

# DYNAMITE: A DYNAMICALLY ORGANIZED INK AND AUDIO NOTEBOOK

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## ABSTRACT

Dynomite is a portable electronic notebook for the capture and retrieval of handwritten and audio notes. The goal of Dynomite is to merge the organization, search, and data acquisition capabilities of a computer with the benefits of a paper-based notebook. Dynomite provides novel solutions in four key problem areas. First, Dynomite uses a casual, low cognitive overhead interface. Second, for content indexing of notes, Dynomite uses ink properties and keywords. Third, to assist organization, Dynomite’s properties and keywords define views, presenting a subset of the notebook content that dynamically changes as users add new information. Finally, to augment handwritten notes with audio on devices with limited storage, Dynomite continuously records audio, but only permanently stores those parts highlighted by the user.

## Keywords

Electronic notebook, note-taking, audio interfaces, handwriting, keyword indexing, ink properties, retrieval, paper-like interfaces, PDA, pen computing.

## INTRODUCTION

This paper describes the Dynomite notebook, a pen-based note-taking system that combines the ease of use of paper notebooks with the power of computers. Writing notes is a universal activity of students, executives, scientists, and other knowledge workers. Students take notes during class and review them before exams. Scientists write notes in lab books to document experimental results. Executives take notes in meetings to record action items.

Although computers have proven adept at all manner of data processing, paper is still generally preferred over PDAs and portable computers for note-taking. Studying paper notebooks helped us to understand the affordances of paper [13] where freeform input, spatial layout, and even

doodles (for their visual cues) are an integral part of the note-taking process. The approach taken by Dynomite is to enhance the traditional paper note-taking activity rather than define a new process as personal organizers and portable computers do. In contrast to Classroom 2000 [1], which supports note-taking in a classroom lecture using previously made visual materials (view-graphs), our target is note-taking for any knowledge worker, anyplace.

The design of a portable electronic notebook must address a number of issues. First, what qualities of paper notebooks are important to emulate in an electronic version, and which can we improve upon? Second, since people use notebooks in meetings and at times when they must concentrate on things other than the note-taking process, how can our system obtain keys for indexing while maintaining a low cognitive load? Next, how can we use a computer to help organize and display the information in a notebook? Finally, how can audio augment handwritten notes on devices with limited storage?

Our design provides new solutions in the four problem areas above. An important aspect of paper notebooks is their ease of use. The interface to Dynomite is similar to a standard paper notebook. Users see a screen with the appearance of a page in a traditional notebook and enter freeform hand-written notes that are stored as digital ink. The Tivoli [12] system is similar, in that it emulates whiteboard functionality on a Liveboard. Microsoft’s *aha!* Inkwriter [9] mimics a word-processor by reformatting ink to fit the columns of a page, and allows users to edit handwritten notes. Users of the Paper-based Audio Notebook [14] take notes on paper placed on a digitizing tablet, thus allowing notes to be linked to recorded audio.

Dynomite achieves low cognitive load by using ink without recognition during the note-taking process. However, the lack of text input exacerbates the problem of obtaining keys for indexing. We take a two-fold approach. First, Dynomite allows users to associate properties, or data types, such as “To Do” or “Name,” with a collection of digital ink. Second, Dynomite allows the user to assign text keywords to a page of notes. While Filochat [16] pro-

vides a notebook structure for handwritten notes, it does not address the problem of indexing and retrieval.

Another problem Dymomite addresses is notebook organization. Typically users take notes chronologically on a number of topics and thus actually have a number of distinct topic threads running through one notebook. Dymomite has the ability to retrieve subsets of the notebook by specifying dates, properties, and keywords. The user sees these retrieval results as a view on the notebook, analogous to views in a database system. Users may define and revisit notebook views thereby providing a dynamic organization of the changing content of the notebook. Erickson's Proteus laptop notebook [4] and Classroom 2000 [1] have keyword retrieval, but only over text-based content.

Finally, Dymomite explores the use of audio to augment handwritten notes on devices with limited storage. Audio is recorded continuously and synchronized with the digital ink, but only those portions of the audio highlighted by the user are permanently stored. Users decide whether the non-highlighted audio is deleted or compressed. While Notetime [8], Filochat [16], Coral [10] and others [1,14,15] record audio synchronously with handwritten notes, they do not address the audio storage issue.

