UNIVERSITY OF SOUTHAMPTON

FACULTY OF HUMANITIES

Department of Archaeology

Exploring Novel Technologies for Archaeological Fieldwork

by

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Thesis for the degree of Master of Philosophy

September 2015

UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF HUMANITIES

Archaeological Computing

Thesis for the degree of Master of Philosophy

EXPLORING NOVEL TECHNOLOGIES FOR ARCHAEOLOGICAL FIELDWORK

Thomas James Frankland

The thesis takes a novel approach to the design and evaluation of technologies for archaeological fieldwork. As digital technologies are often developed or appropriated by archaeologists for the purpose of acquiring or improving the management of archaeological data, the thesis instead explores how digital technologies can benefit fieldwork teams by supporting communication and awareness. The thesis begins by demonstrating how the development of archaeological computing has resulted in a focus on developing or appropriating digital technologies that support the acquisition and management of archaeological data. Following this, the results of ethnographic field studies conducted at four excavation sites are discussed. These studies explored how archaeologists communicated on-site, their awareness of one another's activities, and their work practices around existing and novel technologies. The results of the ethnography are followed up with a technology probe conducted at a field school at Itchen Abbas, UK. The findings from these studies were subsequently used to derive design implications for a novel technology aimed at improving archaeologists' awareness and communication when working in the field. A prototype technology was then built, deployed in the field, evaluated and iterated upon, with a final evaluation conducted in the field. The first deployment promoted conversation, however some archaeologists found the visualisations complicated and difficult to interpret. A second deployment was therefore designed to address this. When re-deployed, archaeologists spent a large amount of time discussing the intervention, and also re-appropriated it for playful interaction.

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I, ...[please print name]

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.

[title of thesis] ....

....

I confirm that:

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6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
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Acknowledgements

I would like to gratefully acknowledge that this work could not have been undertaken without the help of the following people.

- My supervisory team: Enrico Costanza and Graeme Earl.
- The members of the PATINA project who offered constructive feedback at meetings and workshops.
- The archaeologists who kindly allowed me to observe their practices in the field, in particular: Simon Keay, Tim Sly, Steven Ellis, Eric Poehler, Blair Poole, Stuart Eve, Guy Hunt and Jess Ogden.
- Andrew Jeffrey, for his assistance with proofreading.
- My wife, Amy, for her patience and support.

Definitions and Abbreviations

CAA – Computer Application in Archaeology

CG – Computer Graphics

CSCW – Computer-Supported Co-operative Work

GIS – Geographic Information System

GPR – Ground Penetrating Radar

HCI – Human-Computer Interaction

IADB – Integrated Archaeological database

LIDAR – Light Detection And Ranging

NLP – Natural Language Processing

NLTK – Natural Language Toolkit

TF-IDF – Term Frequency – Inverse Document Frequency

VERA – Virtual Research Environment for Archaeology

Chapter 1: Introduction

1.1 Rationale

We are living through a time of digital revolution. Over the last decade, our society and many others have been quick to adopt many new digital technologies, with far-reaching consequences for both our personal and professional lives. Archaeology has not been exempted from these changes: archaeologists working in the field are increasingly replacing traditional ‘analogue’ methods with digital ones and introducing new digital methods to support and transform their existing practices.

While digital technologies undoubtedly offer many advantages and new possibilities for field archaeologists, in most cases there seems to be no systematic or critical process by which technologies are selected or tested prior to their adoption. Instead, technologies are often selected for use in fieldwork archaeology based on their perceived ability to either support the acquisition or management of archaeological data. Why this occurs is not entirely clear, however, given that archaeological research is a destructive process and our primary research material cannot be re-consulted or examined, it is perhaps not too surprising. It is suggested however, that by focusing on this limited application, we overlook many of the other potential ways in which digital technologies could support archaeological fieldwork.

For example, digital technologies have revolutionised the way we communicate in our daily lives. Communication is without doubt fundamental to the success of an archaeological fieldwork project, not least because it underpins the development of archaeological interpretation. Formal conversation, informal discussions at the tea break or in the pub, and even idle chat with the archaeologist digging alongside you all help to shape an interpretation of the evidence (May & Crosby, 2004). Technologies introduced to support the acquisition or management of archaeological data may help archaeologists to do their job more efficiently, but they may also reduce the need for archaeologists to communicate with one another. It is suggested therefore that digital technologies could be selected for use in the field with the primary purpose of supporting the significant role conversation plays in the interpretive process.

Communication, and the flow of information around a site, is also strongly influenced by the social hierarchy. Archaeological fieldwork teams are often structured in a very hierarchical manner, which can form a social divide between the archaeologists who produce the data through excavation and those who interpret it (Berggren & Hodder, 2003). This can also result in those archaeologists whose roles are primarily associated with excavation feeling disillusioned, as they perceive their work as little more than unskilled manual labour (Everill, 2008). It is therefore suggested that digital technologies might also be used to empower archaeologists lower down a fieldwork site's hierarchy, in turn allowing for an alternative, egalitarian interpretation of the archaeological evidence, in addition to the current, traditional form of interpretation that is often only produced by the site specialists and directors.

On a large site or in situations where regular communication is difficult, archaeologists working in the field may not be fully aware of the actions or thoughts of those around them. This 'awareness' relates to many aspects of archaeological field practice, such as each archaeologist's knowledge of the holistic interpretation of the fieldwork site, their knowledge of the activities their colleagues are engaged in, and the work being conducted by research or post-excavation teams both on and off the fieldwork site. A digital technology introduced in a fieldwork setting with the aim of improving awareness could have a number of positive consequences for the team. As awareness improves, so too might communication; an improved knowledge of the excavation might suggest new potential topics of conversation or archaeologists to speak to. In contrast, a lack of awareness, as with communication, can have a negative impact on an archaeologist's mood and motivation, due to feelings of isolation. Consequently improving awareness via a digital means might reduce the need for excavators' to attend a 'site tour' and on senior site staff to pass down information, and could therefore be considered disruptive to the social hierarchy of the site.

These three themes, communication, disruption and awareness, represent a small selection of the many that could have been chosen as alternative motivations for introducing digital technologies in an archaeological setting in contrast to the acquisition or management of data. That is not to say that this is not a valid goal, but if we are to make the most of novel technologies, a full exploration of their possibilities is surely warranted.

1.2 Aims of the thesis

The aim of this thesis is to explore how novel digital technologies might benefit archaeologists working in the field. This novelty stems from the technology's primary purpose; as digital technologies are often developed or appropriated by archaeologists for the purpose of acquiring or improving the management of archaeological data, the thesis will instead explore how digital technologies might benefit fieldwork teams by focusing on communication, social hierarchies and awareness.

1.3 Research questions

The thesis attempts to answer the following questions:

- How has the development of archaeological computing lead to a focus on digital technologies that support the acquisition and management of archaeological data?
- How do archaeologists communicate and remain aware of one another's activities while working in the field? How do communication and awareness benefit fieldwork, and what happens when these break down?
- Can the introduction of a novel digital technologies improve archaeologists' communication while on a fieldwork site? How might digital technologies impact the hierarchical flow of information around a site? And could digital technologies improve archaeologists' awareness of each other's activities?

1.4 Research strategy

Much of the research throughout this thesis is conducted via field studies, which take an ethnographic approach to documenting how archaeologists communicate on site, their awareness of one another's activities, and their work practices that exist around both existing and novel technologies. In his 2006 volume, Edgeworth suggests that archaeological research questions form the primary motivation for ethnographic studies of archaeological practice, with the notable exception of ethnographies by Goodwin. The field studies described here form a similar exception, as while they were conducted within an archaeological fieldwork environment, they were primarily motivated by the desire to explore a design space and to derive implications for the design of a new technology. Given these motivations, it was felt that methodologies employed in the field by practitioners in disciplines which regularly design and build novel technologies, such as researchers from computer science, human-computer interaction and computer supported co-operative work were best suited to the needs of the project.

Within HCI, the introduction of ethnographic techniques is associated with the emergence of Computer-Supported Cooperative Work and the Participatory Design (PD) movement. Both of these areas of research were concerned with understanding the social organisation of activities in the workplace, and ethnography offered a means to study this and also technology use 'in the wild' (Dourish, 2006). Much of the ethnography conducted in HCI is also heavily influenced by 'ethnomethodology' (Garfinkel, 1964). Despite the similarity in name to ethnography, ethnomethodology is radically different from the classical ethnographies of anthropology (Button, 2000). Ethnomethodology shifts emphasis away from sociological and anthropological theories to description of the practices involved in the production of natural phenomena (Button, 2000).

Ethnography is typically used in HCI is to support qualitative, or open-ended investigations of a domain or in situ technology use. These methods allow researchers to explore the use of technology in everyday settings, and to find and explore applications for future or novel technologies. In relation to the thesis, these techniques allow further exploration of technical tools use by archaeologists, and will help to identify which aspects of practice novel technologies might best be used to support.

Human-computer interaction researchers will often engage in exploratory research as a starting point for developing design ideas and identifying user requirements that will lead to the design of an initial prototype (Sharp et al., 2007). In the early stages of the research process, HCI researchers will frequently use a wide variety of methods to stimulate design ideas, including ethnography, lab studies, role-play, focus groups, and cultural probes (Sharp et al., 2007). In the case of the thesis it was considered that the most appropriate approach was to conduct a number of small-scale field studies and interviews in the field. These were followed up in several situations with the deployment of a technical probe (Hutchinson et al., 2003), to prompt further exploration of the design space.

A technology probe (Hutchinson et al., 2003) is essentially a technological deployment designed to collect data that inspires new design; they are not prototypes to be iterated, but aim to provoke interesting responses from the users (Boehner et al., 2007). Hutchinson *et al.* (2003) first characterised technology probes as similar to the concept of cultural probes (Gaver et al., 1999) but with an aim of balancing the 'social science goal of collecting information' with the 'engineering goal of field-testing', and the 'design goal of inspiring users and designers to think about new kinds of technology'. The approach to technology probes adopted here however more closely follows the 'light-weight' probes described by Langdale *et al.* (2006). These 'light-weight' technology probes sacrifice some of their technological realism to focus on gaining insights about the users' needs, cultural norms and practices, and more closely resemble the original ethos of a cultural probe (Gaver et al., 1999). They also reduce the technical complexity necessary to a minimum, which was considered important given the difficulties the environmental conditions of archaeological fieldwork might present a prototype technology.

Chapter 2: Literature Review

2.1 Introduction

This chapter outlines previous research exploring how ethnographic methods are used in the disciplines of archaeology and computer science. It also provides an introduction into research conducted around communication, social hierarchies and awareness. It is important to recognise that these themes are broad areas of interest to the scientific research community, and research relating to them would normally be approached from the more specific context of a subdomain; consequently the wealth of literature available on these themes only allows this review to provide a brief introduction to each. Further literature is introduced throughout the thesis where appropriate.

2.2 Ethnographic methods

2.2.1 Ethnographies of archaeological practice

Archaeological ethnography, or ethnographies of archaeological practice, is a relatively recent addition to a much older and more developed tradition of using ethnography to inform archaeological practice, often referred to as ethnoarchaeology. Ethnoarchaeology is the study of living cultures from an archaeological perspective, and incorporates a range of diverse methods to understanding relations between culture and material culture (David & Kramer, 2001).

Archaeological ethnographies merge ethnographic and archaeological practices in order to raise questions and explore contemporary archaeological practice (Hamilakis & Anagnostopoulos, 2009). A number of these studies have now been conducted at archaeological excavations. Edgeworth (2006b) has provided a thorough account of how this research interest developed within the archaeological community, so this review summarises this contribution. In his review, Edgeworth suggests that aside from a few early pioneers, the idea of ethnography of archaeological practice only really arises in the late 80s and early 90s. This was a consequence of theoretical developments made within the discipline, notably the rise of post-processual archaeology, and from outside, due to developments in the philosophy of science. A number of ethnographies were conducted around this time, including Edgeworth (1992), Roveland (2006), Gero (1996) and Goodwin (1994, 2003a, 2003b, 2010). These ethnographies explore a wide range of topics including how theory is grounded in practice (Edgeworth, 1992), gender inequalities in the production of archaeological knowledge (Gero, 1996), and similarities between archaeology and other professional practices (Goodwin, 2003a). It was in part due to Roveland's (2006) interest in ethnography that she introduced the idea of excavators keeping diaries (a subject that is expanded upon later in this review). Around this time ethnography was also integrated into the excavation programs of prominent post-processual archaeologists, such as Hodder and Tilley and Shanks. At Çatalhöyük, these ethnographies included the work of Hamilton (2000), Leibhammer (2000) and Bartu (2000).

Edgeworth's (2006a) volume was one of the first to assemble accounts of ethnographies of archaeological practice conducted by both archaeologists and anthropologists. Aside from updated accounts of previously published ethnographic work, such as the work of Roveland (2006) and Goodwin (2006), it includes accounts of archaeologists' social interactions away from an excavation (Holtorf, 2006), an exploration of the trends in archaeological photography (Bateman, 2006), and even an experimental ethnographic narrative (Erdur, 2006). Many of the contributions to the volume explore the relationship between the construction of archaeological knowledge and the social aspects of fieldwork.

2.2.2 Use of ethnography for supporting design

In his 2006 volume, Edgeworth suggests that archaeological research questions form the primary motivation for ethnographic studies of archaeological practice, with the notable exception of ethnographies by Goodwin. The field studies described here form a similar exception, as while they were conducted within an archaeological fieldwork environment, they were primarily motivated by the desire to explore a design space and to derive implications for the design of a new technology. Given these motivations, it was felt that methodologies employed in the field by practitioners in disciplines which regularly design and build novel technologies, such as researchers from computer science, human-computer interaction and computer supported co-operative work were best suited to the needs of the project.

Within HCI, the introduction of ethnographic techniques is associated with the emergence of Computer-Supported Cooperative Work and the Participatory Design (PD) movement. Both of these areas of research were concerned with understanding the social organisation of activities in the workplace, and ethnography offered a means to study this and also technology use 'in the wild' (Dourish, 2006). Much of the ethnography conducted in HCI is also heavily influenced by 'ethnomethodology' (Garfinkel, 1964). Despite the similarity in name to ethnography, ethnomethodology is radically different from the classical ethnographies of anthropology (Button, 2000). Ethnomethodology shifts emphasis away from sociological and anthropological theories to description of the practices involved in the production of natural phenomena (Button, 2000).

2.3 Communication

> 'Being field-focused, adventure-focused, travel-focused, and technology-focused … archaeologists tend not to be particularly people-focused'
>
> (Zubrow, 2006)

One important aspect of teamwork that is frequently discussed is the importance of communication. Communication is fundamental to the success of any team-based activity, but especially so in an archaeological fieldwork setting as it plays a central role in the interpretative process. Formal conversations and meetings, informal discussions held at the tea break or in the pub, and the conversations archaeologists have while digging alongside one another (figure 2.1), all help to shape an interpretation of the archaeological evidence (May & Crosby, 2004). It is also important that communication is maintained between excavators on-site and specialists off-site, so that, should their specialism be required, they can advise or visit the site. On commercial excavations, good communication between the archaeologists, contractors and labourers is essential. On sites where a JCB is used to remove layers of topsoil, it is important that the archaeologist and driver are able to communicate clearly so that the archaeology is not needlessly damaged. Everill (2008) even observes that communication plays a vital part role in holding a team together through camaraderie and shared experience.

Figure 2.1: Archaeologists discuss their interpretations.

Another reason to explore communication is that is often overlooked by most technological interventions at archaeological excavations. While technologies introduced to support the acquisition or management of archaeological data may help archaeologists to do their job more efficiently, they may also reduce the need for archaeologists to converse with one another. Exploring how technologies might encourage communication between archaeologists is significant to any deployment of technology in archaeological fieldwork, regardless of its primary purpose or the motivation behind it.

As one might expect, the computing community is engaged in a large amount of research that explores how digital technologies support communication. There is too much to explore here, however examples of research topics include how communication occurs within virtual teams (Powell et al., 2004; Suchan & Hayzak, 2001), the influence of gender in communication (Berdahl & Craig, 1996), how barriers to communication might arise (Cramton, 2001), and the support of trust in communication (Iacono & Weisband, 1997; Jarvenpaa & Leidner, 2006; Jarvenpaa et al., 1998; Meyerson et al., 1996; Piccoli & Ives, 2003).

2.4 Disrupting social hierarchies

Hierarchies and their dynamics have long been of interest to social theorists. Constructionism explores how we assign categories to the world and how labels are used to distinguish "types of things or types of people" (Loseke, 2003). Constructionists recognise that this categorisation extends beyond knowing how to refer to objects or people – it informs our actions and behaviours towards them. Consequently, constructionists believe that people categorise things and other people in order to organize and simplify the complex world around us (Loseke, 2003). Another theorist who was interested by social hierarchies was Pierre Bourdieu, the French sociologist, whose exploration of power, development and social change in Algerian and French society led to new ways of thinking about social dynamics. Of particular significance to the dynamics of hierarchies is Bourdieu's concept of 'capital', which includes not only material assets but also social, cultural and symbolic forms of capital (1984). Bourdieu observed that societal power relations and social hierarchies were constructed through the acquisition of such capital, and that, on a larger scale, social order is 'inscribed in people's minds' through 'cultural products' including systems of education, language, judgements, values, methods of classification and activities of everyday life' (Bourdieu, 1984).

