Best Practices for Lecturing with Digital Ink

Richard Anderson
Department of Computer Science and Engineering
University of Washington
Seattle, WA 98195
anderson@cs.washington.edu

Ruth Anderson
Department of Computer Science
University of Virginia
Charlottesville, VA 22904
ruth@cs.virginia.edu

Luke McDowell
Department of Computer Science and Engineering
University of Washington
Seattle, WA 98195
lucasm@cs.washington.edu

ABSTRACT

Systems allowing instructors to write on top of electronic slides with digital ink are becoming widely available. The combination of high quality projected images and rich ink offers new levels of expressiveness while the ability to dynamically add ink to prepared content opens up new pedagogical possibilities. As early adopters of new technology, many computer science instructors are using, or are considering using such systems in their classes. Yet as with all new technologies, the use of these systems is not without risk. In this paper we offer advice to new and potential users based on our extensive personal use, detailed review of video archives, classroom observations, and discussions with and surveys of a large number of students and instructors. Our goals in this paper are to help new users avoid the most common pitfalls we have observed and to alert them to many of the exciting pedagogical possibilities.

Categories and Subject Descriptors

K.3 [**Computers and Education**]: General

General Terms

Human Factors

Keywords

Classroom Presentation, Pedagogy, Tablet PC, Digital Ink

1. INTRODUCTION

There is growing use of systems that augment slide based presentation with digital ink. In these systems an instructor delivers a lecture from a pen computer such as the Tablet PC, writing on top of the slides with digital ink. The slides and ink can be displayed to the class with a data projector, transmitted to student devices, or shown at remote sites. The motivation for using such systems is to gain benefits of both electronic slides and handwriting. Electronic slides allow for high quality digital materials which can be conveniently shared and reused. For Computer Science courses, computer-based presentation has the further advantage that other software applications such as development environments or web browsers can be brought into the lecture. Handwriting is important because it allows for spontaneous introduction of material, breaking away from the scripted effect of slide based lectures. The ability to introduce written material is particularly important when interacting with the audience and controlling the pace at which material is introduced. Figure 1 shows an example where an instructor drew an array and a linked list to make a point about spatial locality.

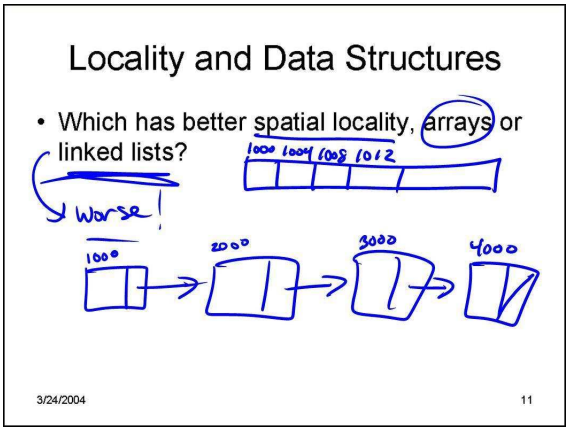

Figure 1: Integrated use of ink and slide content

There are many different systems available for integrating slides and digital ink. The Classroom 2000 system [1] pioneered the use of digital presentation materials with slides and handwriting. There have been a series of academic projects which have developed Tablet PC based presentation systems including Classroom Presenter [2], DyKnow [3], and eFuzion [7]. Commercial applications such as PowerPoint, OneNote, and Journal can also be used from the Tablet PC for presenting slides with digital ink. These systems share the same basic model: a layer on top of slides that can be written on with digital ink. For the purposes of this paper, the choice of underlying system does not matter - most of the advice will carry over across systems.

In this paper, we give advice to help instructors be most effective presenting digital ink-based lectures. Our advice is based on significant observation and study of these systems. We have been involved with a large number of courses at multiple institutions that have used digital ink on electronic slides, and we have also spent hundreds of hours reviewing

Submitted for publication
.

digital archives of classes to see how instructors have used digital ink in lecture. All of the examples and figures in this paper are taken directly from this experience with actual lectures delivered to Computer Science courses. Our main goal is to provide useful information on how to use this technology in the classroom.

