Software for Taking Notes in Class

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***Abstract*— *Although digital devices are replacing paper and pencil in ever more domains, class notes have so far resisted this trend. In part this is because class notes and the note-taking process are unique and different from the tasks supported by existing software. A system to support classroom note-taking should embody seven design principles. A prototype system based on these principles was used in the laboratory and in the classroom by three long-term users. Some users prefered note-taking with the system over pencil and paper, suggesting that taking lecture-notes with the computer is feasible.*
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I. INTRODUCTION

Many students own a notebook computer, some carry it around with them all the time, but it is rare to see anyone in lecture taking notes with one. Naively this seems to be a missed opportunity, as digital documents are superior to hand-written documents in many ways: being searchable, editable, easily sharable, and, most of all, more legible. Of course paper and pencil has its advantages, but there are related tasks where digital devices, such as PDAs or computers, have recently come to replace pencil and paper.

This paper addresses two questions: First, what features are required to support note-taking? Second, how feasible is it to build a successful note-taking application using hardware available today?

II. ABOUT CLASS NOTES

This section surveys the educational significance of taking class notes, discusses the important properties of class notes compared to other digital documents, and surveys previous work on the use of technology to improve or replace note-taking.

A. Why Students Take Notes

According to an old joke, "lectures are a way for the notes of the lecturer to become the notes of the student without passing through the mind of either". If so, learning problems in the classroom can be blamed simply on the inability of the student to copy down all the information the instructor presents. From that it is a small step to the idea that technology should be used to deliver to students the content of the lecture, incidentally making note-taking unnecessary. However the premise, that note-taking is just a way to capture content, is wrong.

Educational psychologists report that note-taking has two functions [1], [2], [3]. First, obviously, the notes produced are useful when reviewing. Second, the process of note-taking itself helps students learn the material in most cases. This is usually explained in terms of encoding: the student's mind receives some inputs from the instructor, both verbal and written on the blackboard, and the task is to assimilate them. In the process of taking notes, the student has to re-express those inputs, and while doing so, the ideas get mentally rehearsed, integrated at a deeper level, or re-encoded mentally in a form that is easier to and remember. Certainly it has been found that taking notes itself promotes learning, whether or not the student ever looks at the notes again [4].

Thus taking notes in class is not an archaic method for recording information, rather it is a technique for engaging the student's mind, thereby facilitating learning. While there is great potential for technology to improve the lecture hall in many ways [5], [6], [7], [8], the view, occasionally heard, that such advances will render note-taking unnecessary is without foundation. Rather note-taking must co-exist with such technology, as many researchers have pointed out.

This paper discusses a use of technology to support note-taking itself. The goal is to let students produce notes which are very similar to what they produce today with pen and paper, but different in being digital documents, and thus more legible, among other advantages, and so better than handwritten notes for purposes of review.

B. Properties of Class Notes

It only makes sense to talk about a special-purpose note-taking system if the ways that class notes are created and used are significantly different from those for other types of documents and notes; this subsection discusses the differences. The points made in this section are based on our own experiences taking notes on lectures, on the literature (although most of these points are too low-level to have been noted by educational psychologists), and on observations of a small corpus of class notes gathered from Engineering students at the University

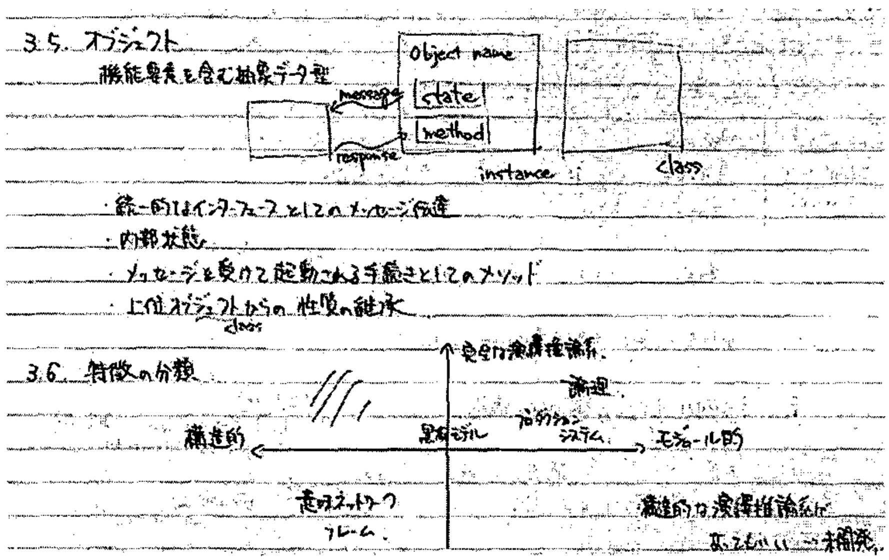

FIGURE 1. EXCERPT FROM CLASS NOTES, FROM A CLASS ON ARTIFICIAL INTELLIGENCE PROGRAMMING

of Tokyo. Since there is a great deal of individual variation in note-taking practices, the discussion in this section is applicable only generally, not universally.

