FieldNote: extending a GIS into the field

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Background

The Mobile Computing in a Fieldwork Environment (MCFE) project (note 1) was introduced in a paper at the 1997 CAA conference in which we described the development of prototype *context-aware* FieldNote systems [Ryan *et al.* 1998]. These are intended for use in both student and research fieldwork, providing facilities for instruction, data recording and information retrieval tailored to the users' requirements. A GPS receiver (note 2) supplies a hand-held computer with a continuous 'awareness' of its location, and this is used both to tag recorded data and to select and display contextually relevant information from a database.

In a context-aware application the computer monitors, and responds to, various aspects of the user's environment [Fitzmaurice 1993, Schilit *et al.* 1994]. In our approach, which derives from Peter Brown's work on stick-e notes [Brown 1995, 1998, Brown *et al.* 1997], the environmental factors can be both physical and logical. Apart from location, physical criteria could include, for example, date and time as measured by the computer's internal clock, and temperature or ambient light level measured by attached sensors. Logical criteria include the author of a note, date of creation, subject keywords and the historical period to which the note refers. Typically, the user can specify a set of criteria to describe contexts of interest and these act as search filters and so define which information is made 'active', or 'triggered', as the user moves through their environment.

Prototype systems have been developed for the 3Com PalmPilot and the Apple Newton hand-held computers (note 3). These were tested in several field projects during the summer of 1997, including surveys of an Iberian/Roman town in Andalucia, upland pastoral settlements in

Corsica, and animal census and behavioural studies in Kenya. In this paper we review the archaeological fieldwork trials and describe subsequent developments in methods of communication between the desktop and hand-held components of the FieldNote system.

FieldNote Tools

We have followed two parallel lines of development, each intended to explore different issues in context aware field computing. The first, based on the PalmPilot, has concentrated on techniques for rapid data entry and on triggering methods. Although initially designed for applications in animal behaviour studies, this system is equally suited to archaeological activities such as surface sampling and recording of photographs. This system is described elsewhere [Pascoe *et al*. 1998, Pascoe *et al*. forthcoming]. In this paper, we are concerned with the second prototype which is based on the Apple Newton.

The Newton prototype has exploited the higher resolution display (320x480 pixels) of the MessagePad 2000/2100 models to provide more detailed mapping facilities. The greater processor speed and expandable memory capacity have also enabled us to explore issues of more precise positioning by storing and manipulating raw measurement data from the GPS receivers.

Internet connectivity and the availability of several different web browsers (note 4) have enabled us to explore ways in which the existing technologies of HTML encoding and the HTTP protocol can be exploited to support the production and exchange of FieldNotes. In an earlier paper [Ryan *et al*. 1998], we described the generation of FieldNotes in HTML format and the use of <META> tags to store contextual information. Amongst the benefits of this approach were a widespread user familiarity with HTML and the ability to use existing tools such as web browsers and editors.

The earlier paper was primarily concerned with the creation, storage and display of textual notes. The system has subsequently been extended to use HTML forms as a means of recording structured data. In normal use, both the forms and the data collected by them are stored locally on the hand-held computer. However, if the hand-held has an Internet connection, either wired or wireless, the forms can be served by a remote machine and data can be transferred to the server using conventional CGI methods. FieldNote data can also be transferred from the server to the hand-held by a similar method.

Field testing at *el Gandul*, Andalucia

An opportunity for field testing of the prototype systems was provided by Simon Keay and David Wheatley of Southampton University. Keay has been conducting a long-term study of the development of urbanism in the Guadalquivir valley and surrounding area (see, for example, Keay 1992). In September 1997 they undertook a programme of survey and surface sampling at the Iberian and Roman urban site of el Gandul.

El Gandul is situated in a sparsely populated area some 20km south east of Seville on the edge of a low plateau. The site, at an altitude of about 100m, is surrounded on three sides by a steep scarp descending to a wide and more fertile valley floor. Today, it is part of a rural estate devoted largely to olive production. Much of the area is unproductive and the thin, stony soil, where not protected by vegetation, is subject to considerable erosion.