There are a broad range of technologies that support handwriting for lecture presentation. These include conventional blackboards and whiteboards, overhead projectors, image projectors, electronic whiteboards and computer projection. Although these all provide facilities for writing, there are significant differences where the various technologies make some things easier, and some things more difficult. The technologies differ both in their direct support for writing, and their broader impact on the classroom environment. Qualities of different technologies include: ability to include other presentation material, archiving, redisplay of writing, quality and color of ink, size of writing area, resolution of writing, ease of writing, direct versus indirect writing surface, pointing mechanisms, orientation of presenter to the audience, range of motion allowed by the instructor, reliability, portability, and cost. With a list of this length, there is clearly no *best* presentation technology, and the choice of technology can be challenging. An instructor is charged with the task of using a presentation technology to the maximal education benefit of his or her students. We are providing advice on one particular technology with which instructors are starting to experiment in the classroom with the hope of sharing what we have learned and promoting better use of teaching tools.

Many good books describe best practices in university instruction. *McKeachies's Teaching Tips* [6] is an excellent example that gives advice on topics ranging from preventing cheating to leading group discussions. Much of the advice in these books seems obvious – although we can all identify instructors who ignore or are unaware of this advice to the detriment of their teaching. An example of the type of advice that occurs in these books, from Bligh [4] is:

> Practice writing at the top of the board and at the bottom. Shoulder movements are difficult at the top. Writing with bent knees and back at the bottom can be tiring. If your line of writing goes up or down, you probably need to move your feet to a more comfortable position.

These books are invaluable to both novice and experienced teachers. First of all, the majority of the advice in these books is right on the money, and second, reading these books leads to reflection on teaching, seeing one's strengths and weaknesses. In this paper, we are presenting analogous advice on digital ink based pedagogy. Although some of it is obvious (at least in retrospect), we believe it is valuable to identify the best practices and risks in using a new technology in order to facilitate its adoption.

In the remainder of the paper we present several guidelines for the use of digital inking systems. In Section 2 we describe specific techniques for using digital ink clearly. In Section 3 we address designing presentations to take advantage of ink. In Section 4 we give examples of deliberate use of ink to convey information. In Sections 5 and 6 we caution the user against several of the pitfalls we have observed in deploying the new technology and in interacting with the audience when using the technology, and then conclude in Section 7.

2. FOCUS ON CLARITY

Using digital ink in lecture opens up new possibilities in terms of both expressiveness and flexibility in presentation. However, using this new power effectively requires attention to a number of details in order to ensure that the presentation is fully comprehensible. In this section we describe several of the most critical factors we have observed in use of these systems.

2.1 Legibility

Information must be legible in order for students to gain anything from it. The obvious advice is to write as neatly as possible, although the excitement of teaching and the goal of concentrating on the audience can make this hard to do. Understanding some of the specific challenges of writing on a Tablet PC can help improve legibility. There is variation between Tablet PCs, so if there is an opportunity to choose between models, it is advisable to determine which supports the easiest writing. Differences between Tablet PCs include the size of the screen, the feel of the pen, the slipperiness of the screen, and viewable angle. Note that Tablet PC pens are generally interchangeable (as of Summer 2004, almost all Tablet PC's are using the same digitizer). Sometimes, it can be difficult to align writing because of *parallax* and other digitizer issues.

Screen real estate is an important issue. The writing area on a Tablet PC is less than on a classroom sized whiteboard which limits the size of things that can be written and the amount of material that can be left up for students. The writing size is generally limited by the size of the instructor's handwriting, not by the number of pixels, so a Tablet PC with a larger physical screen might be preferable to a smaller physical screen – even if they have the same number of pixels.

One thing that is important to do is to plan writing in order to avoid running out of space. It is not unusual to run into a margin when writing - perhaps because writing on a Tablet PC tends to come out larger than writing on paper. The recursion example in Figure 4 has some of the writing running into the margin.

2.2 Color usage

The choice of ink color is made primarily for contrast, either with the slide background or with other ink. It is desirable to have the ink color contrast with the slide text color as well, in order to make it easy to identify ink annotation. For example, if the slides are black text on a white background, blue or red might be good colors for the ink. A blue background with white text and yellow ink can be effective.

