NotePals: Lightweight Note Taking by the Group, for the Group

Richard C. Davis[1], Jason A. Brotherton[2], James A. Landay[1], Morgan N. Price[3], Bill N. Schilit[3]

[1] EECS Department
University of California
Berkeley, CA 94720-1776 USA
+1 510 643 7354
{rcdavis, landay}@cs.berkeley.edu

[2] College of Computing
Georgia Institute of Technology
Atlanta, GA 30332-0280 USA
+1 404 894 7512
brothert@cc.gatech.edu

[3]FX Palo Alto Laboratory
3400 Hillview Avenue, Bldg. 4
Palo Alto, CA 94304 USA
+1 415 813 7220
{schilit, price}@pal.xerox.com

ABSTRACT
NotePals is an ink-based, collaborative note taking application that runs on personal digital assistants (PDAs). Meeting participants write notes in their own handwriting on a PDA. These notes are shared with other participants by synchronizing later with a shared note repository. NotePals is distinguished by its lightweight process, interface, and hardware. This paper describes the design and implementation of NotePals, its web-based note repository, and the results of an informal user study. The results indicate that taking notes on NotePals produces minutes that are comparable to paper in terms of speed and legibility, and the notes are far easier to share with others.

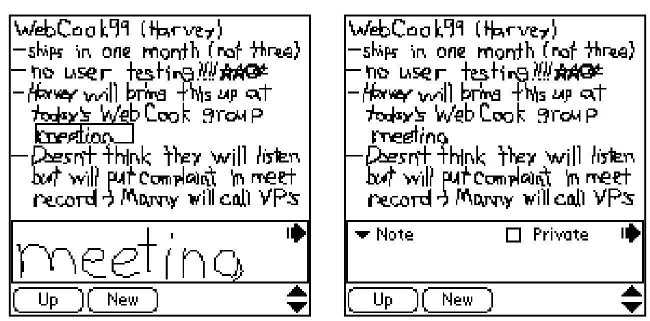
Keywords
PDA, pen-based user interface, CSCW, informal user interfaces, digital ink, mobile computing

INTRODUCTION
NotePals is an ink-based, collaborative note taking application that runs on personal digital assistants (PDAs). The system is distinguished by its support for lightweight collaboration at three levels: hardware, note taking process, and user interface. The hardware used, the U.S. Robotics Palm Pilot, weights only 5.7 ounces (165 grams), easily fits in one's palm (see Figure 1), and sells for under $200 USD. The note taking process allows each participant in a meeting to take his or her own notes in free-form ink. NotePals automatically creates minutes by merging the notes after the meeting, eliminating the need for a scribe.

The NotePals ink-based user interface uses a focus plus context [5] view that attempts to overcome problems associated with the small size of PDAs (see Figure 2a). This allows users to take notes quickly using their own handwriting without relying on error-prone handwriting recognizers or unfamiliar shorthands [6,13].

Figure 1. The U.S. Robotics Pilot fits in the user's hand.

The drive to create NotePals came from the realization that people often leave meetings without a shared understanding or a record of the important points that occurred. Assigning a scribe to record the minutes is one solution, but it is onerous and sometimes produces a biased record. Using computer-based meeting support tools is another solution, but existing tools require an expensive, fixed infrastructure that limits the locations where meetings can be held. Since many people are now carrying small, inexpensive PDAs, we felt that these might provide a better platform for meeting support tools. NotePals is a collaborative note taking tool that lets people walk away



(a) (b)

Figure 2. NotePals' focus plus context interface with (a) focus area active and (b) note attributes area active.

from any meeting, presentation, or class with a *low-overhead* record of what transpired.

Previous research in this area, a survey of PDA users [12], and interviews with potential NotePals users led us to a simple design idea. Meeting participants use NotePals on PDAs for taking notes during a meeting. Afterwards, the participants synchronize their PDAs with their own desktop machines, and their notes are sent to a shared repository. The participants can then use a web browser to view these *merged* notes. They can sort and filter the notes by time, author, project, date, and note type. Figure 3 illustrates the merged **Action Item** notes for a work group.