More recently, interest in the construction of social hierarchies has been explored through the lens of 'actor-network theory' (ANT). This theory examines the actions and interactions of actors within the context of a social network, as a method for understanding the creation of knowledge, traditionally within the domain of science and technology. ANT, and the notion of networks, removes the need to take a top-down approach and apply social theory to the object of study - society's 'vertical space, its hierarchy, its layering, its macro scale, its wholeness, its overarching character - and how these features are achieved and which stuff they are made of' (Latour, 1996).

It has been observed that archaeological fieldwork teams will usually have a strongly-defined social hierarchy (Berggren & Hodder, 2003). In 'Social practice, method, and some problems of field archaeology' Hodder and Berggren (2003) discuss how the historical practice of employing labourers and unskilled technicians has led to the current situation of a 'social divide' between the archaeologists who produce data through excavation and those who interpret it. Chadwick (2003) observes that this divide is further reinforced by the access individuals have to site space, so generally only those running a project have the freedom to 'wander between different trenches and think about wider landscape relationships.' Hodder and Berggren also highlight that the decision-making and planning processes are also often the sole responsibility of the director, with others having little input. This situation has resulted in the disillusionment of many archaeologists at the bottom of the hierarchy, who perceive the work they conduct on a daily basis as little more than unskilled manual labour (Everill, 2008).

In response to these issues, it is suggested that another motivation for creating and developing a technological intervention should be the deliberate disruption of the social hierarchy of a fieldwork team. Wheatley (1995) argues that technologies introduced by archaeologists have a disruptive influence on the practices and theories that were responsible for their adoption. Wheatley is primarily concerned with the transformative effects GIS have had on management practice, but his observation can be extended to any technology that is introduced into an archaeological fieldwork environment. The desired effect of this disruption would consist of two outcomes. The first would be to raise archaeologists' awareness of the social hierarchy, which would likely have a subsequent impact on communication and behaviour. This is broadly synonymous with the concept Garfinkel (1964) refers to as a 'breaching experiment'. The second would be to empower archaeologists to create and share their own interpretations, which would help them to re-engage with the archaeological process and to create a more egalitarian interpretation of the evidence.

2.5 Awareness

Dourish and Belotti (1992) characterise awareness as 'an understanding of the activities of others, which provides a context for your own activity.' (This definition of awareness if also referred to as 'situational awareness'). Awareness is often argued to be a necessary aspect of successful cooperative work (Dourish & Bellotti, 1992; Kulyk et al., 2008), and as such has been a major focus of interest for the computer-supported cooperative work (CSCW) and HCI communities. An individual's awareness is effected by both their environment (physical location, display arrangement and size etc.) and group aspects (communication, use of collaboration tools, team processes etc.) (Kulyk et al., 2008). Awareness is often discussed in relation to both co-located teams (a team working in the same location) and distributed teams (a team working in two or more remote locations).

Awareness technologies tend to present users with an unfiltered, rich dataset, typically a collection of visuals or sounds (Isaacs et al., 2002). This is because interaction occurs at the periphery of a users' attention, and therefore a rich dataset increases the likelihood that a user will notice something of relevance to them (Gaver, 2002). The use of text is often avoided, as it has been suggested that it can increase the chance of task interference, however, Gaver argues that text should not be ruled out but considered by its merits on a case-by-case basis. Awareness technologies were first developed to support tasks within business environments, and although they have been explored in a variety of environments since their introduction, they still continue to embody some of the assumptions about how information might flow within this particular environment (Gaver, 2002).

Workspace awareness has been an area of particular interest to researchers, as it has long been recognised that individuals working in large teams can find it challenging to stay aware of another's interactions and activities within the workplace. Computer Supported Cooperative Work (CSCW) research frequently explores how awareness is achieved in both co-located and distributed teams (Heath & Luff, 1992; Heath et al., 2002). Workspace awareness has been suggested to be created in teams via the following mechanisms (Gutwin & Greenberg, 1996):

- Direct communication: communication through speech or gesture
- Indirect productions: utterances, expressions, or actions that are not aimed at others but that are intentionally public
- Consequential communication: visible or audible signs of interaction
- Feedthrough: observable effects of someone's actions on the workspace
- Environmental feedback: feedback from the environment or the overall workspace that is caused by the indirect effects of someone's actions.

One consequence of research into awareness has been to highlight how fundamental it is to both efficient communication and collaboration (Bardram & Hansen, 2010; Schmidt, 2002). One reason for this is that it provides members of a team with knowledge of when they can work together, a phenomenon Schmidt (2002) refers to as 'appropriate obtrusiveness'. Awareness also helps members of a team to both coordinate their own actions, and to anticipate the actions of others, resulting in better collaborative practice (Gutwin & Greenberg, 2002).

Chapter 3: The development of computing in the field

3.1 Introduction

As stated in the introduction to the thesis, it is suggested that digital technologies developed or appropriated for archaeological fieldwork have been used primarily for the capture or management of archaeological data. Digital technologies are constantly evolving at what often seems like at an increasingly rapid pace, and it is perhaps unsurprising therefore that over the last few decades numerous archaeologists have attempted to provide their fellow researchers with an overview of the latest developments in the field of archaeological computing (Chenhall, 1968; Cowgill, 1967; Gaines, 1984; Reilly & Rahtz, 1992; Richards, 1998; Ryan, 1985; Scollar, 1997; Whallon, 1972; Wilcock, 1978). This chapter will draw on the work of these archaeologists in order to provide an account of the development of archaeological computing to explore how this situation has come to exist. The chapter will also highlight some of the more recent attempts to develop novel technologies for fieldwork archaeologists, and comment on the aims of these projects in relation to those of the thesis.

3.2 A history of using digital technologies to support archaeological fieldwork

3.2.1 The early years

We do not know for certain who the first archaeologist(s) were to use computing in their archaeological practice. Scollar (1982) suggests that the earliest use of computing may have been by Robert Cook during his (unpublished) geological work in 1957. The following year however, Peter Ibm and Jean-Claude Gardin used a computer to aid with their analyses and also published their findings (Cowgill, 1967). Regardless of who was first, over the next decade it is apparent that these early adopters, enthusiastic about the potential benefits of computers, were a minority among the archaeological community, which was generally reluctant to adopt novel 'computerised' methods (Cowgill, 1967).

3.2.2 1960s – 1970s

In the 1960s, most archaeologists who wanted to use a computer were required to spend considerable time coding their data, which they then often had to a submit to a programmer to input into a computer on their behalf (Burton et al., 1970). Consequently, archaeological computing literature from the 1960s is primarily concerned with coding schemes (Scollar, 1982).

Most applications of archaeological computing in the 60s and 70s, such as those described by Chenhall (1968), relate to either statistical analysis or the storage and retrieval of archaeological data. One of the main statistical problems archaeologists focused on was 'seriation', the ordering or sequencing of archaeological units, but many other topics were also explored, such as classification and 'clustering' (Scollar, 1982). Growth in the field of statistical methods for archaeology, which until this point had also been subject to little theoretical or empirical work (Whallon, 1972), also led to advances in archaeological computing.

This resulted in mathematicians and statisticians taking an interest in archaeological problems, and consequently methods largely developed in and for other areas of research were introduced to archaeology, spurring further development (Whallon, 1972). At the same time, processual archaeology, which called for a standardised, scientific approach to archaeological thinking, led to an interest in problems that computing was ideally suited to addressing. Thus the coding of data, and an interest in problems of mathematical and statistical interest, came to dominate archaeological computing at this time.

3.2.3 1970s – 1980s

By the end of the 1960s, there was a growing interest in archaeological computing, reflected in the increased number of meetings that were taking place concerned with the development of analytical and statistical methods for archaeology (Whallon, 1972). This change in attitude was almost certainly due to advances in technology. Towards the end of the 1960s, the advent and introduction of the cathode ray tube monitor (CRT) allowed archaeologists (with the skills necessary to do so) to interface directly with a computer themselves (Burton et al. 1970).

Further to this, a dramatic reduction in data processing and storage costs (Gaines, 1984), combined with decreasing costs of computers in general, meant that by the early 1970s most academic institutions had some type of computer facility available to archaeologists for academic use. However, the freedom for archaeologists to use these facilities was often still restricted.

The 1970s also saw the introduction of word-processing software, which improved the sharing and archiving of archaeological reports (Wilcock, 1978), and the development of graphical techniques, which allowed archaeologists to create graphs and two dimensional maps (Upham, 1979).

In 1975, Harris raised concerns with the influence computing was having on archaeological fieldwork practice. With mobile computing still in its infancy however, this was not due to a change in methods, but was a result of how limitations with the digital technologies of the time were influencing archaeological thought and interpretation:

> "The introduction of a sophisticated sorting device into this essentially human occupation would be anathema, for the quality of such reporting depends on a person's intuition and undivided attention to his stratigraphic problems. An excavation (and its comprehension) is subject to constant change; the excavator should not be bound by a preconceived program or the necessity to allocate time for consultation with a computer. There is also reason to believe that the on-site use of computers may impede recording by acting, not as an aid, but as an excuse for postponing decisive thought in stratigraphic analyses."
>
> (Harris, 1975)

3.2.4 1980s – 1990s

> "If the 1960s was the Age of Computer Experimentation for archaeology, the 1970s was surely the Age of Computer Implementation. With the rapid extension and enhancements of applications perhaps the current decade, the 1980s, will be labelled the Age of Computer Exploitation"
>
> (Gaines, 1984)

By the 1980s, the first articles were being published about using databases, rather than databanks, to support excavation (for example, see the evolution of the Mucking databank (Catton et al., 1978; Moffett, 1985)). The development of the home microcomputer also increased archaeologists access to cheaper, albeit limited, computing (Rains, 1984). Despite the increased availability of smaller microcomputers, mainframe computers in the 1980s were still superior to microcomputers for many archaeological tasks, such as accommodating large amounts of data, using a data base management system, and for more complex analytical procedures (Lock, 1985).

Archaeological computing in the 1980s was still dominated by interests in data management and statistics as in the 60s and 70s, however there was now a more mature third 'ancillary' area interest that included word-processing and graphics (Lock, 1985). The software available to archaeologists limited growth outside of these areas at that time (Reilly, 1985). The 1980s also saw the first use of three-dimensional graphics by archaeologists, such as Spicer (1985), Reilly (1985) and Lock (1985).

3.2.5 1990s – 2000s

By the early 1990s, computers had begun to significantly impact on all aspects of archaeological practice:

> "Computers have had an impact on almost every area within the Project - illustration, display work, finds processing, site planning, training, and public relations. In each case, the aim is to enhance the work being done in terms of speed and quality."
>
> (Huggett, 1990)

In 1997, in order to commemorate 25 years of the computer applications in archaeology conference, Irwin Scollar (1997) conducted a review of submissions to the conference proceedings in order to identify trends in the discipline. The research areas he identified were:

- Statistics
- Database & Site Recording
- Graphics, Image Processing, CAD and VR
- Education, Publication and The Web
- GIS
- Prospection & Remote Sensing
- Simulation and Artificial Intelligence
- Pattern Recognition

Stewart (1996) suggests that by 1989, the discipline of archaeological computing felt that it had 'come of age'. Many techniques that are still frequently used today were being introduced for the first time, such as GIS visibility studies and viewshed analysis (Lock, 2009). Some of the first 'reconstructions' of archaeological structures were created in the 1990s, such as the reconstruction of the temple complex at Roman Bath by Woodwark (1991). Much of this was possible as computers went from items of status to 'one on every desk' Backhouse (2006). Archaeologists also began to consider the wider issues of managing archaeological data, such as topics relating to SMRs, cultural resource management and metadata. Databases had become commonplace, and so attention turned to 'relational databases' and 'integrated databases' (Richards, 1998). The dissemination of archaeology was also transformed with the rise of the web, which led to the creation of the first electronic journals, such as *Internet Archaeology* (Richards, 1998).

3.2.5.1 Fieldwork

By the 1990s, many of the traditional tools used by archaeologists working in the field had a digital counterpart. Many of the devices used by field archaeologists, such as resistivity meters, GPR and other survey equipment could now output data in digital form (Reilly & Rahtz, 1992). The early 1990s also saw the introduction of the Integrated Archaeological Database System or 'IADB', which allowed different media and data to be combined into a single archaeological database (Rains, 1994). One advantage of this was that plans and photographs created or captured on-site could be displayed in context alongside traditional data input from recording sheets. However, although digital cameras existed in the early 1990s, photographs were still primarily taken using film cameras and then scanned, as the cost of digital cameras was too high for mainstream adoption (Rains, 1994).

By the late 90s, and around the time that Microsoft unveiled their first 'tablet PC', advances in computer hardware and software made the prospect of using a relatively powerful handheld computer in the field practical for the first time. Other technologies were maturing and becoming more widely available around this time as well, such as GPS, which was increasingly being used for civilian, rather than military purposes. However attempts to use GPS for archaeological applications before 2000 were limited by 'Selective Availability' (Pascoe et al., 1998), a policy adopted by the US military that decreased the accuracy of GPS signals for civilian use to 100 meters.

One of the first projects to trial the use of handheld computers for archaeological fieldwork was the Mobile Computing in Fieldwork Environments (MCFE) project (Leusen & Ryan, 2002; Pascoe et al., 1998, 2000; Ryan et al., 1997, 1999a, 1999b). The project explored how a handheld computer combined with a GPS could support researchers working in the field by providing them with contextually relevant information or 'FieldNotes'. Case studies were conducted in both archaeology and ecology, with multiple deployments conducted in each case. The system itself was built around supporting note taking, using a metaphor based around electronic 'post-it' notes (Pascoe et al., 1998). Geo-referenced notes were made using a hand-held computer, which could then be retrieved by physically entering a location or by using a map-based interface (figure 3.3). The system was tested for its ability to support archaeological survey in 2000, and was found to considerable improve the speed of data entry (for discussion see Leuven and Ryan, 2002).

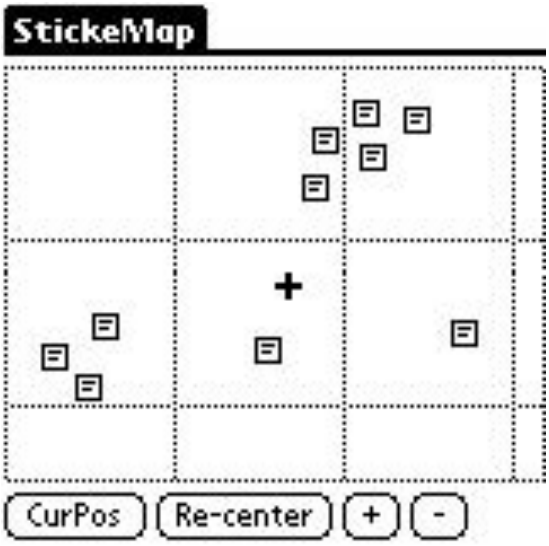

Figure 3.1: Viewing the user's location (the cross-hair) in relation to fieldnotes in the MCFE 'StickeMap'.
(After Pascoe et al., 2000)

Another archaeological project that attempted to link lab and field through the use of mobile computing was the 'Archaeo tool-set' and RAMSES (Ancona, Dodero, & Gianuzzi, 1999; Ancona, Dodero, Mongiardino, et al., 1999; Ancona, Gianuzzi, et al., 1999). The authors developed a prototype system that used a network of mobile, pen-based computers to communicate text and drawings from the field to other archaeologists via the Internet. The authors chose pen-based computers due to the need for a rugged device that could survive in the field. Publications about RAMSES outline the specifications for the system but do not reveal whether it was evaluated or a prototype deployed in the field.

As these examples show, when digital technologies were first introduced into field environments for the first time in the 1990s, they were often used as replacements for traditional methods. This offered numerous advantages, as techniques could be chosen that technologies of the time were capable of replacing, it lowered boundaries for adoption among archaeologists, and also offered clear benefits over analogue methods, such as providing access to data that was normally unavailable in the field. However, it also arguably created a precedent for reinvention rather than experimentation, which may continue to the present day.

3.2.6 2000s – present day

Many of the developments that occurred in archaeological computing at the start of the 21st century resulted from improvements to web-based technologies. At the beginning of the decade, the introduction of broadband improved archaeologists ability to manage and share information online. A few years later, the 'Web 2.0' revolution lead archaeologists to reconsider how their existing data might best be used, with moves to merge different bodies of data and information online and the development of new tools and interfaces for peer-to-peer communication and collaboration (Kansa, 2011). Two relatively new areas of interest in the archaeological computing community, semantic web (Isaksen et al., 2009) and network analysis (Brughmans et al., 2011) emerged as a result of these developments.

By the 2000s, computing had also become an integral part of many aspects of fieldwork practice. Table 1 illustrates the many aspects of fieldwork supported by technology in the 2000s and that still remain the same in the present day. Many of technological advances that occurred at the beginning of the 21st century are still having a transformative effect on today's archaeological fieldwork practice. For example, the invention of the 'camera-phone' in the early 2000s, which in turn lead to the convergence of multiple digital technologies into the 'smart devices' we use today, has had and will continue to have far-reaching consequences for many aspects of archaeological computing.

