the boolean was placed, the remaining data fields of the remaining facet was constructed through the same process as the first facet, a main data field followed by the specific metadata that contextualised it.

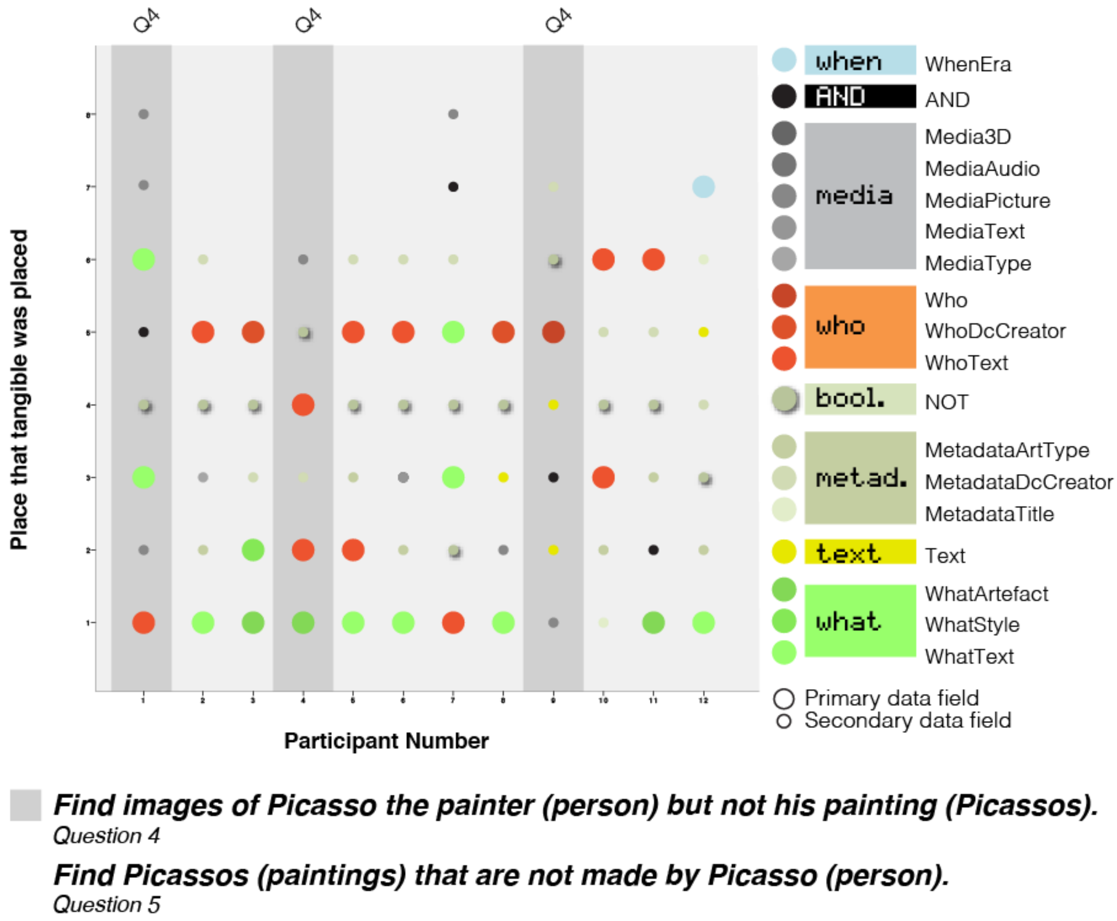


Figure 36. Query 4 and 5 participants' approach

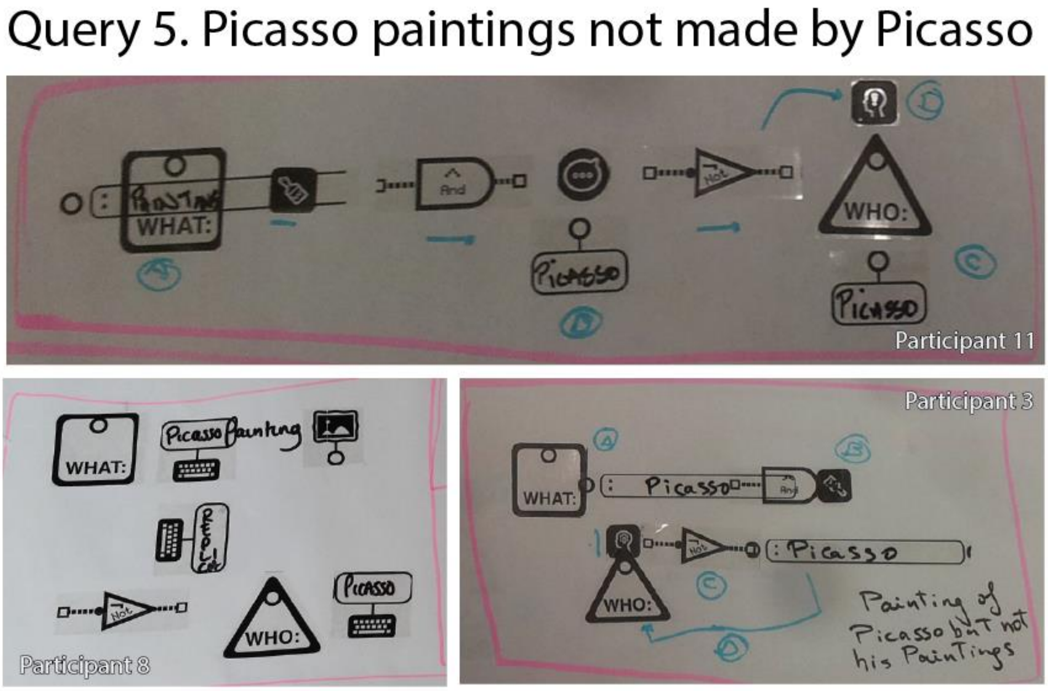


Figure 37. Question 5 - Participants sequence of tangibles picture

The results in the experiment showed that users are have a tendency to make the questions according to the environment that they have been working. For example, participants who work with maps will start their processes from a geographic approach (e.g. maps) instead of a conceptual one (e.g. typing the name of a country) (Figure 39). Users had a tendency to embed their own way of thinking to the query process that they followed. For example, the way in which participants solved Query 1: '*18th Century Europeana objects from France*', was influenced by the particular background of the participant (Figure 38). For example, participants with a museum and history backgrounds had a tendency to be more descriptive and used more metadata elements. In a similar way as a SPARQL query, participants conveyed what they knew about the topic to be more specific about the sentence they were making. Participant 12 also identified that an object catalogued from France can be also something made by a French person. Moreover, while the majority of participants focused on delimiting the date as *18th Century*, only 3 out of the 12 participants indicated the years as well. This was because according to one of them, a century would not be a measure of time but a socially constructed thing. The most basic interpretation of the query could be carried out just by stating when:18thCentury and where:France. But when participants decided to further contextualise the query, they did it by attaching extra metadata elements, such as mediaType, to retrieve any kind of digital depiction of the 'object'. As a result, the tools provided the flexibility for participants to fully express their understanding of what represented each element of the query.

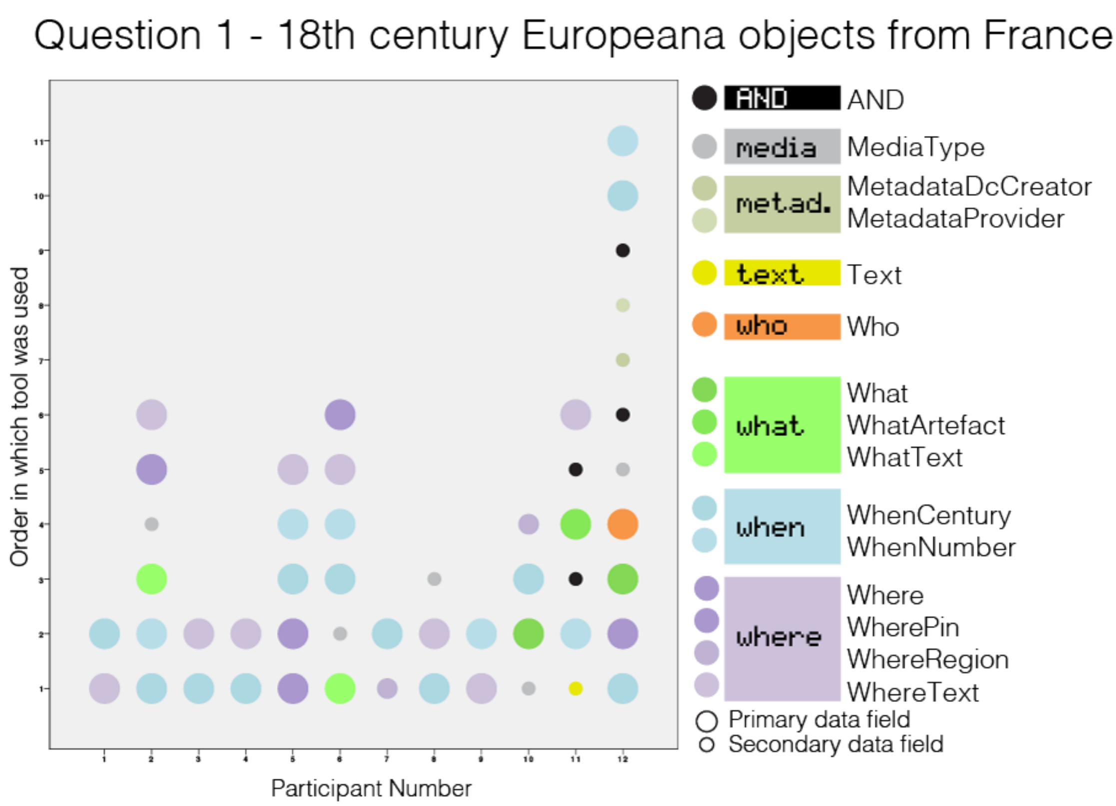


Figure 38. Query 1 Sequences

There is an overarching approach where participants begin searching from larger scopes into detailed metadata elements. UCD approaches enable designers to identify particular approaches that might be beneficial to perform a particular task. For example, 5 participants preferred to use a map to search for things in France. Nevertheless, 3 of these 5 participants still decided to also use France as text attached to the where data field. The experiment shows that participants might be willing to express their queries according to how they understand concepts. The different levels of need of information reflected the way participants constructed their queries. Figure 39 presents a comparison of how participant 12 and 7 attempted to solve query 1. While participant 12 attempted to be very specific, that person demonstrated its state of information need by being more descriptive about the requirements of what was meant to represent the concepts in the query. In contrast, participant 7 defined the bare minimum of concepts to perform the query, and used a map with a latitude and longitude tool to define what might encompass France.

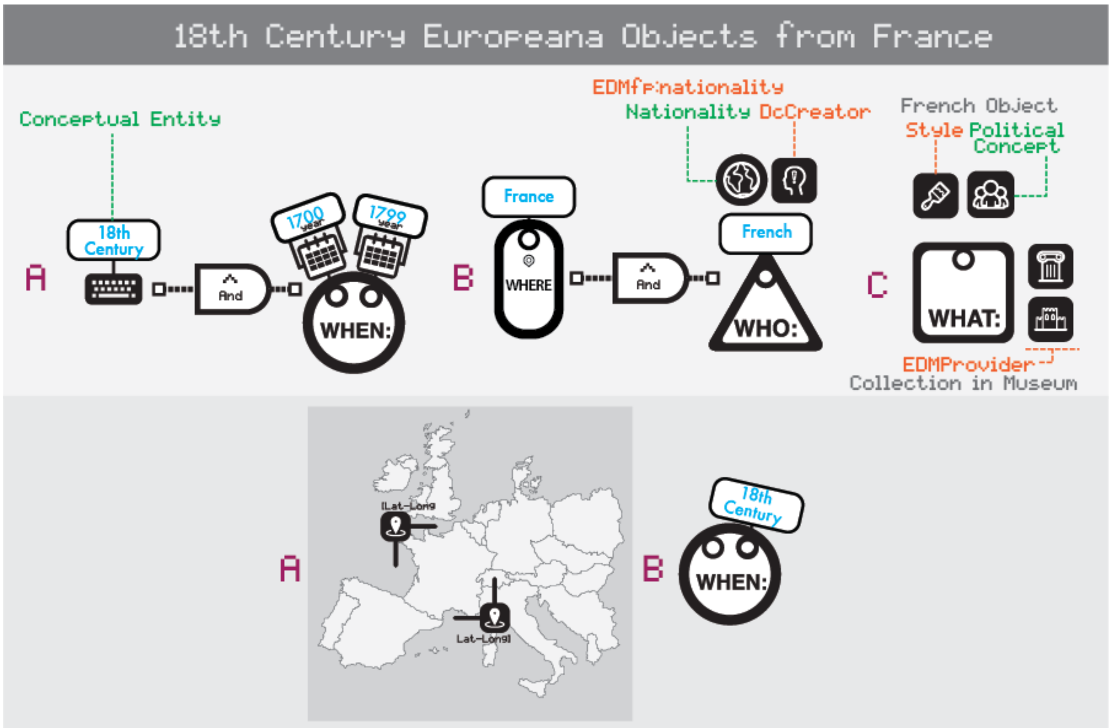


Figure 39. Query 1 – Participant 12 (top) and participant 7 (bottom)

It was observed that despite the different approaches in how participants gave sense to the context of their query, all participants segmented their thoughts through facets in a similar way as if they were writing a sentence. For example, in the open query (Figure 40) the way in which participants began their queries followed a similar pattern of the way in which they solved the given queries. It was observed that participants could follow that pattern because they were reading the query and trying to solve it. But once they had the opportunity to do it by themselves, they structured their thoughts in a similar way.

In the open query, participants attempted to state concepts and/or knowledge they had about a particular topic, which it was commonly based on their own field of work and proceeded to make a complex query to see if it was possible to find anything in the repositories. It seemed as participants were not trying to solve a question but were approaching this process as a discovery or exploratory process. For example, participant 8 looked for *depictions of Abbe Hilda as a monument in architecture from the Anglo-Saxon* *period in the Yorkshire region*, and participant 4 searched for *hi resolution photographs of Roman brickwork where the images were tiled*. In this sense, these participants stated a series of known concepts and structured them together through the tools provided.

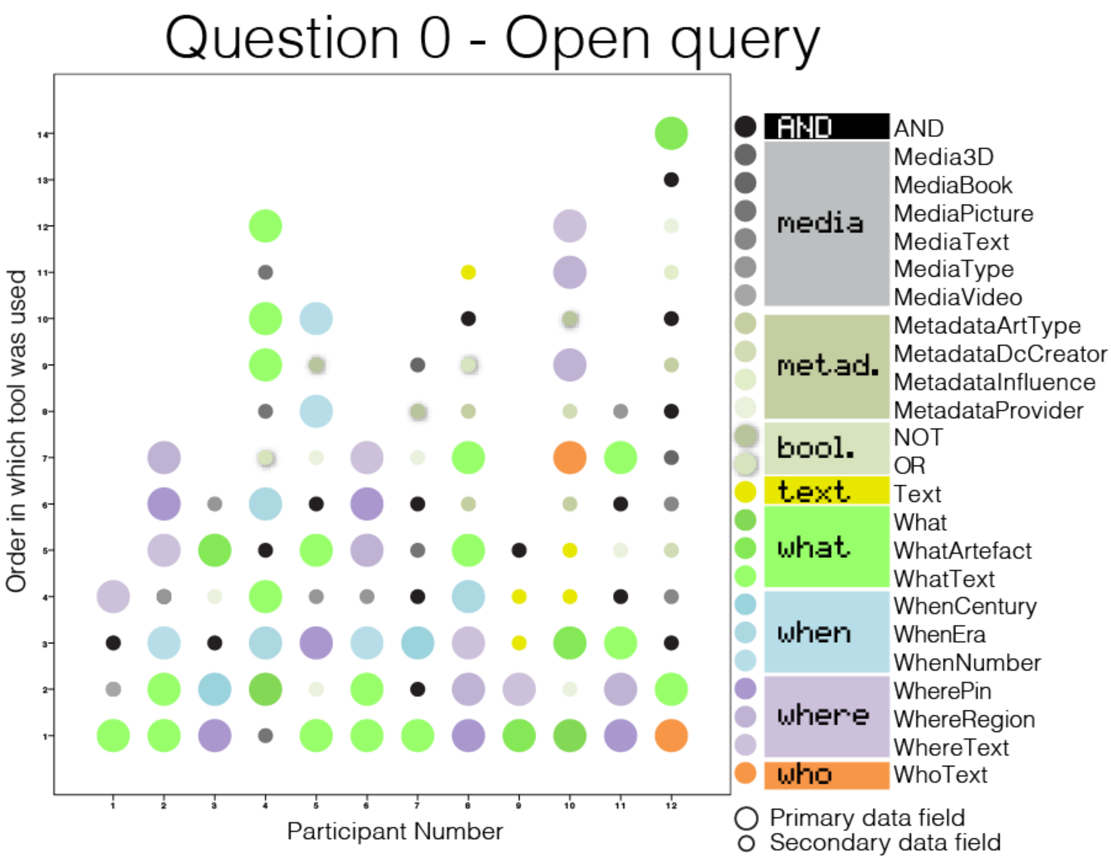


Figure 40. Open query participants' sequence

Having participants from a CH background seem to provide a state of flow where they were able to focus on joining their ideas through aided by the tools. Moreover, the way in which participants attempted to combine different data fields, elements and operators, suggests that they already have a basic understanding of how collections are described but might not be capable of producing a formal online query due to the technical and technologic limitations of how queries have to be produced either through Europeana's API as well as SPARQL Endpoints. Although participants showed different levels of complexity through the amount of data elements to describe their query, when working with Europeana's aggregated fields, could enable users with that might have a tendency to be less descriptive. Alternatively, for participants who have a tendency to be more descriptive, the impreciseness produced by aggregated fields could be reduced by the same extra data elements that they use.

Another interesting observation was that all participants segmented their queries in independent facets. This is to say that they focused on a specific part of the sentence query until that part was fully constructed, and then they proceeded to build the following part. The joint or linkage of the diverse parts of the query was commonly carried out through boolean operators. The way in which participants used the boolean operators did not always fit the way in which booleans worked. For example, participants 7, 9 and 12 presented in Figure 41 show the way in which the concept of AND was used. While these participants were building the open query, they used the AND operator to link concepts, but it was not intended to be used as a logical boolean. For example, participant 12 used AND to link the metadata fields to the what data field. In the example of participant 7, that person made a clear distinction that it had to be a *Romanesque Dragon*, thus forcing the statement of what:dragon and when:Romanesque to be true, since no other type of dragon was requested. Nevertheless, that same participant still followed that same pattern of using the AND as a mental aid to link concepts.

When designing the experiment, it was expected that participants could begin their queries from concepts encompassed by the aggregated fields. The observed participatns' patterns suggest that Europeana's aggregated fields might provide a starting point for their queries. Nevertheless, it is still unclear if participants chosen to begin their queries with those tools because they were influenced by the visual design of the stickers, since they were visually distinct from the rest of the tools. Nevertheless, it is important to highlight again, that participants were not offered the tool until they requested it.

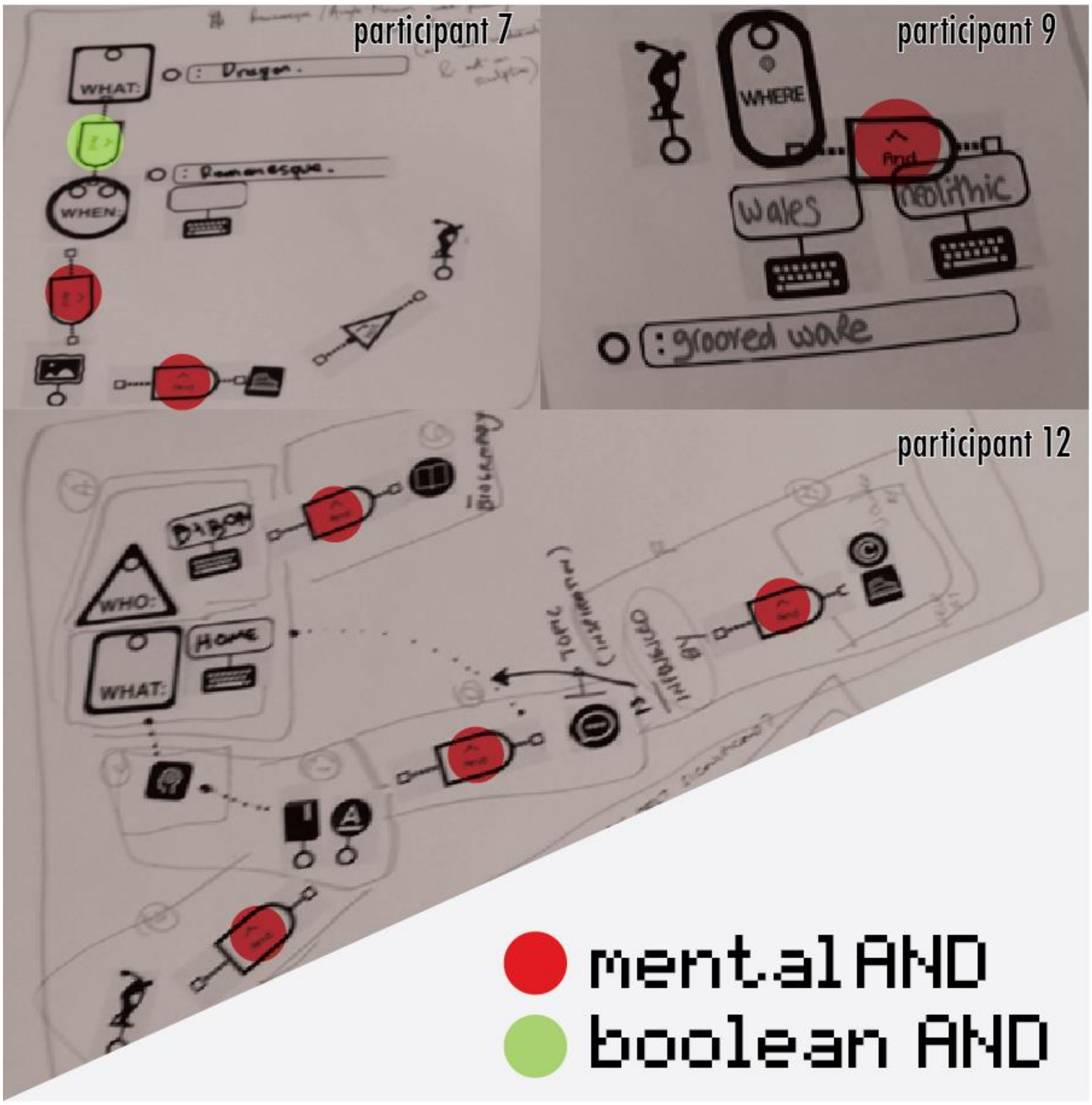


Figure 41. Use of AND as *mental aid* (Q0 - Open Query)

The way in which participants paced the construction of their queries can be associated with constructivist learning approaches, thus highlighting their relation to using physical tools to enhance thinking processes. Participants focused on fractions of a query to refine, expand or contract it, segmenting their thoughts. This thinking segmentation process could be enhanced through TUIs where participants can offload those sections of mental queries onto the physical objects and distribute them in space to focus on them. Participants liked to place the stickers without a specific structure. When participants placed the sticker, they followed the visual connections of the stickers, if they had one. For example, Participant 12 and 7 on the previous figure (Figure 41) show how the stickers provided a visual suggestion of how to connect the different tools and participants linked them without any evident orientation. Participants did not seem to pay much attention to the space available that they had for placing the stickers. This can be due to the fact that the paper used for the experiment had sufficient space to place more than twice the number of stickers than the ones used for the queries. It would be very unlikely that the final TUI would have the dimensions of an A1 standard size paper, such as the one used in the experiment. Nevertheless, the way in which participants used the space allowed them to organise freely without any restrictions. That being said, the only evident physical restriction in the experiment was that when participants placed a sticker, it was very difficult to remove from the paper. One participant placed a sticker and decided that it was not the one required to begin the query. That tool was left there, and the participant proceeded to carry out the alternative part of the query and then returned to that original sticker. When this took place, the coding of the placement of the sticker was not altered; the sequence of the tools were kept according to how participants placed them on the surface.

After performing a frequency analysis (Table 12), it was noted that What, Where, When and Who were used the most. Although, Metadata and Media elements seem high in the analysis, they were always used as an extension of a core query and were never used independently. It was also noted a high number of the AND tool, but it was decided to code it separate from the other operators. This is because as previously discussed, the vast majority of times when this tool was used, was with the purpose to connect ideas and not as a logic statement (Figure 41). As a result, the frequency analysis provided a more representative view of how booleans were implemented in the queries (6.4%). Furthermore, there were many cases where participants attempted to approach a query only through the text object, in a similar way as a Google search (6.7%). Nevertheless, even though their query started in this fashion, all participants proceeded to expand the query by attaching extra elements such as Media or Metadata.

Tangible	Percent
Who-Total	7.1
Who	1.1
WhoDcCreator	1.1
WhoText	4.9
Where-Total	13.1
WherePin	3.2
WhereRegion	2.8
WhereText	7.1
When-Total	9.1
WhenCentury	4.2
WhenEra	1.4
WhenNumber	3.5
What-Total	16
WhatArtefact	4.6
WhatStyle	0.4
WhatText	11
Text	6.7
BOOLEANS	6.4
NOT	5.7
OR	0.7
Metadata	15.5
MetadataArtType	3.5
MetadataDcCreator	4.6
MetadataInfluenced	0.4
MetadataProvider	2.8
MetadataTitle	4.2
Media	12.8
Media3D	1.1
MediaAudio	0.4
MediaBook	0.4
MediaPicture	4.9
MediaText	1.4
MediaType	3.9
MediaVideo	0.7
AND	9.2

Table 12. Tangible Objects Frequency

The main motivation behind this research is to understand how OCH users can grasp the complexity produced by a wide range of CH organisations, especially when the vast majority of searches on the Web are performed with single keyword searches. The experiment showed that the placing tool on a surface, could aid participants to organise and construct their queries. That being said, although many of the queries might force participants to just replicate the query that was given to them, participants still managed to produce a query approach different to the way they commonly search on the Web. Averaging 9 objects per user can be considered a positive improvement in the complexity of the queries bysearching through a multiple keyword and data fields to conceptualise it. Although no participant mentioned a particular reference to any data model they presented a conceptual understanding of relating concepts to find what they were looking for. In this case, even a single or no keyword search can be enriched with attributes provided by a data model where users could search for concepts instead of a particular thing.

When offered the opportunity to search freely (Figure 40), participants showed the disposition to search through complex queries, thus engaging with their level of knowledge about their topic. All participants produced queries related to their research, such as '*sites that contain evidence of pottery style B and coins made by the King Offa, found in a region of a map, that date from 750 to 850*" and "*carved stones of Abbes Hilda from the Anglo-Saxon period from Whitby Abbey in Yorkshire*". These types of questions show the level of knowledge that participants had about the topics and what to ask if they had the tools to do it. Due to the current digital skills of these participants, it is very unlikely that they could perform a query through SPARQL or the API. When working with complex queries such, aggregated fields could help alleviating the understanding of the diverse data fields required to add meaning. Concepts such as region (where:Yorkshire) or eras (when:Anglo-Saxon) could enable users to convey that meaning to the system, and as showed before, these participants would still be willing to further refine the query. It was observed that participants did not follow a standard way to search for time related events. Participants focused on defining time mainly by defining year (3.7%), era (2.8%) or century (1.9%). Another related observation, was that participants only used the TO operator only when they used the year object. Europeana's Data Model Primer (Isaac, 2013) already indicates a conceptual complexity when defining time-space entities. This complexity was also observed when Participant 8 using the term '*Anglo-Saxon'* and defining it as controversial, indicating that other people might differ with the idea of it being a space in time. The use of aggregated fields allows users to combine numerical year values (when:1800) as well as time periods (when:medieval) and still combine them with operators (when:[medieval TO 1800]).

Another thing to consider is that although working with Europeana's content will certainly expand the amount of results compared to searching in a single organisation, results will depend on organisations sharing the content as well as the conceptual ontology embedded in the query. Nevertheless, if there are any retrieved results, they should be highly meaningful to the user due to the relation to the conceptual elements used to find them. All participants recruited in this experiment were aware of many of the different concepts used to describe collections, as well about the different topics covered by CH, as opposite to their technologic knowledge. It will be virtually impossible for any of these participants to use any of the current Web technologies to produce a similar query. But despite this low level of digital literacy or knowledge about any specific data model, aggregated fields can provide users a simplified as an initial engaging point since it was observed that participants commonly began their queries from large concepts.

The approaches observed in UX/UCD experiment displayed patterns where participants commonly began through general concepts that fitted to the different aggregated fields on Europeana's API. Moreover, participants also grouped their thoughts based on the specific section of the queries that were given to them, as well as in their free search. Users can benefit from organised visual facets of queries that encompass the diverse aggregated fields so they can originate their first approach to OCH. Although there are sill a large amount of data fields that can be used, the can be implemented as a posterior result refinement process, since the vast majority of the times where specific data fields were uses was to describe or request concepts that could be considered advanced. For example: providers, art types or the request of a specific media type. This is not to say that the diverse data fields will not be helpful for other users, but that they represent a part of the query that is commonly performed as a data refinement process where users modify the results from an original query. As a first approach for OCH where users might arrive on a visceral state, thus depend majorly on aggregated fields to browse searches based on those terms.

7.6 Conclusion

Europeana has structured their information using the Europeana Data Model (EDM). This data model includes other ontologies to fully describe the collections. Other related ontologies such as Dublin Core and SKOS are used to describe the particular relationships of the data, such as dc:creator, a creator of content as defined by Dublin Core. There is considerable complexity behind the different ontologies that encompass the EDM. This conceptual complexity is minimised by combining some of the data fields through aggregated fields on the API. These aggregated fields will merge several data fields of the ontology within a single term. For example, the aggregated field WHO, will include dc:creator, dc:contributor and skos:prefLabel within that search. Users are still able to perform the search directly by using dc:creator as the only term. The UCD experiment indicated that users prefer to begin their search from a broader term, before detailing through the facets the specific variants of their query.

The results of the UCD experiment informed how users structure their thoughts and how they were able to trace them. The objective of understanding how users engage with OCH was carried out through the queries that they produced through the TUI. A query is always the first approach to explore OCH information. Data visualisation tools for example, need to start with a query. That being said, the TUI built in this research can be used to produce the original query where later visualisations can be derived. In the same way that many museums will provide a particular curatorial perspective already embedded with specific paradigms and organisational patterns, data visualisation tools have embedded in them specific perspectives of how the information is meant to be manipulated. To provide a first engagement with OCH, users have to be aware of the complexity behind it (see Chapter 2), thus remove the paradigms behind searching in single organisation such as a museum or a library.