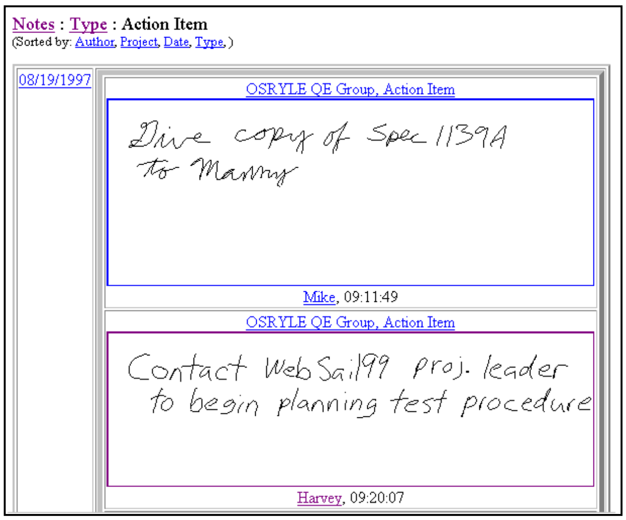


Figure 3. Merged **Action Item** notes in the web repository.

Problems with Existing Approaches

It was important that our design overcome the problems with existing methods, both low- and high-tech, for creating meeting records. Low-tech solutions (i.e., pen and paper) are easy to learn, truly ubiquitous, and inexpensive. Unfortunately, they are also unreliable. Each participant's notes may be incomplete. If instead a scribe takes notes for the entire group, the notes may be biased, the scribe will be unable to participate fully, and some subtle points may be missed. In either case, a single perspective does not suffice. Also, the distribution of the notes can be problematic.

On the other extreme, high-tech "meeting capture systems" [20,16,4] require expensive, specially equipped rooms that often require a facilitator to operate. These rooms are not ubiquitous and thus violate the need to have meetings anywhere, anytime. In addition, the technology often impedes the normal interaction between participants [14]. NotePals finds a middle ground between traditional and electronic solutions, combining the advantages of the two.

Our Choice of PDA

Using PDAs for group note taking was driven by the desire for ubiquity. PDAs are becoming a common tool carried by knowledge workers, who have frequent meetings. For example, colleagues have reported attending meetings with non-technical co-workers where over half of the participants used Pilots [9]. International Data Corp. estimates that manufacturers will ship 5.5 million handheld computers worldwide this year and 16.2 million units per year by 2001 [2,22]. The Pilot is one of the most popular machines in the PDA market. Its popularity seems to be driven by its small size, low price, and easy synchronization with desktop applications [3].

These same factors were important in our decision to use the Pilot as our platform. Its size and price vastly improve the odds that meeting attendees will have one with them whenever and wherever a meeting takes place. In addition, its synchronization model is simple. Copies of data are kept on the desktop and in the Pilot, and they can be modified separately. When the user wishes to synchronize the copies, he places his Pilot in its docking cradle, presses the **HotSync** button, and the copies are merged. Our collaborative application requires only occasional sharing of information, making the Pilot's synchronization model appropriate. It offers as much sharing as is needed without the associated high costs of wireless infrastructure.

Outline

This paper describes the design and implementation of NotePals and describes how NotePals can be used effectively to take meeting notes. The next section describes some scenarios of use to give a better idea on how NotePals would be used in and between meetings. To inform our design we surveyed PDA users and interviewed individuals concerning their note taking habits. These results are presented next. This is followed with a more detailed description of the NotePals user interface and its web-based note repository. We then give some conclusions of our early usage experiences. Finally, we summarize the related work and our ideas for future research.

USAGE SCENARIOS

We see the potential for NotePals in a number of different meeting situations. NotePals can obviously be used in a business setting. Each participant in a meeting can take their own notes and later the merged notes can be viewed on the group's web server. There are several ways to organize the note taking process. For example, notes can be shared or private, and participants can take them in turns, simultaneously, or selectively on points of particular interest. Instead of explicitly requiring one of these policies, our design allows any of them to take place. The web-based notes repository allows viewing and filtering of the notes in several different ways. This is important because meetings are ad-hoc and systems that impose an explicit meeting process will be rejected [7].

NotePals can also be used in classroom settings. Students at U.C. Berkeley can purchase notes taken by paid note takers for many large courses, but these are not available in smaller classes. With NotePals, students in any class could get notes created by their peers. Sharing their notes with the other students in the class may help students take better notes and might also set the tone for a collaborative, rather than competitive, educational experience.

The following scenario illustrates how NotePals might be used in business meetings. The characters include Harvey, Mary, Mike, and Art, who are all quality engineers at OSRYLE Software, and Manny their manager.

Scene 1: Harvey Steps Into the Office at 8:00 AM

Harvey pulls his Pilot out of his pocket and browses his notes from the last quality engineers group meeting. He goes to the last page and sees his **Next Meeting** note for a group meeting at 9:00 AM today.

Harvey decides to read the meeting agenda on his desktop. Using a web browser he views the page for the groups shared notes. Clicking on the **Next Meeting** link, he brings up all notes of this type. The last one is Manny's **Next Meeting** note, which held the agenda for today's meeting. "Hmm, Manny will announce next year's budget."

