KNOWLEDGE-BASED EXPLORATION OF MULTIMEDIA MUSEUM COLLECTIONS

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SCULPTEUR is an EU/IST funded collaborative research project concerned with the application of knowledge and semantic web technologies to the problem of multimedia information management in the cultural heritage domain. An important aspect of the project is the development of a semantic layer centred on an ontological representation of the domain which facilitates novel concept based retrieval, browsing and navigation as well as more traditional content and metadata based modes. Implications of extending the media collection to include 3-D models is also being addressed. The paper presents a brief progress report on the project.

1. Introduction

SCULPTEUR[1] is an EU/IST funded project which involves five major European galleries, the Uffizi in Florence, the National Gallery and the Victoria and Albert Museum in London, the Musee de Cherbourg and the Centre de Recherche et de Restauration des Musees de France (C2RMF) which is the Louvre related art restoration centre. These galleries maintain substantial digital archives of their collections and these collections, comprising of digital objects (images, 3-D models and videos together with textual information and metadata) are very rich sources of knowledge in the cultural heritage domain. One of the main aims of the SCULPTEUR project is concerned with the enhancement of facilities for exposing, searching and sharing the knowledge implicit in these collections.

Other technical partners in the project include Centrica in Italy and ENST in Paris. The technologies now available for exploitation are evolving rapidly, notably in the area of web services and the semantic web and the SCULPTEUR project makes extensive use of semantic web technology, not only to provide effective annotation of the museum collections enhancing retrieval, navigation

and browsing, but also providing an effective platform for interoperability with other systems and a potential base for reasoning and data mining.

This paper provides a brief progress report on the research and development in the SCULPTEUR project, concentrating on the use of ontologies as a basis for exposing the implicit knowledge in the collections and the development of what we call the semantic layer above the raw media which provides the explicit conceptualisations of the domain and associations with the media objects which together facilitate semantic navigation, browsing and retrieval as new modes for exploring the archives.

Another aspect of the SCULPTEUR project is to extend the browsing, retrieval and navigation facilities of the digital museum archives to a wider range of multimedia types. Most museum archives concentrate on 2-D images of their collections but increasingly museums are recognising the value of 3-D visualisation not only for researchers, curators and historians but also potentially as a way of bringing some realism to virtual museums for the public and for e-Learning applications in the cultural heritage domain. The challenges of content based retrieval of 3-D models are being addressed in the project using features extracted from the stored mesh representations and texture maps.

2. Related Work

The SCULPTEUR project is related to and builds on previous work in several fields. A major source of inspiration comes from previous work on the ARTISTE [2] and a large body of other published work on content based image retrieval systems [16]. The idea for the semantic layer and knowledge base draws on previous work at Southampton [20] and semantic web technology [21]. Semantic web techniques are being used increasingly to publish heterogeneous museum collections on the web [17,18].

3. The Semantic Layer

One of the significant challenges of the project is to develop the semantic layer centred on an ontological description of the cultural heritage domain relevant to the museums with whom we are collaborating. The starting point for the development of the ontology was the conceptual reference model (CRM) [3] developed by the documentation standards committee of the International Council of Museums (CIDOC) [4]. The aim of the CRM is to support the exchange of relevant cultural heritage information across museums, based on shared semantics and common vocabularies. Users of the CRM represent a growing community, and other standards communities are recognising it as a

valid standard and are attempting to integrate it in other areas such as multimedia [19]. Working closely with the museums is necessary to extend the core CRM to enhance the particular areas relevant to each museum and to develop mappings between museum metadata values and concepts in the ontology. This is a difficult and time consuming manual task but the mappings are then used to build the associations between the digital objects with which the metadata is associated and the semantic descriptions in the ontology. This bridge across the semantic gap facilitates search for media objects via the concepts and relationships in the ontology as well as via more usual content and metadata based searching. The semantic layer also exposes the richness of information surrounding the media objects themselves, enabling searches to focus not only on the media objects but also on the broader range of entities in the semantic layer.

