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MEMENTO: a digital-physical scrapbook for memory sharing

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Abstract The act of reminiscence is an important element of many interpersonal activities, especially for elders where the therapeutic benefits are well understood. Individuals typically use various objects as memory aids in the act of recalling, sharing and reviewing their memories of life experiences. Through a preliminary user study with elders using a cultural probe, we identified that a common memory aid is a photo album or scrapbook in which items are collected and preserved. In this article, we present and discuss a novel interface to our MEMENTO system that can support the creation of scrapbooks that are both digital and physical in form. We then provide an overview of the user's view of MEMENTO and a brief description of its multi-agent architecture. We report on a series of exploratory user studies in which we evaluate the effect and performance of MEMENTO and its suitability in supporting memory sharing and dissemination with physical–digital scrapbooks. Taking account of the current technical limitations of MEMENTO, our results show a general approval and suitability of our system as an appropriate interaction scheme for the creation of physical–digital items such as scrapbooks.

Keywords Physical interfaces · Mixed-media environments · Tangible user interfaces · Pen and paper user interfaces · Memory sharing · Reminiscence · Story telling

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1 Introduction

Classical scrapbooks are albums into which flat physical items (e.g. photographs) or written notes can be pasted [1]. The creation of physical scrapbooks or “scrapbooking” has evolved beyond the basic hobby of pasting newspaper clippings, magazine articles and photographs in books [2]. Technical innovation and an increasing interest in artistry have changed the nature of this activity. The proliferation of digital media and the Internet has sparked an interest in “digital scrapbooks”, not just basic slide-shows or pages of digital media items [3].

In contrast with scrapbooks, our own studies [4] and the work of others in POEMS and the Living Memory Box [5–7] has shown that tangible objects (not just flat objects, photographs and newspaper clippings) can be used to afford a digital–physical space suitable for memory sharing [8]. Digital memory boxes attempt to leverage one interaction paradigm (storing keepsakes in a box [9]) into a physical–digital space. We do not explore the collection of memories using tangible 3D objects.

We have based our research on our early ethnographic studies of elders in situ, who reported the use of physical scrapbooks in common use for memory collection and sharing. While physical scrapbooks [2, 4] are common and tools to create digital ones are emerging [3], little research has explored the physical–digital scrapbooking divide and the problems and opportunities it affords in a pervasive computing environment, Sect. 2.

Pervasive or ubiquitous computing is an evolution of computing beyond simply the desktop, PDA or mobile phone paradigm [10, 11]. The central premise for this evolution is that computational and interaction support for people's activities can be seamlessly embedded into their environments. The goal is to have computers blend into the environment by offering context-aware support while the activity in question becomes the focus (meeting, event, work task, etc.) [12, 13]. With pervasive

computing, while the environment becomes saturated with computational support, the devices and interfaces will tend to disappear [14, 15]. The goal for this paradigm is to allow people to focus their attention on the activity at hand rather than on the tool (computation) they are using in the activity [16, 17].

The pervasive computing paradigm, in tandem with evolutions in computing infrastructure, has spurred researchers to explore novel forms of human computer interaction where the interfaces tend to become more natural and tend toward the “invisible” [18–21]. With any computer technology, whenever a person is aware of the hardware or software due to some limitation such as form factor, errors or unnatural mode of interaction then their focus on the activity is perturbed. Such perturbations allow the seams between the activity and the tool to become visible and hence the fluid interaction with the tool is reduced.

While there are a large number of business scenarios where pervasive computing can be applied, it is in the social environment where the notion of invisible or seamless computing shows much promise and appeal [16, 22, 23]. Social environments with many people such as the home, community centre or nightclub are ill suited to the single-user desktop computing paradigm. To support interaction in such environments researchers in pervasive computing are exploring multi-user, multi-device and multimodal interaction [15, 19].

Research in multimodal natural interaction can be broadly categorized into interfaces that support innate human faculties (sight, movement, touch, hearing, gaze) or learned skills (reading, drawing, writing, speech, typing). Ongoing research has been undertaken on natural pen and paper-based interfaces underpinned by computational support to interpret content input [24–26]. Little research has addressed the use of pen and paper both as a user directed mechanism for the input of content along with application control. We aim to address this in our MEMENTO research [4, 17, 27, 28].

Mobile computing has changed the nature of media and its use as a memory aid. Take, for example, digital photography that has changed the nature of photography and the photographic process. Rather than a shoebox full of hundreds of physical photos we are rapidly moving to a world of large hard disks filled with tens of thousands of photographs. Mobile computing has refocused both research and development on the physical–digital nature of many media items. Meanwhile, current digital photography applications offer many features that are primarily focused on single users editing, publishing or printing images. This is opposed to natural composition tools like photo albums that allow individuals to compose and annotate collections of photographs using the physical media itself.

The act or process of recollecting or narrating past experiences or events is a common form of memory sharing by both young and old people. This sharing can be undertaken collaboratively or recorded in a form suitable for dissemination to others [29]. For older

people, it is often used as reminiscence activity to enhance social and intellectual fitness [29–31].

Much of the early study of reminiscence was undertaken in the field of psychotherapy and geriatrics [29], which has been fed into the multidisciplinary field of gerontology and more recently the field of gerontechnology. Some of the reported benefits of reminiscence include: improved self-image, intergenerational understanding, and increased social interaction [31]. Other perceived benefits are reported through anecdotal evidence. These include: finding meaning and purpose in one’s life and improve well being. Clearly, the exact benefits exacted by a particular elder, by these factors, are difficult to measure and hence not well understood [31].

To promote reminiscence and memory sharing activities, we developed MEMENTO, our prototype digital scrapbook application, merging the advantages of the physical world of tangible scrapbooks with the sharing and collaborative possibilities offered by the online world.

Our user study for MEMENTO consisted of seven participants between the ages of 16 and 32, across a range of technical to non-technical backgrounds and is more fully described in Sects. 5 and 6. The participants were given a tutorial asking them to consider the scenario of a distributed family, using MEMENTO to interact with digital–physical scrapbook pages that they and others created. The goal in developing MEMENTO is to explore its suitability in terms of effect and performance for sharing and disseminating memories.

The remainder of the paper is organized into seven main sections. Section 2 describes our early user centred design work. In Sect. 3, we introduce the user view of MEMENTO. In Sect. 4, we describe the architecture of both MEMENTO and the underlying multi-agent system. Section 5 describes our evaluation in terms of its goals, participants and user tasks. In Sect. 6, we describe the results and evaluation of our study. In Sect. 7, we relate our work to other work in this field. In the final section, we reflect on our approach, and make some concluding remarks on the usefulness of pen and paper interfaces for memory sharing.

2 User-centred design: cultural probes and memory sharing

Our own qualitative ethnographic study of elders [4] and their approaches to memory sharing relied on the use of a cultural probe [32] to gather information on memory sharing activities in the home. In this study, a group of elders gathered a range of information on their own lives without intervention from ethnographers, as shown in Fig. 1. Elders were the focus of this study due to their rich life experiences and the wealth of knowledge and past and ongoing opportunities for memory sharing.