Scene 2: The Quality Engineer's Meeting

The quality group has gathered in a conference room. Manny glances at a note from last week's meeting on his Pilot. "It looks like Mary was the last person to take minutes. Mike, can you get them for the next 15 minutes?" Mike starts a new page on his Pilot, and begins to write in his own handwriting. Manny flips to the agenda on the **Next Meeting** note from last week and then adds a **New Meeting** note. "Let's start with project updates. Harvey?" Harvey expresses his concern that WebCook99 is going to be shipped in one month with no user testing. The other engineers at the meeting voice similar concerns.

Fifteen minutes later Harvey starts taking the minutes. Then Manny announces the budge, "I'm afraid it's going to be the same as last year - no increase." The engineers spend the remainder of the meeting bartering for next year's projects. At the end, each person has written down in NotePals a list of assignments and due dates using **Action Item** notes (see Figure 4). Once Manny and the engineers return to their offices and synchronize[1], they can use a web browser to view the action items for each engineer or the entire group.

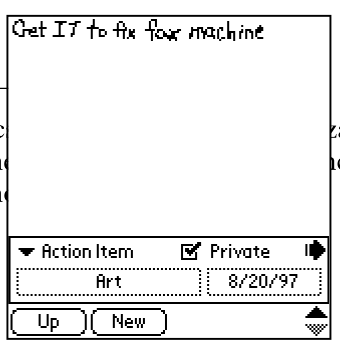


Figure 4. An **Action Item** note.

[1] U.S. Robotic … zation software so the engin … chronize from any office, n …

Scene 3: Harvey at the WebCook Meeting

Harvey enters the WebCook meeting room, where the meeting is already taking place and starts to take notes. As each engineer reports on their progress, Harvey points out the testing that still has to be done for each section. The engineers take their own notes and tend to ignore Harvey's points on user testing. Later, when the team synchronizes their notes, Harvey's commentary on the testing progress will be interspersed with the engineering reports. While many of the engineers may have ignored Harvey's points, his comments are contained in the meeting record.

DESIGN INTERVIEWS & SURVEYS

To focus our design we interviewed co-workers who attend meetings, added note taking questions to a survey of PDA users, and studied the previous work in this area.

Our interviews found that meeting participants make lots of notes during meetings. These notes often are of different types: to-do items, important points heard, questions asked, summaries of meetings, names of contacts and attendees, and other notes. These types were the impetus for the stationery types described below. This use of different note types is consistent with the findings of previous research on note taking [23]. The interviews also showed that people often look at their notes later when writing reports, checking for to-do items, or writing meetings summaries. A major problem is the accurate reporting of meeting results when the scribe is not well versed in all the topics [15].

A survey of 142 PDA users [12] found that note taking was the most popular application of Apple Newton users (of six applications), but was far less popular with Pilot users (ranked fourth of six). Note taking was also cited as the most common task (of seven) that users performed on paper rather than on their PDA. The most common reasons cited for not using the PDA were slower speed, small screen size, and difficulty with handwriting or stroke (e.g., Graffiti on the Pilot) recognition. The respondents reported using their Pilots in meetings "often." These results show that PDAs, and in particular Pilots, are often carried to meetings, but the size and recognition systems are problematic for taking notes. NotePals tries to overcome these problems.

NOTEPALS

We chose to implement the prototype NotePals system on the U.S. Robotics Palm Pilot PDA. This platform has several advantages that we have described above. The Pilot also has several limitations that we had to overcome. Two of its strengths, size and synchronization model, both pose challenging design problems.

While the Pilot's size makes it easy to carry, it makes it very difficult to draw on. NotePals notes need to be in ink rather than Graffiti text if the system is going to comparable to paper in ease of use, but some users complain that the Pilot's writing surface is so tiny that their hand obstructs their view of the screen while they are writing. This is not so much of a problem on a large sheet of paper where text can be spread out. Resolution is also a problem. In our interviews, we found that a few users take notes on pads that are similar in size to the pilot screen, but they can write very small on these pads, and the Pilot's 160 by 160 pixel resolution makes it difficult to write small.

The size and resolution problems can combine to make taking legible ink notes on a Pilot a real challenge, and the situation is not likely to improve much over time, since the Pilot's size is part of what makes it so popular. Our system addresses this problem with a novel focus plus context user interface that attempts to simplify the process of taking notes and improve their legibility.