Table 1: Ways in which archaeologists employ technology in the field (After Tringham & López, 2001)**.**

Type	Description
Reconnaissance /exploration	Non-destructive survey techniques, both inter-site and intra-site, are essential 'discovery' technologies, employed to locate possible sites and reduce excavation costs.
Recording	Photography, video, mapping, drawing, scanning – digital technologies and CG are changing the traditions of archaeological field recording.
Excavation/ Sampling	Digging techniques that move beyond the trowel, frequently include intensive sampling for micromorphology, DNA, soil chemistry.
Conservation	In-situ preservation or extraction, digital imaging is used to document the current and changing state of conserved materials.
Inventory	Recording and management of data (including finds in their context of each depositional event) is one of the more daunting tasks in archaeology, as collections can contain hundreds of thousands of pieces. Digital technology is helping to make the unmanageable tolerable.
Analysis	In-field use of the media record and specialists' analyses of faunal, human, architectural, and paleaoethnobotanical remains, including ethnoarchaological observations.
Presentation	In-field presentations to officials, tourists, other archaeologists, ourselves.
Reporting	Presentation via the internet - webcam and beyond to augmented reality - digital technology and CG can permit the archaeological field experience to be transmitted to potentially thousands of interested stakeholders 'live'.

While it is clear from the table above that there are numerous ways archaeologists 'might' use technology in the field, an emphasis has clearly been retained on both data acquisition and management. And while technological limitations might have lead to this situation in the past, from the early 2000s, technology was sufficiently powerful and robust to provide a platform for numerous uses in the field. The reason, it seems, is that archaeologists at this point in time begin to **purposefully** prioritise the capture, rather than interpretation of data, while in the field.

> "Today's archaeologists labour under the intolerable moral burden that one of their principal methods of obtaining data simultaneously destroys that data. The force of the statement 'excavation is an unrepeatable experiment' is not diminished despite its status as something of a professional cliché. The response of most archaeologists to their burden has been to attempt to record during excavation everything in sight and as far as is possible everything beyond sight. As a result, modern excavations carried out under any but the most stringent rescue conditions generate a quite staggering quantity of data."
>
> (McVicar, 1985)

Over twenty-five years have passed since McVicar made this observation, but it still reads true for modern fieldwork archaeology. Archaeologists have seemingly come to place a large amount of significance on the creation and curation of the archaeological 'record' (Patrik, 1985). As Zubrow (2006) puts it, 'There is never enough data'. Zubrow also observes that as problems become more sophisticated and techniques become more widely available, the amount of data archaeologists are expected to collect also increases. Consequently, technological innovations that might improve the quantity of data captured at an excavation, or improve the fidelity of that data, are regarded as especially noteworthy among archaeologists.

Large international research projects, which are often associated with having a strong impact on the development of archaeological theory and practice, are also responsible for this trend. Often situated thousands of miles from the home of an institution, field seasons at an overseas excavation are often spent acquiring large amounts of data to be analysed on return to home. For example, by acquiring mainly laser scan data, HD photos and videos, Levy et al. (2010) managed to accumulate 1,373 GB of data in their 2009 excavation season. This was a dramatic increase on the previous season's total, and consequently the authors suggest that they are in the midst of a 'data avalanche'.

Starting from the early 2000s, a small number of projects have challenged traditional thinking by exploring their motivation for introducing a novel technology on-site in a fieldwork context. These primarily data-centric interventions include the work of Avern *et al.* (2011), who is helping Nikon to develop a grid-free, sub-millimetric survey system, the work of Ellis and Wallrodt (2011), who have implemented a 'paperless' recording system at Pompeii, Italy using Apple's iPad, and the VERA project (Baker et al., 2008; Clarke & O'Riordan, 2009; Fisher et al., 2010; Warwick et al., 2009), which has taken a more radical approach to exploring innovation by introducing technologies such as motion tracking and smart pens. The following section explores some of these projects in further detail.

3.2.7 Archaeological 'tinkering'

Before exploring some of the more recent projects to develop digital tools for fieldwork, which are often conducted in collaboration with computer scientists or other technology professionals, it is worth pausing to consider the process archaeologists often go through when adopting new digital technologies.

While not always the case, the adoption of new technologies by archaeologists is often well thought-out, with a rigorous process in place and wider consultation conducted with various stakeholders. However, due to the unusual requirements working in archaeology (and especially field archaeology) can present for a technology, there is also often an element of appropriation, where archaeologists will build or modify existing tools to address their specific needs. Many archaeologists find this 'tinkering' an enjoyable part of the development process (Zubrow, 2006). It is also often necessary, as mainstream hardware and software providers tend to build and design their technology products to fulfil the needs of their largest customer base, which are often industries outside of archaeology. Concerns with the robustness of digital technologies (such as those outlined by Backhouse, 2006), and their appropriateness to the theoretical demands placed on them by the discipline of archaeology, are also potential reasons as to why archaeologists often choose to retain control over the development and function of their tools.

This tradition is both longstanding and not without its critics. For example, in 1985, Lock criticised archaeologists developing their own database programs, arguing that the commercial packages available at the time were much better than anything an archaeologist could create, and that the writing of these programs was taking on more importance that their eventual use in archaeology (Lock, 1985). Huggett discusses how archaeologists are attracted to the latest technologies and 'cool toys' without critically examining their potential (Huggett, 2004). Backhouse (2006) describes the process of adoption of technologies by archaeologists as reactionary and sporadic, suggesting that archaeologists view the situation as 'we have a problem, this may be a solution'.

Furthermore, time and budgetary constraints, especially in the commercial sector (which is where the majority of fieldwork in the UK is conducted (Everill, 2008)), compound these issues, and also limit the potential for technologies to be tested, compared and evaluated.

3.2.8 Theoretical concerns

From the chapter so far, it might be assumed that the author takes a technological determinist view to the development of fieldwork practices. This is not the case, and while archaeological theory has not been a major point of discussion in this chapter, it is considered worthwhile pointing out that theory has both driven the development of computing, and been influenced by it. In his article examining this topic, Zubrow (2006) sees theory mirroring the development of computing over time, suggesting that as technology improves, one sees a 'decreasing scale both in machines and questions'. (Gidlow, 2000; Huggett, 2000; For further discussion, please see Lock, 1994; Zubrow, 2006).

One negative example of how archaeological theory and computing are linked is the impact structured recording methods have had, and continue to have, on the formalisation of archaeological thought. Pavel (2010) suggests that because many archaeologists now record their data in a standardised manner, this does not allow for interpretational variation, and that archaeologists can therefore no longer express relativistic views. While these changes mean that archaeologists can no longer 'hide behind open scenarios nicely wrapped up in gobbledygook', Pavel argues that data recording methods force archaeologists into having an interpretation, and that this 'generally leads to the de-gradation of archaeological skills'.

3.3 Introducing novel technologies in a fieldwork context

3.3.1 The MAGIC Platform

The MAGIC (Mobile, Augmented reality, Group Interaction, in Context) platform attempted to blend the physical and virtual worlds using a mobile and collaborative system (Nigay et al., 2002; Renevier et al., 2001, 2005). The study for the system was based on archaeological prospection, as this involves a large amount of mobility combined with teamwork. Task and activity analysis were performed on archaeologists conducting archaeological prospection in Alexandria, Egypt, and the scenarios generated from this were used to inform the design of the system. Although the system was based on archaeological prospection, once built it was not possible to test the system in this environment.

The system itself consists of a head mounted display, camera, magnetometer, GPS and a pen computer (figure 3.4). This combination of components allows a user to interact with digital objects in the physical world, such as entries in a database, and physical objects in the digital world, such as tools or the material being researched. These forms of interaction are referred to by the authors as 'clickable reality' and the 'augmented field'. 'Clickable reality' allows a user to select a region within their field of view using the stylus and to create a digital representation of it. By using this function, the object is uploaded to a shared database and its location is recorded. Similarly, a digital object can be brought into the user's view of the physical world by manipulating it using the stylus.

For collaborative use, it was envisaged that archaeologists could use the 'clickable reality' function to capture a find and send it to a remote colleague or specialist for identification and analysis. As the location of these physical objects is recorded, they could also be visualised in-situ, which the authors refer to as the 'augmented field'. The authors suggest that this would be useful in situations where archaeologists wish to make comparisons between the current and removed archaeological contexts.

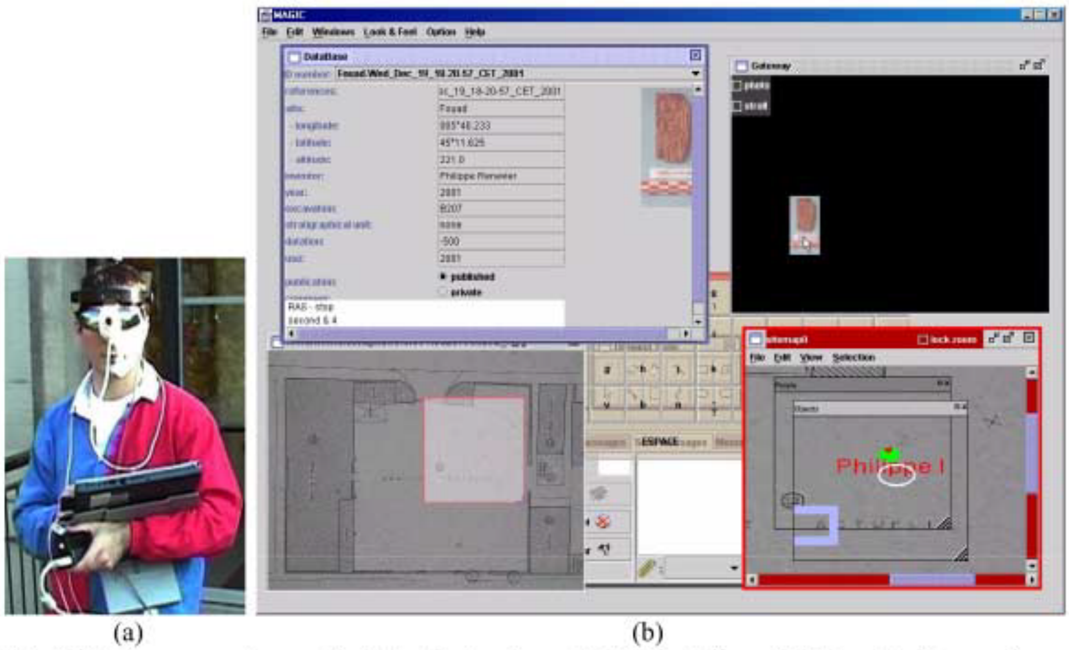

Figure 3.2: (a) A user wearing and holding the hardware for the MAGIC platform (b) User interface (After Nigay et al., 2002)

3.3.2 The VERA Project

One of the most relevant projects to the thesis is the VERA (Virtual Research Environment for Archaeology) project (Baker et al., 2008). This project was one of the first to explore many of the usability issues associated with the introduction of new technologies at an archaeological excavation. By investigating the work practices of archaeologists and ascertaining how and where technologies could be introduced into a fieldwork setting, the team hoped to improve the flow of information, both on site and in post-excavation. The setting for the VERA project was a long-established research dig and field school run by the University of Reading, which was excavating the remains of a Roman town at Silchester, Hampshire.

The Integrated Archaeological database (IADB) has been a key component of VERA from the project's outset (Clarke et al., 2002). The project was initially most concerned with data management, and they hoped that the IADB would aid in creating a situation where "the information flows seamlessly from excavation, through post-excavation to publication and archive" (Lock, 2003). In 2005, the site was provided with wireless internet access, and the archaeologists decided to trial hand-held PDAs and a ruggedised tablet PC for on-site recording (Clarke & O'Riordan, 2009). While these devices proved problematic for numerous reasons, having direct access to the network was valued highly by the archaeologists.

In 2007, the VERA project was funded to continue to explore a VRE for archaeology, and two new technologies were chosen for evaluation, the Nokia N800 Internet tablet and digital pens and notebooks. From the outset, the VERA team decided that a major focus would be on usability, and they applied participant observation methods such as diary studies, user testing and one-to-one interviews. VERA conducted several usability studies, which included a diary study, workshop and interviews. The diary study aimed to gather information about the archaeologist's work patterns and how they are supported by digital technologies (Warwick et al., 2009). Participants were asked to keep a record of their work, recording the activities they were undertaking and the technologies they were using. Participants then also completed a questionnaire rating the technologies they had used.

Experience with Digital Technologies:

- Few participants (12%) had previous experience of the digital technologies used on an archaeological site other than Silchester.
- Only 19% of the professional archaeologists claimed to have experience of using technologies on a site other than Silchester.

The use of new technologies:

- There was some resistance to the use of new technologies on the excavation, especially on the part of the more experienced archaeologists.

- Some felt that the conditions were too hostile for computer hardware and worried about the potential cost of damaged equipment.
- Supervisors were concerned that new students found it challenging enough to learn about the archaeology without being confronted with unfamiliar technology.

The use of the tablet was highly limited by the weather, with sunlight making it hard to read and rain preventing it from being used at all. In contrast, the use of digital pens and notebooks was much more successful, and helped the archaeologists to speed up entry into the database while reducing the amount of time necessary to digitise the paper records in post-excavation (Fisher et al., 2010). However, problems arose from the notebooks, which due to printing costs were provided to the students blank, differing significantly from the preformatted context sheets they were used to using. This lack of structure resulted in the students missing things out, and they were less inclined to have their work checked.

The participant observation studies showed that while archaeologists quickly overcame concerns with the robustness of technology in the field, they became uneasy when using a recording system that did not fit with existing practice (Clarke & O'Riordan, 2009). This situation was not helped by previous attempts to introduce technology on site, which had left the team feeling reluctant to adopt a technology that was perceived as not being strictly necessary. The studies also revealed archaeologists had concerns with the integrity of the data recorded using unfamiliar technologies, which did not fit with the existing verification routines on-site. While unfamiliar technologies raised concerns, familiar technologies, such as laptops and Wi-Fi, were a source of frustration for the archaeologists, as their unreliability in the field meant that they fell short of the expectations users had for them from everyday experience (Warwick et al., 2009).

3.3.3 Wearable Computing

Wearables have been of interest to archaeologists for over a decade. In 2001, a workshop was held which brought together archaeologists from Birmingham University, English heritage and other organisations to discuss how best wearable computers could support archaeologists working in the field (Baber et al., 2002). Baber suggests two reasons why wearable technologies are particularly suited to archaeologists. The first is that wearables can technologically augment 'traditional' field archaeology skills. As the VERA project (Warwick et al., 2009) discovered, the success of introducing new technologies is often dependent on their impact on traditional workflows, and wearable computing may offer a way to circumvent these issues. The second is that wearable technologies offer an opportunity to collect new types of data or traditional data using new methods (Baber et al., 2002; Cross, 2003; Cross et al., 2000).

Figure 3.3: ‘WearCAM’ wearable, configured to take pictures every 20 seconds.
(After Cross et al., 2000)

Examples of other research in this area include wearable computers designed to aid professionals and non-professionals explore museums or excavations, such as WHYRE and ARCHEOGUIDE. The WHYRE prototype was a wearable system which allowed an individual to focus on exploring a museum or site while also receiving contextually relevant information based on their location (Cinotti et al., 2004). In contrast, ARCHEOGUIDE (Vlahakis et al., 2002) uses a headset and augmented reality to provide the wearer with a reconstructed view of a historical monument by superimposing a virtual reconstruction over the archaeological remains.

Since 2005, there has been little to no research that has explored the use of wearables for archaeological fieldwork. One reason for this may be the difficulty in engineering a wearable prototype (figure 3.5) that is robust enough for archaeological fieldwork (Baber et al., 2002). Wearable devices cannot be easily concealed or removed, and may be worn while an archaeologist is engaged in physical activity. Consequently, they must be able to withstand the rigours of fieldwork more directly than other technologies that might be deployed in the field.

Another reason might be the maturation and public adoption of mobile technologies that has occurred in the last few years. Many of the proposed benefits of wearable technologies in 2001 related to the portability and mobility of computers, and many of these issues have now been addressed by the introduction of smartphones and tablets. For example, two of the scenarios where Cross (2003) felt wearable technologies might benefit archaeologists, by allowing them to consult digitised maps and reports in the field, and finding his or her location using an integrated GPS receiver, are tasks that are now routinely conducted using iPads and other tablets in the field.

3.4 Summary

Examining how and why digital technologies are designed or are appropriated for archaeological fieldwork suggests a number of reasons as to why archaeologists tend to use technologies that focus on data recording and data management rather than focusing on other motivations.

1. Preservation of the record

Archaeologists only get one opportunity to excavate; therefore a higher value is placed on the capture of data at an excavation than the use of technology for other means. This data becomes the primary record, and is therefore a form of preservation. The fidelity and management of this data therefore becomes an act of preserving the archaeology itself.