The probe was built around a series of open-ended questions on how they share memories, what supports this, with whom they share, where and when. Technol-



Fig. 1 Results of one cultural probe consisting of 30 photos, a detailed diary of reminiscence activities during a period of 10 days, text and photo collages, and 1 h of tape recording

ogy was not the focus of this study, but rather the elicitation of details of current memory sharing activities supported by people, places, events or physical items.

In our design process, we handed over cultural probes to 14 individuals from the Port Hacking Probus club in Cronulla, Sydney, Australia after an interview session with each participant. Participants were aged between 63 and 81. The interview session was based on a questionnaire containing ten general questions about the relationships between reminiscence and technology and at this interview we explained how the cultural probes are used. Figure 1 shows material from one cultural probe consisting of 30 photos, a detailed diary of reminiscence activities during a period of 10 days, collages combining text and photos and 1 h of tape recording where context is provided for all photos. The tape recording contained information about the motivation for taking the photograph, the people present and the physical item or technologies used.

The ability to build a written memory in the form of a journal or diary along with the ability to build a scrapbook, as an aid or focal point for reminiscence, is highlighted by a number of the cultural probes from our study. Examples from our cultural probes are shown in Figs. 2 and 3. Such scrapbooks are typically composed



Fig. 2 A lifetime's worth of journals and diaries which are difficult to search and share

of photographic materials (often annotated), written notes, decorative elements and newspaper clippings; see, for example, Fig. 3. The use of photographic materials and clippings as a memory aid to enhance inter personal communication in a variety of areas has been well studied; such areas include genealogy [33, 34], support for social presence [35], social classification [36] and storytelling [37, 38].

As is shown by our cultural probes, diaries, photo albums and scrapbooks provide an excellent means of storing memories and provide a fertile ground for reminiscence activities. We have identified a number of advantages of these physical artefacts, particularly scrapbooks, over purely electronic means of storing memories. These include:

- **Highly personal:** Individuals can construct their scrapbooks in a manner that suits their own individual style and tastes. They can arrange items however they wish in a personal manner.
- **Tactile:** There is a physical artefact that users can touch, see and even smell. They can leaf through pages. They can paste in physical items of interest they encounter in their everyday lives.
- **Flexible:** Scrapbooks can hold anything that can be attached to the pages such as photographs, newspaper clippings, medals, drawings, sketches, etc. They can be arranged in any manner that makes sense to the owner.

However, the physical world of the scrapbook has a number of disadvantages compared with artefacts stored digitally:

- **Sharing :** The only way to show the scrapbook to someone else is to retrieve the physical book. If the scrapbook is left at home while a user is on the move, there is no way for them to show it to others.
- **Collaboration:** Typically, a scrapbook will be kept by only one person at a time. There is no easy way for multiple individuals, such as a number of family members living in different countries, to update and view the same scrapbook.
- **Limited media:** A scrapbook is restricted in the types of media it can contain. It can hold physical items such as photos, newspaper clippings, small physical items that can be pasted into the pages, etc. It cannot hold multimedia items like audio, video, hyperlinks, etc.
- **Searching:** The only way to find something in a scrapbook, or collection of scrapbooks, is to manually search for it by leafing through the pages.

To merge the advantages of the physical world of the scrapbook with the desirable properties of the digital world [24], we developed MEMENTO, our prototype digital scrapbook application using the Anoto pen and paper system [39]. The Anoto system allows physical pen strokes to be recorded by a special pen, and for the pen strokes to be transferred to a computer for processing,



Fig. 3 An annotated scrapbook

either via a USB dock or via Bluetooth. It consists of paper pre-printed with a particular microdot pattern. Each microdot is offset from the central position on a grid pattern. The Anoto pen writes on this paper with regular ink. An infrared camera positioned behind the ink tip of the pen reads a number of these dots and, based on the offsets, calculates a unique page identifier and co-ordinates within the pattern space. The Anoto system is primarily aimed at the pre-printed forms market and for taking digital notes.

3 User overview

3.1 Scrapbook website

MEMENTO allows the user to create a scrapbook website, by interacting with a ‘real’ scrapbook, printed on Anoto paper. In addition to adding regular photographs and written annotations, the user can add digital multimedia items such as audio annotations, digital pictures and video. As the user interacts with the physical scrapbook, their changes are automatically synchronized with a website, and changes can be viewed immediately. The scrapbook website appears as a sequence of navigable pages, with embedded pictures, written annotations and hyperlinks to audio and video clips. Figure 4 shows an example scrapbook page screenshot from a scrapbook website, and a photograph of the physical page that created it.

Notice the audio and video hyperlinks at the bottom of the webpage, and the corresponding user-drawn boxes in the physical page. Clicking on the audio box at the lower left of Fig. 4a plays the audio that has been associated with this image. Similarly, clicking on the video box at the lower right plays the video. This corresponds closely with the way that a user can interact with the physical scrapbook shown in Fig. 4b, as described later.

3.2 Written annotations

The physical scrapbook consists of a binder containing pages of Anoto paper. The user can add written material



Fig. 4 a A page from a digital scrapbook as viewed in the Mozilla browser. b The physical page that created the website page in a, with an Anoto Pen

such as page headings and annotations by writing them with an Anoto digital pen. After a user has finished writing on a page, they must tick the ‘magic box’ pre-printed on the bottom right hand corner of each page, as shown in Fig. 5. The magic box is a particular type of Anoto ‘pidget’, which has special meaning for the pen. Ticking the magic box triggers the pen to transfer the pen strokes stored in its memory via Bluetooth to the MEMENTO system. When the MEMENTO system receives the pen strokes, it interprets the strokes to determine actions or content. Content or new action items are then added to the digital copy which is published on the website.

3.3 Audio annotations

User interface items, such as audio annotations, can be added to the physical scrapbook. To record an audio annotation and associate it with a particular point in the scrapbook, a user must draw a box and label it audio, as in Fig. 6. The user then ticks the magic box, and the pen strokes are sent to the MEMENTO system.



Fig. 5 The Anoto ‘magic box’ pidget, pre-printed on the bottom right of each page



Fig. 6 A user drawn audio box

The system performs handwriting and shape recognition on the pen strokes, and determines that the user has drawn an audio box. The system prompts the user to begin recording using a text-to-speech prompt. The user records some audio with a microphone in their current computing environment. To end the recording, the user ticks the magic box once more.

Once the recording process is completed, the audio recording is uploaded to the website, and can be accessed as a hyperlink as in the example in Fig. 4a. However, the audio recording can also be played back directly from the physical scrapbook. A user simply ‘ticks’ the audio box with their digital pen, followed by the magic box. Once the system receives the pen strokes, it determines that the pen strokes are contained within the bounds of the user-drawn audio box, and it interprets this as a command to begin replaying the audio on a nearby speaker. The mechanism by which devices such as the microphone and speaker are selected for recording and playback is discussed in the architecture section, Sect. 4.

3.4 Inserting pictures

Users can paste pictures and other items into the physical scrapbook. They need a way to synchronize the physical items pasted into the scrapbook with the scrapbook website. Our current prototype has two mechanisms for achieving this. Both mechanisms require the physical item to have a corresponding digital counterpart in the user’s data store, for example printouts of pictures taken with a digital camera, or scanned newspaper clippings.

