Activity-based Information Retrieval: Technology in Support of Personal Memory

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Much information is hard to retrieve because the need to do so was not foreseen at the time the information was stored. This problem appears hard to solve with the aid of computers. However, research in the area of autobiographical memory suggests the use of retrieval cues relating to the kinds of activities in which the user was engaged at the time of storage. These are highly correlated with the time at which the event took place, and thus can be used for indexing, taking advantage of the accurate time-stamps that computers usually apply automatically when information is stored. In the proposed activity-based retrieval system, data on the user's activity are gathered automatically to support retrieval by, for example, browsing through an 'autobiography' of work episodes. The paper discusses some of the difficulties with this approach, and presents the results of three experiments in which autobiographical episodes were reconstructed by means of automatically collected activity data. It concludes with some comments on the technical feasibility and social acceptability of such an approach to information retrieval.

Keywords: Information Systems Applications, Multimedia Information Systems, Office Automation, Memory

1. INTRODUCTION

The advent of the networked personal computer has greatly increased the user's ability to manipulate information of all kinds. Tools now readily available support text preparation, illustration, spreadsheet manipulation, electronic mail, data analysis and, with the advent of systems like the Multimedia PC, audio/video playback and editing. However, the tools for storing and retrieving this information remain primitive, largely unchanged from the tools available on the time-shared systems of the 1960s and 1970s. There have been major innovations since then, such as the desktop filing system [Smith] and efficient methods for free-text search [IBM], but these go only a little way towards enabling users to deal with the explosion of information around them.

The research programme described here has a goal of improving the user's ability to retrieve information and recall events in the workplace. It aims to help in the very wide variety of everyday situations where the user cannot locate information unaided, nor can standard computer-based tools help. For example, the user may wish to locate an electronic note written after a meeting held several months ago, but may remember neither the file-name of the note nor the date of the meeting. Another example, common in these days of widespread videotaping, is to recall an important remark made at a seminar, about which only a brief note was made: what exactly did the speaker say, and where is it on the videotape? As these examples illustrate, retrieval problems are often the result of lack of foresight or simply lack of opportunity to store and index the information at the appropriate time. As our information world expands, this happens increasingly often.

We describe here an approach to the design of information retrieval systems. The approach exploits advances in understanding of human recall and retrieval, and in so-called Ubiquitous Computing technologies [Weiser]. It envisages computer-based systems that explicitly supplement human memory. It envisages personal devices, such as the one in the artist's impression of Figure 1, that support browsing through autobiographical data to find episodes corresponding, say, to the two examples of note-taking above. In this paper, we describe an overall technical strategy based on automatic sensing of time-stamped activity data. We itemise some of the serious difficulties--technical, psychological and social--to be overcome in implementing this strategy. The paper then describes briefly three projects we have undertaken, in which we have built and tested prototype systems. A final section summarises our progress to date towards overcoming the difficulties, and discusses the prospects for an activity-based solution to human memory problems.

Figure 1. A Portable Memory Aid.

2. RECONSTRUCTING EPISODES FROM TIME-STAMPED DATA

One of the characteristics of electronic information, which we employ in our approach to retrieval, is its frequent inclusion of accurate time-stamps indicating time of activity. Files, for example, store the time of creation, access or modification along with the data; videotaped material can include timecode; electronic messages state the time of sending, and fax machines print the time of receipt on incoming pages. These time-stamps can be useful in locating the information. In most instances, however, relying on time-stamps is only of limited use for retrieval, since people are notoriously poor at remembering purely temporal information [Michon].

Research in the area of autobiographical memory offers a solution to this problem, for it suggests that people often use retrieval cues relating to the kinds of activities in which they were engaged at the time of the event [Reiser]. Such activities are of course highly correlated with the time at which the event took place. Thus the human activities of Figure 3 correlate with the electronic processes of Figure 2. We believe