2. A traditional focus on statistics and data

The discipline of archaeological computing initially developed with a strong focus on statistics and data analysis. The problems field archaeology attempted to answer, and the methods it used to do so, were influenced by the constraints of computers at the time. As technologies improved and became increasingly capable at helping archaeologists address other problems, mathematics, statistics and data analysis remained topics of interest.

3. Technological restraints

As digital technologies developed, they became better at handling different forms of data. Early prototypes used in the field tended to focus on written or textual records, because these were more suitable for use on low-resolution devices that lacked the processing power to handle imagery or mapping. When mobile devices became capable of capturing and depicting imagery, a dichotomy had developed between tasks suitable for the field (recording), and those suitable for the lab or office (everything else).

4. Optimising period of data collection

Because of the time and cost associated with working in the field, archaeologists spend more time capturing data on-site for analysis off-site. The continued development of modern recording methods such as LIDAR, photogrammetry and laser scanning both enables and drives this trend.

5. Ease of adoption

As the results of the VERA project demonstrate, developing technologies that replicate traditional tools and methods are far more likely to be embraced and adopted by archaeologists. Most traditional tools are designed to support recording rather than interpretation, which aside from the traditional diary or excavation notes, is conducted by more ephemeral processes such as conversation or internal dialogues.

6. Reinvention versus experimentation

Due to the unusual demands of archaeological fieldwork, archaeologists often develop digital technologies for the field themselves. Another motivation is the act of ‘tinkering’, which for many archaeologists is considered an enjoyable way to spend time. It is suggested that archaeological ‘tinkering’ has held back the development of archaeological computing, as archaeologists developing their own technologies have spent considerable time reinventing existing functionality rather than experimenting with new ideas. The consequence of such a development process has typically resulted in technologies that are very appropriate to performing specific tasks, but also that are often technically limited compared to more mainstream or commercial products.

Chapter 4: Ethnographic field studies at Portus, Italy; Pompeii, Italy; Chester, UK and Itchen Abbas, UK.

4.1 Introduction

An ethnomethodological approach was the primary methodology used during field studies conducted at four excavation sites, and around four weeks of time was spent in the field in total. The sites included a UK-based academic field school, a UK-based commercial excavation and two international academic excavations. The field studies focused in particular on how archaeologists communicated on site, their awareness of one another’s activities, and their work practices around both existing and novel technologies.

4.2 Methodology

As researchers working within the discipline of archaeology, it would be easy to assume a good knowledge of the work practices and behaviour of archaeologists in the field. However ethnographers have long recognised the importance of viewing a familiar situation as an ‘outsider’, and the increase in valuable insights this can yield (Blommaert & Jie, 2010). Furthermore, an ethnographer will most likely make their observations with a particular point of view or ‘lens’, for example, a HCI practitioner might choose to pay particular attention to the manner in which individuals interact with their environment, or may instead choose to focus on their social interactions. It is through this act of making a motivated choice in what to study that an ethnographer often becomes far more aware of the nuanced behaviours and work practices of a group than the group members themselves (Blommaert & Jie, 2010).

Ethnography has also been used extensively in human-computer interaction research as a method that helps researchers to collect and organise data. It is also frequently used as a qualitative method for evaluating the success of a design. Ethnography is often contrasted to laboratory methods, as both can provide answers to certain questions, but ethnography is often seen to offer a more realistic view of how technology is used in an everyday setting. A form of ethnography that is frequently used in human-computer interaction research, but rarely in the social sciences, is referred to as ‘ethnomethodology’. An ethnomethodological approach attempts to avoid imposing theory on the analysis, instead observing how the actions and interactions of the participants result in the creation of social structure and order (Garfinkel, 1968). A typical output of ethnography in human-computer interaction research are a set of ‘implications for design' (Dourish, 2006), which are presented as a concise set of practical findings or observations that are used to inform the design or provide user requirements for a technological prototype.

In addition to taking an 'ethnomethodological' approach to the field studies, the structure and choice of observations were based on the 'distributed cognition' model. Distributed cognition is a theory originally developed by Edwin Hutchins (Hutchins 1995), in order to provide a more balanced theoretical treatment of problem solving in real work situations (see examples in Hutchins 1995; Heath & Luff 1992; Salomon 1993), and in order to supply a new framework for cognitive science. From a methodological perspective, extensive field work was carried out in order to become familiar with work practices on each site. This entailed observing the work, making copious field notes, recording events and then transcribing and encoding these. Particular attention was paid to recording changes in what distributed cognition refers to as 'representational states', i.e. changes in how information was being represented within the cognitive system as a whole. Consequently, observations were recorded of the way work on each field site was being performed by focusing on the division of labour between archaeologists, between archaeologists and (digital) artefacts and between archaeologists and their environment.

The data collected during the field studies consisted primarily of descriptive field notes (based upon a distributed cognition model), with the addition of photographs and sketch maps to provide context to the notes. These notes were then structured and analysed based upon 'grounded theory'. The rationale behind using this technique was to create a set of analytic codes and categories that were developed directly from the field notes and not from any pre-existing theories or social biases. Because of grounded theory's aversion toward using predetermined ideas, particularly hypotheses, to guide the interpretation of data, it was felt that this technique strongly complemented an ethnomethodological approach to data collection. Data was coded and assigned to a set of abstract categories, and then further refined based on multiple passes of the field notes. A narrative was then constructed around these categories, and is presented in the following chapter.

4.3 Portus

Portus (Fiumicino), the maritime port of ancient Rome, is the focus of a series of excavations conducted by the University of Southampton in conjunction with the British School at Rome, the University of Cambridge, and the Soprintendenza Speciale per i Beni Archeologici di Roma. An ethnographic field study was conducted at Portus over a period of five days. Staff and students from the University of Southampton and British School at Rome were observed and recorded while engaging in a variety of activities, and were also interviewed regarding their practices.

Observations were made of the site staff's day-to-day behaviour while working on the site, which included activities such as excavation, site survey, photography and pot cleaning. Interviews were conducted with the site director, survey and finds specialists, site photographers and archaeologists.

Following several days of observation where archaeologists were primarily excavating in several different trenches across the site, it was apparent that conversations about the archaeology would occur dependent upon the activities the archaeologists were currently engaged in. It was apparent that when two or more archaeologists were actively engaged in some task while situated together in the same trench, they were unlikely to discuss the archaeology or features of that area. However, if one of these archaeologists stood up, or moved out of the trench to stand on the edge, conversations about the archaeology were much more likely to occur. One hypothesis might be that having a higher vantage point allows archaeologists to see 'the bigger picture', and facilitates the observation of subtle patterns in the archaeology. Alternatively this may function metaphorically – with the distance encouraging reflection, without necessary introducing any practical benefits to visual interpretation.

A similar scenario was also seen to occur when an excavation supervisor would approach a trench where other archaeologists were working. On the majority of these occasions, the supervisor would remain on the edge of the trench, discussing the archaeology with the archaeologists working within. If one of these archaeologists became increasingly engaged in this conversation, they were often observed to stand up or move to join the supervisor on the edge of the trench as well. In addition to this, once a conversation was established between two archaeologists on the edge of the trench, other archaeologists would move to join them (figure 4.1). These conversations were witnessed to grow quite large, and would occasionally involve five or six members of the excavation team. This behaviour raises a number of questions, for example, does this movement in some way act as a gesture to others, inviting them to join the archaeologist in reflecting on the archaeology? Or might this movement stimulate the archaeologists to think in a particular way? Alternatively there may simply be a perception among archaeologists that a conversation held on the edge of the trench is more 'archaeological' and is therefore more enticing to join in with.

Figure 4.1: Archaeologists discussing the features of a trench at Portus.

Another behaviour that was interesting to observe at Portus was the amount of time spent by members of the excavation team in areas of the site other than the one they were allocated to work in. This time was often spent either in conversation with other members of staff or examining the contents of the various trenches across the site. Based on the informal interviews conducted at the time, it appeared that this behaviour was highly beneficial to the archaeologists, as it not only improved their personal knowledge of the site but also their ability to interpret how the area they had been allocated to work in related to the emerging picture of the site as a whole.

4.4 Pompeii

Following the success of the Portus field study, a smaller field study was conducted at Pompeii based around a team of archaeologists from the Pompeii Archaeological Research Project: Porta Stabia (PARP:PS) and from the Pompeii Quadriporticus project (PQP). The main reason for conducting this study was to assess how the team of archaeologists at Pompeii has benefitted from replacing traditional paper-based methods of field recording with Apple's iPad. Staff and students were again interviewed and observed while working on site.

Recently, iPads have been used at several archaeological sites for immediate 'trench-side' recording and access to data. Due to coverage on National Geographic and a press release by Apple, the use of iPads by archaeologists by the Pompeii Archaeological Research Project received a large amount of attention. However, the University of Cincinnati have also used iPads at other sites they are excavating in the Mediterranean, and iPads are additionally being used by archaeologists by other fieldwork archaeologists, such as the team working on the Sangro Valley project at Abruzzo, Italy (Motz & Carrier, 2012).

At the time of the study, the archaeologists from PARP:PS were excavating the internal features of rooms which formed part of an insula located on the 'via Stabiana'. The study was conducted towards the end of the archaeologists' excavation season, and they were therefore observed engaging in a variety of archaeological activities that included both the excavation and recording of archaeological material. The smaller team from the PQP were conducting an architectural survey of the nearby quadriporticus.

Figure 4.2: Recording a section at Pompeii using an iPad.

iPads were used to access and enter data into a central database, create plans and drawings (figure 4.2), access reference materials, keep journals, create Harris Matrices and to plan future activities. Two iPads were allocated per team (each team were allocated a room in the insula). One of the iPads was allocated to the supervisor in each team was therefore referred to as the 'supervisor iPad'. The other iPad was shared between the entire team. The 'supervisor iPad' was primarily used by the supervisors to update their journal, which documented the evolving interpretation for that room. The survey team each had their own iPad, and the various specialists and directors either had their own iPads or borrowed them from others when needed.

Many of the activities the field staff were using the iPads for closely resembled the superseded paper-based methods. For example, field data was entered into a database that closely mimicked the layout of the paper form. For many of the archaeologists, the main advantage to using the iPads didn't come from improvements due to digital recording, but the fact that, once synced, data was accessible by anyone on-site. Consequently, all the data for a specific trench, context or find, and all the specialists' reports relating to it, could easily be consulted and compared to the immediate archaeology. Some supervisors suggested having this data available to them had improved their capacity to interpret the archaeology, and the archaeologists involved with the architectural survey felt this was the best feature of using the iPads, and regularly accessed and edited each other's data. The use of iPads on-site has also removed the need to digitize paper records and plans, meaning that after a field season publication occurs much faster, and has also improved the security of data as well, as everything on the iPads is regularly backed-up to a server.

The use of the iPads was also transforming existing practices. For example, survey data had become more integrated into the drawing and planning process. This was because the iPad allowed digital media to be viewed within various drawing applications on the device, meaning that survey data could be used to provide an outline or template for archaeologists' detailed drawings and plans.

In the vast majority of cases, the field staff interviewed during the field study described the introduction of the iPad on-site as a positive change. It was clear the archaeologists enjoyed using the iPads simply by their willingness to explain their experiences, volunteering large amounts of information with little prompting. Several archaeologists, who regarded themselves as 'technophobes', revealed that they had adjusted to using the iPad with little difficulty, often describing it as 'intuitive' and 'easy to use'. Even the most sceptical of archaeologists admitted that the iPad had 'lots of potential'.

The majority of archaeologists at Pompeii, including the site director, suggested in their interviews that the introduction of the iPad has positively benefited personal communication across the site. However, the majority of archaeologists that were interviewed also struggled to pinpoint specific reasons for why this had occurred, while the director referred to this phenomenon as an 'intangible' improvement to communication. One obvious suggestion is that there is a level of hype associated with using the iPads, although this might have been expected to diminish after three years of using them.

Another possibility is that the iPad provides an immediate, shared point of reference for the archaeologists. This may not stimulate new strands of conversation, but once a conversation has begun the ability to be able to view associated data, information or visuals might allow a richer and longer conversation to develop (figure 4.3). The following extract from field notes collected at Pompeii describes one such situation:

"I decided to observe the architectural survey team early one morning. When I arrived I watched three archaeologists, two students and one supervisor, using their iPads to check exactly what had been recorded the previous day. From what I could see the supervisor was checking a list or spreadsheet, while the students were checking the database and viewing plans and maps while answering his questions. When two other students arrived, the conversation was briefly disrupted but then quickly continued, with one of the recently arrived students also pulling out his iPad to join in the conversation. The supervisor subsequently checked that their Harris Matrices were up to date, and set all the students individual tasks for the day. Before they set off to start work, he also informed them that he would upload some photos to their iPads necessary for the work he had just set them."

Figure 4.3: Morning briefing for the PQP team.

4.5 Chester

Ethnographic field studies were also conducted at Chester, UK, at an excavation that was being run by a large commercial unit. The field study was conducted over a period of two days with a small team of field archaeologists who were conducting a trial excavation on the edge of the city.

On arrival on site, it was immediately clear the archaeologists were feeling despondent, due primarily to a lack of archaeological features to excavate, despite the geophysical survey conducted earlier on the site suggesting otherwise. Throughout the two days spent in the field, the field archaeologists often shared negative stories of working in commercial archaeology.

Despite their praise for their current excavation manager, many of these staff related stories of how managers would abuse their positions in the company hierarchy, by doing things such as demanding that new staff to a site, and with less experience of working in archaeology, take potentially unsafe and unpleasant tasks that more experienced archaeologists would refuse.

The archaeologists also explained how awareness had been actively discouraged on sites they had worked on in the past. When one of the excavators was working on a previous site with very few finds of interest, they found by chance a silver coin. As one might expect, the field archaeologists were excited by this discovery and wanted to know more, however the project officer at the excavation disciplined the archaeologists for stopping their work to look at it.

Despite these problems, the archaeologists were generally apathetic to the possibility of positive change occurring in their discipline. Managers were seen as resistant to change (described as 'Victorian' by one archaeologist), and on-site supervisors were no better, regarded as the 'manager's puppets'. There were also negative feelings toward the IFA (a group set-up to support commercial archaeologists in the UK), as the opinion was that it masqueraded as a helpful body but only really cared about those in managerial positions.

Despite these complaints, the team observed at Chester were clearly very tight knit and there was strong sense of camaraderie. The supervisor was well respected by the other archaeologists, who frequently comment on how good a leader he is. The archaeologists spend a lot of time discussing the archaeology they have found, and these discussions often involve every archaeologist on the site. These conversations usually occur around the trench, with one archaeologist occasionally jumping in to probe certain areas.

In terms of technology, the archaeologists used a metal detector on site, and several occasionally stopped work to use their mobile phones. One archaeologist explained to that he was using his mobile for Facebook and Twitter, and would take pictures of the archaeology to tweet and share with his followers, who would often then retweet these pictures. Communication was important to him, and he saw his phone as important due to the remoteness of archaeological sites. Another archaeologist discussed how they used Facebook to keep in touch with other archaeologists and for finding new work. They also mentioned how they had used Facebook to start a protest group due to not being allowed a tea urn on one site, and therefore having to bring their own tea. This group was now a large, popular forum for archaeologists on Facebook and had quickly grown in popularity.

4.6 Itchen Abbas

The final field study to be conducted was at a student field school run by the University of Southampton at Itchen Abbas, near Winchester, UK. For many of the students attending this field school this was their first experience of practical archaeology. Staff and students working on the site were interviewed and observed over two days.

On the first day of the study, the students were taken on a site tour provided by the supervisors and director. During this short tour, the site director explained the site's historical significance to the students. They were then shown several of the test pits dug in advance of their arrival, and the visible archaeological features were explained to them. Finally they were shown examples of good and bad practice with the basic tools and equipment they were provided with to excavate the site. Following their tour, most of the students interviewed felt that they had a good understanding of the overall archaeology of the site.

Figure 4.4: Supervising students at Itchen Abbas

However, speaking to students the following day resulted in a very different response. Only a small number of the students interviewed had any concept of what was been found in the trenches being dug on-site other than the one they were working in. Those who did have a better understanding had acquired this by discussing their work with their friends working in different trenches at the tea and lunch breaks.

Often supervisors would stand on or crouch at the edges of a trench (figure 4.4). However, because the trenches were small and mostly shallow, the supervisors could also point at and excavate features without needing to enter them. In contrast to this, the junior supervisors helped the students to excavate from within the trench while also occasionally stepping out to direct them from the edges.

Throughout both days, a number of conversations occurred between students and supervisors while standing on the edges of their trenches (figure 4.5). At these times, there was usually some conversation that related to interpretations of the archaeology, especially when these conversations involved one or more supervisors. Students might switch topics of conversation like this due in part to the effect of my presence as an observer on the students (the Hawthorne effect), and also due to their desire to be seen as competent by the site supervisors.

Figure 4.5: Supervisors and students interpret a trench at Itchen Abbas field school

While supervisors would often direct and observe from the edges of a trench, students would often stand and look into a trench when they don't know what task to do or course of action to take. Consequently, supervisors often encouraged the students to work harder when they observed them in this situation. Interestingly, many of the students who were unaware of the developments elsewhere on site also indicated that they were concerned about stopping or moving away from their trench, in case the site supervisor interpreted this negatively and disciplined them for not working.