These four sets of features provide many of the benefits of both paper and computer note-taking systems. The next section covers a study on notebook usage that helped inform the design of the system. Following that we describe our current implementation of Dymomite. Next we report on a pilot Dymomite user study, followed by conclusions.

## **NOTEBOOK USAGE STUDY**

In order to better understand how paper notebooks are used, we conducted an artifact walk-through with eleven people on their note-taking habits. All but one of them were Xerox employees. Five were executives, three were managers, and three were researchers. All used notebooks during meetings and talks to record tasks, events, and ideas. Many used their notebooks to "think on paper," that is, to sketch ideas for later presentations, papers, or computer programs. Three of the notebooks were bilingual in English and Japanese.

We interviewed people in their offices with their notebooks at hand. The sessions were video-taped for later analysis and lasted approximately one hour. We asked people a variety of questions on their note-taking practices, and had them show us illustrative examples from their notebooks. The interviewer first inquired about the types of notebooks they used, the ways in which they took notes, and how they used notes over time. We asked about the potential of audio as an enhancement to the handwritten notes. Finally, we asked about their frustrations with their current notebooks and their ideas for an ideal notebook.

## **Notebook Types**

We first asked people to describe the physical attributes of their notebooks. Everyone used paper for their primary note-taking. Their notebooks were either 1) standard spiral-bound, blank-book type, 2) loose-leaf binders such as Daytimers, or 3) simple pads of paper. In addition to these, one person carried a large calendar, which he used to record future appointments or time critical tasks. Another person used a small notebook, which fit in his pocket, for occasions when he needed his hands free to greet people. He would then transfer notes from this notebook to a larger bound notebook for further development.

A few people used PDAs and notebook computers in addition to their paper notebooks. PDAs found utility mainly for calendar items or short "To Do" items. Notebook computers were used mainly for typing notes during travel. However, people preferred handwriting to typing, saying that it was easier to listen while writing than while typing.

## **Note-taking Practices**

We then examined people's notebooks, and asked them to describe their techniques for recording information. Although people had their own note-taking styles, we saw many similarities in their note-taking conventions. These broke down into three areas: the organization of their notebook, the structure of each page, and the marking of specific items within a page.

### *Organization*

People tend to use two organization methods for paper notebooks: chronological and by subject. Loose-leaf binders and multi-section spiral-bound notebooks are useful for subject organization, whereas a blank notebook or date book is good for chronological organization. In our study, all people recorded their notes chronologically. One person had separate chronological notebooks for separate projects, creating a type of multi-section notebook, but most people kept a single notebook for all work. People's preference for chronological organization is apparently not determined entirely by notebook type, as we saw people with loose-leaf notebooks also use chronological organization.

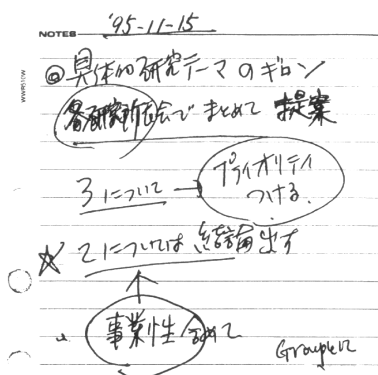
### *Structure*

All people had devised systems for structuring their notebooks to create one logical page per topic. Many people drew lines to separate topics in their notes: long lines for a major topic change and short lines for a related topic. Most everyone preferred to start their note-taking sessions on a new page. To conserve paper, one person folded his note pages in half vertically so that he could use each half as a separate page. People commonly recorded items such as the date, topic, and names at the top of a notebook page.

### *Marking*

Everyone had ways of marking important items. People described "To Do" items as particularly important entries in notebooks. These items were universally marked, most

commonly by an asterisk or circle, although one person used arrows and another underlining. Many people marked keywords, either by underlining, or putting them in the margin. Figure 1 shows circled “To Do” items and underlining.



**Figure 1: A sample notebook page showing circled “To Do” items and underlined text (in Japanese).**

### Review and Retrieval Practices

The interviewer then asked people if they used the information in their notebooks. Most saw their notes as a personal record, which they could consult as needed. Although people admitted to reviewing notes infrequently, everyone had times when they needed to access information in their notebook. Many people reviewed notes from a previous meeting prior to a meeting on the same topic. Most reviewed their “To Do” items, checking to see which still needed to be done. A common practice was for people to revisit, check off, or cross out “To Do” items. One person copied her uncompleted “To Do” items from the previous week’s notebook pages to the current week’s pages. As mentioned above, people made special notations such as asterisks or circles for items they wished to review. One person kept items for review on the otherwise blank left hand side of the notebook.

