Developing Personal Technology for the Field

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Abstract: This paper is concerned with developing personal computing aids for the mobile fieldworker. A description of mobile computing and context-aware technology is given, suggesting how hand-held computing devices that are aware of various factors of their userís environment (such as location) could be helpful. In particular, the concept of a stick-e note is introduced as a general-purpose context-aware technology that we have developed.. The needs of fieldworkers and the suitability of stick-e note technology to their tasks is addressed, and a number of areas where stick-e note technology could help are identified. The design of a prototypical sticke-e note system that attempts to meet these needs is introduced and an account given of an extensive trial of this prototype in assisting in a behavioural study of giraffe in Kenya.

Keywords: Context-aware; Fieldwork; GPS; Mobile computing; PDA; Stick-e note

1. Introduction

The work described in this paper is being conducted as part of the 'Mobile Computing in a Fieldwork Environment' (MCFE) project [1] funded by JTAP [2] at the University of Kent at Canterbury. The aim of our project is to combine and develop various technologies to aid individuals in a variety of fieldwork environments. In particular we have experimented with connecting small hand-held computers with GPS (global positioning system) receivers to provide a very mobile device that is aware of its location.

The disciplines in which fieldwork forms a significant component are diverse. We are concentrating on archaeology and ecology, subjects in which two members of our team have a background. There are many common tasks that span the multitude of fieldwork environments, and it is our aim to develop ideas and prototype applications that can assist in such common tasks. Additionally, in order to provide an attractive solution to potential users, we have sought to minimise the costs involved by creating new software applications and concepts that utilise existing and readily available hardware.

This paper discusses the enabling technologies that have we have exploited, developed and employed in our prototypes, how we have evolved them to meet the needs of mobile fieldworkers, and finally describes how successful they have been in the context of some practical field trials.

2. Mobile Computing

There is much research being carried out in the field of mobile computing. However, it mostly concentrates on how to provide flexible wireless networking protocols, and support for remote database and file systems that allow a user to roam about whilst transparently maintaining a connection with their networked resources [3]. A typical target user of such technology is the mobile professional who carries around a laptop computer to allow them to conduct business in a variety of locations. However, for the ecologist or archaeologist fieldworker these are not suitable technologies because (a) carrying a laptop computer into the field is simply not practical, and (b) often they will be working in scenarios where the infrastructure for wireless communication with a central resource is poor or prohibitively expensive.

The particular niche of mobile computing that we are interested in is that of hand-held computers. These go under a variety of guises such as palmtop computers, PDAs (personal digital assistants), etc., but will be referred to as hand-held computers throughout this paper. The aim of the hand-held computer is to provide a computing package with a form factor that allows it to be

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easily carried around and ideally of a small enough size to fit in one's pocket.

3. Context Awareness

The aim of context-awareness research is to exploit a knowledge of the user's environment such as their current location. In a paper coining the term 'context-aware', Schilit et al. define such systems as those which 'react to an individual's changing context' [4]. This is a particularly useful concept in mobile computing as, unlike a desk-bound PC, hand-held devices are likely to operate in continually changing environments (e.g., the location at which a user operates their hand-held computer is likely to change rapidly and frequently) and can therefore make use of a lot more contextual information than a static desktop PC.

A device may be aware of various contextual elements in its environment. For example, location may be obtained from a GPS receiver [5], a list of people nearby can be ascertained through an active badge network [6], time established from an internal clock, nearby computing resources divulged from a networked directory, share information obtained from a stock exchange pager service, and so on. Using this information the mobile computer can adapt and respond to its user's changing environment, such as by providing additional services and information tailored to the particular environment [7]. In fieldwork the user is especially concerned with working with the current environment, be it an archaeological site or African savannah, and hence is an area ripe for exploiting context-awareness.

4. Stick-e Notes

We have created a general-purpose context-aware technology based on an idea originally conceived by Peter Brown called *stick-e notes* [8,9]. The stick-e note concept has arisen from the development of an electronic version of the Post-It note (the yellow paper notes that can be temporarily affixed to desktops, computer screens, etc.). Instead of sticking paper notes to a physical location, stick-e notes allow a user to attach electronic notes written on a hand-held computer to a location that is derived from an attached GPS receiver. Should a user encounter a location that matches the location of a stick-e note stored on their hand-held computer (i.e., a stick-e note was previously attached to this location) then it is *triggered*. This act of triggering can take a variety of forms including running a program, but more commonly involves re-displaying the triggered note to the user. Stick-e notes are far more flexible than their manual counterpart, allowing a variety of electronic objects (e.g., documents, forms, programs, etc.) to be attached to a wide diversity of contexts (e.g., location, time, temperature, etc.) or combination of contexts.