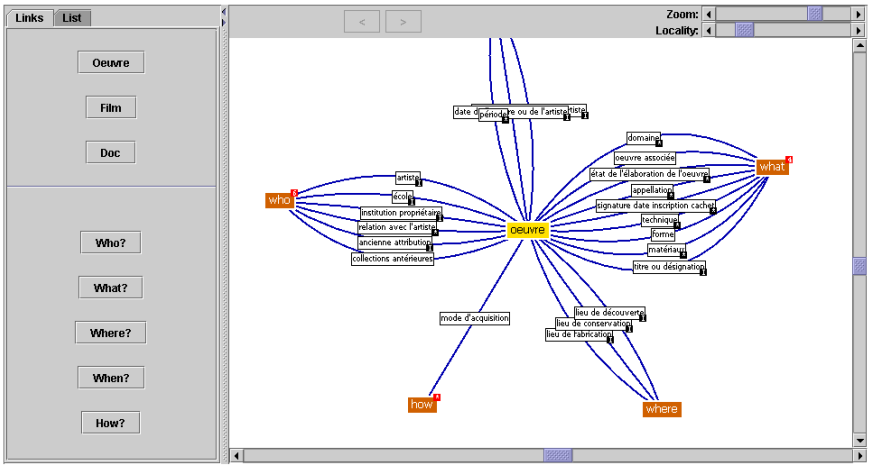

Figure 1: Concept Browser displaying simplified view of CIDOC CRM ontology

A concept browser interface is provided to allow users to explore the ontology graphically. This requirement has exposed some interesting user interface problems. In order to provide a rich description of the domain, the ontology becomes large and complex and forms a valuable base for reasoning services and interoperability services. Particular users, however, will in most cases not require access to the whole ontology and will be overwhelmed by its complexity. Simplified views with direct entry points to parts of the ontology, appropriate for dealing with specific query types, have been developed. Who, what, when, where and how type queries can be launched by entry point buttons. Users are able to navigate to a concept and view the instance information for the concept which is present in the database. Instances may be selected by the user and used as the basis for a query to the system for more information. Figure 1

shows the concept browser in action. The software is based on the public domain Touchgraph package [5] which we have extended and adapted to our needs.

4. Multimedia and Multimodal Retrieval

An earlier project, ARTISTE, integrated a variety of 2-D content based image retrieval algorithms together with metadata based retrieval into a prototype information system for museums. In SCULPTEUR we are extending the database to include other media types including 3-D models of artefacts and video of artefacts and museum galleries. In order to support content based retrieval of 3-D models, several 3-D feature extraction and matching algorithms have been implemented so far and integrated with the 2-D retrieval facilities in the system. These include the shape distribution descriptors from the Princeton Shape Retrieval and Analysis Group [6], the histogram descriptors from Paquet and Rioux developed as part of the Nefertiti system [7] and the Area to Volume Ratio descriptor [8] which is a single statistic giving the ratio of the surface area of the model to its enclosed volume.

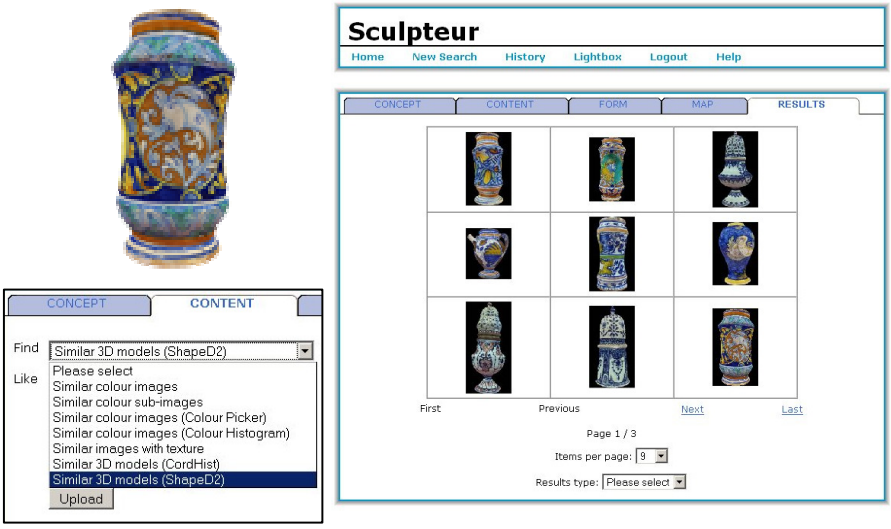

Figure 2: Top nine results for a query vase

An example of a 3-D model used as a query and the top nine matches from the collection are shown in Figure 2. Once significant numbers of models are associated with particular concepts in the ontology, we have the basis for developing classifiers to automatically assign new models to concept classes. We have developed a prototype classifier agent which uses support vector machine technology to support such activity.

The system combines semantic and multimedia content analysis technologies to enable multimodal searching. Frequently, querying by an individual facet such as metadata or image colour is not sufficient to meet user demands.