4.7 Summary

Ethnographic field studies were conducted at four fieldwork sites in the UK and abroad. One of the primary observations, and of particular interest to the theses, is recognising that archaeologists stand up or move away from the trench to engage in interpretation, and that, if presented with an opportunity, archaeologists will engage in behaviour that provides them with a better holistic understanding of an excavation.

The observation of archaeologists working at Portus, Pompeii, Chester and Itchen Abbas all highlighted that more often than not, interpretation occurs either standing away from the archaeology or at the edges of a trench. The amount of time that archaeologists spent away from their own trench while talking with colleagues and looking into other trenches at Portus and Chester might suggest that having an awareness of the entire archaeology of a site is not just something that is desirable but is fundamental to engaging in field archaeology.

However there are many barriers to being able to do this, such as time pressures, the size of the site, guilt at not working etc. This awareness can also be achieved through a site tour, but this again depends on the excavation having a conscientious director or supervisor to facilitate site tours, and them having the time to do so.

Observing how archaeologists at different levels of the hierarchy moved around a site also indicates that an archaeologists' mobility at an excavation will usually relate to their position in the hierarchy. The studies conducted at the field school at Itchen Abbas suggested that supervisors and students behaved differently around both individual trenches and the entire site. Students tended to remain closer to the area they had been allocated to work in, whereas supervisors tended to be more mobile. The field studies at Portus and Itchen Abbas also highlighted that supervisors generally spend more time at the edge of an excavation area than within.

It has also been demonstrated that communication and awareness play a critical role in the success of any archaeological excavation. Through awareness and communication, archaeologists are empowered with contextual knowledge. This allows them to more confidently interpret the features they are excavating, and to make a greater contribution to the overall interpretation of the site. Supervisors and specialists benefit by acquiring a greater knowledge of where their attention should be focused. Specialists can also better optimise their often limited time on-site, and prioritise where their advice is given, by, for example, suggesting correct sampling procedures before archaeological features are excavated.

If the social hierarchy was successfully disrupted this would also have consequences for archaeological practice. Increasing communication and awareness results in better-informed archaeologists, and therefore reduces the need for direct supervision. This means that archaeologists can be deployed based more directly on their strengths, and not based on their previous experience as a supervisor or manager.

Chapter 5: Technology probe at Itchen Abbas

5.1 Introduction

One of the main themes to emerge from the field studies conducted at all the locations analysed was that archaeologists would often spend a large proportion of their time standing at the edge of trenches, often engaging others in conversation. This theme was considered worthy of further exploration for a variety of reasons. One of these was a lack of interest from the site teams in documenting these conversations, despite field analysis suggesting that these conversations often shape and change the progress of an excavation. Instead, these conversations were largely ephemeral and, it is assumed, will be forgotten a long time before the site is published. Another reason is that these conversations were observed to involve all members of the excavation team, including both junior excavators and supervisors, so could provide information pertinent to the construction of social hierarchies on the site. Finally, because these conversations occur in a predictable physical location, the process of setting up and running a technical intervention could in theory be simplified and streamlined. In light of these reasons and more, and in addition to the field studies conducted at Itchen Abbas, a 'technology probe' was also deployed at the field school to further explore archaeologist's activity around the edges of trenches.

5.2 Technology probes

A 'technology probe' (Hutchinson et al., 2003) is essentially a technological deployment designed to collect data that inspires new design; they are not prototypes to be iterated, but aim to provoke interesting responses from the users (Boehner et al., 2007). Hutchinson *et al.* (2003) first characterised technology probes as similar to the concept of cultural probes (Gaver et al., 1999) but with an aim of balancing the 'social science goal of collecting information' with the 'engineering goal of field-testing', and the 'design goal of inspiring users and designers to think about new kinds of technology'. The approach to technology probes adopted for use at Itchen Abbas however more closely followed the 'light-weight' probes described by Langdale *et al.* (2006). These 'light-weight' technology probes sacrifice some of their technological realism to focus on gaining insights about the users' needs, cultural norms and practices, and more closely resemble the original ethos of a cultural probe (Gaver et al., 1999). They also reduce the technical complexity necessary to a minimum, which was considered important given the difficulties working at a remote archaeological fieldwork site might present.

The technology probe deployed at Itchen Abbas was conducted by placing small spherical markers wherever archaeologists stood by the edge of a trench for a predetermined amount of time. As the markers accumulated, it was hoped that the archaeologists would become increasingly aware of their own and others behaviour around the trench. Spherical physical markers were chosen to best represent the style of location marker typically used in augmented reality and wayfinding applications. In this manner, the technology probe can be considered a minimalistic prototype of an augmented reality application.

5.3 Breaching experiments

By drawing attention to a behaviour that is so common to the archaeologists that it generally goes unobserved, the technology probe is also a ‘breaching experiment’. Breaching experiments are research procedures that purposely disrupt ordinary actions in order to highlight the social structures of everyday life. Breaching experiments were first introduced by the sociologist Harold Garfinkel, who suggested they could 'produce reflections through which the strangeness of an obstinately familiar world can be detected' (Garfinkel, 1964). Crabtree (2004) has since evaluated how breaching experiments can be incorporated into HCI research. He suggested that breaching experiments should not be regarded as being 'disruptive', but instead as 'provocative', in that they provoke practice and make it visible for design reasoning (Crabtree, 2004).

In one of the better-known examples of Garfinkel's breaching experiments, he asked his students to act as if they were boarders in their own home, omitting them from the 'common sense knowledge of the social structures' of this environment. As part of this study, they were requested to conduct themselves in a polite fashion, to avoid getting personal, to use formal address and to only speak when spoken to. Many of the students reported that family members responded with astonishment, bewilderment, shock, embarrassment and anger, and that they struggled to make the actions of the students intelligible by demanding explanations of them or by attempting to identify other motives of the students such as stress or illness. Another good example of a breaching experiment was conducted by Mann (2004), who used a series of breaching experiments to challenge everyday notions of surveillance in modern society. By creating portable 'sous-veillance' cameras (using personal cameras to film surveillance cameras), the perspective on who is watching who is disrupted and the everyday acceptance of surveillance is challenged.

5.4 Experiment design

The probe was conducted by placing small coloured markers at locations where archaeologists stood for a minimum of thirty seconds while in close proximity to the edge of a trench. In later experiments, the colour of the markers corresponded to the experience of the archaeologists observed. In all cases, the archaeologists' responses to the markers were recorded and assessed via observation and interview. A camera was also used to document activities in and around the trench over the duration of the experiments, which took place over three days.

The first two experiments were conducted to test the feasibility of placing markers across the excavation. Following the smaller experiments, two larger ones were conducted for longer periods of time (90 minutes and 1 hour). The first of these focused on the largest trench on the site, approximately ($5m^2$). For the second, markers were placed over the entire site, but only in locations were supervisors had stopped at trenches. As the excavation site spanned a large area, the markers in this case do not record every position the supervisors stopped at, but are representative of the times when their behaviour could be documented.

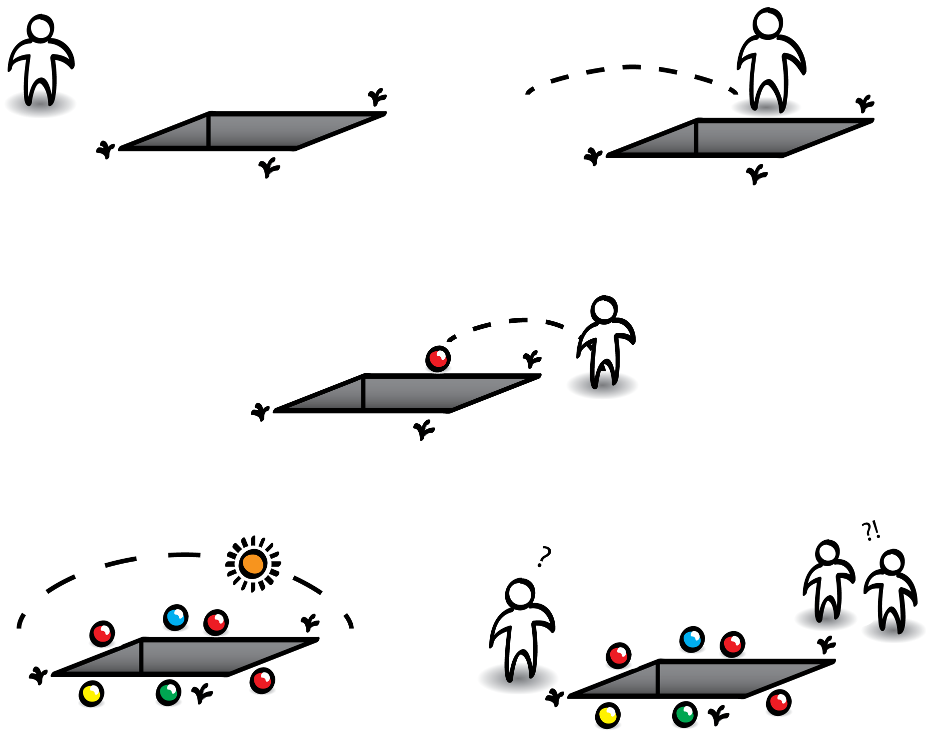

Figure 5.1: Diagram showing how markers accumulate during the experiment.

5.5 Results

5.5.1 1st Experiment

Trench size: $1m^2$ (being expanded to a 2m x 1m)

Activities observed: digging with mattocks, clearing spoil.

Marker colours: one.

Results: As the students were taking turns to dig, a large number of markers were placed toward the back of the trench where the students were working. In contrast, only two markers at the front of the trench the marker were placed, representing the location where a supervisor had stood to observe the students working. The students and supervisors were confused by the placement of the markers, which to them appeared to them to be placed at random.

Figure 5.2: Placement of markers around the 1st trench at Itchen Abbas.

5.5.2 2nd Experiment

Trench size: 2m^2

Activities observed: bailing out water, planning a section.

Marker colours: two (students and supervisors).

Results: The students and supervisor were stationary for large amounts of time around the trench as a result of the activity (planning) they were engaged in. An interesting pattern emerged in that the supervisor spent more time standing on a trench edge that was perpendicular to the locations the students were working in. The students and supervisor worked as normal with little change to their behaviour.

Figure 5.3: Placement of markers around 2nd trench at Itchen Abbas.

5.5.3 3rd Experiment

Trench size: 5m^2

Activities observed: digging with mattocks, trowelling, clearing spoil/

Marker colours: four (trench supervisor, other supervisors, student 1, student 2)

Results: The approximate placement of the markers can be seen in figure 5.4. It is apparent that the markers cluster around two sides of the trench, concentrating in areas corresponding to the archaeological features of the trench. It is also apparent that supervisors spend much more time on the edge of the trench than the students do. The supervisor in charge of the trench was accepting of the markers being placed around it but referred to them as 'a little bit sinister'. The students did not associate the placement of the markers with periods of pause or reflection.

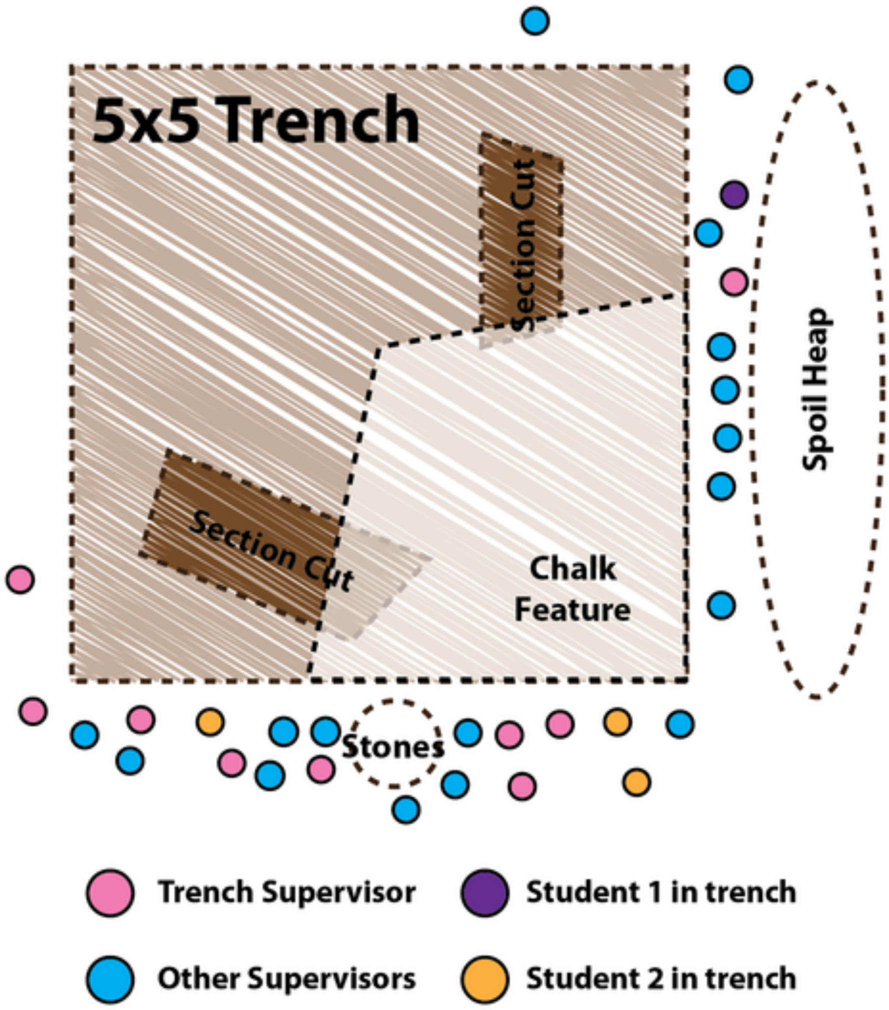

Figure 5.4: Diagram showing final placement of markers in the 3rd experiment.

Figure 5.5: Placement of markers around 3rd trench at Itchen Abbas.

5.5.4 4th Experiment

Trench size: entire site

Activities observed: supervision, some excavation

Marker colours: two (supervisor, junior supervisor)

Results: the experiment was set-up to further explore the observation that supervisors appeared to be more mobile than junior members, who appeared to work between one or two trenches. The placement of markers after a period of one hour can be seen in the figure 5.6.

The trench where experiment 3 took place had no markers at the end of the hour. This was because one of the more senior supervisors on the site was working within the trench, so other supervisors tended to bypass it. It was also positioned at the far end of the site, away from the majority of other trenches. A similar situation existed in trench one, however the other supervisors could better see this trench from the rest of the site, so would occasionally move to the supervisors position at the top left of this trench for a conversation with them. There are no markers around the rest of this trench, despite other students working on features of archaeological interest located here while the experiment was being run.

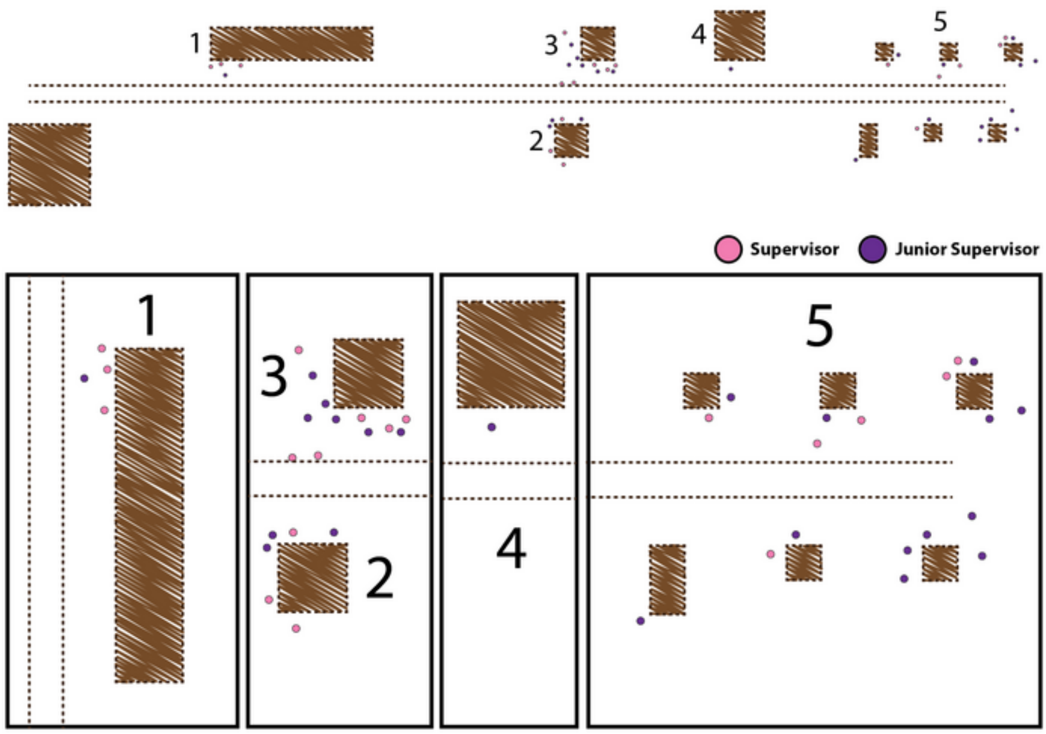

Figure 5.6: Diagram showing final placement of markers in the 4th experiment.