Our original stick-e note prototype was implemented on a Hewlett-Packard DOS-based hand-held computer that was linked via its RS232 port to a Garmin GPS receiver. We developed a program that allowed the user to write textual notes and attach them to a context that could consist of a location, time, or date (we picked these three contexts in particular as they could all be easily and automatically obtained). Using the same application the user could also walk around an area whilst the device automatically monitored the environment and triggered any matching stick-e notes. The user could directly view the last triggered note or look through the history list of triggered stick-e notes, where a triggered note would remain until it was dismissed. Essentially, the aim of this program was to provide a simple electronic Post-It note function.

5. Assessing the Needs of the Fieldworker

The aim of the MCFE project is to apply stick-e note technology to aid in fieldwork activities. To ascertain how stick-e notes could most usefully be applied and what features would be required, we worked with a group of MSc ecology students from the Manchester Metropolitan University who were taking part in various fieldwork projects during a one week field trip to the Isle of Mull, Scotland. The projects being conducted varied from bird censuses to assessing populations of snails. It quickly became apparent that there was a common ground of data collection activities that stick-e notes would be most useful for. There is a variety of support for the fieldworker back at the base camp, for example, using a laptop computer with GIS (geographical information systems) or database packages. However, computing support in the field is scarce, and it is in precisely this area that stick-e notes could help, as the following points illustrate:

Automated data collection: where the stick-e note system can automatically record a subset of the necessary data from the environment, such as timing and location information.

Integrated GPS: to provide 'accurate' location data automatically tagged to observations recorded in environments where determining position is often difficult due to bad mapping or homogeneous landscapes.

Guided tours: where stick-e notes provide information about the specific area and artefacts in it, perhaps also providing field exercises. The field-guide and observers books could become a set of stick-e notes that provide expert information or advice that is customised to the current environment.

Shareable data: where a group can share notes recorded out in the field by downloading information to a common base machine in the evening and then uploading relevant data in the morning. For example, a group working on vegetation may record an interesting bird sighting so that the bird census group can locate and investigate the site in more depth the next day.

Safety and backup: provided by downloading the data collected to a portable PC at the base camp each night. This could then be transmitted back to a 'home' computer by email or a more conventional form of communication such as posting a disk.

Data export: as the data is already in electronic form it can easily be exported in the appropriate formats for use on a PC spreadsheet or GIS application.

The new technology was well received by the ecologists, and led to a request to use our next prototype for a two month behavioural study of giraffe in Kenya during late summer of 1997. The rest of this paper discusses the advances made in the stick-e note technology based on the experiences in Mull, and details how well the resulting second prototype (this time developed for the PalmPilot platform) performed in the two month Kenya trial.

6. Designing a Stick-e Note System for the Field

Due to the limited amount of development time before the expedition and the single user nature of the trial, we chose to concentrate our efforts on the design and development of stick-e note technology just for the hand-held computer. The desktop PC support was limited to a simple backup utility that allowed stick-e notes to be exported to a PC environment. The design of the stick-e note prototype for the hand-held device commenced with a fundamental reconsideration of what exactly a stick-e note is.

The original conception of stick-e notes envisaged them as electronic Post-Its aiding in field-workers' activities by allowing data to be recorded in the form of a note and attached to a particular context or set of contexts, e.g., attaching a 'saw rare orchid here' note to the orchid's location. In addition to automatically tagging such context information to a note for reference purposes, the program could automatically 'pop-up' the note on the screen the next time the user's context matches the one recorded. The notion of context (e.g., location) and content (e.g., orchid) being distinct and discrete entities is firmly defined by such an 'electronic tagging' model. However, is this distinction a valid one? Historically this differentiation was due to the attempt to create an electronic parallel of the Post-It note where there is obviously a separation of the notes written on the Post-It note and the physical object that it is attached to. However, with the increased richness of context that can be expressed in the stick-e note model (e.g., times, temperatures, etc.) the distinction between context and content begins to break down and blur. For example, if taking a series of temperature readings at various locations around a volcano, is the temperature a context or is it content? It could in fact be considered as either or even both. Therefore modelling stick-e notes in terms of separate content and context seems to be increasingly unsatisfactory; in principle the user might want to use any combination of fields for triggering.

If a stick-e note does not consist of content and context, what does it consist of? Considering the data collection tasks typical in fieldwork, the primary aim is to record data about various circumstances of the user's current situation. For example, recording the location, temperature, and acidity levels of various sample points around a volcano. The role of a stick-e note then, could be to model a *situation* in terms of a set of recorded *circumstances*. Rather than compartmentalising attributes of a stick-e note into content and context, paralleling conventional Post-It notes, the stick-e note can be thought of as an entity defining a situation and the specific set of circumstances therein. There are an infinite number of possibilities about what circumstances could represent, e.g., soil type, weather conditions, colour, heart rate of user, variety of apple, chewing gum flavour, etc. In this new situation model of stick-e notes each of these are treated as equals, and the typical dominance of location as the context to which other values are attached is removed and replaced with a rich variety of potential contexts.

In fieldwork scenarios a large portion of the collected data is of a structured and repeatable nature, e.g., in a bird census during the Mull field trip a standard set of data was recorded for each bird sighting (species, distance, sighting or call, etc.). In such work it is inefficient to treat each stick-e note as unique, requiring that for each new note a user must define the circumstances that comprise the situation and then specify the value for each of them. It would be much easier for the user if a stick-e note template could be defined once and then subsequent stick-e notes created from this template. Then the user simply has to fill in the appropriate values (some of these may be completed automatically, such as location, time, and date, etc.).

The simple Post-It note user interface metaphor of the conventional stick-e note prototype also needs to be updated to accommodate the changes in the underlying model of what a stick-e note is. Rather than a single textual note, a number of circumstances need to be presented to the user. A familiar method that could be used for this purpose is a form-based interface where each field of the form corresponds to a single circumstance. Templates could be constructed by the user in terms of defining the fields of a form and the types and attributes of those fields. Stick-e notes could then be generated from one of these templates and displayed in a familiar form-based representation that could be intuitively used by users who need not even be aware of the underlying stick-e note technology.

It is worth considering at this point what makes stick-e notes any different from tools such as databases and GIS (geographical information systems). Considering database technology, the domain of research is in developing optimum structured storage models for sets of data and providing facilities to update and query that data. As for GIS, the primary activity is of analysing and visualising data by associating data with geographic locations. In comparison, the central theme of stick-e note technology is in the exploitation of context-awareness in order to capture, recall, and view information about the user's current environment. Although there are overlaps in all three technologies, they are complementary ones. Database technology could provide an underlying storage model for stick-e notes, or perhaps they could be stored as HTML pages. Similarly, GIS could be employed in a stick-e note system to aid in visualising some notes. Indeed, we are actively examining the use of these technologies to provide a note management infrastructure [10]. However, it is only the stick-e note technology that is seeking to exploit an awareness of context and to do this across a wide range of tasks, from initial data collection to retrieval and visualisation, in a consistent and uniform way, i.e., with the stick-e note.

7. A Prototype Stick-e Note Fieldwork Tool

The prototype was intended to be a general-purpose stick-e note tool, with the focus of the Kenyan work on the need to create and store new stick-e notes rather than recall, update, or view previously recorded ones. The 3Comm PalmPilot linked to a Garmin-45 GPS receiver was used as the hardware base for the prototype, and a laptop PC was used to backup the stick-e notes. The stick-e note software for the PalmPilot was designed and developed as three separate applications: the *StickePad* to create new stick-e notes, *StickePlates* to create new stick-e note templates, and the *StickeMap* to visualise stick-e notes with location circumstances via a map. The reasons for this division were fourfold.

1. To reduce the apparent complexity of the small display by segmenting the program into functionally disparate areas, i.e., functions for defining a stick-e note template, creating and editing a new stick-e note, and visualising the collection of recorded stick-e notes (corresponding to the function of the StickePlates, StickePad, and StickeMap programs respectively).
2. Separating the template definition part into a distinct program allows a data collection manager to define a standard set of templates

which are given to the fieldworkers with the StickePad and StickeMap but, importantly, without the StickePlates program. In this way the fieldworker is prevented from altering the template definitions.

3. The spirit of stick-e note technology is to treat all contexts as equal and as such there should be the potential to visualise the stick-e note data by a variety of different context views, not just a map for location contexts. By separating the location visualisation function from the main program a precedent is set whereby visualisation programs based around other contexts may be developed and added to the system.
4. The resource limitations of the 3Com Palm Pilot on which the prototype was developed (and, indeed, other hand-held hardware) favour a model whereby a selected group of small programs can be uploaded to perform a specific task rather than one monolithic program that is likely to include features which are redundant in some tasks.

The prototype provides support for the specific contexts of location, date, time and compass bearing. However, to enable users to record other contextual data a set of general types were provided which could be used to model other contexts. These general types included support for Boolean, notepad, and number types. Another type of list was provided that facilitated the storage of an undefined number of values for one circumstance, e.g., a list of people present in a room. Using the StickePlates program a stick-e note template can be constructed by defining the circumstances in terms of a name and one of these contexts or general types, and various attributes can be specified such as ranges, value limits, and step amounts in the number type. Figure 1 shows a 'Field Notes' template (indicated by the current selection of the templates list in the top right corner of the screen) defining four circumstances. These can be edited by clicking on them or added to by clicking the 'Add' button. Alternatively, an entirely new template can be created by selecting the 'New' button.

Once a set of templates have been created the user can author new stick-e notes in the StickePad application. Upon creating a new stick-e note the user is presented with a form-based display showing the names and default values of the circumstances. Where possible the StickePad will fill in fields automatically, such as

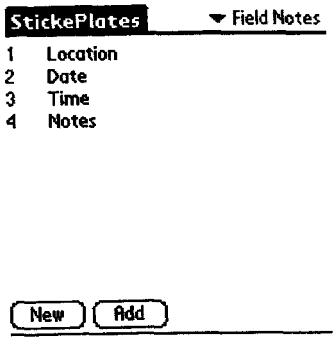

Fig. 1. Defining a field note template in the StickePlates program.

completing date, time, and location fields with the current values of those contexts (using data from the internal clock or from the attached GPS receiver). The user can then edit the remaining fields or adjust the ones already completed by clicking on the appropriate circumstance; this is shown in Fig. 2 where the time field of a stick-e note is being edited.

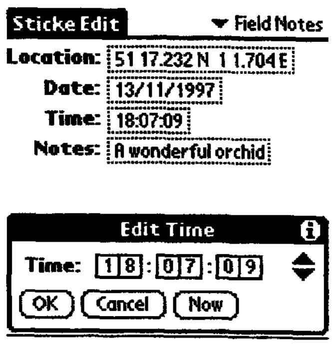

Fig. 2. Editing a new stick-e note in the StickePad program.

Having created some stick-e notes the user can either view them by scrolling through the list of all created stick-e notes in the StickePad or by viewing the ones in the surrounding area on the StickeMap. As shown in Fig. 3, the StickeMap plots the stick-e notes that contain a location circumstance as icons around the user's current location icon (this is the '+' sign in Fig. 3 and is derived from an attached GPS receiver).

The background grid's attributes can be altered and the map zoomed in and out using the plus and minus buttons. Clicking on one of the icons transports the user to the StickePad application to view or edit the represented stick-e note.

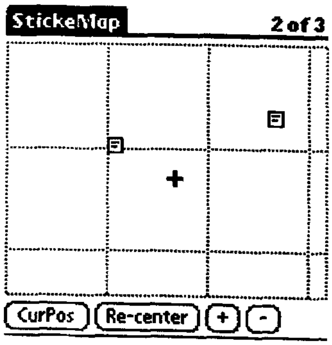

Fig. 3. Viewing the stick-e notes and current position in the StickeMap program.

8. A Field Trial in Kenya

The first major trial of this prototype was carried out with a group of ecologists working at Sweetwaters Reserve near Nanyucki, Kenya. The main aim of the reserve is to provide an environment conducive to the continued success of the black rhino population there (approximately twenty in number currently). In order to do this a number of studies are being conducted to investigate how various elements of the reserve ecosystem interact and affect the rhino population, with the goal of using this data to aid in the management of an optimal environment for them. The trial of the stick-e note prototype concentrated on the work of one ecologist in particular, Kathy Pinkney, who carried out a two month behavioural study of giraffe. The focus of this study was to gain a better understanding of the daily behaviour of giraffe and, in particular, their feeding habits and the resultant impact they have on the vegetation within the reserve.

During the first few days in Kenya a number of hardware issues were resolved. Firstly, the adequate robustness of the device was proven, after it suffered a number of falls and worked without fault during long periods of exposure to the strong midday sun and the dusty environment. Secondly, it became apparent that the physical ergonomics of the device were well suited to the environment. The small and light PalmPilot and GPS receiver were easily stowed in separate pockets whilst still being linked by the data cable, so adding little burden in terms of additional equipment to carry around, and also being immediately accessible when needed. Thirdly, the 'notepad' configuration and Graffiti pen-based data entry method were also successful. The Graffiti handwriting recognition system used in the PalmPilot can be learnt by a fieldworker in a matter of minutes, and after approximately two days of occasional usage Kathy was working at a speed similar to a pen and paper equivalent, with few errors.

The notepad form factor of the PalmPilot was a natural transition from the paper notebook method of recording data, and provided an intuitive way to enter data via a pen that included the facility to draw on the screen to make sketches or diagrams. Finally, the uncorrected GPS signal gave a location within a hundred metre error radius which proved accurate enough for marking the location of groups of giraffe.

The stick-e note system was used from the very start of the project, with pen and paper only being used to sketch out some designs for stick-e note templates. These templates were developed in a prototypical process, modifying them as it became clear what could be achieved within the constraints of the physical environment, e.g., considering factors such as how close one could approach a giraffe without disturbance. The ability to modify templates whilst in the field was useful as any adjustments could be effected immediately. A set of templates were quickly fashioned.

Scan template: We would search on foot for a group of giraffe and when within observational distance a scan survey of the group as a whole was conducted, noting the number of males, females, sub-adults and juveniles in the group.

Focal template: Having completing the scan survey, one giraffe would be selected to provide the focus of a much more detailed observation where timed changes in behaviour (e.g., walking, standing, feeding, etc.) and detailed data on the feeding behaviour were recorded.

Vegetation template: After the group of giraffe had moved out of view the details of the local environment were noted in a form that contained fields such as the percentage cover of Acacia trees.

Faeces template: Unlike the other three templates, which recorded data in relation to a giraffe observation session, this template was used independently of any observations of giraffes. It was used to create forms that documented the location and state of any samples of giraffe faeces that were collected.

These four templates provided the necessary means to carry out the data collection tasks for the whole study (although later on in the study a vegetation survey was conducted that required the creation of some more detailed templates for recording vegetation details).

Recording data on one giraffe in the focal study proved to be the most stressful test of the stick-e note system, both in terms of the amount of data entered and the speed required. Stick-e notes derived from other templates were easily completed with no immediate time limitations. However, in the focal study, data had to be entered quickly enough to keep up with the rapidly changing behaviour of the giraffe. Initially some general data about the giraffe is entered such as its age, sex, etc., and then a detailed list of behaviour is recorded including different types of activity such as walking, walking and ruminating, standing, standing and ruminating, out of sight, and feeding. A screen shot of the behaviour list circumstance from a focal study stick-e note is shown in Fig. 4.

Fig. 4. A circumstance of a stick-e note detailing giraffe behaviour.

The focal observations would typically last for 10 to 30 minutes (and rarely extend over an hour) during which time hundreds of behaviour changes could be recorded. Recording the behaviour was an intensive task where the giraffe could change feeding levels in the trees, etc., very quickly, requiring a lot of observation data to be rapidly entered. This data entry tended to come in spurts, where the giraffe would typically stand or walk for some time and then engage in a few minutes feeding activity again. During the spurts great demands were made on the user interface.

A number of helpful user interface features of the stick-e note software made the process of entering the data much easier than the conventional paper-notebook approach. Firstly, all the timing data of behavioural observations were automatically recorded by the stick-e note system which tagged each behaviour change entered with the current time, eliminating the need to carry and operate a stop watch. A counter feature was also provided that allowed numeric fields to be incremented by using two of the PalmPilot's hardware buttons, therefore not requiring the observer to look up from a telescope (and possibly lose the subject from the field of view) whilst counting the number of bites the giraffe took off a particular branch. Finally, the PalmPilot's short-cut mechanism was used whereby a character, or short sequence of characters, can be mapped to a word or phrase, therefore reducing the amount the user has to write. According to Kathy, it would have been difficult to record the same amount of data possible with the stick-e note system in a conventional manual system without the help of a second person to make timings and write notes.

Making the stick-e note software as fast as possible and adding automation features where appropriate (e.g., automatically time-stamping behaviour items in a list) can help in minimising interactions during data recording. However, it is not necessarily the number of interactions that is important but how distracting they are to the user's current task. For example, in using the overloaded hardware scroll buttons of the PalmPilot, the user is able to increment and decrement numbers without needing to look away from the telescope; the user can feel the buttons and press them without any need to look at the device. This principle of eyes-free operation allows the user to continue to use the device in parallel with their current task. Although other tasks may not be as intensive as observing giraffe behaviour, it is likely that many personal technologies can benefit from approaching the interface design as a non-interfering background activity to aid the user's current work with minimal distractions.

One final area that the prototype was used for was in helping identify individual giraffes. The patterns of spots of some giraffe provide a distinctive marking with which to recognise them in the future. To record the pattern for such future reference, a drawing application was used on the PalmPilot (called 'DinkyPad') to make a sketch and to assign a name to the giraffe.

When conducting a focal study one of these

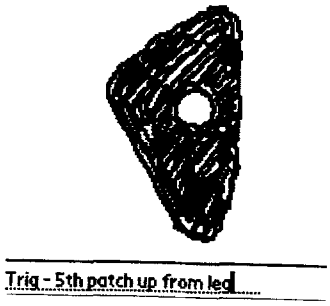

Fig. 5. Recording identifiable marks of giraffe in the DinkyPad program.

sketches can be made and then referenced from a stick-e note by adding the name of the giraffe to it (see Fig. 5).

Having recorded all this information in the field, the stick-e notes were downloaded to the desktop PC at the research centre each night. Transferring them onto disk every week, they were taken to the Doctor's surgery at Nanyucki (the nearest town) where the Doctor's email facilities were used to send a copy of the data back to England. The distributed backups provided a much more secure way of storing the data than the ecologists well-guarded notebook!

9. Conclusion

The stick-e note software not only provided an electronic counterpart to the fieldworker's conventional paper notepad, but also provided many features that improved upon it in terms of both usability and speed. Automatic entry of the current values of location, date and time into the appropriate fields of a new form and the time-stamping of elements in a list provided critical time savings; whilst features such as the overloaded hardware buttons, which allowed the incrementing or decrementing of numbers without the need to look at the device, provided an enhancement that made recording data while looking through the telescope much easier. Some features provided new functionality altogether, such as being able to see immediately on a map where all the stick-e notes are in respect to the current location.

A good indicator of the success of the system is how well it was received by the users. Kathy, the ecologist using the prototype in the ecology field trial in Kenya, found the system to be very useful and believed it provided a great utility to her work to the extent that it would be difficult to collect the same amount and variety of data in a manual system without a second person to assist.

In general, all the ecologists at the research centre were very interested in the technology even at this early stage, and were keen to use it for the benefits of saving time in data collection, being able to download the data to a PC instead of typing it all in again, and also to be able to create many backups of their data. It would appear that there is a gap in the ecological-computing market that complements desktop based applications such as GIS (that are useful for processing collected data) with tools that aid the user whilst in the field for data collection, viewing, and updating purposes. Stick-e note software on small hand-held devices seems an ideal solution for such a market.

In summary, the current prototype and its trial in Kenya have shown that the development of stick-e note tools on hand-held devices is possible, that they are useful, and that there is a user demand for them.

10. Future Work

In addition to streamlining the current stick-e note prototype based on a hand-held platform, the role of the desktop computer will also be investigated. Currently just used as a backup repository, there are a whole range of issues to be addressed regarding the desktop PC, including how large sets of stick-e notes can be managed, how stick-e notes can be shared amongst a group of users, and how the collection of stick-e notes can be integrated with other desktop technologies such as databases and GIS. Other aspects of a potential stick-e note infrastructure will also be explored including wireless communications between hand-held devices and a base computer, and the possibility of peer-to-peer forms of communication between hand-held devices in the field. Of course, the rapid development of the available hardware technology will also influence our work, such as the ability to take digital photographs from a hand-held computer.

The aim of stick-e note technology is to exploit context-awareness in the capturing, recalling, and viewing of information. Trials conducted to date have concentrated more on the capturing aspects of stick-e notes, but have offered insights into how the triggering (i.e., recall) mechanism could be developed and also suggested possible methods of visualising a collection of stick-e notes on a hand-held device. In addition, it is also our intention to develop a more diverse range of contextual services in the form of a flexible module that can be customised to the particular needs of the task at hand.

Hopefully, by exploring these issues and developing further prototypes, we will be able to provide an even more valuable tool to the fieldworker. If successful it should mean that the fieldworker need carry less equipment into the field yet be able to do more work, and new types of work, with less effort than before.

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