The core urban area is partially surrounded by high tree-covered banks in which masonry walls are occasionally exposed. An unusually high density of surface finds probably results from current agricultural practices. Bare soil is maintained between the olive trees planted over most of this area. Whilst this practice ensures that no other plants compete for scarce water and nutrients, it appears to encourage serious erosion during the frequent winter rains. The rains wash out the finer components of the soil matrix, each time exposing more of the archaeological material, stone and bedrock.
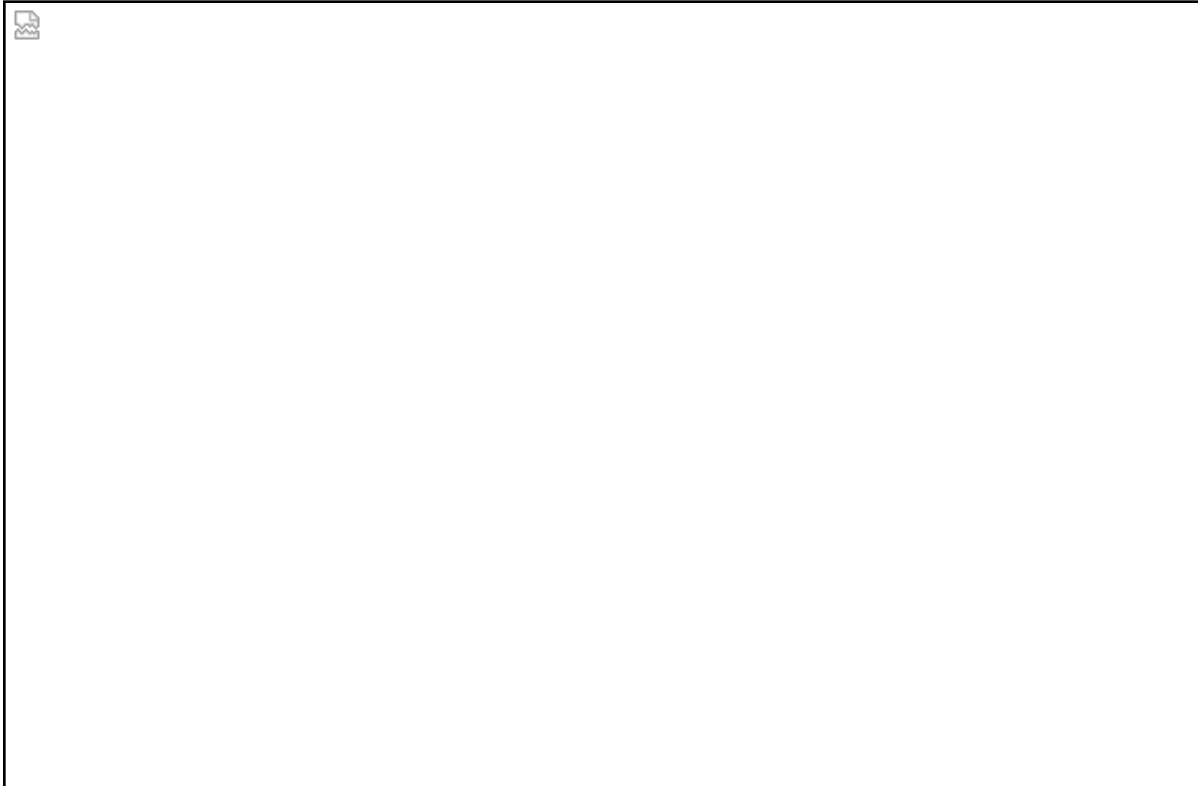
Figure 1: The Newton based FieldNote system being used to record an extant wall fragment.

Soil erosion resulting from agricultural practices is a problem in many parts of Spain. Despite making it easier to find material on the surface, it is also a concern as many sites are being rapidly and irrevocably damaged. The need to understand the effects of the erosion on archaeological remains and to find ways to preserve the sites is a major concern to local archaeologists. We hoped to demonstrate that the FieldNote system could be a valuable tool in conducting rapid evaluations of such threatened sites.