Junior members of the supervisory team supervised trenches two and three, which also acquired the most markers throughout the hour they were being observed for. There was general interest in the contents of these trenches, which resulted in frequent discussion between the senior and junior supervisors. Trench 4 was extended earlier in the dig and nothing of particular interest was found here. The one marker at its edge represents a conversation between students and a junior supervisor that may have been a chance encounter close to the trench.

The small student test pits (marked 5 on the diagram), were being supervised by two junior members of the site team, which is why there are generally more purple markers here than pink. Of interest is the trench in the top left corner in which none of the students were working, the two markers indicate a conversation between a senior and junior member of the excavation team about the next course of action to take here. The trench beneath this one in the diagram, with just one purple marker, was still being dug while the test was conducted, suggesting little interpretation could occur while the students were working in it and obscuring the features from view.

While conducting this larger test, a number of students enquired about the purpose of the experiment. Instead of explaining the purpose (which could have compromised the experiment), this was used this as an opportunity to discover their interpretation of what was occurring. Only a few students had any suggestions, and some even suggested that the markers were being placed to purposely confuse or annoy the archaeologists at the excavation. In contrast, while the supervisors were bemused by the experiments, they did not ask questions except in the tea and lunch breaks.

With this final experiment, it is important to acknowledge some of the limitations that resulted from expanding the scope of the study to the entire site. One of these was the inherent bias that resulted from only having one experimenter on site. Clearly it was not possible for the experimenter to monitor all the trenches across the site at once, and therefore the results only represent a sample of the locations where archaeologists stood next to trenches over an hour period. In order to optimise the number of markers placed in this timeframe, the experimenter frequently followed archaeologists as they moved across the site, placing a marker where they paused to talk to others. Furthermore, as with the previous experiments, the purpose of this larger study was to explore behaviours around the edges of trenches. Consequently, archaeologists pausing to observe others or to engage in conversation who were not located on the edges of trenches were not recorded as part of the experiment. While this may have missed out on interesting observations, again the limitations of having only one experimenter restricted what could or could not be recorded.

Unfortunately, time was limited to run this study at the field school, and therefore some behaviours associated with standing on the edges of trenches could not be observed. In particular, and perhaps worthy of future study, it would be of interest to explore the temporal aspects of marker placement, in particular focusing on the time spent by individuals in each location marked. This could perhaps be done without adding too much additional complexity to the study through the use of different coloured markers, with colour representing discrete periods of time. It would also be interesting to observe how markers accumulate over time, so for example, whether one archaeologist pausing at a trench encourages other archaeologists to adopt the same behaviour, as witnessed in the field studies.

5.6 Summary

Perhaps unsurprisingly, the vast majority of markers placed through the study indicated locations where either supervisors or the site director had stopped to discuss something with the students while they worked in the trench (indicated by blue or pink markers, see diagram). This observation further confirms observations made in the ethnography, which suggest that the higher an archaeologist is positioned in the site hierarchy, the more mobile they are around the excavation, and the more time they spend observing the archaeology. In contrast, the less experienced students were very reluctant to leave the trench in case they were disciplined. As a result, students were dependent on the site tour and conversations with other students to improve their awareness.

Unfortunately, both site staff and students found it difficult to infer what the markers represented. While planning the study the decision was made to not tell the staff or students what the markers represented, as it was felt this would alter their behaviour and consequently bias reactions to the markers. Throughout the experiments, the students questioned its purpose and even suggested a number of their own theories. However, none guessed the experiments true motivation, and perhaps because of this, they did not stimulate much conversation or reaction. One possible reason for this could also be that, due to the archaeologists being briefed that a study was to be conducted at the field school, they felt asking questions would interrupt or influence it's success (the demand effect, see Orne 1962). Another possible explanation is that the students felt they could not engage with the study without appearing as if they were not working, as hinted at previously in the observations from Itchen Abbas.

Therefore, while the experiments conducted at Itchen Abbas failed as breaching experiments, they did confirm that archaeologists spend significant amounts of time in conversation with members of the team at the edge of a trench. It also confirmed that more senior members of the excavation team are more likely to do this. Because these team members are often charged with the task of interpreting the site as a whole, then a knowledge of where and when they are likely to have these discussions (at the edges of a trench), suggests an interesting design space for a technology focusing on communication, hierarchies, and awareness.

Chapter 6: Technological intervention

6.1 Introduction

Based on the ethnographic field studies described in chapter 4, and the technology probe described in chapter 5, a number of design implications were derived for a novel technology that aims to benefit archaeologists' awareness and communication when working in the field. These implications informed the design of an intervention, which was then built, deployed in the field, evaluated and iterated upon, with a final evaluation also conducted in the field.

6.2 Implications for design

1. **Archaeologists are more likely to discuss the archaeology when positioned in specific locations**

Identifying a moment in the excavation process where there is a greater probability that archaeologists are discussing their interpretation, such as when they are on the edge of a trench, opens up opportunities for 'capturing' that interpretation. It also suggests that an archaeologist's position in and around the trench could potentially be used to reveal the activity they are currently engaged in, an important consideration when building a context-aware system.

2. **Archaeologists benefit from awareness, but not all archaeologists have the mobility granted to them by the social hierarchy to engage in this behaviour**

The time that archaeologists were observed to spend away from their own trench while talking with colleagues and looking into other trenches suggests having an awareness of the site is both desirable and useful. Designing a technology that achieves this awareness for archaeologists who are generally not as mobile, such as students at a field school or archaeologists working on a commercial excavation, could benefit their work and might also have a disruptive impact on the social hierarchy.

3. **Technology can promote or enhance conversation by creating a shared point of reference**

The field studies conducted at Pompeii suggest that any technology can create a shared point of reference for a conversation, such as a visualisation, could have a beneficial impact on conversation across the team.

6.3 Initial concept

Based on these implications, an intervation was proposed that would capture conversations between archaeologists, process this information and then visualise it in such a way that it could be easily understood. As the content of these conversations is normally exclusive to those participating, this was clearly a provocative concept.

Initially, the intervention planned to capture audio, then transcribe the audio data captured on-site to text. Consequently research was conducted to identify methods that might be used for achieving this. However, this research unfortunately revealed that transcription methods have a number of limitations. The possibility of manually transcribing the data was ruled out by the quantity of audio data that would be captured on-site. However it was also recognised that machine-based transcription software frequently suffers from a high level of error in its accuracy (referred to as the word-error rate). In lab conditions, the word error rate is typically around 10%, which compares to a 1% word error for manual transcription (Benzeghiba et al., 2007). Listening to audio that had been captured in-situ at previous archaeological excavations reveals that there is frequently a large amount of background noise present (such as wind and the sound of archaeologists using trowels). In experiments conducted by Lippman, word error rates increase from less than 10% to 23% when channel variability and noise were added (Lippmann, 1997).

While the issues identified with audio transcription provide a clear technical challenge to overcome, the time spent solving them could easily present a barrier to exploring the theoretical issues around awareness and communication. Furthermore, as the visualisation process would abstract this data further, it was decided that a more accurate source of data was first required to evaluate the benefits of the intervention **before** attempting to use captured audio as the input for the system.

6.4 Audio capture

6.4.1 Identifying a proxy for captured audio

Therefore, it was decided that an alternative needed to be found that would allow a focus on development and deployment, and consequently, exploration of the theoretical issues. To most closely resemble transcribed audio as possible, it was decided that the chosen text should be written in an informal and conversational style, and should contain explanations and interpretations of the archaeology while also discussing other less relevant topics.

One possibility is to use textual data obtained from blogs. Often written in an informal, conversation style, blogs mirror conversations in many ways. However, while there are a number of archaeologists who write blogs, bloggers rarely engage in the rapid exchange of information that would be representative of conversation, instead choosing a specific topic for each post. Given an archaeological blogger's audience, this topic is also often of broad archaeological concern, rather than specific to a particular trench or find. Finally, blogging is often a solo endeavour, and thus comparison between different bloggers for the purposes of evaluation was likely to be difficult.

6.4.2 Diaries as a proxy

Another possibility is to use the diary entries of archaeologists created while working in the field. In many ways, using diaries counters many of the issues presented by blogs: they are kept by archaeologists as a log of their daily activities as well their thoughts, they record the on-going interpretation of a site in very specific, often technical language, and will often contain more intangible ideas that are not be recorded via other means.

6.4.2.1 Diaries in archaeology

Traditionally the majority of archaeological recording was done using diaries, however forms have increasingly replaced diaries as the primary form of recording on most excavations (Berggren & Hodder, 2003). Diaries and archaeology have a long history. Antiquarians would often keep a diary or field journal as a way to create a narrative about what had been discovered through excavation (Hodder, 1989). As archaeology became more rigorous and scientific, diaries were no longer used. However, with the move to post-processual archaeology and a growing interest in reflexive practice and phenomenology, diaries found a place in the discipline again.

The use of diaries as a reflexive practice was pioneered by Roveland at the Pennworthmoor excavations in 1993 (Roveland, 2006). Working in a small team of five, Roveland encouraged the team to 'reflect upon their experiences and record them in their diaries'. The two most well-known cases of diaries being used to support reflexivity in archaeology were at the excavations at Leskernick, which investigated Late Neolithic and Bronze Age remains on Bodmin Moor in Cornwall, southwest Britain, directed by Barbara Bender, Sue Hamilton and Christopher Tilley, and the excavations at Çatalhöyük project, directed by Ian Hodder. The use of archaeological diaries has been discussed in a number of publications (Bender et al., 2007; Berggren, 2009; Farid et al., 2000; Hodder, 1999, 2000, 2003; Tilley et al., 2003). Diaries are now increasingly being used as a way to disseminate information about an excavation to the public (often in the form of a blog), and students are also frequently required to keep a diary to aid the process of learning to excavate.

6.4.2.2 Diaries and Human-Computer Interaction

HCI research has also on occasion explored the intersection between diary writing and technology. The familiar (Clarkson et al., 2001) was an early project to based around diaries. The researchers designed a deployment using a camera, microphone and other sensors mounted into a wearable and toy. This sensor data was used for skin and face detection, speech detection and gesture classification. By recognising from this data the activities the user was engaged in, the familiar would generate an automatic diary for the user's day.

This project clearly overlooks an essential aspect of diary writing, which is that diaries are written not only to aid recollection of past events, but also to aid the writer in reflection on their own experiences. The act of writing a journal or diary entry is for many people enjoyable and cathartic. More recent explorations of diary writing and journaling have recognised this, and have designed to support it. Lindström et al. (2006) explored the notion of diary writing from the perspective of affective computing. Their study again used sensor data and biofeedback, but instead of automating the diary process, they used the data obtained from these sensors to create visualisations that encouraged diary writers to reflect on their mood and emotions.

The 'Wandering Mind' project described by Pirzadeh et al. (2013), takes the research behind the affective diary one step further. Based on a literature review and interviews, the authors researched the process of reflection and built a tool to support their findings. Their tool 'wandering mind', is a journaling application that is designed to support what the authors state are the three stages of reflection: awareness of uncomfortable feelings and thoughts, critical analysis, and development of a new perspective. The authors chose to build visualisation tools into their journaling app to support this process. For example, being able to visualise past patterns in emotions helped raise the users awareness to their feelings and charts their personal growth.

6.4.2.3 The Çatalhöyük diaries

After considering the diary data available, including whether to introduce diary writing as a new activity to an excavation where it had not been done before, it was decided that the diaries created at Çatalhöyük were the most suitable to use for the purposes of the intervention.

By studying the archive of diaries from Çatalhöyük, it became apparent that archaeologists would often respond to one another's posts, which would result in threads that were reminiscent of conversation.

Another advantage was the size of the dataset. The archaeologists have been making diaries at Çatalhöyük since 1996, and between 1996 and 2011 there were a total of 1781 unique diary entries submitted to the database. The size of the dataset allows the prototype to be tested for accuracy with a much larger corpus. Additionally, all of the data generated at Çatalhöyük is released on a creative commons licence, which meant that this data could be freely used in the visualisations without any concerns around copyright.

Furthermore, as Southampton University sends a fieldwork team annually to Çatalhöyük, a prototype could be developed and deployed live on-site at Çatalhöyük. Consequently this presents an opportunity to compare data between years and potentially see patterns emerging over time.

6.4.2.4 Challenges

Unsurprisingly, there were also problems identified with choosing to use diaries as a proxy for conversations. One of these was that diaries follow a particular narrative style that is alien to conversation, and feature a large amount of references to discrete temporal events that would probably not arise in typical conversation. In addition, because the diaries were both typed and made publicly available at Çatalhöyük, they were also subject to a level of editing that is not possible in conversation. However, despite these issues, it was felt that diaries presented the best choice as a proxy for conversations without using manual or machine transcription.

6.5 Data processing

As the diaries from Çatalhöyük presented a large textual dataset, it was decided that methods for filtering and organising this dataset should first be explored, so that the textual data could be processed and filtered into a form of data that would be possible to visualise. A long-standing goal for computer science research has been machine-comprehension of natural language, and years of research have revealed that this is an extremely difficult problem. However, all of this research has also resulted in the creation of a variety of open-source software that facilitates some simpler processing procedures that can be used to extract information from text quickly and easily, and these were consequently explored to see if any of them would be appropriate for processing the data from Çatalhöyük.

6.5.1 Natural-language processing

Ultimately, the approach that was decided to be most suitable for extracting data from the diary corpus was one used in the work of Dearman *et al.* (2010). The authors behind this work were interested in whether they could obtain contextually relevant information for a specified location using reviews from popular community driven location review sites, such as 'Yelp'. To extract information from these reviews, the authors first split each review into sentences. Following this, the authors used a PoS (Part of Speech) tagger to label each of the words in a sentence with their respective part of speech, for example, as an adjective, noun or verb. Finally they created an 'activity finder', which paired the verbs they identified with nouns if they were less than five words away in the sentence. The resulting 'verb-noun pairs', were phrases such as 'drink-coffee', or 'buy-things'. The authors then evaluated these pairs by asking participants with knowledge of the places reviewed to provide a list of their own activities to compare to the verb-noun pairs, and to validate the top forty verb-noun pairs for each location. The accuracy of the forty most common verb-noun pairs was found by the authors to have a mean precision of up to 79.3%. When compared to the participant-generated activities, the verb-noun pairs were recalled up to 55.9% (with the maximum possible score being 70.2%). Given the success of their approach, the authors' methods for creating verb-noun pairs were appropriated for the thesis, but were also extended to include 'adjective-noun pairs' as well.

6.5.1.1 Methodology

To analyse the diaries using natural language processing (NLP), the natural language tool kit (NLTK) was used (Bird, 2006), which is a natural language processing library for Python. Scripts were written in Python (and using Django, a web development plugin for Python) to convert the Çatalhöyük diary entries (downloaded from the Catalhoyuk website as .txt files) into entries in an SQL database, associated with any relevant metadata (time, date, author etc.). At this stage, any diary entries written in Turkish were discarded, due to the difficulties in parsing them with NLTK. This was done manually based on a visual pass of the database, fortunately due to the small number of Turkish entries this was not a laborious process.

Custom scripts were then written using the NLTK to separate each of these diary entries into individual sentences. Having done this, a NLTK parser was used to 'tokenise' the text of each sentence (essentially isolating each part of a sentence that could be considered a word). A corpora of standard stopwords (included in the NLTK) were then used to remove stopwords from the text (common words such as 'and' and 'in'). Finally the Stanford Part of Speech (PoS) tagger was used on the dataset, which was the same as the one used in the research of Dearman *et al.* (Dearman & Truong, 2010), as described previously, to assign each word in the copora it's correct part of speech (verb, noun, adjective etc.).

Based on the work of Dearman *et al.* (2010) discussed previously, it was decided that each user's diary entries would then be parsed to identify all of their 'verb-noun pairs' and 'adjective-noun pairs'. To generate these pairs the nouns in a sentence were identified, and then the sentence was searched to find the closest associated adjective or verb to that noun. It is acknowledged that there are some weaknesses with this process (as the nearest adjective or verb to the noun is not necessarily directly associated semantically), however processing these phrases so that the semantically correct noun-verb and noun-adjectives were extracted was considered prohibitively challenging, given that word proximity provides an adequate level of accuracy.

References to specific archaeological features in each sentence were also identified, for example, 'Building 5', or 'Unit 20303'. Every verb-noun pair, adjective-noun pair and archaeological feature was then added to the database, where it was associated with the diary entry it was extracted from (and consequently the user who wrote it).

Consequently, the types of NLP phrases extracted from each diary were:

- Verb-noun pairs – e.g. dig trench, excavate pit, wash pot
- Adjective-noun pairs – e.g. brown soil, glazed pot, red ochre
- Archaeological feature – Building 5, Area 32, Trench 2, Feature 543, Unit 23464

6.6 Visualisation

The primary aim of visualising the audio data was to promote awareness of conversations and topics among archaeologists across a site. Because of this, the design of the visualisations was influenced by previous efforts in HCI to create interfaces that support this goal. Awareness interfaces were first developed in HCI to support tasks within business environments, and although they have been explored in a variety of environments since their introduction, they still continue to embody some of the assumptions about how information might flow within this particular environment (Gaver, 2002).