1. The most typical use of class notes is for review by the person who created them. As such, notes do not have to be stand-alone documents; rather they are good enough if they serve to help retrieve memories of what the instructor was saying or writing.

2. Class notes are used typically reviewed during the semester; they are not used as permanent records. For these reasons class note are generally rather "sloppy", in terms of layout etc., compared to other documents.

3. Text generally is in short chunks: full sentences are rare and paragraphs non-existent. Most instructors write only key phrases on the board, explaining the relationships between phrases only orally and/or graphically, and most students follow suit.

4. The spatial arrangement of class notes is important [9]. In contrast to the essentially linear nature of many documents, class notes are essentially two-dimensional, reflecting instructors' use of blackboard space.

5. Text and graphics often appear together. For example, text is underlined, words are connected with arrows, phrases appear in boxes, and so on. These points are illustrated in Figure 1. Despite the unfamiliar language (Japanese) this is instantly recognizable as class notes — it could not be mistaken for a recipe, a schedule, meeting minutes, or any other type of document — which illustrates the distinctiveness of class notes, and the need for a specific type of editor.

6. Class notes can be moderately long. A student in a lecture generally sets out to absorb everything, and typically records as much as possible of the new class content.

7. Class notes are usually written under time pressure.

8. Eighth, most classroom note-taking is done sitting down, at a desk with enough space to rest a pad of paper, or a notebook computer and maybe a mouse.

*9. Class notes are revised relatively infrequently. In con*trast, the time involved in creating many documents of other types, such as articles or plans, is typically dominated by the reorganizing, rewriting, and other editing phases. (However some educators advocate review and revision of class notes [3]; and for many serious students this means re-copying the notes. There is an opportunity here: if class notes are digital then revision does not require re-copying.)

Thus class notes have fairly distinctive physical properties and are used in fairly specific ways.

C. Pen-Computing and Various Types of Notes

In contrast to document creation, which as long been one of the classic "killer applications" for personal computers, the creation of notes, that is, of records primarily intended for ephemeral or personal use, has only recently become a candidate for computer support. However thanks to the recent proliferation of digitizing tablets integrated into various mobile devices, paper is becoming obsolete in more and more domains. This section surveys pen computing as it relates to various forms of note-taking.

Probably the greatest success of pen-computing is in "vertical" applications. Here much of the information required is predictable and handled by forms with check-boxes etc., but there is also the occasional need to enter free-text and diagrams, typically in pre-defined areas. Users of these systems differ from students in that they typically create only small amounts of such notes at each use, and in that they often work without a desk or even while standing.

Another common type of note-taking is that done by office workers, especially the production of notes in meetings. Such users differ from students in that they are usually more selective in what they write down. As such, knowledge workers are often satisfied with a small-screen PDA, and are often willing to put up with sub-optimal input methods, since volume of notes is less and the time pressure is less continuous than for students in lecture. Also, meeting notes differ from class notes in that they are typically used primarily as resources to support upcoming action. Information needing to be retained is typically recorded in a more permanent way after the user gets back to his desk. Thus there are fewer problems with notes which were clear when created but after some months, when the context has been forgotten, are hard to interpret. For office workers the technique of storing notes as "ink without recognition" [10] or "digital ink" [11], that is, storing the notes in bitmap form, is often acceptable.

A related use is notes to record ideas. For example, architects in the early stages of a project may need to sketch out some concepts, approaches, or designs, and show them to a client or co-worker, save and organize them, or send them to someone else. Notes of this type are, unlike class notes, created at the speed of the user's own thoughts.

Another use of notes is in personal notebooks for long-term use, as used by some engineers, authors, and researchers. As these may be used to support the creation of products based on a integration of a large quantity of information gathered over months or years, indexing and restructuring become major concerns [10], [12], [13], much more so than for class notes.

III. Design Decisions

The above factors provide an explanation for why almost no-one takes class notes using a computer: the requirements are unique. This section proposes seven principles for the design of tools for taking class notes.