The construction of the TUI was carried out by implementing off the shelf electronics and used materials such as paper that can be easily accessible. It was mentioned that TUIs commonly require complex set ups as well as specialist equipment. By reducing the complexity of the setup and the materials used, its distribution capabilities can be enhanced. Nevertheless, once the original set up has been made, it is easy to execute the application since it runs on a Web browser while a TUIO app (server) is running. The use of standard Web languages such as JavaScript, HTML and CSS can also encourage its adoption. TUIs are commonly produced by HCI experts and people with technical backgrounds, and normally use complex programming languages that are difficult to adopt by general audiences. If a particular pyfo, sensor or actuator has to be modified, it will also involve advanced skills to modify it. However, Computer Vision systems such as TUIO, allow embedding interactive properties to any object by attaching a fiducial to it. Unlike the TUIs commonly produced by experts, in the case of this prototype, once users learn how to work with Europeana's API, it should be relatively easy to modify the syntax of the query or modify the shape of the pyfo.

In addition, the design of the pyfos has followed design principles to produce a visual communication system with the user. Users identify pyfos by shape, colour and volume. The use of these elements creates a conceptual relationship with the data fields (such as 'who', 'what', and 'when'). All the different pyfos repeat the same kind of affordances according to their kind of shape and volume. This creates a consistency that eases the communication between users and the system.

The methodology of design introduced in the previous chapter brings an understanding of the different paradigms of the engagement with information from the different CH organisations. Working with TUIs involves understanding many of the interactions that take place ‘beyond the screen’. The TUI provides a way to focus on the physical tools as an aid to structure and pace the user thoughts. The use of physical objects helps users to re-trace their actions and loose fear of making mistakes because they can isolate the specific thought section and work with it again through an epistemic engagement.

The final evaluation discussed in the next chapter shows how participants used the tools and the different interactive strengths and weaknesses of the system. In addition, it presents the different engagement processes that users went through while querying OCH information through the TUI.

Chapter 8: Methodology A-Posteriori. Interaction Design, Implementation and Evaluation

This chapter discusses the final implementation of the TUI prototype based on the information gathered from the UX/UCD experiment. It discusses the design principles that facilitate users to grasp the tool affordances of the system. The information gathered in the analysis phase through a survey, as well as surveys by the European Commission, Europeana, and research about search logs on the Web, have indicated that the vast majority of OCH users will arrive to their first engagement in a visceral and conscious state. The UCD experiment presented in the previous chapter showed that even though CH professionals can perform a formalised query related to their fields of interest, they will not have the skills to do so under the current tools provided in OCH. This is because currently, even using the API, users are required to have certain knowledge of query languages, as well as of the different data fields contained in the model in order to produce a meaningful query in a semantic way.

This chapter also presents the final evaluation of the TUI prototype and results. The group sample of the system evaluation mixed participants who work with CH and users with no CH background. This chapter describes the different demographics such as digital generation, digital literacy, and their perception about digital information on the Web. Participants took place in the evaluation phase of the interactive system where its Usability, Engagement and UX was tested. The evaluation presented users with 7 pre-defined queries and a chance to explore Europeana content using the TUI. These actions were recorded and further coded and analysed. This chapter discusses the different strengths and weaknesses of the system. The last chapter discusses how the system can be improved, the areas where TUIs can be implemented, and how the role of tangible interaction can enhance OCH engagement with information in the future.

8.1 Extended Interaction Design Methodology (SA&D/HCI-M) applied in this research

The approach used in this research for the development of the prototype consists in the combination of two different methodologies (see Appendix A for a detailed explanation of each methodology):

a. The System Analysis & Design and the HCI methodology (SA&D/HCI)

b. The Problem-Solving methodology (M)

In addition, the design process also included a User Centred Design approach, where users explain the potential tools required for the interactive system and which need to be integrated in the design process, and the possible interaction behaviours that might take place when interacting with the system.

The SA&D/HCI, developed by Zhang et al. (2006, 2004) provides an understanding of human factors, such as affective, physical and cognitive constrains. In addition, it fits with the requirements of the systems development lifecycle (SDLC), which according to Radack (2009), is the process commonly followed by information technology specialists. However, when working with TUIs, the interaction design process usually falls outside the traditional scopes of how an interactive system is used. For this reason, it makes sense to extend this methodology by integrating it with the Problem Solving methodology (M) as devised by Munari (2004), which aims to identify how the tool is meant to help the user to solve the particular problem. This is to say that while the SA&D/HCI works on the development of a tool for a particular task, the Problem-Solving methodology will try to identify what users actually require to solve a particular problem, without producing further complications (Figure 42, see also Appendix A).

The integration of these two methodologies includes a series of different phases. These phases are: Project selection and planning, Analysis, Design, and Implementation. The general steps that can be followed for other projects are described in Appendix A, while the specifics of how these phases were implemented in the case of this research and Europeana are described next.

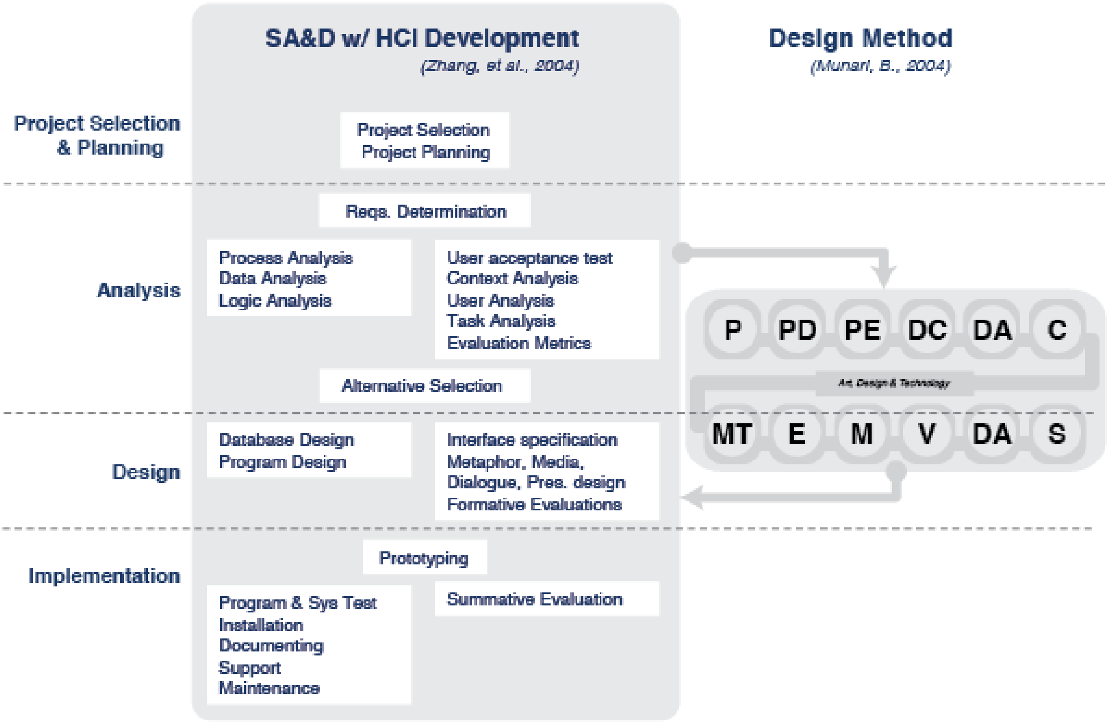


Figure 42. Proposed Methodology

Project Selection and Planning

The first stage in the development of the prototype was to identify what is the system meant to do. In this case is to query OCH data. To do this, it was identified that this querying process could be carried out through Europeana, which provides different levels of access and re-usability of its content. As a result, the interactive system focuses on querying Europeana data through their API.

Analysis

The analysis phase investigates how such queries might take place. This process is described in Chapter 6 that fully introduces Europeana as a case study, and details the different data fields used to describe the collections. In addition, it also describes diverse boolean operators that can be implemented by users to further contextualise queries. Europeana API queries requires Apache Lucene syntax, which is also further described in Chapter 6. Due to the fact that the interactive system is meant to be used by general users, it cannot be expected from them to know about the meaning of the data fields in the Europeana Data Model (EDM).

This phase, calls for an understanding of the current state of the end users and their current skills to query Europeana. For this, a UX/UCD experiment is carried out, where users who work with Cultural Heritage (CH) are selected to show a scenario of how they would carry out querying tasks in Europeana. Having general users as end users means that it is very likely that they will arrive under a visceral or conscious state of need of information as presented in Chapter 3. This means that even though they might know what to search for, they will not have the skills or further knowledge to produce a meaningful query that embraces the contextual complexity behind the EDM. For this reason, participants with a CH background arriving in a conscious state, are expected to have some understanding of what is behind OCH or Europeana and the context in which it might be described, but will not know the technical terms used and the syntax to produce the query.

8.1.1 EXPANSION Creating Pathways to Design and Evaluate Tangible User Interfaces

When developing user interfaces (UI), HCI draws from many disciplines such as Psychology, Sociology, Art and Design among others. Studying human cognition and how it relates to interaction design is a relevant task that can benefit from many academic disciplines, design practices and interdisciplinary fields. Nevertheless, introducing those external perspectives complicates communication and collaboration between the people involved in the development of an interface. The main purpose of expanding the HCI and Software Development with Visual Communication methodologies in this research was to produce a final methodology that considers solving human factor problems, such as the engagement with the information or the construction of a TUI, in a way that can be easily integrated to standard Software Development methodologies. It is through Theory Extension as defined by Repko (2012) that theoretical and methodological gaps can be reduced by modifying a particular theory or perspective when solving a problem. In this case, that problem is the engagement of OCH knowledge through queries that embrace the complexity and conceptual elements that describe such collections.

Interaction design methodologies already relate to different academic disciplines such as Psychology and Social Sciences, Design practices such as Graphic Design and Industrial Design, and interdisciplinary fields such as Information Systems and Cognitive Engineering as discussed by Rogers et al., (2011) (Figure 43). Each of these disciplines provides particular benefits. As presented in the prior chapter, the majority of TUIs have explored novel ways of promoting more meaningful interactions, as expected by HCI communities, but there are very few examples that focus on the distribution or construction of the TUI as part of that HCI methodology. In addition, HCI and Software Development approaches, have set aside the role that physical objects and materiality play when interacting with the computer, as it takes place with TUIs.

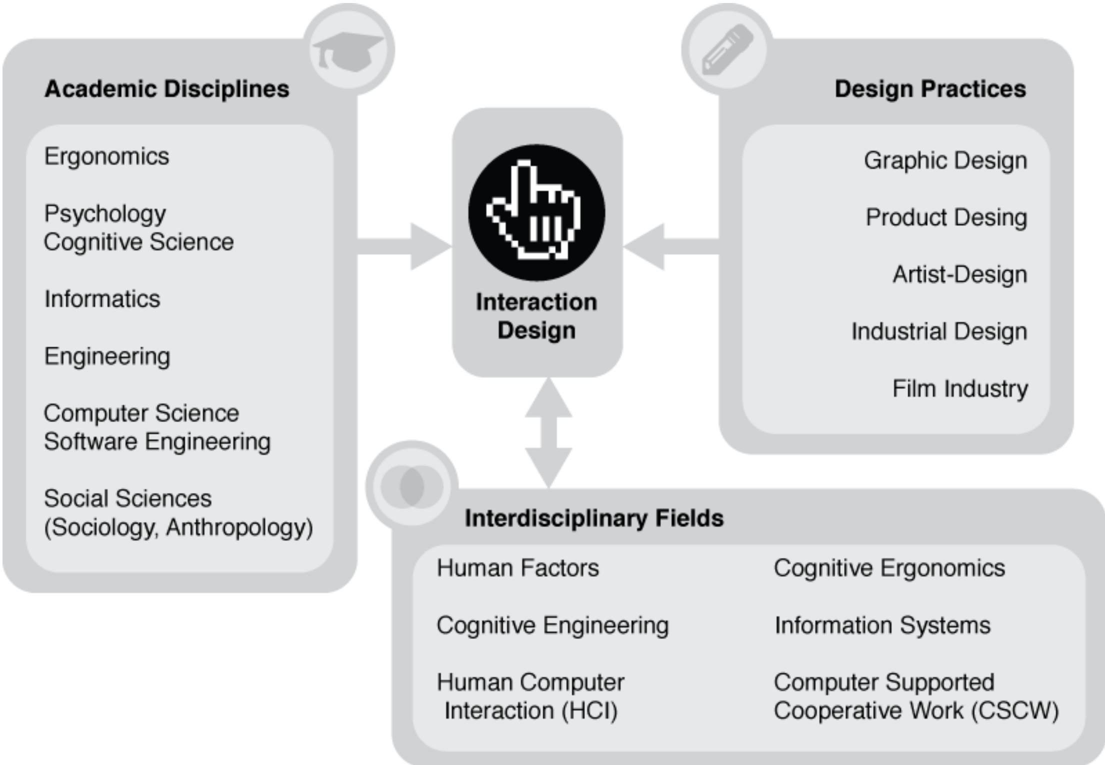


Figure 43. Interaction Design Approaches

As presented by Dix et al. (2004:196), and Rogers et al. (2011:12), there are four main phases that interaction design must include:

1. **Requirements**. The first stage identifies what is needed, followed by an analysis of different types of interactions and task models to understand the interactive processes needed.

2. **Design.** This involves the process of deciding how to make real the interactivity proposals devised in the previous stage.

3. **Iteration and Prototyping**. The designed elements are prototyped and tested so improvements can be made. Evaluation can be done directly on paper sketches. Nevertheless, it is strongly recommended to perform evaluation processes on prototypes close to what the final version might look like.

4. **Implementation and deployment**. Once the system is tested and finished, it needs to be released. This process might also include developing manuals, and tutorials or final modifications.

This interaction design methodology can be used as guidance for an essential set of phases that are to be carried out when designing an interactive system. To expand such methodology to an OCH environment, it is important to consider the groups involved in the creation of an interactive system, and the users that the system is meant to help.

Design

The information given by the UX/UCD experiment, provided the design process within the SA&D/HCI methodology the foundational elements for the interface specifications, including syntactical and lexical decisions, such as choosing how tool affordances and information was to be conveyed to end users (see Appendix A for an extended discussion on this). As said before, the SA&D/HCI design process was extended with Munari's Problem Solving (M) methodology to analyse what the problems were when interacting with OCH or Europeana data and solve them. Therefore, the SA&D/HCI-M design process served to develop not only the interactive tools, but tools focused in aiding the end user to solve any given problem. These include as mentioned before, the problems of engaging with OCH knowledge depend on the technologic (e.g. using a computer), technical (e.g. knowledge of data fields) and conceptual (e.g. understanding of ontology) complexity required to produce a complex query that fully embraces OCH.

The SA&D/HCI-M embraces the design process originated from a user perspective. Based on the use of TUIs, the design process should consider how end users, particularly on the Web, can access these kind of systems, which includes solving issues such as how to distribute the system, how users can build it and use it. Chapter 4 discussed how TUIs can be complex systems that might be difficult to implement or to build by general users without having the expertise about the programming and electronics normally used. Therefore, such problem-solving methodology facilitates the design process in order to produce the tools in such a way that satisfy the software or system requirements, but also to solve the necessities of users. This design process will explore how the lexical and syntactic elements of the system will be produced. This is because users will interact through metaphors as well as real world objects (e.g. tokens). Therefore, the TUI process includes the exploration of materials and technologies that facilitate the distribution and construction of the system.

Implementation

Once the elements of the interactive system were designed, the final prototype was built and tested. The assessment was carried out through a heuristic evaluation with a suggested sample of 10 to 15 participants as discussed by Hwang and Salvendy (2010). To explore users' cognitive processes, the evaluation took place as a minimal guided environment as described by Piaget (2013, 1952). Users were not guided on how the interactive system works in order to find out if the TUI is able to communicate the affordances of the system among general users. The logic behind this is supported by the fact that minimal guidance environments allow participants to pace their actions through a constructivist process (Papert, 1993).

Through different pre-designed queries given to the participants, users were expected to find particular collections by producing complex relationships of the concepts and logical elements by mimicking such query. These queries were given to the participants in pieces of paper where they could read it. Some of the queries were broken into two parts, where they had to modify the query. The purpose of having a two-phase query was to explore the ease to modify or refine a query that was already built. In constructivist environments, as discussed by Papert (1993), there is no single way of solving a question, nor a right or wrong answer for what the task was created. The queries designed for the evaluation aimed to provoke participants to engage with the different conceptual and technical elements of Europeana's API. For example, '*Find fashion objects from 1800 to 1900 from Italy; or from Wales',* was designed for participants to engage with the dates, locations and objects through the different aggregated data fields (see Chapter 7). In addition, participants were also given the chance to freely explore using the interface. While on one hand, the pre-designed queries aim to explore the capability of expressing a query, on the other, the free query is aimed to explore a query based on their own need of information.

All participants' actions and task completion times were recorded. Participants were also asked to fill a survey where they described their digital generation and literacy, as well as the way in which they search and understand information on the Web (see Chapter 7 and Appendix C). The survey also asked participants if they took part in the UX/UCD experiment, in case there were any major differences in their interactive behaviours. Once the experiment finished, participants were asked to fill up a usability questionnaire. This questionnaire was based on the System Usability Scale (SUS) (Brooke, 1996), where a set of questions are given to the participant to identify the strengths and weaknesses of the system (Appendix C). The score adds up to a maximum of 100. Although this numerical value of 100 does not represent a percentile or a specific grade, it can be used to produce a reference point of how usable is the system. In the case of the SUS, it can be interpreted as a threshold where 50 or 60 would be the bare minimum of expected errors or usability issues, and 100 a system that presented no usability issues whatsoever. Although these measurements are context specific, and there is no definite value or numerical result to define usability (Brooke, 1996), the SUS scale can be used to provide an understanding and a methodology to identify usability issues.

The SUS survey consisted of 20 questions. Furthermore, participants were asked to rate their perception of the system. The survey as well as the evaluation of participants was carried out through a form presented on an interactive tablet. The form was designed using iFormBuilder (iFormBuilder, 2015); when users finish the input of their information, the data is sent to a server, where it can be further downloaded and analysed into any computer.

Participants' task completion times were analysed using descriptive statistics with SPSS. In addition, participants' queries were also recorded and their engagement behaviours annotated through the observation. The combination of the task completion time, the SUS analysis, and the Engagement observations facilitated the understanding of the system's capabilities to demonstrate how TUIs can aid the interaction with the computer and ease the engagement with complex sets of information. Despite the interaction design methodology presented in this thesis also considered the distribution process, the evaluation of distribution and adoption was not carried out since it falls out of the scope of this research. The main objective, was to explore how TUIs can facilitate (and perhaps enhance) the engagement with OCH by providing a pathway to produce complex queries, where users embrace such mental complexity through the different elements of Europeana's data model.

8.2 Applied Design Principles for Query and Distribution in OCH

The User Centred Design (UCD) approach aids to the understanding of common user behaviours and requirements. It is recommended that design processes address them by providing meaningful experiences for users. Visual and communication principles enhance the UX by adding meaning according to users' needs to the diverse objects than contain a range of affordances that convey a wide range of interactions. Common interaction design approaches, especially on the Web, have failed to leave the screen, thus limiting interactions to a mouse and a keyboard. The interaction design methodology in this research called for an iterative process that acknowledges role of physicality and materiality to smooth and facilitate users' interaction. Nevertheless, the design process of TUIs is not limited to the users' performance when they use the tool (e.g. Usability, UX). TUI designers need to take into account the role that distribution and adoption of TUI systems have to play when developing such tools.

Firstly, distribution can be described as the process in which a system or technology is provided to the end user. Arguably, distribution could be related to Pervasive and Ubiquitous computing perspectives where there is an attempt to understand how physical environments and computer networks can adapts to users and client behaviours (Weiser, 1993, Satyanarayanan, 2001). Although these perspectives aim for theoretical applications for computational processes of everyday environments and users, they exemplify the process of placing such technologies 'in the wild'. There is very little literature that focuses on TUI distribution as the process of providing TUIs in the same way as GUIs. The vast majority of GUIs are based on the Window, Icon, Menus and Pointer (WIMP), and every home with a personal computer is very likely to have the same setting with perhaps different screen sizes and resolutions. TUI designers have to provide the physical tools that will replace the WIMP interaction style. The design methodology in this thesis offers such opportunity to explore how distribution could be alleviated in order to provide a TUI tool to end users on the Web. For example, this can be done through assembled or pre-assembled kits, as well as DIY kits or through sets of instructions that show how to build the TUI from scratch. There is some evidence of research that attempts to solve this problem by producing toolkits that facilitate designers with toolkits for TUI production and prototyping

(Klemmer et al., 2004, Lee et al., 2004b, Costanza et al., 2010, Greenberg and Fitchett, 2001). Nevertheless, these approaches still require a high level of digital literacy.

Secondly, adoption can be considered as the process after the interface has been successfully distributed and users proceed to implement their own concepts to it. This latter process can be analysed either from the physical or digital aspects of the system. There are a growing number of DIY communities on the Web and CH organisations that shows that users are willing to adopt and enhance technologies (Tanz, 2015, Morzov, 2014). Websites such as Instructables or Make, as communities, have heavy technologic DIY projects where people build, adapt and re-shape thousands of projects. The use of microcontrollers and sensors such as the Arduino, MakeyMakey, LittleBits or RPi has made it easier for non-technical users and designers, to develop creative projects that enable embodied interaction. In the particular case of TUI adoption, projects such as the dTouch Sequencer and the Deity Collector has showed a examples of adoption where general users were willing to implement and extend a TUI system (dtouch, 2016, Pereda, 2012). The design of TUI systems should consider these types of adoptions and extensions by these communities, who at the end are meant to use them.

When designing TUIs for the Web, designers should consider how is the interface going to be used beyond the parameters in which it was tested. Therefore, to facilitate its adoption and distribution, Web TUIs can make use of Web standard technologies, as well as making use of consumer grade electronics and materials. The prototype presented in this thesis followed these two perspectives in it's design process: [1] providing a system that can be easily distributed and [2] that uses Web standard technologies to promote its adoption and adaptation.

One of the main restrictions with TUIs is that they are difficult to re-purpose them to do other tasks. This is not only due to their physical affordances, but also due to the technical complexity behind their development. It is unlikely that general users will have the skills to re-write the interactions embedded in the pyfos. Nevertheless, providing the interactions through a Web based system such as a Web browser or Web App, allows the TUI to remotely connect to other programs or websites designed by other people. In addition, due to the physical nature TUIs, the design process has also been influenced through potential users' requirements such as building and tinkering with consumer level computer equipment.

8.2.1 Design for Web Adoption of TUIs through Computer Vision

The interface part that is displayed on the table is not much different to a website. It has been built by using elements such as Divs, text fields and images. The interface can be opened and be fully operational on browsers such as Firefox, Safari and Opera in Windows, Mac and Linux. The input is created from an open framework protocol for tangible multitouch interfaces called TUIO as well as the keyboard for text input (TUIO, 2014). TUIO detects computer vision objects (e.g. fiducials) and assigns an ID to each fiducial, making them distinct from other fiducials. TUIO can also detect specific fiducial related data such as X or Y position, rotation angle, or entering or exiting the webcam detection field. TUIO will detect every activity or change implemented on the objects based on three principles: enter, update and exit.

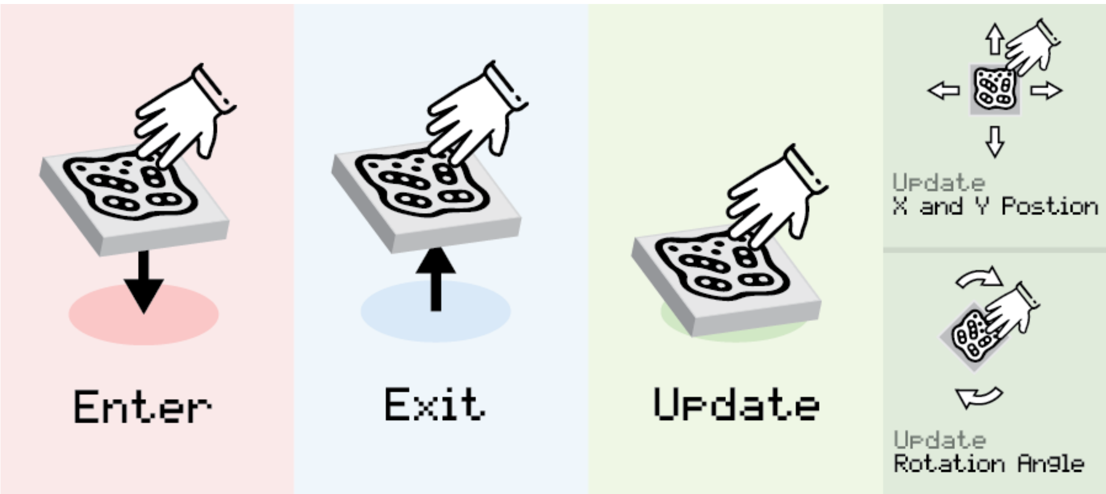


Figure 44. TUIO basic action principles

To send data from TUIO to the Web browser, TUIO uses a WebSocket. WebSockets allow Web services (e.g. browsers) to connect to a technologic client (e.g. TUIO) thus providing communication between them (Fette and Melnikow, 2011). The WebSocket used in the system is a Socket.IO especially designed to interact with JavaScript called npTuioClient; it allows writing JavaScript to interact with the data provided from the WebSocket. There is a wide range of Socket.IOs to work with TUIO. Nevertheless, it was decided to use npTuioClient (Rusadi, 2013), because it does not require the user to open any kind of port or to perform any special configuration on their computer. To enable it, users have to copy a browser plugin into their browser plugin folder. This way, all TUIO commands are captured and forwarded as JavaScript calls. Once these calls are in JavaScript they can be used to modify and interact with any of the HTML DOM elements through any of its languages (Figure 45). By using JavaScript, HTML and CSS, this project aligns to the most appropriate recommendations for Web standards (W3C, 2013). This is the reason why the project can run virtually on any Web browser, making it more accessible if placed in the wild. As mentioned above, the interaction data is provided by TUIO. TUIO as a framework is the first attempt to standardise touch and physical objects (TUIO, 2014). Even though there is no standard yet for the Web, TUIO provides the best environment for Web users to implement since it is an open architecture. This should allow and promote users to implement and extend this kind of interfaces.

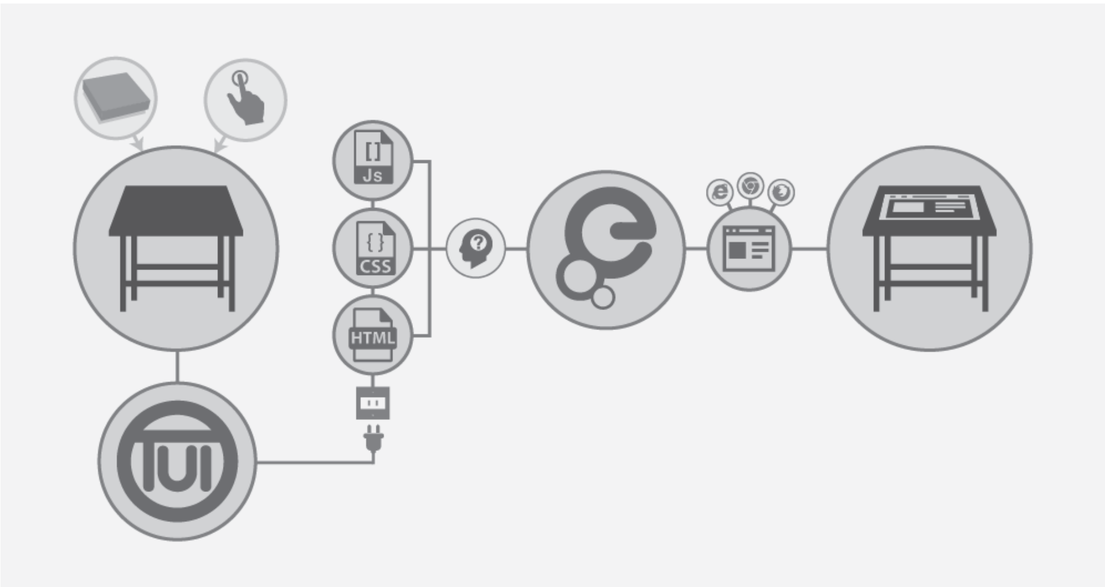


Figure 45. Technology specifications – connecting TUIO as a Web browser

The behaviours observed in the UX/UCD experiment provided an understanding of the different data fields that might be relevant for users when producing queries in OCH. These behaviours include the way in which users might use the aggregated fields and combine them together. Users should understand the different affordances, combinations and properties of the different pyfos. On one hand, the pyfo will enable the user to produce the syntax required to produce a query. This process will take place without the user noticing it. On the other hand, the visual and physical affordances of the pyfos will aid users to understand how these different pyfos could be used through its affordances. These affordances depict the diverse Europeana API aggregated fields as concepts and how they could be related.

Based on the observed user behaviours, users are likely to begin their engagement through the diverse aggregated fields and attempt to connect them as a query. For this reason, it was decided to encompass an aggregated field as an individual object or pyfo. As a result, the different facets of the query will be produced based on the concepts produced by the aggregated fields. Within these objects, logic boolean operators are added to each object in order to further construct the query. When users interact with the tools, it will produce two layers of action. First, a technical and conceptual action takes place, where the user relates to the concepts provided through the aggregated fields, and second, where the user relates the concepts and applies logic to add or remove concepts.

Figure 46. Table-top TUI prototype

Each data field is assigned with a specific colour and shape that will help the user to identify them. The design of the pyfos is based on the concept of the data field they represent so users can map them on to the interactive surface. Boolean operators are implemented as part of the sensory-motor affordances, embedded into each one of the pyfos. Users can identify the different pyfos through a conceptualisation process that is followed by a cognitive process, where they will relate the different concepts or data fields and the sensory-motor actions. The affordances will be communicated to the users through a staged cognitive process. This process is built in different stages through a conceptualisation process where users construct the objects from basic visual elements such as points or lines. Further on, these points and lines construct more complex visual elements based on shape, colour and texture. The concepts and affordances that are to be conveyed through the pyfos are not visual. Therefore, they require a construction of a visual representation system that can be recognised by users. According to Wong (1993) it is through visual representation that users can understand and relate concepts and actions to any given object (Figure 47). In this case the pyfos have the role of provide the support similarly to faceted searching. Faceted searching has been used in different Web scenarios and heritage organisations such as libraries to provide an understanding of the data fields or vocabularies, searching, and disambiguation (Fagan, 2010). Nevertheless, users are still required to produce a query and combine a wide range of *facets* or concepts and logic operators. That being said, the pyfos have the role of providing the browsing tools which help users identifying meaningful elements to produce their queries (Frost et al., 2000).

