Dingwall, L., S. Exon, V. Gaffney, S. Laflin and M. van Leusen (eds.) 1999. Archaeology in the Age of the Internet. CAA97. Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 25th Anniversary Conference, University of Birmingham, April 1997 (BAR International Series 750, CD-ROM). Archaeopress, Oxford.

Mobile Computing for Real Time Support in Archaeological Excavations

Massimo Ancona, Gabriella Dodero, Vittoria Gianuzzi, Carlotta Fierro, Vincenzo Tinè, Antonella Traverso

Abstract

The paper presents a joint ongoing project between archaeologists and computer scientists at the University of Genova. The goal of the cooperation is the development of a hardware/software integrated system to be applied to stratigraphic excavation; such a system is based on two new technologies: wireless mobile computing and pen-based man-machine interfaces.

1 Introduction

Modern field archaeology is now employing various methodologies for analysis and retrieval of research results. Computers are increasingly used, for cataloging stratigraphic data and finds (Stratigraphic Unit records), for photogrammetry and topography, and for teledetection (from satellite to low flights).

Various computing technologies and tools have been investigated for their usefulness in field excavations, such as DataBases, CAD, GIS, Remote Sensing. They have proven largely applicable and allow a significant increase in quality and quantity of a posteriori data analysis. Several programs exist which support the archaeologists' work off-line, during the data analysis phase, and the development of Internet provides an easy way for remote database access. This is obviously possible in every university or museum laboratory. On the other hand, fewer tools have been made available to support field work (e.g. the French system SYSLAT); and real-time cooperation between field scientists and those at Universities, museums etc. is still to be achieved.

Present technologies such as the above offer a limited support to site excavation, since the most widely used hardware and software configurations cannot be installed close to the excavation site. Thus, the time and place where archaeological data is collected is far from that of computer data entry and analysis. Moreover, communication possibilities such as those currently offered by Internet and related services such as email are not currently available in the field.

The consequences of both data processing delay and lack in communication could become relevant. Since the duration of an excavation campaign is limited, and transportation costs are significant, it is important to take the right decisions on the spot, with the availability of archaeological databases and possibly consulting specialists who are in some far away museum or university. At present, contextual analysis of finds in the field cannot rely on adequate computing support, which is usually available at later phases only, that is during the synthesis phase.

The project described in this paper aims at reducing this gap as far as possible by making use of wireless mobile computing. The project results from interdisciplinary cooperation among archaeologists, architects and computer scientists, and it takes advantage of combined advances in computer technology, such as wireless communication and computing, together with visual programming. Portable communicators, such as palmtop computers, can now provide sufficient electric power to computing peripherals by means of accumulators of reasonable weight. Such tools provide advanced user friendly interfaces based on electromagnetic or passive pens which "write" on shock-proof liquid crystal screens. Mobile computing is a challenging technological field, where advances in telecommunication and improved software for handwriting recognition should be expected in the next future, so as to increase their availability. Applications to field archaeology constitute an advanced testbed for experimenting with these new technologies as well as for design of innovative visual software.

In the next Sections we shall introduce two technological innovations being employed in the project, that is wireless mobile computing and pen-based man-machine interfacing. Then, we shall discuss how software to support field work can be designed, and what use can be foreseen for it.

2 Wireless computing

Advances in cellular communication, wireless LAN and satellite services will soon support an increasing number of *mobile users,* as described in (Imielinski and Badrinath 1994). In the near future, millions of people will connect to information sources while moving for their job by means of their *personal digital assistants*. These devices provide the computing power of a workstation in a smaller, lighter package called the *palmtop or hand-held computer*. Several applications can be executed on devices such as Hewlett Packard's HP100LX, Apple Newton and AT&T's EO. Communication is supported by infrared light, high-speed radio or cellular phones.

The main obstacle to a wide use of mobile computers is the accumulators autonomy, which does not allow for transmissions to be "long", either in time or in distance. Users should operate disconnected for most of the time, and man-machine interaction software should be designed so as to minimize transmission time. Mobile operators must operate locally as much as possible, and network connections should take place as fast transactions; otherwise the weight of accumulators should significantly increase. A strategy for effective interactions is the basis for each successful application.