The first mechanism involves having a number associated with each digital item and its physical counterpart. The user traces around the item to be pasted in the scrapbook with the digital pen. This indicates to the system the size and location of the digital counterpart to place on the website. The user writes the number of the item within the bounding box they just drew, and then they paste the item into the scrapbook where they have indicated. The number tells the system which digital item to display at this location.

The second mechanism also involves the user tracing a box around the physical item, indicating the bounds of the physical item. Rather than keeping track of the number of each physical and digital item, they simply label the box they just drew as ‘pic’, as illustrated in Fig. 7. The user is then prompted to select the picture to add to this location in the scrapbook. The user’s data store of images is displayed on a nearby screen (the

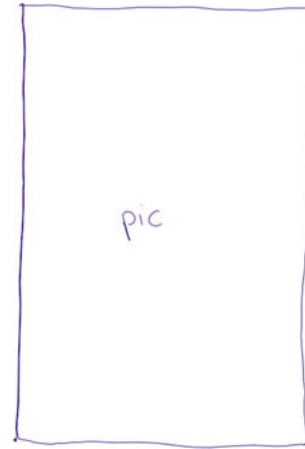


Fig. 7 The box a user draws to indicate the location of a picture in the scrapbook

process by which the screen is selected is described in Sect. 4), and the user selects an image from their personal data store.

For our next version of MEMENTO, we envisage a simplified synchronization process whereby the user can periodically place the scrapbook under the gaze of a high resolution digital camera. The physical items will be extracted from the image. Template matching algorithms will be applied to match the image to the corresponding image in the user’s data store. When there is no corresponding digital image, the extracted image segment from the high resolution camera image will be published in the scrapbook website.

3.5 Inserting video

Users insert video by a similar process. They draw a box and label it “video”. The system prompts them using text-to-speech to select a video from their data store using a nearby screen. They make the selection, and the video is uploaded to the website. It is accessed as a hyperlink. The user can also access the video directly from the physical scrapbook by ‘ticking’ the video box with their pen. The video is played back on a nearby screen.

3.6 Collaboration with the digital scrapbook

Consider an example of an extended family of siblings, cousins, parents and grandparents living across the world. When a user updates their own physical scrapbook, it can become one of many pages stored in a collaborative scrapbook website, shared by many family members. In addition to updating their individual physical scrapbooks with important life events, they can also then print off pages from the scrapbook website that were created by others in their family. The physical scrapbooks consist of ring binders which users can take pages out of, and insert updated/new ones. MEMENTO keeps track of



Fig. 8 A user-drawn video box

‘stale’ pages for users, and prompts them when they should reprint a page. Users print out the new pages on Anoto paper so the newly printed physical pages can still contain the ‘active’ items, audio, video, etc.

3.7 Trails

Users can construct personalized ‘trails’ through the scrapbook. Trails consist of particular points of interest to a user. Considering a scrapbook of a wedding, for example, a number of guests may keep their own physical scrapbooks of the wedding, all accessible from the same website. Such a collaborative scrapbook could potentially become quite large. Individual users may wish to highlight particular items in the scrapbook of interest, such as photos or videos showing members of their own family.

To construct a trail, a user draws a number of five-pointed stars which they label appropriately (e.g. The Groom’s trail), next to items of particular interest. The system recognizes such stars as the user draws them, and prompts the user to draw the next point in the trail or finish the trail. To finish the trail, the user simply ‘ticks’ the star they just drew with the digital pen. Trail stars then appear as hyperlinks to the next point on the trail in the scrapbook website. To follow a trail in the physical scrapbook, the user ticks a star with their digital pen. The system prompts them to turn to the page containing the next point in the trail, using text-to-speech.

3.8 Integrating physical and digital media

At this stage, we reconsider some of the advantages of digital media given in Sect. 2 as applied to the digital scrapbook.

- **Sharing** : In cases where the user leaves their scrapbook at home, they can still show it to their friends and family by accessing it on the web.
- **Limited media**: The user can now add multimedia items to their scrapbook, such as audio and video.
- **Searching**: All written annotations in the scrapbook are passed through a handwriting recognizer. It is now a trivial matter to provide a text search feature for the scrapbook website.
- **Collaboration**: Multiple users distributed over large distances can construct multiple physical scrapbooks on the same topic which they can share via the scrapbook website.

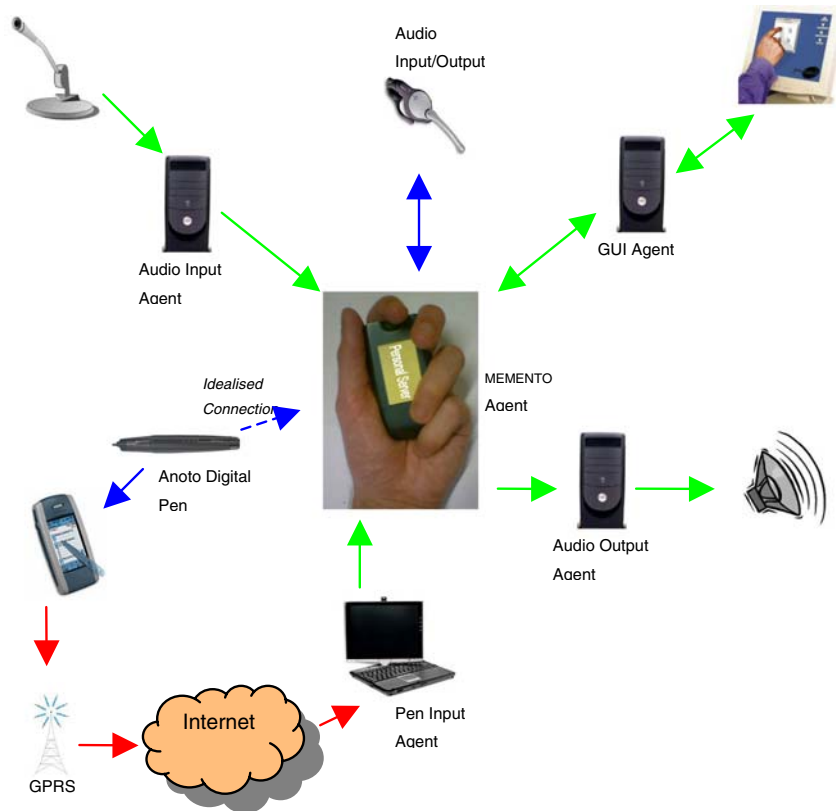
4 Architecture

The MEMENTO system is designed to operate within our multi-agent multimodal architecture [27]. The model consists of an agent-based architecture spanning multiple autonomous computing devices in a user’s personal area network (PAN), Personal local area network (PLAN) and personal wide area network (PWAN). We call this the user’s virtual personal server space (VPSS). Application processing agents, such as the MEMENTO agent, can reside on the user’s home server, their office computer or a portable computation device such as Intel’s Personal Server [40]. Agents coordinate through a context-plane service. The aim is to make available, through the context-plane, the following aspects of service: details of the devices and services available, the various inputs and outputs that are available, historical usage patterns, current sensed computational and environmental context along with aggregated and inferred contexts. For example, when the context-data indicates the user is in the minimal connectivity PAN environment, application processing will typically take place on their personal server. Input and output agents may reside on embedded systems within the user’s environment (an embedded microphone in their vicinity for example), or they may reside directly on their personal server (an agent controlling pen-based input through a paired Bluetooth Anoto pen for example).