Querying by either aspect on their own is often not enough to constrain the search space and can result in too many hits when large collections are being searched. However, when these search modalities are combined, then new user search scenarios can be supported and much better results are achieved from a user perspective. For example, a user might search for items of furniture in the V&A that have upholstery of a particular colour or texture, or search for religious oil paintings in the Uffizi that used a pigment of a particular shade of blue.

In our approach, the combination of media content semantics (colour, pattern, shape) and application domain semantics (who, what, where, when etc.) is not only used in multimodal searching, but also forms the basis of the classifier, whereby media content semantics can be analysed to classify objects according to art object semantics. For example: flat round objects which are gold/silver/bronze in colour might be automatically classified as coins, medals or metal plates; an oil painting with surface relief of a spider web type pattern might also be classified in terms of severity of craquellure and need for restoration.

5. System Architecture and Interoperability

The SCULPTEUR architecture is shown schematically in Figure 3. It not only involves a data ontology as an integral component in the semantic layer but also a system ontology which captures the concepts and relationships associated with the system itself. An example is the relation between media object types, the feature vector algorithms which can operate on them and the display modules which are needed to render them in a browser. The system consults the ontology to determine which tools and components to use for a particular task. Interoperability between systems is being supported using established interoperability protocols, in particular SRW[9] and OAI[10].

The users' desktop is essentially a standard browser augmented with 2-D and 3-D model viewers, facilities for query formulation such as colour pickers, and uploading facilities for query models.

Giunti, Interactive Labs, the project coordinators, are using the SRW interface to integrate their Learning Content Management System, Learn eXact [11]. The integration is motivated by the recent increased interest by cultural

institutions in reusable multimedia components for learning (called Cultural Learning Objects, CLO) and new technologies, capable of online learning contents delivery and management. The result is a content authoring tool able to create and manage 3D virtual learning environments of Cultural Learning Objects applying e-learning standards like IEEE LOM [12], IMS Content Package [13] and ADL SCORM [14]. The user interface for the Giunti system is shown in Figure 4.

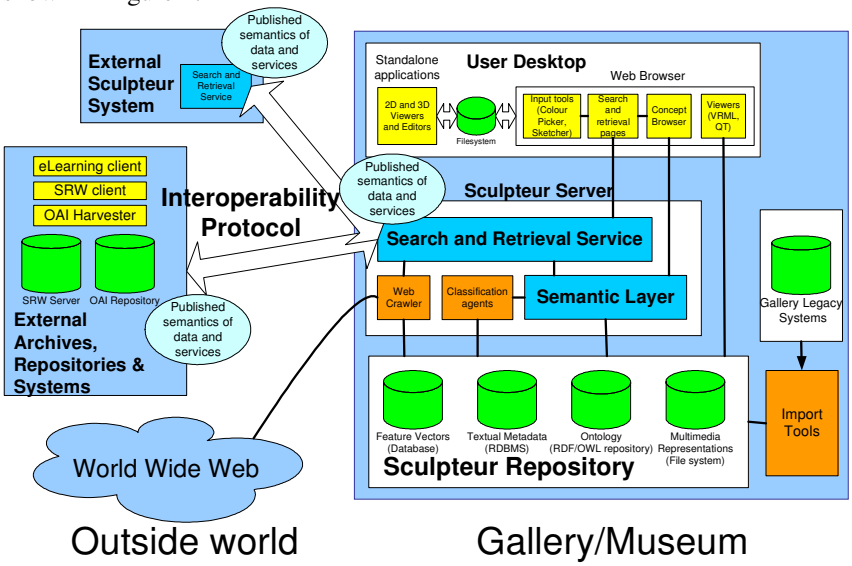

Figure 3. The SCULPTEUR Architecture

6. Conclusions

A novel prototype architecture based on semantic web and knowledge technologies has been presented for the handling of multimedia information in the museum domain. The system provides versatile facilities for browsing, retrieving and navigating around the museum collections and interoperability with other systems and applications. The development of tools for representing and matching 3-D multimedia objects is in progress and the prototype is being tested in the partner museums.

Future work includes enhancements to content and concept based facilities, the user interface and the use of the architecture as a platform for machine learning and accelerated classification activities.