The smallest among mobile units are diskless, in order to be powered by small accumulators; more powerful units can store information on disks, and their weight and size (as well as computational resources) approaches that of a laptop computer. Compared to laptops, the gain is thus in wireless connectivity to information networks.

A typical mobile network is sketched in Figure 1. Three different entities can be identified: mobile computers (labeled mu), mobile support stations (labeled MSS) and fixed hosts. MSS units are workstations with wireless communication interface towards mobile computers, and possibly another interface (wireless or cable) towards a WAN such as Internet.

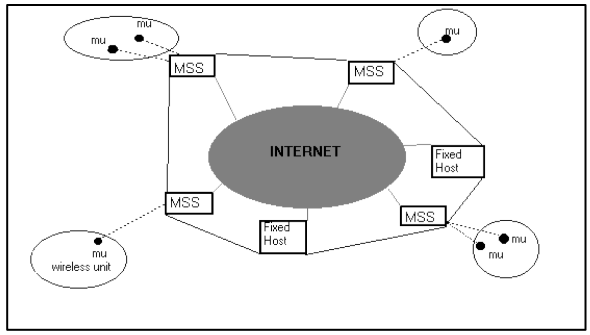

Figure 1: Connecting mobile computers to the Internet.

3 Pen-based computing and visual programming

Palmtop computers cannot input from keyboards for reasons of space and weight; instead, the user interface is based on a pen. A pen replaces the mouse (or other pointing device) in menu-driven software; when a complex command or a text has to be input, some handwriting recognition software has to be used. Such software should recognize at least block letters; of course, advances in recognition techniques are always welcome by users.

This technology, to which an introduction can be found in (Jerney 1994), has been introduced to the market some time ago, among great expectations on the users side, followed by corresponding disillusions for the limited possibilities offered by commercial systems. In retrospect, pen-based computer users now constitute a specialized market niche, that of applications for which these devices cannot be substituted with laptops etc., in contrast to early forecasts where palmtops were assumed to substitute keyboard-based input in all situations (business as well as home). In other words, whenever the keyboard is suitable for input, no pen based device is going to replace it. Ten years from now, voice input should be the primary substitute for keyboards; thus mid-term forecasts for pen-based computers look at their future in the communication field. Notes and sketches can be taken easily with a pen, and they will always represent a primary means for communication among individuals. The application to field archaeology which we are designing is thus best suited to pen-based input as opposed to trackball-mouse interaction.

Applications for palmtops are developed by means of *visual programming*. This technology has been designed to make applications development possible to all users, even those without specific programming knowledge. Visual programming employs graphical information, such as diagrams, sketches, icons and graphical manipulations to describe an algorithm. Related concepts are that of a Visual Programming Language (VPL) (i.e.a programming language whose syntax contains the above non-textual elements) and a Visual Programming Environment (VPE) (that is a programming environment providing visual-based support for some language, which could be a VPL or not). Examples are provided by (Burnett and McIntyre 1995) and by (Repenning and Summer 1995).

An example of VPE which could be useful in applications such as the one we are going to describe is the PenRight software, described in (AST Research Inc. 1993), which allows the design of graphical user interfaces in C or C++ by means of a graphics library, and also allows guided handwriting recognition (i.e. writing block letters in rectangular grids).

4 Mobile computers in field archaeology

Field archaeology is an extremely hostile computational environment. A computer should operate in the field, in the open air, in all possible weather including heat, dust and rain. In contrast to what might happen in urban areas, electric power supply and telephone cable connections is seldom possible on the site: no wires can cross the site, but there might be a nearby building (where archaeologists live during the campaign) where such facilities could be found.

It should be noticed also that a campaign is usually very limited in time, and that a large part of excavation is done by qualified personnel, coming from University or Museum research units, rather than by local, less-qualified personnel. The latter consideration focuses on the aim of optimizing the archaeologist's work in the field, where there is usually a time-wasting delay between excavation and the study of finds. The palmtop computer may provide a good substitute for the diary, where notes and sketches are taken hour-by-hour as excavation proceeds.