The main pyfos were created as hexagon prisms. These prisms will encompass a concept through shape and colour enclosure. Based on design principles, shape, colour and texture are the lowest level of changes that can be implemented on a design to produce variations from it (Krause, 2004). This visual variance will help users to differentiate the different pyfos, thus maintaining the affordance relation between them. The first level of variance of the elements in the pyfo begins with the shape. To reduce the amount of information complexity in the enclosure, it was decided to use simple shapes such as triangles, squares and basic colours such as red and purple (Wong, 1972, Wong, 1999). If more variances are applied, the complexity for users to associate them will increase as well. The final variance will embed a conceptual entity by adding text as a shape. Although participants will associate the word of the data field (e.g. Who, What), the text becomes part of the object itself thus becoming the 3rd variance of shape as freeform. This design variance process will produce a visual communication system that is simple and easy to remember, thus reduce the mental effort required to recognise each pyfo.

The top face of the hexagon prism was enclosed as a plane with a particular shape for users to identify a specific concept or data field. OR and NOT Boolean operators are activated by rotating the hexagonal pyfo 45˚ to each side respectively. To communicate the rotation properties attached to that rotation, each side of the hexagon was accentuated and secondary visual elements were added. The visual nature of a hexagon should invite users to rotate since it looks closer to a circle, compared to other shapes with less faces (e.g. square). When geometric shapes are placed on a surface, it produces different sensorial reactions such as balance, direction and gravity (Wong, 1993, Pinna, 2011:401). This will suggest users how to place the pyfos on the surface and how it can be manipulated. The visual gravity of the object when placed on the surface will motivate users to place the pyfo in a neutral position, at 0˚ rotation, defining it as a starting point. Finally, the text and arrows to consolidate the rotation action are placed.

The combination of all elements presented on the plane of the pyfo should invite users to rotate and assign each Boolean according to the angle it is rotated, thus indicate that the central part is the starting point. The conceptual complexity of the wide range of combinations is conveyed only through the three main variances of design, while the remaining elements of enclosure are repeated among all primary objects to facilitate the communication of its affordance (Figure 47).

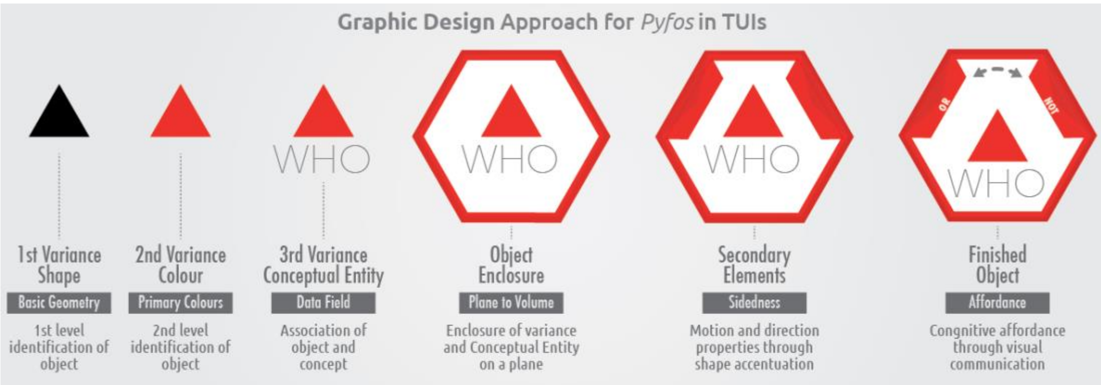


Figure 47. Design Process for Pyfos

Secondary objects were designed for query refinements. Primary objects represent the constant part of the query, and the secondary objects the variable part. This is to say that secondary objects are extra variables commonly added after the primary query has been built. For example, users could search for the term *Dove* (query=what:dove) as a primary term, among things made by Pablo Picasso (qf=proxy_dc_Creator:Pablo Picasso), which is used as a refinement query. For this reason, secondary pyfos will not require Boolean operators. These pyfos will follow the same variance visual system patterns as primary objects, only with a lower colour value. By providing a lower colour value, users can still create a relationship between the primary object and the secondary, but still produce a hierarchical division (Wong, 1993, Shneiderman and Plaisant, 2004, Stone and Open, 2005). There is a perceptual division between the objects that can be rotated such as hexagons and the static objects such as squares. This division will depict that squares have less options, since they have less relational elements and are based only on gravity. This is to say that when users place them they should be less motivated to rotate them, thus making them static. As a result, the visual system depicts primary pyfos with secondary actions (hexagons) and single action pyfos with no secondary action for query refinement (squares).

The query construction pyfos have been distributed into two main groups: Input objects and Fixed Action objects (Figure 48). Input pyfo objects will display the input text field for users to type the text of the query. Input objects can be primary or secondary to define the constant or variable part of the query respectively. Moreover, Fixed Action objects such as Enter or Scroll, will have pre-assigned actions such as entering or clearing query fields, or assigning the amount of results to retrieve in the query. There is also a scroll pyfo object that has the role of scrolling the results after the query has returned data. The scroll pyfo affordances follow the same visual system as the primary pyfos. This tool was designed to allow users to explore the various results retrieved through the system. To submit or delete the API query, a cube pyfo was designed with an Enter and Clear on an individual face. Due to the fact that the cube is the largest object, it should produce the hierarchical effect thus inviting the user to place it until the end. The rectangular shape of a cube makes the object more static than the rest of the other pyfos, thus suggesting a sense of completion to the query building.

The background of the interface uses a dark grey colour (Figure 46). Using dark grey backgrounds, provides a neutrality that prevents an association with any other colour, thus still provide a harmonic composition (Wong, 1999, Heller, 2004). Moreover, the dark background produces a high-level contrast with the fiducial colours, allowing users to visually and mentally map the pyfos with the interactive surface. By mapping the pyfos to the highlighted surfaces, users can offload that mental structure of the query being produced through those highlighted facets. The association of object pyfo and the interactive surface should be produced mainly through the first two-variance levels of shape and colour before any other action affordances are produced. If a pyfo holder of the interactive surface is ‘inactive’, its colour value is reduced and increased again when active. This also helps producing a structured visual map of the data fields that are currently being used in the query.

Figure 48. Query Objects

There is a wide range of ways of producing fiducial objects for interactive purposes such as 3D printing or paper crafting. It was previously discussed in Chapter 5 that interaction design methodologies especially working with TUIs need to consider materiality and the role they play in the development and user interaction. In addition, it was also discussed that TUIs will increase the complexity to distribute them, particularly on the Web. There is very little literature that discusses TUI distribution and ‘in the wild’ adoption by participants. Nevertheless, a small sample of evidence suggests that general users might be willing to adopt and adapt TUIs (Pereda, 2012, Costanza et al., 2010). Although this process is not yet understood, designers have to consider the adoption process when designing pyfos and fiducials. In this case, all markers were designed for paper crafting. Participants can print on paper their pyfos and adapt them if necessary. Web TUIs require having the physical objects where the interaction with the system will take place. Designers and interaction designers need to consider how are those physical objects going to be delivered to the end user.

TUI distribution can be then understood as an interface that is built by the user or as an interface that is delivered to the users’ place of interaction. In the case of this research, the interaction design methodology has considered such distribution process and construction. For example, printing and building hexagonal prisms can be considered to be on a ‘beginner friendly’ paper-crafting level. In addition, although the use of JavaScript and other Web design languages cannot be expected to be known by end users, the fact that the interface is displayed on a Web browser, allows other designer to produce and deliver through the Web different or extended variations of the pyfos. In this case, end users will have to print new pyfos and navigate to that specific Website. There is still a large combination of visual markers and shapes that can be implemented for further interactions. This research can provide the information of how users might engage with OCH through Europeana and the particular ways in which they like to do so.

8.2.2 TUIO Table Final Build

Many of the new (and old) technologies dictate how users should interact with computers. Nevertheless, users should dictate how interactions should take place instead of the technology. TUI paradigms suggest some of the benefits where the interaction with the computer as well as easing users' mental tasks can be alleviated. Nevertheless, the use of TUIs has been limited due to the infancy of its development, as well as the complexity to build them and the technological skills to adopt and adapt them. Developing TUIs through computer vision allows simple objects, such as paper-based models to be embedded with data, thus easing the distribution of its interactive tools.

To build a computer vision system such as the ones based on TUIO, it is required to have an input (e.g. camera) and some kind of output (e.g. screen, projector). The camera recognises the visual patterns and sends the information to TUIO where other programming languages can pick up the data that is being received and apply a set of actions that can be rendered on a display (Figure 49). For interactive tables, a back projection allows object to be in direct view with users without casting shadows over the rendered output, unlike top projection systems. In this case, although back projection requires a matte transparent surface and building its support, for interactive purposes this can be considered a better option since it will not disrupt the rendered display.

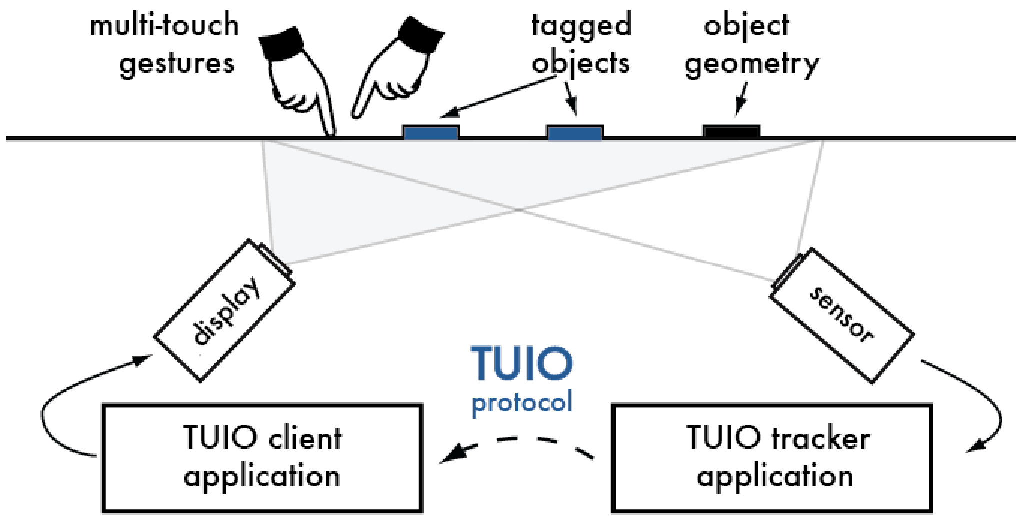


Figure 49. TUIO Basic Setup (TUIO, 2014)

Building an interactive table might present a challenge to some users, since it requires some carpentry skills and tools. For this reason, it was decided to use a wooden box that was easily adaptable for mounting the display surface and projector. Using pre-constructed furniture such as the Ikea Hol Storage Box can ease the construction process, keep low costs and ease its replication. The Ikea Hol Storage Box can be easily dismantled with an Allen key screwdriver and is very light. By removing one of the sides, it facilitates its access and mounting of the projector, webcam and computer. Further on, a mirror has to be placed on a 45˚ angle to re-direct the light from the projector on to the surface display (Figure 50).

One of the sides of the box can be removed to place the projector behind so users cannot see it and keep their attention on the display. To increase the throw range of the projector, a mirror is placed inside the cube in a 45˚ angle to project the image on the top of the table. By doing this, users can fix the scale relationship between the projection and the physical objects. When the display projects 250px, the display can be translated into 6.5 centimetres. Although is not necessary to have a definite size, designers need to be aware of the dimensions of both physical and digital objects when producing these types of tools.

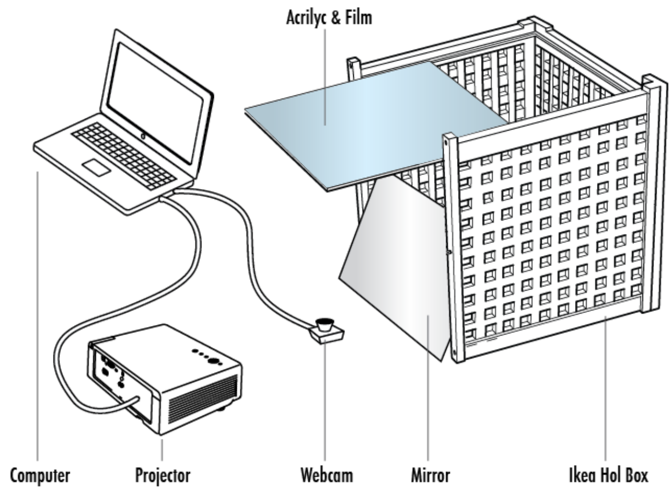


Figure 50. Table construction

8.3 Evaluation of the TUI Prototype

The main purpose of this research was to explore how users could produce complex queries to embrace the full complexity behind OCH knowledge. The evaluation of the TUI prototype was carried out to understand if participants are able to produce complex queries and implement the diverse conceptual elements of Europeana's data fields. Despite that user interfaces are commonly evaluated through comparative studies (see Appendix A.8), this research carried out a single case evaluation process. The literature review showcased a list of GUIs developed in Europeana's hackathons, where each interactive system presents a particular benefit that can present a higher score than other interfaces developed for Europeana. Nevertheless, the problem still remains that on the Web, as well as in Europeana, there is no current query system that facilitates the production of complex queries that embrace the technical and conceptual complexity. For this reason, the evaluation process of this research focuses on providing a holistic understanding of the strengths and weaknesses of querying through a TUI system as an exploration of alternative methods of querying OCH knowledge.

Europeana's API data fields are structured under the Europeana Data Model, which provide a level of reasoning of how the diverse concepts relate to each other. Beside the digital literacy required to query such data, querying OCH data will require users to know that such relations exist. Nevertheless, as observed in the UX/UCD experiments, it is very unlikely that even users with CH expertise, who are aware of the conceptual relationships of the records, will have the skills to produce conceptual relationships through the diverse data fields. The TUI prototype presented in this research, aimed to understand if such complexity behind OCH data models can be alleviated through the use of TUIs.

8.3.1 Participants Behaviours and Demographics

To evaluate the TUI system, a sample of 11 participants was recruited, where first they answered a survey about that can help identifying their search behaviours and digital skills. Form this sample, 5 participants were born in between 1981 and 1995 (Generation Y) and the remaining 6 were born in between 1961 and 1980 (Generation X). Only 7 participants worked in the cultural heritage sector. The remaining 4 participants were from different backgrounds such as Graphic Design and Human Computer Interaction (Table 14, also see Appendix C). Only 3 participants took part in the UX/UCD experiment. Despite that the participants who took part in the UX/UCD experiment were exposed to the concept of OCH, they did not know any of the data fields of Europeana’s API. Only 2 participants were aware of the concept of the Semantic Web, where only one from them was from the CH sector. In addition, only 2 participants claimed that they use Booleans and operators when searching on the Web. From these two participants, only one works in the CH sector. These demographics, suggest that the vast majority of participants do not have any prior knowledge about the concepts used in Europeana to describe OCH collections, even if they took part on the UX/UCD experiment. Therefore, most participants should arrive either a visceral or conscious state of need of information. This is to say that they will have no information or very little information about the conceptual elements and data fields required to query the collections. They might be able to know what sort of questions to make, but will not have the technical or digital skills to produce a query.

The literature review presented in Chapter 4 discussed that TUIs can ease interactions, particularly with users on the low digital literacy level spectrum. In addition, this research aimed to understand how TUIs could aid users to produce complex queries that embrace OCH complexity when users will not commonly have the digital literacy or conceptual understanding of the collections. Engaging with OCH through TUIs should empower users to focus on the content, instead of figuring out how to operate an interactive system, or how to combine data fields through complex syntax, without having prior knowledge about CH topics. The participants recruited for this experiment were asked to rate themselves on how they perceived themselves as Web searchers. 3 participants identified themselves as experts, 6 participants as competent and 2 as novice. This perception of themselves can be used as an indicator of how confident they feel when searching on the Web. This is because only 2 actually use Booleans and operators when searching on the Web, which can be taken as an indicator of the expertise level when searching. Nevertheless, this question was asked in order to provide extra context to the participants' user evaluation results.

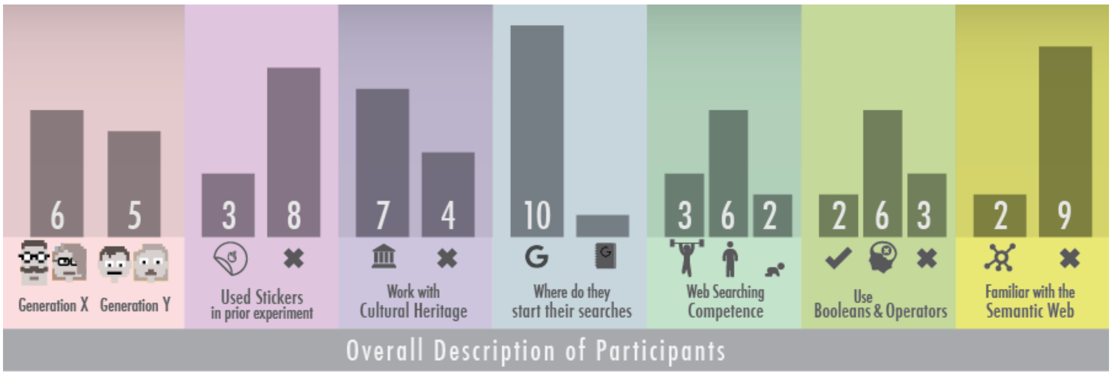


Table 13. Participants Overall Description

ID	Stickers Experim.	Work with CH	Field of work or study	With which particular type of organisation do you work the most?	Visited Orgs Web
11	No	No	healthcare		
10	No	No	training tools		
9	No	Yes	Forestry	Other	
8	No	Yes	Forestry	Other	51-100
7	No	No	graphic design		
6	No	No	n/a		
5	Yes	Yes	Museums	Other	200+
4	No	Yes	1960s artist magazines	Archive	10-50
3	Yes	Yes	Digital humanities	Archive	51-100

2	Yes	Yes	Cathedral burials and monuments	Archive	51-100
1	No	Yes	Human Computer Interaction	Museum	0-10

ID	Physically visit org.	Times used org's Web for research in 12 months	Where commonly start search on the Web	Familiar with Semantic Web	Expertise on Web
11	Yes	10-50	Search Engine	No	Competent
10	No		Search Engine	No	Competent
9	Yes	0-10	Search Engine	No	Novice
8	No		Search Engine	No	Expert
7	Yes	51-100	Search Engine	No	Expert
6	Yes	0-10	Search Engine	No	Competent
5	Yes		Search Engine	No	Novice
4	Yes	10-50	Academic SrchEng	No	Competent
3	No		Search Engine	Yes	Competent
2	Yes	51-100	Search Engine	No	Competent
1	Yes	0-10	Search Engine	Yes	Expert

Table 14. Participants' figures

As discussed in the prior chapter, the vast majority of users will query on the Web using no more than two keywords on their searches and through services such as Google Search. Placing participants within a demographic group and understanding their behaviours and perceptions can help creating an overall consensus of why linking concepts or finding objects through Europeana might prove complicated for different users. 10 out of the 11 participants (Table 14, also see Appendix C) commonly begin their Web searches through search engines such as Google Search, while the one remaining indicated a preference for an academic search engine such as Google Scholar. The participants' responses seem to suggest their preference toward services such as Google Search due to its ease of use. 4 participants indicated that it is extremely easy to find information through search engines, 5 indicated that it was easy and the remaining 2 claimed that is neither hard nor easy to find information (See Appendix C). Despite this perception of ease to search on the Web, and their perception of competence when searching, only 2 participants indicated that they use Booleans or operators when searching (Table 13). If the vast majority of Web users search only using no more than two keywords, and the vast majority of participants do not use Booleans or operators to connect search concepts, it cannot be expected that they will also use data fields to their queries or connect different concepts across a single query.

Participants noted the result of the Search Engine as the highest quality of information in between, academic search engines, university library systems and wikis. 10 participants indicated that is the quality of information provided by the Search engine is fair while the 1 remaining participant rated it as high (Table 15, also see Appendix C). 7 participants indicated that their main problem when searching for information on the Web is that 'information is scattered through too many sources'. 3 participants indicated that they commonly cannot find what they are looking for and only 1 participant indicated that the searching process takes too long. The combination of ease to query and go through the information retrieved is a combination of digital (e.g. use of Booleans and operators) and information literacies (e.g. lateral literacy). The prototype presented in this experiment aims to provide the first engagement with the information, which commonly originates from search engines. Even though search engines simplify many of the processes through their algorithms (e.g. Google's Hummingbird), they are still not perfect, thus users have learnt how to navigate across the diverse results until they find what they want (Knight and Spink, 2008). Independently of the quality of information, search engines dominate the request for information. For example, wikis such as Wikipedia are visited by over 375 millions of individual users per day remain a primary source of knowledge providers on the Web (Van Couvering, 2008). Yet, the vast majority searches will originate from Google Search, especially in the CH sector.

In the case of the prototype presented in this thesis, it presents an enhanced version of searching through a TUI. The interface aims to enhance those cognitive processes when searching the Web, thus considering conceptual relationships of different CH organisations and collections through OCH. It has been previously indicated that this thesis does not focus on the post query processes. It can be argued that those processes belong to data visualisation processes that always take part after some information has been found. Nevertheless, before focusing on data visualisation, users first need to learn or be empowered to find answers before they can display and manipulate them with data visualisation tools. When users enter a query, the search engine will analyse the keywords used using an algorithm and match them across billions of files, thus present the ones, which are supposed to be the most meaningful ones. Search engines present a simplified version of the large range of possibilities that can take place through Web searching, such as the case of OCH.

Although, there is no consensus of how to empower users' querying processes for particular information need (Knight and Spink, 2008), this prototype aims to provide such empowerment to users who arrive in a visceral and conscious state of information need. On one hand, as mentioned by Knight and Spink (2008), the search engine could return more meaningful results if the user provides a more complex query. In the other, the intelligence behind the different ontology elements in a data model can also enhance the quality of the results by contextualising the terms used in a search. For example, when querying, users can express the difference between Picasso the painter and Picasso the car model.

None of the participants surveyed pointed to their digital literacy as a problem or factor when searching the Web (See Appendix B). It can be argued that users expect the technologies to adapt to themselves instead of learning a range of skills to perform such complex queries. In addition, organisations that take part of OCH cannot expect their users to learn Semantic Web technologies, their data models to query their content. As the complexity and specificity of a query increases, so does the quality of the results. The prototype presented in this thesis aims to provide an understanding of what and how different OCH concepts can be used to enrich the quality of their searches. By understanding the concepts used in the query, the user can have a better understanding of why their query is returning a particular set of results and modify it if necessary.

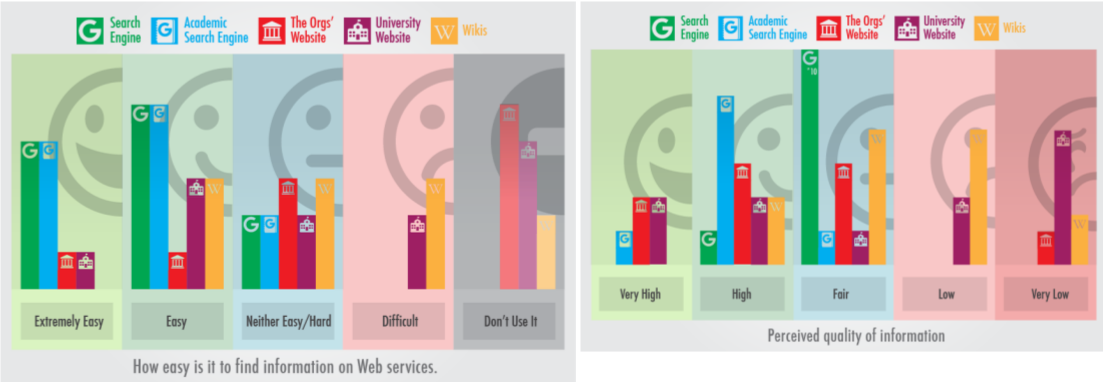


Table 15. Ease to find information on the Web (left) and Perceived quality of information (right)

8.4 Evaluation Results. Engagement and Usability

8.4.1 Engagement

The evaluation of the interactive system took place after participants answered the survey. Participants were explained that the interface was built to search CH objects on the Web. Therefore, there was no indication or suggestion about the cross-domain search capabilities of the system. As previously discussed, the interface works as an interactive table. Different pyfos will represent specific Europeana aggregated fields. When the pyfo is placed on the table, its respective area is highlighted on the display and a text field input is also displayed above it. By rotating the pyfo, users can activate the OR and NOT Booleans, which are attached only to that specific pyfo and data field (Figure 51). By placing the search pyfo cube on the surface, the query is sent to the server and the results are displayed. The display on the table has two main outputs. The lower right of the display, shows the data results through a list of the amount of results found from the different providers (edm:dataProvider), as well as a list of different type of digital object (edm:type). The top panel displays the title (dc:title/title) and the thumbnail of the results (edm:Preview). Such list of previews can be scrolled using the scroll pyfo by rotating it to either side to scroll up or down respectively. Finally, by placing the clear pyfo, users will remove all data from the interface, including results and any text in the form fields. If there are other pyfos on the table, to activate the input back again, the user has to move the pyfo and then the input-cursor will be in *focus* so the user can type the input.

The Enter Key was also used to enter the query as an alternative to the Enter pyfo cube. Also, the Backspace Key was used to delete the text of the input field of an activated pyfo. Although it was not expected that participants would use the Enter Key, it was decided to leave the Web browser functionality of the keyboard so it wouldn't cause major conflicts. For the evaluation process, it was considered to annotate when would participants replace the Enter Key for the Enter pyfo cube. In addition, another keyboard implementation was through the use of the Up and Down Keys to scroll through the results respectively. This implementation was not mentioned to participants and was primarily used in case the scroll pyfo presented too many issues with participants.

Participants were not explained how the interface worked, nor they were explained what Europeana is or how the information is connected. In was indicated that if they required any assistance through the experiment, they could be instructed as part of the interface learning process. In addition, as part of a constructivist learning process, participants were instructed that there were no right or wrong answers and that the experiment was designed to understand how they approach to solve queries related to OCH. The experiment was carried out under as an unguided and minimal guided environment, such as the ones proposed by Piaget (2013, 1952), where the learning process is carried out through users' cognitive processes and Papert's constructivist processes (1993). In these kinds of environments, users progressively construct their knowledge or learning processes. As part of a constructivist experiment, the concept of not having right or wrong answers is based on the principle that users can arrive to different answers or solve problems in different ways. Particularly in the case of this experiment, the objective was primarily to identify if users are able to produce complex queries and relate diverse data fields and not to find a specific collection item. That being said, the task scenarios provided to participants were previously tested in order to make sure that the query would return some results, thus offer participants results to display. The experiment was designed to evaluate the interactive system and its capability to enhance the engagement with OCH data by empowering the user to convey their mental complexity and understanding of concepts through a query system on the Web.

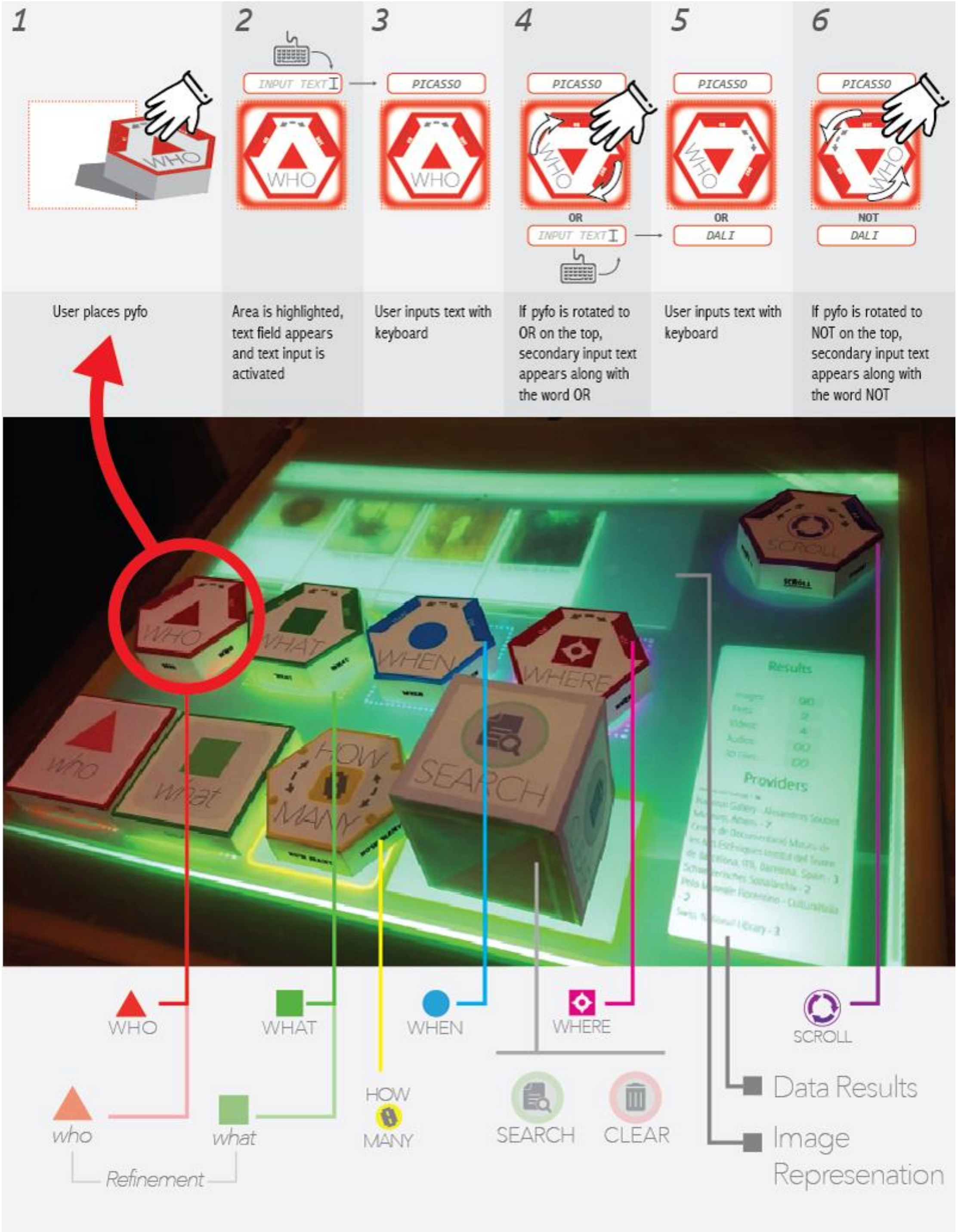


Figure 51. How interface works

The experiment required participants to produce 7 different queries, where some of these queries had a second stage modification (Table 16). These queries were aimed to find particular combinations of Europeana's API data fields. All queries were presented in a randomised order using a short JavaScript shuffling code to generate the sequence for the questions (Pereda, 2016). The questions included identifying authors (e.g. Rodin, Picasso), places, providers, periods of time (e.g. medieval), dates and things, aided as well with Boolean operators. The queries that had a second part (2, 4 and 7) were presented to them after they successfully solved the first part. When participants finished those 7 questions they were offered the opportunity to freely search for anything that they wanted.