The simplicity of the Pilot's synchronization model presents more design challenges. How should shared notes be presented to the user? Should they be presented sequentially by user or interleaved? Can redundant notes be detected, and should they be eliminated or merged? How can notes be linked to presentation slides, audio, or others' notes? Should users be able to keep public and private notes?

In NotePals, a user sees his own notes on his Pilot, but on the desktop he has access to all users' public notes. On the desktop, notes are merged automatically by noting their creation time and "stationery type." Notes can be browsed with a simple interface that allows the user to sort and filter them.

Pilot User Interface

In NotePals, a "note" is a single screen "chunk" of text and other scribbles (see Figure 2b). The screen is not scrollable; the entire note is visible at all times. The user can draw directly on the upper part of this page with the pen, while the lower part holds a **Private** checkbox, and a control for the "stationery type" (described below).

The Focus Area

Drawing directly on the page of notes works well for sketches, but for text the user can open a focus area in the bottom portion of the screen by touching the arrow next to the Private checkbox. When this window is open (see Figure 2a) a small box indicating the current focus location (i.e., the "focus cursor") appears on the page of notes. Now, the note page can be thought of as a context area. Words written in the focus area will also appear in the little box in the context area *scaled down* by a factor of three. This gives each page a total resolution of 480 x 327 (as opposed to the Pilot resolution of 160 x 160).

This organization allows the user to fit much more text on a page, and it keeps the user's hand out of the way while writing, so the entire note page can be seen. As the user writes, he can make a right to left swipe in the Graffiti area to move the focus window forward to a new blank area. A top right to bottom left swipe will move the focus cursor to the beginning of the next line. Users can also move the focus cursor by dragging it in the context area or tapping on a new location.

Stationery

A page's "stationery type" indicates what kind of information is in the note. The default type, **Note**, is the simplest kind of stationery and causes the note to be treated like a plain piece of paper with writing. Notes can be given more specific types, such as **Action Item,** which will allow them to be sorted and indexed together with other notes of the same type.

Some stationery types have additional attributes. For instance, Figure 4 shows an action item note that has the name of the person responsible for the item, and the due date filled in at the bottom of the screen. There are currently four types of stationery in NotePals. **Note** and **Action Item** have already been described. There are also **New Meeting** notes than can be given a list of attendees, and **Next Meeting** notes that can be given a date, start time, and end time for the next meeting.

Privacy

The **Private** checkbox, seen in all of these figures, controls others' access to notes. If this box is checked, the note will not be uploaded to the public note repository. Both public and private notes are uploaded to the private note repository.

Navigation

NotePals stores all notes in a project folder so users can keep the notes they take for each work group separate. Within each project folder, notes are sorted by the time they were created. The user can browse through a large number of notes in a project in a view that shows thumbnails, creation times, note types, and privacy for five notes at a time. Users can also move to earlier and later notes within a project when they are in the edit view, as seen above.

Web-based Note Repository

As mentioned earlier, when the user wishes to synchronize the notes on his Pilot with those on the desktop, he puts his Pilot in its docking cradle and presses the **HotSync** button. This uploads new notes to one or two central repositories (private and/or public). These repositories are simply web servers that can accept uploaded notes from the desktop that the Pilot synchronizes with. The web server takes

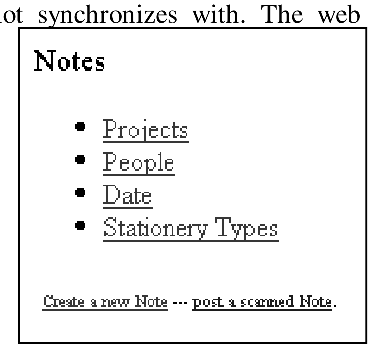


Figure 5. Main menu of the notes browser

responsibility for storing and sorting all the notes uploaded to it.

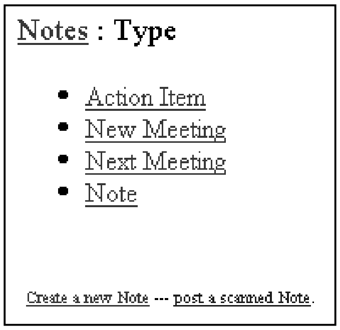


Figure 6. Notes browser: list of note types.

The URL used to upload notes is also used to view notes. Pointing a web browser to this URL brings up the notes browser shown in Figure 5. The first browser page presented to the user is a list of the types of attributes that appear on each page. Clicking on one of these attributes will present the user with a list of known values for that attribute. For example, clicking on **Stationery Type** leads to the screen in Figure 6, a list of known stationery types. Then, if the user click on one of these hyperlinks, he will be presented with the notes with that attribute. Clicking on **Action Item** in Figure 6 will lead to the page shown in Figure 3, which lists only action items. In this view, notes are sorted by creation time and tagged with their other attributes. In these first steps into the browser, the user is able to focus his attention on a subset of notes.