Let us now introduce mobile computers in the above scenario. The proposed system consists of a workstation, and two or more mobile computers connected to the workstation by radio devices. The workstation is installed in some building close to the excavation site, and it is connected to Internet by telephone cables or satellite (note 1). Mobile systems provide pen-based input, and support local computations (data acquisition and preliminary analysis) as well as remote computations, which result as transactions on the workstation. Remote computations include data base queries, comparisons with previously entered data, contacts between mobile computers and scientists in the nearby or remote areas and anything else which could be done by means of Internet. The mobile computer is thus a mean to extend the archaeologist's diary with real time communication possibilities and data base automatic updates.

Transmitting a sketch or a snapshot of interesting finds, and comparing it with an image database of similar finds in the same or related area; or sending it to a colleague asking for his/her opinion and receiving almost immediate feedback: situations like the above ones may significantly reduce delays and make the excavation campaign much more productive.

Let us examine field work in more detail for a better understanding of how mobile pen-based computers may support it. Archaeologists usually bring their diary into the field, where they collect daily notes. These notes are later copied to standard forms (such as those supplied by the Italian Ministry of Cultural Heritage). Usually the site is not connected to the computer center, so all daily work is transcribed and elaborated after the daily work, many hours later, when the archaeologist is back in the lab. When a database or a colleague has to be consulted, to collect additional information, or to analyze data, snapshots or finds, before a decision on how to proceed is taken, someone has to physically travel to or from the site.

Mobile computers, as said before, may perform two functions: on site data entry, as soon as finds are identified, and data processing possibly by remote connections.

4.1 Data entry

The excavation site is usually marked by a regular, square grid (approx. 2-3 meters each edge) identifying areas to be excavated. Each square in the grid is separately considered and in turn it is subdivided into smaller sections (approx. 30 cm. each edge), by means of strings. This subdivision allows easy identification of the exact position of finds at the current level. The current level is inspected, removed earth is sieved, and finally the fine grid is remapped at the next lower level. When current level is lowered, track is kept of the previous one by marking its orthogonal projection to vertical sides of the excavation: thus, we end up with a vertical grid too, in order to be able to identify finds proximity in 3D space.

Finds at each level are cataloged and then separately stored in boxes (one per square and level in the large grid). Information to be kept for each find are:

1. spatial information: its position in the tridimensional grid and its size;
2. additional spatial details (if needed): the shape, by means of a sketch or snapshot;
3. classification: possible material, colour traces, status and so on;
4. additional data (to be determined later): possible origin and period.

We then have to collect both textual and spatial information.

Textual information is locally collected on the palmtop computer by means of selectable menus, or by handwriting (if a few letters or numbers are sufficient). Menu-based classification is thus strongly recommended.

Visual information may consist of sketch creation and retrieval, find positioning in the 3D grid, spatial relationships to other finds such as on-top-of, and association of sketch to related textual information. The availability of special purpose software on top of a drawing system would be useful. Each find can be sketched on the screen of the palmtop by means of the magnetic pen; it can then be measured and related to the grid, measuring its distance from grid edges. The sketch can also be automatically adapted to measures once they have been taken (e.g. zoomed, rotated, stretched,...) for a more realistic appearance.

The use of a graphic-based object-oriented system such as that described by (Ancona and Nieddu 1992), allows the separately manipulation of each object (find), which encapsulates all relevant attributes as defined by the archaeologist. Each object may also be spatially and thematically related to other objects, by linking them with distances and comparing attributes, in order to be able to recall them on the screen.

At the end of each working day, and at the end of the campaign, all acquired data is downloaded to the central workstation and automatically inserted in the site database. Each new object is related to and eventually linked to other existing objects. Further analysis is then possible: for example thematic 3D maps of the site are automatically updated with new finds, as soon as they are cataloged.

4.2 Database query

The above presentation is centered around the advantages given by a palmtop computer in a site. We shall now examine in more detail what facilities are given by a mobile unit, that is by communication to the central workstation and through it to other networked computers. The latter features become extremely important whenever in a "traditional" excavation campaign, work should be temporarily suspended, or slowed down, until new information is collected and new directions for further excavation are derived from it.

