RAMSES: a mobile computing system for field archaeology

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Abstract. RAMSES (Remote Archeological Mobile Support Enhanced System) is an outdoor application of mobile computing to field archaeology, whose prototype has already been field tested in Summer 1998 at the site of Poliochni in Greece. The requirements for both hardware and software are illustrated; the system is composed by a fixed station, acting as object repository, and a few mobile units which input archaeological evidence by means of electromagnetic pen. The software components on both fixed and mobile systems and their interaction are described as well.

Topics: Handheld, wearable and environment-based appliances, Linking virtual worlds and physical worlds, Applications in arts and entertainment.

1 Introduction

When people like computer scientists think about archaeologists, the first character that strikes their mind is Indiana Jones, or, if you prefer, the figure of some old, wise gentleman with colonial hat on. Reality is quite different: working outside the civilized world is no way easy or funny. Moreover, the introduction of high technology in hostile environments (rain, cold, dust, heat etc.) today is still a challenge not simple to win.

From an engineering point of view, one of the main problems in Field Archaeology today is COMMUNICATION. If you search for tools or systems that can help archaeologists to locate new working areas or catalog thousands of objects, you can find a lot; but if you think of time spent between site excavation and publication of results (the head and tail of every archaeological research) you realize that a large amount of time is wasted for people in main digging camp to wait for return of their colleagues bringing finds from the field.

Let's see an example: we find a good place for excavations and we start to dig. When we find something interesting, we have to:

⋆ locate where the find is: its bidimensional coordinates and depth; its relative position with respect to neighboring finds;

⋆ draw a realistic sketch and take a note of color, material, possible use and

dating if already known;
⋆ if the find is significant, even critical for further excavations, it could be great to have a system that allows us to communicate our discovery to other scientists at base camp, sending them its description, drawing or snapshot in real time;
⋆ in case of doubt, a comparison with other finds from the same area in previous campaigns, or from related areas, could be extremely useful.

At the end of the working day, and at the end of the campaign, all collected finds and the notes accompanying them must be analyzed and reorganized to fill the report forms and to make what has been found available to other scientists, possibly in electronic form on a site data base.

Today, such an integrated computer based system doesn't exist yet, if archaeologists have to communicate about latest finds, they are forced to leave the excavation site and go back at least to the camp (or they give up the idea of communicating, and store the finds for later show). Well, the aim of RAMSES project is the development of that system.

At present a prototype system is already working, using a network of mobile, pen-based computers which allows archaeologists to communicate in real time, from the excavation site, not only with text, but also with drawings, to other fixed hosts and to the rest of the scientific community (using a fixed host as a gateway to Internet).

The project results from a cooperation among archaeologists and computer scientists at our University, belonging to DARFICLET, the Department of Archaeology and Classical Phylology, and to DISI, the Department of Computer Science of the University of Genova. 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 [11]. In Summer 1998, the prototype has already been field tested in the island of Lemnos, Greece, at the prehistoric site of Poliochni by the archaeological team.

The next Section describes the main requirements for a network operating in an archaeological field. Then, the functions of the two main software components, respectively running on the mobile and the fixed system, are explained. Details on how data is exchanged between the two systems is also given.

2 Wireless and Pen-Based computing for archaeological fieldwork

Laptop computers, which support a stationary working environment at different locations (such as both home and office) may already provide some of the useful features in field archaeology [9], as stated in the Introduction.

However, to allow real-time communication (networking) from the site, true mobility is needed, with **wireless communication**, such as radio connections. In fact, in contrast to what might happen in urban areas, electric power supply and telephone cable connection is seldom possible on an archaeological site: no wires can cross it, but perhaps there could be a nearby building (where archaeologists live during the campaign) where such facilities could be found. High costs and low bandwidth/reliability tradeoffs have important consequences on how wireless networking is supported. Client/server program execution, distributed file systems and data bases are not trivially made available on a wireless network. Software challenges lie both in adapting and redesign of existing pieces of software, and in design of novel applications especially addressing needs of mobile users.