From this point, the user can modify his view of the data simply by clicking on various hyperlinks on the page. Clicking one of the attribute names near the top of the page will change the view to be *sorted* by that attribute. Clicking on an attribute next to a note will refine the view to include *only* notes with that attribute. For example, clicking on **Harvey** in Figure 3 will present the user with a similar page, which contains only those Action Item notes taken by Harvey. At the very top of the page is a list of the attributes that the user has refined his view by, and the user can return to a previous stage in browsing by clicking on one of these attributes. With this simple, single-click query mechanism, the user can easily browse the notes in the repository.

Advantages of NotePals Approach

NotePals has a number of advantages over paper notes and electronic meeting capture tools, and it alleviates a number of the problems with using small PDAs for note taking.

Shared notes taken with NotePals overcome many note taking problems mentioned earlier. There is no need for every individual in a meeting to take complete notes. Instead, attendees can rely on others to share the work of taking notes, and write down only those parts that are particularly important to them. This also eliminates the need to appoint a scribe for the entire meeting, though it may be useful to have scribe duties rotate during the meeting. Also, since users are free to add notes from their own point of view at any moment, these shared notes will more accurately reflect the perceptions of different individuals at the meeting.

The fact that NotePals can be run on inexpensive hardware using existing infrastructure differentiates it from many groupware tools. The notes repository can be used by any group that has a web server and networked workstations. Most members of the group should have Pilots, but they are inexpensive and may already be in use by many group members. Also, NotePals runs on PDAs, which can be brought into most environments, whereas other tools require meetings to occur in specially equipped rooms.

The small size of the Pilot was a problem, but the focus area helps to alleviate this. The user can fit a moderate amount of text on every page, at the slight expense of legibility and ease of entry. Entering notes is more difficult than on paper because the focus cursor must be moved. Using two Graffiti strokes simplifies this process. While notes may be difficult to read on the Pilot, they appear full size on the web-based notes browser for later review.

The use of stationery types allows the notes browser to sort and index notes. Without stationery, a large repository of notes would have to be browsed sequentially. With stationery types, the user can form more complex queries such as, “Show me the all of the action items Harvey took down yesterday.”

Finally, ink-based notes are suited to the target task: human to human communication. NotePals’ informal user interface relies on the fact that unrecognized handwriting requires little cognitive overhead by the note taker. Users can focus on the notes being taken, and not on remembering Graffiti strokes or figuring out how to format an idea in ASCII text.

USAGE EXPERIENCE

To better understand how easy it is to take legible notes with NotePals, we conducted an informal user study that measured writing times, reading times, and reading errors. While the results of this study are not statistically significant, they give an indication of NotePals’ usability and show where to focus our attention in the future.

The study was divided into two parts. In the first part, ten participants took notes on both paper and NotePals, and we compared their writing speed. In the second part, ten different participants read the notes generated in part 1, and we compared reading speed and number of reading errors between paper notes and NotePals notes viewed on the web.

Part I: Writing NotePals Notes

Methodology

In the first part of this study, we presented participants with two sets of PowerPoint presentation slides and asked them to copy them onto paper or into NotePals. The participants were told to take notes as if they were going to be read later by a friend. We used lecture slides from a computer science class that averaged 33 words in length and contained no pictures or diagrams. We measured the time participants needed to copy each slide, as well as the number of critical incidents. Critical incidents were defined as occasions where the normal flow of note taking was interrupted (e.g., the user had trouble moving the focus cursor).

We used a within-groups experimental design. The participants were divided into two groups. The first group used NotePals for the first set of slides and paper for the second set. The tasks were reversed for the second group. The change in order controls for variance in writing times due to the differing slide contents. Before using NotePals, the group was given a five minute tutorial on how to use the system. Each set of slides consisted of one practice and one measurement slide. The results from the practice slide, which allowed participants to get used to taking notes in both conditions, were discarded.

Participants and Environment

The ten participants were all members of a CSCW class. All were electrical engineering and computer science graduate students. One reported he used a PDA "very often," one reported "often," six reported "a few times," and two reported "never." All participants copied the same slides concurrently. This may have subjected them to some task anxiety since those writing on paper often finished before those writing on Pilots.

Results and Discussion

The time needed to write varied widely among the participants. We compared the time to take notes on NotePals with the time to take notes on paper. NotePals took on average 64% longer for each participant. The median increase was 60%.