Query	**Question**	
1	Find paintings by Leonardo Da Vinci	
2	Look for cats provided or that come from Egypt	… then look for mummy cats also from Egypt
3	Look for objects (anything) dated between 1525 and 1527	
4	Find any ceramic from Spain	… ceramic not tiles from Spain and not from France
5	Search for sculptures or paintings that were made by Rodin and not by Picasso	
6	Search for medieval coins held in the United Kingdom	
7	Find fashion objects from 1800 to 1900 from Italy	… or from Wales

Table 16. Experiment sample queries

Participants' completion time was measured to test the performance of the interactive system. The free search time was also measured. The measurement of the completion time started when participants finished reading the question and stopped when they activated the search action. The same process was carried out on the secondary questions. It was indicated to participants that they could take the time required to solve the query, particularly for the free search where the time was measured when they began placing the first pyfo on the table, and stopped when they verbally indicated that they were finished using the system.

The quality or validity of the query was not considered as a factor for the task completion rate and time. The experiment aimed to analyse if the system was capable of providing the contextual structure for the participants' understanding. That being said, the study showed a 100% completion rate.

It was expected that the first questions would take longer for participants to finalise. In this case, participants averaged 1 minute 6 seconds. Participants were figuring out how to solve the questions, find out about how the interface worked and learning how to make the query combinations. Nevertheless, it was noted that the task completion time dropped considerably after the first query was performed, since none of the following cases averaged over 50 seconds (Table 17, also see Appendix C). Participants had the opportunity to explore and work directly with conceptual elements of the query without focusing on learning how to operate the interface. The benefits of TUIs were noticeable where direct manipulation allowed participants to focus primarily on the conceptual elements of the query instead of focusing on how to operate the interface.

Users showed ease when learning how to operate the system. For example, it was observed that implementing the boolean operations by rotating the pyfos required participants to experiment no more than 1 or 2 actions when learning how to implement such actions. These actions were expected to be challenging for the users, but it was observed that only 4 of 11 participants rotated the pyfo to the opposite side, thus activating the other boolean (See Appendix C.3). Nevertheless, this process only took a few seconds to correct, and participants learned through a quick experimentation how to implement the booleans. In was also observed that when these 4 participants learned how to use the booleans, they performed a gesture as a sign of obviousness and showed confidence showing that they figured out how to use the tool. This suggests that the participants who had to spend those extra seconds figuring out the boolean operators did not represented any major effect on their actions and did not broke the state of flow of their query process. The remaining participants noted the OR and NOT on the pyfos and deciphered how to use them.

Task completion times were based on conceptual elements such as understanding what the question meant and the translation of the question task element into the tools of the interface. It was noted that in task questions 3, 5, 6, and 7, participants took longer time to solve the question, while in the tasks 1, 2 and 4 all participants scored completion times under 40 seconds (Table 17, see also Appendix C). The short task completion time could be attributed to the type of question asked (Table 16). In other words, these questions did not generate any conceptual complexity, where users had to deeply analyse the question in hand. For example, question 1: ‘*find painting by Leonardo Da Vinci’*, there is a clear thing (What:painting) and person (Who:Leonardo Da Vinci) to be searched for. The same can be said about questions 2 and 4 where there is a clear definition of what can be defined as a place (Where:Spain/Egypt) and a thing (What:cats). In the case of task 3, participants had to introduce two numbers to define the start and end dates for the query. Questions 5 and 7 required use of booleans and/or dates. In this case, participants had to implement over 4 terms on the query. Furthermore, these two queries were very similar in task completion time and did not presented any conceptual issues that hindered the interaction process. In the case of question 6, the term Medieval, seemed to raise cognitive dilemmas where participants were wondering if they should encompass the term as a What or a When. In this case, participants were explained that the term medieval could be implemented in the What secondary field (What2) which is used as a refinement query in the API.

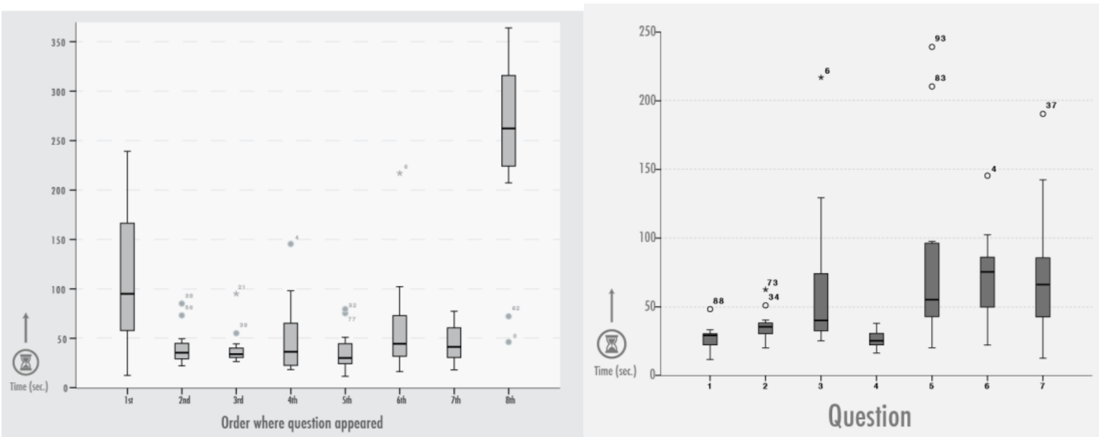


Table 17. Completion time by (left) question sequence and (right) question number

To provide further understanding, task completion times were compared between their task number and sequence. In the particular case of question 5, it seems to be grouped with the tasks that took longer to complete. This task had a large completion time when it appeared on the first place compared to the remaining ones. It can be suggested that the length of the query where users have to select different terms, as well as the different operators, might prove challenging as a first task, where users are still understanding the functionality of the interface. Nevertheless, the evidence suggests that since the most of the tasks that appeared first tend to remain higher than the following ones, indicates that users managed to learn how to use the interface quickly. Taking this into account, task question 5 could be considered as a question that was solved quickly and offered no further conceptual complications, such as 1, 2 and 4. Following this same order and task number approach, tasks 6 and 7 still remain as queries that took longer to solve since they appear to have same task completion times on other cases.

Participants solving question 6 had to think how to implement the term 'medieval'. In this case 3 participants used numerical start and end dates and the remaining 8 worked with the date as What. Participants had to think how the term medieval could fit within the pyfos. One participant even went further and indicated post-medieval, while another one indicated the specific centuries. These two participants (P2 and P5) work in the CH sector, thus suggest they had the knowledge and the information need level to perform such query in an informed way. The remaining participants produced such query by using the term Medieval as part of What (What:Medieval Coin) or a refinement of the query (What2:Medieval) (Table 18, See also Appendix C).

Query 6 - Search for medieval coins held in the United Kingdom						
P1	What:Coins	What2:Medieval	Where:United Kingdom	P2	What:Medieval Coins NOT Post	Where: United Kingdom
P3	What:Coins	When:100 To 900	Where:United Kingdom	P7	What:Medieval Coins	Where:United Kingdom
P5	What:Coins	When: XV TO XVII	Where:United Kingdom			

Table 18. Query 6 participants' queries

While the aggregated fields provided the conceptual structure for the queries, the pyfos aided users to structure their thoughts and further visualise the extent of the complexity of the queries. Users were able to implement quickly complex queries in a way that represented what they were looking for. After the pre-designed queries, participants were offered the opportunity to use the interface to explore freely. Participants averaged over 4 minutes of interaction using multiple pyfos and Booleans. During this free exploration, only two participants produced more than one query (P3, P5), while the remaining 9 only produced one query (see Appendix C).

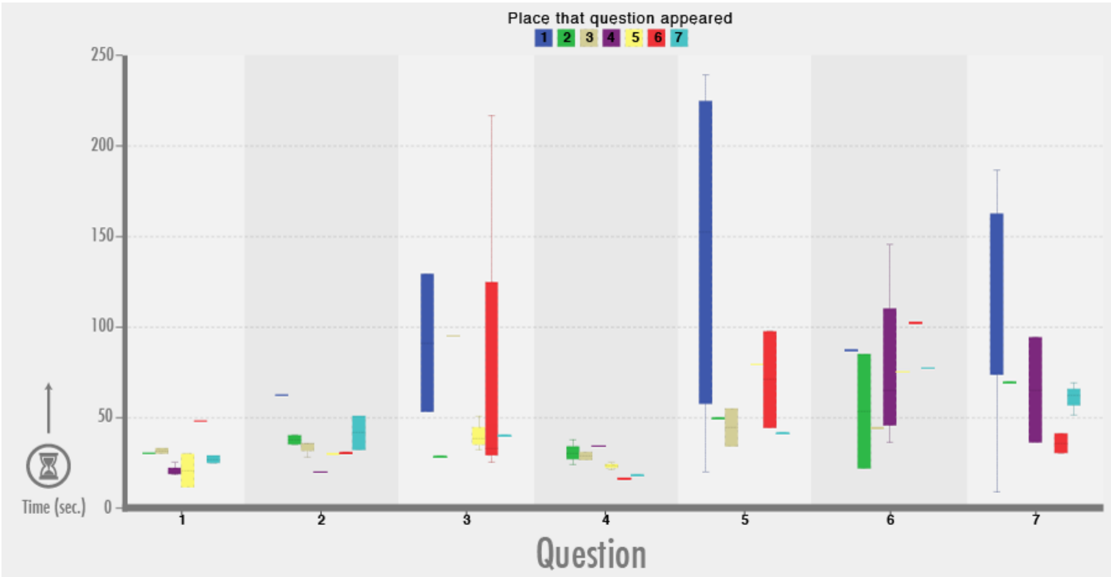
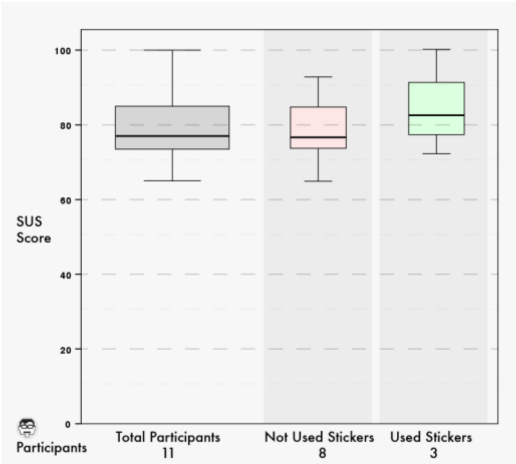


Table 19. Completion time by sequence and number

8.4.2 Usability and System's Performance

Based on the System Usability Scale (SUS), the system's usability performance averaged 80 points out of a hundred. Such score can be considered positive, since as previously mentioned, it is positioned on the higher score (100) of the usability threshold. Although 3 users who took part on the UX/UCD stickers gave the system a higher score over the 8 remaining participants who did not took part on the prior experiment, there was no real significant difference on their overall score (Table 20, also see Appendix C.5). As mentioned before, interacting with OCH requires not only the technical skills to produce the syntax for the queries, but also an understanding of the conceptual elements within the data model used to describe the collections. That being said, none of the participants had any prior knowledge about the data model or data fields. The prior UX/UCD experiment with the stickers suggested that users with a CH background would have a good understanding of the possible data fields. Nevertheless, there was no major difference in the way the queries where structured when using the system, between uses who worked in CH (7) and the ones who didn't (4). Both groups managed to produce complex queries promptly. The high SUS scores suggest and short task completion times suggest that users adapted to using the system quickly and engaged with the expected complexity with the information.



ID	SUS Score
1	76.7
4	85.55
6	84.075
7	64.9
8	92.925
9	75.225
10	76.7
11	72.275
2	82.6
3	100.3
5	72.275

Table 20. System Usability Score Results

The use of the interactive system did not seem to generate any stress when interacting with it. The interactive system aided participants with the cognitive tasks such as the construction of the query, as well as providing a conceptual reference of how the collections could be explored. Users managed to convey their thinking process and their own interpretation of the queries aided by the pyfos. The questions presented to the participants aimed produce the engagement with diverse data fields and operators to evaluate if the interactive system could convey the complexity behind OCH and provide users with the tools to query it. Many of the questions presented were designed as a two-step query. This is to say that when the first part of the query was ready and the participant already retrieved some results, they would have to perform a refinement of their previous query to adapt it to the second part of the query (Table 16). When users modified the queries to solve the second part of the question, they did it in a very fast way as presented on the task completion times (see Appendix C.2).

It is important to mention that although the question task could be solved in different ways. The question suggested a specific set of data field combinations to be implemented. Nevertheless, it was the own participants' thinking process and conceptual mapping that was individually input through the pyfos. For example, task number 2, which was separated into two sections, asked for a participant to '*look for cats provided or that come from Egypt'*, then on the second refinement, '*look for mummy cats also from Egypt'*. In this case participants managed to solve this second part by mapping What:cats OR What:mummy as well as What:cats What2:mummmy. In this particular scenario, both approaches returned the same results (Table 21).

what:Cats & where:Egypt

what:Mummy Cats & where:Egypt what:Cats & what2:Mummy & where:Egypt

Table 21. Task query 2. Different query approaches by participants

The pyfos can offer the user an introductory level of the type of terms that can be used to query Europeana through the aggregated fields. Nevertheless, it is the user who has to communicate their own interpretation of the terms through the strings of text they have to type on the query fields. For example, one participant who does not have a CH background interpreted the term 'mummy' as in 'mother'. In this case, participant used What:cat NOT What:kitten What2:Mother to solve the query. This query returned two different artefacts that depicted *Bastet,* an Egyptian mother goddess.

Although the system enabled this level of flexibility for the user to articulate what the question meant to him/her, it does not fully communicate the technical aspect of how collections are arranged within the EDM. This might the reason why participants found the interface to be flexible to produce the queries that were given to them. The interface managed to produce a basic engagement with the data model through the aggregated fields. For example, the question '*search for medieval coins found in the United Kingdom',* aimed to explore how participants might work with time and objects (Table 22, also see Appendix C). The term what:medieval will bring information where the dc:title contains the term medieval. This is the reason why many of the results will show post medieval coins. Nevertheless, once the term NOT *Post* is introduced, the results become more specific of what can be expected to be defined as medieval, at least from a non-general user perspective. Alternatively, by introducing the term when:medieval, the results are heavily limited to two results. Finally, by specifying the range of centuries within the when data field returned no results. The example in the bottom right corner shows the results of Italian coins, just before introducing the where:United Kingdom term, to illustrate the use of when.

what:Medieval coin & where:United Kingdom

what:Coins & when:Medieval & where:United Kingdom

	
what:Medieval Coins NOT Post & where:United Kingdom	what:Coins & when: XV TO XVII (missing where:UK = empty results)

Table 22. Query 6 difference of results

There is an evident difference of results based on the different ways in which participants combined the data fields, terms and operators. The way in which aggregated fields incorporate different elements of the EDM, changes what sort of objects are returned. All participants in this experiment did not knew any of the data fields, thus were not able to either know if the term *medieval* was a concept of time or not. Particularly these kind of space-time concepts as described by CIDOC CRM (2013), will be 'fuzzy' due to its complexity to be described. In addition, Participant 2 who had a History background also described the term medieval as 'controversial'. Defining complex concepts such as medieval requires a level of specialty that currently Dublin Core (DC), one of the data models where the EDM is based on, is not capable of fully describing due to its own limitations. For this reason, medieval specialists have extended DC into the Dublin Core Pre-modern Manuscripts Application Profile (PMAP) that enables the description of medieval artefacts (Bair and Steuer, 2013).

Conveying the diverse concepts described in the EDM was one of the weakest characteristics of the interactive prototype. Nevertheless, the fact that participants are already engaging with the data model showcases the potential that these kinds of interactive approaches have on the engagement with information. As mentioned before, the majority of participants on the Web will arrive on a visceral or conscious state of information need. For this reason, none of them will be aware of how to implement the data model when they produce queries. Based on this experiment, users produced their own understanding of concepts. In scenarios where concepts that can be considered less fuzzy, such as countries, numerical dates, centuries, objects (e.g. plates, coins, vases) or names of authors, participants did not display major complications in their attempt to conceptualise them.

Participants found that the interface was flexible enough to make the queries that they needed. The fact that the Europeana aggregated fields provide a simplified version of the EDM, helped users to grasp those few concepts and combine them to their thinking process. It is still unclear how the system can further facilitate more complex descriptions or detailed data fields (e.g. dc_relation, dc_subject, dcterms_provenance) that can empower users' queries without increasing its complexity. Nevertheless, it can be suggested that based on the experiment and the UX/UCD observations, a constructivist approach might provide the granularity level of complexity for the users. Users will still have to adapt their thinking process behind a data model, but based on the evidence of this experiment, TUIs can aid with the mental tasks.

The interface managed to provide the tools for users to devise an exploratory strategy and re-adapt it when necessary. 5 participants agreed and 6 strongly agreed that the system allowed them to experiment with different ideas for the queries (see Appendix C). The ease of the tools facilitated exploration and allowed users to focus on the task in hand. The engagement with the system was constant and maintained a state of flow with the vast majority of participants. Only one participant (P5) entered the query before it was fully constructed. The remaining 10 participants constructed the full sentence before entering the query. Participants were fully focusing on the sentence that they were trying to build and not on whether it would return any results or not. This is the reason why as discussed on Chapter 4, integrating the display with the pyfos can facilitate its engagement with the system. Participants should not have to be looking into two interactive spaces, which can disrupt the interaction process. That being said, 5 participants (see Appendix C) pressed enter when producing their queries instead of using the enter cube. The fact that participants had to type on a keyboard placed aside of the display or interactive surface, although momentary, disrupted the actions they were performing. When typing users had to fully pay attention to the keyboard and stopped looking at the pyfos. Arguably this is when they pressed the Enter key instead of looking back on the objects. All participants who used the Enter key were asked why did they pressed enter and all of them responded that it was because 'it just felt natural' or they didn't think about it and just did it. Interacting with the keyboard has become natural to many users maybe to the fact that it has been the main peripheral used in computers for a long time. When designing the interface, there was an attempt to remove keyboard input. Nevertheless, the fact that users have to describe concepts, it was very difficult to do it through the tangible objects. Nevertheless, it is safe to say that the vast majority of users will know how to use a keyboard.

Participants found the interface easy to use (Table 23, also see Appendix C). As previously mentioned, all issues noted were related to users conceptualising data elements and concepts instead on system interaction. The interface successfully motivated participants to think and be conscious of what they wanted to find. The fact that participants scored the interface as highly stimulating, suggests high levels of engagement as well. The interactive system provides a pathway for users to enhance their cognitive and processes, thus stimulating exploration. This stimulation became evident as well where participants showed a high level of flow. Participants did not enter the query until they had finished formulating their question. All participants constructed the query and re-arranged the objects and ideas and they entered the query until they were happy with their final combination.

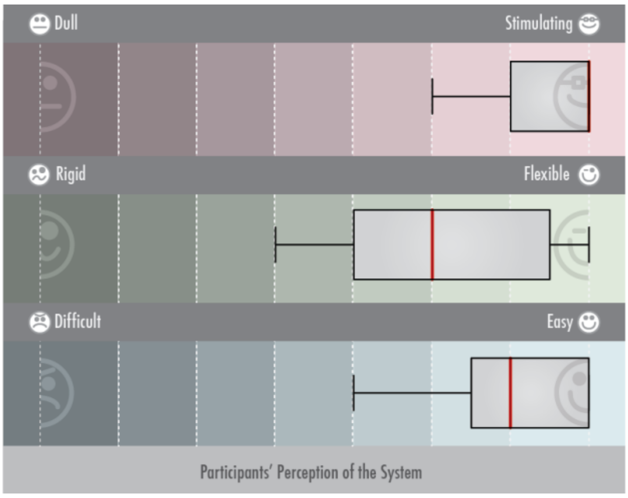


Table 23. Participants' Experience with the System

It was observed that 3 out of 11 participants (P2, P3 and P5, see Appendix C) did not perceive the hierarchical conceptual division between 'the main query' and the 'faceted query' objects. Nevertheless, after those participants realised that, the remaining pyfos had the Boolean options, they understood that they had more options with them and figured out that they could use those instead.

The system did not present any major interactive issues. Although this research did not focus on the visualisation of the results, users were still able to navigate through the visualisation gallery of retrieved items. Users were able to scroll by rotating 45˚ to either side to scroll through those results. Nevertheless, participants rotated continuously as an infinite knob. Due to the technical difficulty, it was not possible to implement this on the interactive system. Participants were explained how the scrolling worked. The metaphor of spinning to scroll was recognised by the users but the scroll pyfo was not intuitive enough to convey that they had to rotate only 45˚ and stop. Alternatively, participants managed to intuitively recognise and implement the rotation for the remaining pyfos and after they were explained about the scrolling action, it was easy for participants to use it in the way that it was designed.

The How Many objects was not used in the query tasks. It was used until it was noted to them that they could select how many records to retrieve. The vast majority of participants left it in 96 records, which is the maximum, indicating that they didn't see any reason to retrieve fewer records. Moreover, the lower right panel, where data and content providers were listed and counted, did not drag as much attention as the display panel. Participants only noted the object count return and not the organisations where the data came from. Nevertheless, this is also part of visualising the data and based on the user centred design perspective, the vast majority of users might not decide to segment their query to a particular organisation.

When handling the objects, participants were careful when placing them for the first time. Nevertheless, that carefulness was reduced when they needed to manipulate the object and spin it. Paper crafted models are commonly perceived as less sturdy, but they are easy to reproduce as well. Implementing hexagonal shapes provide stronger edges thus making them sturdier. Once participants felt the objects they grasp them confidently.

8.5 Conclusion

Overall, the system received positive results. With a 100% task completion rate, participants were able to perform complex queries quickly regardless of their digital background. When exploring if TUIs could facilitate the creation of complex queries in OCH, it was concluded that the system manages to reduce the technologic complexity behind the querying languages, as well as the technical complexity of the data models and operators. The participants handled successfully a high level of conceptual complexity, while the system supported their individual interpretation and formulation of the query. Users managed to think and represent the different conceptual elements behind the data model aided by the TUI.

There was no difference in the performance and the completion times between participants that work with CH and the ones who don't. Although some of the CH background participants implemented particular organisational paradigms that did not fitted the EDM when producing the query, the system's epistemic properties enabled those keywords to be implemented in a different data fields without producing any major concern for the participant. For example, when users were asked to '*look for objects (anything) dated between 1525 and 1527*', participants with a library and history background used the keyword 'object'. This example shows why conveying a specific concept through the query in Europeana will still require users to adapt some of the ontological representations of the data model. Nevertheless, those factors can be regarded as data model issues and not interactive issues. This is the case for instance, when making a distinction between fictional and real people. CIDOC and EDM specifies that a fictional character is not a person, thus in order to retrieve such data, the model do not use the conceptual element 'who' but 'what'. Although the system was not able to provide a solution for this, it manages to enable a way for users to start engaging with the diverse data models for the first time for most of the participants.

It was also observed that the process of users adapting their way of thinking to a specific ontology is a big challenge, which can be alleviated through the epistemic activities provided by TUIs. In constructivist activities, there is a different conception about what a mistake means, since different learners can arrive to a particular result taking different paths. The TUI system encouraged that exploration without producing stress, considering that participants arrived on a visceral and conscious state of need of information. When the participant was given a query to make, they produced the whole idea before activating the search action. The task was considered completed until the statement was finalised and the search action was triggered. Participants produced the query, entered search and then proceeded to view what the interface returned. It is important to highlight that the queries were designed with the idea of encouraging thinking about the different ontological representations and operators that construct a query or an idea.

Although the technical and technologic complexities were alleviated by the system, there are still many challenges regarding the communication of ontological representations of knowledge, such as the difference between fictional and real people, or space-time relationships. Nevertheless, the interface triggered analytical thinking processes required to engage with OCH information. By providing context to what is to be searched and attaching a semantic element to the query, users can ensure the meaning of what they are asking, thus what the query will return.

Finally, the constructible nature of the system opens the possibility to distribute TUIs on the Web. The use of fiducials can also be implemented on opaque surfaces instead of an interactive table. The interactive table can also produce a more immersive experience since the pyfos and display are in the same surface and the users do not have to distract their attention between them. The use of tangible interaction seems also to aid with complex mental tasks and invite users to experiment in an enjoyable way.

Distributing this kind of systems can be facilitated by the use of standard Web technologies such as JavaScript and HTML. In addition, APIs facilitate the public's engagement with OCH content. This can promote the storytelling empowerment that many CH organisations are looking to provide to their communities.

Chapter 9: Discussion, Conclusion and Future Work

This research presented a Tangible User Interface that enabled people to produce complex queries in the Online Cultural Heritage (OCH) ecosystem. Users produce such queries by combining diverse data fields and logical operators aided by physical objects or pyfos that communicate with the computer, thus help the user produce extensive lines of syntax. To develop such interactive approach, this research provided: [1] an understanding of what Online Cultural Heritage is, and note the differences of their alternative versions that do not contribute to the knowledge transfer on the Web. Such theoretical underpinning is another contribution where [2] this research identified diverse information-user relations such as information production, sharing and engagement as the information lifecycle in CH. When coupled with Ackoff's DIKW model, it provides the structure of user-information (and data) relationships within different sectors and phases of the information lifecycle.

Such findings, provide CH professionals as well as Interaction and Information Designers to understand the role that the Web, and the knowledge held in it relates to the users from a theoretical perspective. This is further implemented through a real practical scenario where [3] a novel research framework was developed to understand in detail the ways in which users might attempt to query OCH knowledge. The literature review identified that [4] users will have different behaviours based on their level of need of information. This will affect their query making process when approaching the system. For this reason, before designing the interactive system, an a-priori methodology phase took place. The a-priory phase of the research framework can help designers understand the diverse query making processes that users might carry out. For example, the results of the experiments showed [5] that users will group their thinking structures through constructivist approaches, thus building up gradually the complexity of their queries.

Finally, the research framework introduced a [6] interaction design methodology which merges a problem solving and a HCI and Software Design perspective. This methodology embraces a problem-solving approach and integrates it to a standard procedural method commonly used by interaction designers and developers. The interaction design methodology as an a-posteriori process facilitates the production of a tool that queries OCH knowledge, and embraces hedonic challenges that might hinder its adoption.

9.1 Discussion

There has been a large range of innovations and disruptions that have taken place with the creation of the Web, and the fast pace at which interaction technologies are being developed. These innovations are not foreign to the CH sector. Semantic Web technologies have changed how information can be manipulated through the Creation, Sharing and Engagement of Information stages as presented in Chapter 3. In addition, interaction technologies such as the development of Tangible User Interfaces (TUI) as discussed in Chapter 4, along with other novel and related interaction approaches such as the Internet of Things and Ubiquitous computing, are challenging the way in which users are expected to interact with a computer through GUIs. This is not to say that all TUIs are inherently better than GUIs. TUIs stand out over other interaction approaches because they feed from the meta-cognitive approaches that enable direct manipulation with an interactive system. This, in many cases, facilitates the ease of the system learnability and engagement. In addition, TUIs enable interaction with complex concepts. TUIs can provide users with a way to offload their mental processes to objects that aid them to organise their thoughts and construct their ideas.

One of the main challenges behind TUIs are the complexity that it takes to build and to distribute them. A large set of TUI experiments rely on lab-based systems and complex programming languages that hinder their adoption and expansion. The methodology produced for the development of the prototype in this research, aimed to create a tool to produce queries that facilitated a foundational layer of engagement with the concepts behind the EDM through its API. In addition, the interaction design methodology recognised users' requirements in order to offer a range of common tools and behavioural pathways required to query OCH or the EDM through the system. Finally, the methodology expansion of the SA&D/HCI-M provided the chance to think, not only of how the tool was meant to be used, but also in the way in which it could be adopted and built.

Designing TUIs differ from GUIs since these are deployed over a standard interaction paradigm through the Window, Icon, Menus, and Pointer (WIMP) or through touch-screen system that offer a similar input. What changes is the metaphors and representations that interact with the WIMP. TUI users are required to run the interactive software as well as building and installing the physical objects to interact with the system (e.g. pyfos). In the case of museums, libraries, or any other organisation, the building of the in-situ interactive systems seems to be more common, due to the fact that they are built by specialists for the end user. Nevertheless, this research has approached this engagement question from the Web Science perspective, where interaction takes place on the Web and not on a laboratory or within an organisation. It can be expected that Web users will be interacting from home or more likely outside of the geographic boundaries that provide OCH information such as museums, galleries or archives, as well as other CH related organisations (e.g. schools). In addition, it has to be considered that end users will not have either extensive programming knowledge or tinkering skills to build complex electronic or wooden tools. The interaction design methodology used for this interactive prototype, considered these limitations and targeted them through the use of papercraft, standard Web languages, and pre-built cases that can be relatively easily adapted for interactive displays thus keeping low costs.

The TUI prototype presented in this research, enabled general users to produce complex queries by embracing many of the concepts used in the EDM to describe more accurately the collection or objects being searched. Querying across OCH can be produced as a questioning process, as well as a navigation process such as data visualisations. Nevertheless, the unhindered reach across the wide range of CH sectors is what makes OCH different from just being on the Web. Conventionally, each CH organisation has produced their own specific managerial structures, which reflects how they organise and present their knowledge. As a result, many of their users had adapted the way they think and work to that particular organisation. For example, as presented in Chapter 2, many artefacts which are virtually the same are described in a different way in different organisations. In other words, both will be talking about the same thing, but through different descriptive approaches. This was also observed in the way that participants used particular terms to query the data. Users implemented different terms to describe to their best understanding and agency the term *Medieval*. This was not only in the sense of the data model description, such as defining it as a thing or as a measure of time, but by removing the term post-medieval or indicating the specific centuries or years that comprise such concept.