Figure 9 shows that the Anoto digital pen communicates with the MEMENTO agent by using a Bluetooth connection to a phone to make HTTP requests over GPRS. Ideally, we would like the Bluetooth pen to communicate directly with the personal server. However, the current generation of pens is only capable of using the Bluetooth dial-up networking profile, typically only offered by phones. In addition, the pens must make an HTTP lookup to the Anoto global paper lookup service (GPLS) located on the Internet to determine where to send the pen strokes. Not unexpectedly, this communication overhead creates a significant lag in sending data from the pen to the MEMENTO system. We have successfully modified the Bluez [41] Bluetooth protocol stack for Linux to offer the dial-up networking profile for the pen directly. However, we noticed that this is somewhat unreliable, and Bluetooth connections appeared to drop out approximately 50% of the time. In any case, the pen must still make the HTTP lookup to the Anoto GPLS, and so the lag is still significant. For our user study, we felt reliability was more important than the slight reduction in lag. So we conducted the user study using the pen paired with a GPRS phone.

Figure 9 also illustrates that the pen input agent currently runs on a Tablet PC. We have leveraged the Tablet PC’s handwriting and gesture recognition capabilities to recognize the user-drawn interface elements.

Fig. 9 Scrapbook architecture. The MEMENTO agent running on a personal server coordinates with input/output devices in a user's personal area network and personal local area network



4.1 Agent bootstrapping process

In order to bind input/output agents to the current application processing agent, an identification component is invoked on the input/output agent when a user wishes to use it. The identification process can consist of various biometric or signal identification mechanisms (such as thumbprint, retina scanners or recognizing a user by their voice/handwriting). The current prototype uses a manual GUI based login mechanism for user identification. Once the identification component of an IO agent has identified the current user, a bootstrapping process takes place to bind the agents to the MEMENTO agent.

Consider the example of a user who wishes to playback some audio by ticking an audio box in the physical scrapbook with their pen. The user requires a pen input agent acting on their behalf, and an audio output agent for the playback of the audio. The context plane [27] is responsible for binding the pen input agent and audio output agent to the MEMENTO agent. Our current implementation of the context plane uses a shared tuple space abstraction for agent coordination called LIME, or Linda in a mobile environment [42]. Figure 10 illustrates the binding process.

2. The pen agent requests the data plane location of the grammar and interpreter (see [27] for more details on these components), and binding information for the MEMENTO agent.
3. The pen agent loads the grammar and interpreter for the scrapbook application from the data plane [27].
- 4-6. The identification component of the audio output agent triggers it to bind to the MEMENTO agent in a similar manner.
7. When the user ticks an audio box, the pen input agent sends a command to the MEMENTO agent.

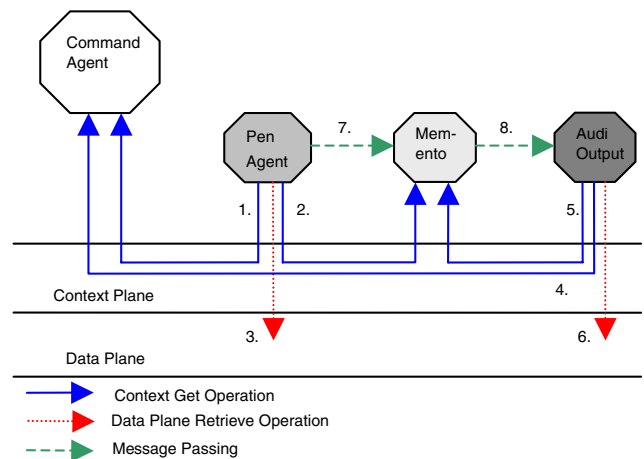


Fig. 10 Context-plane mediated input and output agent configuration

1. The identification component in the pen input agent invokes the bootstrapping process. The pen input agent requests the *Application With Focus* context from the user's *command agent* through the context plane. The command agent typically runs on the user's personal server.

8. The MEMENTO agent loads the audio clip to be played from the data plane, and streams the audio to the attached audio output agent.

5 Exploratory user study

MEMENTO is at the level of a solid prototype implementation: it pushes technology to its current limits to provide a natural interface to support reminiscence activities based around the creation, refinement and use of multimedia scrapbooks. It represents a solid first step toward our goal of providing a smart environment, with embedded computing resources which can support the types of reminiscence activities that seemed important to the participants in our cultural probe experiments.

At this stage of the work, it is important to learn the following:

- Can people use the novel interface elements of MEMENTO to construct multimedia scrapbooks?
- Are there elements of the interface that pose particular problems?
- Do people consider MEMENTO a useful support for reminiscence?

Given these goals, we designed a qualitative think-aloud experiment [43] where the participants would work through a series of tasks involving elements of the interaction and then provide effective data in a questionnaire about this experience and their views of the potential role of MEMENTO-like interaction for supporting reminiscence. Essentially, MEMENTO represents a proof-of-concept level implementation and we have designed the following evaluation to assess whether it represents a promising direction for natural interfaces to support reminiscence.

5.1 Experimental design

We defined a series of tasks that would introduce experimental participants to the features of MEMENTO, in stages, in the following order:

- The overall idea of synchronized digital and physical versions of a scrapbook.
- The basic Anoto pen and paper interface was introduced with participants creating text entries in an existing scrapbook and, at the same time, participants were shown how these entries were automatically synchronized in the on-line version.
- The MEMENTO support for audio was introduced, with participants creating their own audio annotation and verifying its successful addition to the synchronized online scrapbook.
- The MEMENTO support for creating trails was introduced and participants were asked to use these in a meaningful scenario for sharing memories.

We considered it important to learn about user responses to these aspects for several reasons. First, we were concerned that the MEMENTO interface is so different from most user experience. It is important to determine how users respond to some of these basic elements. Secondly, given our driving motivation to support reminiscence, we chose to identify and evaluate those MEMENTO interface elements that are most important. Our cultural probe experiments, as well as the literature on the importance of associating audio with images, indicate that audio linked to images is a fundamentally important interface element. Moreover, the user view of the elements for adding video and physical photos are essentially very similar. So, our understanding of the audio interface elements is a foundation for understanding others. The decision to evaluate the trail interface element was based upon its critical role in helping people share memories, both by selecting parts of the scrapbook that a user wants to explicitly share with particular people and by forming an ordered selection from parts of the scrapbook.

We now summarize the background of the participants in the study, the detailed user tasks and their associated data collection and the questionnaire administered at the end of each user trial to collect data on affective aspects.

