Personalizing the Capture of Public Experiences

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ABSTRACT
In this paper, we describe our work on developing a system to support the personalization of a captured public experience. Specifically, we are interested in providing students with the ability to personalize the capture of the lecture experiences as part of the Classroom 2000 project. We discuss the issues and challenges involved in designing a system that performs live integration of personal streams of information with multiple other streams of information made available to it through an environment designed to capture public information.

KEYWORDS: Ubiquitous computing, capture and access application, personalization, pen-based note-taking, educational application.

INTRODUCTION
Automated capture of live experiences for later access is a general theme in ubiquitous computing research. Most approaches to the problem focus capture exclusively on either the shared public experience or just the private experience of an individual within a group setting. For an individual, the memory to preserve for later review is characterized as a personalization of the public experience. In this paper, we investigate the challenges of supporting the synergy between public and personal experiences through the individual personalization of a live group experience.

To focus the investigation of this problem, we will look at the classroom lecture setting. We have built up significant experience in the capture and access problem for this domain through the Classroom 2000 project. The Classroom 2000 project is an experiment in the application of ubiquitous computing technology to education. We have created an environment that captures much of the details of a live university lecture and automatically provides Web-accessible multimedia-augmented notes that weave together the different captured streams of information in a form that supports student and teacher review. More information on the history of the project is contained elsewhere [1]. Before launching into a discussion of the issues and solutions for effective personalization of the public captured experience in the classroom, it is important that we motivate why this feature would be useful in practice.

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Motivating Personalized Capture in Classroom 2000
The Classroom 2000 project has undergone an interesting evolution with respect to personalized and public capture. Initially, we provided students with pen-based computers for personal note-taking; after each lecture, the personal notes were automatically linked with a shared audio recording of the lecture [3]. In addition, the lecturer's public presentation, done on an electronic whiteboard, was also captured and linked with the audio. This initial attempt failed for two reasons:

- The student devices were unsuitable in terms of performance, resolution and network connectivity.
- Students who took personalized electronic notes tended to copy exactly what the instructor wrote on the electronic whiteboard, despite knowing that that information was already being captured. We will return to this point at the end of the paper when we discuss evaluation.

This last point is particularly important. The most positive reactions from students to the overall value of capture came from those students who did not ever use the personal note-taker, and the least positive reaction came from those who used the personal note-taker every lecture. This observation is consistent with Grudin's commentary that in groupware systems it is important to understand who does the work and who gets the benefit [11]. The value of having personalized notes did not outweigh the effort involved in using the student note-taking devices. This is especially true when the personalized notes tended to be exact replicas

of the instructor's notes, which would be publicly available after class for all participants. For those students who chose not to capture personalized electronic notes, the end benefit was the same as those who did: they still had a copy of the instructor's notes, and with less effort.

In reaction to this failure, we scaled back our capture goals, focusing exclusively on the capture of public information—information that is seen or heard by all in the classroom. Currently, this public information consists of presentation slides with instructor annotations, Web pages viewed during class and the recorded audio and video. Extended use of the capture system over the past two and a half years has provided us with a deeper understanding of the perceived value of the capture service for the intended audience of teachers and students. There are now two reasons that justify re-introduction of personalized capture in the classroom —student demand and a desire to promote a better form of class engagement.

From surveys of students who used Classroom 2000 for at least one 10-week term, we have a clear indication that the students would like to have their own notes, currently taken on paper, more tightly integrated with the public captured notes. In an open-ended question asking students to name the single feature they would like added to Classroom 2000 many indicated a desire for student note-taking devices. When asked explicitly, 62% (of 239 respondents) either strongly agreed or agreed (32% were neutral) with the statement that the value of the captured lecture notes would increase if their personal notes were included. These results provide a motivation for providing students with a way to electronically capture and integrate their personal notes with the public captured notes.

The reason to support more tightly live integration and personalization of capture is to encourage a better form of engagement in class activity. 71% (of 353 respondents) indicated that the capture made the class more engaging and 61% (of 308 respondents) indicated that the capture allowed them to pay better attention. These results are encouraging. When asked about the changes to their note-taking practices, 31% (of 320 respondents) indicated that they took fewer and 24% took no notes at all in classes that were captured. On the surface, this also seems like a positive effect, except that a number of students admitted that taking no notes sometimes meant that the mind would wander during lecture. Others admitted that though they value taking their own summary notes, in captured lectures their own notes are less valuable compared to the public notes and so they take no notes at all.