People occasionally needed to retrieve specific information from their notes. This information was typically a name, a telephone number, or a URL. People reported searching for this type of information chronologically. Thus they would estimate where a certain date might be in their notebook, and then search using the dates written on the pages. In these cases, marks made during recording were as helpful for retrieval as for review. For example, topics and names marked with circles or asterisks, or placed in a special position such as the top or side margin, aided this search.

### Reuse Practices

People also reused their notes, for example in email messages, presentations, papers, and computer programs. Generally, the information in people’s notebooks was in an abbreviated form and would be reworked before reuse. This reuse usually involved transferring information from notes into their computer. Two people reported transfer-

ring notes from their notebook to a piece of paper, for further development prior to computer entry.

### Audio Notes

Few people had used audio recorders to augment their note-taking, and none of them was happy with their past experiences with tape recorders or Dictaphones. Three people had tried using a Dictaphone to record their thoughts, but were frustrated by the task of transcribing the audio, and of finding information on the tape. One person felt uncomfortable talking to a machine. Another person said he would like to record conversations, but preferred paper to record his thoughts since he felt more comfortable “thinking on paper.” Some people noted that on occasion they would have liked to record some comment or dialog during a meeting. Although recognition of this event was obvious, it was often delayed, and more than one person suggested a tape recorder that could “start three minutes ago.”

### Frustrations with Current Notebooks

Many people expressed dissatisfaction with their current note-taking practice and showed interest in more systematic approaches. Some people attended classes to learn note-taking systems such as the Daytimer™, but after a while found it required too much constant updating. We then asked people to comment on their frustrations with their current note-taking systems, and received a range of responses that we categorize below into three areas.

#### Note-taking

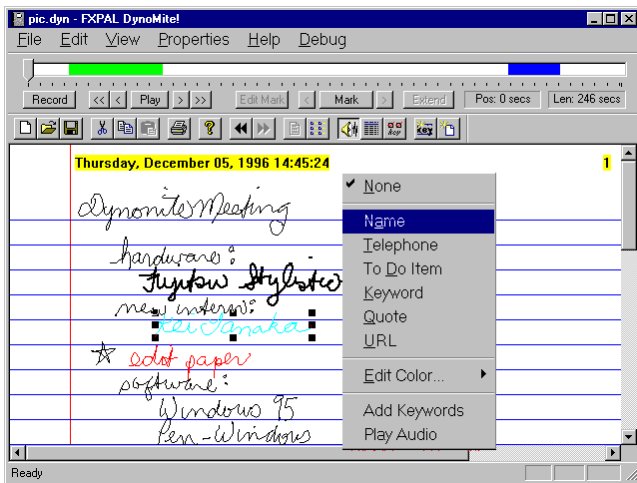
People felt that they could not put sufficient detail in their paper notes during a meeting because they couldn’t write fast enough or because they became involved in the meeting. People who used PDAs complained that data entry was too slow due to the delay caused by handwriting recognition, and that the screen size was too small to input sufficient information. People who used notebook computers said they had difficulties thinking and participating in conversations while typing.

#### Review and Retrieval

Many people had difficulty organizing and finding information in their notebooks. People explained that information on any particular topic was scattered throughout their notebook, and that finding this information required a linear search through the pages. Since review was time consuming, many people did not do this regularly, which led to the complaint that they were forgetting important items that they had recorded.

#### Reuse

Half of the people mentioned the lack of information flow between their notes and their computer. In order to reuse information in notes for e-mail or presentations, people had to transcribe their handwritten notes. While notebook computers avoid this problem, people complained that these were too heavy, and had the problem of thinking and



**Figure 2: Dynomite notebook page showing ink properties (in color) and ink written during audio highlights (in bold). Highlights are also shown as bars on the audio time line. The property “Name” is being applied to the ink selection.**

typing mentioned above. Information flow was also a problem for users who took notes in multiple places: calendar items written in notebooks had to be transferred to the calendar, and phone numbers to an address book.