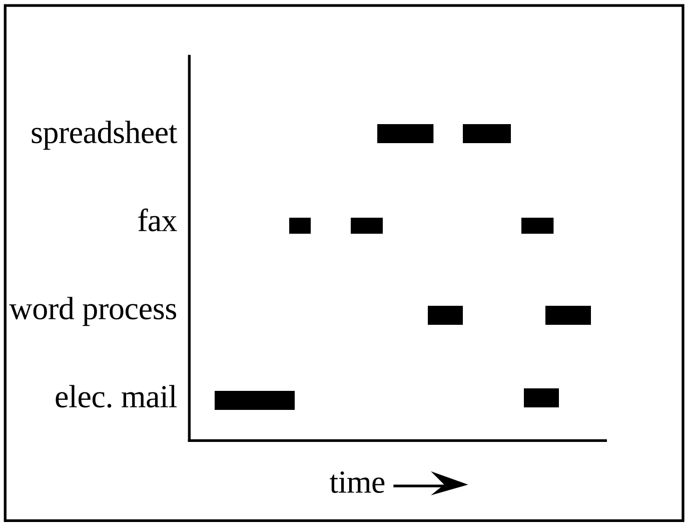

Figure 2. Electronic Information Activities

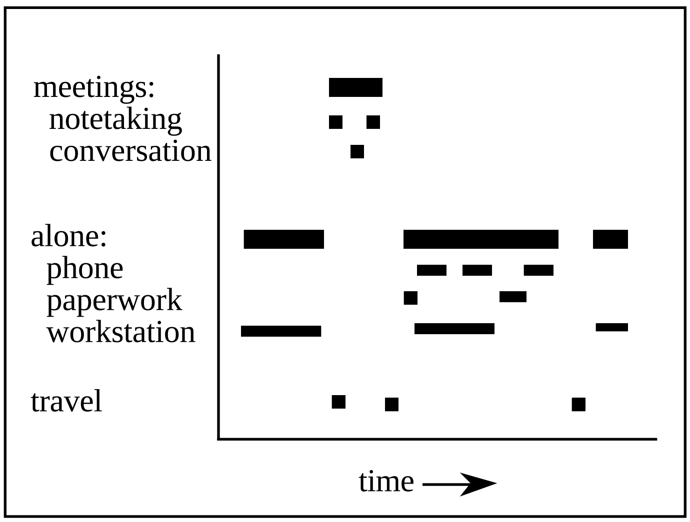

Figure 3. Human activities corresponding to Figure 2.

that it should be possible to generate records of such activities with no effort on the part of the user. Our approach is to use these records as a basis for locating electronic activities and their related information.

Our method thus involves monitoring human activity and linking it to electronic activity. We have explored a number of methods of capturing the human activities of the workplace: changes in location, telephoning, use of workstations. These activity data do not correspond particularly closely to users' recollections of events. We have therefore developed episode recognisers that transform the raw activity data into episode descriptions that resemble users' recollections quite closely. For example, from location data we can identify meetings with others and periods spent alone.

Activity-based retrieval has been inspired in part by recent work by Tulving, Baddeley and others on models of episodic and autobiographical memory [Tulving, Brewer, Baddeley86]. Linton, for example, has proposed a hierarchical model of memory in which events and episodes are formed from smaller units, which she calls elements and details [Linton]. The work of Bjork and his colleagues, on limits to retrieval capacity and on the value of contextual clues, has provided valuable pointers [Bjork78, Bjork88]. Both Linton and Baddeley have described long-term effects, helping us to identify problems to which activity-based retrieval might be applied [Linton, Baddeley77, Pinto]. We have also been encouraged by the work of Schank and others on various systems that exploit aspects of human autobiographical memory [Schank, Wilson, Lansdale].

3. THE CHALLENGES OF THE ACTIVITY-BASED APPROACH

The design and construction of an activity-based retrieval aid presents a number of challenging problems, which include:

- *Understanding the user's needs for retrieval tools.* There is little or no published data on human retrieval problems in the workplace. They are undoubtedly frequent, but it is hard to assess the value of building tools to solve them.

- *Automatic sensing of activity.* The activity-based approach depends on sensing activity data automatically, in a manner that does not require intervention by the user, and indeed that the user can be unaware of. The technology for this is largely unavailable, because there has been very little need for it.

- *Reconstruction of episodes from activity data.* Technologies that sense activity collect large amounts of very fine-grain data, far too detailed to be of use in retrieval. The user needs to be able to browse through a reconstruction of episodes that match his or her recollections; these episodes often have durations of minutes (e.g., telephone calls), hours (e.g., meetings) or longer. A major problem, therefore, is to develop algorithms for converting fine-grain activity data into records of recognisable episodes.