Though we are explicit in our desire to reduce the need to copy notes off the board, taking notes in some form increases the likelihood that some individual processing of the lecture information is occurring and we want to encourage that. We hypothesize that tools to personalize the lecture in the form of well-integrated student notes will encourage more active engagement in the class material. It is a research goal of this work to be able to test that hypothesis. Before we can do that, however, there are some research issues to address in providing appropriate personalized capture and access capabilities within the public setting. This paper will address those issues and make the solutions concrete with respect to the classroom application.

Overview of Paper

We begin with a brief review of previous capture and access work as it relates to the personalization of public experiences. To support the live integration of public and personal streams, we built a Java-based client-server system, called StuPad, to leverage off the existing infrastructure that existed in Classroom 2000. As we investigated the "correct" system to provide to the students, we encountered many different issues related to capture and access that were specific to the building of StuPad for the classroom setting, but yet are generalizable to the area of supporting personalization of the capture of any public experiences. We will discuss the specific decisions made for StuPad and address the more general questions uncovered. We provide some preliminary evidence investigating how personalized capture affects note-taking behavior. We conclude with some discussion of future directions in this area.

RELATED WORK

What is actually being captured is an important distinction among capture/access applications. The captured information or activity can be viewed as a series of streams that are either public or personal. Public streams represent information and activities that are seen by all participants in the live experience *at the time of capture*. Public streams are assumed to be available to at least all of the attendees at the live experience (during the capture phase). Personal streams represent information and activities that are being viewed or created during capture by only one person and are not intended for public viewing during later access. The distinction between public and personal actually defines a continuum which would allow for levels of collaborative experiences that are shared by some subset of individuals both during the live experience and afterwards during access.

Public Capture Systems

Support for the automated capture of a meeting or a lecture is a common goal for public capture systems. The classroom lends itself nicely for research into capture and access. Systems in this area capture with various degrees of automation significant streams of information present in the classroom. Commonly captured streams include a slideshow presentation, audio, ink written on an electronic whiteboard, visited Web pages, or arbitrary program executions. Examples of these systems include work on Classroom 2000 [1, 2, 3], MANIC [15], AutoAuditorium [5], STREAMS [7], and Authoring on the Fly [4, 6].