### The Ideal Notebook

Finally, we asked people to comment on an ideal note-taking system. Almost all of them wanted a pen-based system. It was important for them to have control over the appearance of their notes. Most wanted the ability to edit their notes by cutting and pasting, and to dynamically reorganize their notes by moving related items to a single location. Many people expressed concern with the physical attributes of their notebooks, stressing that small size and light weight were essential. One person wanted access to the Web and other digital information while taking notes in a meeting. In general, people wanted a system that provided an organized note-taking structure without a lot of cognitive overhead.

### Summary

We found that workers were generally dissatisfied with their note-taking process and were willing to try new tools and ideas. The study pointed out ways we could help people take notes, including the abilities to:

- input freeform notes as on paper, but also to edit and arrange ink on the page;
- create arbitrary structure, including one logical page per topic, to group notes appropriately;
- mark keywords, names, or “To Do” items;
- support retrieval beyond the visual scanning offered by paper notebooks.

## DYNOMITE DESIGN

Based on our notebook usage study, we designed and implemented the Dynomite system to augment and enhance existing note-taking practices. Our design goal was to include support for free-form input for arbitrary structure, marking of key items, and versatile retrieval. In addition, we wanted to explore the potential of adding audio to the traditional note-taking process.

### Free-form Input

Because people preferred writing to typing, Dynomite uses pen-based input. Since current handwriting recognition is neither fast nor entirely accurate, notes are stored as digital ink. Figure 2 shows the interface to the Dynomite notebook. The notebook is organized as a sequence of note pages. A date is automatically inserted at the top of each page. The size of a note page is determined by the user; an unlimited amount of space is available by scrolling and a new page can be requested at any time. The background for a note page can be selected by the user according to their notebook preference or to the note-taking task at hand. Example backgrounds are lined pages with left-margins (as shown in the figure), graph paper, or plain white pages.

Pen strokes are entered on a page of notes and are stored in a structure which includes their time-stamp and property. Pen strokes are clustered by time, so that strokes created sequentially without a pause are grouped. Several gestures are available to assist with the input, as in Tivoli [12]. An insertion gesture creates more space above and below the point of insertion, a delete gesture deletes the last group of strokes, and an undo gesture repeatedly reverts the last change. A horizontal line gesture causes a new page of notes to be created, as in the Marquee [15] video annotation system. Additionally, groups of strokes can be selected and dragged to arbitrary locations on the page.

### Marking

One of the major shortcomings of paper notebooks is the fact that locating a specific piece of information known to be in the notebook is difficult. In the notebook usage study, users reported searching for specific information by making special marks near important notes, or by writing important notes at a particular location on a page (*e.g.*, the side margin). Dynomite applies this notion by providing two ways to mark notes electronically. The first method is to assign properties to selected ink, where properties might include “To Do” item, “Name”, or “URL.” Each property has a different color. The notion of properties is motivated by the fact that users already tend to identify particular information (*e.g.*, “To Do” items and names) using stars, circles, *etc.* The second method for marking notes is by entering text keywords. These two approaches are discussed below.

Properties are information types associated with selected ink, analogous to data types in a programming language.

Created	Modified		Keywords
09/12/96 11:10:31	09/12/96 11:10:31		wireless
09/12/96 11:08:06	09/12/96 11:08:06		audio
09/12/96 11:06:15	09/12/96 11:06:15		video

**Figure 3: A table of contents showing note pages' creation and modification date, properties (icons) and keywords.**

Properties are associated with ink and not with the entire note page, so that the item can be easily identified on a page and also so that all ink with a particular property can be retrieved and shown at once. This use of properties for retrieval is quite different from “color” and “thickness” ink properties in most drawing programs.

Properties are effective because it is easier for users to select the type of information than to describe its content. Dynamite has a default set of properties, which include “To Do” to indicate that the note is a reminder for the user to perform a particular task, “Name” to indicate that the note is the name of a person, and “URL” to indicate that the note is a WWW address.

Properties can be assigned to notes either before or after the ink is written. If the user knows he is about to write a note with a certain property, he can select that property from the property menu and begin writing. Properties are indicated to the user by the color of the ink. After writing, properties can be assigned to ink by selecting the desired strokes and choosing a property from the menu. Pen strokes can be selected in two ways. First, the user may click near a stroke, causing all strokes in the same time-grouping to be selected. Alternately, a group of strokes can be selected by dragging a selection rectangle. Figure 2 shows the property “Name” being assigned to a selected group of strokes.