- *Building powerful portable or hand-held terminals.* A memory aid is unlikely to be useful unless it is always accessible. The terminal for browsing must therefore be small enough to be carried with the user, and yet capable of displaying useful amounts of information; it must also support an appropriate user interface.

- *Hiding unwanted features of the distributed environment.* The memory aid must also be connected to the user's store of episode data. The distributed technologies for this are mostly available or in prospect for the near future. However, it remains a challenging problem to package them in such a way that the inexpert user is unaffected by their frequently strange behaviour and can confidently rely on them for day-to-day memory support.

- *Designing and building usable retrieval tools.* The construction of such tools is not just a long-term goal: to support experiments, prototype tools must be built and tested at stages along the way. A particular problem in testing these tools is that they must support real retrieval tasks, caused by real memory lapses. Therefore they must be designed and implemented to a high enough standard to be used in earnest during the experimental period.

- *Safeguarding the user's privacy.* This problem, although last in the list, is often first in the mind of participants. The activity-based approach involves collecting and analysing data about the user's personal activities; most users regard this as an infringement of their privacy. Any networked system of this kind will inevitably arouse serious concerns over possible misuse, e.g., by management, and over the general ethics of using technology in this fashion.

Our approach to these problems has been to mount a number of experiments, each one addressing several of the problems from a particular angle. Three of these are described in the sections that follow.

4. PEPYS: AN AUTOMATIC DIARY GENERATOR

We have developed a program, called Pepys, that generates diaries automatically. It uses activity data gathered from active badges: these use infra-red coded signals, picked up by wall-mounted sensors, to inform a central server of badge-wearers' locations [Want]. It incorporates a recogniser that looks for episodes of three basic types in the raw badge data: gatherings of two or more users (e.g., meetings), periods spent alone by users, and travel by users between locations in the building. The diaries are prepared and distributed daily to users via electronic mail; a typical diary is shown in Figure 4. A more detailed description of the system and its use may be found in [Newman91b].

We have conducted preliminary studies of the accuracy and usefulness of Pepys. These two aspects are of course closely linked: errors in Pepys' reconstructions reduce users' interest in it as a retrieval aid. Some errors are difficult to eradicate because they reside in the raw data. For example, users forget to wear their badges, or wear them at waist level where they sometimes are not sensed by the system. The result is that other users receive diaries listing periods 'alone' when in fact others were present. Discounting errors caused by faulty data collection, the accuracy of Pepys' episode recognition is high, at least 90 percent. This has been enough to encourage a number of interesting uses of diaries, for example to remind the user of commitments made yesterday that imply follow-up work today. Visitors to EuroPARC have found Pepys useful in writing trip reports -- an application that we find gratifying since we identified this possible use at the outset.

Diary for Tuesday, October 30, 1990

14:14 In office [50 mins]
15:04 In and out of event in Nathan's office; with W. Nathan, R. Hatton [45 mins]
15:50 In office [10 mins]
16:00 In Conference room [4 mins]
16:05 Attended part of event in Commons; with B. Andrews, M. Morton, R. Hatton [7 mins]
16:13 Mostly in office [44 mins]
16:57 Attended event in Wright's office; with P. Wright [7 mins]
17:04 Looked in on event in Morton's office; with I. David, M. Morton [1 min]
17:05 Mostly in office [2 hr 3m]
    17:05 In office [5 mins]
    17:11 In event in office; with P. Wright, I. David [1h 2 mins]
    18:13 In office [36 mins]
    18:50 Meeting in office; with W. Nathan [13 mins]
    19:03 In office [5 mins]
19:09 In 2nd floor rear area [2 mins]
19:11 Last seen

Figure 4. An example of a diary generated by Pepys.

5. VIDEO DIARIES: TESTING THE USE OF VIDEO RECORDINGS TO ENHANCE RECALL

Reliance solely on location-based episodes, as in Pepys, limits the utility of the memory aid. For example, during long periods spent alone in one's office there is insufficient detail to support recall; when several meetings involve the same people it is difficult to distinguish one meeting from another. One way of solving this problem is to provide video recordings of these episodes. There are some severe technical problems with this approach, but we were interested in investigating its usefulness so that we could judge whether the problems were worth solving. We therefore built and tested a Video Diary System, based around the capture and browsing of low-quality time-lapsed video [Eldridge].