A. Provide a Pen for Freehand Drawing

As a preliminary study, 5 subjects attempted to take notes using a standard notebook PC with a mouse. In class it proved impossible to keep up, and in a controlled study where subjects were asked to copy a page of notes, it took about twice as long, on average, with the computer than with pencil and paper. The most salient problem was the difficulty of drawing diagrams etc. with the mouse. It seems, unsurprisingly, that a pen is necessary for taking class notes.

(Of course there do exist students who take notes in class using just a keyboard. One of our friends uses a standard text editor, Emacs, to take notes; thus his re-encoding task is to convert the instructor's words and 2-D boardwork, plus his own thoughts, into linear textual content. This sort of extreme re-coding while listening is probably beyond the ability of most students.)

B. Provide a Keyboard for Text Input

A pen computer by itself, however, is not enough for taking class notes. Although the presence of graphic elements is a hallmark of class notes, it is nevertheless the case that most class notes consist mostly of text. For text input the keyboard is of course at an advantage.

Most obviously, typing produces text which is more legible than notes on paper, and even more so compared to handwritten notes on a tablet. While someday handwriting recognition may be good enough to automatically convert written notes to typeset notes, today's recognizers demand that the user either write very carefully or take the time to correct errors. Typing also produces text which is more editable and more searchable. Also, for many users, keyboard input is faster and less tiring than writing on paper.

Thus, despite continuing improvements in the resolution and feel of digitizing tablets, unless they are even better than paper the keyboard will remain at an advantage. Parenthetically, there are alternative text input methods for pen computers, including soft keyboards, stroke-based alphabets, and predictive methods, however these have not yet gained general acceptance, especially for entering substantial volumes of text.

Based on these arguments, a note-taking system should provide support both pen and keyboard: a pen for drawing a variety of graphic elements, and a keyboard for text input.

C. Provide a Mouse or Equivalent for Positioning

In the preliminary test of note-taking with the computer, using a common drawing tool, users frequently moved the dominant hand back and forth from keyboard to mouse, as positioning and menu-selection were interleaved with text entry. In particular, a significant amount of this tool switching was involved in selecting the text entry point, inputting the text, then moving the cursor to the next text entry point. (For pure pen computing, of course, there is no such tool-switching, since the hand and fingers can do both positioning and writing.) Assuming that the time cost of keyboard-to-pen switching is greater than the time cost of keyboard-to-mouse or keyboard-to-trackball/trackpoint/touchpad switching, note-taking systems should include a mouse or equivalent.

Thus a device for taking class notes should include keyboard, pen and mouse. To minimize tool switching time, it is desirable to make most functions available from more than one modality. For example, the user is sketching, he/she already has the pen in hand, and so would probably prefer to create an oval, say, by tapping on a menu or icon. On the other hand, if the user is typing and wants to create an oval, he/she would probably prefer to invoke that by a keyboard shortcut.

Similarly, both pen and mouse should always be available as pointing devices, If this is implemented straightforwardly, attempts to use the pen to select objects or to position the cursor may, when the pen slips, be misinterpreted as input, resulting in unwanted short lines. Various countermeasures are possible [11], however a helpful simple fix is the addition of a "remove flak" function to let the user delete all very short lines which have not been grouped into larger objects.

D. Optimize Text Positioning and Entry

The tool-switching overhead is worsened if the application requires the user to create text boxes. For many drawing tools, to put some text somewhere can require 4 preliminary steps: 1. select the "insert text" icon, 2. move the mouse to the desired location, 3. click to set the left edge of the text box, 4. drag and release to set the right edge of the text box. Of course, some applications allow the omission of steps 1 and 4, but step 3 is generally required, even though only step 2 is logically necessary.

This overhead becomes larger for class notes, where text is the bulk of the content, and the text appears in small chunks scattered over the screen.

Our solution is for the system to do "automatic text-box generation"; in effect the system is always in text input mode. Thus the user only has to do step 2. For example, in order to put two words on the screen, one indented below the other, the user simply moves the cursor to where he wants the first word, types it, then moves the cursor to where he wants the second word, then types it. There is no need to click before typing.

This somewhat radical solution is workable for two reasons. First, class notes are mostly text, so it is reasonable for text input to be special; unlike most drawing tools, which handle text objects consistently with other objects, and so require the user to to select the "enter text" mode before typing anything. Second, students edit or move existing text less frequently than they enter new text, so it is reasonable to make text input a privileged operation.