Despite the particular agency of the user, it can be expected that a very low percentage of users will have enough expertise about a specific data model to fully convey the expected conceptual description through their query. The use of data fields that embrace the diverse ontologies that describe the collections, can empower users to retrieve specific results that can be more meaningful in their learning experience. Currently, the vast majority of CH searches originate from search engines such as Google Search or Wikipedia (Blackwood, 2014, Rasmussen et al., 2010, Kay et al., 2015). This was also observed on both participant surveys (see Appendix B and C). In addition, as it was indicated in Chapter 6, the vast majority of Web searches (over 90%), will be limited between one or two keywords (Spink and Zimmer, 2008, Nielsen, 2001, Jansen et al., 1998, Jansen and Spink, 2006, iProspect, 2006, iProspect, 2004). In comparison, all users who participated in the system evaluation produced complex queries through keywords, operators and data fields to convey their understanding of what they were looking for. In this case, participants attempted to convey their understanding through diverse concepts instead of one or two keywords, as it would be expected by general users.

None of the participants had the technical skills to convey complex queries on the Web. The interactive system facilitated such query making process. The prototype developed in this research, presents such engagement though an initial and very basic level of the full complexity behind OCH, or in this case the EDM. Nonetheless, the evaluation showed positive results that indicate this might be a way forward. On one hand TUI systems can facilitate the understanding of the possible affordances of the system's tools. On the other hand, the physical properties of the TUI prototype, provides a constructivist approach were users can offload their mental processes to the objects. By reducing the complexity commonly attached to interactive system, it was observed that users were able to focus on the task in hand. Users isolated particular segments of a query, such as focusing only on the dates or on the geographic location, before constructing a final query that contained the whole query statement.

Before developing any kind of interactive system, it was important to identify what sort of tools were required to engage with OCH. For this, organisations and developers need to identify the different digital and information literacies, as well as the different behaviours behind the diverse states of need of information. User Centred Design (UCD) approaches can provide the methodology to understand what and how are users require to perform a particular task. It was identified that users required to engage with complex combinations of concepts and through the literature review presented in Chapter 4, it was suggested that TUIs could aid with this challenge. Nevertheless, being a Web interactive system, this required to be put to use by general users in their own environment (e.g. house, school). TUIs are commonly built, installed and maintained by specialists such as IT departments in museums or computer scientists, or at least not by general users. The interaction design methodology identified this as a problem, due to the fact that general users would have to build the system at home. The problem-solving methodology presented in Chapter 5, provided the approach to design an interactive system that considers such limitations, thus promoting its distribution and adoption. This is not to say that this would eliminate the inherent problem of distribution commonly associated with TUIs, but to provide a pathway for other TUIs to follow this approach.

What has been encompassed as OCH in this research, presents a vast set of knowledge from a wide range of organisations and individuals. In addition, there is a growing interest in the role that Semantic Web technologies have or will have in the CH sector. That being said, this research originates from the idea that OCH as an ecosystem presents an already functional socio-technical system, as all Web systems, with vast sets of data and information ready to explore. CH organisations, information specialists and interaction designers among others, have explored how this information can be facilitated to general users, as well to expert audiences. This research aimed to understand how to facilitate the different levels of OCH complexity to general users through an interactive system. The methodology used in this research recognised how users might engage with OCH knowledge through Europeana's API and adapted those approaches through the diverse pyfos in the TUI system. The TUI prototype presented in this thesis facilitated users to convey different levels of complexity through their queries regardless of their digital and information literacy.

9.2 Conclusion

The work presented in this research aimed to understand how OCH knowledge can be facilitated through the use of TUIs. The problem was approached from an inter-disciplinary understanding of the CH sector on the Web and the construction of the OCH ecosystem. First, it was necessary to identify how the Web has influenced the changes in the CH sector and the different social interactions between it and their users. Secondly, the thesis identified information and the visitors' needs as the pathway that triggers the different requirements of how a new generation of CH visitors might interact with OCH knowledge. Many of the information held by CH organisations can be facilitated through a wide range of Web and digital technologies, such as Linked Data and novel interaction methods developed by the Human Computer Interaction (HCI) sector. These novel approaches enable the introduction of external sources of information into the information lifecycle in CH.

Information outside of the traditional boundaries of the CH sector can be included through Semantic Web technologies such as the use of Linked Data and ontological models to enable the inference and quality of information used to describe the collections. Nevertheless, despite that CH organisations are producing these vast sets of structured data, as discussed in Chapter 6 and 7, there is a lack of engagement with this knowledge, as well as a lack of engagement with the original provider or owner of the information.

This thesis offers a methodology to understand why general users are not exploring CH knowledge as part of an OCH ecosystem, and the methodology to mitigate this problem. The traditional approach by CH organisations has been to provide the engagement primarily to the content held in their organisation. This is why they have produced tools and pedagogic approaches that aim to explore what can commonly be seen 'on display', thus limiting to alternative descriptions and storylines, thus reducing the understanding of any given collection solely from that organisation's point of view. The way in which information is normally presented to general end users in the CH sector has frequently emulated a linear catalogue search. Nevertheless, the fact that CH organisations are looking into ways to enhance the engagement with their collections as well as external collections on the Web, evidences their own need to offer digital tools to empower their staff and visitors. When engaging with CH collections through OCH, the conceptual and organisational boundaries are blurred, and general users will require to query such information in a way that encompasses the complexity and extension that describes the OCH collections.

The process of querying the Semantic Web or OCH in this case, is commonly carried out through querying languages such as SPARQL. Querying in this way has been referenced as a *Tell and Ask* approach, where users have to tell the system what is there so the engine can search for it. Alternatively, organisations such as Europeana have provided APIs where users can query the data through diverse data fields that eases the engagement with the data model. Despite that the approach through the APIs allows users to remove the complexity of the querying languages, the data models are still extensive and complex. There is an evident shortage of interactive tools that enable general users to fully embrace OCH complexity and find or explore according to their own needs. Although this research has been carried out to enhance the engagement with OCH, its interaction design methodology can be transferable to other information querying processes. The methodology followed in this research can enable OCH and other Web organisations to produce tools that can engage with the current technologies (e.g. browsers, off the shelf electronics) and skills (e.g. paper crafting, connecting a projector) for their users.

The interaction design methodology developed for the prototype to explore how users engage with OCH knowledge was based on a foundational interaction design methodology such as the SA&D/HCI and expanded with a problem-solving methodology (M) that aids developers to include factors not commonly considered to be part of a software. Developing TUIs rises parallel interaction questions such as the role of materiality, adoption, construction and users' cognitive processes that are embraced and explored by the expansion of the methodology. In addition, the design methodology also embraces users' input through UCD experiments that advises the design process what sort of tools might be required and how they could be used in a final prototype.

The final evaluation of the interactive system demonstrated that participants can work with complex interactions and relate different concepts from the data model. The system reduced digital literacy issues, associated to negative interaction behaviours, such as the fear to make mistakes when exploring. The system helped users to offload their ideas and thinking processes on to the objects. This enabled them to mentally isolate the diverse facets of a query, thus having the possibility to modify that individual part without having to re-structure or re-think the whole query. Despite that the system worked mainly through the aggregated fields and operators, it still enabled participants to convey the complexity of what they were looking for, and in the way they interpreted the description of the collections.

There are large sets of CH data already available in OCH that is not being used by their general audiences on the Web. OCH calls for a user empowerment to embrace such engagement with those sets of data. Similarly to museums, that formed themselves by hosting material culture primarily for high skilled or academic individuals, OCH is currently being held by an intangible barrier produced by the high levels of digital literacy required to access and engage with it. While museums and libraries became organisations that are meant to study and share the knowledge of the communities' culture, thus become centres of knowledge, OCH requires to produce that next step in digital evolution, where such knowledge becomes accessible for their communities. Currently, there is a large gap that includes the technical and technologic barriers, that hinder the engagement from the community. Interaction methodologies on the Web have to consider the different users approaches triggered from the diverse states of need of information. These different needs will produce a range of behaviours that shape how interaction might take place. This research focused on users on a visceral and conscious state of need of information, thus enabled them to produce complex queries. Users produced queries that used diverse data fields and operators to convey what they were looking for, and searched across the OCH spectrum through Europeana's API.

The use of TUIs can help by reducing learnability processes to operate an interactive system. In addition, the playful activity and direct manipulation can motivate users to explore the different affordances of the system. This benefit also promotes engagement with the content they are exploring. The system managed to provide what can be described a browsing-querying approach. While on one hand, the pyfos present browsing parameters that help users identifying specific data fields through the second layer of engagement, on the other, it provided the technical elements to merge the such data fields with the specific query they were meant to produce. The prototype presented in this research offered a way to conceptualise the different definitions used in the data model. Moreover, querying processes present challenges that are not limited to OCH. Due to the novelty of the Web, and the Semantic Web in particular, researchers still need to understand how users can engage with large sets of data and information through the diverse data models and concepts. Alternative approaches such as Data Visualisation and Recommender Systems enable the engagement with the data, which are commonly carried out through pre-stipulated routes of particular samples of data or tasks that can be performed on the data. The approach carried out in this research was to provide such initial stage of engagement with the content so it can be further visualised. This first engagement with OCH takes place by empowering the user to query the specific concepts required to retrieve a set of objects or data that is meaningful to the users' question. It is this initial understanding of the conceptual complexity that can offer the initial set of data to the data visualisation tool. But most importantly, is that whatever the query, it will help the user to understand what is it that is being queried and how to further manipulate the question to refine the results.

9.3 Contributions and Future Work

The purpose of this research was to explore the ways in which Tangible User Interfaces (TUIs) can help users to produce complex queries that embrace the complexity behind the knowledge (information and data), as well as the logic used to describe collections in OCH.

This thesis presents a novel research framework to produce a TUI that can enable users to produce such type of complex queries. Although the case study was implemented within the Cultural Heritage sector, the interaction paradigm can be transferable for alternative knowledge sector. Moreover, one of the primary contributions can be attributed to the development of the research framework as a methodological structure which considers creative and technical sectors involved in OCH as well as in the interaction design development process. Such interdisciplinary approach should pave the way for interaction designers to approach the development of interaction systems beyond the utilitarian or hedonic properties.

The disruptive properties of the Web have accelerated the evolution of sectors such as the CH, where this thesis presents another interdisciplinary understanding coined as Online Cultural Heritage (OCH). The understanding of the CH sector from the Web Science and socio-technical approach, enables this thesis to produce what can be considered a more accurate representation of CH organisations which become part of the OCH ecosystem by contributing with knowledge as the construction of information and data that is made not only accessible but meaningful for users. Prior definitions such as Online Museum or Library, as well as Digital Museum or Library among others, no longer represent the engagement and/or activities that take place in and outside the Web. This research provided an understanding of how users will relate to OCH through knowledge by engaging with the information. The concept of information is therefore defined as the coupled element of data and information and meaning. Using Ackoff's DIKW model to structure such understanding, enabled this research to define the role of diverse CH organisations on the Web, as well as defining the hierarchical engagement levels for the TUI system.

The a-priori methodology carried out in this research also provides a novel understanding into how to explore possible interactions before starting any interaction design methodology. This process can help other developers what are the possible tools that users might use when presented in a particular scenario. The findings in this research showed that most of the participants like to construct segments of queries and join them together, thus producing a large and more complex query with their particular thinking structure. Although this research focused primarily on the Engagement with Information, it can be acknowledged that within the DIKW model, despite that users engaged primarily through querying, this process enabled them to produce meaning from such process. By producing the connections between the data and information facilitated through the pyfos, users were able to conceptualise the knowledge (as in data and information) concepts behind the EDM.

It was discussed that this lack of engagement derived from the complexity to understand the data and concepts, and the required technological and technical skills to use it. The methodology followed in this research targeted these two main challenges through the use of TUIs.

By modelling the information lifecycle roles in OCH, enabled to produce an understanding of the diverse relationships that users can have with OCH/CH knowledge, information or data. The diverse roles of Information Production, Sharing and Engagement present different challenges for interaction designers. This research highlights those differences, focusing primarily in the Engagement with Information, as the process into providing interactive environments that enabled users to produce such complex queries that embedded OCH knowledge and logic.

There is a growing development on the research and use of TUIs, paired with publications that illustrate their benefits when working with pedagogic content and sense making of knowledge. Nevertheless, the use of TUIs seems relatively unexplored in Web related interactions. This is because TUIs commonly require general users to buy or build extra interactive components, which require money and effort. In addition, TUIs are commonly developed and tested in lab based and controlled environments. For this reason, this research considered the idea of a TUI that can be built at home and incorporated that idea into the interaction design methodology. The Web is no longer just for digital data. Current technologies have evolved, and now allow users to download and build physical objects as well. Examples such as the use of 3D printers, laser cutting, and paper crafting, allow developers to distribute physical objects, where some of them can be easily replicated at users' homes. That being said, the current prototype presented in this research presents the idea of a TUI that connects to the Web and that can be distributed on the Web. This approach can provide researchers with novel perspectives to explore learning environments that fall outside of the ownership of the organisations, or groups that provide the learning materials.

The TUI prototype produced in this research enabled users to learn quickly how to operate the interactive system. This quick system learnability process motivated users to focus on the diverse concepts of how collections are described across OCH. The data models behind OCH break organisational boundaries commonly set by CH organisations. The system aided users to avoid such boundaries and focus primarily on how they though a particular collection could be described. When querying through Europeana's API, users engaged through simplified version of the data model that collects several properties and classes from the EDM. Despite that the API aggregated fields present a conceptual simplification, they are still complex to implement. The system provided the cognitive tools to combine the API fields, operators and keywords in complex queries. The experiments and evaluations showed that this was the first time that participants engaged with OCH by using such foundational fields but increasing the query complexity by combining them together along with Boolean operators.

It was expected that through the use of TUIs, participants would learn quickly how to use the system, and that was confirmed in the evaluation. It was observed that the system helped users to focus primarily on the querying task. This helped them to raise questions about how they should use the different data fields to conceptualise their understanding of the query. Users still need to understand how the data models and concepts are structured if they are to produce a meaningful query or retrieve something that depicts what they were looking for. This still presents many new questions of how users might understand the ontological definitions in data models. Nevertheless, the results of this research suggest that TUIs can facilitate this process.

This research presents how OCH knowledge can be facilitated to general users as a first query system. This rises further questions, of the processes users can follow to visualise and manipulate results among other post-query processes that could be facilitated through TUIs. In addition, there are still large sets of data fields from the API that can still be used to enhance the accuracy of the queries, instead of depending solely on aggregated fields. Working with TUIs opens many questions that go beyond interacting on a screen.

The methodology developed in this research indicates that designers have to incorporate materials and the use of those materials for construction of TUIs as part of the iterative process of an interactive system. While the work with TUIs focuses primarily on the interaction that users will have with the system, there is still the need to understand how these interfaces will be distributed on the Web. The system was developed with off the shelf consumer electronics and materials. In addition, although the interaction design methodology directed the TUI design to a system that could be built by general users, it is still unclear if general users would be willing to build it and use it at home. It was discussed in Chapter 4 and 6 that many users are willing to adapt and tinker with the original setup, the distribution of the TUI system can be promoted through pre-assembled kits that facilitate its construction. Since the display of the TUI system is rendered through a Web browser, other designers can produce alternative versions of the system. Once the display box is set, the pyfos and JavaScript of to make the fiducials interact can be modified. Paper-based pyfos can be re-designed, thus changing what they do and the way they look, so they can be used for those alternative versions of the system. The new pyfos can be delivered to the end user through the same website, where the user just has to print and build them. Finally, the user will have to load and display the new website that contains the interactive display and the new actions for the pyfos and start using the interface. Alternatively, it can be expected that different organisations and specialist areas in the CH sector will require a certain range or combination of pyfos. That being said, these further implementations on the system can be stored together and produce a library of actions and physical affordances where other CH organisations or even individuals can import into their own display table or exhibition. Alternatively, CH organisations can produce pre-designed sets of pyfos designed to explore a particular collection such as Renaissance painters, Second World War historic places. This is one of the many benefits of using Computer Vision technologies in TUI systems. As mentioned in Chapter 4, the fiducials can enable physical objects to be embedded with a wide range of actions to interact with the computer. Although, this might still present some challenges to some general users, this approach presents a more accessible and cheaper option than distributing expensive electronics, that are comparatively more complex to set up and adapt. To evaluate these kind of comparative studies, usability and engagement evaluations such as the ones carried out in this research (e.g. SUS scale) can be performed. Such results produce continuous or metric data (Graham, 2011), which differs from binary data (e.g. yes/no answers). When working with continuous data, it can be suggested to implement an ANOVA statistical analysis to compare the difference in usability and engagement between the diverse interactive systems or features to be tested (Dix et al., 2004p. 334).

CH organisations inside and outside the OCH ecosystem can benefit from this research and provide novel ways to engage with their collections and provide more meaningful ways to engage with their content. The use of TUIs in OCH has not been fully embraced, among other things, because its development does not involve common interaction design procedures, and their staff commonly in charge of producing interactive content on the Web commonly lacks the skills to work on all the areas of TUI development in OCH. The adoption of TUI systems can be also promoted by using standard website building languages such as HTML, CSS and JavaScript. There are still non-standard languages and frameworks such as TUIO that are not considered standard for the Web, but they still provide the protocols to combine them with these aforementioned technologies.

9.3.1 Limitations and Future Implementation

While the experiments aimed to explore how TUIs can facilitate the querying process. There are still many ways in which users can engage or explore OCH content. This research focused on querying, due to the fact that it is the most likely way in which users will begin their exploration. Nevertheless, despite that the TUI prototype successfully managed to facilitate the elaboration of complex queries, there are still a large number of elements that can be implemented to explore Europeana's repository. In addition, it is still unclear how will users behave when they don't have pre-designed queries. The open-query aimed to initiate such discussion. Nevertheless, it does not fully explain how can users combine question making processes with querying making ones, or vice versa. Further experiments can be carried out to explore how users will originate a question making process from a particular topic (e.g. learning or finding facts about specific collections), and evaluate their learning experiences.

The diverse interactive systems presented across the diverse Europeana hackathons have showcased a wide range of interaction, input and output systems that can help increasing the diverse tasks that can be implemented through the TUI prototype. That being said, further experiments which introduce such implementations (e.g. geo-search, search by corpus, image-recognition), have to be tested and catalogued to provide an understanding of which type of input systems work better for the diverse *levels of need of information*, and the different fields of research. It was highlighted that one of the main weaknesses behind TUIs was the limitation of re-adapting such systems for different tasks that they were not designed for. That said, this will require a more certain approach where comparative studies are carried out to explore their usability and engagement evaluations for each type of specific tasks within OCH, such as finding a particular text, exploring collections from a geo-location or exploring images by colour.

The evaluations carried out to test the interactive system did not implemented comparative studies. Although, there is large body of research that use comparative studies to evaluate engagement and usability as well to compare the performance between a TUI and a GUI, this research performed a non-comparative study to evaluate the system. Despite that previous research has suggested that TUIs have a tendency to perform (see chapter 8), especially in engagement evaluations, due to their novelty effect, there are still a gap in the understanding of how much TUIs actually out-performs (if any) more common GUIs used to query OCH knowledge. Moreover, such comparative studies can provide an understanding of the diverse strengths and weaknesses of diverse ways into producing queries with different elements of TUIs, GUIs and alternative inputs such as speech and gesture based actions.

9.3.2 Final thoughts

There is still a wide range of opportunities for an OCH TUI system. For example, the implementation of the diverse data fields from a wide range of data models, as well as the extended syntaxes from Apache Lucene. This would have to be carried out by altering the current JavaScript code and updating the IDs of the fiducials from TUIO. Nevertheless, by expanding the amount of query items, users might feel overwhelmed by them. Further research can be carried out to explore how to physically produce pyfos that enable the implementation of additional data fields, where users can still connect and extend their ideas through querying or visualisation. In addition, CH organisations or specialists can also expand the pyfos or data fields based on their own information needs.

Web APIs are increasingly becoming more popular since they ease the adoption of technology since they ease the development of tools to engage with different sources of data such as Europeana. In the particular case of the CH and OCH sector, different frameworks such as IIIF, Omeka and D3, can also help enriching the information elements in the queries to engage with OCH collections. Since all Web APIs work through HTTP services, their implementation is relatively straightforward, as well as the rendering of the data on Web browsers, such as the TUI prototype in this research. The to provide an API to engage with the data or other APIs allows designers to extend the possible actions that can be implemented on the system. For example, Europeana’s metadata can also be rendered through IIIF’s API on the browser. IIIF specialises on rendering and manipulating high resolution images on the Web. Therefore, by combining both Europeana and IIIF APIs, designers can integrate the querying and the high-resolution rendering, as a visualisation tool, in one single application on the Web.

Embedding data through computer vision could also be carried out by using a web cam. For example, a kit could be produced for users to retrieve a list of diverse data fields and embed them to any give fiducial. In a very similar way that RFIDs are written, users could attach a particular JavaScript action that makes an API call and link it to a particular fiducial ID. Several scripting applications such as Scratch programming that offer a visual interface to produce small programs or series of scripts that be easily assembled as puzzles. In a similar manner, this approach can prove beneficial for non-Web literate users, so they can also produce their own pyfos. If such system is produced, users will have a large variety of tools to query or explore OCH. Finally, once users have produced a combination of pyfos, they can share that set to other users.

In regard to the system's performance, there were some usability issues that need to be addressed as well. Some participants (see Chapter 7) did not recognised the difference between the primary pyfos (who, what) and the secondary pyfos for the refinement queries (who2, what2). Two participants indicated that they would like to have primary objects closer to them, due to the fact that they thought that the ones closest to them were primary elements. If the query does not implement a boolean operator, it is possible that users will grab the object that is closer to them. Making the object smaller and/or visually indicating its lower hierarchy could solve this as well.

This research demonstrated that TUIs can help users to produce complex queries in OCH. The system offered a quick learnability and helped users to use diverse data fields and operators from Europeana's API. The queries produced by the participants to engage with the different concepts used to describe collections in OCH. It was previously discussed that TUIs enable users with low digital literacy skills to engage with computer interaction and complex concepts. The evaluation of the OCH TUI developed for this research suggests that TUIs have the potential to enable low digital literacy and particularly general users to engage with the system in a way that does not hinder their engagement with the content. There is still much work to do to understand more complex OCH interactions with TUIs. Nevertheless, this research can work as a foundation for CH organisations and developers as well as HII and HCI researchers in the exploration of knowledge through TUI-Web interfaces.

Glossary

CH – Cultural Heritage

Common ground - basis agreed to by all parties for reaching a mutual understanding. (wordnetweb.princeton.edu/perl/webwn).

Crowd Intelligence – Knowledge produced by groups, which provides a better results or decisions than the ones made by a single group or individual.

Data – When information is formatted, it is transformed into data. Data is factual and commonly used for performing tasks that might be limited to the affordances of its data system.

Databases - A structured set of data held in a computer, esp. one that is accessible in various ways.

Digital libraries - a collection of digital resources selected according to certain criteria and made accessible for retrieval over computer networks.

Disruptive technology – a new technology that generates new products or services that require an organisational change in organisations.

Fiducial(s) – visual marker that can be recognised by a computer. Fiducials are attached to physical objects so they can perform computational tasks.

Four Walled *(Organisation)* – The organisation or part of the organisation that is not on the Web. Four walled organisations can still be digital but not necessarily on the Web.

Information - a set or collection of data about a specific thing.

Interface – point of interaction between the user and a computer.

Knowledge - A set of information or skills obtained by interacting with the world.

Knowledge producer – Individuals or groups who study a topic and use share that information.

Linked data – a method of publishing structured data so it can be interlinked and become more useful (Wikipedia).

Meaning – Allows data to be transformed into information. Makes data useful.

Need – The reason why users ask a question.

OCH – Online Cultural Heritage

Semantic database – Database with a conceptual data model.

Social Machine – A system that exists only through a symbiosis in between society and computer programs (e.g. Wikipedia).

Sustaining technology – a technology that allows a service to be extended or improves the performance of specific products or services through their same organisational criteria.

System – connected elements such as software and hardware to perform a computational task. It might be referred also as a group of interfaces working together.

Tangible User interface – an interface that uses physical objects to interact with a computer

User generated content – Content produced and distributed on the Web by common users.

Web 2.0 – technology that allows users to easily write and produce content on the web (e.g. blogs, wikis).

Wisdom - deep understanding and realization of people, things, events or situations, resulting in the ability to apply perceptions, judgements and actions in keeping with this understanding**.** (Wikipedia) In this research, it is used as the result of the process of data-information-knowledge-wisdom from Ackoff.

Appendix A Description of Methodologies

A.1 System Analysis & Design and HCI Development Methodology

Systems are designed to be used by people and for that reason they should include a human-centred perspective. Moreover, it is necessary to understand what is the system supposed to do (e.g. produce queries in Europeana), plus what is the system supposed to do for the user (e.g. provide the structure to combine multiple data fields and operators in a query). Simultaneously, information specialists work on information systems attempting to make information useful for users. They commonly follow the systems development life cycle (SDLC) where they can plan, create, test and deploy an information system (Radack, 2009). Zhang et al. (2004, 2006) argued that most of the System Analysis and Design (SA&D) literature focuses very little on design aspects of a system. Although the SA&D methodology is commonly used and understood by information system groups, there is still a misconception about the role that HCI plays in the SDLC process (Zhang et al., 2004). Moreover, even though there is a design phase in the SDLC process that considers HCI perspectives, there is still a lack of understanding of the different human factors (e.g. cognitive, affective and behavioural) and their impact that they have on problem solving and interaction with the information system. Meanwhile the SA&D relies heavily on HCI for its usability performances, there are alternative studies that have proven that usability is not the only way to know a system's adoption (Zhang et al., 2004). Following this, on one hand SDLC aims to improve how information can and will be used in an organisation. On the other, HCI focuses on how humans will interact the system (interface) and in this case the system that interacts with the information. This division has attempted to be solved through the combination of both perspectives. Figure 52 (b) presents a methodology where SA&D is extended with HCI. This extended methodology includes user factors such as affective, physical and cognitive constrains. The area in the methodology highlighted in pink, identifies parts where an HCI perspective is used, while the blue section, shows the SA&D perspective.

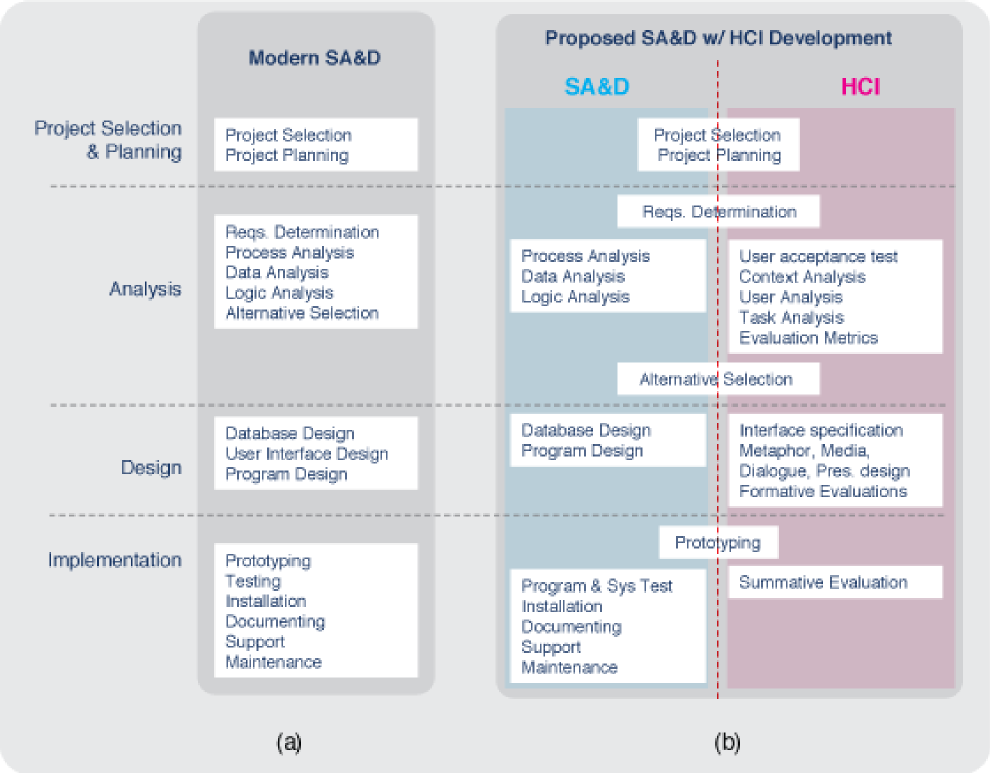


Figure 52. SA&D vs. Human-Centred HCI Methodology (Zhang et al., 2004)

Project Selection/Planning. The needs of the organisation are identified and classified. Furthermore, potential projects are proposed and studied to identify if they are viable solutions or not (Valacich et al., 2012: 88). In this case SA&D and HCI have the same process.

Analysis. It is here where the system requirements are identified and design proposals are presented. The user acceptance test as part of the HCI process includes context, task and user analysis in order to confirm if the system is capable of fulfilling the user's requirements (Zhang et al., 2004). It focuses merely on functionality ignoring *cosmetic* issues. Evaluation metrics focus on HCI goals such as learnability, efficiency, satisfaction and effectiveness. These metrics are commonly task related. They will provide a reference point related to usability or user experience strengths and/or weaknesses. As an iterative process, the alternative selection might include possible recommendations from test subjects (users), colleagues, etc.

The analysis phase includes an analysis of the physical, technical and organisational context. The physical context aims to identify where are the tasks going to be carried out and who is going to take part in the interaction with the system. The technical context identifies the different technologies, platform and hardware required. Lastly, an organisational context is investigated to know if the system will interact with other organisations or entities. This can be aided by an analysis where demographic data, cognitive styles, affective traits and job-related factors such as an understanding if the system will be used for work or leisure purposes. When designing interfaces, it is relevant to know what are the minimum requirements that users might have to make the system work. Particularly with TUIs that are meant to be distributable, it involves analysing accessibility of materials and ease of construction as part of the technical context.

Design. It is here where the issues identified on the previous sections are solved through a user interface. This is commonly done through interface specification the tools of the interface represent the tasks that the interface can perform. This process also includes syntactical and lexical decisions (e.g. metaphor and visualisation design, media design and dialogue design). There is also a formative evaluation to identify design problems so they can be solved.

When designing the interface, it might prove beneficial to identify particular questions that users might ask (e.g. who, where, when) on an OCH system. These formative questions offer the aforementioned users' lexical and syntactical decisions that will require to be further implemented as tools.

Implementation. It is the final process where prototyping takes place. Prototyping is a process of both HCI and SA&D. Further testing is recommended to fine-tune the system. Summative evaluations are carried on to confirm if the project fulfils its goals. They can also offer information about the strengths and weaknesses of the system. For example, specific targeted users should test it for a period of time to find issues that were not noticed on previous evaluations.