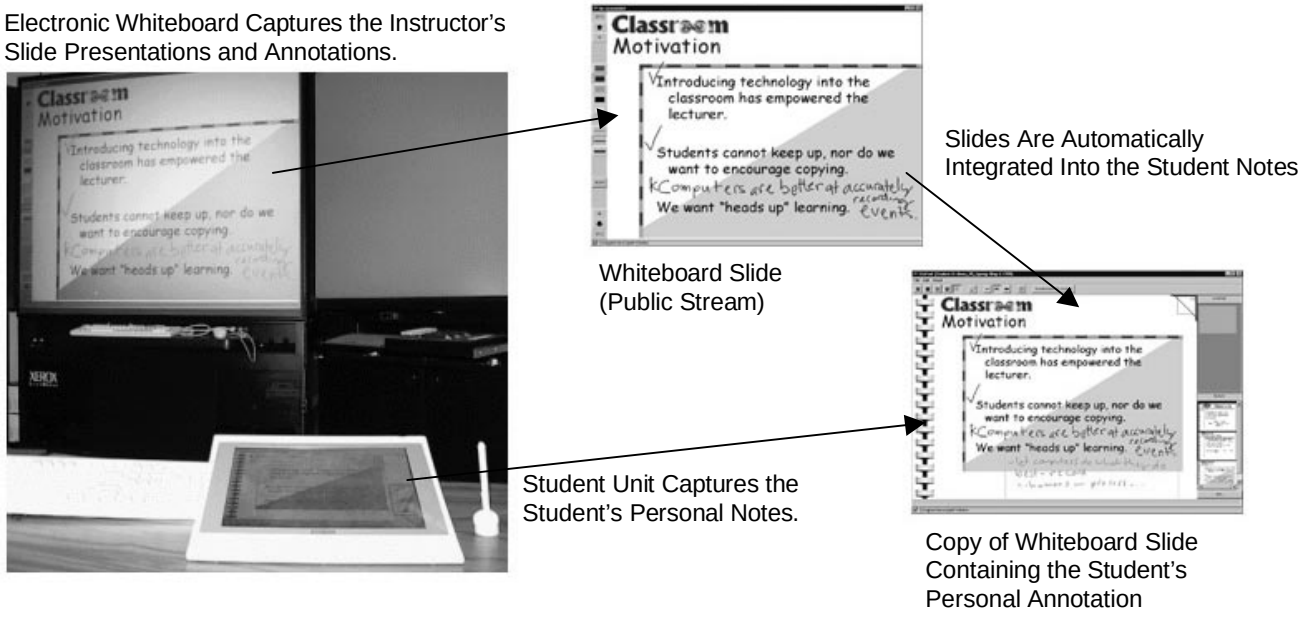

Figure 1: The StuPad system as used in classrooms already supporting the public capture of the Classroom 2000 system.

Private Capture Systems

While considerable research effort has focused on the capture of public streams, other work has focused on capturing personal streams of information, most notably, handwritten notes. Examples of systems that record personal streams, usually along with the audio of the meeting, include Audio Notebook [16], Dynomite [21], Xcapture[9], and FiloChat [20].

Collaborative Capture Systems

Systems that provide collaborative capture usually involve a shared, sometimes distributed, public surface upon which a group of individuals may place artifacts, such as with a shared whiteboard. Examples of this class of system are We-Met [22], DOLPHIN [17], Tivoli [12]. An interesting collaborative access system is NotePals, in which individuals take separate notes during a meeting and those notes are then merged during the access phase with the separately captured public presentation [8].

While existing research has covered most aspects of capturing and accessing public and private streams, no system has concentrated on the integration of public streams with private streams *during the capture phase*. StuPad was built to examine this integration because it is believed this will aid in the personalized capture task of note-taking during a classroom lecture. We will now address in detail some of the design challenges in producing an effective integrated capture environment for personalizing capture within a public experience.

SEPARATING CAPTURE AND ACCESS

We separated the design problem into two phases, capture and access, because users perform different tasks with different physical interfaces in those distinct phases.

In the classroom setting (the capture phase), students record their personal experience in the form of handwritten notes.[1] After class (the access phase), students review the lecture experience by skimming through their notes (which includes personalization of the public notes), revising them, and, in the case of Classroom 2000, using them to index into specific points in the lecture experience for further review of audio or video. A capture interface needs to maximize personal annotation capabilities whereas an access interface should mainly support rapid browsing and cross-referencing through traversal of indexes.

We must also consider the physical interfaces available to students inside and outside the classroom. Inside the classroom, we control what devices are available for students to use; therefore, we are able to design StuPad to run on networked computers attached to pen-based video display tablets, as shown in Figure 1. Outside the classroom, where it is not possible to assume that all students will have a particular kind of input device and display, StuPad is designed to run on networked computers with the more traditional keyboard/mouse interface.

[1] Initially, we are explicitly excluding typed notes in the classroom. Though we may ultimately provide this form of input, it still does not remove the desire to have pen-based interaction.

STUDYING THE CAPTURE PHASE

StuPad in the capture phase, StuCapture (shown in Figure 2) provides students with an interface that supports the live integration of public and personal streams of activity. We sought a reasonable complement of familiar paper-like functionality augmented by useful electronic functions. To allow students to personalize the public lecture experience we needed to:

- determine which public streams to make available to the students and decide how students would distinguish between the streams and manipulate or personalize them;
- allow students to dictate the pace of interaction without interrupting the lecture's natural flow; and
- resolve competition between public and personal annotations on a shared capture surface.

We will briefly describe the StuCapture interface before addressing these issues.