Notable early examples of awareness interfaces include 'the dangling string' (Weiser & Brown, 1996) and the AmbientROOM project (Ishii et al., 1998; Wisneski et al., 1998). Since then, awareness interfaces have been developed to improve knowledge of others activities (Skog, 2004), improve communication at home (Neustaedter et al., 2006), in communities (Redhead & Brereton, 2009), in the workplace (Dabbish & Kraut, 2004; Johan Redström, Peter Ljungstrand, 2000), and to change people's behaviour (Jafarinaimi et al., 2005; Varoudis, 2011).

6.6.1 Ambient displays

One method HCI researchers have used to successfully encourage awareness is deploying ambient displays. Ambient displays are designed so that the information they depict does not distract users. Instead, they seek to engage with the periphery of a user's attention. They are only occasionally noticed and therefore interactions with the display are opportunistic (Plaue et al., 2004). They are also usually employed within the context of architectural space (Wisneski et al., 1998). In recent years research in this area has also examined the impact this has on individuals within the space, for example, exploring how their movements might change (Varoudis, 2011). Occasionally they will also take the form of physical objects, such as lamps or pinwheels (Wisneski et al., 1998). However both these forms of ambient display require support from a level of infrastructure that often does not exist in outdoor or rural environments, which raises interesting challenges for designing an ambient display for the context of archaeological fieldwork.

6.6.2 Visualising text-based datasets

A large amount of visualisation research has also been motivated by the desire to make large document collections more accessible and easier to browse. Document cards (Strobelt et al., 2009) is one such project, which attempted to use visualisations to provide an overview of a large collection of documents. Inspired by 'top trump' cards, images and key terms from documents were extracted using text mining techniques, and combined to create a visual index card for each document in the collection. The project found that the document cards provided a more efficient and fun method for browsing, recognising and overviewing large collections of documents. Another project, Jigsaw (Stasko et al., 2008), used a complex system of multiple visualisations to highlight connections between entities identified within text-based collections. Deployed on multiple monitors, the aim of Jigsaw is to present analysts with a tool to explore how entities identified in collections are connected in multiple ways.

A similar example of this trend is ThemeRiver (Havre et al., 2002), which is an innovative project that explores how themes in large document collections can be visualised over time. The visualisations, which are automatically generated from a large corpus, appear similar in style to stacked area charts with the width of each band influenced by the strength or popularity of a topic at a given point in time.

In contrast to the previously outlined research, FeatureLens (Don et al., 2007) uses data mining techniques to analyse single and multiple documents and identify where text patterns occur in each paragraph of a text document. These patterns are then visualised to allow the viewer to study correlations between the identified patterns. See Eick et al. (1992) for a very similar project. Also choosing to focus on single texts, the Docuburst (Collins, Carpendale, et al. 2009) system creates interactive radial visualisations that provide an overview of a text at a glance, and help users to select passages of interest from the text. The visualisations generated using Docuburst are unusual as they are based on comparisons between keywords and synsets obtained from WordNet (Miller et al., 1990). Consequently the researchers behind Docuburst suggest that visualisations produced using it are superior to other approaches as they depict content based on a 'human-centred' view of language.

Word trees are a form of interactive visualisation that uses keywords in context (KWIC) to explore single documents (Wattenberg & Viégas, 2008). A search term is used as a 'root', and the subsequent words in a sentence containing the search term branch from this root to show all the possible permutations of sentences contained within the corpora. The Netspeak WordGraph (Riehmann et al., 2011) combines this approach with other techniques such as PhraseNets to create word trees with greater complexity.

Bridging these two approaches are projects such as FacetAtlas (Cao et al., 2010), which visualises both the global and local relations between text document collections. In this visualisation, global relations are displayed using a density map; and local relations are displayed using a graph layout of nodes and edges. A flexible approach was taken by the researchers behind the STREAMIT project (Alsakran et al., 2011), which focused on the problem of continuously evolving text streams of varying size, such as news articles. The researchers developed a system that analysed and clustered incoming documents, and then visualised them for the user in an interactive interface that encouraged further exploration.

6.6.3 Methodology

The visualisations were created using Graphviz (https://pypi.python.org/pypi/graphviz), an open source graph visualization plugin for python. Graphviz provided the functionality required to generate several different graph-based visualisations based on descriptions of graphs in a simple text language, which were then used to generate diagrams suitable for display in SVG format. Two methods were selected for visualising the data, one a network graph, and the other, an adjacency matrix. It was decided that these two forms of visualisation were appropriate to depicting the content of the diaries in the following ways.

The network visualisation (Shneiderman, 1996) (figure 6.1) depicted users as nodes, and the proximity between nodes was determined by how many of the same verb-noun and adjective-noun pairs featured in two user's diary entries. Line thickness was also mapped to this variable to reinforce this association.

The adjacency matrix (Sheny & Maz, 2007) (figure 6.2), presented the data from the excavations as a table, with users, archaeological features and verb-noun and adjective-noun pairs extracted using NLP depicted in different permutations on both axes. Different size circles were used to show the extent of correlation between rows and columns. In addition to this, due to the number of row/column combinations that had no correlation, heatmap shading was applied to indicate which combinations had data present.

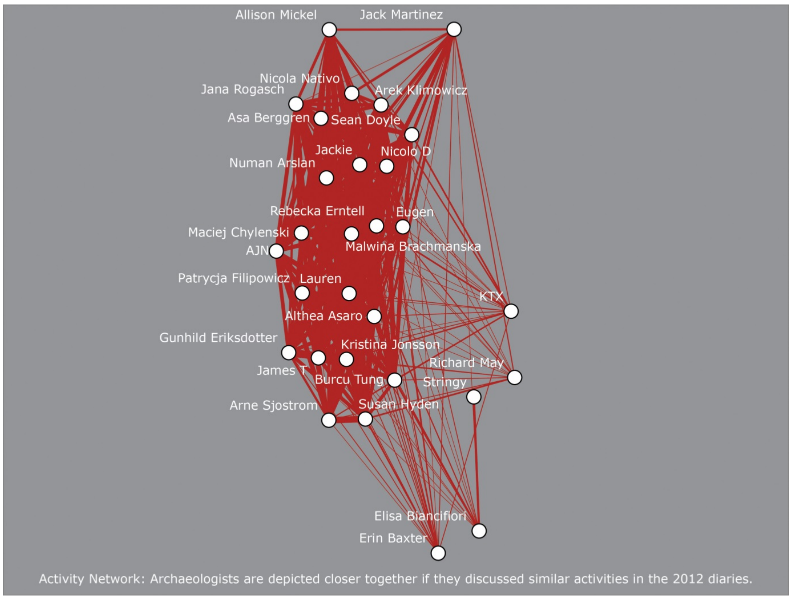

Figure 6.1: Example of the network visualisations deployed at the Çatalhöyük excavations.

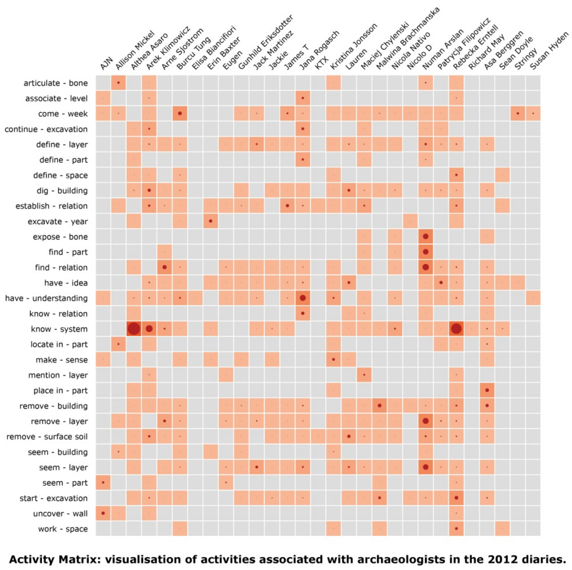

Figure 6.2: Example of the adjacency matrix visualisations deployed at the Çatalhöyük excavations.

The advantage to using network visualisations was that it reflected the group dynamics; the links between people could be seen to not only represent similar language but to reflect where conversations were actually taking place on-site, or perhaps where they should be taking place. In contrast, the adjency matrix allowed archaeologists on-site at Çatalhöyük to explore the data from the diaries in much greater detail. For example, an adjacency matrix that depicted users against features might show where archaeologists were currently working on-site, or a matrix of verb-noun pairs against features might show what kinds of activities were occurring in certain locations.

The excavations at Çatalhöyük cover a large geographic area and usually involve around 150 – 200 participants during a single field season. Due to the size and complexity of the excavations, it was decided a single ambient display would be set-up in an area of high footfall. Çatalhöyük is situated in a remote, desert location, and therefore the prototype was purposefully designed to be robust and simple to operate. A 15" digital photo frame was used for depicting the visualisations on-site (figure 6.3), as this had the advantage of being both robust and capable of depicting the visualisations at a high enough resolution for text to be readable at a distance, in contrast to many ruggedised portable tablets available at the time. Visualisations were rendered as static images and shown as a looping slideshow. An iPad was also available to use as a secondary display for the visualisations on-site, positioned by the side of a trench for archaeologists to glance at while working in the field.

Figure 6.3: Digital photoframe used to depict visualisations at Çatalhöyük excavations

6.7 1st deployment at Çatalhöyük

6.7.1 Complications with the deployment

On arrival at Çatalhöyük it became apparent that there were a number of limitations that first needed to be overcome before the system could be deployed. The first of these was a number of subtle differences between the database deployed on site and the database that formed part of the web application that the system used to acquire the data to run the NLP scripts for previous years. Therefore time had to be spent developing a method that would allow the data exported from the site database to be compatible with the scripts created to run the natural language processing.

Another issue, compounding the previous problem, which was the lack of a high-speed broadband Internet connection at the site. At Çatalhöyük, the only connection available was a 56kbps dial-up connection, the use of which was shared between the entire team. This made obtaining the files necessary to run some of the scripts, such as python libraries, difficult or even impossible.

Another issue was the scale of the excavations at Çatalhöyük. The majority of archaeologists lived and worked in a large building, which consisted of a central courtyard with adjoining labs, offices, living quarters, a museum, kitchen, dining area and common room. Due to the size of this building and the number of archaeologists on-site, it was not apparent that there was a single location where the visualisations could be situated so that they would be visible to everyone.

In an attempt to address this issue, the deployment was situated near to the kitchen and dining area, where there was a high footfall during lunch and dinner times (figure 6.4). However, while this ensured the display was visible, by locating it in a busy hallway with no line of sight from any of the adjoining rooms, it became very difficult to discreetly observe archaeologists interacting with the display.

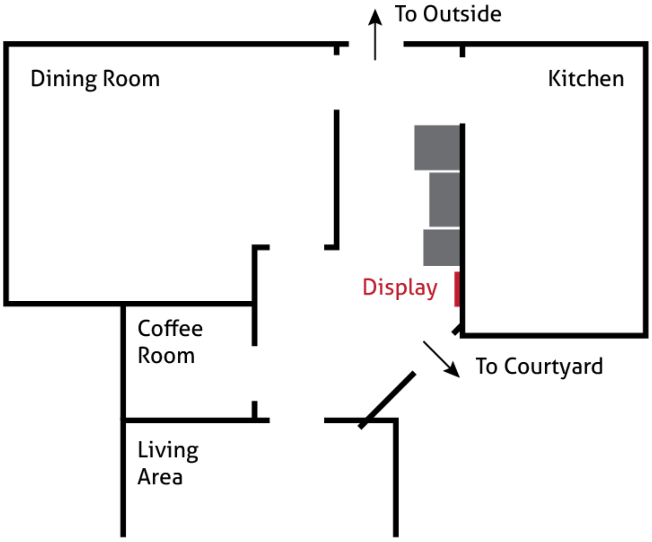

Figure 6.4: Location of ambient display in 1st deployment at Çatalhöyük

6.7.2 Evaluation methodology

It was decided that observations and informal interviews would be the best method for establishing the initial success of the visualisations. While many of the issues that had arisen while deploying at the site had been unanticipated, it was recognised that a level of flexibility would need to be maintained so that the existing work practices of archaeologists on-site were respected. As a consequence, any kind of evaluation that resembled a lab study was ruled out, as this would present a restriction to the archaeologists fulfilling their daily schedule.

Observations were made of the archaeologists while viewing the display. The observer was located in the dining room, which provided a view of the display but was unfortunately too far away to accurately record discussions about the visualisations. It was however possible to record dwell time in front of the visualisations, and also how many people viewed the visualisations at one time. Informal interviews were also conducted with archaeologists throughout the duration of the deployment. In total 12 archaeologists were interviewed. Only archaeologists who actively wrote diaries were chosen for interview, and as a result the majority of the interviewees were field archaeologists, however those interviewed also included an osteo-archaeology specialist, conservator, team leader and database expert. As the archaeologists working on-site were under pressure to complete their work to schedule, it was decided that interviews would be conducted in the field rather than in close proximity to the display. This had the added advantage of offering a chance to ascertain how much information from the display the interviewee could recall. If the interviewee found it difficult to answer a question, the visualisations were provided on an iPad to aid with recall.

6.7.3 Results of the 1st deployment

The archaeologists typically preferred the networks to the matrices, and when interviewed would often describe interesting trends or patterns they had spotted. However there was also some suggestion that the network visualisation was preferred because it was perceived as being more attractive to look at, rather than because they felt they were useful.

In contrast to this, the adjacency matrices were often described as too complicated. Several of the interviewees suggested that the complexity of the adjacency matrices put them off engaging with the display, as they felt these were too difficult to understand at a glance, and they felt they would need a long time studying them, which they neither had the time or inclination to do so. One archaeologist, summarising the differences of opinion expressed about the two diagrams, said *"reading a map is easier than looking at a mileage chart"*.

One interesting observation was that there was a much greater chance that someone would stop in front of the display if someone else had already paused in front of it. A conversation would also often result from this behaviour, suggesting that the visualisations had the potential to promote conversation between the archaeologists.

When interviewed about the display, many of the archaeologists suggested that they liked the idea of being able to discover what others were working on or who to talk to about a particular topic. The displays also had a positive impact on the number of diary entries that were created by the archaeologists, in part so they could see their data on the display, but also to increase the size of dataset to better represent their activities on-site.

One positive aspect to the visualisations revealed by the interviews was that the archaeologists appeared to appreciate being directed to speak to other archaeologists they did not directly engage with on a daily basis. However the archaeologists only described their intention to speak to these archaeologists in the interviews, and had not directly engaged with them as a result of seeing the visualisations. A couple of the archaeologists also suggested that the information depicted in the display would be especially useful for the orientation of new archaeologists to the site, as the diagrams, and the network visualisation in particular, accurately depicted many of the working groups on-site, and could suggest who to speak to regarding a particular subject or area of the site.

There was initially a large amount of interest in the visualisations from the archaeologists when they were first made available to the archaeologists on-site, and most stopped in front of the display screen to study the visualisations. Unfortunately however, when the data was updated, there was noticeably less interest in the display. This might suggest a novelty factor played a significant role in motivating archaeologists to interact with the visualisations. However, archaeologists did return to the display after the informal interviews were conducted, suggesting that conversations about the visualisations might also increase further engagement.

Other concerns that were raised with the visualisations included that they only represented the users who write diaries, and that the archaeologists who wrote the most diary entries were over-represented in the data. Another suggestion from archaeologists who were at Çatalhöyük for their first time, was that references to archaeological features and specific users were only relevant to seasoned excavators. There were also demands for greater transparency regarding how the diary data was used to create the visualisations depicted on the screen.

6.8 2nd deployment at Çatalhöyük

In order to overcome the issues identified in 6.6.3, it was decided to return to Çatalhöyük the following year to evaluate whether a revised visualisation could address these.

6.8.1 Methodology

For the second deployment, it was decided to remove noun- and adjective-pairs from the analysis, and instead to focus on the most frequently occurring keywords, selected from the corpus using a technique known as TF-IDF. The TF (term frequency) is a measure of how often a word appears in a document, similar to the keywords extracted from the diaries. The IDF (inverse document frequency) measures how rare this word is within the corpus, or in this case, the diaries. A script was written that calculated the TF-IDF for each keyword used by each diary author, and then the highest TD-IDF values (the most frequently used keywords, unique to an individual) were used to create an individual visualisation for each user (see example in figure 6.5). By using a simpler approach to processing the diary corpus, It was hoped that this modification would address archaeologists concerns relating to the transparency of methods used to generate the visualisations.

The revised visualisations were again created in GraphViz using the network layout, however this time both archaeologists and keywords were displayed as nodes, with archaeologist nodes connected to one another via shared keywords. The number of links between nodes, and the style in which they are depicted, was simplified in order to aid interpretation. Once rendered in GraphViz, the visualisations were exported into Adobe Illustrator, where the legibility of the text and visual appearance was improved, addressing another concern raised by archaeologists viewing the visualisations in the first deployment.

Figure 6.5: Example of a keyword network visualisation shown at Çatalhöyük during the 2nd deployment.