Care needs to be taken to make sure that ink colors contrast with the slide background. We have observed many instances when the slide background changes (say from blue to white), and the instructor continues to use the same color which is almost invisible on the new background. (Students may not notice the new ink, and consequently say nothing).

Choosing colors for contrast can be tricky. One thing to keep in mind is that the same RGB colors can appear very different on different devices and viewing situations. For example, different viewing angles of a LCD can make green look black. We have seen colors which were very easy to see on the Tablet PC, but almost disappeared when displayed with a data projector.

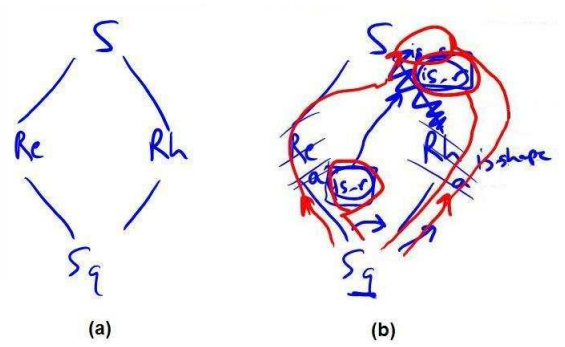

Figure 2: (a) is a base diagram used in a discussion of multiple inheritance. (b) shows the result after many different points had been illustrated on the same diagram.

A cute trick that some instructors have used is to intentionally use an ink that matches the slide background, to erase content on the slides. An instructor who used a blue background discovered that the blue pen was perfect to use to erase mistakes on his PowerPoint slides, so that he could then correct them with ink.

2.3 Clutter

A number of problems emerge when ink is cluttered. First, when ink is overdrawn, the new ink is not distinct from the old. The Tablet PC ink is solid, so multiple strokes of the same color merge. Common patterns have been observed where an instructor will make multiple underlines close together (e.g., underlining both terms and variables) but the separate marks are not visible to the viewers. Another problem with clutter is that it can become difficult to find the new ink as a viewer. This is especially the case when the marks are made in areas that already have writing.

An additional cause of clutter is when one slide is used to convey many different points. For instance, in one lecture the same basic diagram of diamond inheritance shown in Figure 2a was used to illustrate nine distinct points, leading to the confused state of Figure 2b.

One solution to the clutter problem is a periodic clean up of the slide. Many instructors will erase all the ink on the slide when it starts to be cluttered. For instance, we observed one instructor who cleaned a slide up to ten times during the discussion. This technique can be effective, as long as there is no ink on the slide that needs to be saved. This does not work if there has been a diagram created with ink, and the instructor wants to remove the attentional ink from it. Unfortunately, it is often difficult to selectively erase ink strokes to clean up a diagram. However, some Tablet PC pens include a button on the eraser end of the pen that can greatly simplify this process, when supported by the presentation software.

Color can be used to mitigate the effects of clutter. When things get too messy a new color can be used. This allows new attentional marks to be distinct from the older ones. However, after the second color is introduced, additional colors do not have much added benefit.

2.4 Pacing

One advantage of writing is that it leads to displaying material at a rate that is comprehensible for students, both

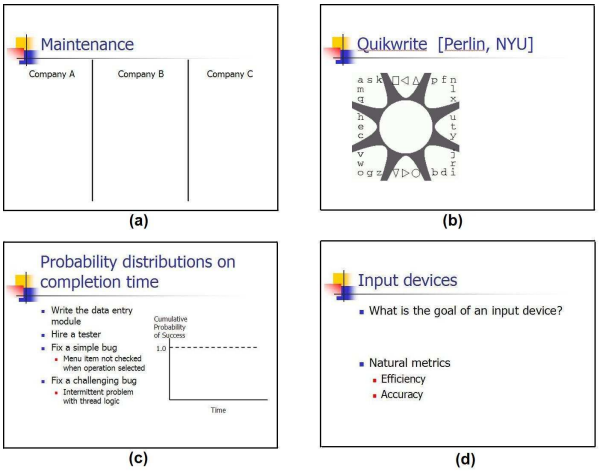

Figure 3: Slides designed for ink use: (a) Collective Brainstorm (b) Template for demonstrating a writing system (c) Graph drawing (d) Space to answer question

for listening and for note-taking. This advantage is often stressed by blackboard style instructors. It is important that writing remain visible long enough for students to comprehend the ink. A common mistake in a slide based lecture is to change or erase the slide immediately after writing has been completed.