How the Capture Interface Works

The student's capture interface (Figure 2) contains separate sections for private note pages that the student alone controls, copies of whiteboard slides that the instructor is presenting (including the instructor's annotations) that the student can annotate, and Web pages that have been traversed by the instructor during class. Overviews of each section are provided on the right in the form of custom-built navigation bars for the private notes, whiteboard slides, and Web page history. Dynamically updated thumbnail images of private notes and whiteboard slides provide a quick overview of lecture activity. Tapping on a thumbnail of a page will load that page into the main canvas area in the center of the screen, where students can add personal annotations to a page of notes. In the main canvas, the pen allows for digital ink annotations and simple navigation through "flicking" motions in the top-right corner (to advance a page) and along the left-hand binding (to go back a page). The Web navigation bar lists URLs visited by the instructor. Tapping on a URL will open a separate browser window to view (and navigate from) that Web page.

Making Public Streams Available to the Individual

The instructor's whiteboard slides, annotations and Web pages visited are public streams that are incorporated into the student capture interface. When designing the capture system, we had to determine which of the public streams to make available to students, how the streams are distinguished, and how students should be allowed to manipulate those streams. Figure 2 shows how three main sections of the student interface allow for easy distinction and switching between three streams, a private notebook, a combined personal/public lecture stream and a browsable Web stream.

As students are provided with public streams that can be manipulated, there is the danger of modifying the public

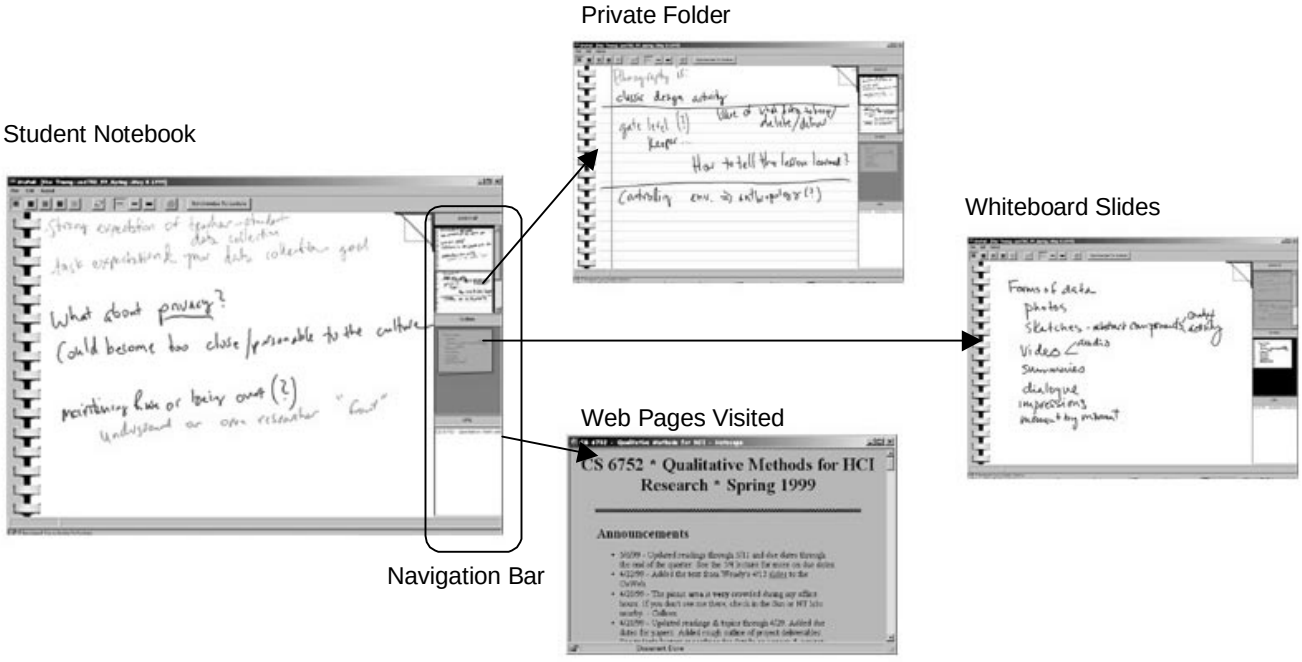

Figure 2: The StuPad Capture (StuCapture) interface.

content so much that it no longer reflects what actually happened in class. For this reason of preserving the public record, we decided to allow students only the capability of adding annotations to the whiteboard slides with instructor annotations already on them. Students could not delete slides or instructor annotations. Similarly, URLs visited could not be removed from the Web stream, though students could freely browse using the public URL stream as launching points.

