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The 3COORsystem for data recording in archaeology

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Summary - *The 3COORsystem project is a technological solution aimed at overcoming the drawbacks imposed in archaeological excavations by the traditional recording protocols, namely the use of an archaeological grid and the necessity of exhaustive data recording (object description, drawing, photo). 3COORsystem is composed of several subsystems that share a common database structure (3COORdatabase). The 3COORpda subsystem is devoted to field data recording following the standard working protocols for archaeological excavations established years ago for the Sierra de Atapuerca sites. The 3COORpda application is installed in a number of standard Personal Digital Agendas (PDAs) that are used by the archaeologists as mobile terminals for data input. A single standard laptop acts as the server and central data repository and Bluetooth and Wi-Fi wireless communication technologies are used in order to wirelessly connect all mobile devices. The system includes capabilities such as creating objects, searching them, and drawing them and its main features are usability, easy to learn, reliability, efficiency, scalability and security.*

Keywords - *Fieldwork, Computers, Database, Pleistocene, Atapuerca.*

Introduction

Archaeology was one of the first disciplines in social sciences to incorporate computers both in the fieldwork and in the lab, specifically for repetitive tasks, for the statistical analysis of excavated items and for creating databases (Hietala, 1984; Chernorkian, 1996; Texier, 1985; Snow *et al.,* 2006; Watzman, 2004). This trend continues nowadays towards the complete integration of computer and information technologies in all aspects of scientific work. Fieldwork, however, seems to remain unaffected by this trend, since the methods and technologies currently in use in archaeological excavations have evolved very little, and traditional working protocols still play a major role in most excavations. Nevertheless, it is useless to incorporate a computer in our work if its presence does not improve our interaction with the subject of our research, i.e. the archaeological site. The expected improvements derived from this technological updating are a reduction of the time employed in repetitive tasks, error reduction, and the ability to obtain real-time analytic information (stratigraphic, archaeoestratigraphic and spatial) to support fieldwork.

Any handbook of archaeology highlights the importance of the strategy and organization of the excavation and the relevance of data recording methodologies (Minelli & Peretto, 2003; Renfrew & Bahn, 1998; Roskams, 2001). The process of archaeological excavation includes recording all the contextual information about the objects found, as a basis for future scientific research. Archaeological methodology varies according to the site characteristics and chronology (Pleistocene, Holocene, urban, cave, open air) but its basic feature is always the definition of documentation protocols.

Given the obsolescence of current archaeological data recording technologies in comparison to the widely available modern computer technologies for data management, Atapuerca's Research Team (EIA) began in 1997 an ambitious project aimed at creating an integrated system, with a unified database, to computerize both the fieldwork and the subsequent scientific research. This project gave rise to the 3COOR system, a global solution with a modular architecture, for field data recording and eventual data transfer to a central repository.

In a joint effort, Fundacion Atapuerca, IBM Corporation and Atapuerca's Research Team defined the basic elements and the technological components of the system. Eventually, the project evolved towards an information system (3COORsystem) subdivided in a number of specific modules (3COORfieldwork, 3COORmuseum) sharing a single database structure (3COORdatabase) which is the core of the whole system (Laudon & Laudon, 2000). A key part of the whole solution is the data model that allows the representation of the entire set of data needed for the solution. In order to design the data model, Atapuerca's Research Team and IBM worked very closely and carefully to represent in the database all important information.

Here we present the 3COORpda subsystem of the 3COORfieldwork module, a set of technologies aimed to field data recording and subdivided in three subsystems: 3COORpda, 3COORlocus and 3COORdesktop (Fig. 1).

3COORpda is a computer application for data recording that follows the working protocols established for the archaeological excavations at the Sierra de Atapuerca sites (Carbonell *et al.*, 2001). These protocols were developed according to the basic principles of Pleistocene archaeology, which include recording the topographic location in a three-dimensional reference system (x,y,z) and a simple description of objects. In addition, the user may draw objects freehand and the drawings are automatically positioned in a two dimensional reference system. The information is stored at the mobile device as a bitmap and it is then compressed and sent to the server by calling a remote stored procedure at the server side.