3. PLAN FOR INK USE

While digital ink presentation systems can be used with slides that were originally designed for other presentation mediums, such use does not take best advantage of these systems' capabilities for the introduction and dynamic modification of content. This section describes several issues related to designing slides specifically to support ink use in lecture. Figure 3 shows examples of several slides designed for ink use.

One key design issue is leaving adequate blank space on the slides for inking. We have observed many examples where an instructor wanted to add a diagram to a slide, but the small amount of space available resulted in a diagram that was very cramped and hard to understand. Instructors need to anticipate where inked diagrams will be useful, then allow ample space for such inking along with any accompanying attentional marks or clarifications. In addition, pre-created diagrams need to be large enough to enable the instructor to easily write inside of them.

A second aspect of leaving space relates to allowing adequate room for student note-taking. Frequently, instructors with prepared slides will distribute handouts with small versions of each slide for such note-taking. Typically, students can write smaller on such handouts than an instructor can write with digital ink, so recording basic inking is not a problem for students. However, the instructor has the advantages of being able to re-use slide space by erasing and of being able to use contrasting colors. These options may not be available to most students. To ensure that students have adequate space for note-taking, it may be necessary to split material across multiple slides or to leave adjacent slides blank.

Regarding note-taking, we have also observed several in-

structors who intentionally omit key words, phrases, or results from their slides in order to fill in the "answers" for these quantities during lecture (see Figures refs:rea and 3d). When paired with handouts of the slides, this approach is consistent with the philosophy of using "guided notes" [5] and research has shown leads to improved student recall [4]. This practice enables instructors to solicit these answers through classroom discussion as time permits, and helps to ensure that students remain attentive during lecture (writing down such answers) even when slide handouts have been provided. Some systems for digital ink presentation, such as Classroom Presenter, permit instructors to add notes to their slides that only appear on their Tablet PC, not on the version that is displayed to the class. Such notes are an excellent way for instructors to remind themselves of the precise phrasings and results that they wish to use for such answers.

Instructors can also design slides to foster other kinds of discussion (or to remind them to start such discussion). For instance, a slide might include a blank pair of axes for discussing and graphing some quantity (Figure 3c), or several blank columns for brainstorming/comparing different approaches (Figure 3a). Alternatively, instructors might use a standard symbol (such as a picture of a brain or a question mark) to indicate points where discussion would be helpful. Such prompts also serve to remind the instructor to not focus only on the technology but to foster classroom interaction.

4. USE INK TO CONVEY MEANING

One important use of ink is to make connections between speech and content. Ink can draw focus to the current formula and diagram, and can significantly aid comprehension. In addition, such ink can be used to resolve deixis in speech (e.g., circling the variable x, when saying "this variable"). It is very important to make sure that the ink remains clear, so that the viewer can see where the ink is and it does not obscure slide content.

There are also many opportunities for ink that not only draws attention but also adds extra meaning to the slide. For instance, we have frequently observed that lecturers will make a brief ink jot next to each item in a bulleted list that they are discussing, but some go further. For example, one instructor added sequential numbers next to each point in a list as it was discussed, in order to emphasize the multiple types of items. Other such informational markings we have seen include the use of exclamation marks to emphasize the importance of a point, and the use of pluses and minuses to note the relative merits of different points.

On the negative side, we have also observed situations where purely attentional marks bewilder the audience by unintentionally conveying additional meaning. For instance, if a horizontal dash sometimes conveys "negative" and sometimes is just an attention jot, students may be confused. Likewise, instructors need to be careful that arrows and attentional markings are not mistaken for letters or numbers. Such pitfalls can be avoided partially by planning ahead with slide design, and partially by periodic reflection during the lecture.