Our main tasks were to shadow the conventional recording methods used in these studies, and to supplement the structured records with observations recorded beyond the main sample area. Figure 1 shows the FieldNote system in action. The GPS receiver and battery pack is carried in a jacket pocket and connected to a small antenna mounted in the hat. A second cable links the receiver to the hand-held to provide continuous update of location and raw GPS measurements. The current location can be displayed numerically in a popup window, or graphically on a background map. The latter also shows the location of other notes recorded in the area (Figure 2).
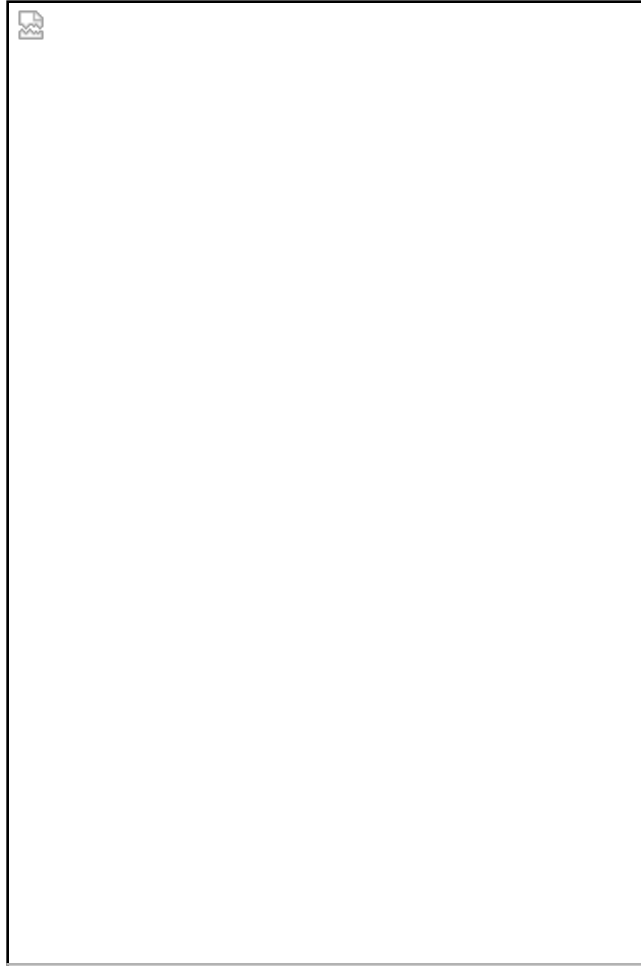
Figure 2: Newton screen shot showing the background map and popup location window.

A second GPS receiver was placed with its antenna at a known location. Raw measurements from this receiver were continuously logged on a laptop computer kept in a vehicle. By using differential post-processing techniques, it is possible to use data from the static receiver to correct many of the errors in the recorded position of the mobile receiver. Experience suggests that we are able to achieve accuracies of the order of 5m using the pseudorange measurements from our Trimble receivers (note 2).

A photographic record is an important aspect of any archaeological survey. We spent two days recording and photographing extant features and details of the local topography, including exposed walls, dense concentrations of artefacts and possible entrance routes into the town. A conventional photographic record often consists of little more than a film and frame number with some descriptive text. In some cases,

details of camera lens and shutter speeds may also be recorded. A datestamping camera back may also be used to label each frame, and other methods such as video with accompanying voice notes may also be employed.
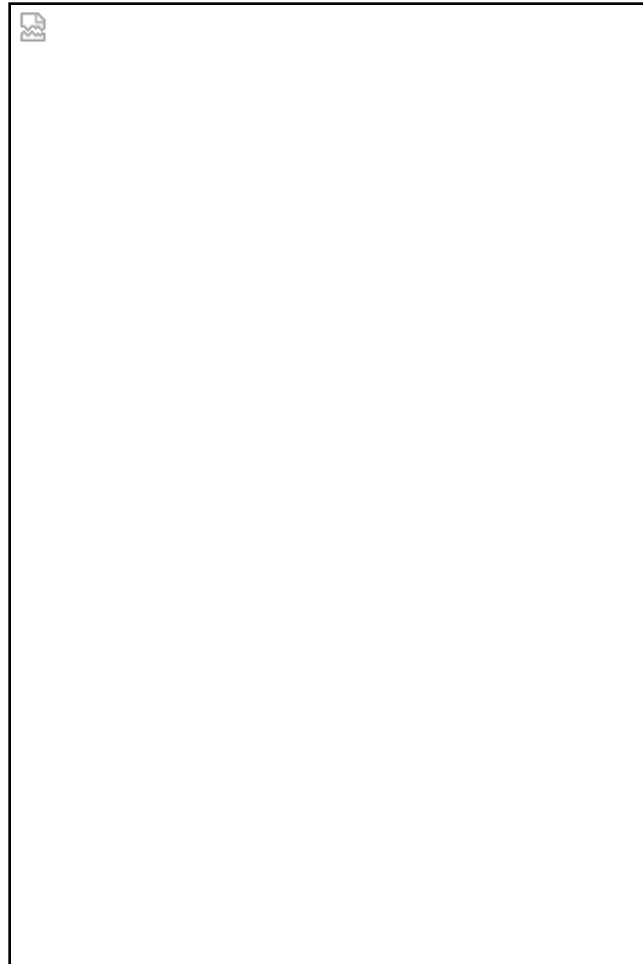
Figure 3: Newton screen shot showing an HTML form for recording photographs.