5.2 Participants

The user study involved seven users, enough to give a good indication of the broad usability of MEMENTO [43]. We recruited a range of users who had no had previous experience with the prototype. We asked users to fill in a short questionnaire about their background before the experimental trial. A summary of their responses is shown in Table 1. Users were asked to indicate their level of experience with regular computer desktop environments such as Windows or Mac OS in terms of little/none, days, weeks, months or years, and to evaluate their own level of computing experience in terms of expert, very confident, reasonably confident, not confident or have not used a computer before.

5.3 Set up and user briefing

Notably, we recruited young users for this study, rather than the population of elders in the cultural probe experiment that informed our choice of reminiscence elements and motivated the work. This deserves explanation. As this is the first user study with MEMENTO, we wanted to evaluate it with participants who are more likely to learn quickly and be flexible and, especially, we needed users who would not be confused or distracted by the system delay.

All tasks were based on the scenario of a group of family members and close friends attending the same

Table 1 Summary of background of study participants

| Participant ID | Sex | Age | Occupation | IT level | IT time |
|----------------|-----|-------|---------------------|----------------------|---------|
| 1 | M | 20–30 | Engineering student | Expert | Years |
| 2 | F | 20–30 | IT student | Expert | Years |
| 3 | M | 20–30 | IT student | Expert | Years |
| 4 | M | 20–30 | Med student | Expert | Years |
| 5 | M | < 20 | High school | Very confident | Years |
| 6 | M | 30–40 | Cabin manager | Not confident | Years |
| 7 | F | < 20 | Arts student/model | Reasonably confident | Years |

wedding. We collected media (digital photographs and videos) taken for a wedding. The first page of the scrapbook is the one shown in Fig. 4a, b in the overview above.

The experiments were conducted in a laboratory, with one of the authors leading each participant through the stages of each task and the questionnaire, recording participant' comments and other events and answering any questions.

There was an introductory briefing. Participants were told about the pen and paper interface and were warned to expect a delay of about 20–30 s to send the pen stroke data wirelessly to the scrapbook system. Participants were asked to think aloud during the exercise. They were advised that we were evaluating the system, not them, and that we welcomed their comments and feedback at any time. All participants agreed to be videotaped.

System logging recorded the time for task segment completion. In addition, each user action was logged, together with the system's interpretation of the participant's intent. From this, we could determine when there had been recognition errors.

5.4 Task 1: familiarization and creating audio

The participants' first task was to imagine they were a family member, and to annotate a wedding scrapbook. They were supplied with three scrapbook pages, the first of which was complete; the other two contained only pictures. Participants were asked to view the scrapbook pages on the scrapbook website. They were asked to access the audio and video on the first page by clicking on the hyperlinks. They were also shown the physical scrapbook and shown how to play the audio by ticking the audio box, then the magic box.

This stage of the task introduced the idea of a synchronized physical and web version of a scrapbook. It enabled us to see whether participants could work out how to play the audio and video on the web, by clicking on the audio/video indicator. It also introduced interaction with MEMENTO to play the audio.

Next participants were asked to annotate pages 2 and 3 of the physical scrapbook with some text. The text was specified, to avoid any stress or embarrassment in having to invent their own text. Participants verified that the text they had written was uploaded to the scrapbook website, after they had ticked the magic box. This stage

involves the basic Anoto pen and paper functions and helped familiarize participants with the look and feel of the physical interaction.

Finally, participants were asked to record some audio for the second page of the scrapbook. The text to be recorded was provided. This was particularly important for this case. Previous informal experience in public demonstrations has been that people are typically quite uncomfortable about recording audio; the main problem was that they had trouble deciding what to say, especially as this was done in front of a stranger and it would be stored.

As a lead into the audio-creation, the demonstrator provided participants with a brief tutorial as to how to draw boxes that would be correctly recognized by the Tablet PC gesture recognition API. Just as in the case of the text annotations earlier in the task, participants verified that their recording was reflected on the scrapbook website.

5.5 Task 2: creating a trail for sharing memories

For this task, participants were asked to imagine they were taking part in the creation of a collaborative scrapbook. They were given two printouts of pages that had been created by others, and asked to insert them in their personal scrapbook. Participants were asked to imagine that the printouts were from pages created by their cousin and sister who live in different countries. Participants were asked to imagine they were the bride or groom (as appropriate).

In essence, this task called upon participants to highlight portions of the scrapbook that would be of particular interest to their overseas grandmother who was unable to attend the wedding. To do this, participants would construct a trail through the extended scrapbook.

Participants were asked to find content that highlighted:

- The ring-giving at the wedding ceremony.
- The cutting of the cake.
- The throwing of the bouquet.

Here too, participants were relieved of the need to decide what to share. Again, system logs recorded the time for task completion, recognition errors and any difficulties the participant encountered while completing the task.

5.6 Post-task questionnaire

Finally, participants completed a 19-item questionnaire. The first block of questions asked about the effect of the delay, in terms of how frustrating it was and how it affected participant's ability to use MEMENTO. We then asked them to rate the difficulty of using the main interface elements: writing text, recording and playing audio, making and following trails. Since we expected some problems with recognition errors, where MEMENTO failed to recognize a user's actions and they had to repeat it, we asked participants to give two ratings, one taking any errors into account and another discounting such errors.

The next set of questions asked about the usefulness of each MEMENTO interface element: the automatically generated digital scrapbook, synchronized with the physical one; the audio, video publication of the material to all; the possibility of shared print versions and trails.

Next, participants were asked if they thought they would use a MEMENTO-like system to make scrapbooks. We also asked if they had made any scrapbooks previously: it is likely that people who never have made scrapbooks would be less likely to do so with MEMENTO than people who had.

The remaining questions were open-ended, asking what participants liked most, least, what feature(s) they would most like to be changed and general comments.

6 Results and evaluation

We report the results of the study in terms of the performance and affective outcomes. We begin with the performance data, which captures how well participants were able to complete the tasks. Within these results, we also report participant's comments. We then report the affective results from the questionnaire.

6.1 Performance results

We summarize the time to complete each of the tasks and subtasks in Table 2. Before discussing these, we note that our experimental design involved think-aloud usage with participants being encouraged to ask for assistance or discuss any aspect they wished. This means that time must be interpreted cautiously. However, they do give an indication of the difficulty of tasks and we will use them to give an indication of whether people were able to complete tasks within reasonable timescales and without frustration. The times also give an indication of differences between the participants. Of course, as we observed the participants and kept details of the think-aloud protocols, we were also able to interpret the time data.

The first three rows of results for Task 1 are as follows. The first line, labeled *playback*, is the time from when the user played the first audio clip from the physical scrapbook to the time they played the video clip where this indicates

- The time to listen to the audio.
- Follow the instructions to play the video.
- Find the point to tick in order to play the video (at the lower right of Fig. 4b).

The maximum is just over 2 min but most participants took about 1 min. All participants completed this task without difficulty.

The second row, annotation, starts when they played the video clip and includes:

- Writing *The Ceremony* at the top of the scrapbook as a heading.
- Writing *The exchanging of rings* underneath the photograph.
- Writing *Adam with the best man and usher* on turning to page 3, under the first photo.
- Writing *Adam with the brides maids* under the second photo.