Comments from the participants and our observations indicate the time difference could be reduced if it was easier to move the focus cursor. Some participants suggested snapping the focus cursor to a grid or moving the cursor using a button or gesture in the focus area rather than in the Graffiti area. One user suggested giving advance warning when approaching the edge of a page. These results and reactions are encouraging and warrant further study.

Part II Reading NotePals Notes

Methodology

In Part II, we recruited 10 new participants. Each participant read a set of notes written by a participant in part I (a different set was used for each participant). Participants were asked to read the slides out loud to the best of their ability, correcting themselves when necessary. They were told that accuracy was more important than speed. We measured the time needed to read the note and the number of errors made. An error was defined as a misread word, letter, or symbol.

Participants were again divided into two groups with the first half reading the first set of notes on the web and the second set on paper. As before, the second group did the tasks in the reverse order. The first reading in each set, the practice slide, allowed participants to get used to the particular handwriting they were reading.

Participants and Environment

Nine participants were electrical engineering and computer science graduate students or post-docs, and one was a civil engineering graduate student. All participants but one spoke English as their native language.

The participants read notes one at a time in a private office. The web-based notes were shown on a Netscape browser at full size. The web-based notes were roughly the same size as the paper-based notes when displayed on a 21" Samsung SyncMaster monitor at a resolution of 1152 x 882.

Results and Discussion

The time needed to read varied widely among the participants. We compared the time to read NotePals notes on the web with the time to read notes on paper. The NotePals notes took on average 37% longer for each participant. The median increase was 21%. Two participants took twice as long to read the web notes. Removing these outliers results in an average and median increase of only 14%.

Together, one of the outliers and another participant made a total of twelve errors in reading the notes on the web, while the rest of the participants made a total of two errors on the web. There were a total of only two errors among all of the participants reading on paper.

The small number of errors when reading paper notes suggests that shared, handwritten notes are quite legible. It took most participants (eight) a slightly longer amount of time to read notes on the web and most (eight) made few errors. These results suggest that most users can take acceptably legible notes with NotePals.

Informal Usage of NotePals

In addition to this informal study, we have been using NotePals for several weeks and continue to evaluate the design. Two of us used NotePals to take shared notes at a conference. Others have created shared notes recording comments on designs and presentations. Also, a number of colleagues at Xerox have given us reactions to NotePals.

These experiences have shown us several things. First, our usage shows that NotePals can help complete useful work. We also noticed that users' writing size and their ability to read their own, scaled handwriting varies significantly from user to user. However, some users did not mind poor readability on the Pilot, as they mainly use the structure of the scaled handwriting to guide future writing. Nonetheless, allowing the user to select the scaling factor and the size of the focus area would be useful.

We also noticed that several users had problems confining their handwriting to the focus area, which would often cause them to touch the context area and move the focus cursor to an undesired location. Enlarging the focus area slightly might help this. Other solutions might include an "Undo" command for cursor moves and using heuristics to ignore accidental focus cursor moves.

Many users commented that they would like to be able to read others' notes (e.g. meeting agendas) on their Pilots. Some also said they would like to mix Graffiti text with ink. Both of these improvements appear useful, and we will consider adding them to NotePals.

RELATED WORK

Work related to NotePals lies in two main areas: meeting capture tools and personal note taking applications.

Electronic Meeting Rooms

Much work has been done on Electronic Meeting Systems (EMS) [14,16]. These systems typically consist of 10-20 personal computers linked together in special meeting rooms running custom software. The software often organizes meetings by dividing the proceedings into three phases: idea generation (brainstorming), organization (grouping), and prioritization (voting).

EMS has been shown to improve the quality of group decisions and the time needed to reach agreements. However, the hardware needed to run these systems makes them prohibitively expensive and impossible to use in many settings. They are also better suited for certain types of structured meetings, such as those focussed on decision making or idea generation. NotePals imposes less meeting structure and supports a wide variety of meeting styles.

Xerox PARC has a long tradition of exploring the value of collaborative tools for meeting capture [20,18] and "salvage" [15]. Unlike the Arizona tools, these tools support unstructured, sketch-based interfaces. Although NotePals is fairly limited compared to many of these systems, it was influenced by there informal interfaces. Again, NotePals attacks the fundamental problems of these systems: cost and ubiquity. Meeting rooms equipped with LiveBoards [4] and other special equipment are expensive and do not support our goal of allowing meetings to occur whenever, wherever.

NotePals has some similarities to Wang's Freestyle [11], which allowed users to share ink-based annotations of documents on the desktop. Unlike NotePals, Freestyle does not automatically organize notes.