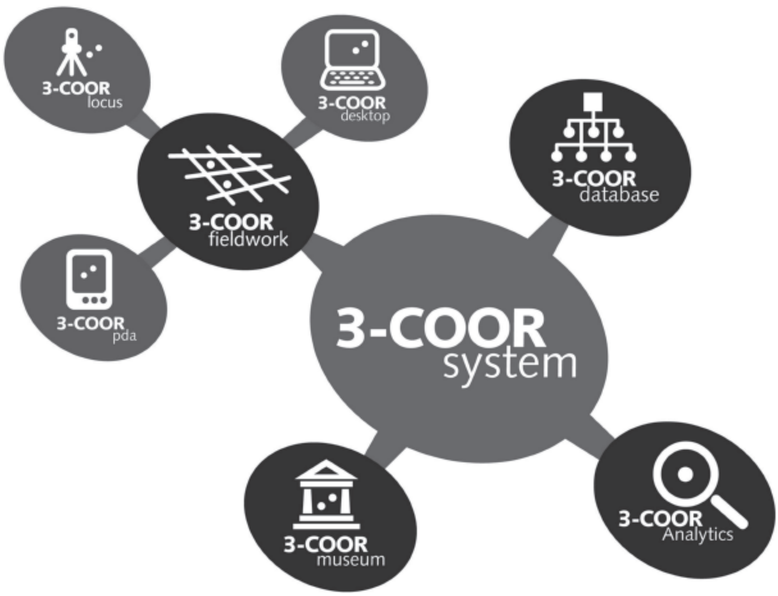

Fig. 1 - Structure and architecture of 3COORsystem.

3COORlocus (currently under development) is an automatic system for 3D positioning and 3COORdesktop is a computer application for data flow management. 3COORdesktop is the tool for the control and administration of the data flow, the communication networks and the field database. It is also used on a daily basis to export the records from the field database to the main database (3COORdatabase)

The current working protocol with 3COORfieldwork is as follows. The archaeologist uses a standard Personal Digital Agenda (PDA) incorporating the 3COORpda application as a terminal for data input (Fig. 2). The user navigates through several screens and the system guides him or her in the process of data recording (Fig. 3). Moreover, 3COORpda guarantees that the user fills in all the fields defined as "required", it incorporates "input masks" to control for input data format and lists of values for certain fields. Since the 3COORlocus system is currently under development, the archaeologist still relies on the use of a metric tape and a laser level to obtain the coordinates (x,y,z) manually. Once the user has recorded all the required information for a set of objects (1 to 20 objects) found in a single square he or she is able to send these data to the field database, resident in a laptop at the field. A unique identifier is automatically generated in the laptop for each object and sent to the PDA. The unique identifier has the form S-YY L Q N, where S is an acronym for the site, YY are the last two figures of the year, L is the layer, Q is the name of the square and N is a consecutive number that is set at zero every year for every square. As an example we have ATA08 TD10 F15 1 as the unique identifier for the first object found in the square F15 at the TD10 level of Gran Dolina in the 2008 season at Atapuerca. A plastic, self-adhesive, label containing its unique identifier both in plain characters and using a bar code (Dibble *et al.*, 2007) is printed and attached to the plastic bag containing each single object. Once the archaeologist has completed this working cycle, the same PDA may be used by any other member of the excavation team to record new items. Eventually, the field database is exported on a daily basis from the excavation server (the laptop) to the main database (3COORdatabase).

This system may be used to work simultaneously in several sites, hundreds of meters apart.

Fig. 2 - Working with 3COORpda in different sites: At the left Abric Romaní (Capellades, Catalonia, Spain); and at the right Gran Dolina (Burgos, Castilla y León, Spain).