Arguably an interactive system can be on a perpetual beta. After implemented on a wider context, evaluations and can provide information about how to improve the different aspects of the interface. Moreover, it can present different extendibility (upgrades) that can be applied on the system.

This is a methodology that proposes a human-centred perspective that can help manage the development of the project. Furthermore, it provides a holistic vision of the process where external and/or additional methodologies from different disciplines can be introduced, but it was developed from a heavy managerial perspective. Nevertheless, it is important to know the aspects in which collaboration from other fields might be introduced.

A.2 Interaction Design and Graphic Design Methodology

From a design perspective, problems are born from a *necessity*. By providing a solution to those necessities, there is usually an improvement in the quality of life of people (Munari, 2004: 38). This is one of the most important missions of design. However, there are many cases where the industry tries to impose solutions to designers that do not address this objective. Moreover, the industry tends to create *fake necessities* that mislead people's perceptions of what is needed in order to sell a product or service. When designing tools and interactive systems, the development requires assisting users in solving their necessities. If tools are developed as a mean for organisations to find use of their system, that approach does not necessarily aims to help the user. This approach forces users to follow the institutional or organisational perspective. This problem-solving methodology proposed by Munari, promotes experimentation through creative thinking thus aiming to solve those human needs. When designing interfaces, designers need to think beyond what the tool will do or how it might perform. Designers need to think how might the tool (system) solve or assist solving that particular necessity. This then means that methodologies such as HCI, SA&D and software development methodologies aim to solve the problem from the system perspective. This process attempts to make the system more human approachable, commonly done through human-centred interactive design methodologies. While Munari's methodology identifies the necessity of why we even need a system after all. The following design methodology identifies a creative process for design and problem solution.

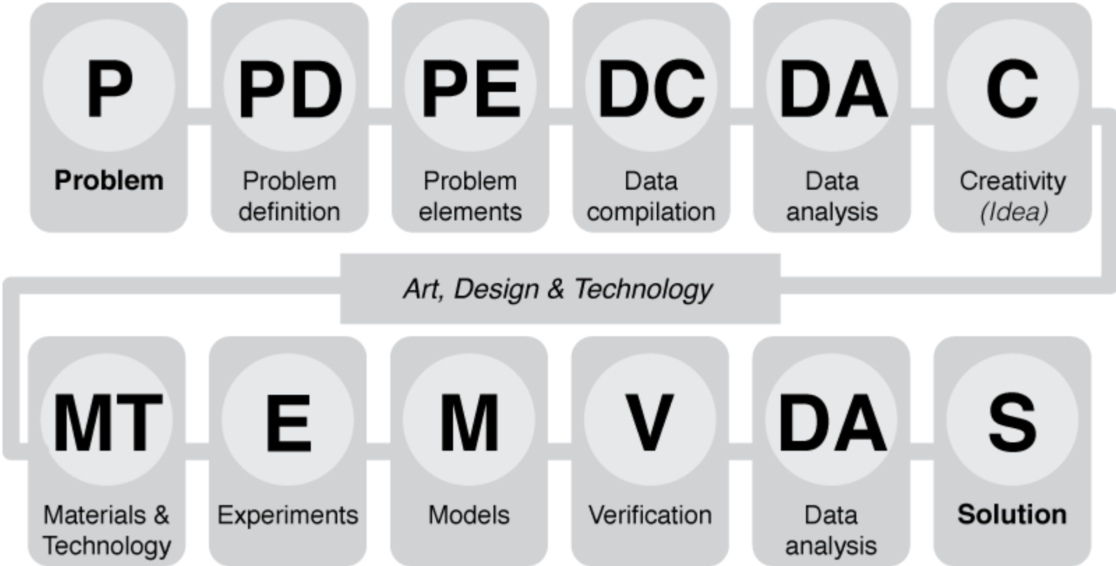


Figure 53. Design Method (Munari, 2004)

Problem. A problem cannot be solved by itself and when it is solved, it stops being a problem. For this reason, it needs to be identified what are the causes of such problem.

Problem elements. In order to understand the problem better, we need to break it apart and study it from different perspectives.

Data compilation. In this step, there is a gather of information about the different elements found in the problem. Moreover, after studying and ***analysing*** the information, several ***creative*** solutions can be proposed.

Art, Design & Technology. Although it is not mentioned in the original methodology, art, design and technology has been introduced where such elements are studied and proposed as part of the development process. This is considered relevant because there is the need to identify technologies that can assist or become part of the design tools. The reason for this is that with the quick evolution of technology, it is necessary to investigate both, technology and technique updates to improve the design. Technology and design skills should not limit the creative process and the generation of ideas. For this reason, creativity and materials and technology, are connected through this step, and as a process in the design method, it will be iterative.

Materials and technology. It is here where experimentation with technology and materials occurs. There is a need to identify what might be relevant to implement to solve the problem.

Experiments. It is through experimentation that the materials and technologies implemented can be tested and studied. From this experimentation process, several ***models*** can be proposed thus presenting several technical possibilities. Models have to be tested before producing a prototype that can be presented as a ***solution***.

It is until this stage that 'sketching' processes takes place. There are additional field methodologies that assist in the creation of such designs. Nevertheless, this has been widely applied through the visual communication industry. This methodology provides a structured pathway for creative thinking. As mentioned before, this can be integrated with further methodologies to enrich the creative processes.

A.3 Integrating Methodologies

As seen, although there are many methods and procedures to develop interactive projects, the methodologies mentioned in the previous section will require integration, adapting them into a unified process. Many of these methodologies have been developed for working in groups and with clients or companies. Such methodologies provide a framework as a guide to visualise what to expect when developing projects. In the case of HCI and Software Development methods, it becomes evident that although they consider human factors through their testing, they are still systematically based on studying how the tool will work on the user, instead on how a user might want to use a tool. Moreover, Design Methods provide a more experimental vision where aesthetics and communication play an essential role. It is proposed then that by integrating such methods we can produce a system that can communicate visually and provide the rigour of HCI and Software Development testing.

The methodology proposed in Figure 42, extends HCI, Software Development and Design procedures. The main objective is still to produce a computational system that will allow the exploration of OCH knowledge, in this case, a downloadable TUI. Although such systems rely heavily on technology, as the HCI literature mentions, it is important to consider human factors. Therefore, the connection and communication that occurs between the system and the user needs to be also taken into account. For this, Graphic Design as a visual communication system provides the tools that can facilitate such process.

When working with interactivity, there is always the need to communicate visually what each tool in the system is intended to do. For this reason, after performing the Analysis phase, one can recur to Munari's problem solving methodology to assist the design phase of the HCI development (Figure 42). This should enhance the process just before the Formative Evaluations and the Implementation phase. Once Implementation starts, it is up to the HCI methods to test the strengths and weaknesses of the system. Such phase involves less creative processes where design elements do not play an essential role.

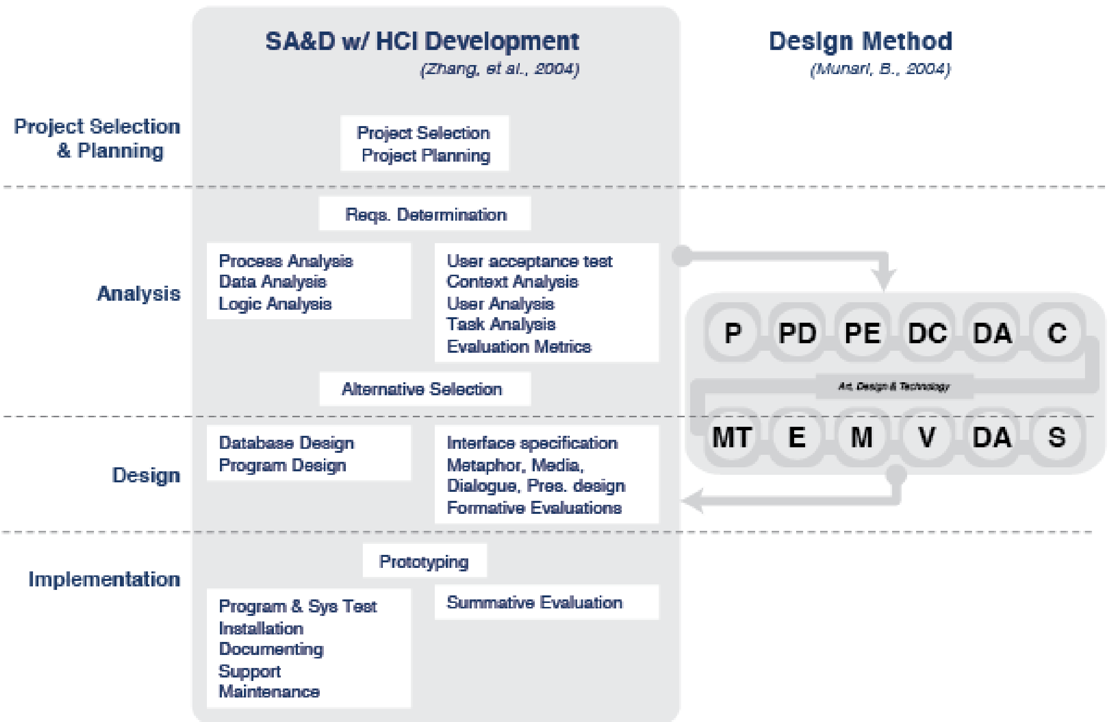


Figure 54. Proposed Methodology

The purpose of incorporating these steps, is an attempt to produce a process where design and interaction design play a central role in order to smooth communication between the system and its users. This should not be a rigid process. This is to say that it can be modified to adapt different timelines and project scales. What it is meant to illustrate are the common milestones in HCI and where design might be used as a parallel method to provide a wider perspective to the process.

A.4 Evaluation Methods

Emotional experiences such as fear, frustration and excitement can occur when interacting with a computer. Many of these experiences are triggered according to the good or bad design of the interface. It important to know if what has been developed is going to be used in the way that was envisioned. Also, it is relevant to identify any kind of errors and issues that might trigger negative experiences (e.g. helplessness, frustration).

In the case of CH collections and places, the visitor looks for different experiences as it was already mentioned. Therefore, it has to be taken into account that there can be an extensive set of motivations behind using a specific interactive system. Designers then, need to understand how the tool designed is being used and its performance, along with their requirements and needs. Under User Centred Design, systems are meant to help people achieve their goals based on their specific necessities beyond the tool itself (Wright and Blythe, 2007, Blythe et al., 2007, Blythe et al., 2004:8, Forlizzi and Battarbee, 2004). This perspective is deeply linked with design and particularly with product design in the sense that focuses in providing a meaningful experience. Arguably, users are no longer looking for a product or a tool. In this sense, interactive systems are capable of provoking emotions, and User Centred Design takes advantage of that to enhance interactivity. This becomes relevant because the approach selected in this research (TUIs), is capable of provoking embodied reactions that are part of that emotional enhancement that occurs beyond the tool. Most importantly, once a TUI system is developed, it is also relevant to test its performance, since it is nonetheless a tool. Within this, the emotional response that such tools can produce will also be tested, thus measuring the level in which it promotes engagement. There are a wide variety of methods and processes to measure the qualities of an interactive system, but testing TUIs seems to be two-folded. On one hand, usability testing is used as a standard way to test systems performance thus ignoring human emotions and experience. On the other, although used, very little work has been done to understand and standardise user experience (UX) and engagement testing.

The following sections provide an overview of the different testing methods, followed by the proposed method for testing and measuring the TUI experiments.

A.5 Evaluating Usability and Participatory Design

Usability testing is one of the most common methods in HCI for testing the performance of an interactive system. These tests involve users working with the interface in a common scenario performing usual tasks. These performances are generally evaluated through questionnaires and interviews in a subsequent stage.

Testing

Testing consist in asking the user to interact with the system, analysing and measuring these. When performing tests, is essential to identify what particular aspect of the interface is being tested. During testing the user carry out a specific set of tasks that might be standard, but there might be others where the user will perform exceptional requests. For this, *task analysis* is recommended. In this approach, it is required to define a set of usability goals to be tested, for example, ISO 9241 standard focuses on effectiveness, efficiency and satisfaction. These goals can be achieved by identifying how long a user takes to learn to use the interface, and for how long can they remember how to use it. Furthermore, the time that a user requires to perform a task can be measured and how much did they liked or disliked working with several aspects or parts of the system (Shneiderman and Plaisant, 2004:16). The primary approach is to let users use the system and to incorporate testing into the design process.

In the case of *participatory design*, it focuses on providing design ideas while users are testing a mock-up or a conceptual design of an interactive system (Shneiderman and Plaisant, 2004:126, Pommeranz et al., 2012:365). These iterations will provide the necessary information to improve the design process. This testing process is carried out in a short period of time that can comprise days to even hours. Compared to traditional ethnographic studies this might seem short. This is because it is meant to be an iterative process where the design phase is supplied with enough data to enhance its usability based on a user centred design.

Evaluation

There are several methods available for analysing the results of the performances of the users. These can be done by observing users, asking users and/or experts for their opinion, testing users' performance, and by developing tasks where designers can predict the efficacy of the interface and compare it (Rogers et al., 2011:345). The literature shows that a very common way to measure the scores is by using a *likeability framework* (Devi et al., 2012, Zaman and Abeele, 2007). This approach allows the evaluation process to identify the strengths and weaknesses of the interface with the analysis of the tests.

A.6 Evaluating Engagement and Interactive Experiences

Most of the testing in HCI methodology involves usability as the main way to understand how well the interactive system performs. Nevertheless, it has been argued that users engage with a system beyond the tool itself. Engagement and UX are based on the emotions and human responses that occur when using a specific tool. In the literature, several theories have proposed to focus on the hedonic aspect of an interactive system (Hassenzahl and Tractinsky, 2006, Wright and Blythe, 2007). It has been stated that some sectors of the HCI community do not like focusing merely on specific tasks or a specific sample of experiences when testing the interfaces. Arguably, designers are searching for a wider and more general set of emotional instrumentality such as stimulation, personal growth, identification and evocation (Hassenzahl and Tractinsky, 2006, Law et al., 2007). Therefore, it can be said that through UX and engagement, designers are trying to deliver an experience instead of trying to prevent usability issues. Hassenzahl and Tractinsky (2006) devised a framework identifying the different facets of users internal state when engaging with the interactive system. Although human emotions are more complex, this framework provides an initial perspective of the emotional relationship with the interactive system. Figure 55 shows some of these experiences. Furthermore, when using a specific product or interactive system, UX can unfold under different contexts. For instance, there are three main categories*: experience, an experience,* and *co-experience* (Forlizzi and Battarbee, 2004). *Experiences* are events that occur while we are conscious. They can be described as they happen. *An experience* is more difficult to be described at the moment; it lacks that "self-talk" process. These experiences can be commonly described after they have happened. They will produce behavioural changes after the *experience* has happened. A *co-experience* occurs under a social condition. There will be different social situations that will alter how *experiences* take place. Through social interaction with an interactive system, users can produce meaning and different emotions together. Moreover, this *experience* can happen without using the system. For instance, users can see how other people might use the system before using it. They can learn and see what is the interface about and learn how to use it before approaching it for the very first time.

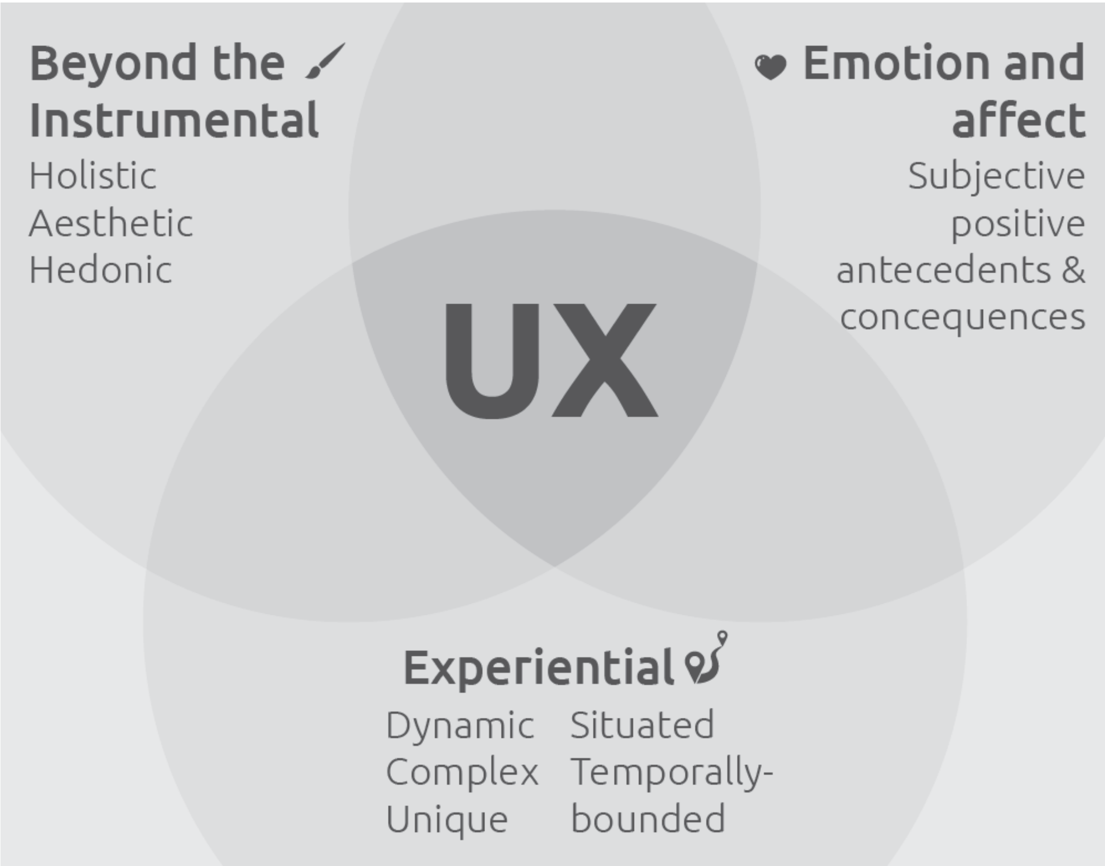


Figure 55. Facets of UX (Hassenzahl and Tractinsky, 2006)

Evidently the emotions provoked by user interfaces are complex and they can extend the capabilities of an interface. The experiences that occur when interacting with a system, are directly coordinated with the previously mentioned affordances and usability.

UX and engagement require further time and testing compared to a standard usability test. Experiences do not occur on a single time window or isolated from human emotion. Therefore, Scalability of experiences (Forlizzi and Battarbee, 2004) aims to give a comprehensive account of how experiences are built. It is argued that the experiences created when using an interactive system or produce might change through time. Smaller experiences will build up to construct a bigger experience that becomes the overall resultant experience. In this process is relevant to follow how UX develops, what are the aspects of the system the users liked, and this needs to be considered when developing an interactive system.

In section 4.1, Figure 42 presented a process that includes SA&D with HCI development assisted with a design methodology that includes the creative process. The proposed methodology indicates an iteration process between the design, creative and developments tasks. Moreover, it was also proposed by the extension of the design methodology (Figure 53) that identifying materials and technologies played an important role. Munari's problem solving methodology (2004) as a design process, serves as an introduction to how UX measures and identifies the scalability of experiences. Especially when working with TUIs there is a deep relationship between the user and the artefact, and the sensations that working with a specific material and tool will produce on them (McCarthy and Wright, 2005b, McCarthy et al., 2004:80, McCarthy and Wright, 2005a). In most cases, UX and engagement is deeply linked to human emotions and to how emotions are produced by interacting with products, and in this case, interactive systems. UX testing and measuring methods play an important role as well. However, communicating emotions and measuring them is not a simple task. Once it has been identified what sort of human responses are to be identified, a metric needs to be applied so it can be used pragmatically.

Evaluation

In recent years, psychologists have been researching how to categorise and measure emotions. There is an approach that distinguishes verbal (*subjective*) and non-verbal (*objective*) responses (Desmet, 2005). Non-verbal comprises the expressions or the responses produced physically by the body. For example, anger and fear have specific facial expressions, as well as surprise and relaxation are materialised through body posture. Expression changes can be coded following specific theories such as the Facial Action Coding System (FACS) that provides an emotion expression coding (EMFACS), a FACS Interpretive Dictionary (Ekman and Rosenberg, 2005), and the Maximally Discriminative Facial Moving Coding System developed by Carrol Ellis Izard (Desmet, 2005). The same process to measure physiologic reactions can be applied to the human voice, where changes to the pitch and speaking rate among others can be used to produce a similar coding system to measure such changes. In addition, emotions can manifest themselves as a wide range of responses in the human nervous system. These manifestations such as blood pressure, pupillary responses, brain waves and heart responses among others can be measured as well. Despite useful, it has been argued that such methods have a 60% - 80% accuracy, can only measure between six to eight emotions and cannot asses them simultaneously (Desmet, 2005).

Contrary to non-verbal approaches, verbal approaches depend on self-report. Commonly, users respond by expressing their emotions through rating scales (Desmet, 2005). But translating emotions to rating scales is not straightforward either since there is no direct translation from emotion to a word; not that we have enough words to describe every single emotion that we feel and express them in a specific scale. To solve this problem, researchers have been using pictures to represent the different scales of emotions. There are a wide variety of tools that work under this theory allowing users to express emotions. The Self-Assessment Manikin developed by Lang, was originally designed for measuring emotional responses to advertising (Morris, 1995). Through this tool (Figure 56), users can express how much they feel in control or happiness, and depict a wide range of emotions through a continuous nine-point scale (Irtel, 2008).

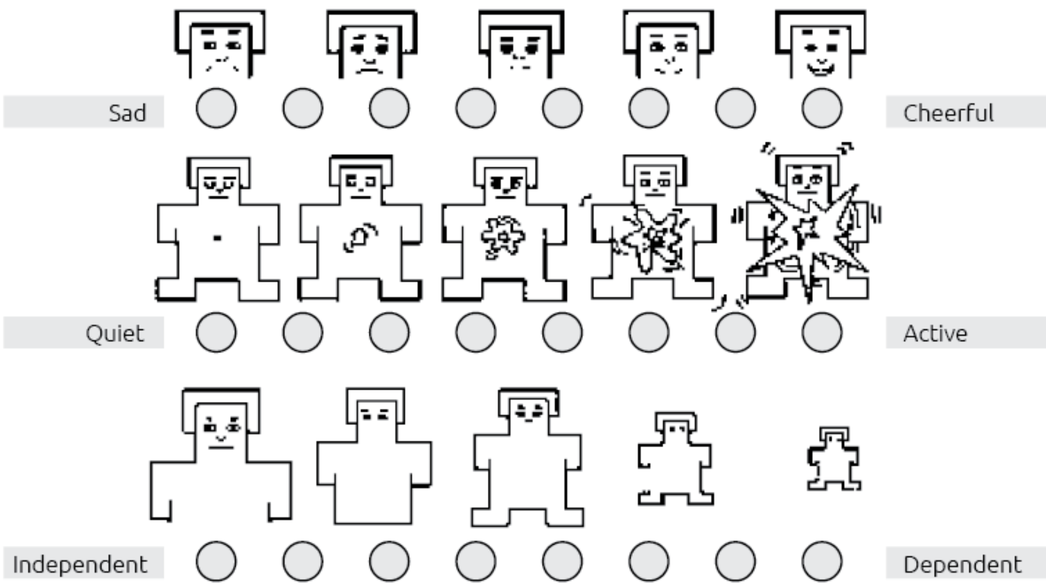


Figure 56. Self-Assessment Manikin (Lang, 1980)

The use of cartoon images to represent human emotions seems to be attracting more attention in the UX literature due to the fact that they are particularly efficient to portray human emotion (Desmet, 2005). Another example of the same type is PrEmo (Rengersen, 2014). PrEmo identifies 14 emotions: 7 pleasant and 7 unpleasant. PrEmo takes the cartoon images to the next level by adding animations where the emotions are expressed. Similarly, to Lang's measurement system, it is through these animations that users choose the five-level scale to decide the level and specific emotion to which they relate (Figure 57).

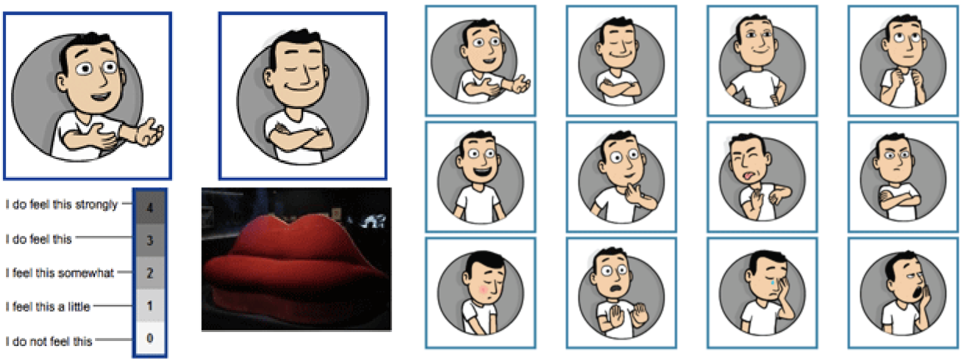


Figure 57. PrEmo by SusaGroup

Moreover, PrEmo provides a graphing system that allows visualising the results of the different emotions selected by users and the relation with a specific object or product. By visualising different aspects of what made users select an emotion can provide the tools to understand why some specific stimuli occurs. In this case, it can be used to identify precise sections of an interactive system or a particular feature of the design and understand how they create specific emotions. Certain aspects of an interactive system can produce a negative emotion. If a user encounters a positive emotion he or she will try to produce it again thus avoiding negative ones (Desmet, 2005).

Other systems such as IShoU (Kocsis, 2013) present a self-reporting system that also focuses on human emotions and thoughts. The system consists in a kit where users can report a wide range of emotions including social experiences.

Figure 58. IShoU

IShoU was originally developed to test visitors in a museum so they can report when they interact with a specific digital exhibit. The potential of this tool is the accessibility of having a self-report system on a tablet such as the iPad. IShoU provides in a similar way a data visualisation tool to analyse the results. The potential of using this kind of system relies on the capability of users self-reporting in a less intrusive way.

Although using non-verbal testing methods is more expensive due to the technology and kits, the literature suggests that they can provide more accurate results. One of the main differences that separates them form verbal methods is that they can be used across cultures. Subjective feelings can only be applied through self-report thus making it difficult to apply to diverse cultures (Desmet, 2005). Moreover, stopping users so they can express their emotions might disrupt the *flow* of the interaction, unlike non-verbal testing where users don’t have to stop to self-report their emotions. Systems such as IShoU and PrEmo offer the opportunity to use verbal testing with minimum *flow* disruption.

The process of user evaluation of UX, engagement and usability depends on a quantification of human behaviours, actions and processes systematically annotated by an observer. This annotation process can be eased through the applications discussed in this section. Alternatively, CH organisations and researchers do not have to depend on them completely. There is a wide range of online and offline applications that can also aid with the annotation and test user surveys. Alternatives such as Google Forms, Typeforms, JotForm, WuFoo, among others, offer the opportunity to use digital surveys to capture survey data. Nevertheless, the vast majority of such applications require a computer for users to input their responses. When working with TUIs it can be suggested to remain on a non-GUI format to maintain a level of flow between the experimentation process and the transition to the survey software. In this case alternatives such as iFormBuilder (iFormBuilder, 2015) where surveys can be implemented as a Web application. This Web application can be further deployed on a tablet or mobile phone (Figure 59). Arguably, the benefits of engaging users through a portable device, should allow users to isolate themselves faster to answer the survey. Moreover, users might feel more privacy in personal screes such as in a tablet than on a larger screen such as the ones in computers and personal notebooks where more people might see the results.

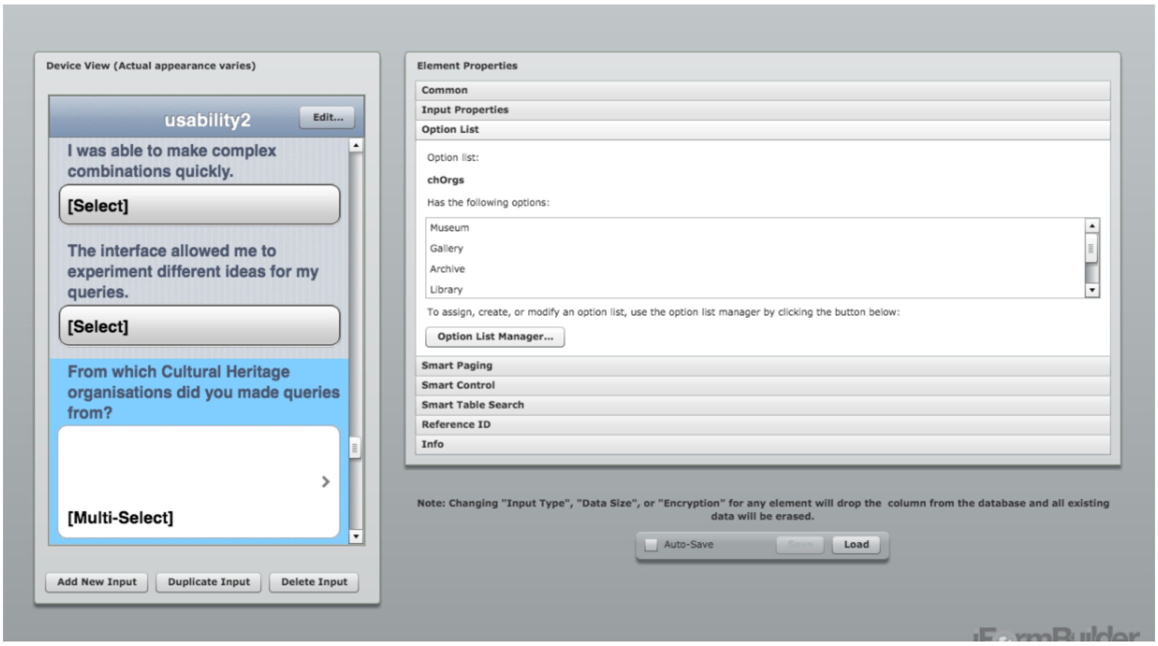


Figure 59. IformBuilder

UX and Usability testing will provide information of what sort of elements are being under-used. They can pave the way for design implementation. Nevertheless, there is a communicative process between the object and the user that goes beyond the performance of the tool. Moreover, the aesthetic quality of the system and its elements can produce emotions thus enhancing engagement and usability.