All participants completed this task successfully within time ranging from 2.5 min (participant 2) to a little under 4 min (participants 1, 6 and 7). This set of results is a form of base level measure of success in learning to use the Anoto pen and paper, without the MEMENTO interface elements. It also served as a familiarization task.

The third row of data is for the time from completion of the annotation subtask until completion of recording and playing an audio. This is the first real test of the novel elements of the interface. This involved:

- The demonstrator describing how to do the audio creation task.
- The participant practicing the drawing of the box and writing *audio* near it.
- The participant recording the required message.
- Waiting till it had been transferred to the system.
- Then ticking the audio box and then the magic box to make the audio play.

The table shows that two participants (1 and 7) experienced recognition errors in this subtask. Even so, two others took longer. Importantly, all participants completed Task 1 successfully.

The first part of Task 2 required participants to read a half page motivation for making a trail, an introduction to the notion of a trail, the details of how to draw the stars that define each point on the trail, practice in drawing these followed by making the specified trail over three nominated images. Times in the table are from the end of Task 1 to the completion of the trail. Participants took somewhat more than 5 min to over 13 min. It is notable that four participants experienced some recognition errors in this subtask. This is due to the problems they had in drawing the five pointed star that marks each point on the trail. This appears to have slowed these participants but, even so, they completed the trail creation successfully.

Table 2 Times taken for the tasks and subtasks

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---------------------|----------|------|----------|------|------|-----------|-----------|
| Task 1 | | | | | | | |
| Playback | 0:50 | 0:60 | 1:00 | 0:50 | 0:60 | 02:10 | 01:30 |
| Annotation | 3:50 | 2:40 | 3:20 | 2:30 | 3:20 | 03:50 | 03:50 |
| Audio record + play | 5:10 (1) | 3:30 | 7:30 | 3:30 | 3:40 | 06:50 | 05:30 (1) |
| Task 2 | | | | | | | |
| Construct trail | 8:30 (1) | 6:30 | 8:40 (2) | 5:30 | 9:10 | 10:00 (2) | 13:20 (3) |
| Follow trail | 2:10 | 1:30 | – | 1:50 | 2:20 | 01:30 | 01:40 (3) |

Times are rounded to the nearest 10 s. Participant identifiers correspond to those in Table 1. Numbers in parentheses show the number of recognition errors that occurred. For example, Participant 1 experienced 1 such error when recording the audio and another when constructing a trail. The dashes (–) for Participant 3 indicate she did not attempt this task

The last row of the table shows the time from completing construction of the trail to the time of completing traversal of it. All but one participant completed this, with four taking somewhat over a minute and a half, and this includes participant 7 who experienced three recognition errors. The incomplete result is because there was a system error, which prevented participant 3 from doing this task. Excluding this, all participants were able to successfully complete Task 2.

Overall, the results indicate that all participants who attempted any subtask were able to complete it, even participant 7 who suffered a total of seven recognition errors. At the same time, it seems that the participants had difficulty with the five-pointed star for trails.

6.2 Affective data

The answers to the closed questionnaire are summarized in Table 3. The first two rows of results explored the effect of the delay involved in sending data from the Anoto pen to MEMENTO. The first row shows responses about frustration. On the semantic differential scale of one to six, (1 not frustrating, 6 very frustrating), the mean response was four (median four) indicating that participants found the delay frustrating, as one might expect.

The next row shows how much participants judged that the delay affected their ability to complete the task (1 no effect, 6 a large negative effect). The mean is two (median one). All but participant 1 saw this as much less a problem than the frustration. At the same time, as already reported, all participants who attempted the subtasks did succeed in completing them so that the affective data reflect the unacceptability of the long delay. We were not at all surprised by this response. In fact, part of the reason for asking about these aspects was to ensure that participants could express frustration about the delay: they were then explicitly asked to ignore the effect of the delay in their rating of the various aspects of the system.

6.3 Ease of use

Participants again used the one to six scale to rate ease of use of system functions: writing text, recording audio,

playing audio, making trails and following trails. For each function, participants gave two ratings, the first attempting to ignore the effects of any recognition errors, the second including these effects. All participants indicated a difficulty level of one (i.e. lowest difficulty) for the task of writing text when discounting recognition errors. This base level is related to the basic functionality of the Anoto pen. Participant 6 indicated a difficulty level of two for this task when considering recognition errors despite the fact that the system made no errors for that task.

Participants gave a mean difficulty level of 1.4 for recording audio without recognition errors, or 2.0 when considering them. Participants 1 and 7 experienced recognition errors while drawing the audio box; both gave a higher difficulty rating when considering recognition errors. With the exception of participant 6, those who did not experience recognition errors rated both questions with the same value. On a scale of one to six the values are low, indicating participants found drawing their own interface items to be relatively easy. Indeed, all participants except 1 and 2 rated this at level 1, ignoring errors, the same rating as the base level writing task. This suggests that most users found the audio interaction element natural and easy to learn and use, allowing for recognition errors.

It can be seen that the playing of audio was also rated as easy with all but participant 6 rating it 1, with or without errors. This indicates participants found the action of ‘ticking’ a box was easy. Here again, although participant 6 had experienced no recognition errors they gave a slightly higher score for this situation. Similarly for following trails, all participants but one indicated a difficulty level of one (only participant 1 indicated a level of two).

Participants found constructing trails to be the most difficult task segment, with mean values of 1.86 and 3.0, ignoring and considering recognition errors, respectively. Participants 1, 3, 6 and 7, who experienced recognition errors, gave a higher difficulty rating when considering recognition errors for the task. However, participant 3 also indicated a higher difficulty rating when considering recognition errors, perhaps indicating she found the five-pointed stars difficult to draw.

Following trails was rated as easy with score 1 for all but participant 1 who rated it 2 under both situations

Table 3 Participant responses to closed questions

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|-----------------------------|-----|-----|-----|-----|-----|-----|-----|
| Delay | | | | | | | |
| Frustration | 5 | 5 | 3 | 5 | 3 | 3 | 4 |
| Effect on completion | 5 | 1 | 1 | 1 | 1 | 2 | 3 |
| Ease of use-errors/+ errors | | | | | | | |
| Writing text | 1/1 | 1/1 | 1/1 | 1/1 | 1/1 | 1/2 | 1/1 |
| Recording audio | 3/4 | 2/2 | 1/1 | 1/1 | 1/1 | 1/2 | 1/3 |
| Playing audio | 1/1 | 1/1 | 1/1 | 1/1 | 1/1 | 1/3 | 1/1 |
| Making trails | 4/5 | 2/2 | 1/3 | 1/1 | 2/3 | 2/4 | 1/3 |
| Following trails | 2/2 | 1/1 | – | 1/1 | 1/1 | 1/3 | 1/1 |
| Usefulness | | | | | | | |
| Synchronized physical + web | 2 | 1 | 1 | 4 | 2 | 1 | 1 |
| Audio/video | 2 | 1 | 1 | 5 | 1 | 2 | 1 |
| Published some | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| Published all | 5 | 5 | 2 | 2 | 2 | 3 | 3 |
| Print others | 3 | 1 | 1 | 3 | 1 | 1 | 1 |
| Trails | 2 | 1 | 2 | 2 | 2 | 5 | 1 |
| Likely to use | 6 | 1 | 2 | 2 | 2 | 5 | 1 |
| Previous scrapbooks? | No | Yes | No | Yes | No | No | Yes |

Participant ID is as in previous tables. Lower numbers indicate low ratings of frustration, low effect on completion and low difficulty. In the questions on usefulness, lower numbers indicate more useful. On likely to use, low numbers indicate more likely

and participant 6 again gave a higher rating for the case of errors in spite of experiencing none. He consistently gave higher ratings for the recognition error situation, even in the case of the three subtasks where he did not experience them, suggesting that he was indicating an attitude to the effect of such errors as having impact in general.

