

# Human-Computer-Giraffe Interaction: HCI in the Field

Jason Pascoe, Nick Ryan, and David Morse  
University of Kent at Canterbury, Canterbury, Kent CT2 7NF, United Kingdom.  
JP@ukc.ac.uk, NSR@ukc.ac.uk, DRM@ukc.ac.uk

## Introduction

This paper presents some findings and proposals for new research that have arisen from our work on the "Mobile Computing in Fieldwork Environments" project at the University of Kent at Canterbury [1]: a project that is sponsored by JTAP (JISC Technology Applications Programme) [2]. Our main research interest is in the development of novel software tools for the mobile fieldworker that exploit existing handheld computing and sensor technology. The work described in this paper concentrates on examining the special needs and environment of the fieldworker, reflecting on the HCI features required for a successful PDA (Personal Digital Assistant) for use in the field.

## The Very Mobile Nature of Fieldwork

Handheld computing appliances are typically envisioned as tools within the businessperson's domain, where the executive is accompanied by a subset of their business data stored on a PDA. During a meeting at the office or whilst commuting to work on the train, the PDA allows them to work with their data at a location of their choice. However, the world of the businessperson is far removed from the environment of the fieldworker. Perhaps one of the most striking differences can be seen in terms of usage patterns. The businessperson will normally be seated at a desk to use their PDA, or perhaps with the PDA rested on their lap. We could therefore describe this as portable computing rather than truly mobile computing because although the user can roam anywhere with their PDA, it is generally with the intention of bringing computing resources to use within a static workplace rather than to use them whilst on the move. The fieldworker's environment, however, is a much more dynamic one, where the PDA will be utilised throughout the course of the user's work, often spread over a wide geographic area. That is, the usage of the PDA is truly mobile.

Static usage of PDAs pose HCI challenges based around the problems arising from the ever diminishing size of the hardware, e.g. examining how software displays can be adapted to the dramatically smaller PDA screens. However, at least the environment of use is still in common with traditional desktop or laptop PCs. Mobile usage of PDAs offer even more challenges as not only do the issues of miniaturisation have to be addressed but also the completely different user environments too. We believe that the requirements of computing hardware and software intended for mobile usage are significantly different from that of their statically used counterparts, and it is these different requirements and how to satisfy them that we are interested in. We have concentrated our efforts in the areas of ecological and archaeological fieldwork in particular, as two members of the project have backgrounds in these areas and we have a number of contacts that are keen to trial our prototypes. However, the ideas and prototypes we have been developing are intended to be widely applicable and are not solely aimed at these areas. Indeed, much of our work is valid for applications that require mobile usage but are outside of the fieldwork arena altogether, e.g. PDA tourist guides [3].

## Four Characteristics of the Fieldworker User

The nature of fieldwork has been described in general terms as highly mobile, where the fieldworker will use the PDA throughout a variety of environments during the course of some work. More specifically, the most common form of fieldwork carried out is data collection. The aim of this activity is to record data about the environment that the user is exploring. The unique nature of mobile usage requirements within this context can be identified by four characteristics:

*Dynamic User Configuration.* The fieldworker will want to collect data whenever and wherever they like but it is extremely unlikely that there will be any chairs or desks nearby on which to set-up their computing apparatus. Nevertheless, the fieldworker will still want to record data during observations whether they are standing, crawling, or walking (all of which would be quite normal in fieldwork conditions).

*Limited Attention Capacity.* Data collection tasks are oriented around observing a subject. Depending upon the nature of the subject the user will have to pay varying amounts of attention to it. 'Snapshot' observations require little more than recording the current state of the subject at a particular point in time. However, many observations are carried out over a more prolonged period of time during which the fieldworker must keep constant vigil on the subject to note any changes in state, e.g. observing giraffe behaviour. In these situations the user needs to spend as much time as possible in observing and to minimise the time devoted to interacting with the recording mechanism.