Personal Note Taking Tools

NotePals shares many characteristics in common with previous personal note taking tools. Dynomite [23] and the Audio Notebook [21] both rely on ink-based notes without handwriting recognition. Dynomite runs on pen-based laptop computers using a traditional windowing user interface, while the Audio Notebook combines a paper-based notebook with specialized audio hardware. Both of these tools are focussed on synchronizing audio recordings with personal notes. Dynomite's mechanism for tagging chunks of ink with labels influenced our inclusion of stationery types for notes. Other research systems use standard ink formats for exchanging ink-based notes made on larger PDAs with desktop machines [17].

NotePals also has similarities to some existing commercial note taking applications. In particular, a cursor is used to allow easy entry of ink-based notes in both the Newton note taking application and in aha! InkWriter [8]. The Newton can reduce the text at the insertion point by either 50% or 75%. Both the Newton and InkWriter automatically fill text that reaches the edge of the page, as in a traditional word processor.

The Vmacs system [10] takes a radically different approach from NotePals. Instead of offering a more natural user interface for meeting participants to take notes, it offers a powerful and efficient note taking interface for an expert user, such as the meeting scribe or facilitator. Though an interesting approach, we did not want to rely on having an expert user around to take notes and we wanted to support informal, ink-based note taking.

NotePals differs from all of these note taking tools by its support for creating shared, collaborative notes. It also differs by its support for very small PDAs.

FUTURE WORK

Our usage experience showed us a number of ways to improve the note-taking interface, and we hope to integrate these ideas into our design. We also see many interesting ways to explore NotePals beyond these simple fixes.

Note taking is a personal activity, and one person's view of transpired ideas and information might not match another's. It is not clear how a person's note taking behavior will change when he is aware that a colleague is taking notes at the same time. We would like to investigate how the ease of creating shared notes affects note taking behavior.

It is also unclear how to deal with conflicting perspectives in shared notes. Perhaps the note repository should be organized more like a web-based discussion group so that differences can be resolved online. After uploading to the repository, more CPU-intensive algorithms could be run. We have considered adding a ink-based search mechanism [19] or possibly combining off-line handwriting recognition with a clustering algorithm to extract or group related notes. These issues need to be examined further.

Another interesting area to explore with NotePals is synchronization with other media such as typed meeting agendas, presentation slides, or audio. The timestamp for each note could be used to link it to a specific moment in an audio record, or perhaps the presentation slide that was being presented at the moment the note was taken [15]. Another approach would be to upload documents such as presentations or agendas to both the web repository and the Pilot, allowing users to annotate them. Other researchers have found that students find some value in electronic notes that are taken on top of a copy of the presenter's material [1].

CONCLUSIONS

NotePals offers a lightweight, inexpensive way for people to walk away from a meeting with shared "captured" information. The shared notes generated by groups using NotePals overcome many of the problems with traditional meeting notes such as uneven note taking responsibility and limited points of view. It uses simple, inexpensive equipment that can be obtained by many workgroups and supports any style of meeting in any setting. NotePals' informal, ink-based user interface combined with a focus plus context view avoids many of the problems with taking notes on small PDAs, letting users focus their attention on taking notes. While it appears to take somewhat longer to write on NotePals than on paper, most users are able to take legible notes in a reasonable amount of time.

ACKNOWLEDGMENTS

Thanks to Chris Long for including our questions in his PDA survey. We also thank Gene Golovchinsky, who had many fruitful discussions about NotePals with us. We also appreciated the helpful comments of Jock Mackinlay and Tom Moran. Thanks to Joe Sullivan for supporting this project.

REFERENCES

1. Gregory D. Abowd, Christopher G. Atkeson, Cindy Hmelo Ami Feinstein, Rob Kooper, Sue Long, Nitin ``Nick" Sawhney and Mikiya Tani. "Teaching and Learning as Multimedia Authoring: The Classroom 2000 Project". *Proceedings of Multimedia '96*, November, 1996.

2. Mindy Blodgett. "Laptops Packing More Bang," *Computerworld.* May 26, 1997. http://cwlive.cw.com:8080/home/print9497.nsf/All/SL21note.

3. David Einstein. "Shirt-Pocket Computing Revival: U.S. Robotics Device Jots Notes, Keeps a Calendar". *San Francisco Chronicle*. Tuesday, June 17. C4. http://www.sfgate.com/cgi-bin/chronicle/article.cgi?file=BU44818.DTL&directory=/chronicle/archive/1997/06/17.

4. Scott Elrod *et. al.* "Liveboard: A Large Interactive Display Supporting Group Meetings, Presentations and Remote Collaboration". *Proceedings of Human Factors in Computing Systems*, ACM CHI '92, Monterey, CA, May 3–7, 1992. pp. 599-607.