A typical example could be that of a find whose significance is given by contextual information (other finds from the same site), which may influence future excavation in the site. For example, various pavements of the same kind in different areas of the site may suggest the existence of a road connecting them, so that it may be important to look at intermediate grid positions where the road may still be hidden. In this case, immediate communication (through the fixed unit) among people in different areas of the site may allow an immediate update of current situation.

Another example is the assessment of relevance of an object which cannot be related to other finds in the local site database.The opinion of an experienced person, whether at the fixed station or remotely accessible at some museum, has to be consulted before taking further decisions. A digital snapshot (taken with a digital camera) may also be sent with the message/query. Searching non-local databases may also be needed: this latter feature is however limited by the availability of computerised data and compatibility in the internal organization of different databases. In the future, this problem as well as that of making graphical queries, could well be solved.

5 Conclusions

This paper presented how wireless communication technology, as nowadays available inside a palmtop computer, may be integrated with man-machine pen-based interaction, in order to develop field archaeology support tools. Application scenarios in field archaeology have been examined comparing present with future situations.

Innovations in this project include:

1. substituting handwritten notes, sketches etc. in the field and eliminating computer data entry and post-elaboration by means of a single integrated system;
2. real-time communication by means of a fixed workstation located close to the site: communication to/from the workstation, among mobile computers in the site, and possibly over a WAN;
3. use of object-oriented technologies for finds storage and retrieval, on the mobile computer as well.

The project results from a cooperation among DISI, the Department of Computer Science of the University of Genova, and ISA, the Institute for Archaeology and History of Ancient Arts in the College of Humanities. Researchers from both institutions have been investigating the feasibility of an information system for field archaeology; as a result the system described above is now being prototyped. The end-user for such a system is the Italian Archaeological School in Athens, which has been responsible for more than 60 years of campaigns in the site of Poliochni, in the Greek island of Lemnos (see Tinè *et al* 1997) for archaeological references). Funds for supporting such efforts have been given by CNR, the Italian National Research Council, within the three year national project "Cultural Heritage" (1997-1999). Demonstrations of the first prototype are planned for end of 1997.

Note

1 To give some figures taken from specifications of existing systems, a mobile computer may connect directly to the fixed host within one mile distance; for longer distances, or to overcome obstacles like hills, repeaters (i.e. antennas) should be installed.

Bibliography

Ancona, M and Nieddu P, 1992 A Trip to Object-Oriented Land, *The Euromicro Journal*, 35, 195-202

Burnett, M M and McIntyre, D W, 1995 Visual Programming, *IEEE Computer*, 28(3), 14-16

Imielinski, T and Badrinath, B R, 1994 Wireless Computing, *Communications of the ACM*, 37(10), 19-28

Jerney, J, 1994 Mobile Insights: the Bright Future of Pen Computing, Pen-based Computing, *The Journal of Stylus Systems* (electronic version)

AST Research Inc., 1993 *Penright! Pro API Reference Guide*, Fremont, CA

Repenning, A and Summer, T, 1995 Agentsheets: A Medium for Creating Domain-Oriented Visual Languages, *IEEE Computer*, 28(3), 17-25

Tinè, S, *et al* 1997 Poliochni 1991-1995. I nuovi dati, *Monographies Scuola Archeologica Italiana di Atene, Roma*, L'Erma di Bretschneider, in press

Contact details

Massimo Ancona[1], Gabriella Dodero[2], Vittoria Gianuzzi[3]
Dipartimento di Informatica e Scienze dell' Informazione
Universitá di Genova
V.Dodecaneso 35, Genova 16146
ITALY
[1]e-mail: ancona@disi.unige.it
[2]e-mail: dodero@disi.unige.it
[3]e-mail: gianuzzi@disi.unige.it

Carlotta Fierro, Vincenzo Tinè, Antonella Traverso
Instituto Scienze Archeologiche e Storia dell'Arte Antica
Università di Genova
V. Balbi 4, Genova 16126
ITALY