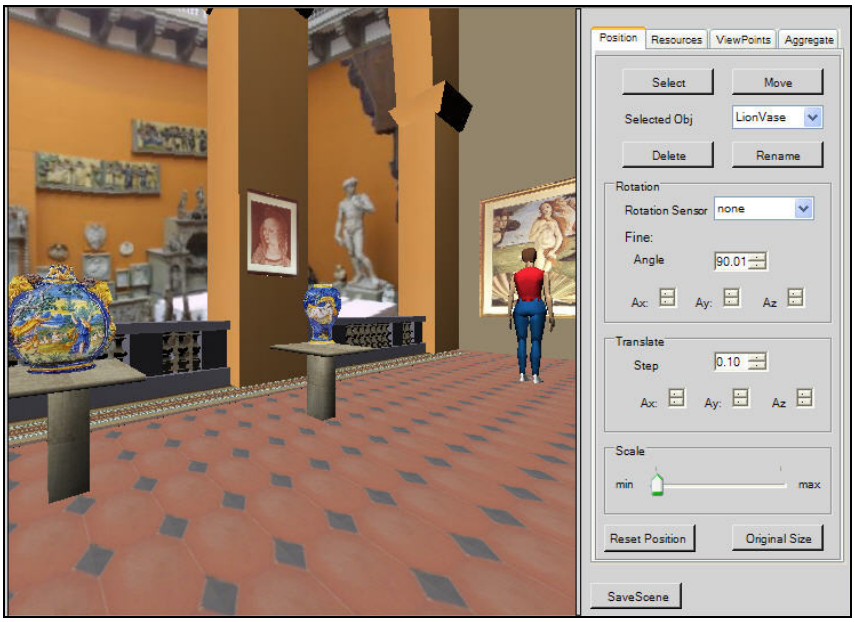

Figure 4: Giunti e-Learning System, User Interface

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References

1. SCULPTEUR IST-2001-35372 http://www.sculpteurweb.org
2. Lewis, P. H., Martinez, K., Abas, F. S., Ahmad Fauzi, M. F., Addis, M., Lahanier, C., Stevenson, J., Chan, S. C. Y., Mike J., B. and Paul, G. (2004)

An Integrated Content and Metadata based Retrieval System for Art. IEEE Transactions on Image Processing 13(3):pp. 302-313.
3. The CIDOC Conceptual Reference Model, http://cidoc.ics.forth.gr/
4. The International Committee for Documentation of the International Council of Museums, http://www.willpowerinfo.myby.co.uk/cidoc/
5. Touchgraph, http://www.touchgraph.com
6. R. Osada, T. Funkhouser, B. Chazelle, D. Dobkin, "Matching 3D models with shape distributions", in *Proc. Shape Modelling International,* IEEE Press, Genova, Italy, 2001, pp. 154–166.
7. E. Paquet, M. Rioux, "Nefertiti: a Query by Content Software for Three-Dimensional Models Databases Management", in Proc. International Conference on Recent Advances in 3-D Digital Imaging and Modeling, May 12-15, 1997, pp. 345–352.
8. C. Zhang and T. Chen, "Efficient Feature Extraction for 2D/3D Objects in Mesh Representation", ICIP 2001, 935-938, 2001, Thessaloniki, Greece.
9. ZING, Search and Retrieve Web Services, http://www.loc.gov/z3950/agency/zing/srw/
10. OAI, Open Archive Initiative, http://www.openarchives.org/
11. Learn eXact, www.learnexact.com
12. IEEE LTSC LOM, http://ltsc.ieee.org/wg12/
13. IMS Content Package, http://www.imsglobal.org/content/packaging/index.cfm
14. ADL-SCORM, http://www.adlnet.org/index.cfm?fuseaction=scormabt
15. ARCO project, http://www.arco-web.org
16. A. Smeulders, M. Worring, S. Santini, A. Gupta, R. Jain, "Content-Based Image Retrieval at the End of the Early Years", in *PAMI*, volume 22 of 12, 2000, pp 1349-1380.
17. E. Hyvönen, M. Junnila, S. Kettula, E. Mäkelä, S. Saarela, M. Salminen, A. Syreeni, A. Valo, K. Viljanen, "Finnish Museums on the Semantic Web. User's Perspective on MuseumFinland". In Proc. of Museums and the Web 2004 (MW2004), Arlington, Virginia, USA, March 31 - April 3, 2004.
18. E. Hyvönen, S. Saarela, K. Viljanen, "Ontogator: Combining View- and Ontology Based Search with Semantic Browsing". Paper presented at the international SEPIA Conference, Helsinki, Sept. 18-20, 2003.
19. J. Hunter, "Combining the CIDOC CRM and MPEG-7 to Describe Multimedia in Museums", Museums on the Web 2002, Boston, April 2002.
20. P. Lewis, H. Davis, M. Dobie, and W. Hall, "Towards Multimedia Thesaurus Support for media-based Navigation". In Proc. of Image Databases and Multi-Media Search, Series on Software Engineering and Knowledge Engineering 8, pp 111–118. 1997
21. The Semantic Web http://www.semanticweb.org