These specific design decisions can be generalized to suit other situations. The capture phase consists of collections of streams. For each stream, there may be one or more sources for the stream, such as the whiteboard slide, instructor annotations and personal annotations in the lecture stream of StuCapture. If at least one source for a stream is public, then limited manipulation is allowed. When all sources for a stream are personal, the individual can be granted unlimited privileges to create and destroy information. Implementing this simple policy allows the individual to personalize a captured stream without necessarily destroying the true capture history.

Supporting the Individual's Pace

Once we provide the individual multiple streams to interact with, some of which reflect other activity the individual cannot control, we need to think about ways to maintain the individual's interaction freedom and control of pace. StuCapture provides a panel of collapsible navigation bars so students can quickly navigate between streams and within a stream. Additionally, the navigation bars provide a history of all the information that has been captured up to that point in time.

Students do not have to capture notes on the same page as the instructor. Furthermore, if they only take notes on the same page as the instructor's slide, then they can dismiss all the thumbnail panels besides the one for the whiteboard slides. Similarly, if students only take notes on blank sheets of paper, they can dismiss all panels except for the personal stream. This feature was designed to support the note-taking habits of different types of students. StuCapture knows the state of the public lecture. The page the student is writing on has a green box around its thumbnail, and a red box is placed around the slide the instructor is presenting at the front of the room. This form of visual cue provides students with a way of quickly being able to judge where they are with respect to where the instructor. Additionally, students can easily "catch up" and stay with the lecture by tapping on a synchronization button. This simple synchronization feature frees the student from having to follow at the same pace as the lecture. The synchronization is broken by any student activity that occurs off the current lecture page.

Resolving Competition between Public and Personal

When students choose to add personal annotations on the same slide as the instructor's slide, two sets of annotations compete to populate the same capture surface. This brings up a space issue —how can we provide enough room for all of a student's notes, especially if the lecture slide is dense with prepared material or additional lecture annotations? Furthermore, while the students know where the instructor has written, they have no knowledge of where the instructor will next write. Nor does the instructor know where the students have written (because that is personal information). As a result, it is possible for the instructor to overwrite an area where a student has added his/her annotations to a slide. These two problems together create a competition that exists between the sets of public and personal annotations for space/area on a capture surface