E. Support Text Decoration from the Keyboard

In order to reduce the need for tool switching, it is important also to minimize the time spent using the mouse during text entry. For existing tools there are many common actions that affect text but which generally require mouse actions. For example, highlighting, underlining, font changes, and adding ovals or boxes around text are all generally done with the mouse. This means that an operation such as underlining is usually done in two steps: 1. select a region of text by dragging with mouse, then 2. select a menu command with the mouse. After this there is often a third step, where the user moves the cursor back to the text region to continue work on it. (Of course power users may use shortcuts to speed Step 2.)

To avoid the need for Step 1, a note-taking tool should have implicit text selection, so that operations apply automatically to the text chunk the cursor is currently in.

F. Provide a Large Inventory of Text Decorations

In class notes there are many graphic objects which are logically text decorations but which, in most drawing tools, have to be drawn separately, such as brackets and ovals enclosing text chunks. These are a nuisance to draw, not only because of the menu selection time, as noted above, but also because of the time spent positioning them appropriately in relation to the text. In our system, therefore, these also are provided as text operations: there are commands for surrounding the current text chunk (whether single- or multi-line) with a box, an oval, big parenthesis or big brackets, or for adding an arrow pointing down, to the right, and so on. These operations automatically position the decoration in the correct position and in the correct size relative to the selected object.

Even with these features, taking class notes still requires a fair amount of work positioning pen-drawn graphics and keyboard-entered text in close proximity. This is the reason why it is important for the drawing surface to be the screen itself, rather than a separate tablet.

G. Automate Common Drawing Sequences

In the preliminary studies, subjects took a lot of time drawing mundane things, like the x and y axes of a graph, building them up from graphic primitives. Therefore a tool for class notes should provide such common objects. It is also helpful if objects come with dummy text in standard positions. For example, after generating x and y axes a user will generally next want to add labels to them, and after creating a sigma will generally want to add lower and upper limits. To avoid the need to individually position such text, the system should provide dummy text, which the user can then simply select and edit.

The set of common text decorations and graphical objects should be user-extensible.

IV. IMPLEMENTATION

A system embodying the above design principles was built, in Java for the sake of rapid development.

The source code is about 4000 lines. Both Japanese and English versions can be downloaded from `http://www.cs.utep.edu/nigel/notetaker/` or `http://nigelward.com/notetaker/`. The system was tested on the best hardware available in late 2001, namely the Panasonic CF-02 and Fujitsu FMV-BIBLO MC3/45 Notebook PCs with passive touch-sensitive displays.

V. Preliminary User Studies

Studies were done to determine whether the design outlined about is a good one and whether it is adequate for the task.

Three students were recruited to try out the final, full-featured version of NoteTaker in class. Two kept using it beyond the planned ten class sessions: one for a semester and one for two. Altogether they have produced the equivalent of 100 A4 sheets of notes, for classes including HCI, Artificial Intelligence, Software Engineering, Control Theory, and The Essence of Humanity. In addition in the lab 10 students came in to take notes from videotaped lectures with both pencil and NoteTaker.

Asked what they considered to be the advantages of NoteTaker over pencil and paper, all users said that the notes produced were more legible. Other factors mentioned included the ability to take notes faster, the ease of adding, correcting, and moving objects, the ability to search, and the ease of back-up.

Asked about the disadvantages of NoteTaker, all users mentioned that they couldn't draw complicated graphics neatly; this was expected given the hardware used. There were other comments about hardware issues, notably battery life. Some users felt self-conscious using a computer in the classroom. One user found it hard to keep up in equation-heavy lectures. Another pointed out that if the instructor provided lecture notes on paper it was easier to just annotate these.

In general notes taken with NoteTaker were very similar in content and layout to notes taken with pencil and paper, suggesting that students were able to keep up with the lecture while using it. In the videotape-based study one of the subjects remarked that he was able to pay more attention to the blackboard while using NoteTaker than with ppaper, but one reported the opposite. The long-term users didn't mention this as an issue at all. Probably this depends on individual preferences.

More on the evaluation appears elsewhere [14], [15], [16].

VI. Prospects

Many of the hardware problems noted by our users are gone or alleviated in the Tablet PC, which uses an active digitizer and has operating system support for pen event handing and ink rendering. This hardware became available only last fall, and and currently the only software intended for classroom use is Livenotes, which is primarily a communication tool [17]. However we are planning to port our system to the Tablet PC, and Microsoft has preannounced an application called OneNote whose marketing literature evokes the possibility of classroom use, although the feature set previewed so far does not seem adequate for this.

One way or another, over the next few years some students will end up buying and using computers to take class notes. Looking even farther ahead, as the general student population continues to improve in computer literacy and typing speed, as hardware improves, and as class hand-outs become digital, taking class notes with computers will become even more attractive.