Mobility is not the only requirement for a network in the archaeological site. Like most other outdoor computing environments, field archaeology is an extremely hostile computational environment. A computer should be operational in the open air, in any possible weather including heat, dust or perhaps rain: most laptops are often non-operative under such conditions. The need of being used while standing (or in some uncomfortable position) puts additional restrictions on the use of keyboard, mouse or trackball for input. Last but not least, weight of the device (which is mostly due to accumulators) should be carefully considered.

These requirements can be met by a mobile computer, which inputs from **electromagnetic or passive pens** which "write" on shock-proof liquid crystal screens. A pen immediately replaces a mouse (or other pointing devices) in menu-driven software; when a complex command or a text has to be input, some handwriting recognition software has to be used. An introduction about this technology can be found in [6].

2.1 Wireless networking outdoors

There are several kinds of "networking" environments already (or soon to be) operative in the outdoors. They may rely on high-speed cellular communication, satellite services or, as in our case, on radiofrequency. The connection to a wireless LAN and the use of a mobile device introduces the concept of AirAwareness[10], i.e. the capability of being always on-line and having the access to information anytime and anywhere. In the next future, millions of people shall connect to information sources while moving for their job by means of their personal digital assistants, as described in[5].

The major infrastructures available for data communication are Analog *Cellular systems* and *Packet Radio* systems. Both have been discarded, for our application, however, due to some their features. These include limited system capacity and low data services (about 20 Kbps from a stationary user), too low to allow transmission of drawings and snapshots of finds. Moreover, since different protocols have been adopted by different states, it could be difficult to provide a software and a target system widely usable in every excavation site, without considering the possibility of having no connection service provided at all.

Technologies like *Dual Band GSM* or *Iridium* were already foreseeable when our project started (and are available now): they have been considered out of this project's interest because of the low bandwidth they too support. Satellite coverage of areas of archaeological interest is not easy found. For these reasons we investigated the radio frequency communication devices, taking into consideration the need of being operational (almost) worldwide without obtaining special permissions for frequency use.

Among Radio Frequency systems, we selected the *Frequency Hopping Spread Spectrum* Radio technology, which offers high speed (about 2Mbps) along with reasonably secure communication data links, low power consumption and a coverage radius of about one mile without repeaters. Moreover, no license is required, and its use is accepted also in military areas, so the equipment can be easily transferred into every excavation site. The distance/speed tradeoffs for our application were all in favor of speed, and the one mile coverage was considered sufficient for most sites.

The scenario of a mobile network within an archaeological field is thus as in Figure 1. Three different entities can be identified: mobile computer units (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. A wireless network consisting on one or more fixed workstations, and two or more mobile computers connected to a wireless LAN by radio devices, is sufficient for the needs of most archaeological excavations. The workstations are installed in some building close to the excavation site, and they are connected to Internet by telephone cables or satellite.

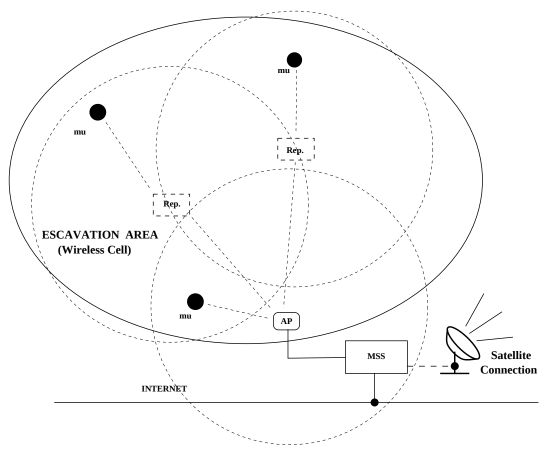

Fig.1 An archaeological site and its wireless network

Remark that in most sites a single support station is sufficient to support all MUs. It follows that we do not have the problem of locating the user unless in a very large site, which would require just a few fixed support units (see Figure 1). Even in this case, since archaeologists move by walking, MUs execute transactions while being relatively still. However, we may have a problem of elective disconnection[7], when the archaeologist is working in an inaccessible area (e.g., underground).

To this purpose, each MU has a large caching capability: it can support long periods of work without connection, thus a caching model is more suitable than a remote access model [1]. Remote access is relatively rare and only on specific user requests, where a peak of communication from the MU to the support station is needed. Typically, peak situations arise during remote data acquisition, that is in case a data acquisition device has been connected to the MU. Examples of such devices are GPS, a digital camera, or a metal detector (assuming the site includes metallic tools, coins etc. among possible finds).

The devices we are presently using are:

Palmtop computer Telxon PTC 1134 as mobile device; it runs Windows 3.x for Pen and the drawing tool has been developed using 16bit C++ and graphical libraries. The choice of such a development environment is motivated by the need to optimize tools performance on small configurations like the 16-bit one we presently have, while preserving upward compatibility for future expansions on 32-bit machines. The system is fully operational, mobile unites communicate on the network by using asynchronous message exchange (email messages) and emulated shared memory (shared directories and files).

Pentium based PCs, and DEC Alpha stations, running Windows NT and Lotus Notes operate as objects repositories (Lotus servers).

ARLAN Aironet Access Point which provides transparent wireless connectivity between the fixed station and one or more mobile computers. It incorporates industry standard IEEE 802.1d Spanning Tree protocol.

The choice of a 16-bit computer has been taken at project startup, in 1996, because of the high cost (at that time) of shockproof, weatherproof computers based on 32-bit CPUs. Even more significant is the limitation on disk capacity, which is 40MB, which obliged us to carefully select the operating system and support software. Thus, Windows for Workgroup was installed, instead of using a distributed technology like DCOM or Corba, which would not fit into such constraints. Obviously, in case further funds will be available for prototype engineering into a product, new versions of RAMSES will incorporate more advanced software support.

3 Archeo: the mobile archaeological system

Let us examine field work in more details for better understanding how mobile pen-based computers may support it. Archaeologists usually bring their paper and pencil diary in the field, where they collect daily notes. These notes are the most important, and often the only, means to record and eventually later reconstruct archaeological evidence, which is being excavated day by day. Off the field, diaries are used to extract the official archaeological reports, that is, a selected portion of their contents is copied to standard forms in order to document excavation results to the archaeological scientific community.

Several authors, like [8], consider location-awareness as an essential feature of mobile systems. RAMSES is not "location-aware", in that no GPS is connected to the mobile computer, and software is not monitoring current position. Field archaeology however requires to be aware of positioning, at various scales of resolution: these topographical information are input by the archaeologist to the system. The largest topographical unit to be considered is the *site*, an area of interest which has variable dimensions, usually very large ones as well. A site cannot be excavated at the same time in all of its surface; a selected portion of it where excavation activities are operational is called *test*. If possible, an interpretation directs a selection so that an unitary portion of the site is treated at the same time, such as a single building. It can be further subdivided into smaller units called *sectors*, whose size and shape may encompass further interpretation, e.g. a room inside a building, or may just be convenient portions of an interesting area. Inside a sector there may be several *stratigraphic units*, each of them being a convenient unit of archeological information and the basis for cataloging. A stratigraphic unit may have a volume by itself (e.g. a wall), or just be a profile or section (e.g. plain ground where several bones were found lying).

As interpretation of finds proceeds, stratigraphic units may be aggregated to form a structure called *archaeological context*, an example of which could be a small building, composed by the four walls delimiting it. Other relationships among stratigraphic units can be spatial (above, below, inside,...) sequentialization (referred to excavation time sequence: a wall has been excavated during 1996 campaign, another in 1997), and stratigraphical (referred to dating of finds: previous, subsequent, contemporary,...)

Figure 2 shows a typical section as could be reconstructed from some stratigraphic units.

The test in an 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.

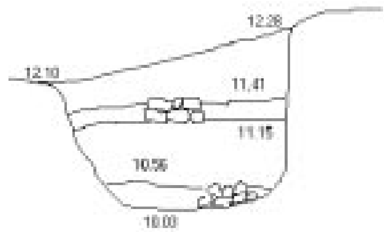

Fig.2 A section

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

We then have to collect in our "digital diary" textual, visual and spatial information. The next Subsection shall detail how.

3.1 Data Entry: Drawings and Text

Textual information is locally collected on the palmtop computer by means of selectable menus, or by using special input software like the T9[12] software system, or handwriting recognizers. Until speech recognition devices shall become widely available on palmtops, textual input shall be rather difficult, and menu-based classification shall be much better achievable. If a whole text has to be entered, we developed a special software called WordTree [4] that speeds up input of text on pen-based devices.

Visual and spatial information may consist on 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.

We designed the special purpose software **Archeo** on top of a drawing system. 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 more realistic appearance. Attachment of a snapshot taken by a digital camera may be useful for the most significant finds.

The use of a graphic-based object oriented tool, allows to separately manipulate 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 same attributes, in order to be able to recall them on the screen. In a side window, textual information can be attached to objects as annotations.

Specifically, two kinds of views are possible for each test, the map and the section. In *map mode*, objects (that is, finds) can be inserted by drawing them on the screen or by inserting some points and then interpolating a curve; they can be later merged inside a stratigraphic unit, and stratigraphic units may be merged into contexts. The correspondence of screen coordinates to surface measures is immediate; depth is also available on request. In *section mode*, inserted objects are only shown (if they belong to the selected section).

See Figure 3 for a view of Archeo interface.

Other functions are typical of drawing tools, like filling, zooming, gridding and the like; in case of zooming into some area, a global view of the whole test is kept in a side window. All acquired data can be downloaded to the central workstation and automatically inserted into the site object store (and made available, via Internet, to remote scientists). 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.

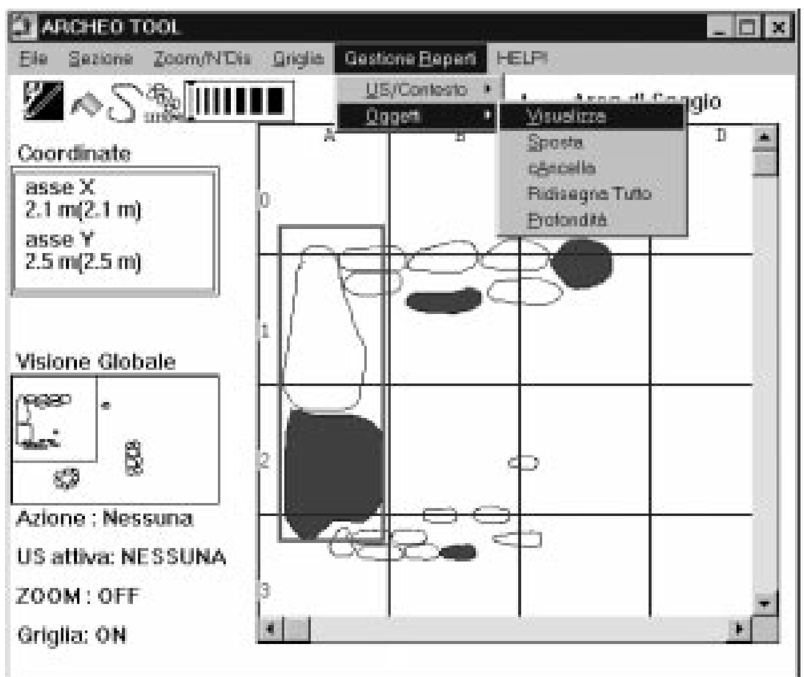

Fig.3 Drawing with Archeo

4 ADE: Archaeological Data Environment

ADE is the receiver/container application installed on fixed hosts present at base camp. All of the portable computers present in the field can connect to ADE to send or receive information. ADE purposes are: to provide physical storage for portable computer's data, to manage the radio network, to connect the base camp to remote host with WAN, acting as gateway to Internet.

The application is quite complex, and its cooperative nature has suggested the use of a powerful development tool: **Lotus Notes**. Notes allows the definition of etherogeneous documents and their storage over different machines using the proprietary method of "Replicas", which synchronizes Notes distributed database. This method is particularly efficient in low band networks such as telephone networks. Moreover, Notes automates every workflow process on documents making it easy to share information between remote posts. The last, but not least, feature of Notes is the possibility of Internet automatic document publishing (which are translated into html) and forms (so people physically far away can augment the data base by introducing their own form-based documents) using the DOMINO web server technology.

ADE consists on a collection of Notes documents glued together by a Navigator, scripts and agents. Scripts perform actions when events (like clicking a button in a form) are caused by users choices. Agents are automatically activated at given schedules (e.g. daily).

ADE documents are hypertextual documents including personal annotations by archaeologists, drawings, digital images, and a wide amount of data about referenced finds. They can be filled in by connecting at the fixed host, at base camp, or after a communication to/from a portable computer (thus receiving Archeo's data, drawings etc.).

In defining ADE documents, care has been taken to obtain total compatibility with the sheets required by Italian Ministero dei Beni Culturali, mandatory for every campaign in Italy. This causes a great improvement in the traditional archaeological fieldwork, because the so called "field diary notes", taken during actual digging work, need not be copied to official documents later on: we can now print out official documents from the field diary notes themselves.

Figure 4 shows a schema of possible communication to/from ADE.

Our system provides novel features with respect to other archaeological information systems, due to different attitudes towards data manipulation as in group activities. Notes allows to keep multiple copies (replicas), even incomplete ones, of each object repository, to be stored on different client computers. Consistency of multiple independent replicas, even when simultaneously updating the same object, is kept by Notes itself: in fact, it contains proprietary synchronization software to such purpose.

Any user, either mobile or stationary, and even connected via Internet from the University labs, may independently retrieve, update off-line and then send back to the server a selected data subset: for example, a replica may collect objects belonging to a specific test in the whole site, or to a certain period of time over all the site, or to stratigraphic units at the same level in several tests.

5 Archeo-ADE communication protocol

We have already remarked that power consumption is high when transmitting, and that power availability is limited by the weight of accumulators. Then, communication to/from the mobile system should be carefully designed.

Two kinds of information are exchanged through the wireless network: short messages (such as e-mails, or data sequences originated by remote DB queries) and long messages, represented by visual information like maps, snapshots, large drawings. They require two different mechanisms:
(1) synchronous communication in a client/server interaction fashion,
(2) asynchronous communication by means of shared files.

The system is asymmetric by nature, since handshaking cannot be activated by the fixed station when the MU is unreachable, and the MU cannot be always "listening" for incoming messages in order to save power. Hence, synchronous communication can only happen via an handshaking protocol always activated by the MU playing the role of the client with respect to the fixed station (server).

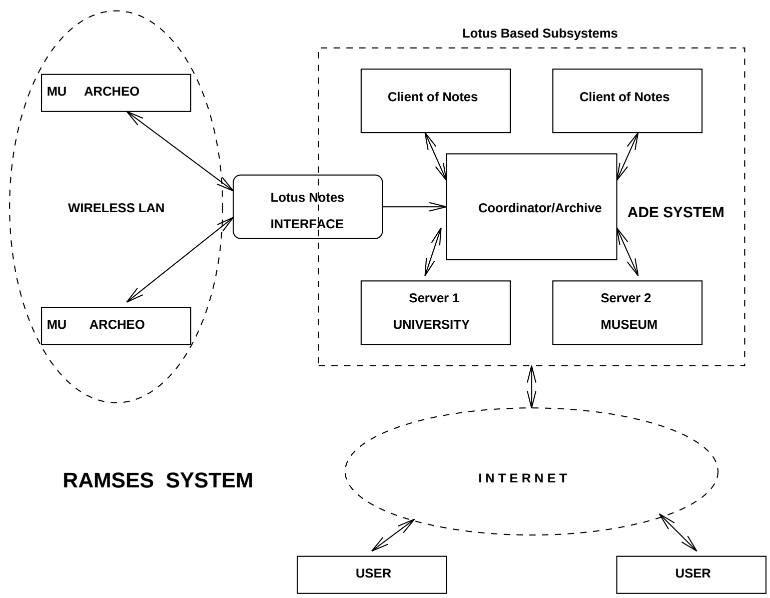

Fig.4 Possible links to/from ADE

Data exchange via shared files optimizes large data set transfer and, if files are stored on the fixed station, it may be used also when some MU is disconnected or in stand-by. The advantages are:

(a) shared files can be maintained on a queue on the fixed station when data and messages cannot be immediately sent to the MU,
(b) files are always recorded on the fixed station, thus offering a higher reliability, and coherence in case of multiple updates by many MUs can be enforced;
(c) when the fixed station is unreachable or battery is in lower state, data can be maintained on the MU local storage until the connection is established or battery are changed.

In this way we optimize both fast data exchange in real time of short messages and larger data information exchange, with minimal delays due to disconnection periods or battery discharge. All data exchange is always under user control for preventing early discharge of battery avoiding data losses.

6 Conclusions

This paper has presented how mobile computers, integrating suitable communication technology, as nowadays available inside a palmtop computer, may be used to develop field archaeology support tools. Application scenarios in field archaeology have been examined comparing present with future situations.

The most innovative aspect for field archaeology derived by our communication scenario is the possibility, for a scientist, to achieve true collaboration with colleagues, like he were on the site, thus reducing mobility costs of an excavation campaign. Similar considerations hold for several outdoor activities, where the rapid changing of the technological scenario and the need of ad-hoc solutions lead to the application of mobile technology based on wireless links supporting multimedial Data Base access.

Examples of applications can be found in the Cultural Heritage area, where the ongoing ESPRIT project TOSCA (Tourist Orientation and Support in Cultural Assisted tours) the aim of which is to provide visitors with the audio/video information needed for a cultural sight, the possibility of accessing a remote database and connecting to service centers, through mobile wireless computers. TOSCA is based on two types of services: Multimedia Personal Terminals connected, by means of mobile radio, wireless/contactless local loops, to available communication platforms, which allow a regular information updating and remote access to ISDN; and Personal Digital Assistants, the operability of which is restricted to a particular location (indoors, Museum or Gallery), which provide interactive guidance. In TOSCA some problems are very close to those we faced in RAMSES, like data base remote access, or those that we will consider in the future, like the use of speech instead of pen to insert textual information. An important feature of RAMSES which TOSCA lacks is the possibility of inserting textual and graphical information into the data base, and the special attention that has been paid in minimizing the use of both memory and battery.

The developed technology is not restricted to the Cultural Heritage area since it is applicable, with suitable modifications and extensions, to other fields such as for supporting patients and medical personnel in hospitals. Some pioneering hospitals are already experimenting mobile computing and wireless LAN technology, and applications reported in the literature include: the Good Samaritan Hospital (OH,USA), the Liverpool Women's Hospital (UK), the North Carolina Hospital, and others. The aim of these projects is to provide doctors and nurses with personal wearable handheld computers, linked via wireless networks to a server, which collects in a repository all clinical records and information on patients. Handheld computers run a specially designed application which completely replaces traditional paper-based management of clinical records.

All of them adopt the FHSS Technology for the wireless communication, since it appears to be the best for small areas, for its low power consumption, high transmission speed and lack of interference with medical equipment. Moreover, since there is no restriction for access to the radio frequency bands used by FHSS communications, this technology has been widely implemented by idividual vendors. Applications have been developed using technology provided by Symbol Technologies, Aironet, or Netwave. For example, Good Samarital Hospital portable and handheld computers are wireless connected to the network via Aironet PC2000 Type II PC Cards and Aironet PC2000 Wireless LAN Adapter [2].

Hospital applications, even if indoor, are closer than TOSCA to our experiences, both for user interface and features, since the palmtop is heavily used as an input device. The same authors are presently undertaking a similar project.

Acknowledgements

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).

The authors gratefully acknowledge the programming efforts of several Computer Science students who developed the various releases of RAMSES.

Further details on this project are available at the URL:
http://www.disi.unige.it/person/DoderoG/pub_pfbc.html.

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