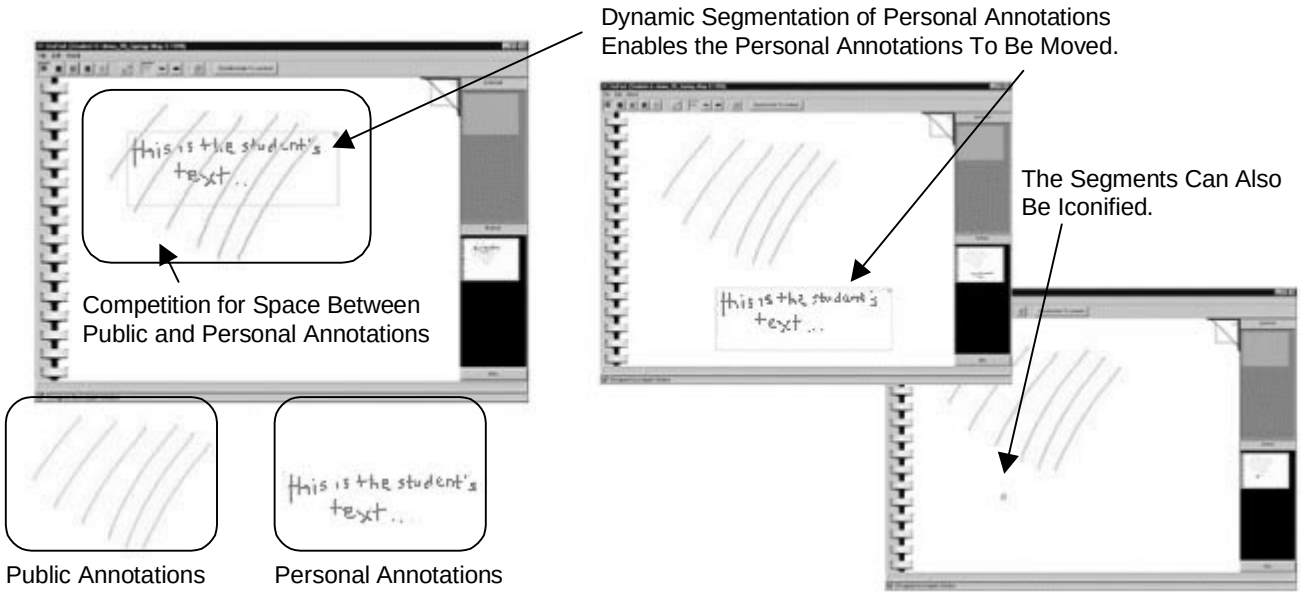

Figure 3: Resolving Competition For Space Between Public and Personal Information.

(the slide). There are a number of possible solutions, all of which are possible in StuCapture.

- One simple way of resolving this issue is for students to disallow annotation of the whiteboard slides. This removes all competition for capture real estate, and is a strategy that can be adopted by any user of the StuCapture interface. However, there is a cost to this strategy, and that is the risk of losing the context of a comment. We frequently rely on collocation of personal notes beside public information to make the note-taking more efficient. When notes are written on completely independent surfaces, there is a tendency to revert to copying.

- We can provide additional personal space on the individual's view of the public stream, similar to a margin, where the lecturer's annotations cannot reach. We can adopt a collapsing or scaling strategy of the public information that would enlarge the personal margin space.

- Finally, we chose to segment annotations so that student notes are clustered together. This would allow either the automatic or manual repositioning and even collapsing of personal annotations (see Figure 3).

STUDYING THE ACCESS PHASE

StuPad in the access phase, StuAccess provides students with an interface to browse an integrated and synchronized view of all captured streams of information (see Figure 4). An effective access interface poses many challenges, including how to:

- synchronize all captured streams;

- support rapid browsing to find points of interest for further exploration;

- preserve the context of what was happening in the public setting as personalization occurred; and

- modify the captured record during review.

We will briefly describe how the access interface works before addressing these general design issues.

How the Access Interface Works

A timeline is the unifying mechanism for displaying and coordinating the replay of a lecture. As shown in Figure 4, two adjacent panels display the student's and the instructor's perspective on the lecture. At any given timepoint during the lecture, the left panel shows what was on the main canvas of the student's unit and the right panel shows what was on the instructor's electronic whiteboard at the front of the room. A "scrub" on the timeline at the bottom of the screen shows the time during the lecture. The scrub can be dragged back and forth to advance both panels, and any active audio or video stream (displayed using a RealPlayer™ module from RealNetworks). All handwritten annotations for a given page are drawn on the canvas areas in light gray until the lecture time passes the time at which they were created and then they are redrawn in their actual color. Web pages visited during class are shown in a separate panel as a list; clicking on a URL opens up a separate browser window displaying that URL.

These captured streams and additional media augmentation (audio/video) are associated so that by toggling the "Play"