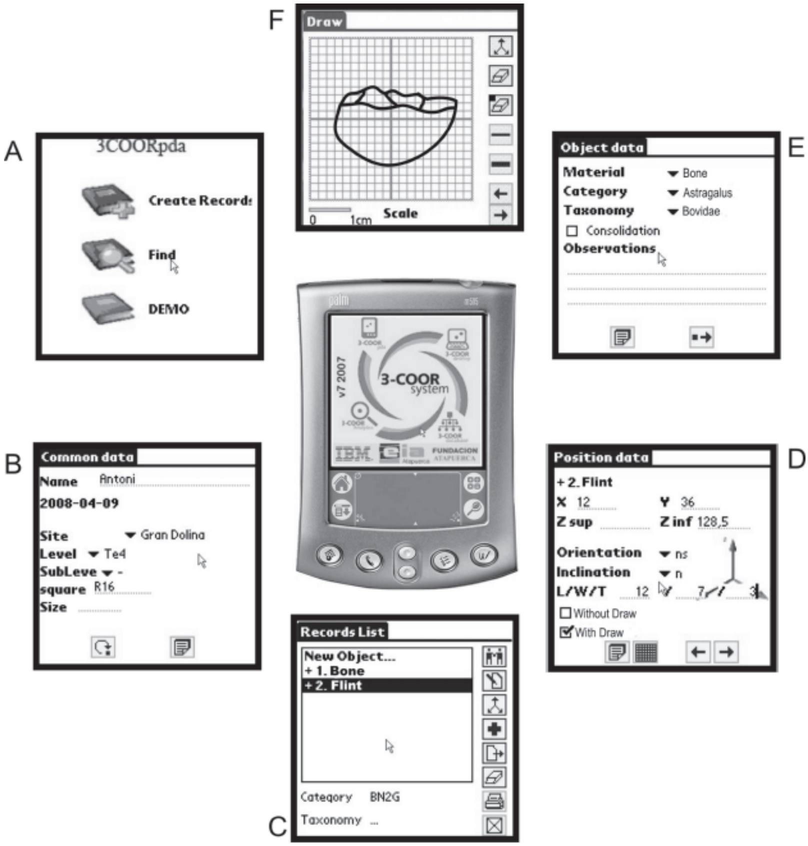

Fig. 3 - Some screens of 3COORpda application running on PDA: A) first screen to select one option: recording data, find objects in the fieldwork server database or enter in demo option module to begin practice in the system; B) screen to define the user, the site, layer and square; C) screen to input a list of objects to be recorded (actually the system is limited to 20 objects per operating cycle); D) screen to input coordinates orientation, inclination and size of the object. W/L/T states for length, width and depth ; E) screen to describe object; F) screen for drawing.

A single laptop, which also runs the 3COORdesktop software, is required as central data repository. A number of PDAs distributed among the working localities are used as mobile data input terminals (Fig. 4).

Technical overview

Bluetooth and Wi-Fi wireless communication technologies (Harte, 2004; Ohrtman & Roeder, 2003) are used in order to wirelessly connect all mobile devices. Concerning communication needs, the solution was designed taking into account that PDAs' batteries should last 5-6 hours of intensive use. At the same time, the solution should enable the deployment of PDAs at different localities in the same excavation site. Consequently, Wi-Fi technology was chosen to interconnect the localities more than 25 m and up to 200 m apart, because of its higher distance range but higher energy consumption. In contrast, Bluetooth technology was chosen to directly link PDAs to the laptop or bridge the PDAs to Wi-Fi gateway devices, because of its lesser use of energy and reduced communication