*High-Speed Interaction.* The subjects of some time-dependent observations are highly animated or, more commonly, have intense periods or 'spurts' of activity. The fieldworker is normally a passive observer whose work is subject-driven, therefore during these spurts of activity they need to be able to enter high volumes of data very quickly and accurately, or it will be lost forever.

*Context Dependency.* The fieldworker's activities are intimately associated with their context. For example, in recording an observation of a giraffe, its location or the location of the observation point will almost certainly be recorded too. In this way the data recorded is self-describing of the context from which it was derived. Further applications of the data often involve analysing these context dependencies in some form, e.g. plotting giraffe observations on to a map.

The relative importance of these four factors can vary with different fieldwork. For example, in testing our prototype software we have been involved with two projects: a giraffe observational study in Kenya [4], and an archaeological survey near Sevilla, Spain [5] (we refer mainly to the Kenyan work in this paper). The giraffe behavioural study strongly exhibited all four of these characteristics, whereas in the archaeological study the characteristics of limited attention capacity and high-speed interaction were not so pronounced. The differences lie in the nature of the data collection subject; giraffe are very animated whereas roman pottery is quite static. However, these attention and speed factors are still of importance in archaeological fieldwork because although, the pottery may well be fixed in absolute terms, the archaeologist will walk around an area and note any interesting subjects he passes by. Therefore, relative to the observer, the focus of observation is changing quite rapidly, and the amount of attention that can be paid to observations, and the speed of recording them, are limiting factors as to how quickly the fieldwork can be completed.

## **The Features of a Prototype Fieldwork Tool**

We have constructed some prototypes to experiment with providing fieldworkers with mobile computing technology that aims to satisfy these requirements. We have concentrated on developing novel software applications that use existing hardware, but we have carefully examined the various hardware devices available and evaluated their suitability for fieldwork environments through the following criteria:

*Pen User Interface.* We found that the flip-open 'clam-shell' pocket computers equipped with miniature keyboards were not suitable for fieldwork environments, where the user is typically standing whilst operating the device. Although ideal for static situations where it can be rested on a work-surface, in-hand use of these devices requires both the user's hands and often involves a clumsy method of typing with the thumbs. Pen-based interfaces on a pad-like device provide a more ergonomic solution that can be held in one hand if simply viewing data, and generally use some form of handwriting recognition for entering data. They provide a natural substitute for the fieldworker's paper notebook, similar in size and operation, and suitable for use by the user in many different dynamic situations (e.g. whilst walking).

*Small form-factor.* The fieldworker may already be burdened with a variety of equipment in the field. Therefore, both in terms of space to stow the device and the amount of equipment to carry, a small form-factor is essential. Ideally, the device should fit in a trouser pocket.

*Battery-life.* A typical fieldworker will spend a day in the field before returning to a base camp. Therefore, a device that can be used for at least a whole day without requiring replacement batteries is desirable.

*Robustness.* The very nature of the environment makes it necessary to have devices that are able to cope with knocks, drops, and the general conditions of outdoor life, including heat, dust, rain, etc. In short, a very durable device is required.



*Connectivity.* The process of data collection is not an end in itself. The collected data will need to be downloaded to a desktop computer for analysis and detailed study once the fieldwork has been completed. Therefore, a device that can be easily connected to a PC is necessary.

Based on these criteria we chose the 3Com PalmPilot as the most suitable device. There are a number of specialised manufactures of ruggedised mobile computers, but we wished to select a device that was reasonably priced, widely available, and suitable for a variety of mobile environments, not just in fieldwork.

In developing the first software prototype we wanted to provide some easy-to-use tools that allowed the fieldworker to collect data in electronic form. These would provide us with a platform for experimentation of our ideas to make data collection easier and quicker by the provision of various forms of assistance on the PDA.

The tools took the form of a suite of three prototype programs based on the stick-e note metaphor [6,7] in which notes are seen as being attached to a context. For example, a description of a shard of roman pottery could be tagged to the location of the find. However, rather than just recording simple textual notes, fieldworkers can record quite elaborate sets of data such as behavioural descriptions. To accommodate this requirement, we extended the stick-e note metaphor by eliminating the distinction between context and content. The resulting stick-e notes consist of a variable number of elements that can be viewed as both data and context (due to the self-describing contextual nature of field observations). The following describes the basic purpose of each of the three stick-e note programs:

*StickePlates.* Most data collection work involves recording observations as standard sets of data (e.g. recording the date, time, location, pottery type and description, for each archaeological find). The StickePlates program allows the user to define a number of note templates that describe such sets of data by defining the elements they contain.

Figure 1 - Using the StickePlates program to create a template for giraffe observations.

*StickePad.* This program provides the recording facilities with which the user can create new notes, based on a predefined template, or modify existing ones. The StickePad will be the most frequently used tool, so it is especially important for this program to be designed in harmony with the fieldworker's mobile usage characteristics.

**Sticke Edit** ▼ Scan

Date: 4/9/1995  
 Time: 18:16:12  
 Location: 0 1.085 N 37 0.32  
 Total no: 0  
 No of males: 0  
 No of females: 0  
 No of sub-adul: 0  
 No of juvenile: 0

Done Delete ▼

Figure 2 - Recording a new giraffe observation note in the StickePad.

StickeMap. A map screen is provided that offers an alternative method of visualising and selecting notes to the StickePad's simple sequenced list. Icons denoting notes are overlaid onto the map and can be selected in order to view or edit their contents.

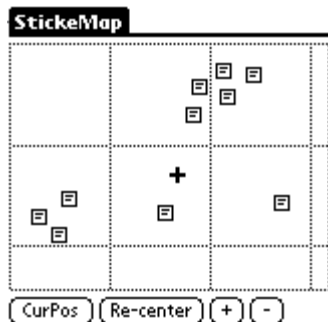


Figure 3 - Viewing the user's location (the cross-hair) in relation to the recorded notes (the note icons) in the StickeMap.

We have tested the system in a number of environments, the most rigorous of which was a two-month behavioural study of giraffe in Kenya. In this trial a willing ecologist, Kathy Pinkney, replaced her paper notebook with our prototype for the entire period of her fieldwork, using it for all of her data collection tasks. The focus of her research was to investigate the feeding behaviour of giraffe in order to assess their impact on the vegetation within the Sweetwaters game reserve. In order to do this effectively she needed to collect a large amount of raw observational data of giraffe feeding.

The simple form-based interface of our prototype software embodied the design philosophy of PalmPilot software: "if it needs a manual then it's too difficult to use". Rather than providing a radically new interface design from what the ecologist may have previously encountered, we instead sought to provide innovative features set within a familiar interface metaphor. This approach allowed Kathy to quickly learn how to use the system on the plane flight from England to Kenya. Once in the field she created a number of templates to define data sets for observations including vegetation surveys, giraffe behavioural observations, and giraffe faeces records. The prototype software proved itself almost indispensable in the recording of giraffe behavioural observations in particular: as through a combination of automation and optimised modes of interaction, more data was recorded at a much faster rate than would otherwise have been possible with a single observer using a manual recording medium.

Each day of the two-month study the PalmPilot software was used to record giraffe observation data, which was then downloaded to a laptop computer at the research centre each night. This data would be electronically shipped back to England every two weeks when collecting supplies from the nearest town (which also happened to have a Doctor's surgery offering an email service). At the end of the study approximately 6000 observations had been recorded. Apart from a few minor bugs in the code, the prototype performed at a level that allowed the ecologist to complete more work, in a way that was both faster and easier, than is possible in a manual system. The HCI factors in the prototype that led to this success can be formulated as two general principles:

**Indirect Operation.** Providing interface mechanisms that minimise the amount of user-attention, though not necessarily the amount of user-interaction, that is required to perform a particular task.

**Context-Awareness [8].** Imbuing the device with the capability to sense its environment.

The remainder of this paper describes in detail how both of these principles were applied in the prototype system and discusses our work on further enhancements and research arising from our experiences in the field.

#### Indirect Operation

The principle of indirect operation seeks to satisfy the needs of the fieldworker with respect to their characteristics of dynamic user configuration and low attention capacity. An example of a task in the Kenyan fieldwork that illustrates both of these characteristics particularly well is the detailed giraffe observation. During one of these observations the ecologist was often hiding behind vegetation, walking through the bush, or crouching over a telescope. Data needed to be recorded in any of these circumstances. Additionally, observing a giraffe's detailed feeding behaviour (such as the number of bites taken from a particular acacia tree) required a great deal of attention. This is especially true when observing from a distance through a telescope, where, unless the user pays constant attention, the giraffe can quickly move out of the field of view.

Conventionally, handheld computers require the direct attention of the user for the duration of the task. During this period all of the user's attention is focused onto the device. For example, to select a document the user will hold their PDA in one hand, select the document with the pen held in the other, and all the time be looking at the device in order to correctly operate the interface. In a fieldwork environment this distracting process can negatively affect the quality of the work. Note that it is not the number of interactions occurring that is the important factor, but the amount of attention that they require from the user.

Indirect operation attempts to remedy this situation by transferring interaction tasks to modalities that require less of the user's focus of attention. As a small experiment of this idea, our prototype software overloaded two of the hardware buttons of the PalmPilot device with a configurable increment and decrement function. These buttons could then be used to manipulate sequential data with less attention from the user because the buttons provided enough tactile feedback without requiring them to actually look at the device. The user could configure the amount decremented or incremented by these buttons for particular types of data (e.g. tree height may increment in units of five metres and giraffe bites in steps of one). This feature was most usefully employed in counting giraffe bites off a tree: here the ecologist could keep a running total of the number of bites taken whilst simultaneously observing the giraffe through the telescope. In effect, this is an eyes-free form of human-computer interaction.



Figure 4 - The ecologist observes the giraffe whilst simultaneously recording data on the PalmPilot using indirect interaction techniques.

We are exploring other methods to maximise the indirect operation of our prototype. The touch-sensitive screen provides one opportunity. If divided into selectable areas, let us say four quadrants, a particular function or data value can be assigned to each of the quadrants, e.g. a tree species selector where top-left = acacia, top-right = uclea, bottom-left = scutia, bottom-right = other. The user can easily identify the four corners of the screen with their thumb and hence operate the interface in eyes-free mode (especially if some form of audio feedback is given). Although we may not be able to divide the screen into enough areas to support all functions or data types we can certainly implement the most frequently required options to optimise for an eyes-free mode of operation.

Our interest in indirect operation is not only limited to eyes-free forms of interaction but also covers other methods that attempt to reduce the amount of focus required by the user.

One-handed operation is such a method. Although the user may need to look at the screen, one-handed operation allows them to operate the device with one hand whilst continuing to perform tasks with the other. Such a facility is useful in many diverse situations, not just in fieldwork. For example, consider the businessperson who wishes to consult their diary and to-do lists for the day whilst walking to work with their briefcase in one hand and their PDA, retrieved from their pocket, in the other. In such circumstances the hand that holds the device also has to perform the interaction tasks necessary. Small devices such as the PalmPilot are ideally suited to this type of activity as they can be easily held in one hand whilst leaving the thumb free for manipulating the screen or buttons. We are planning to implement specially designed over-sized controls, such as a full-screen slider bar, that can be used to edit a variety of different data types and that are easily operable by thumb.

Thus far we have only discussed operating on individual portions of a complete data set or task. We also inherently need an indirect operation method of navigating between these individual features. For data collection activities the ubiquitous form-filling interface (as was used in our prototype) could be structured as a set of ?layered? screens, one for each data element. The user would then be presented with a sequence of these screens that are optimised for indirect operation, much like filling in a questionnaire question by question. Note that, as with many of the

features presented, this would be an optional enhancement to the existing system rather than a replacement, because if the user's attention is not pressed then they may prefer to work with the data in the 'bigger picture', e.g. viewing the whole form whilst editing a small field within it.

The areas of the prototype interface that proved least successful in the Kenyan trial were the operations that let the user navigate through the data. For example, to edit a note the user had to decide which field of the note to select, perform the editing operation using the type-specific controls, return to the list of fields, and then decide the next field to edit. Although easily executed, when the user's concentration is directed elsewhere, such as at a giraffe, the number of decisions and manipulative processes involved in selecting and modifying the data appropriately become a distraction to the main task at hand. We hope to minimise this cognitive load through combining our ideas of layered sequential screens (eliminating the field selection process) with those of eyes-free or single-hand controls (which aim to reduce the complexity of data manipulation).

We are designing these interface techniques based on a model of fieldwork process and environment, not on a model of fieldwork data. Although some elements of interfaces are created to manipulate particular types of data, it is the user's task and environment that shape the design of our interface. Identical data may have completely different interfaces depending on the user's task or environment. For example, in the field the ecologist may want a simple and direct interface that is oriented to recording data quickly, whereas back in the laboratory the user will likely view the same data in a much more rich and complex form, such as in a GIS (Geographical Information System). It may be tempting to encode the visual interface into the logical template descriptions (as is often the case with HTML documents) but this severely limits the flexibility and portability of the data model. Therefore, we have been careful to keep interface and data models distinct in our prototypes.

One final opportunity to exploit indirect operation lies in the new hardware capabilities that are becoming available in-built on PDAs or available as attachments. For example, microphones are becoming more prevalent with handheld computers and provide opportunities for voice recognition, whilst small vibrating units (typically used by pager software) offer the developer with another means of providing feedback to the unfocused user.

#### Context-Awareness

The fieldworker is generally equipped with a plethora of equipment to assist in the observation process. In the Kenyan study, for example, a map and compass would have been required to pinpoint location and a stopwatch required for recording time series data such as giraffe behavioural observations. However, rather than taking more equipment out into the field, we believe that a fieldworker endowed with a PDA will actually take out less. The reason for this apparent paradox is that we wish to assimilate as many of the other equipment interfaces into the PDA as possible and to automate their operation. In addition, instead of providing an electronic 'copy' of the device, we aim to embed the appropriate function within the task it is related to. For example, automatically entering the current location into a new observation note. This is achieved by making the PDA aware of its context through various attached or embedded sensors so that it is able to supply contextual information when needed.

In our prototype we made our programs aware of two elements of their context that are useful in a wide array of activities: time and location. Knowledge of time is easily obtained through the unit's own internal clock, and this can be used to provide various timing functions that eliminate the need for a stopwatch. Location was provided through an attached GPS (Global Positioning System) [9] receiver that could pinpoint the user to within 100 metres anywhere in the world (given an unobstructed view of the sky). The GPS receiver was a separate unit attached via a serial cable, but we expect GPS receivers, or an equivalent technology, to be integrated with PDAs in the near future. However, decisions on the nature of the physical hardware integrated with the device need not limit context-aware technology, as from a few basic sensors a number of software-derived contexts can be generated. For example, a tide-level context

can be computed from the location and time contexts. Similarly, a 'dominant vegetation context' can be derived from a location and GIS vegetation map. In fact, the complexity of contextual information possible has spurred us into developing a Contextual Information Service in a separate research project.

One of the characteristics of the fieldworker described earlier was the need for hi-speed interaction. Context-awareness can help in this area by automating some of the fieldworker's activities. In the prototype software the StickePad automatically defaulted any time or location fields of a newly created note to the current clock or GPS reading respectively (see figure 2).

Even such a seemingly minor enhancement made the ecologist's job much easier. For instance, recording giraffe feeding behaviour through a telescope would normally have required two people, one to dictate the observations being made through the telescope and the other to use the stopwatch to record the times and details of the rapidly occurring events. However, the prototype system allowed a single person to perform both tasks by automatically completing the timing information as soon as the user indicated a new event had taken place, leaving them to simply enter a code for the behaviour. Combining this with an indirect mode of operation to enter the event details would provide an even speedier form of data collection.

The image shows two overlapping windows from the StickePad application. The top window, titled 'Sticke Edit', has a 'Scan' button in the top right corner. It contains four input fields: 'Date:' with the value '4/9/1995', 'Time:' with '18:16:12', 'Location:' with '0 1.085 N 37 0.32', and 'Total no:' with '7'. The bottom window, titled 'Edit Lat & Longitude', has an information icon in the top right. It features two rows of numeric input fields with directional arrows. The first row shows '0 0° 01.085' followed by 'N S' arrows. The second row shows '0 37° 00.323' followed by 'E W' arrows. At the bottom of this window are three buttons: 'OK', 'Cancel', and 'Here'.

Figure 5 - Editing a location field in the StickePad illustrates how context-awareness can be used to expedite data collection; in this case by automatically entering the user's location (derived from an attached GPS receiver) and allowing it to be easily updated via the 'Here' button.

Another characteristic attributed to the fieldworker is their context dependency. As mentioned earlier, the data being collected is effectively a description of various elements of their context and at a later date the complete collection of data will be compared and analysed from the perspective of one or more of these contexts. For example, the collected notes could be plotted in a GIS (Geographic Information System) in order to visualise and analyse the data from a location context perspective. Equipped with a PDA we can effectively bring cut-down versions of these context visualisation tools into the field, where not only can we view the various notes that have been recorded but also our presence relative to them [5]. In the prototype we implemented a StickeMap program to demonstrate a form of context visualisation by plotting the recorded notes and user's current position on a configurable map (see figure 3). Visualising data using contextual information provides a powerful mechanism that allows the user to gain an overview of the data from a particular contextual perspective, to filter information that they are interested in, and also to look for patterns in the data.

Triggering information and tasks by context is also an interesting area that we are exploring in our next generation of prototypes. When taking pre-recorded data back out into the field we can ask the PDA to automatically display this information, or trigger it, when entering the same context. For example, when updating a vegetation survey, the ecologist will be automatically notified upon reaching the location of a sample point and will have past data for that site automatically displayed. There are a wealth of potential applications that could utilise triggered information, consider the following examples:



Descriptive prose describing the general ecology, geology, archaeology, etc. of a particular site.

The observation history of a giraffe being attached to the actual animal itself (utilising its radio-collar as the sensor to indicate a 'near-giraffe' context).

A warning message attached to the site of a river and a heavy rain context, so that the fieldworker is alerted of flash floods prevalent in the area during bad weather.

In short, a whole field-guide could be compiled from various information sources that are automatically made available to the user in the appropriate circumstances. The limited storage resources available on most PDAs make carrying a whole encyclopaedia of information impossible, but contextual information can help filter out the relevant subset of data to download for a day's work. We envisage a three-tier system of storage and context filtering:

Home-base repository. This is the central stationary store of information contained at the fieldworker's permanent home location, e.g. the research laboratory.

Project-dependent repository. A portable subset of the complete data store that is taken with the ecologist to assist in a particular project, e.g. in the form of a laptop computer stored at the base-camp.

Task-dependent repository. This contains a highly specific set of information that is tailored for use during a particular task, e.g. the data carried around on the user's PDA during a day's work.

Filtering out the relevant data for each of the lower layers is achieved by specifying the context of the project or task. For example, if the user specifies that they will be working in the Log-Chogia area today and will be looking for giraffe, then notes relevant to this task and area can be automatically downloaded to their PDA and presented to user at appropriate points throughout their day's work. At the end of the day, newly collected information can also be uploaded to the project repository and may be used by other fieldworkers in subsequent days.

## Conclusions

We have introduced the environment of the fieldworker as one that is significantly different from the typical businessperson user and have presented our belief that this different environment should fundamentally effect the approach taken in the provision of PDA resources. In order to qualify these differences, four characteristics peculiar to the working environment of the fieldworker have been identified from which a selection of hardware criteria and a prototype software system have been developed.

Based on successful trials of the prototype in different fieldwork projects, we have attempted to identify the essential HCI features of PDAs for the field and have defined two important principles. The first, indirect-operation, seeks to provide alternative interface mechanisms that can be operated without the direct focus of attention of the user. The second, context-awareness, provides a method of automatically recording, presenting, and filtering information through a knowledge of the user's current environment. We have found that a combination of these two principles can deliver very effective solutions for the fieldworker and, in many cases, the mobile user in general.

## Future Work

In the summer of 1998 we are planning another extended trial of our prototypes in the Kenyan game reserve. This next generation of prototypes will include our ideas for user-interfaces that

are optimised for indirect operation in an even more observationally intense application. We will be working with an ecologist who intends to track the movements of rhino throughout the day to observe their behaviour. This activity also lends itself to an exploration of how the idea of triggering could be usefully employed; one interesting prospect is to trigger information about individual rhinos based on the user's current location, time, rhino footprint observations, and various other contextual factors.

Also under investigation at the University of Kent at Canterbury is how context-aware palmtop computers can be used as aids to using the public transportation system (where real-time timetable information could be generated from the current position of the transport). In an effort to provide general support for context-aware computers we are also developing a Contextual Information Service that aims to simplify the capture, representation, and manipulation of contextual information.

#### Acknowledgements

The 'Mobile Computing in a Fieldwork Environment' project is funded by the UK higher education 'Joint Information Systems Committee' (JISC) under its 'JISC Technology Applications Program' (JTAP), grant number JTAP-3/217. Many thanks are due to Kathy Pinkney and Alan Birkett of Manchester Metropolitan University, and Simon Keay and David Wheatley of Southampton University. Their assistance and enthusiasm, and their stimulating fieldwork projects have provided us with ideal environments in which to develop and test our ideas.

#### References

'Mobile Computing in Fieldwork Environments' project homepage, <http://www.cs.ukc.ac.uk/research/infosys/mobicomp/Fieldwork/index.html>.

JISC Technology Applications Programme homepage, <http://www.jtap.ac.uk/>

'GUIDE' project homepage, <http://www.comp.lancs.ac.uk/computing/research/mpg/most/guide.html>

Pascoe J Morse DR Ryan NS. Developing Personal Technology for the Field, *Personal Technologies*, submitted for publication.

Ryan NS Pascoe J Morse DR. Enhanced Reality Fieldwork: the Context-aware Archaeological Assistant, in V. Gaffney, M. van Leusen and S. Exxon (eds.) *Computer Applications in Archaeology 1997*, forthcoming.

Brown P Bovey JD Chen X. Context-aware Applications: from the Laboratory to the Marketplace, *IEEE Personal Communications*, 4(5), 1997.

Pascoe J. The Stick-e Note Architecture: Extending the Interface Beyond the User, *International Conference on Intelligent User Interfaces*, 261-264, 1997.

Schilit B Adams N Want R. Context-Aware Computing Applications, *IEEE Workshop on Mobile Computing Systems and Applications*, 85-90, 1994. Global Positioning System Overview, <http://www.utexas.edu/depts/grg/gcraft/notes/gps/gps.html>

Global Positioning System Overview, <http://www.utexas.edu/depts/grg/gcraft/notes/gps/gps.html>