Another way to assign properties is by using a template note page. In this case ink written in pre-defined regions is automatically given specific properties. For example, a template note page could be defined with a box for “To Do” items or with a region along the left-hand margin for keywords, as suggested by practices observed in the usage study. Another example is a note page template for telephone messages with regions at the top of the page for name and telephone numbers.

In addition to properties, Dynamite allows text keywords to be associated with a page of notes. This enables keyword-based retrieval. In contrast to properties, which describe the type of information contained in the note, keywords describe the content. Because keywords reflect more general information, they are assigned to the entire note page and not to a particular bit of ink. Text can be entered in several ways. One, keywords can be selected from a list of previously entered keywords. Two, keywords can be

typed using a pop-up keyboard. Three, keywords can be written in a keyword entry box and recognized using handwriting recognition software. Keyword indexing is also used in Marquee [15].

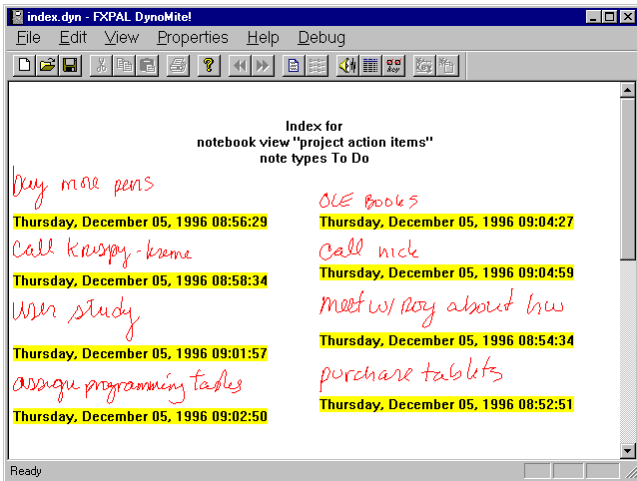
### Review and Retrieval

Figure 3 shows a table of contents for browsing the notebook where each row gives information about a page of notes. The first two columns show the creation date for the note page and the date of last modification. Following the dates are icons that tell which properties are present on each page. Finally, the table shows the keywords associated with each page. For example, in Figure 3, the first entry is a page created on September 12 that contains ink with the telephone number and name properties, and has the “wireless” keyword. Tapping the pen on a page entry jumps to that page and tapping on a column heading sorts by that field. Sorting makes it easy, for example, to find the most recently modified page, or to bring all pages with “To Do” items to the top of the list.

**Figure 4: Retrieval toolbar requesting all notes with “To Do” property and keyword “wireless”**

In order to help users find and organize information in their notebook we introduce the notion of views. A view is a subset of the notebook content selected by a query based on time, properties, and keywords. Dynamite views are analogous to views in a database system; they display subsets of the records. Figure 4 shows the interface for creating a view, which currently allows query by property and keyword. In this case, the user is retrieving all note pages with “To Do” items that have the keyword “wireless.” The view is displayed to the user in one of two ways. If the user presses the “Table of Contents” button in the view interface (see Figure 4), a table of contents is displayed as in Figure 3, except that only those notes satisfying the query are included.

If the user presses the “Ink Index” button, an index page is created by extracting from each note retrieved by the query that ink with the selected properties, and laying it out on a new page. The creation date of the ink is added as a caption. Figure 5 shows the ink index page for the view specified in Figure 4. It presents on a single page all notes with the “To Do” property on pages with the keyword “wireless”, allowing the user to quickly view all relevant information. In addition, items on the index page are hyper-linked back to the original notebook page in case more context is needed.



**Figure 5: Ink index page for the keyword “wireless” and the property “To Do.”**

Once a user has gone to the effort of creating a view, they may store it for later reuse. In this way, users create virtual notebooks presenting a subset of the notebook contents and revisit them to find the information they need.

### Audio Notes

Although none of the people in our study used tape recorders or Dictaphones, a similar study focusing on audio use in note-taking [16] showed that if audio were indexed and accessible it could enhance note-taking practices. Thus Dynomite provides a means to record audio synchronously with digital ink, and a way to manage audio storage.

When enabled, audio is recorded continuously and time stamped synchronously with the pen strokes, similar to other systems [8,10,16]. However, since Dynomite is intended to run on mobile devices, which do not have much storage, only those portions of the audio “highlighted” by the user are stored permanently. In contrast to the audio-only device of Degen *et al.* [3], in which marks are created at a single point in the audio, Dynomite highlights can be created for variable length audio segments.