Our goal was to create a system capable of storing many days' or weeks' worth of video images and of supporting rapid random-access to these images. We based the system around an in-house video network which provides a camera and monitor in each office and open space, with a central crossbar video switch accessible to workstations in the building. With this system it is possible to switch cameras so as to keep an individual almost continuously within view, and to route the video signal to a single recording station. Automatic switching, without the user's intervention, is achieved by means of the active badge system mentioned above. The badge server is linked to a client application, Tracker, which it notifies of each new location of the user; Tracker then transmits a suitable request to the video switch. Video output is fed to a workstation where a frame grabber digitises each frame and displays it on the screen. In order to store several weeks of data, we use exchangeable magneto-optic disks, storing quarter-size (one-sixteenth area) frames at the rate of 6 to 12 per minute, and using colour dithering to reduce the data further, to about 25K bytes per frame. With this relatively unsophisticated compression scheme we can normally fit at least two weeks' worth of data onto a single 650M byte disk.

We tested the ability of the Video Diary to assist recall. Subjects were asked to remember the activities of a particular day under three conditions: unaided, with the help of Pepys diaries, and with both Pepys and the Video Diary. Each subject was asked, on different occasions, to recall the activities of a previous day of recording; these recalls occurred after 1 day, 1 week, 2.5 weeks and 4 weeks. The average results from three subjects are shown in Figure 5. There was a clear indication that the Video Diary helped users remember their activities, particularly over longer periods of recall. It was also clear that the presence of people or objects acts as an important cue in recall, reaffirming our original research hypothesis. Although the Video Diary often helped, it also occasionally confused the user by presenting a video image that could not be related to a recalled event.

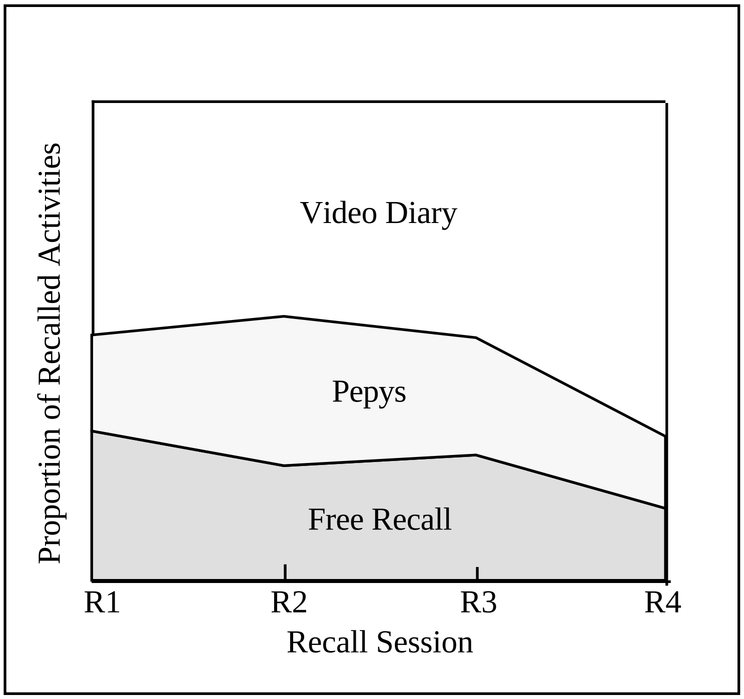

Figure 5. The number of basic activities recalled for each of the three conditions over the four recall sessions. The plot shows the number of basic activities recalled for each condition summed over the previous conditions. Thus the plots for Pepys and Video Diary conditions show the increase in the number of activities using these memory aids.

6. EXPERIMENTS IN TRACKING PAPER DOCUMENTS

The location-based episodes of Pepys are often too coarse in grain, and need supplementing with other forms of activity to provide the necessary detail. An episode description such as “11:23 In office [1h 26m]” is both too uninformative and too long in duration to be useful for some retrieval tasks. Taken in combination, however, several types of activity can provide adequate precision. We envision the possibility of a multi-activity record including a wide variety of entries such as “11:30 Reading letter from J Smith [2 mins]”.