Ink can also convey meaning not only with its shape, but also with its color. We've previously discussed the importance of ink having good contrast with other displayed material, and a change of colors can be used to emphasize different points. In addition, instructors sometimes use different colors to represent different kinds of information or activity. Figure 4 shows[1] an example where an instructor diagrammed unrolling of a recursive function call by drawing a different state box for each function call, then used a different color to separate activities that occurred as the recursion deepened and as it unwound. Likewise, the slide in Figure 5 used color to associate different groups of list cells, with the inner most green node corresponding to the green cell, the middle red node corresponding to the red cell, and so on.

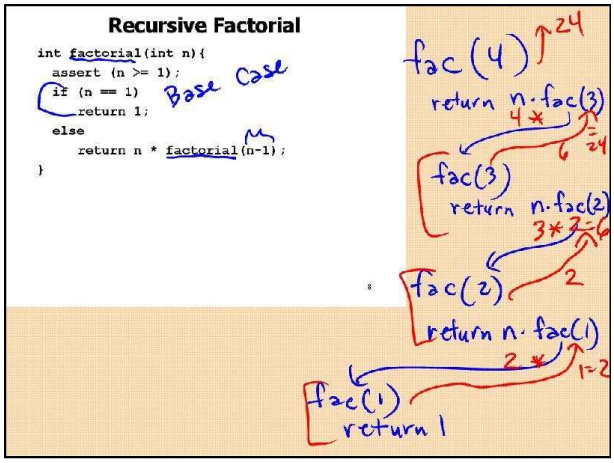

Figure 4: Color used to distinguish between different phases in recursion

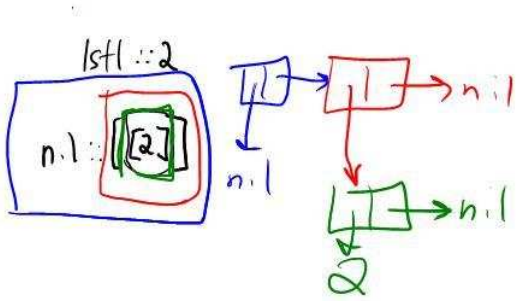

Figure 5: Color used to show correspondence between a list and a cell representation

5. PREPARE FOR NEW TECHNOLOGY

It is essential to become familiar with the technology before the start of class, to minimize disruptions caused by technology. Instructors often underestimate challenges in deploying a new technology in the classroom. In classes we surveyed where there were negative reactions to digital ink presentations, the predominant complaint was that the instructor had trouble with the technology. The survey responses included:

> The setup and unreliability associated with the system contributed significantly to lost class time.

[1]Figures 4 and 5 were originally in color, but in a printed copy may not convey full information.

> It was somewhat distractive in that our instructor was just learning the system - other than that it could be a very effective tool once the instructor learns how to effectively use it.

In our experience, we have separated technology problems into *breakdowns* and *fumbles*. Breakdowns are when the technology is not working and class can not proceed. Fumbles are short term interruptions which break the flow of the class. The cost of breakdowns is a loss of instructional time, while the cost of fumbles is to draw attention to the technology and distract the class from course content. Delays at the start of class because of difficulty in set up can be considered as a type of a breakdown. A fact of academic life is that breaks between classes are very short. To ensure that setup is done in a timely manner, it is necessary to plan out how the setup will be done, and possibly arrange for assistance. In-class breakdowns depend on the complexity of the setup and maturity of the system. A few breakdowns and disruptions will be tolerated by students, but regular failures that disrupt the course will be noticed. In the worst case, the instructor must be willing to fall back and use a different technology.