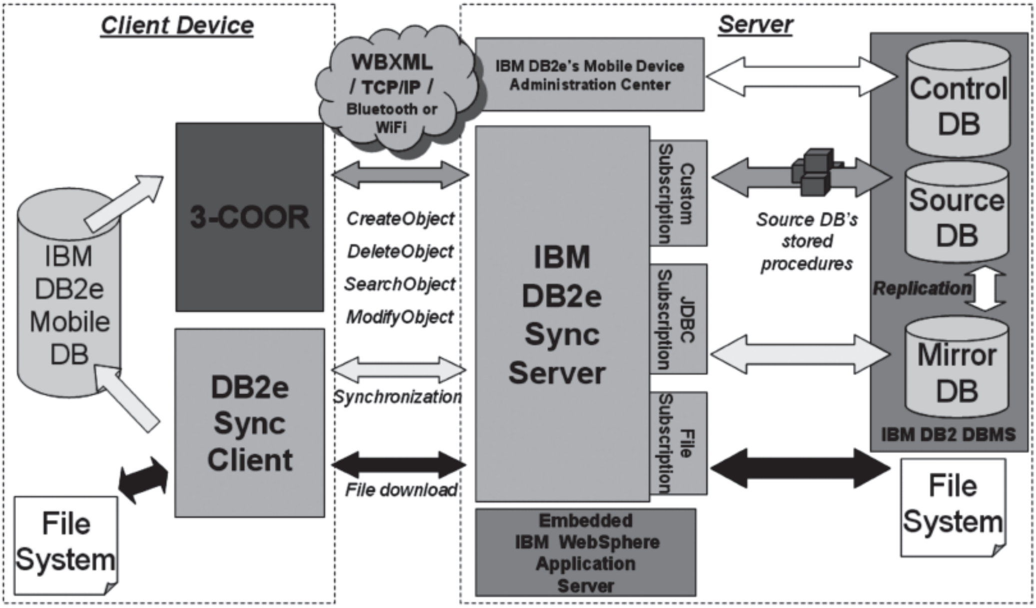

Fig. 4 - Architecture overview diagram of the 3COORpda solution. It represents the two main systems of the solution, that is the client and the server, and displays the main components of each system. JDBC stands for Java Database Connectivity, an application programming interface for Java that defines how a client may access a database. DB2 DBMS is the Database Management System for the DB2 Database.

range (Fig. 5). A gateway is an electronic device that interconnects two networks, in our case it connects the local Bluetooth network and the Wi-Fi long distance network.

Mobile application

The mobile application was designed and developed as a custom application. Its main goal is to provide researchers with a powerful tool which allows them to introduce new objects, search for already introduced ones, perform modifications of retrieved data from existing objects, and finally delete selected objects. All scientific data are stored in the mobile database installed on the PDA, and can be classified as master data and object data. The synchronization client's purpose is mainly to facilitate the provisioning of master data and the remote upload and installation of new versions of the application.

The core 3COORpda application stores and retrieves data from the local mobile database and handles the user interface and the execution of remote procedures calls. A remote procedure call (RPC) is a technology that allows an application to cause the execution of a procedure sitting in another system. We can take as an example the remote procedure call used to create a new object and get its newly generated unique identifier. This remote procedure allows the creation of a new object by using the information introduced by the researcher. For every new finding sent to the excavation server, a unique identifier must be automatically generated and sent back to the client application in order to inform about the successful creation of the object record and display it on the PDA's screen.

It is important to note that data exchange between the client and the server is performed by using Wireless Application Protocol (WAP) Binary XML (WBXML), a binary representation of XML (Extended Markup Language) which allows the transmission of XML documents in

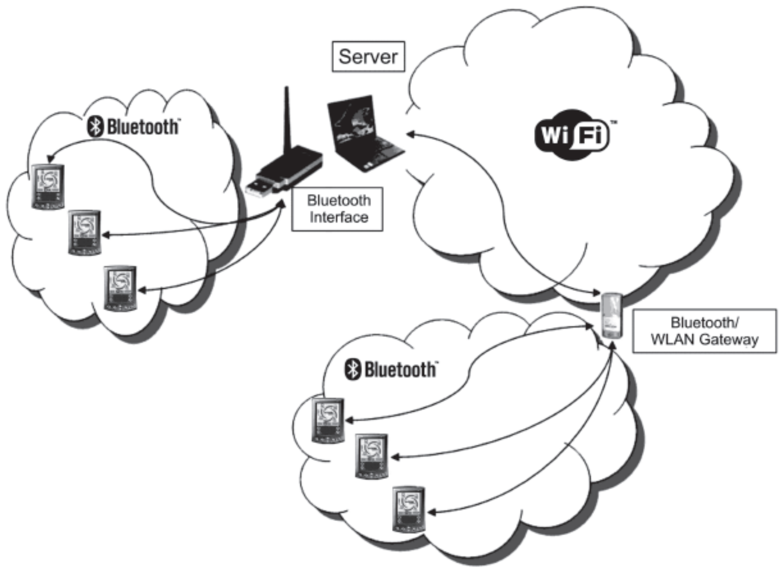

Fig. 5 - The communication infrastructure diagram of 3COORfieldwork

a compacted manner. XML is a standard meta-language for information exchange (Bressan *et al.*, 2005).