5. George W. Furnas. "Generalized Fisheye Views." *Proceedings of ACM CHI'86 Conference on Human Factors in Computing Systems.* pp. 16-23. 1986.

6. David Goldberg and Cate Richardson. "Touch-Typing with a Stylus." *Proceedings of ACM INTERCHI'93 Conference on Human Factors in Computing Systems.* pp. 80-87. 1993.

7. Jonathan Grudin, Ed. <u>Groupware and Cooperative Work: Problems and Prospects</u>. The Art of Human-Computer Interface Design. New York: Addison-Wesley. 1990.

8. John Jerney. "aha's InkWriter for Magic Cap," *Mobilis: The Mobile Computing Lifestyle Magazine.* (August): p 5, 1995. http://www.volksware.com/mobilis/august.95/aha1.htm#xaha1.

9. Greg King. Personal Communication. August, 1997.

10. Fred Lakin, John Wambaugh, Larry Leifer, Dave Cannon and Cecilia Sivard. "The Electronic Design Notebook: Performing Medium and Processing Medium," *The Visual Computer.* **5**(4): pp. 214-226, 1989.

11. Stephen R. Levine and Susan F. Ehrlich, Eds. <u>The Freestyle System: A Design Perspective</u>. Human-Machine Interactive Systems. Plenum. 1991.

12. Allan Christian Long, Jr., James A. Landay and Lawrence A. Rowe. "PDA and Gesture Use in Practice: Insights for Designers of Pen-based User Interfaces". *Proceedings of Submitted to CHI '98*,

13. I. Scott MacKenzie and S. Zhang. "The Immediate Usability of Graffiti". *Proceedings of Graphis Interface '97*, Canadian Information Processing Society. 1997. pp. 129-137.

14. Marilyn M. Mantei. "Observation of Executives Using a Computer Supported Meeting Environment," *International Journal of Decision Support Systems.* **5**(June): pp. 153-166, 1989. Elsevier.

15. Tomas P. Moran *et. al.* ""I'll Get That Off the Audio": A Case Study of Salvaging Multimedia Meeting Records". *Proceedings of Human Factors in Computing Systems*, CHI '97, Atlanta, GA, March 22-27, 1997. pp. 202-209.

16. Jay F. Nunamaker, Alan R. Dennis, Joseph S. Valacich, Douglas R. Vogel and Joey F. George. "Electronic Meeting Systems to Support Group Work," *Communications of the ACM.* **34**(7): pp. 40-61, July, 1991.

17. Kaori Oomika, Atsushi Naito and Masaki Nakagawa. "Idea Memo PDA in Scalable Handwriting Interfaces". *Proceedings of Seventh International Conference on Human-Computer Interaction (Design of Computing Systems: Social and Ergonomic Considerations)*, HCI International '97, San Francisco, CA, Elsevier. August 24-29, 1997. pp. 455-458.

18. Elin Ronby Pedersen, Kim McCall, Thomas P. Moran and Frank G. Halasz. "Tivoli: An Electronic Whiteboard for Informal Workgroup Meetings." *Proceedings of ACM INTERCHI'93 Conference on Human Factors in Computing Systems.* pp. 391-398. 1993.

19. Alex Poon, Karon Weber and Todd Cass. "Scribbler: A Tool for Searching Digital Ink". *Proceedings of Human Factors in Computing Systems*, CHI '95, Denver, CO, May 7-11, 1995. pp. 252-253.

20. M. Stefik, D. G. Bobrow, G. Foster, S. Lanning and D. Tatar. "WYSIWIS Revised: Early Experiences with Multiuser Interfaces," *ACM Transactions on Office Information Systems.* ACM Transactions on Office Information Systems. **5**(2): pp. 147-167, 1987.

21. Lisa J. Stifelman. "Augmenting Real-World Objects: A Paper-based Audio Notebook". *Proceedings of Human Factors in Computing Systems*, CHI '96, Vancouver, Canada, April 13-18, 1996. pp. 199-200.

22. Joanne Taaffe. "Windows CE Drives Rise in Handheld Device Sales," *Computerworld.* May 21, 1997. http://cwlive.cw.com:8080/home/online9697.nsf/All/970521windows.

23. Lynn D. Wilcox, Bill N. Schilit and Nitin "Nick" Sawhney. "Dynomite: A Dynamically Organized Ink and Audio Notebook".

Proceedings of Human Factors in Computing Systems, CHI '97, Atlanta, GA, March 22-27, 1997. pp. 186-193.