Although this study shows that some students like taking notes using a computer, we do not know whether doing so truly improves learning. Thus there are several important open questions.

1. Who can benefit from using computers, how much, and in what circumstances? We would like to know whether computer note-taking is more or less appropriate for students of different types, where the factors may include degree of affinity for technology, degree of computer literacy, level of typing ability, learning style, age or intellectual maturity, study habits, various attitudinal factors, and personal note-taking style.

2. How does computer use affect class notes? We would like to know, for example, whether the use of computers tends to make notes be more literal or more selective, whether using the computer allows or encourages users to take more or fewer notes, whether using the computer takes more time or attention, and so on.

3. How does computer-based note-taking affect review? We would like to know, for example, whether having more legible notes improves retention per time spent, whether having cleaner notes encourages students to spend more time reviewing, whether students actually take advantage of the improved searchability and editability of computer-based notes, and so on. We would also like to know whether digital notes are best reviewed on the Tablet PC screen, on a big screen, or printed out.

4. What side-effects arise? Since digital notes are more legible, and easier to copy, it is possible that they may encourage note sharing and weaken the incentive for students to pay attention in class, or even to attend. On the other hand, having more legible notes may encourage studying together and collaborative learning [7], [17]. It may also improve the efficiency and efficacy of homework.

5. What should educators do? It would be good to know what attitudes, note-taking styles and study habits to encourage so as to not adversely affect classroom participation and discussion dynamics.

6. How will note-taking with computers fit with other

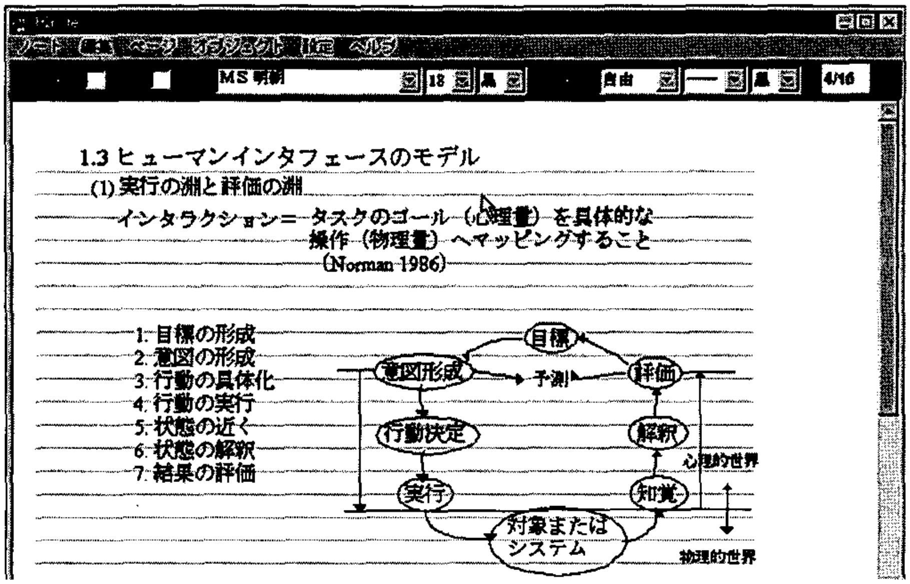

FIGURE 2. NOTETAKER SCREENSHOT. THE MAIN PANE SHOWS CLASS NOTES FROM A CLASS ON COGNITIVE MODELS OF INTERFACE USE.

technology for the classroom? especially making the audio portion accessible from the class notes [8], tools for organizing and indexing digital notes [18], techniques for sharing notes among students [7], and ways of making the instructor's notes and other materials directly available to students [5].

VII. CONCLUSIONS

This paper started with two questions: what hardware and software features are required to support note-taking? and, is it possible to build a successful note-taking application today using common hardware?

Regarding the hardware question, digitizer quality was the main issue. However even hardware with a low-quality digitizer was found usable by some, and now, with the availability of Tablet PCs, this problem is almost solved.

Regarding the software question, the needs of students taking class notes are fairly clear, and they are not satisfied by existing drawing tools or editors. Important features require to meet these needs include the use of pen, keyboard, and mouse-or-equivalent, support for fast text entry at arbitrary positions, and support for common text decorations and drawing sequences. Barring the appearance of new technologies that radically change the nature of text entry, note-taking, or human learning, any application for taking class notes will probably need these features.

Finally, regarding the overall question of the feasibility of taking class notes with the computer, for at least some students, this is possible today and can be preferred to paper. The next step is to evaluate the effects on learning outcomes.

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