Internationalization

Another interesting technical feature of the mobile application is the possibility to switch from one language to another dynamically. Archaeological excavations not only involve people from different disciplines and fields of knowledge but they usually involve people from different countries who speak different languages. That is why the idea of adding internationalization to the solution was under consideration from the very beginning. Moreover, because the PDAs are usually exchanged from one person to another, it is important to be able to switch from one language to another in a fast way. The first thing to be taken into consideration is what elements of the application need to be available in different languages. Form titles, button's texts, labels, alerts' messages, and dropdown lists need to be translated. In order to enable the dynamic translation of the whole application hash table and multilingual tables were used. A hash table is a table that associates key numbers with values. In our case the hash table contains numerical codes for e.g. type of material (1, 2, 3, 4….) and other tables record their equivalences in different languages (In English: 1 = limestone; 2 = flint, 3 = quartzite… In Spanish 1 = caliza; 2 = sílex; 3 = cuarcita… and so on).

System 3COORfieldwork distinguishes between the working language in which the data are stored (e.g. English) and the interface language in the PDA selected by the archaeologist who at the time was working (e.g. German). This ensures a single language for the final record of the data and multiple interfaces consistent with the linguistic diversity.

Data management

3COORpda is basically based on IBM's DB2 Everyplace, a mobile database and a database synchronization software. It is important to differentiate two kinds of data: master data and object data. On one side, master data represents all the static information such as the list of skeletal elements (scapula, humerus, radius...), the site's names (Trinchera Dolina, Trinchera Elefante…) or the stratigraphic layer (TD10, TD9, TD8…) which must be loaded into the mobile device before collecting any object data. On the other side, object data represents all scientific information related to found objects.

Interactions between PDAs and the central excavation server usually occur at the excavation and interactions between the central excavation server and the laboratory computer take place at the laboratory, where the data should be exported from the central server and imported into the laboratory computer (Fig. 6).

System evaluation

Development of 3COORpda system is the result of the interaction between EIA and IBM engineers. The aim of this project was threefold: 1) to develop a feasible computer application able to fit the data recording requirements of archaeologists whilst being compatible with the already established working protocols; 2) to progressively replace the standard manual data recording methods by computer processes; 3) to expand the limits of the EIA and to elaborate a ready to use solution, suitable to be used in virtually any archaeological context, whatever the characteristics of the site. Additional requirements were usability, easy to learn, reliability, efficiency, scalability and security.

An essential feature of the technological solutions provided by IBM was wireless communication. Although nowadays wireless technologies are widely used, in 2001 the idea of creating 3COORpda as a wireless solution was highly innovative. At the time the project began hardware and software were far from being as reliable and efficient as they are today, and the engineers had to deal with severe technical troubles. One of the 3COORpda functions more affected by the initial underdevelopment of wireless technologies was label printing. The initial system requirements included the printing at the field of the unique identifier for each recorded item on a self-adhesive label. The first option tried out was using fax-like direct thermal printers connected to the PDAs through an infrared communications port. However, these labels were extremely short-lived, and the information was hardly readable just a few months after printed. Ticket printers based on thermal transfer technology produced long lasting labels but they were inadequate to be used in the field and lacked Bluetooth or Wi-Fi interfaces. This shortcoming has been recently overcome with the use of low-energy ticket printers with a wireless interface.