The photographic recording form shown in Figure 3 allows the user to enter basic details and automatically records the name of the user, the date and time, and the location at which the note was made. Subsequently, we have started to examine the use of an inexpensive digital compass to add information about the orientation of the camera.

Another day was spent on a more wide-ranging survey of the area. The plateau rises behind the town to form a shallow surrounding bowl. There are several tombs in this area, some of which have been excavated. A few are of Roman date but most are much earlier, several dating back to the chalcolithic. Here, we made notes on each visible

tomb and recorded a number of photographs, including several general views of the urban area to the south.

Most of our remaining time was spent collecting *ad hoc* observations from the outer parts of the town beyond the area covered by the sampling grid. These records would be fed into the growing collection of background information on the site, and used to fill out the story told by the quantitative sampling.
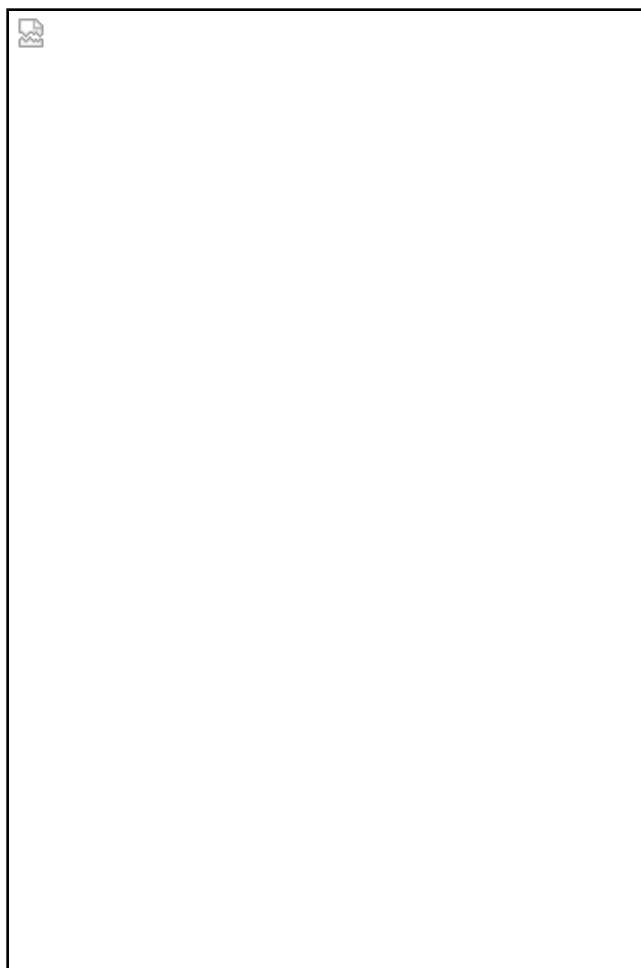
Figure 4: Newton screen shot showing an HTML form for recording surface samples.

Finally, we visited each of the sample points at which surface material had been collected. The notes collected at these surveyed locations would later be used to check on the accuracy of our GPS post-processing software. At the time we used our basic text note system to record these locations and made no attempt to duplicate the full content of the paper records of surface finds. However, in anticipation of further work at this site, we have subsequently produced

an example HTML form that could be used to replace the paper forms ([Figure 4](#)).

Collecting data in the field is only one phase of the FieldNote cycle, a sequence of processes designed to support ongoing research and repeat field visits ([Figure 5](#)). Field data is uploaded to a desktop GIS or database where it becomes available for display, analysis and possible transformation. Later, a subset of the available data can be downloaded to the hand-held machines to provide contextual support for a subsequent field visit.