6.8.2 Evaluation methodology

The second deployment was run over four days. A video camera was located next to the display, and filmed the area in front of the display constantly for two days. The evaluation of the second deployment was conducted using video analysis of the archaeologists engaging with the display.The evaluation consisted of two measures, dwell time in front of display, and a qualitative analysis based on the conversations archaeologists were recorded having in front of the display.

Filming interactions in front of the display allowed a measure of 'dwell time', the time archaeologists spent in front of the screen, to be recorded. Time was recorded from when an archaeologist entered the frame to look at the screen, to when they exited the frame following the interaction. If multiple archaeologists engaged in an interaction with the display, then the timer ran from when the first archaeologist entered the frame until the last archaeologist exits the frame (the complete duration of the interaction). Dwell time was also logged in respect to group size, so that comparisons could be made between individuals and groups.

Conversations in front of the display were also filmed, transcribed and utilised (alongside dwell time) to gauge the effectiveness of the display. By minimising the experimenter's presence while the audience was viewing the display, this reduced some of the biased responses (occurring from the demand effect) which might have occurred in the interviews from the first deployment.

6.8.3 Results of the 2nd deployment

On average, individuals spent 47s in front of the display, with the shortest 12s and longest 2m 20s. Throughout the revised intervention, numerous conversations occurred in front of the display. For groups standing in front of the display, the average dwell time was 2m 3s, with the shortest being 21s, and the longest 5m 37s. It is clear from this data that archaeologists were spending a much larger amount of time in front of the display than originally anticipated. Furthermore, it is clear that discussions that taking place in front of the display dramatically increase the time that archaeologists spend in front of it, doubling it on average.

Another unexpected consequence was the emergence of a new, playful interaction with the diaries, with the goal of purposefully manipulating the visualisation. Because a visible link between the writer and keyword had been established, several archaeologists purposefully wrote multiple diary entries containing a word or phrase they wanted to see on the display in the hope that the keyword analysis would pick this up. This action encapsulated a number of playful elements: deliberately adding a word to an entry without it being obvious the purpose of the diaries was being subverted, friendly competition among the archaeologists as to who could get their words to appear first on the display, and further engagement with the display through conversation with colleagues once their word or phrase had appeared in the visualisation.

Unfortunately, the video analysis also revealed that a number of archaeologists expressed negative feedback about the revised visualisations. Primary among these was dissatisfaction with the words used to link the archaeologists together, which were not seen to provide any interesting information about that relationship. This could be interpreted as a criticism of the technique used to extract the keywords. However it might also be an indication that the archaeologists had reservations about being linked in this manner, as this feedback presents a complete contrast to the feedback from first deployment, where archaeologists were linked using a similar method but the words linking them weren't revealed, and they expressed a strong preference for this type of visualisation.

6.9 Summary

The chapter outlines how, based on several design implications derived from the field, two interventions were designed and evaluated with the aim of capturing archaeologist(s)' conversations at the edge of a trench in order to benefit their awareness and communication while working in the field.

Unfortunately audio transcription presents a difficult technical challenge, so diary entries were used as a proxy for these conversations. Data processing was done using NLP and the NLTK, based on methods described by Dearman (2010). Finally, visualisations were created based on this data to be displayed on a small ambient display.

The visualisations were deployed at Çatalhöyük, and while they did promote more conversation, the archaeologists found some of the visualisations complicated and difficult to interpret, and also criticised their lack of transparency.

Consequently, a second deployment was developed based around keywords extracted from the diary entries using TF-IDF. Archaeologists spent a large amount of time discussing the visualisations, and they also appropriated the displays for playful interaction. However, some of the archaeologists did not find the visualisations useful and did not understand how they might be of benefit to them.

6.10 Further work

Based on these interventions, a concept for a novel technology is proposed, based on a small, mobile device that would capture audio from the edge of a trench, process this data and visualise the filtered dataset on an ambient display to improve awareness and encourage conversation. Referred to as 'audio pegs', this concept derived from an attempt to combine small audio recording devices with pegs archaeologists typically place in the ground at an excavation to create a grid that aids recording.

The purpose of these pegs would be to examine whether archaeologically relevant conversations could be captured and shared with the entirety of an excavation team, with the aim of improving awareness and stimulating conversation. It is hoped however that archaeologists will be amenable to augmenting their excavation space with these pegs as they are a tool archaeologists are already familiar with using. It is also believed that pegs, which can easily be moved from one location in the ground to another, have good potential for re-appropriation by the archaeologists.

6.10.1 Design challenges

One significant problem that arises from this concept is how to balance capturing all the audio from the trench (which offers archaeologists the least privacy and would result in a large amount of data being generated) against reducing the audio capture to a point where important conversations could be missed. Numerous options were considered including activating the recorders via voice and proximity, and by offering control of the recorders to the archaeologists.

Even when heavily filtered, it is anticipated the intervention will capture a large amount of audio data. In order to extract information of interest from this audio, it would be advantageous therefore to first transcribe the audio data into textual data. Recent advances in computation and natural language processing make this possible, and the widespread availability of open-source libraries and resources for natural language processing make the design of a prototype easier.

Once the audio is captured, transcribed and processed to identify useful information, this data needs to be conveyed to the archaeologists on-site. It was felt that the most appropriate way to do this would be through a visualisation. Archaeology has recently seen an increased interest in the use of mobile devices for both accessing and capturing data on-site. This development is perhaps unsurprising given the increased demand for consumer technologies such as tablets and smartphones. However, the willingness of the archaeological community to adopt these devices opens up a new range of interactions with technology that are possible in a fieldwork setting, especially in situations where in the past laptops have not been appropriate.

6.10.2 Final concept

A conceptual design is therefore proposed for a system where conversations between archaeologists are captured, the audio is transcribed and processed (using techniques such as natural language processing) and the resulting data then visualised in the form of an ambient display (either on a shared display or on an individual’s mobile phone or tablet) to increase awareness (figure 6.6).

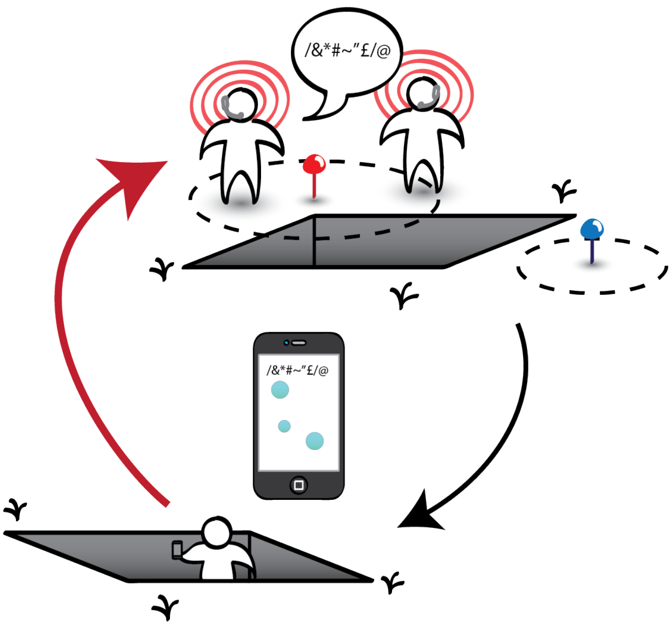

Figure 6.6: Diagram showing the path of information created via the technological intervention

Chapter 7: Discussion

At the beginning of the thesis, it was suggested that the development of archaeological computing has lead to a focus on digital technologies that support the acquisition and management of archaeological data. In chapter 3, a number of reasons for this were identified. The main reason for this trend is likely due to emphasis archaeology places on the primary record. The data captured provides a new record, and concerns regarding the fidelity and preservation of this data drive technological development.

However, the thesis also identified a number of other reasons that might be attributed to this trend, such as historical development of archaeological computing which in its early years had a strong focus on statistics and data analysis. Technological limitations also may play a role, as written or textual data is easier to display and input into a device than other, richer forms of media.

Archaeologists may also choose to optimise the time available to them in the field by focusing on data capture. If they are limited in terms of time and money, archaeologists might choose to focus on recording so they can postpone analysis until they are back at their home institution or laboratory. Finally, as the results of the VERA project demonstrate, archaeologists are more likely to adopt novel technologies that resemble the traditional tools and methods they are familiar with.

Establishing the possible motivations behind this trend is significant because it highlights many positive reasons for archaeologists to continue developing and appropriating digital tools to assist them with the capture and management of archaeological data. However, by conducting field studies at several different locations, the thesis also identified a number of reasons as to why developing technologies based around other motivations might be of equal importance to the archaeological community.

The observation of archaeologists working at Portus, Pompeii, Chester and Itchen Abbas all highlighted that more often than not, interpretation occurs when archaeologists are standing up, with a vantage point away from the archaeology or at the edges of a trench. This is significant, because identifying a moment in the excavation process where there is a greater probability that archaeologists are discussing their interpretation, such as when they are on the edge of a trench, opens up opportunities for 'capturing' that interpretation via technological means. It also suggests that an archaeologist's position in and around the trench could potentially be used to reveal the activity they are currently engaged in, an important consideration when building a context-aware system.

It was also found that if presented with an opportunity, archaeologist would engage in behaviours such as moving around the site or talking with others in order to obtain a better holistic understanding of the excavation. The amount of time that archaeologists spent away from their own trench while talking with colleagues and looking into other trenches at Portus and Chester suggests that having an awareness of the entire archaeology of a site is not just something that is desirable but fundamental to field archaeology.

Through awareness and communication, archaeologists are empowered with contextual knowledge. This allows them to more confidently interpret the features they are excavating, and to make a greater contribution to the overall interpretation of the site. When archaeologists work in isolation, they feel they are engaged in unskilled manual labour (Everill, 2008). However, when allowed to talk with their colleagues and contribute to the collective understanding of the archaeology, they become much more engaged and involved.

Furthermore, the field study at Itchen Abbas suggests students would have even more to gain from improving their awareness. It was apparent from the deployment that supervisors often find it difficult to simultaneously teach students and to keep abreast of the latest archaeological developments across the site. Students can achieve awareness through a site tour, but this depends on the excavation having a conscientious director or supervisor to facilitate this, and them having the time to do so. Raising students' awareness of one another's activities and of the latest interpretations of the site by using digital technologies could build their confidence, reassure them that they are engaged in the correct activity, and alleviate some of the pressure from the supervisors.

Increasing archaeologists' awareness results in better-informed archaeologists, and therefore reduces the need for direct supervision. This would mean that archaeologists could be deployed based on their strengths and not on their previous experience as a supervisor or manager. This potentially disruptive effect to the social hierarchy could have other benefits, such as allowing supervisors and specialists to focus their attention where it is needed most. Specialists could also better optimise their often limited time on-site, and prioritise where their advice is given, by, for example, suggesting correct sampling procedures before archaeological features are excavated.

The technological interventions at Çatalhöyük presented further evidence that archaeologists will spend time improving awareness where possible, as the time spent in front of both displays was considerably greater than expected. Designed as ambient displays suitable for spending only a short time in front of, it was surprising to see archaeologists spending large periods of time exploring the visualisations and discussing them with their colleagues.

The field study conducted at Pompeii suggested that technology could create shared points of reference for conversations, improving communication across the team. This was again shown at Çatalhöyük, where archaeologists in groups would spend far longer in front of the display than those looking at them alone. The display also provided a focal point for new conversations, with archaeologists joining an individual or group if they observed them standing in front of the screen.

Feedback from both the first and second deployment at Çatalhöyük suggested that archaeologists reacted negatively to the content of the visualisations because they didn't understand how this was generated from the diary entries. Because archaeologists spent more time in front of the displays than expected, these findings might suggest that an ambient display was not the best method for displaying the visualisations at the excavation. Instead, an interactive display, which might allow archaeologists to explore the dataset underlying the visualisation and act as a starting point for deeper conversations, would seem to better suited to supporting the behaviours observed at Çatalhöyük.

The surprise discovery that archaeologists were re-appropriating the intervention in the 2nd deployment in a playful manner hints at an interesting way to encourage adoption among archaeologists. As Everill (2008) indicates, camaraderie is valued more among archaeologists than workers in other professions, as it provides a way to deal with the often-tedious work and poor working conditions archaeologist's face on a daily basis. A technological intervention designed with playfulness in mind might both avoid the issues around the adoption of the new technologies identified by the VERA project, and help archaeologists to bond, communicate and collaborate.

Chapter 8: Conclusion

8.1 Overview

In the introduction to the thesis, it was suggested that the development of archaeological computing has lead to a focus on digital technologies that support the acquisition and management of archaeological data. In chapter 3, after reviewing the history of the development of technologies for archaeological fieldwork, a number of reasons for why this trend may have occurred were identified and discussed.

Following this, the results of ethnographic field studies conducted at four excavation sites are discussed. These studies explored how archaeologists communicated on-site, their awareness of one another's activities, and their work practices around existing and novel technologies. The results of the ethnography are followed up with a technology probe conducted at a field school at Itchen Abbas, UK. The findings from these studies were subsequently used to derive design implications for a novel technology aimed at improving archaeologists' awareness and communication when working in the field.

These implications informed the design blueprint for a prototype technology, which was then built, deployed in the field, evaluated and iterated upon, with a final evaluation also conducted in the field. The first deployment at Çatalhöyük was found to promote conversation, however some archaeologists found the visualisations complicated and difficult to interpret, and also criticised their lack of transparency. A second deployment was therefore developed based around keywords extracted from the diary entries using TF-IDF. Archaeologists spent a large amount of time discussing the visualisations, and they also appropriated the displays for playful interaction.

The findings from the ethnography, technology probe and deployments all highlight the importance communication and awareness have in the success of an excavation. They also support the idea that technology could have a role in supporting this. Through awareness and communication, archaeologists are empowered with greater contextual knowledge. They may also become more engaged with the excavation and make a greater contribution to the overall interpretation of the site. Students' may benefit from this in particular, however supervisors and specialists could also benefit by having more time to focus their attention where it is needed most.

8.2 Limitations

As outlined at the beginning of chapter 6, the intended design of the intervention was limited by the accuracy of machine-based audio transcription, and therefore had to be replaced with an appropriate proxy. While the diaries used for this purpose proved to be an adequate replacement for the purposes of the NLP processing, it is likely that a very different visualisation would have resulted from having conversation data as the input into the system.

This also meant the intervention could not explore issues around privacy and the willingness archaeologists would have shown towards having their conversations captured. It is possible that archaeologists at Çatalhöyük may have been more accepting of the intervention if they had directly inputted data into the system via conversation on-site.

8.3 Future work

There are numerous ways in which the work in this thesis could be taken forward. One of these would clearly be to take the knowledge gained from the intervention conducted at Çatalhöyük and use it to design an intervention based around the edges of trenches, as suggested in the research from chapters 4 and 5. The concept of audio pegs might be one such intervention, however it would be interesting to examine the potential of other location-based technologies, especially given the proliferation of GPS in modern mobile technologies.

The deployment at Çatalhöyük also failed to explore any of the issues that might be raised by recording archaeologists conversations. As highlighted in chapters 4 and 5, archaeologists will often have conversations about the archaeology at the trench edge, and capturing these could prove useful to the recording and interpretation of a site. However, recording conversation raises issues around privacy, and also with how to process the data collected. Therefore, an intervention which explores these issues further and ascertains whether audio captured on-site could be useful to archaeological interpretation is considered worthwhile is recommended.

However, the deployment at Çatalhöyük also raises other interesting topics for future work. One idea would be to explore the potential of an interactive version of the visualisation, which would allow archaeologists to further interact with and explore the data behind them. Despite being designed for 'ambient' viewing, both deployments demonstrated that the visualisations were viewed by archaeologists for much longer than anticipated, and this therefore opens up the possibility of archaeologists engaging in a much deeper and more meaningful way with the dataset than previously assumed. Allowing archaeologists to explore the data, improve their awareness and discuss the latest diaries/conversations, would also present the most direct way of addressing the criticisms raised in the first and second deployments.

It would also be interesting to explore how the form-factor of the deployment influenced archaeologists interpretation of it. Archaeologists working in the field are unlikely to have such a large and well-equipped site hut as the one located at Çatalhöyük, so a deployment that was instead designed to be viewed on a tablet or mobile would perhaps be more appropriate and also viewed in a completely different manner, especially as it would be competing for the same time an archaeologist would usually spend excavating.

The second deployment also recognised that archaeologists re-appropriated the system in a playful manner. This is particularly relevant given the findings of the VERA project, which demonstrated that a resistance to and pessimistic view of new technologies can often be a significant barrier to adoption among archaeologists. Therefore, it might be worth engaging in further work to explore whether technologies purposefully designed to encourage a playful type of interaction could overcome this barrier.

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Appendix A Ethics

The research described in this thesis is covered by all appropriate University of Southampton ethics procedures. For the field trials the first application has University of Southampton ECS ethics ID: 3030. After modification another approval ID: 6991 was gained. The thesis was also supported by a separate ethics application for the lab studies of the visualisations: original: 2471, first revision: 2471, second revision: 9036. The MPhil also relates to two applications for PoN (the provenance note taking application developed in parallel to this work). The IDs for those are: 3375 and 3374.