We have built a prototype system, called Marcel, to recognise episodes concerned with paperwork [Newman91a]. As with Pepys, our aim is automatically to produce episode descriptions that match users' recollections. Marcel uses a video camera mounted over the user's desk to identify the documents on the desk surface. Images from the camera are fed to a frame store where they are digitised and thresholded. The resulting binary image is processed to extract features of the document that can be used to construct a unique descriptor; an activity database stores descriptors together with the time and location of identification. The primary features used for descriptor generation are the positions of the ends of the lines of text on the page. The descriptor includes an encoding of each line's left-hand end relative to the left margin, and of the line's length, as shown in Figure 6.

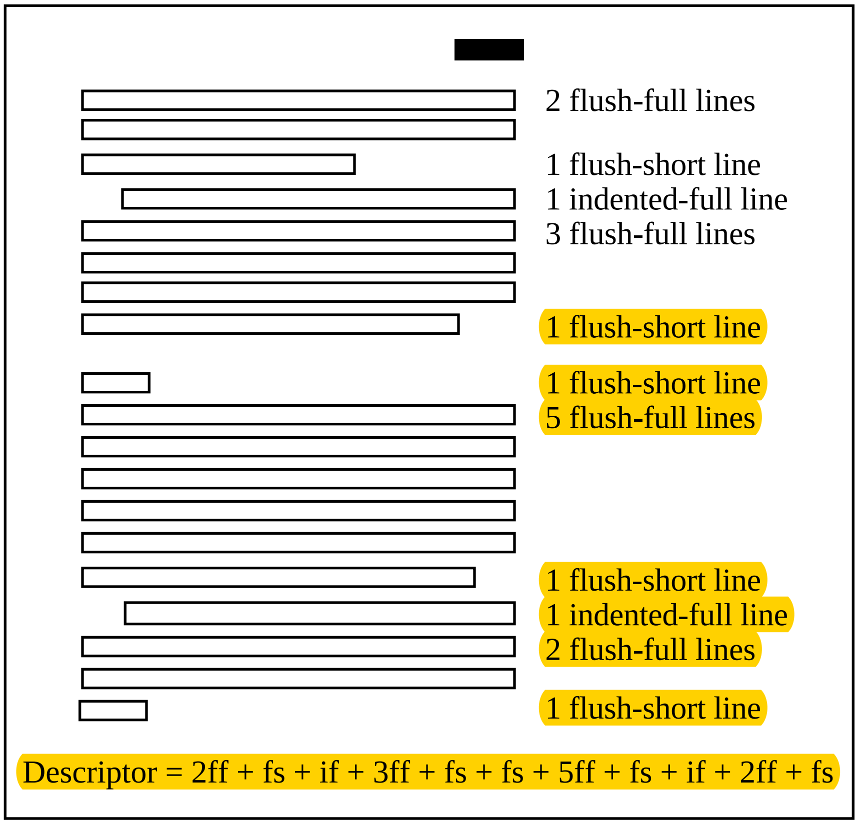

Figure 6. Generating a descriptor from line end positions.

Marcel's database stores the text content of each page, indexed by its descriptors. Documents may be entered into the database either via a desktop scanner and optical character recognition, or directly from an electronic master, such as might be sent to a laser printer. We have been able to achieve reliable recognition of documents in the database, even under relatively poor lighting conditions and with interference from other objects on the desk, such as the user's hands. Rotated documents are recognisable up to a tilt angle of approximately 15 degrees. Recognition time, using a Sun SparcStation/2, is about 8 seconds. These performance figures appear adequate to support experiments in using document-related episodes for retrieval.

7. CONCLUSION: RESULTS FROM EXPERIMENTS

These three experiments have provided some initial indications of solution strategies for the problems listed at the start of this paper. They have been augmented by other experiments, but space does not permit reports of these in this paper; they include construction of a portable note-taker which keys the user's notes to points in a video or audio recording [Lamming], and recent work on the analysis of workstation activity [Flynn].

7.1 Understanding the user's needs for retrieval tools

In order to estimate the need for memory aids, we have conducted some preliminary studies of workplace activity. These suggest that the recall of workplace activities is largely reliant on episodes of four types: meetings with other people, phone conversations, workstation-based tasks and paperwork. Further studies, aimed at categorising the types of memory problems encountered, are in progress at the time of writing.