One of the keys is to gain familiarity with the technology before the start of the course. It is important to run practice sessions which are the *full* length of a class and not just a few minutes, since there are some problems that appear only after an extended period of time, for example, a screen saver may come on or the machine may go into a power save mode. (A particularly embarrassing failure occurred with a password protected screen saver and an unknown password). It is necessary to practice the set up procedure a number of times, and understand the range of things that can go wrong. Advance experience with the presentation device (such as a Tablet PC) is also important in order to be able to recover from unexpected events and to avoid various fumbles. For instance, Tablet PCs generally allow the screen to be in landscape mode or portrait mode. Once, one of the the authors accidentally rotated from landscape to portrait mode by hitting a button on the side of the Tablet PC, and did not know how to rotate it back (causing the image to be displayed sideways on the public display). Other Tablet PC related problems that have been observed in class include hovering pens triggering unforeseen actions and background processes interpreting pen motions as gestures. On some convertible Tablet PCs, changing from laptop configuration to slate configuration can have unexpected side effects such as changing the screen orientation or altering power settings. One issue to mention (which is not Tablet PC specific) is to ensure that there is an adequate battery or access to power and an adapter cord available. Finally, more than once we have heard of instructors forgetting the Tablet PC pen. One option is to anchor the pen to the Tablet PC; another is to purchase an extra pen.

6. ENGAGE THE AUDIENCE

A risk inherent in using new technology in the classroom is that the technology becomes a distraction rather than a complement. Recovering from breakdowns quickly and becoming familiar with the technology is one aspect of addressing this problem, but another is for the instructor to consciously maintain focus on the audience. In particular, when delivering a lecture from a pen based computer there is a temptation to look at the computer instead of the audience. The problem is not specific to this technology — it is common to see instructors talking to the blackboard, or to the PowerPoint slides on the laptop. However, we have observed this as a common issue in lecturing from the Tablet PC, and the form factor of the device exacerbates the problem. If the tablet is lying flat, the viewing angle is much greater than for a laptop, so the eye gaze problem can be worse. Direct manipulation of the screen also can contribute to the instructor not looking at the audience. The best practice is to conscientiously look at the audience, and be aware of the risk of focusing on the Tablet. Another action that can help is to periodically move away from the Tablet. Some instructors use a style where lecturing from the Tablet is intermixed with pointing at the screen.

One opportunity that this technology may provide is to allow the instructor to be mobile while lecturing. For instance, some configurations allow the instructor to hold the Tablet PC while it is connected wirelessly to the projector. Some instructors take advantage of this to move around in the class. One nice example of how this can be used to increase student engagement is when instructors take the Tablet PC into the audience in the style of a TV talk show host and allow students to write directly on the Tablet PC.

7. CONCLUSIONS

Good teaching is not about technology, it is about interacting with and conveying information to an audience. Presentation technology plays a supporting role in this, but should not get in the way. As a growing number of computer science instructors begins experimenting with systems that support slides and digital ink, we hope to aid these new users by reporting the results of our extensive observation of use of these systems. In this paper we have outlined a number of best practices for the use of digital ink in lecture in the hope that these guidelines will help new users avoid the most common pitfalls and alert them to the pedagogical possibilities available with these systems.

8. REFERENCES

[1] G. D. Abowd. Classroom 2000: an experiment with the instrumentation of a living educational environment. *IBM Systems Journal*, 38(4):508–530, 1999.

[2] R. Anderson, R. Anderson, B. Simon, S. A. Wolfman, T. VanDeGrift, and K. Yasuhara. Experiences with a Tablet PC based lecture presentation system. In *SIGCSE'04*, pages 56–60, 2004.

[3] D. Berque, T. Bonewrite, and M. Whitesell. Using pen-based computers across the computer science curriculum. In *SIGCSE'04*, pages 61–65, 2004.

[4] D. A. Bligh. *What's the use of lectures?* Jossey-Bass Publishers, San Francisco, CA, USA, 2000.

[5] W. L. Heward. Guided notes — improving the effectiveness of your lectures. *Tomorrow's Professor*, 495, June 2003.

[6] W. J. McKeachie. *Teaching Tips: Strategies, Research, and Theory for College and University Teachers.* Houghton Mifflin, 10th edition, 1999.

[7] C. Peiper, E. Chan, R. Campbell, J. Bresler, and J. Al-Muhtad. Expanding education through active space collabortion. In *Workshop on Pervasive Computing Education, PerEd'04*, 2004.