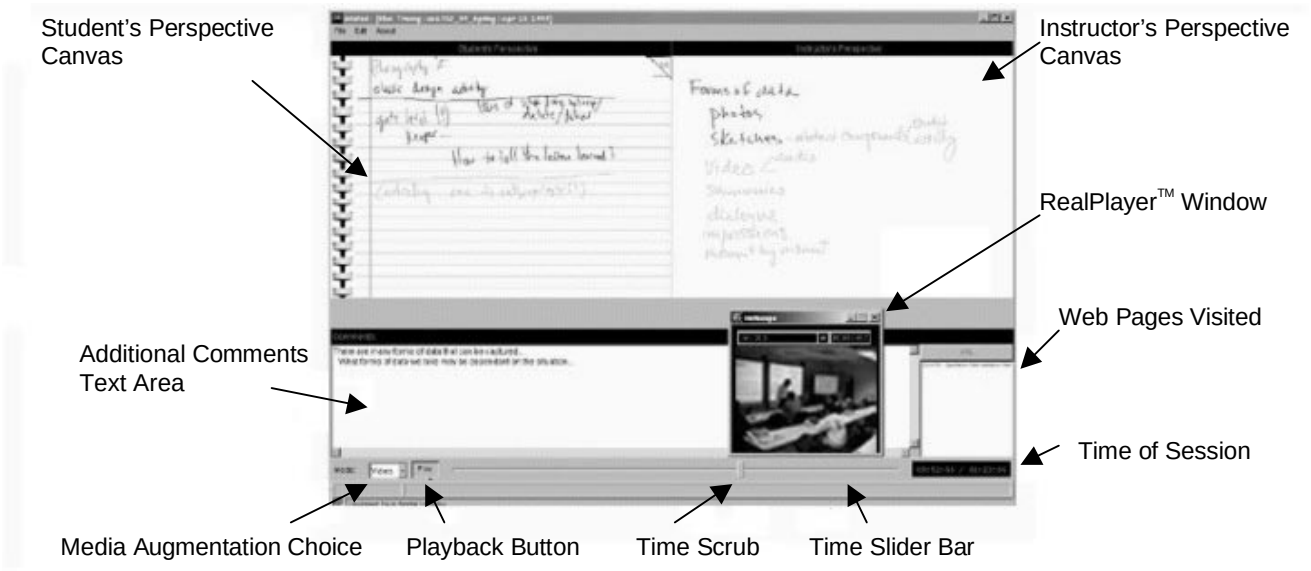

Figure 4: The StuPad Access (StuAccess) interface.

button, all the captured streams are played back in real time, synchronized to one another. Students can add additional comments to their notes for that lecture in a textbox provided near the bottom of the screen.

Synchronization

By time-stamping events during the capture phase, it is possible to reconstruct a history of what happened during the live lecture experience. The student can playback all streams of the lecture in real time from any part of the lecture. The integration of public streams with the personal streams makes the synchronization task harder, as we must check to see which streams were actually captured at any given timepoint. For example, it is possible that audio/video were not captured for a particular lecture and therefore synchronization to that stream is not necessary. It might be the case that the student arrived late for class and only started taking notes some minutes after the public lecture commenced. The issues here are not only reconstructing or playing back valid streams, but also allowing the student to visualize which streams are active and when.

Support for Rapid Browsing

Individuals usually do not want to replay an entire experience, especially if they were in attendance during the live event. Therefore, it is necessary to support the task of rapid browsing to locate points of interest and starting points for limited playback. With an increasing number of captured streams, there is a lot of information to search through to find any point of interest. Thus the issue here is to allow users to be able to quickly skim through the captured data to approximately locate the points of interest. Once that has been accomplished, the system should also allow the user to get at the exact point in time of each point of interest.

To support a quick skimming action, a time slider bar is placed at the bottom of the screen allowing the user to specify how far into a lecture to offset the time. So as a user drags the slider bar forward and backward in time, she sees the lecture streams flipping past quickly with annotations being drawn as well. Once the student finds the page that contains the point of interest, clicking on the handwritten ink (either the student's writing or the instructor's) will force the system to synchronize all lecture streams to the exact point into the lecture when that ink stroke was created.

The access interface does more than provide playback. There is a limited but effective foreshadowing feature. When viewing a particular slide from a lecture that has annotations written on it, all annotations that exist once the lecture is complete are faintly drawn on the access panels. This allows the user to quickly see all of the future content of a slide. This future context better supports the task of accessing particular points in the lecture.

Maintaining Context

Because we allow the student a lot of freedom to navigate during the capture phase, it is easy to have the student's personal notes fall out of context with what is happening publicly. For example, a student could be completing some personal annotations on the instructor's third slide even after the instructor has moved on to the fourth slide. As the instructor is presenting the fourth slide, (s)he will most likely be talking about the content of that fourth slide. Thus when the student reviews the personal notes, the audio that is associated to his/her personal notes is not necessarily related to the notes. To preserve some of the context of what was happening publicly, StuAccess renders not only the student's perspective of what was happening during class, it also includes the instructor's perspective, specifically the main electronic whiteboard. So while the student's perspective panel renders the student's personal notes on the third slide, the instructor's perspective would render the fourth slide.

Modification During Access

Since it is often hard to capture everything during the live experience (the pace might be too fast), it is often necessary to add additional information into one's notes afterwards. The accessing of the notes typically occur in an environment outside of the classroom, where we cannot assume that students will have the same physical devices that they used as they captured their notes inside the classroom. