Wearable Technology for Crime Scene Investigation

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Abstract

In this paper we report the concept and initial prototype of a device that can be used to support evidence recovery at a crime scene. The key elements are radio frequency identification (RFID) tags that are fitted to evidence bags, which provide an association between the bag’s content and an evidence log. The log contains such details as a description of the objects (provided through speech), images of the scene or the objects (captured through digital cameras), the time of recovery, the location of recovery (captured through either global positioning system or through ultrasonic positioning equipment) and the ID of the person who recovered the object. Subsequent analysis can also be linked to the RFID tag.

Keywords: Distributed Cognition, Resources for Action, Crime Scene Investigation, RFID, Position tracking, Wearable Computers

1 Introduction

Crime Scene Investigation has always sought to apply new technologies and new procedures into its activity in order to support the goal of producing credible evidence in a safe and reliable manner. The procedures that guide crime scene investigation are not solely to encourage proper scientific practice, but also to take cognizance of subsequent uses to which the evidence might be put. This means that the actions involved in finding material, collecting the material, analysing the material and then interpreting the analysis are performed by several people in several places in support of several goals using different representations. The representations need to be “reliable, information, efficient, clear, accurate and malleable.” [1]. These requirements can be taken further into functional requirements [2]:

i. provide a common reference for communication;
ii. provide a ‘communal memory’;
iii. provide support for collaboration;
iv. provide a mechanism for multiple manipulation of objects;
v. support flexible content-reconfiguration.

In addition to these requirements, we feel that it is essential for the technology to provide a means of supporting activity that does not interfere with current patterns of work and activity, e.g., if a computer system was introduced that required the scene of crime officer to continually stop ongoing activity in order to type information into the computer, this could interrupt their procedures. Furthermore, issues of contamination mean that it is necessary to make sure that any equipment taken into a crime scene has not be previously exposed to other scenes. In terms of requirements, we propose ‘Seamless integration with current practice’ and ‘Minimal risk of contamination’ to be added to the above list.

2. Designing a Prototype

The design for the MsSAM prototype followed standard human-centred design practice. In other words, a task analysis and series of field explorations were conducted [3]. These lead to a set of requirements for a system to support contemporaneous logging of evidence during recovery. In addition to studying the activity of CSI, we have also been developing a theory, based on Distributed Cognition that relates evidence recovery to the notion that items at the crime scene represent resources for action, in terms of identification, recovery, analysis etc.
Whilst it is relatively easy to conceive of ways in which information can be collected and digitised, there remains a need to maintain focus on the actual work of the crime scene investigator. In this aspect, it is useful to draw an analogy with electronic patient records and evidence recovery and crime scene reports. Nygren et al. [4] showed, patient records do not only contain data—they also, by the physical state of the records show how often the patient has been seen, or by the signatures on the forms who has provided treatment, or by the use of pencil or pen whether comments are definite or not. The point is that the patient records are both containers of information and means of representing additional information. It is likely that the evidence bags used in crime scene investigation, and the accompanying paperwork, could function in a similar manner. This means that simply replacing physical objects with digital versions might solve some problems, but introduce new ones. To some extent, the idea of tagging evidence bags (using bar-codes in the LOCARD system or RFID in our system) goes some way to retaining the physicality of evidence bags, but more work is needed to understand how the forms and other records are used within the system.

MsSAM Prototype
The prototype is built on a $x^3$ (Chi-three) wearable computer designed and developed at The University of Birmingham [5; 6]. The $x^3$ uses a PC104 embedded PC board, and has SVGA out, two serial ports, on-board LAN and four USB ports. It is fairly small, measuring 170 mm x 40mm x 100mm.

The main unit is a 166 MHz Pentium class chipset (expandable to up to 3.4GHz). The processor runs Windows XP and the application is written in C#. A Micro-Optical head-mounted display can be used (with its own power source and data converter). A Fortuna Global Positioning System (GPS) is used for tracking the users’ location. The RFID reader is a Texas Instrument unit [RI-STU-BB27-03]. THE RFID reader and GPS are connected to the serial ports. The USB ports are used by an Intel VGA web-cam, a microphone and headset, and a three-button mouse. The right mouse button is used to handle image capture and description, i.e., click the right mouse button once to preview the image, again to capture the image (which then prompts the user to speak a description) and then again to complete the recording of the description. The left button is used to start recording of scene descriptions. When the RFID tag is read, the user is prompted to provide a description of the item and its location (and then click the left button to end recording).

3. Preliminary Evaluation
In this evaluation, the point of reference is the manner in which items are recovered. As an item is selected for recovery, the details are recorded. We presented naïve users with three items to recover. In this instance, the use of naïve users is seen as a benefit: if we had asked people with significant experience of using paper-forms but no experience of using the prototype, the experimental design would have been asymmetric, and any difference in performance due to the familiarity of one condition and relative unfamiliarity of the other.

Procedure
The use of the MsSAM prototype was compared to the conventional practice of writing out evidence labels and logs.

In a paper-based system (see figure 2), there is a need to record the same information more than once, e.g., the information recorded on the evidence labels is the same as that recorded in the log, and for the information to be entered from paper into a computer back at the office.

In order to make the experiment a reasonable reflection of actual practice (even though we were using non-experts in this trial), we presented participants with three items to recover. In the paper condition, evidence labels and a log were completed; these included entering date, time, location, investigator ID and a brief description of the item. In the MsSAM prototype condition (see figure 3), date, general location and ID are captured automatically. The user can take a photograph of the item, and is prompted to provide verbal descriptions of the item and its precise location.

Figure 1. Prototype laid out on desk.
The $x^3$ is towards the top of the picture; the sensors (RFID, camera and GPS) are to the right; the user interface (headset and head-mounted display) are to the left. The evidence bag and blood swab, in the centre of the picture, are tagged with RFID chips to provide unique identification.
Figure 2. Completing a paper evidence log

The experiment was run as a within-subjects design because it was felt that variations in approach might affect results. Thus, having the same people complete both conditions (counter-balanced to minimize order effects) could reduce possible contamination of results by approach. As it was, there were still observable differences in approach between participants, and these differences did not always transfer between conditions. For example, in the paper condition, some participants completed a label for each item and then completed the log as a whole, while other people completed a label and log entry for each item before moving on to the next; in the MsSAM prototype condition, some participants took a photograph of all the items and then put them into their containers, while others took a photograph of an item and bagged it before moving on to the next item.

Nine people took part in the experiment (8 male, 1 female, with a mean age of approximately 25 years). All participants were students in the Electronic, Electrical and Computer Engineering Department and none had previous experience of CSI work. All participants had received instruction on completion of evidence labels and logs, and demonstration on how to use the MsSAM prototype.

Figure 3. Recovering an item using MsSAM prototype

Results

The experiment compared to the time to complete the recovery process. The number of words in each audio log was also compared with the paper labels and logs.

The Results section is divided into two parts. The first part compares completion time for the two conditions to provide a coarse-grained comparison, and the second part examines the number of words in each description, to provide a more fine-grain comparison.

Completion Time

Figure 4 shows the mean times to complete the recovery of three items for each condition.

![Figure 4](image)

A paired t-test was performed on the results and revealed a significant difference \( t(8) = 4.071, p < 0.05 \)

Detail in Descriptions

By counting the numbers of words in the descriptions created by the participants, we can compare the level of detail provided by each system. This is a crude measure, in that just because someone produced more words does not mean that the description was ‘better’, but it provides a point of comparison for the two systems.

<table>
<thead>
<tr>
<th></th>
<th>Location</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td>4.7 (± 1.3)</td>
<td>5 (± 1.7)</td>
</tr>
<tr>
<td>MsSAM</td>
<td>8.7 (± 5.8)</td>
<td>8 (± 2.6)</td>
</tr>
</tbody>
</table>

The number of words differs between the two conditions. A t-test was performed on the data and revealed that while location yielded a significant difference \( t(8) = 2.57, p<0.05 \), description marginally failed to reach significance \( t(8) = 2.22, p =0.57 \) . Observation of the trials suggested that, for the paper-based condition, people might be satisfied with short, basic descriptions, e.g., ‘screwdriver’, while for the spoken description people tended to add more information ‘Blue handled posi-drive screwdriver’. None of the participants did more than provide a brief description of the item, i.e., none of the participants provided additional comment on the item. Experienced CSIs might make different use of the facility to provide...
descriptions, and this is a question to explore in subsequent studies involving CSIs in the ‘crime-houses’ that are set up for training crime scene investigation practice.

In addition to providing verbal description of items and their location, participants in the MsSAM condition were able to take photographs of the items. Figure 5 shows that there was a degree of consistency in the capture of such images across participants (figure 5 shows 3 rather than 9 images simply to minimize space requirements).

Figure 5. Images of a business card capture during the evaluation

Conclusions

The evaluation demonstrates a significant difference in the time taken to recover items using the MsSAM prototype, in comparison with the completion of paper labels and logs. Comparing the systems in terms of the number of words in the descriptions suggested that the paper-based system had slightly fewer words. However, this difference in word-count is probably not sufficient to explain the overall performance difference. If we assume that the recovery of each of the three items took approximately a similar time, then the per item times for the two conditions can be calculated as 96.3s (paper) and 64.5s (MsSAM). If we assume that one can write at about 4 seconds per word, and speak at about 1 second per word (which are assuming that the activity is fairly slow), and multiply these values by the average number of words recorded on both label and log for paper, this gives around 24s and 32s for paper and 5s and 7s for MsSAM. In either condition, there is a discrepancy of around 60s for the two conditions. This can be explained firstly by the time taken to manipulate items (in both conditions) and secondly by the time taken to capture images in the MsSAM condition. This implies that, while the MsSAM prototype requires a degree of manual interaction with the system, e.g., in terms aligning the camera and pressing mouse buttons, there is still sufficient evidence to suggest that it is more ‘hands-free’ than the paper-based version which required participants to continually switch between holding an item and using the pen.

It is important to note that we are not ruling out the use of note-taking at the scene. We see the MsSAM prototype as being a means by which truly contemporaneous data collection is performed, and these data can form the basis of the crime scene report. However, from a Distributed Cognition perspective, the very act of writing notes and drawing sketches may well influence the manner in which the crime scene is explored and thought about. Having an automated system that supports the logging of recovered items would not eliminate the opportunity to sketch and write notes at the scene.

Furthermore, having image capture aligned with evidence recovery means that the CSI is able to photograph items in order to comment on the position in situ and on any interesting aspects of the physical appearance of the scene. In related work, we have shown how it is possible to annotate digital images with sketches Cross et al. (2003), and it is possible that a similar implementation could be created for this project.

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REFERENCES