A.7 Evaluation in Design Processes

The visual aspect of the system plays an essential role in the process of informing the user what might be the best way to achieve what he or she wants. Visual Communication/Design has above all an understanding of how the communication between the design and the receiver (user) happens. Therefore, this is an important part where the user first engages with the instrumental and beyond instrumental parts of an interface. Designers need to produce an informed concept that conveys a message (information) through a wide set of contexts. To produce this effectively, the design process requires testing as well. Usability and Engagement tests will provide information that can eases the relationship between the user and the interface. Nevertheless, the problem of effective visual communication between the designed object and the user will still be present. Therefore, it requires testing. There are three main evaluations in design: [1] quantitative studies, where success rate of the communication can be tested and provide a statistical result; [2] qualitative studies, where by observation and interviews users can present their emotions and individual responses and [3] final evaluation, where the previous study results are calculated so the designer can produce a judgement toward the aesthetic, ethic and technical aspects of the design (Vilchis, 2002:154). CH organisations have to analyse further responses to their organisations since they become external transmitters of the message, once the design or system is placed under their control. These evaluations can be integrated with the Usability and/or Engagement testing process.

In the process of evaluation, as said before, the designer needs to know what is the user looking for and how they approach the designed object. This is because there is a wide range of cultural, historic, technical, symbolic and conceptual factors where the users/receivers approach the visual message (Figure 60). In order to address this, other method relevant to mention is a coding scheme that focuses in four concepts devised to identify what is the user trying to do. These concepts can be identified as (Suwa et al., 1999:6-7): perceptual, functional, conceptual and physical. The context in which the users will approach the aesthetic elements will play an essential role in the communication between them and the interactive system. Adaptive Decision Making theory indicate that users approach interfaces differently according to their particular culture and the nature of the task they are performing (Hartmann et al., 2007, Sutcliffe, 2009, Lavie and Tractinsky, 2004, Zaman and Abeele, 2007). This means that 'beauty' or the aesthetic quality can be biased, since it will depend on the context of the users. Nevertheless, the design aspect has more influence on how the visual elements affect the decision making of the users as well as the emotional stimuli that it creates.

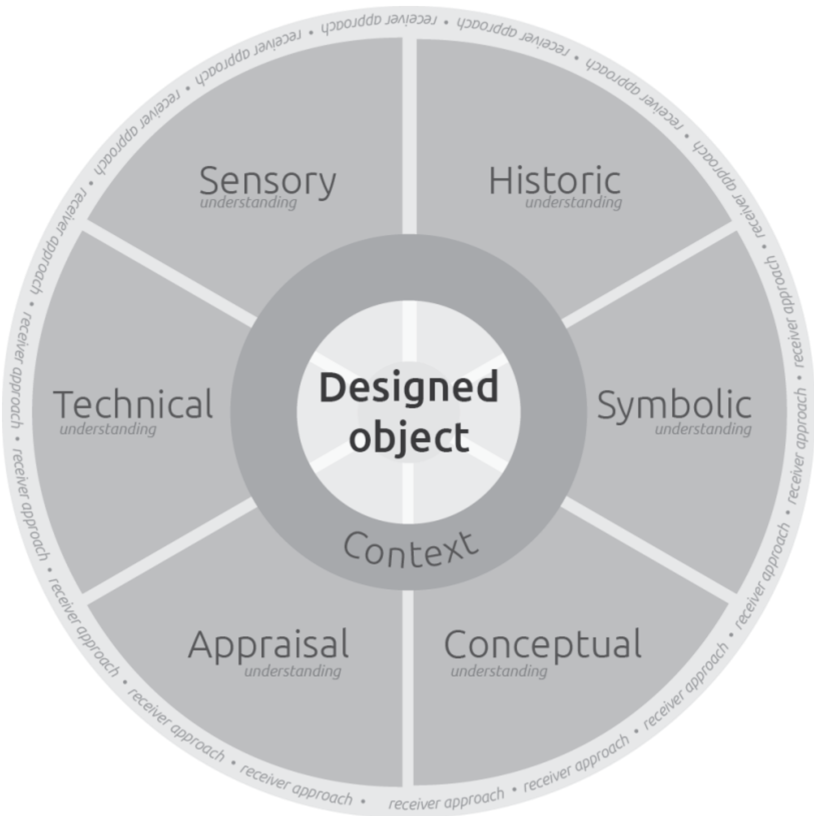


Figure 60. Approaches to the designed object (Vilchis, 2002:105)

These concepts can provide a categorisation to identify and analyse the results of different user types and how they are affected by the design elements. Although there are many techniques for evaluation, design testing can follow very similar procedures as UX and

Usability. Previous work has shown that design evaluation and testing is implemented through observation, interviews and making predictions (Stone and Open, 2005:23, Moreno, 2009, Vilchis, 2002, Lavie and Tractinsky, 2004, Hartmann et al., 2007).

A.8 Integrated Methodology in the Context of TUIs

The previous section has provided an overview of the different Usability, UX and Engagement methods for evaluating user interfaces. Most of the literature dealing with user interface evaluation has heavily focused on GUIs, and no standard evaluation methods for TUIs have been established so far. The common process of evaluation for TUIs has been carried out by either comparing them to a GUI equivalent, or by producing alternative versions of an interface to compare their performances. Such comparative studies can be carried out by scoring the positive and negative scores of engagement and usability. Zaman et al. (Zaman and Abeele, 2007, Zaman et al., 2012), produced a 'likeability framework' to carry out such studies. Nevertheless, carrying out comparative studies between TUIs and GUIs can return biased scores, since according to Zaman et al (Zaman et al., 2012) there is a sense that GUIs are commonly perceived as a lesser or damaged version. In addition, it has been noted that TUIs will also carry a level of novelty that will affect comparative results (Cheng et al., 2011). Nevertheless, such level of novelty can be reduced after they use the interactive system for the first time. This means that users might be willing to explore further when they are presented with a new interaction paradigm or a new way of exploring knowledge. This might prove challenging when producing the evaluation method since evaluation processes tend to have a high cost for organisations, thus might prove difficult to test a wide range of interfaces, which so far seem to fail to facilitate the cognitive and technical tools to produce complex queries in OCH. The evaluation of the interactive system carried out in this thesis aims to understand the holistic strengths and weakenesses of the system as an interactive method that enables users to produce complex queries in OCH.

TUIs can be tested through single case evaluation studies that focus on identifying specific positive and negative characteristics. They can also provide information for a new design concept or to produce new theories around the design project. Nevertheless, Zaman et al. (2012) indicated that the problem with this kind of studies is that they can lack detail to make a well-informed claim about a specific area of the interactive system. User Centred Design approaches can be implemented in the form of case studies and scenarios to compare the performance of the same interactive system. The problem of user centred approaches is that they can become subjective, because users' perspectives are heavily influenced on the place where they are being used or tested (Zaman et al., 2012). In addition, tangible interaction calls for an evaluation method that takes into account the novelty aspect of using physical objects and the physical reaction of interacting with them (Xu et al., 2008, Vissers and Geerts, 2014). Taking all this into account, the literature review provided in the section above within this chapter, helped in the context of this research to develop a holistic perspective, offering a way forward to integrate a TUI interaction design and evaluation methodology that embrace the different tangible properties, as well as their relationship with Usability, Engagement, and communication performance qualitative and quantitative information.

As said, due to the novelty of TUIs, there is no evidence of an industry standard for evaluation. Therefore, the interaction design methodology proposed here integrates the SA&D/HCI method proposed by Zhang et al. (2004) which focuses on the development of the interactive tools as a software development process, and the problem solving methodology established by Munari (2004) to assist understanding how people might attempt to use a particular tool. The final interaction design methodology (SA&D/HCI-M) (Figure 42) presents a streamlined process that begins with [1] the identification of a project, in this case Europeana, as introduced in Chapter 3. The SA&D/HCI interaction design methodology on its own, has as a main purpose to produce a particular tool that offers a specific service, but is not aimed to solve a problem. This is to say that this first stage (identification of a project) was carried out to understand what the user needed and the role that Europeana had to play as the infrastructure provider. This was followed by [2] an Analysis phase where specific demographics and end user groups are identified. These different groups and how they relate to Europeana and OCH are fully described in Chapter 6, where Europeana is investigated as a case study.

The first two phases of the SA&D/HCI interaction design methodology, [1] Project Selection and [2] Analysis, provide an understanding of the current and potential technologies as well as the interaction paradigms that can be implemented. For example, comprehend the way in which Apache Lucene syntax is used to construct queries and how these different data model fields can be mixed through the queries. The data models such as EDM play an essential role in the understanding of the complexity behind the queries, and how these queries can take place in different stages of the information lifecycle as discussed in Chapter

1 and 2. This thesis has argued that users have not entirely embraced the full complexity behind OCH, due to the challenges of the technologies used to engage with the information. For this reason, this thesis explores the idea that TUIs could alleviate such complexity, thus enhancing the engagement with OCH. To identify how such engagement might take place, Chapter 2 and 3 presented potential interaction paradigms that could be implemented within Europeana's technologic and technical context. A task analysis helped to identify the different expected goals to be achieved by the users, such as learning about a particular CH topic. The process of learning about a particular CH topic is also influenced by the users' different needs of information, described in Chapter 3. This research has focused primarily on users who arrive on a visceral and conscious state of information need, as part of an initial stage of discovery.

The third phase of the SA&D/HCI methodology, [3] the design phase, involves the process of developing the different affordances of the system. This is the first time where the user interface begins to be sketched. This phase aims to design a set of metaphors and visualisations to depict the mental model of the system. Zhang et al (2004) discussed that this process can be aided through Media design. This thesis presented the extension through Munari's Problem Solving methodology to enhance the way in which tools are designed. In TUIs there are many interactions that do not depend on the interactive system. The development of TUIs requires that designers pay attention to human actions that take place beyond the screen that commonly depend on embodied cognition. In this case, Munari's methodology is included to solve or enhance the original SA&D/HCI approach to design a tool.

The difference is that while the SA&D/HCI focuses on the tool as part of a computer system, Munari's methodology focuses on the physical tool as an independent object with a particular objective, even as a standalone object. Through Munari's methodology, the interaction design process explores the different properties that embrace the cognitive understanding and empowerment of the user. This is carried out through a User Centred Design approach where users inform the interaction design process of their particular behaviours and of how they would use and approach the interactive system to query Europeana. This experiment is described as part of the case study in Chapter 6, where the user expressed what tools were meaningful for them. In addition, Munari's methodology proves the limitations of designing a physical tool that requires downloading, distributing and the possibility of being modified or personalised. SA&D/HCI rarely focuses on de distribution of a system, which from Munari's methodology perspective, it is a problem.

The interaction design methodology considers not only the results of the evaluation process, but also the current problem to solve in a human environment. This is to say, that despite that the interactive system is meant to provide the engagement with OCH information, and if an interactive system by itself manages to solve such engagement problem, as a software tool, it has fulfilled its purpose. Nevertheless, there is still the need to build the pyfos, construct a table and promote its use. Those factors do not depend on Usability, Engagement or any performance of the tool, but on the efficiency of the design focused to solve that problem of distribution. The merge of these two methodologies enable an understanding of human as well as technologic factors when designing the tools before prototyping for evaluation.

To understand users' behaviours, the iterative design process is informed by a User Centred Design process, and can act as an initial UX and Engagement method that attempts to understand specific emotions that users might feel when engaging with OCH data. Those users will provide information on the requirements to be implemented on the final prototype. The iterative design process will recruit participants with interest and knowledge in the topic, or people that might require use of OCH knowledge. According to Wilson (2009:295) these type of participants focus more on the tasks instead of trying to figure out what sort of information might be behind the OCH structure. It is very likely that participants who already work with CH will have a larger grasp of how collections and objects are described throughout OCH, independently of the specific metadata or data fields. Specialists can help identifying advanced settings that might help some general users. In a posterior stage, after tools have been implemented and the prototype needs to be tested, a mixed specialised background of participants could be used in order to evaluate the performance of the tools.

Once the tools have been produced, the design process leaves Munari's methodology and returns to SA&D/HCI, and implements the tools on the interactive system as part of a prototype that will be further tested and evaluated. Within this design phase the development of the interface is based on the user analysis, users' goals as part of a task analysis, and their current needs of information to engage with OCH collections. In this phase, the affordances of the tools can be explored as part of the interactive system (pyfos) and the design of the physical object as part of a pyfo (e.g. volumetric design of tokens). This is to say, that the implementation phase has considered the metaphor and different visualisation principles from HCI, but also the skills to build the tokens so they can be used as pyfos, as part of the didactic and dexterity required. This phase and the resulting design elements are described in Chapter 6.

The final phase of the SA&D/HCI is where the prototype is finalised and evaluated. The methodology presented in this thesis aims to understand how the engagement and understanding of OCH could be facilitated on the Web. For this reason, there is still a need to identify particular strengths and weaknesses of the system, but the primary concern is to identify how is OCH data can become accessible and meaningful to users from a wide range of digital literacy and backgrounds. The evaluation of the interface should be carried out with a sample between at least 10 and 15 participants as suggested by Hwang and Salvendy (2010). Their study aimed on providing enough qualitative data for usability discount methods such as heuristic evaluations and cognitive walkthroughs. According to Hwang and Salvendy (Hwang and Salvendy, 2010) , Macefield (2009), Molich (2010) and Sauro (2013), there is no consensus on the amount of participants to secure at least 80% of the usability problems in a system evaluation process. For example, researchers such as Virzi (1992) and Nielsen and Landauer (Nielsen and Landauer, 1993) have argued that at least 5 users are required to unveil around 80% of usability problems, this approach was challenged by Spool and Shcroeder (2001), contending that 5 users would only unveil 35% of the usability problems. In addition, they indicated that a sample between 13 and 15 participants could identify one severe usability problem. In addition, other researchers such as Faulkner (2003), Woolrych and Cockton (2001) and Lewis (2006) have challenged the 5± and even the 8± user sample as well. The evaluation phase of the methodology carries out Usability, UX and Engagement processes to discover problems and advantages when using the TUI system to engage with OCH information. Thirteen users participated in this research, and following the literature review above, it was established that this number can provide enough information similarly to the Usability discount methods, both in the UCD process in the analysis and design phases of the SA&D/HCI, as well as the problem-solving methodology. The evaluation phase of this methodology calls for an understanding of behaviours and emotional responses as well as the performance of the system. Therefore, the usability studies and their statistical analysis can be used to draw information that further explains why users behave or reacted in a particular way and vice versa (Macefield, 2009, Molich, 2010, Sauro, 2013).

Another consideration of the evaluation phase is that TUIs are commonly tested in situ or in a lab based location. For this reason, designers have to be aware that users will have to travel where the interface is based or vice versa. In contrast, most GUIs can be tested in any computer and require no special settings. In some cases, many of these interfaces can be tested remotely, thus increasing the chance of having large numbers of participants. When measuring usability, it is common to assume that larger number of participants might provide more detailed information about the users and their performance (Molich, 2010). Nevertheless, many organisations with tight budgets might struggle to fund large studies for their prototypes.

Finally, the evaluation can be recorded and this process can be aided by different technologies such as the ones described in the Evaluation section in this chapter. Considering costs and the ease to transform the survey data, in the case of this research, iFormBuilder will be used to record the survey for each participant. This application provides a user interface to convey the *Likert* scale and facilitates the organisation of content. In addition, it can also be displayed in a tablet or phone not connected to the Web. This facilitates the mobility of the evaluator when testing the interface in any location or and avoids having to use a computer to record the participant data. Once the data is stored it can be downloaded from the iFormBuilder cloud and stored in a computer for the analysis.

Appendix B UX Experiment as part of a UCD Process

B.1 Compiled User Experience/User Centred Design Survey

When were you born?	
1961 - 1980	9
1981 - 1995	12
Do you visit the website of any of these organisations for your research?	
No	3
Yes	18
Can you physically visit any of the organisations that you work with the most?	
No	3
Yes	18
Do you work with cultural heritage?	
No	1
Yes	20
Do you use the Web to find information about your topic?	
x	1
No	1
Yes	19
Where do you commonly start your search in the Web?	
Academic Search Engine (e.g. Google Scholar, Web of Science)	4
Search Engine (e.g. Bing, Google)	16
The organisation's website (e.g. British Museum, National Library)	1
What are the main problems you face when searching for information?	
x	5
Information is scattered in too many sources	10
Lack of training or digital skills in using IT resources	1
Required material is not available	5
Your level of expertise when searching on the Web is…	
x	1
Competent	17
Expert	3

Are you familiar with the concept of the Semantic Web?	
Have an idea	5
No	8
Yes	8
Do you use search operators and symbols when you perform queries on a search engine such as Google? (e.g. $, @, #, “”, intitle: , filetype:)	
I don't know them	8
I know about them, but don't use them	7
Yes, I use them	6
Your level of expertise when searching on the Web is…	
x	1
Competent	17
Expert	3

Ease of Search		Quality of Information	
Search Engine (e.g. Bing, Google)			
x	2	Fair	13
Difficult	2	High	2
Easy	8	Low	2
Extremely easy	5	Very high	1
Neither hard nor easy	4		21
Academic Search Engines (e.g. Google Scholar, Web of Science)			
x	2	x	4
Difficult	2	Fair	2
Easy	11	High	10
Extremely easy	3	I don’t use it	1
I Don’t Use it	1	Very high	4
Neither hard nor easy	2	Total	21
Total	21		
The organisation’s website (e.g. British Museum, National Library)			
x	5	x	3
Difficult	3	Fair	6
Easy	7	High	7
Extremely easy	1	Very high	5

N/A - I don't use this resource	1
Neither hard nor easy	4
Total	21

Total	21

B.2 Extended User Experience/User Centred Design Survey 1

ID	When were you born?	Do you work with cultural heritage?	What is your main research topic about?	Add your particular cultural heritage organisation that you work the most with.	Do you visit the website of any of these organisations for your research?	How often have you visited their website for your research in the last 12 months?
In UX- Experiment						
12	1961 - 1980	Yes	Museology	University	Yes	200+
10	1961 - 1980	Yes	Digital humanities and spatial humanities	Ordinance survey	Yes	51-100
6	1981 - 1995	Yes	Archaeology		Yes	10-50
8	1981 - 1995	Yes	Archaeology early medieval	Big Heritage	Yes	0-10
11	1961 - 1980		Social media non-formal learning	University	No	0-10
1	1961 - 1980	Yes	maritime cultural heritage	Archive, Library	Yes	101 - 200
5	1981 - 1995	Yes	Underwater Cultural Heritage	Museum, Gallery, Archive	Yes	101 - 200
2	1981 - 1995	Yes	Maritime archaeology	University of Southampton, NAS, EH	Yes	101-200

3	1981 - 1995	Yes	Early Bronze Age maritime connections of the Levant	Museum, Archive, Library	Yes	51 - 100
4	1981 - 1995	Yes	3d Reconstruction		Yes	101-200
7	1961 - 1980	Yes	History	Other	Yes	51 - 100
9	1961 - 1980	Yes	Neolithic Settlement	Education, Schools	No	
Not in UX Experiment						
13	1981 - 1995	Yes	Archaeology & Nationalism Studies	Archive	Yes	51 - 100
14	1981 - 1995	Yes	Prehistory	Company	No	0 - 10
15	1981 - 1995	Yes	Prehistory	University	Yes	10 - 50
16	1981 - 1995	Yes	conservation	Museum	Yes	51 - 100
17	1981 - 1995	Yes	Digital Heritage/Early Modern Archaeology	university, community history group	Yes	10 - 50
18	1961 - 1980	Yes	ICT for dissemination of Cultural Heritage	Museum, Heritage Sites	Yes	10 - 50
19	1981 - 1995	Yes	Archaeology	Museum, Public administration	Yes	10 - 50
20	1961 - 1980	Yes	Archaeology	Museum	Yes	0 - 10
21	1961 - 1980	Yes	Maritime Archaeology	Library, University	Yes	101 - 200

ID	Can you physically visit any of the organisations that you work with the most?	In the last 12 months, how often have you visited their website for your research?	Do you use the Web to find information about your topic?	Where do you commonly start your search in the Web?	Search Engine (e.g. Bing, Google)

UX- Experiment					
12	Yes	200+	Yes	Search Engine (e.g. Bing, Google)	Easy
10	No	200+	Yes	Search Engine (e.g. Bing, Google)	Extremely Easy
6	Yes	10 - 50	Yes	Search Engine (e.g. Bing, Google)	Extremely Easy
8	Yes	0 - 10	Yes	Search Engine (e.g. Bing, Google)	Extremely Easy
11	Yes	10 - 50	Yes	Academic Search Engines (e.g. Google Scholar, Web of Science)	
1	Yes	51 - 100	Yes	Search Engine (e.g. Bing, Google)	Neither hard nor easy
5	No	0 - 10	Yes	The organisation's website (e.g. British Museum, National Library)	Extremely easy
2	Yes	10 - 50	Yes	Academic Search Engines (e.g. Google Scholar, Web of Science)	
3	Yes	10 - 50	Yes	Search Engine (e.g. Bing, Google)	Easy
4	Yes	51 - 100	Yes	Search Engine (e.g. Bing, Google)	Easy

7	Yes	10 - 50	Yes	Search Engine (e.g. Bing, Google)	Easy
9	Yes	10 - 50	Yes	Search Engine (e.g. Bing, Google)	Easy
Not in UX Experiment					
13	Yes	10 - 50		Search Engine (e.g. Bing, Google)	Easy
14	Yes	0 - 10	Yes	Search Engine (e.g. Bing, Google)	Extremely easy
15	Yes	0 - 10	Yes	Search Engine (e.g. Bing, Google)	Neither hard nor easy
16	No	0 - 10	Yes	Search Engine (e.g. Bing, Google)	Difficult
17	Yes	0 - 10	No	Search Engine (e.g. Bing, Google)	Difficult
18	Yes	0 - 10	Yes	Academic Search Engine (e.g. Google Scholar, Web of Science)	Neither hard nor easy
19	Yes	10 - 50	Yes	Search Engine (e.g. Bing, Google)	Easy
20	Yes	10 - 50	Yes	Search Engine (e.g. Bing, Google)	Easy
21	Yes	200+	Yes	Academic Search Engine (e.g. Google	Neither hard nor easy

				Scholar, Web of Science)	

ID	Academic Search Engines (e.g. Google Scholar, Web of Science)	University Library Website	The organisation's website (e.g. British Museum, National Library)	Wikis or social knowledge systems (e.g. Wikipedia, Wikis, Forums)	•Search Engine (e.g. Bing, Google)	Academic Search Engines (e.g. Google Scholar, Web of Science)
UX- Experiment						
12	Easy	Easy	Easy	Easy	Fair	High
10	Extremely Easy	Easy	Easy	Extremely Easy	High	Very High
6	Easy	Extremely Easy	Difficult	I Don't Use it	Fair	High
8	I Don't Use it	Neither Hard nor Easy	Neither Hard nor Easy	Easy	Fair	I don't use it
11						
1	Easy	Neither hard nor easy	Difficult	Extremely easy	Fair	High
5	Extremely easy	Extremely easy	Extremely easy	Easy	Fair	High
2						
3	Easy	Neither hard nor easy	Neither hard nor easy	Extremely easy	Fair	Very high
4	Easy					
7	Easy	Neither Hard nor Easy			Fair	High
9	Easy	Neither Hard nor Easy			Fair	
Not in UX Experiment						
13	Difficult	Easy	Easy	Easy	Fair	High

14	Extremely easy	Neither hard nor easy	N/A - I don't use this resource	Extremely easy	Very high	Very high
15	Neither hard nor easy	Neither hard nor easy	Easy	Easy	Fair	Fair
16	Easy	Neither hard nor easy	Easy	Neither hard nor easy	Low	Fair
17	Neither hard nor easy	Difficult	Easy	Neither hard nor easy	High	High
18	Easy	Neither hard nor easy	Difficult	Extremely easy	Fair	High
19	Difficult	Easy	Easy	Extremely easy	Low	Very high
20	Easy	Neither hard nor easy	Neither hard nor easy	Easy	Fair	High
21	Easy	Difficult	Neither hard nor easy	Easy	Fair	High

ID	**University Library Website**	**• The organisation's website (e.g. British Museum, National Library)**	**• Wikis or social knowledge systems (e.g. Wikipedia, Wikis, Forums)**	**What are the main problems you face when searching for information?**	**How many hours per week do you spend online?**	**How much of this time is spent searching information on the web?**
UX- Experiment						
12	High	High	Fair	Lack of training or digital skills in using IT resources	21-30	1 - 25%
10	Very High	Very High	Fair	Information is scattered in too many sources	31-40	1 - 25%
6	Very High	High	Very low	Required material is not available	31-40	51 - 75%
8	Fair	Fair	Fair	Required material is not	21-30	26 - 50%

				available		
11						
1	Very high	High	Very low	Information is scattered in too many sources, required material is not available	11 - 20	1 - 25%
5	Very high	Very high	Low	Information is scattered in too many sources, required material is not available	31-40	26 - 50%
2						
3	Very high	Very high	Low	Information is scattered in too many sources, required material is not available	31-40	51 - 75%
4						
7	Very high	Fair			31-40	26 - 50%
9		Fair			31-40	26 - 50%
Not in UX Experiment						
13	High	High	Fair	Information is scattered in too many sources, required material is not available	More than 40	26 - 50%
14	High	Very high	Fair	Information is scattered in too many sources, required material is not available	More than 40	1 - 25%
15	Fair	High	Fair	Information is scattered in too many sources	21 - 30	26 - 50%
16	Fair	Fair	Low	Information is scattered in too many sources	31 - 40	1 - 25%
17	High	Very high	High	Required material is not available	21 - 30	26 - 50%
18	Very high	High	Very low	Information is scattered in too many sources, required material is not available	31 - 40	26 - 50%
19	Very high	High	Low	Required material is not available	11 - 20	1 - 25%

20	Fair	Fair	Low	Required material is not available	31 - 40	1 - 25%
21	Fair	Fair	Low	Information is scattered in too many sources, required material is not available	21 - 30	51 - 75%

ID	Your level of expertise when searching on the Web is…	Do you use search operators and symbols when you perform queries on a search engine such as Google? (e.g. $, @, #, “”, intitle: , filetype:)	Are you familiar with the concept of the Semantic Web?	Have you used Europeana?
UX- Experiment				
12	Competent	I don't know them	No	No
10	Competent	Yes, I use them	Yes	No
6	Competent	I know about them, but don't use them	No	Yes
8	Competent	I don't know them	No	No
11		I don't know them	Yes	No
1	Competent	Yes, I use them	Have an idea	No
5	Competent	I don't know them	Have an idea	No
2	Competent	I don't know them	No	No
3	Competent	I know them, but don't use them	Yes	No
4	Competent	I know them, but don't use them	Yes	No
7	Competent	I know about them, but don't use them	No	No
9	Competent	I know about them, but don't use them	No	No
Not in UX Experiment				
13	Expert	I know them, but don't use them	No	No
14	Expert	Yes, I use them	No	No
15	Competent	I don't know them	Yes	No
16	Competent	Yes, I use them	Yes	Yes

17	Competent	I don't know them	Yes	Yes
18	Competent	Yes, I use them	Yes	Yes
19	Expert	I know them, but don't use them	Have an idea	Yes
20	Competent	Yes, I use them	Have an idea	No
21	Competent	I don't know them	Have an idea	No

B.3 Extended User Experience/User Centred Design Participant's Sequences

QueryID	Question
1	18th century Europeana objects from France
2	List of objects that contain the name "Sofia" in their title.
3	List of objects which contains the word "painting" in its description
4	Find images of Picasso the painter (person) but not his painting (Picassos).
5	Find Picassos (paintings) that are not made by Picasso (person).
6	Pottery artefacts found in London
0	Free Query

TangibleID	SequenceID	QueryID	UserID
MediaPicture	1	0	4
MediaPicture	1	3	8
MediaPicture	1	4	9
MediaType	1	1	10
MetadataTitle	1	5	10
Text	1	1	11
Text	1	2	3
Text	1	2	4
Text	1	2	7
Text	1	2	9
Text	1	2	10
Text	1	2	11
What	1	0	10
WhatArtefact	1	0	9
WhatArtefact	1	5	3
WhatArtefact	1	5	4
WhatArtefact	1	5	11
WhatArtefact	1	6	3
WhatArtefact	1	6	4
WhatArtefact	1	6	9
WhatText	1	0	1
WhatText	1	0	2

WhatText	1	0	5	WhereText	1	6	8
WhatText	1	0	6	Who	1	2	12
WhatText	1	0	7	WhoText	1	0	12
WhatText	1	1	6	WhoText	1	2	1
WhatText	1	2	2	WhoText	1	5	7
WhatText	1	2	5	AND	2	0	7
WhatText	1	2	6	AND	2	5	11
WhatText	1	5	2	Media3D	2	6	4
WhatText	1	5	5	MediaPicture	2	0	1
WhatText	1	5	6	MediaPicture	2	2	1
WhatText	1	5	8	MediaPicture	2	5	8
WhatText	1	5	12	MediaType	2	1	6
WhatText	1	6	11	MediaVideo	2	0	1
When	1	1	12	MetadataArtType	2	5	2
WhenCentury	1	1	2	MetadataArtType	2	5	6
WhenCentury	1	1	3	MetadataArtType	2	5	10
WhenCentury	1	1	4	MetadataArtType	2	5	12
WhenCentury	1	1	8	MetadataProvider	2	0	5
WherePin	1	0	3	MetadataProvider	2	0	10
WherePin	1	0	8	MetadataTitle	2	2	2
WherePin	1	0	11	MetadataTitle	2	2	3
WherePin	1	1	5	MetadataTitle	2	2	4
WhereRegion	1	1	7	MetadataTitle	2	2	6
WhereText	1	1	1	MetadataTitle	2	2	7
WhereText	1	1	9	MetadataTitle	2	2	9

MetadataTitle	2	2	10	WhereText	2	0	9
MetadataTitle	2	2	11	WhereText	2	1	3
MetadataTitle	2	3	8	WhereText	2	1	4
NOT	2	5	7	WhereText	2	1	8
Text	2	4	9	WhereText	2	6	3
Text	2	6	8	WhereText	2	6	9
What	2	0	4	WhoText	2	5	4
What	2	1	10	WhoText	2	5	5
WhatArtefact	2	6	11	AND	3	0	1
WhatStyle	2	5	3	AND	3	0	12
WhatText	2	0	2	AND	3	1	11
WhatText	2	0	6	AND	3	2	5
WhatText	2	0	12	AND	3	4	9
WhatText	2	2	5	AND	3	6	3
WhenCentury	2	0	3	AND	3	6	11
WhenCentury	2	1	1	AND	3	0	3
WhenCentury	2	1	7	Media3D	3	5	6
WhenNumber	2	1	2	MediaAudio	3	5	6
WhenNumber	2	1	9	MediaPicture	3	5	6
WhenNumber	2	1	11	MediaText	3	5	6
Where	2	1	5	MediaType	3	1	8
Where	2	1	12	MediaType	3	5	2
Where	2	2	12	MetadataArtType	3	5	5
WhereRegion	2	0	8	MetadataArtType	3	5	11
WhereRegion	2	0	11	MetadataDcCreator	3	5	3