7.2 Automatic sensing of activity

We have learned that the accuracy and comprehensiveness of available sensing technologies leave a lot to be desired. Active badges frequently 'lose' people, and sometimes receive spurious signals off reflective surfaces; video cameras have limited fields of view. We have also learned that so-called 'unobtrusive' technologies are often much more distracting to users than one would anticipate. This is an area where more work is needed.

7.3 Reconstruction of episodes from activity data

We have found episode reconstruction to be one of the more difficult aspects of activity-based retrieval. The development of a recogniser to support the generation of Pepys diaries, for example, involved several months of design effort; results to date on analysis of workstation activity suggest that this may pose an even harder problem. Given the inaccuracies and other flaws in the data we collect, and our limited understanding of how to apply meaning to activity, we expect this to be a continuing research challenge.

7.4 Building powerful portable or hand-held terminals

Progress towards building networked hand-held terminals has been described in [Weiser]. It is now feasible to build a device measuring 65 x 80 mm incorporating a display, control buttons, a pen interface, and an infra-red link for communication (Figure 7). We anticipate that our research will ultimately rely to a large extent on such devices.

Figure 7. Model of a hand-held terminal.

7.5 Hiding unwanted features of the distributed environment

While it may ultimately be possible to build some of the necessary sensing technology into a portable memory aid, there will always need to be a link to the ubiquitous environment that surrounds the user. We see increasingly clearly, however, that the memory aid must present itself as a personal device to the user, and hide the complexity of the distributed infrastructure. Another major issue will be the provision of safeguards to privacy so that, for example, two users' wireless devices can exchange information securely in the presence of a third user.

7.6 Designing and building usable retrieval tools

By focusing on specific areas of application we have been able to attain an adequate level of usability in several of our prototypes. The Pepys diary system has been particularly successful, maintaining a small community of 'converts' a year after its introduction, i.e., well after its novelty must have worn off. We have come to appreciate that systems which aim to support human memory retrieval may require special attention to the user interface; otherwise the cognitive load imposed by interaction can outweigh the reduction in load on the user's memory. There is a need for low-intensity user interfaces that demand little or no attention from the user [Newman90].

In building prototypes of relatively narrow functionality, we have had to give considerable thought to how to ensure that the tools would actually be used during the experimental period. In the case of Pepys, users were encouraged to wear their badges by providing other badge applications, such as a program that automatically unlocks the main entrance to the laboratory when the user clicks a button on the badge. Marcel has been extended to permit limited forms of interaction with the document as it lies on the desk surface, and has been shown useful for tasks such as machine translation of foreign words [Newman92]. Until we can build full-scale retrieval aids we anticipate that our prototypes will need to include such add-on benefits for the user.

7.7 Safeguarding the user's privacy

The design of a device to record episodes of activity data must address privacy issues head-on. Our programme therefore maintains two threads of research: one is aimed at understanding the nature of privacy issues and of other social issues raised by the programme; the other investigates ways of designing the technology to protect the user against loss of privacy. Our studies of the social issues have focused on the active badges and on the boundary between what is public and private, a boundary that is many ways tacit but whose infringement can cause considerable distress[Harper]. The studies help us, therefore, to see this boundary as something we can affect by our designs, and that we should only affect in ways that are acceptable to the user. They have also made clear to us the user's need for control over the entry of technology into his or her work environment.

In designing the technology to support activity-based retrieval, therefore, we have built in safeguards against unnecessary access to data, and have provided users with controls and with the ability to opt out. The data gathered from badges for use by Pepys has, from the start, been encoded so as to make it extremely difficult for unauthorised programs to use. More recently we have introduced higher-level controls that allow individual users to identify other users who may have access to information about their location, past or present.

Some of these safeguards are, we hope, temporary precautions necessitated by the highly distributed architecture we are forced to use in the absence of a more personal device. However even a completely personal device will not solve all problems of privacy. Any such device would be capable of sensing activity that the owner does not see (e.g., if it is left in the office when the user takes the day off), and would remember details for ever that the owner would soon, perhaps thankfully, forget. However we believe a personal memory device will, in the long run, offer its users benefits that far outweigh any drawbacks, and that go some of the way towards enabling them to manage the information that surrounds them in the workplace.

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