The motivation for highlighting is the observation that users tend to manage audio by creating marks that identify important passages [16]. In one system [11] the user wrote “HA” (for “hear audio”) in the notes whenever interesting audio occurred. Our goal was to move from *implicit* marks about important audio passages to *explicit* marks that the system can understand. This has two advantages. First, it provides a means for the computer to make informed decisions about audio storage reduction. Second, highlights act as indices into the audio in cases where no notes have been taken.

Users initiate audio highlighting by pressing the “Mark” button shown in Figure 2, or by drawing the highlighting gesture. The audio highlighting starts a fixed amount of time in the past (as suggested by people in the note-taking



**Figure 6: Audio toolbar showing timeline, highlighted regions of audio, plus controls for playing, recording, editing, and highlighting.**

study) and remains on for a fixed amount of time. Both the start offset and duration can be set by the user. The user can press the “Extend” button, to extend the length of time that the audio is highlighted, or can end the highlighting by pressing the “End Mark” button, or can simply let the audio highlight period run out. The Listener [6] system uses a different approach to allow saving of audio segments from a telephone conversation. We are investigating how to automate the audio highlighting process by recognizing the audio characteristics of a specific speaker or speakers. For example, highlighting may be turned on when the notebook’s owner is talking. This can be done using a speaker segmentation algorithm [17].

Research has shown that one difficulty with audio is the fact that it is not visible [5]. Thus, Dynomite indicates audio highlighting to the user in two ways. First, pen strokes made during highlighted audio are displayed in bold (see “Fujitsu Stylistic” in Figure 2). Second, a horizontal timeline shows regions of highlighted audio as colored horizontal bars, similar to previous audio displays [2,7]. This provides a visual display of the entire audio recording period and the highlights within the period. This interface allows access to audio when no notes have been taken and, as described below, it also serves as an interface to edit and play highlighted regions after recording.

Figure 6 shows a close-up of the timeline and controls for highlighting and playback of audio. Users play audio by positioning the audio cursor on the timeline and pressing the “Play” button. The arrows adjacent to the “Play” button skip the audio to 1 or 5 seconds ahead or behind the current position. The user can also play only highlighted regions and can skip between these regions. Editing a highlighted region is performed by pressing the “Edit Mark” button, and dragging the endpoints of the highlight to the desired position. When satisfied with the editing, the user can store the notes, at which point non-highlighted audio is either deleted or compressed.

Storing only highlighted audio requires less storage space which is important for a mobile device. A more subtle advantage is that it serves to de-couple ink and recorded audio. For example, if users have no interest in the current topic of discussion, they may want to refine notes taken previously in the meeting. In this case, it is unlikely that they want the current audio linked to these notes.

### DYNAMITE USER FEEDBACK

Dynomite incorporates four design decisions which require user studies to validate. First, we need to determine



whether our overall interface for a pen-based notebook is workable. Second, we need to evaluate the usefulness of properties and keywords for low-overhead indexing. Third, we should examine the use of these indices to organize and display information in the notebook. And finally, we need to determine whether audio highlighting is useable and useful. With our current implementation of Dymomite, we have begun gathering initial user feedback on the overall interface for pen-based note-taking and on the use of properties and keywords for indexing. In addition, we have performed a pilot Dymomite user study to test the usability and usefulness of audio highlighting.

### **Overall Interface Feedback**

We asked several of our colleagues to use Dymomite for note-taking. Five people used Dymomite in meetings, and four others used Dymomite to take notes on videotaped presentations.

People directed some comments at the hardware -- Dymomite is currently implemented on a Fujitsu Stylistic-1000 running Microsoft's Windows 95 and Pen Services. The screen is somewhat small, the viewing angle is limited, and there is a slight delay between the time a stroke is written and when it appears on the screen. However, users had no major difficulty taking notes with this hardware, and commented that they liked the feel of writing on the device.

People liked the editing capabilities provided by Dymomite, in particular the ability to delete selected pen strokes and the ability to move notes from one place to another. One person commented that he particularly liked the ability to shift existing notes down the page and to insert a new note into this space. He said this "made his notes better organized."