Overall, participants found most tasks easy to complete.

6.4 Usefulness

This part of the table shows responses to a series of questions about the value of:

- Maintaining a synchronized physical and digital scrapbook.
- Being able to access audio/video from a regular scrapbook.
- Having the option to have the scrapbook automatically published on the web for particular people.
- Having the option to have the scrapbook automatically published on the web for everyone.
- Being able to print pages from other peoples' scrapbooks, all from the same website.
- Constructing trails through a scrapbook of your pages and others'.

These descriptions are verbatim from the questions. The overall picture is a strong endorsement of usefulness of most aspects, with ratings of one in most cases and two for several others. The striking digression from this pattern applies to making the web version available to all. Having the scrapbook publicly on the web earned a quite strongly negative rating from participants 1 and 2, and borderline positive for participants 6 and 7. This is in stark contrast to having the scrapbook sharable by particular people. This would seem to indicate that

participants would only be comfortable sharing their scrapbooks online with some form of access control.

Participant 4 commented that he could not see the point in printing other people's pages from the website. (However, other participants mentioned that they particularly liked this feature.) Participant 4 saw no point in being able to add in audio or video to the scrapbook. He did like the ability to add in plain written annotations to an online scrapbook. All other participants rated the ability to add audio and video highly (one or two), though most participants were somewhat uncomfortable recording their own voices.

The final closed questions explored whether participants would use the digital scrapbook itself. Participants who had not made scrapbooks previously rated the likelihood they would use MEMENTO to make a scrapbook as two (quite positive) or five (quite negative). Participants 2, 4 and 7 had previously made scrapbooks and two of them gave the two strongly positive ratings.

Participant 7 had created a number of scrapbooks in the past and expressed the desire to be able to associate music with her scrapbook, rather than her voice recordings.

6.5 General comments

The last section of the questionnaire invited general comments. On the whole participant feedback about the scrapbook was quite positive. A number of participants (particularly those who had constructed scrapbooks before) expressed an interest in using the scrapbook. "The system was very good; I would definitely like to use this for my own photo albums".

For the least liked aspects, most participants mentioned the large delay in waiting for the pen strokes to be transmitted after ticking the magic box. Participant 3 also mentioned that having to tick the magic box at all got quite tedious.

Most participants also mentioned one of the aspects they most liked about the scrapbook was simply the ability to annotate their photographs with a digital pen, and have this uploaded to their website. Other items participants liked included the ability to access other people's scrapbooks (and print off their pages) online and the ability to access digital items in a physical medium by ticking boxes with a pen. A number of participants commented positively about trails, for example they were 'neat'; other participants thought they were not too important.

Some participants gave some suggestions for additional features in the scrapbook. Participants 3 and 6 expressed the desire to have the scrapbook 'improve their handwriting' when annotations were uploaded through handwriting recognition. Participant 6 suggested the scrapbook could provide particular styles such as bold headings and various kinds of calligraphy and decorative effects by recognizing hand-drawn equivalents. Participant 7 particularly wanted to be able to add in her favourite songs to her scrapbook.

7 Related work

The literature contains a number of examples of pen and paper based interfaces. Wellner's seminal work on pen and paper interfaces, his DigitalDesk [24], consisted of an augmented reality desk in which digital projections were used to enhance paper-based work.

Johnson et al.'s [44] XAX system completes the document 'loop', going from structure, to image, to paper, to image and back to structure. They utilize document scanning or fax to bridge from the physical world back to the digital. Two dimensional glyphs printed on the document are used to do the document recognition. Experiences gained from observing users are presented in the paper.

PaperLink [25] is a system for hyperlinking from real paper to electronic content. It consists of a highlighter pen augmented with a miniature video camera and activating tip switch, which allows marks on paper to be associated with electronic content, and also some rudimentary OCR capabilities. The user highlights a portion of the text and then points the camera to a command pattern on a 'command bookmark', which allows an action to be associated with the highlighted text, such as the creation of a hyperlink.

The audio notebook [45] consists of a device for taking notes and interacting with a speech recording. It is a combination of a paper notebook and digital audio recorder. Audio recordings are indexed using the pen strokes from the note taking activity, and also on acoustic structuring using a phrase detection algorithm. Users navigate the audio playback using the notes they took during the recording, as well as with standard audio controls on the device. The device is evaluated for use as a note taking device used by students during lectures, and by reporters during an interview.

The Palette [46] is a means of controlling an electronic slide show (power point presentation) by means of printed index cards using a barcode scanner. The index cards consist of the printed presentation slides and a barcode. The presenter controls the slideshow by manipulating the index cards, placing them under a barcode scanner, causing the relevant slide to be displayed. The paper presents a user study with 13 participants performing an identical presentation task.

Mackay and Fayard [47] have developed a number of augmented reality paper-based applications, which they call 'Interactive paper'. Ariel provides augmented engineering drawings for construction engineers on a large bridge building project. Video Mosaic is an augmented paper based system for editing and rearranging of digital video using paper based story boards. Cameleon consisted of a study of paper-based flight strips for French air-traffic controllers. Mackay et al. recognized the unique affordances offered by paper flight strips not offered by other attempted digital air-traffic control projects. Instead of attempting to replace flight strips, they worked to enhance them using RFID tags, and overhead camera based recognition techniques.

More recent work by Mackay et al. [26] consisted of a study of the journal keeping practices of research biologists at the Institute Pasteur in Paris. Their final prototype, the 'a-book', included a paper journal notebook placed over a tablet to digitally record the user's pen strokes, and an 'interaction lens' consisting of a PDA with attached camera which is used as a see-through tool or lens to link the physical paper with the digital counterpart. Using the interaction lens, the user can add in additional digital items, such as hyperlinks to digital items, or references to physical items, such as animal specimens in the biologists' lab. Mackay's work strongly emphasizes the importance of a participatory design process, involving users at every stage.

Tablet-based systems and e-books, such as XLibris [48] attempt to provide some of the advantages of paper over purely digital documents by allowing the user to add digital ink directly to a digital document on a tablet screen. XLibris provides for rapid searching of text, sharing of an individual's annotations for collaborative document reading activities, and 'linking by inking', in which text from user ink annotations is recognized and queried against a collection of documents. Unobtrusive links to related documents are placed in the margin. Support of manual linking is provided by circling an ink symbol to create a multi-way link to all instances of the same symbol. The authors note the importance of open-ended evaluation techniques to understand the impact of their system on the real world.