In an extended project, such as that being undertaken at el Gandul, the site may be visited by survey teams, research students, geophysicists, soil scientists and other specialists at different times over a period of several years. The aim of the FieldNote system is to enable each of these groups to take appropriate background information into the field and, in turn, to contribute to the overall collection of site information.
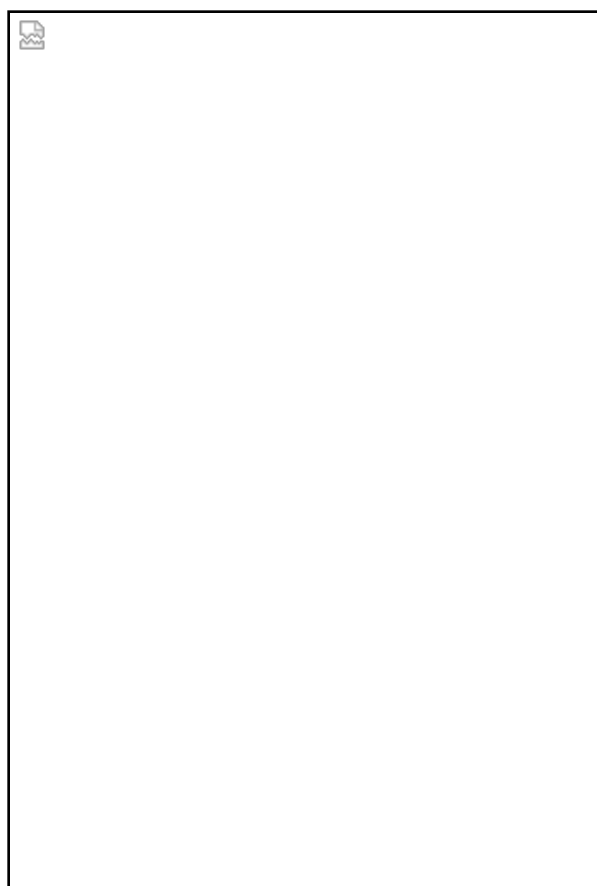

Figure 5: The FieldNote cycle, a process designed to support ongoing research and repeat field visits.

Back at the desktop

The main role of the desktop component is to provide a general-purpose FieldNote management system. In its most basic form, this might be little more than a simple database offering storage and retrieval of textual notes and structured tabular data. More typically, a combination of a simple GIS and database package would be used to implement such a system. We are pursuing this route in order to develop a simple system that can be taken into the field on a laptop computer. However, this approach has limitations. Most current GIS are poorly equipped to handle complex attribute data and most DBMS are equally unsuited to handling spatial and image data.

FieldNotes are spatially referenced and our design allows them to include a range of objects from text, through structured data and images, to sound and video sequences. Some of these data types are beyond the capabilities of most current hand-held devices but, to allow for future development, we have based an experimental desktop system on Illustra, an extensible 'object-relational' database management system (note 5). In particular the DBMS has been extended to provide

- a significant level of GIS functionality in the database server, including support for vector and raster spatial data,
- support for imprecise and uncertain dates, and
- support for other types including photographic images.

The result is a single system with no artificial fragmentation of the data model between 'spatial' and 'attribute' data. This has made it possible to build simple client programs to display and analyse the full range of data represented in the FieldNotes.
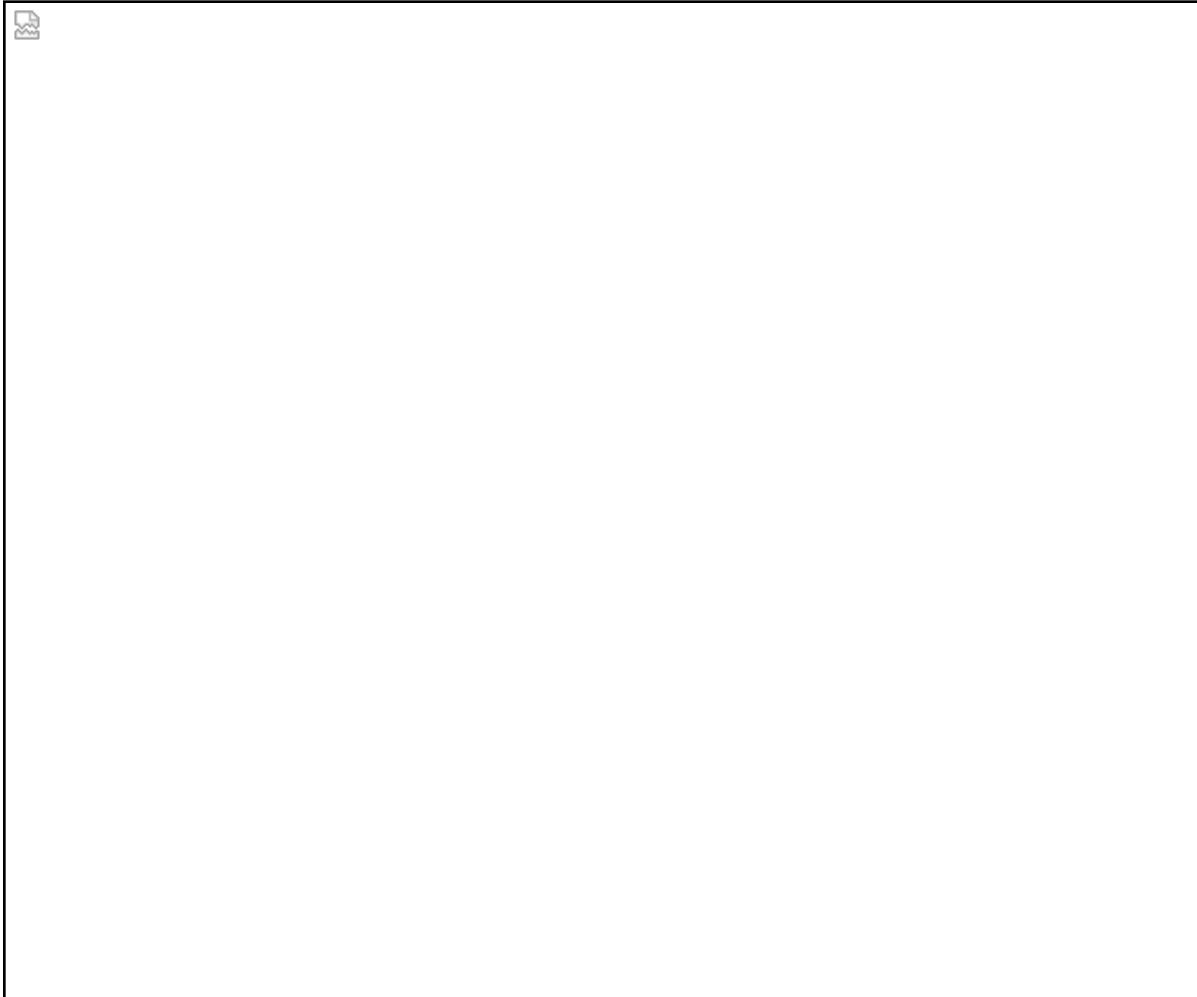
Figure 6: The prototype FieldNote Desktop system showing a set of notes collected at el Gandul, Andalucia, in September 1997.

The desktop 'front-end' program (Figure 6) is a relatively simple application written in Tcl/Tk [Ousterhout 1994]. Tcl is a simple scripting language and Tk is a toolkit extension for building graphical user interfaces. The versions used here run under unix with Tk as an X Window System toolkit, but recent releases of Tcl/Tk are also available for Mac and PC platforms.

The program functions in a similar way to many GIS display modules in that it allows different collections of geometric information to be retrieved and overlaid to form composite maps. A limited number of map manipulation and analytic functions are also provided. All data manipulation is performed by the database server and this front-end program is little more than a user interface. The simplicity of the program lies in the fact that it only performs two basic tasks, query

composition and map display. Queries are dispatched to the server and results are returned as text, images or vector data, each in a form that can be readily displayed by the program.

The underlying data model and query interface between front-end and database server will be described elsewhere [Ryan in preparation]. Here, we concentrate on the exchange of FieldNotes between desktop and hand-helds.

Exchanging FieldNotes

When working autonomously in the field, the simple text note system stores notes as HTML files on the hand-held. Similarly, the HTML forms used for structured data entry are also held as local files and accessed directly by the web browser. Normally, when the contents of an HTML form are submitted, the browser expects to pass them to a program such as a CGI script on a remote server. However, we have been able to exploit a useful property of Steve Weyer's Newt's Cape browser to store form content locally. We anticipate that such a feature will become widely used in browsers designed for mobile devices because of the frequent need to be able to work off-line.

Alternatively, when the hand-held is provided with an Internet connection, the forms may be held locally or served by a remote HTTP server. Form contents can also be submitted in the conventional way to a program running on the server host. This program then inserts the new note data into the main database. To the user, there is little difference between the autonomous and network modes of operation. Other than brief delays and a few status messages when connecting to the remote HTTP server there is little to distinguish the two modes. The only difference in network mode is that it is also possible to load a form used to bulk upload collections of notes and form contents from the hand-held to the database.

A similar transparency applies to transfers from the server to the hand-held. In the field, the user defines a set of criteria that define the range of contexts of interest. This then determines which of the locally stored notes will appear on the moving map display. If triggering is enabled, this also determines which notes will be triggered when the user enters the associated active space.

When connected to the network, a similar approach is used to select FieldNote collections for downloading to the hand-held. The example FieldNote loader form in Figure 7 is created dynamically from the

database. Listboxes present choices based on the current content of the database.
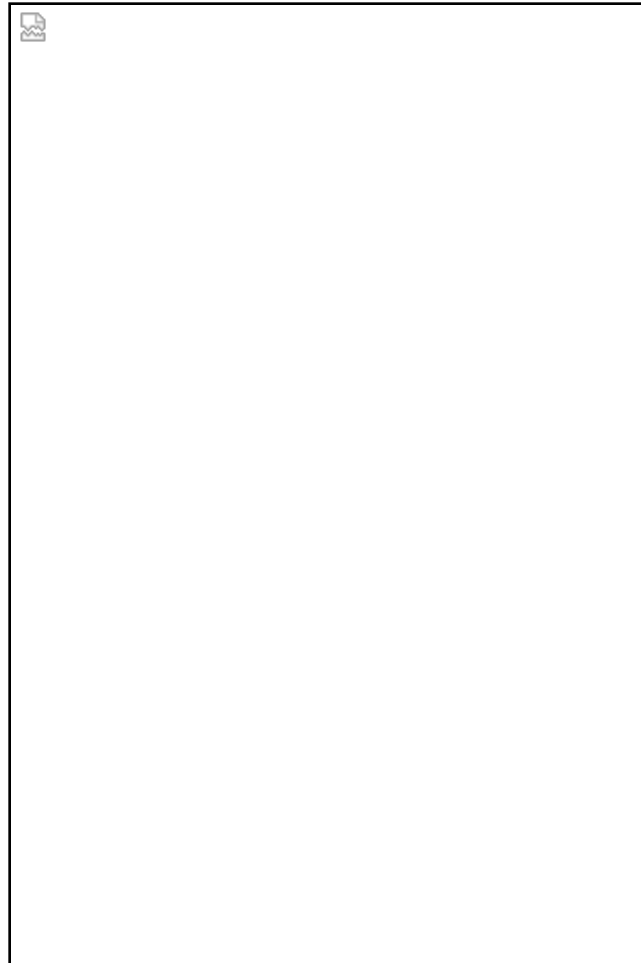

Figure 7: FieldNote loading form. The user defines their required physical and logical context and submits the form to the server. All FieldNotes matching the required context are then downloaded from the server to the hand-held.

Three significant benefits accrue from using essentially similar mechanisms for recording and selecting notes irrespective of the availability of a network connection. Firstly, it results in an overall simplification of the task of implementing the system. Secondly, testing is simplified because it is possible to simulate much of the field behaviour of the system whilst the hand-held is physically connected to the network. Thirdly, the transparency of access to the GIS and database offers the possibility of using live connections through some form of wireless network. If this approach were used, it would no longer be necessary to decide exactly which notes were to be loaded before leaving for the field. Colleagues back at base and in the field would also

gain immediate access to new data as it was collected.

Although we have discussed the 'desktop' component as part of a static system located at the users' base, it is possible to take a simplified system into the field on a laptop machine. As mentioned earlier, we anticipate using a simple GIS and database for such a purpose. An HTTP server and appropriate CGI or other programs is needed to complete this 'mobile desktop' system.

Two methods have been tried so far, both with a reasonable degree of success. The first uses Microsoft Personal Web Server and Active Server Pages (ASP). This is a method of generating dynamic web page content programmed in VBScript, JScript or other scripting languages. The second approach is more conventional, and less vendor-specific, and allows us to implement similar systems on both PCs and unix servers. It uses Perl as the main scripting language. Perl is widely used as a CGI scripting language on a variety of platforms, and various add-on libraries can be used to provide database connectivity. In the current PC version, one such library can provide connections using ODBC.

A third method that we are only just beginning to investigate uses Java and either JDBC or a native Java API to provide the database connection. This offers the possibility of greater integration between the desktop components. A GIS interface, similar to that described here but written in Java, could include most of the communication functions currently handled by ASP or CGI scripts. The greatest benefit of a Java based approach, however, would come from implementing our context aware applications as applets. This would offer even greater platform independence than can be achieved with our current mix of HTML and native coded applications. Our target here would be to run a cut-down version of the desktop GIS interface as an applet on the hand-held machine. This, however, must wait for adequate Java implementations for the hand-held machines.

Conclusions and future development

The desktop system has a user-interface offering basic GIS capabilities and enables collections of FieldNotes to be integrated with conventional spatial data. Data collected in the field can be used to form one or more layers in an existing GIS or, indeed, used as the basis for creating a GIS from scratch. The flexibility of the FieldNote architecture offers the possibility of developing highly detailed and intensively annotated spatial information systems over the lifetime of a project. GIS are widely

used as display and analysis tools, but this annotation approach can be seen as concentrating on the Information System aspects of GIS. Notes can be selected for display or downloading to a hand-held in preparation for subsequent field visits. In due course, we intend extracting other information from the GIS for use in the field, making the hand-held system act as a selective extension of a desktop GIS.

There are several benefits to our HTML based approach to data collection and the use of HTTP to transfer data between hand-helds and GIS. Not least amongst these is the widespread user familiarity with these mechanisms, and the wide range of existing tools that can be used with this system.

Platform independence has been a major factor in the development of the World Wide Web. Following Apple's bizarre decision to drop their Newton range, much of our future work will now need to be based on other devices. The hand-held computer market is still in its infancy and appears to be set for substantial growth over the next few years. Indeed, several new products are scheduled for release in the period between submission and publication of this paper. Despite this rapid rate of development, it is clear that most manufacturers regard Internet connectivity and web browsing facilities as a major requirement for these devices. Although the context-aware core of our systems will need to be re-written for different platforms, the form handling and data transfer components will work on any suitably equipped machine.

The transfer mechanisms described here have been used to exchange FieldNotes between a desktop GIS or database and the field computers. So far, this has only been done when both machines are connected by a wired network. However, the approach offers the possibility of direct access to the GIS whilst in the field. Perhaps the simplest method would be to use a GSM mobile telephone to provide an Internet connection, via a service provider, to the HTTP server back at base. Although appropriate for individual users working in areas with adequate GSM coverage, this would not suit all applications. The cost of individual mobile units and call charges could prove prohibitive for larger groups of users, and many field locations lack GSM coverage.

An alternative that we intend to explore in a future field season is the establishment of a local area network in the field. Perhaps we might call it a Field Area Network, or FAN? This would use a conventional laptop computer as a local server located at a field base or in a vehicle and providing similar facilities to those described here for the desktop system. In its simplest form, wired connections between laptop and

hand-helds would be used to exchange data whenever a user returns to the field base or vehicle. Alternatively, a 'live' network could be established using short-range radio links. This would offer the possibility of exploiting communication between users and immediate access to information recorded by colleagues. Where appropriate, a single mobile telephone could then provide communications between the laptop and the team's remote base.

Acknowledgements

Notes

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2. The Global Positioning System (GPS) receivers used in this project include simple hand-held navigational devices such as the Garmin GPS45, and custom built units based on the Trimble 'SVeeSix CM3' and 'Lassen SK8'. The Trimble devices are single frequency receivers supplied as a bare circuit board and intended for integration in devices such as vehicle navigation systems. These receivers can provide raw pseudorange data which, when processed with suitable differential corrections, can result in a position accuracy of a few metres. Since the 1997 field trials reported here we have obtained a pair of Canadian Marconi Allstar receivers. These are similar to the Trimble devices, but also provides carrier phase data that can be used to obtain sub-metre

accuracy.

3. The hand-held computers used so far in this project are the 3Com PalmPilot and PalmPilot Professional, and the Apple Newton MessagePad 130, 2000 and 2100 models. Following the demise of the Newton, we will continue to use these machines as long as they prove useful, but we are likely to move to machines running Windows CE for future projects.

4. Web browsers for the Apple Newton include the commercial products NetHopper by AllPen Software Inc. and LunaSuite Ranger by Lunatech Research, and the Newt's Cape shareware browser by Steve Weyer.

5. A license to use the Illustra DBMS was initially provided by Illustra Inc. under their University Grant Program in July 1994. Since Illustra was acquired by Informix, John Pickford (Northern Europe ATG Manager, Informix Europe) has been instrumental in ensuring continued support for our spatio-temporal database research under the Informix Engines for Innovation programme.

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