One issue raised by all users was stroke grouping and selection. Currently, strokes made within a short time of one another are automatically grouped. Selection of any stroke in the group causes selection of the entire group. This is advantageous in some respects, since it makes for easy selection of words and phrases. On the other hand, it is not yet possible to select individual strokes from the group, so for example, you cannot delete one word from a grouped phrase. One user realized this, and changed the pace of his note-taking accordingly. However, in the future, we will allow for spatial as well as temporal grouping.

### **Marking**

The same nine users were then asked to comment on the usability and potential usefulness of properties. In general people liked ink properties. They clearly saw them as a useful means to index notes for later review and retrieval. One person commented that "properties seem pretty natural," and went on to say they were well worth the small extra effort. In some cases, people used properties to replace their paper-based marking schemes such as circling

keywords. In other cases, people retained marks, in particular underlines. All users added properties after the note had been written. This could be due to the fact that a pull-down menu had to be used for property selection rather than, for example, a property palette.

Our default set of properties consists of "Name", "Telephone", "To Do", "Keyword", "Quote", and "URL". However, people wanted to define their own properties. For example, one user wanted a property for "Ideas", for ink that refers to ideas for future work, or "Expenses" for ink about business expenses. Another user wanted a property "Headings." He suggested this would be used for viewing an outline of notes; retrieval would show an ink index page with only "Heading" ink. In the future we plan to allow users to define their own personal properties.

### **Audio Highlighting**

For the pilot study on audio highlighting, we asked four people to take notes on Dymomite. We showed them different video presentations, telling them they would be given a quiz on specific information contained in the videos afterwards. An initial learning phase for audio and ink note-taking allowed the users to become familiar with the synchronization of audio and their notes. In this phase they were not instructed on audio highlighting. After this learning phase, users were shown a second video. This time, they were instructed on the use of audio highlighting and were given one specific topic, among several covered in the video, that they would be quizzed on. They were told that while they could edit the highlighted regions after watching the video, non-highlighted regions would be deleted before the quiz.

The users were able to turn the highlighting on and off, using the "Mark," "Extend" and "End Mark" buttons, whenever the topic occurred in the video. Highlighting seemed to be a low enough overhead task, so that users took notes as usual. All questions were answered from the highlighted audio or the handwritten notes. This indicates that given a task where users can identify the important information, there is no obvious disadvantage to employing audio highlighting.

Our experience corroborated two findings from Filochat [16]. First, people appeared to be learning to take fewer handwritten notes and rely more on the audio. Second, people wanted to improve their handwritten notes afterwards by playing back portions of the audio. Dymomite facilitates this task by allowing users to visually navigate the audio using the audio timeline and also to automatically skip from highlight to highlight in playback mode.

### **CONCLUSIONS**

A notebook usage study showed a common desire among knowledge workers for improved note-taking tools. After examining the utility of traditional paper notebooks, we designed and built a system that merges the ease of paper

notebooks with the power of computers. We identified four design challenges that need to be addressed in order to meet users' expectations. The most important of these is how to make any new system as easy to use as paper. Other issues were how to add indexing information without taking too much of the user's attention, how to provide organization capabilities, and how to augment handwritten notes with audio on a portable device.

The Dynamite system addresses these issues with a coherent set of features. First, Dynamite provides a paper-like interface using digital ink with editing capabilities. We avoid interactive handwriting recognition because it interferes with note-taking. However, this exacerbates the problem of obtaining keys for indexing. Thus Dynamite provides properties to easily describe the data-type of some ink, and keywords to describe the content of a note page. Keywords and property indices can be used to create views, or subsets, of the notebook. These virtual notebooks provide an organization that automatically updates as new note pages are added. Additionally, Dynamite provides explicit audio highlighting, allowing the system to make intelligent decisions about storage management and allowing users to visually navigate through important audio segments.

Although our user studies are far from complete, we are encouraged by our observations thus far. The basic Dynamite interface is easy to use. Properties are fairly natural to apply, and their potential usefulness in review and retrieval was noted. Views seem to address a generic problem of chronological notebooks: having multiple topic threads interspersed throughout. To be sure, the audio highlighting feature is most beneficial when people can recognize important audio. However, anecdotal evidence from our users indicates that people do realize, although perhaps with some delay, when an important audio event has occurred.

We are currently planning longer term studies of Dynamite usage. Our next step is to deploy a large number of devices in the field, allowing users to accumulate and use a collection of notes. As Erickson [4] points out, the important question is how electronic notebooks "will really be used over a long period of time."

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