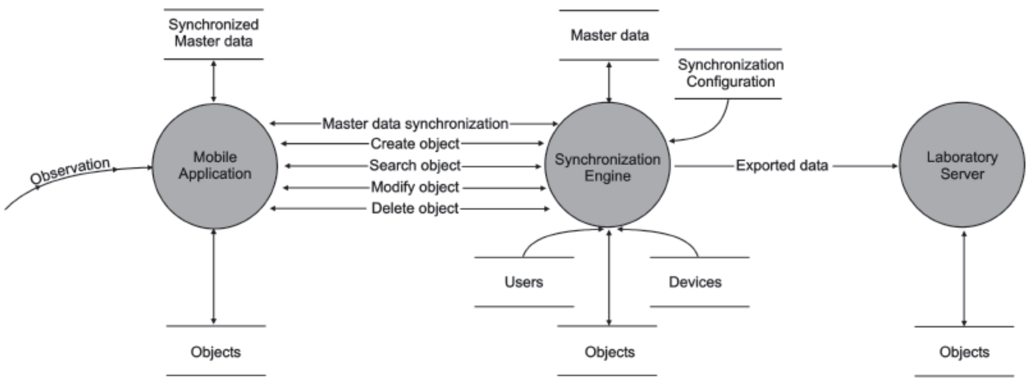

Fig. 6 - Information flows between three different systems: a PDA, the central excavation server, and a laboratory computer.

Designing of the graphical user interface also experienced unexpected difficulties. At an advanced stage of development, a graphical designer was requested to improve the look and feel of the application. In order to do so he added new coloured buttons and backgrounds. The results were spectacular and the application looked much nicer than before, but all the new colours had to be removed. This was because the use of coloured backgrounds and buttons, in combination with the sunlight hitting the PDA screen made almost impossible reading the screen.

The second aim, replacing manual recording procedures by computer recording protocols, has been only partially achieved, since many features like voice recording or sketch drawing still remain unimplemented. Nevertheless, the data recording protocol has been successfully incorporated, apart from some minor aspects like photo recording. However these shortcomings are essentially caused by hardware limitations, since the capabilities of 3COORpda to incorporate new functions and improvements are unlimited.

Concerning the last aim, spreading the system, it has been entirely fulfilled thanks to the help provided by IBM in the process of transferring technology to other research teams. Both the teams of Pinilla del Valle (Madrid, Spain) (Arsuaga *et al.,*2008), leaded by E. Baquedano, and Lazaret Cave (Nize, France) (Lumley *et al.*, 2005), leaded by H. de Lumley, are currently using the 3COORpda system in their fieldwork.

The adaptation of 3COORfieldwork to these sites has been fairly straightforward since, before incorporating the 3COOR system, both of them followed the same working protocol than the Atapuerca team. Thus, the data structure was very similar. Nevertheless, 3COORfieldwork is susceptible of being adapted to other working protocols by just adjusting the data structure of the 3COORdatabase. In summary, 3COOR may be adapted to almost any particular case whilst preserving its general features and performance.

The future

3COORfieldwork is currently a continuously evolving robust system that fits the requirements imposed by fieldwork at Pleistocene archaeological sites. It must evolve to comply with new requirements (photography, sketch drawing…), to improve its performance incorporating more advanced hardware and software solutions and, finally, to help archaeologist to improve their efficiency at the field.

Originally designed for PALM OS devices, 3COORpda is currently migrating to JAVA platform (Schildt, 2007) to allow the system to be installed in a variety of devices and systems which will be used to support new functions (photography, labelling…).

A remarkable component of the systems is 3COORdesktop, the management application of 3COORfieldwork developed in PHP, a widely-used scripting language specially suited for Web development. 3COORdesktop is devoted to control the data flow between the field database and the PDAs, to create lists of recorded items, and to check for errors in the field database. In addition, it incorporates the ability to create 2D and 3D graphics with the spatial distribution of the recorded items, providing the archaeologist with a real-time tool for decision making. The archaeostratigraphic projections allow the archaeologist to follow the progress of the excavation vertically and horizontally in real time. This module has evidenced the importance of both historic (from other field seasons) and present information in decision making at the field.

In summary, all the modules of 3COORsystem were designed to break the so common pattern "a site/a system". Although each site has its own peculiarities, the archaeological method is universal, and we feel it necessary to create an easily available technology in order to increase research efficiency both in the field and in the lab.

With this in mind, our next aim is to integrate in 3COOR an automatic system for x,y,z coordinates recording called 3COORlocus. It will allow each single user to obtain, quickly and accurately, the position of any item in the site, making the traditional and inefficient archaeological grid entirely superfluous. 3COORlocus will be based on last generation robotic total stations controlled by the fieldwork laptop by mean of wireless technology.

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