Paper augmented digital documents (PADDs) [49] uses the Anoto digital paper system [39] to bridge the physical and digital worlds of documents. Electronic documents can be edited and manipulated online, then printed out on Anoto paper. Physical ink annotations created by the reader will be stored with the online version. A system architecture is proposed that manages

the correspondence between paper and digital copies or documents, allowing the integration of physical pen strokes back into the original document. A prototype of the concept consists of an add-on for Adobe Acrobat documents in PDF format.

Books with voices [50] consists of barcode augmented paper transcripts for oral-historians, allowing indexed access to the audio or video source material using a PDA. Current practice of oral historians is to look mainly at the transcripts only when researching material, as accessing the source material is too time-consuming. In the Books with voices system, paper transcripts of a taped interview are constructed with accompanying barcodes. An oral historian, who wishes to view the source material from a particular point in a transcript, uses a barcode scanner attached to a PDA to immediately access the relevant audio/video segment on the PDA. This offers the oral historian the benefit of accessing a level of emotion for relevant passages not found in the paper transcript, and also to clarify the text and observe non-verbal cues. The authors conducted a user study and questionnaire with 13 participants consisting of three tasks related to summarizing sections of a video enhanced oral history transcript, plus short editing tasks. The questionnaire consisted of 20 multiple choice questions addressing users' backgrounds, current practices and opinions of the system.

In contrast to MEMENTO, these systems have not explored the usefulness of paper based interfaces for the field of memory sharing. Also, they have not provided a means of allowing individuals to draw their own user interface command elements, such as the audio box, on paper, recognized by the computational environment using handwriting and shape recognition technologies. This interaction technique has relevance beyond that of memory sharing. See our previous work, [27], for more applications of this concept.

8 Conclusion

We have presented the MEMENTO system, our memory sharing and dissemination application. We have shown that it is possible to realize a physical digital scrapbook and our evaluation suggests it is suitable for memory sharing or dissemination activities.

We have reported our exploratory evaluation and now return to the questions it was intended to answer.

8.1 Can people use the novel interface elements of MEMENTO to construct multimedia scrapbooks?

Our evaluation involved observation of participants as they learnt about and used MEMENTO as well as their perception of the ease of use and usefulness of each of the functions it supports. Notably, our participants were young and had considerable computing experience and this would partly account for the fact that they were not

discouraged by the shortcomings of the current implementation of MEMENTO, with its 20–30 s transmission delays and some recognition errors. Overall, the evaluation indicated that the participants were able to quickly learn both the basic Anoto pen functionality involved in writing annotations as well as the basic features of MEMENTO, supporting the synchronization of the physical scrapbook with a digital on-line form, the addition of audio and the playback of audio. For all these tasks, all participants rated the ease of use as high and they completed the tasks quickly, considering the transmission delays. There was similar positive evidence about the following of trails and rather less positive evidence about creating them: a good part of this was due to the difficulty participants had in drawing the particular star shape we chose for this task. Overall, the participants quickly made use of the novel MEMENTO features to create multimedia scrapbooks, even though none had had any previous experience of this type of interface. Given the novelty of the interface for these people, the evaluation indicates that this type of interface, that maps between the physical and digital world, is easy to master, at least for these young and technically confident users.

8.2 Are there elements of the interface that pose particular problems?

In terms of ease of use, we did identify a problem in the details of the trails. The fact that MEMENTO linked the physical to the digital world also meant that some of our participants wanted the benefits of features that are readily available in the digital world: the improvement of handwriting and more pleasing headings. There was also concern about the availability of the digital scrapbook, with all participants favouring restricted publication for people like the grandmother in the evaluation scenario but two participants being unwilling to have the scrapbook public. As we had expected, the currently unavoidable transmission delay of around half a minute had a severe detrimental effect on the interface: indeed, we had to design the evaluation with particular care to enable participants both to cope with this and to see past it.

8.3 Do people consider MEMENTO a useful support for reminiscence?

Two of our seven users indicated they would be unlikely to use a system like MEMENTO, perhaps because these individuals do not create scrapbooks. The other participants seemed intrigued by the idea of creating a scrapbook in a natural, physical format but with the possibility of adding digital elements. Indeed, five of the seven participants indicated they would like to use a system like MEMENTO, and this included one participant who indicated they do not make scrapbooks. Of course, these comments need to be tempered. The participants

may have been trying to be polite! Perhaps more importantly, the novelty of the interface may have had a *whiz-bang* effect where the participants found the novelty appealing and were, therefore, particularly positive.

We began this paper with a description of our study of the reminiscence activities of older people. It was this that motivated us to explore the novel interaction of a system like MEMENTO, with the possibility of making a physical record in an almost conventional scrapbook and, at the same time, having it available digitally as well as providing the possibility of integrating much richer media than are normally available in physical scrapbooks. Our evaluation study enables us to make the following observations about the major contributions of MEMENTO, both as a potential support for reminiscence and as an important step forward for ubiquitous computing.

8.4 Synchronized physical and digital scrapbook

MEMENTO has explored the potential of support for users to move between digital and physical forms of a scrapbook. MEMENTO allows a user to create a paper scrapbook, which is automatically synchronized with a web-based digital version. Our users were readily able to move between these and interact with each. The physical scrapbook has significant attraction. This is partly in terms of the tactile experience. However, more importantly, it makes it easier to have natural social interaction while working on the scrapbook at a table, with others, perhaps recording discussion and joint recollections of the events captured in the photographs. Most users saw this as useful, indicating the benefit of the digital form for sharing memories, especially with people who were far away. The user concerns about privacy clearly indicate the need for care in engineering these aspects in future applications of this type.

8.5 Augmenting a scrapbook with interface elements created by the user to define audio elements

The support for the user to draw interface elements is an important new direction that MEMENTO has explored. In the case of audio elements, the user study indicated that this was extremely successful, in terms of learnability and perceived utility, with all participants succeeding in the task and most regarding it as useful. All participants were able to learn about this aspect and successfully make use of it. Most judged it easy to do this even when recognition errors came into the assessment and all did, when discounting these.

8.6 Creation and use of trails through the scrapbook

This is another instance of the novel approach of drawing your own interface command elements with a pen and paper and then using this. The trails take

MEMENTO beyond pure personal reminiscence where this is one version of the scrapbook. It supports sharing memories with particular people. For example, in our evaluation, users imagined they were making a trail for their grandmother; one would expect this to differ from the trail that one might make for a school friend. All users in our study were able to follow trails readily and, although our choice of symbol posed problems, most participants were able to create a trail. Most saw value in trails created for particular people.

At this stage, we have only performed a preliminary and exploratory evaluation of our approach and of our particular implementation of MEMENTO with young people. The system still has severe technical limitations, particularly due to the transmission delay problems. It also requires laboratory use, with the audio and network infrastructure.

Our user studies have shown encouraging results in affect and performance. It seems that this approach has considerable appeal and promise and that our particular implementation is quite learnable, with participants quickly adjusting to the idea of drawing interface elements onto a page and then interacting with them. The physical digital interface is still a very young technology and field of research. We expect further technological improvement to facilitate this form of human computer interaction.

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