MetadataDcCreator	3	5	4	MediaPicture	4	0	2
NOT	3	5	12	MediaText	4	0	2
Text	3	0	9	MediaText	4	0	12
Text	3	3	8	MediaType	4	0	2
Text	3	5	8	MediaType	4	0	5
What	3	1	12	MediaType	4	0	6
What	3	2	12	MediaType	4	1	2
WhatArtefact	3	0	10	MetadataDcCreator	4	5	12
WhatArtefact	3	2	1	MetadataProvider	4	0	3
WhatText	3	0	11	MetadataTitle	4	2	5
WhatText	3	1	2	NOT	4	5	2
WhatText	3	5	7	NOT	4	5	3
WhenCentury	3	0	7	NOT	4	5	5
WhenCentury	3	1	5	NOT	4	5	6
WhenCentury	3	1	6	NOT	4	5	7
WhenCentury	3	1	10	NOT	4	5	8
WhenEra	3	0	4	NOT	4	5	10
WhenNumber	3	0	2	NOT	4	5	11
WhenNumber	3	0	6	Text	4	0	9
WherePin	3	0	5	Text	4	0	10
WhereText	3	0	8	Text	4	4	9
WhereText	3	6	4	What	4	2	1
WhoText	3	5	10	What	4	6	3
AND	4	0	7	WhatArtefact	4	1	11
AND	4	0	11	WhatText	4	0	4

WhenEra	4	0	8
WhenNumber	4	1	5
WhenNumber	4	1	6
WhereRegion	4	1	10
WhereText	4	0	1
WhereText	4	6	11
Who	4	1	12
WhoText	4	2	12
WhoText	4	5	4
AND	5	0	4
AND	5	0	9
AND	5	1	11
MediaPicture	5	0	7
MediaType	5	1	12
MetadataDcCreator	5	0	12
MetadataDcCreator	5	5	10
MetadataDcCreator	5	5	11
MetadataProvider	5	0	11
NOT	5	5	4
Text	5	0	10
Text	5	2	5
Text	5	5	12
WhatArtefact	5	0	3
WhatText	5	0	5
WhatText	5	0	8
WhatText	5	5	7
WherePin	5	1	2
WhereRegion	5	0	6
WhereText	5	0	2
WhereText	5	1	5
WhereText	5	1	6
Who	5	4	9
WhoDcCreator	5	2	1
WhoDcCreator	5	5	3
WhoDcCreator	5	5	8
WhoText	5	5	2
WhoText	5	5	5
WhoText	5	5	6
AND	6	0	5
AND	6	0	7
AND	6	0	11
AND	6	1	12
MediaPicture	6	5	4
MediaText	6	0	12
MediaType	6	0	3
MetadataArtType	6	0	8
MetadataArtType	6	0	10
MetadataDcCreator	6	5	2

MetadataDcCreator	6	5	5
MetadataDcCreator	6	5	6
MetadataDcCreator	6	5	7
MetadataTitle	6	5	12
NOT	6	2	1
NOT	6	4	9
WhenEra	6	0	4
WherePin	6	0	2
WherePin	6	0	6
WherePin	6	1	6
WhereText	6	1	2
WhereText	6	1	11
WhoText	6	5	10
WhoText	6	5	11
AND	7	2	1
AND	7	5	7
MediaBook	7	0	12
MetadataDcCreator	7	1	12
MetadataDcCreator	7	4	9
MetadataProvider	7	0	5
MetadataProvider	7	0	7
OR	7	0	4
WhatText	7	0	8
WhatText	7	0	11
WhenEra	7	5	12
WhereRegion	7	0	2
WhereText	7	0	6
WhoText	7	0	10
AND	8	0	12
MediaPicture	8	0	4
MediaPicture	8	5	7
MediaType	8	0	11
MetadataArtType	8	0	8
MetadataDcCreator	8	0	10
MetadataProvider	8	1	12
NOT	8	0	7
What	8	2	1
WhenNumber	8	0	5
AND	9	1	12
Media3D	9	0	7
MediaPicture	9	2	1
MediaVideo	9	2	1
MetadataArtType	9	0	12
NOT	9	0	5
OR	9	0	8
WhatText	9	0	4
WhereRegion	9	0	10

AND	10	0	8	Text	11	0	8
AND	10	0	12	WhenNumber	11	1	12
NOT	10	0	10	WhereRegion	11	0	10
WhatText	10	0	4	MetadataProvider	12	0	12
WhenCentury	10	1	12	WhatText	12	0	4
WhenNumber	10	0	5	WhereText	12	0	10
MediaPicture	11	0	4	AND	13	0	12
MetadataInfluence	11	0	12	WhatArtefact	14	0	12

B.4 Participants Issues when working with stickers

UserID	QueryID	IssueID	Comments
3	6	2	User missed the What to specific object
11	2	3	Typed object. (Not necessary)
1	1	4	Used Map
1	4	3	Stated NOT WHO:Person
7	1	4	Used Map
7	5	3	Creator NOT WHO:Person
5	1	3	Used Both Dates and Century
5	0	3	Where has it been shown
8	0	2	LOGIC of AND and OR
9	6	3	Didn’t' type Pottery as a What. Used object icon only.

Issue ID Key Reference

1 - Positive	2 - Negative	3 - Information	4 - Interface

Appendix C TUI Prototype Evaluation

C.1 TUI Evaluation User Survey

ID	Born	UX Stickers	Work	Work CH	Org Most	Org Most
11	1961 - 1980	No	healthcare	No		
10	1981 - 1995	No	training tools	No		
9	1961 - 1980	No	Forestry	Yes	Other	CADW
8	1981 - 1995	No	Forestry	Yes	Other	Natural Resources Wales
7	1981 - 1995	No	graphic design	No		
6	1961 - 1980	No	n/a	No		
5	1961 - 1980	Yes	Museums	Yes	Other	Interpretation
4	1981 - 1995	No	1960s artist magazines	Yes	Archive	
3	1961 - 1980	Yes	Digital humanities	Yes	Archive	
2	1981 - 1995	Yes	Cathedral burials and monuments	Yes	Archive	
1	1961 - 1980	No	Human Computer Interaction	Yes	Museum	

ID	Web of Org	Often 12m	Phsically Org	In the last 12 months, how often have you visited their website for your research?	In the last 12 months, how often have you visited their place for your research?	Use Web
11	No		Yes	10-50		Yes
10	No		No			Yes
9	No		Yes	0-10		No
8	Yes	51-100	No			Yes
7	No		Yes	51-100		Yes
6	No		Yes	0-10		Yes
5	Yes	200+	Yes			Yes
4	Yes	10-50	Yes	10-50		Yes
3	Yes	51-100	No			Yes
2	Yes	51-100	Yes	51-100		Yes
1	Yes	0-10	Yes	0-10		Yes

					Ease to find Information	
ID	Start Search	Search Engine (e.g. Bing, Google)	Academic Search Engines (e.g. Google Scholar, Web of Science)	University Library Website	The organisation's website (e.g. British Museum, National Library)	Wikis/social
11	Search Engine (e.g. Bing, Google)	Extremely Easy	I Don't Use it	I Don't Use it	Neither Hard nor Easy	Easy
10	Search Engine (e.g. Bing, Google)	Extremely Easy	I Don't Use it	I Don't Use it	I Don't Use it	Difficult
9	Search Engine (e.g. Bing, Google)	Neither Hard nor Easy	Difficult	Difficult	Difficult	Neither Hard nor Easy

8	Search Engine (e.g. Bing, Google)	Easy	Difficult	I Don't Use it	Extremely Difficult	Easy
7	Search Engine (e.g. Bing, Google)	Easy	I Don't Use it	I Don't Use it	Neither Hard nor Easy	Easy
6	Search Engine (e.g. Bing, Google)	Easy	I Don't Use it	I Don't Use it	I Don't Use it	Neither Hard nor Easy
5	Search Engine (e.g. Bing, Google)	Neither Hard nor Easy	Neither Hard nor Easy	Easy	Easy	I Don't Use it
4	Academic Search Engines (e.g. Google Scholar, Web of Science)	Extremely Easy	Easy	Extremely Easy	Neither Hard nor Easy	Easy
3	Search Engine (e.g. Bing, Google)	Extremely Easy	Extremely Easy	Neither Hard nor Easy	Easy	Easy
2	Search Engine (e.g. Bing, Google)	Easy	Easy	Neither Hard nor Easy	Difficult	Easy
1	Search Engine (e.g. Bing, Google)	Easy	Easy	Neither Hard nor Easy	Easy	Easy

			Quality of Information			
ID	**•Search Engine (e.g. Bing, Google)**	**Academic Search Engines (e.g. Google Scholar, Web of Science)**	**University Library Website**	**• The organisation's website (e.g. British Museum, National Library)**	**• Wikis**	
11	Fair	Fair	I don't use it	Fair	Fair	
10	Fair	I don't use it	I don't use it	I don't use it	Fair	
9	Fair	I don't use it	I don't use it	Fair	Low	

8	Fair	High	I don't use it	Very low	Low
7	High	I don't use it	I don't use it	High	High
6	Fair	I don't use it	I don't use it	I don't use it	Low
5	Fair	High	Fair	Fair	I don't use it
4	Fair	Very High	Very High	Very High	High
3	Fair	High	Very High	Very High	Fair
2	Fair	High	High	High	Low
1	Fair	High	High	High	Fair

ID	Problem Srch	Your level of expertise when searching on the Web is…	Do you use search operators and symbols when you perform queries on a search engine such as Google? (e.g. $, @, #, “”, intitle: , filetype:)	Hours Online	Are you familiar with the concept of the Semantic Web?
11	Information is scattered in too many sources	Competent	I know about them, but don't use them	11-20	No
10	Information is scattered in too many sources	Competent	I don't know them	11-20	No
9	Required material is not available	Novice	I don't know them	11-20	No
8	Information is scattered in too many sources	Expert	Yes, I use them	More than 40	No
7	Information is scattered in too many sources	Expert	I know about them, but don't use them	31-40	No
6	Information is	Competent	I don't know	11-20	No

	scattered in too many sources		them		
5	Information is scattered in too many sources	Novice	I know about them, but don't use them	6-10	No
4	Required material is not available	Competent	I know about them, but don't use them	31-40	No
3	Required material is not available	Competent	I know about them, but don't use them	11-20	Yes
2	Information is scattered in too many sources	Competent	I know about them, but don't use them	31-40	No
1	The search process is too slow	Expert	Yes, I use them	More than 40	Yes

C.2 Final Experiment Participants Completion Times

Participant	Question	Order	Time1 (Secs)	Time 2 (Secs)
P1	7	1	142.40	15.00
	5	2	49.56	
	4	3	26.55	21.21
	6	4	145.47	
	1	5	30.00	
	3	6	217.00	
	2	7	32.16	63.16
	8	8	46.27	
P2	7	1	12.59	1.53
	3	2	28.44	
	6	3	44.36	
	2	4	20.08	24.12
	1	5	11.57	
	4	6	16.31	30.01
	5	7	41.30	
	8	8	252.21	
P3	5	1	2.27	
	2	2	40.31	48.39
	3	3	95.13	
	1	4	18.39	
	4	5	25.24	28.03
	7	6	45.06	13.01
	6	7	77.39	

	8	8	364.04	
P4	3	1	53.26	
	4	2	38.03	51.03
	5	3	34.06	
	1	4	19.35	
	6	5	75.36	
	7	6	34.31	10.39
	2	7	51.02	11.18
	8	8	266.28	
P5	7	1	190.47	16.27
	6	2	85.12	
	5	3	55.17	
	1	4	25.28	
	4	5	21.13	34.12
	2	6	30.51	23.39
	3	7	40.05	
	8	8	609.00	

Participant	Question	Order	Time1 (Secs)	Time 2 (Secs)

P6	6	1	87.06	
	2	2	35.39	13.26
	1	3	30.16	
	7	4	98.14	38.07
	3	5	51.06	
	5	6	97.59	
	4	7	18.13	34.05
	8	8	328.52	
P7	5	1	95.02	
	7	2	73.24	24.59
	2	3	28.08	25.09
	6	4	55.25	
	4	5	23.39	48.37
	3	6	33.04	
	1	7	29.10	
	8	8	72.25	
P8	3	1	129.47	
	6	2	22.08	
	4	3	31.12	22.34
	7	4	40.10	7.28
	2	5	30.18	8.10
	5	6	44.45	
	1	7	25.12	
	8	8	207.19	
P9	2	1	62.53	13.44

	4	2	24.11	132.47
	1	3	33.28	
	6	4	36.33	
	5	5	79.54	
	3	6	25.19	
	7	7	55.13	5.16
	8	8	241.32	
p10	5	1	210.44	
	4	2	30.10	45.11
	2	3	36.06	188.15
	6	4	75.23	
	3	5	38.21	
	1	6	48.26	
	7	7	66.14	11.45
	8	8	262.34	
P11	5	1	239.22	
	1	2	30.53	
	2	3	35.40	32.36
	4	4	34.36	26.40
	3	5	32.00	
	6	6	102.40	
	7	7	73.13	6.20
	8	8	303.13	

C.3 Queries Performed by Participants During Evaluation

Participant	Final Query			Concept Issue	Techno Issue
P1	What:Fashion Objects	When:1800 TO 1900	Where:Italy OR Wales	Word Object	
	What:Sculptures OR Paintings	Who:Rodin NOT Picasso			
	What:Ceramin NOT Tiles	Where:Spain NOT France			
	What:Coins	What2:Medieval	Where: United Kingdom	Medieval Concept	
	When:1525 TO 1527				
P2	Where:Italy OR Wales	What: Fashion	When:1800 TO 1900		What2 used on 1
	What:Objects	When: 1525 TO 1527		Word Object	
	What:Medieval Coins NOT Post	Where: United Kingdom			Keyboard Enter
	Where:Egypt	What:cats	What2:Mummy		
	What: Paintings	Who: Leonardo Da Vinci			
	Where:Spain NOT France	What:Ceramic NOT Tiles			
	What:Sculpture OR Painting	Who:Rodin NOT Picasso			
	What:King	What2	Where		Scroll Issue
P3	Who:Rodin NOT	What:Sculptures OR Paintings			What2 on 1

	Picasso				
	What:Cats	Where:Egypt	What2:Mummy		Rotation Confusion
	When:1525 TO 1527				
	Who:Leonardo Da Vinci	What:Paintings			
	What:Ceramic NOT Tiles	Where:Spain NOT France			
	What:Fashion	When:1800 To 1900	Where:Italy OR Wales		
	What:Coins	When:100 To 900	Where:United Kingdom	Date for Medieval	
	What:Map	Where:World	What2:Medieval		
	Who:William	What:Picture NOT Sculpture			

Participant	Final Query			Concept Issue	Techno Issue
P4	When:1525 TO 1527				Keyboard Enter
	Where:Spain NOT France	What:Ceramic NOT Tiles			Used Refinement What
	Who:Rodin NOT Picasso	What:Sculptures OR Paintings			
	What:Painting	Who:Leonardo DA Vinci			
	What:Coin	What2:Medieval	Where:United Kingdom		
	What:Fashion Object	When:1800 TO 1900	Where:Italy OR Wales	Participant was looking for objects	
	What:Cats OR Mummy	Where:Egypt			
	What	When 000 TO 000	Where		
P5	Where:Italy OR Wales	When:1800 TO 1900	What:Fashion	slowly constructed	What2 and What1 confusion
	What:Coins	When: XV TO XVII	Where:United Kingdom	Conceptual Dates Roman	Presses Enter
	Who2:Rodin	What:Sculptures OR Paintings			What2 on What1
	Who2:Leonardo Da Vinci	What2:Paintings			Misuse of refinement
	Where:Spain NOT France	What:Ceramic NOT Tiles			

	Where: Egypt	What:Cats	What2:Mummy		
	When:1525 TO 1527				
	When:Century	Where:	What, What2		
	Where:Europe	What:Roman	What2:		
P6	What:Coins	What2:Medieval	Where: United Kingdom		Pressed Enter
	What:Cats OR Mummy	Where:Egypt			Confused Rotation
	What:Paintings	Who:Leonardo Da Vinci			
	Where:Italy OR Wales	When:1800 TO 1900	What:Fashion		
	When:1525 TO 1527				
	Who2:Rodin	What:Sculptures OR Paintings			

Participant	Final Query			Concept Issue	Techno Issue
P7	Who:Rodin	What:Sculptures OR Paintings			Search Step by Step
	What:Fashion	When:1800 TO 1900	Where:Italy OR Wales		Rotation confusion
	What: Cats OR Mummy	Where:Egypt			
	What:Medieval Coins	Where:United Kingdom			
	Where:Spain NOT France	What:Ceramic NOT Tiles			
	When:1525 TO 1527	What:Objects		Keyword Objects	
	What:Paintings	Who:Leonardo Da Vinci			
	Where	Who:(Artist)//Deleted	What:Title	Looking for name of artist	
P8	When:1525 TO 1527				
	What:Medieval coins	Where:UK		Concept: UK instead of United Kingdom but did it on purpose	
	What:Ceramic NOT Tiles	Where:Spain NOT France			
	What:Fashion	Where Italy OR Wales	When: 1800 to 1900		
	What:Cats	Where:Egypt	What2:Mummy	Term Provided Confusion	

	What:Sculptures OR Paintings	Who:Rodin NOT Picasso			Liked the Clear Pyfo
	What:Paintings	Who:Leonardo Da Vinci			
	What:Castles	Where:Wales	What2:Conwy		
P9	Where:Egypt	What:Cats Mummy		Who:Cats because seem subject	
	Where:Spain NOTFrance	What:Ceramic NOT Tiles			
	What:Paintings	Who:Leonardo DA Vinci			
	What:Medieval Coins	Where:United Kingdom			
	Who:Rodin NOT Picasso	What:Sculptures OR Paintings			Pressed Enter
	When:1525 TO 1527				Step by step
	Where:Italy OR Wales	What:Fashion	When:1800 TO 1900		
	Where:Llangollen	What:xx	What2:xx		

Participant	Final Query			Concept Issue	Techno Issue
p10	Who:Rodin NOT Picasso	What:Sculptures OR Paintings			
	What:Ceramic NOT Tiles	Where:Spain NOT France			
	What:Cats NOT Kittens	Where:Egypt	What2:Mother	Mummy as in Mother	
	What:Medieval Coins	Where:United Kingdom			
	When:1525 TO 1527				
	What:Paintings	Who:Leonardo Da Vinci			
	Where:Italy OR Wales	When:1800 TO 1900	What:Fashion Objects		
P11	Who:Rodin NOT Picasso	What:Sculptures OR Paintings			Rotated the other Way
	What:Paintings	Who:Leonardo Da Vinci			
	What:Cats	Where:Egypt	What2:Mummy		
	What:Ceramic NOT Tiles	Where:Spain NOT France			
	When:1525 TO 1527				
	What:Coins	Where:United Kingdom	What2:Medieval		
	What:Fashion	Where Italy	When: 1800 to 1900		

	OR Wales		

C.4 Raw Usability Results Before Analysis

ID	Using the interface was:			I think that I would like to use this system frequently	I found the system unnecessarily complex	I think that someone will have to teach me to how to use the interface before using it for the first time
	Difficult: 0 Easy: 7	Dull: 0 Stimulating: 7	Rigid: 0 Flexible: 7			
11	7	7	6	Agree	Strongly Disagree	Disagree
10	6	7	6	Strongly agree	Disagree	Strongly agree
9	6	6	4	Agree	Disagree	Disagree
8	6	6	7	Agree	Strongly Disagree	Disagree
7	4	5	3	Disagree	Disagree	Strongly agree
6	5	6	4	Agree	Disagree	Disagree
5	7	7	4	Strongly agree	Disagree	Strongly agree
4	7	7	7	Agree	Strongly Disagree	Undecided
3	7	7	7	Strongly	Strongly	Strongly

				agree	Disagree	Disagree
2	5	6	4	Strongly agree	Disagree	Agree
1	6	7	5	Agree	Disagree	Disagree

ID	The interface actions were well integrated altogether.	Many of the tools in the system did not work in the same way	I think a lot of people would learn how to use the interface very quickly	The interface was very complicated	I was very confident using the interface	I need to learn a lot of things before using the interface
11	Strongly agree	Disagree	Strongly agree	Strongly Disagree	Agree	Strongly Disagree
10	Agree	Strongly Disagree	Agree	Disagree	Agree	Disagree
9	Undecided	Disagree	Strongly agree	Disagree	Agree	Strongly Disagree
8	Strongly agree	Strongly Disagree	Agree	Disagree	Strongly agree	Strongly Disagree
7	Agree	Disagree	Agree	Disagree	Agree	Undecided
6	Agree	Disagree	Strongly agree	Disagree	Strongly agree	Strongly Disagree
5	Agree	Undecided	Agree	Disagree	Agree	Agree
4	Strongly agree	Disagree	Strongly agree	Strongly Disagree	Agree	Undecided
3	Strongly agree	Strongly Disagree	Strongly agree	Strongly Disagree	Strongly agree	Strongly Disagree
2	Agree	Disagree	Strongly agree	Disagree	Agree	Disagree

1	Agree	Strongly agree	Agree	Strongly Disagree	Agree	Strongly Disagree

ID	The interface had the tools I needed to find what I was looking for.	I can use some parts of the interface for my research.	The interface helped me as a starting point to find information.	It was easy to know what each tool in the interface was meant to do.	I could use an interface like this if it offered the tools that I need.
11	Strongly agree	Agree	Agree	Strongly agree	Strongly agree
10	Agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree
9	Agree	Agree	Strongly agree	Agree	Strongly agree
8	Strongly agree	Agree	Strongly agree	Strongly agree	Strongly agree
7	Agree	Agree	Agree	Undecided	Agree
6	Agree	Agree	Agree	Strongly agree	Agree
5	Agree	Strongly agree	Strongly agree	Agree	Strongly agree
4	Strongly agree	Agree	Agree	Strongly agree	Strongly agree
3	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Strongly agree
2	Agree	Strongly agree	Strongly agree	Agree	Strongly agree
1	Agree	Undecided	Agree	Agree	Strongly

					agree

ID	I learned how to use the interface quickly.	It was easy for me to remember how to use the interface in between questions.	I was able to make complex combinations quickly.	The interface allowed me to experiment different ideas for my queries.	From which Cultural Heritage organisations did you make queries from?
11	Strongly agree	Strongly agree	Agree	Strongly agree	Museum, Gallery, Archive
10	Agree	Strongly agree	Strongly agree	Strongly agree	Archive
9	Agree	Agree	Strongly agree	Agree	Museum, Gallery, Archive
8	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Museum, Gallery
7	Agree	Agree	Agree	Agree	Archive
6	Strongly agree	Strongly agree	Agree	Agree	Museum, Gallery, Archive, Library
5	Agree	Strongly agree	Undecided	Agree	Museum
4	Agree	Strongly agree	Strongly agree	Strongly agree	Museum, Gallery, Archive, Library

3	Strongly agree	Strongly agree	Strongly agree	Strongly agree	Museum, Gallery, Archive, Library
2	Strongly agree	Strongly agree	Agree	Agree	Museum, Gallery, Archive, Library, Other
1	Strongly agree	Strongly agree	Agree	Strongly agree	Museum, Library

ID	I would like to take the interface home to use it for longer	I was able to query across museums, galleries, libraries and archives without any issues.
11	Agree	Agree
10	Strongly agree	Strongly agree
9	Agree	Agree
8	Agree	Strongly agree
7	Agree	Undecided
6	Strongly agree	Strongly agree
5	Undecided	Agree
4	Strongly agree	Strongly agree
3	Strongly agree	Strongly agree
2	Agree	Agree
1	Agree	Agree

C.5 Usability Results Calculations (from previous section)

	Perception of the System			Final SUS Score	
Participant	DifficultEasy	DullStimulating	RigidFlexible	TOTAL	SUS
8	6	6	7	63	93
7	4	5	3	44	65
6	5	6	4	57	84
5	7	7	4	49	72
4	7	7	7	58	86
3	7	7	7	68	100
2	5	6	4	56	83
1	6	7	5	52	77
11	7	7	6	49	72
10	6	7	6	52	77
9	6	6	4	51	75
				Average:	80

Usability Scores							
P	UseFrequently	Complex	TeachMe	WellIntegrated	ToolsNotSame	LearnFast	Complicated
8	3	4	3	4	4	3	3
7	1	3	0	3	3	3	3

6	3	3	3	3	3	4	3
5	4	3	0	3	2	3	3
4	3	4	2	4	3	4	4
3	4	4	4	4	4	4	4
2	4	3	1	3	3	4	3
1	3	3	3	3	0	3	4
11	3	0	3	4	3	4	0
10	4	3	0	3	0	3	3
9	3	3	3	2	3	4	3

FeltConfident	LearnBeforeUse	ToolsNeeded	UseInMyResearch	StartPoint	EasyKnowTool	UseIfOffered	LearnedQuickly
4	4	4	3	4	4	4	4
3	2	3	3	3	2	3	3
4	4	3	3	3	4	3	4
3	1	3	4	4	3	4	3
3	2	4	3	3	4	4	3
4	4	4	4	4	4	4	4
3	3	3	4	4	3	4	4
3	4	3	2	3	3	4	4
3	0	4	3	3	4	4	4
3	3	3	4	4	4	4	3
3	0	3	3	4	3	4	3

EasyRemember	ComplexFast	ExperimIdeas	PlayLonger	QueryAcross
4	4	4	3	4
3	3	3	3	2
4	3	3	4	4

4	2	3	2	3
4	4	4	4	4
4	4	4	4	4
4	3	3	3	3
4	3	4	3	3
4	3	4	3	3
4	4	4	4	4
3	4	3	3	3

Strongly Agree	5
Agree	4
Undecided	3
Disagree	2
Strongly Disagree	1

Negative	5+x
Positive	x -1

C.6 Participants Query Samples

Participant 1

What:Fashion Objects	When:1800 TO 1900	Where:Italy OR Wales

What:Sculptures OR Paintings	Who:Rodin NOT Picasso

What:Ceramin NOT Tiles	Where:Spain NOT France

When:1525 TO 1527

Participant 2

Where:Italy OR Wales	What: Fashion	When:1800 TO 1900

What:Objects	When: 1525 TO 1527

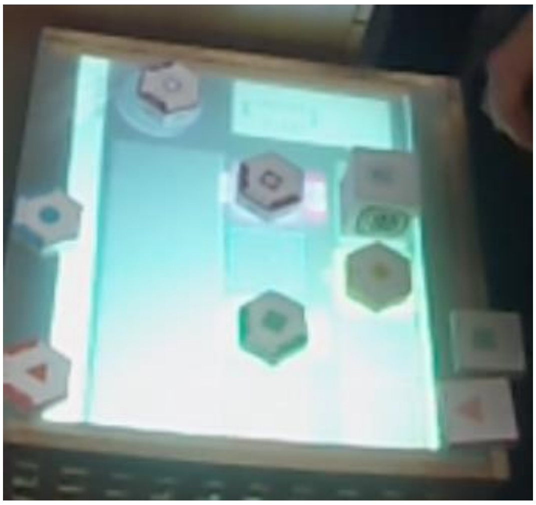
What:Medieval Coins NOT Post	Where: United Kingdom

Where:Egypt	What:cats	What2:Mu mmy

Participant 3

Who:Rodin NOT Picasso	What:Sculptures OR Paintings

What:Cats	Where:Egypt	What2:Mummy



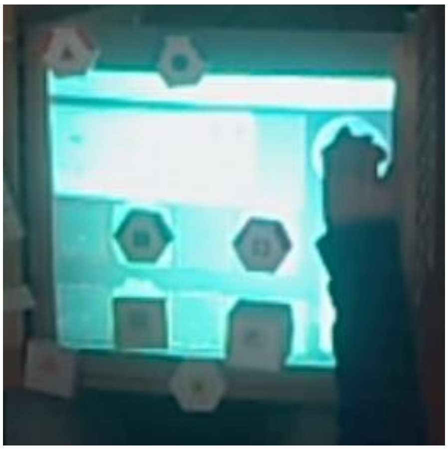
What:Ceramic NOT Tiles	Where:Spain NOT France

Who:William	What:Picture NOT Sculpture

Participant 4

When:1525 TO 1527

Where:Spain NOT France	What:Ceramic NOT Tiles

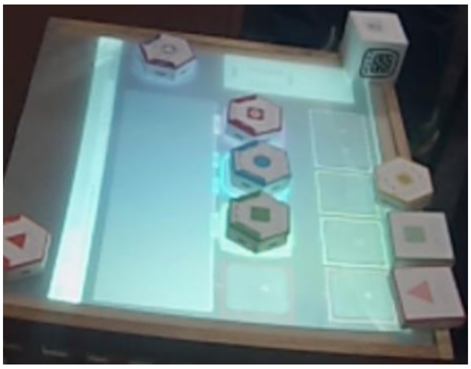


Who:Rodin NOT Picasso	What:Sculptures OR Paintings

What:Coin	What2:Medieval	Where:United Kingdom

Participant 5

Where:Italy OR Wales	When:1800 TO 1900	What:Fashion



What:Coins	When: XV TO XVII	Where:United Kingdom

Who2:Rodin	What:Sculptures OR Paintings

Where:Europe	What:Roman	What2:

Participant 7

What:Fashion	When:1800 TO 1900	Where:Italy OR Wales

What:Medieval Coins	Where:United Kingdom

When:1525 TO 1527	What:Objects

Where	Who:(Artist)/ /Deleted	What:Title

Participant 8

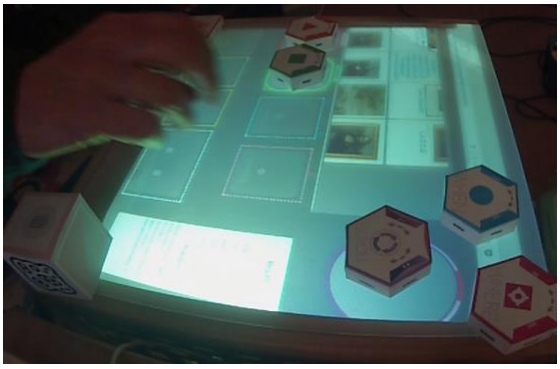
What:Medieval coins	Where:UK

What:Ceramic NOT Tiles	Where:Spain NOT France

What:Fashion	Where Italy OR Wales	When: 1800 to 1900

What:Castles	Where:Wale s	What2:Co nwy

Participant 9



What:Paintings	Who:Leonardo DA Vinci

Where:Spain NOTFrance	What:Ceramic NOT Tiles

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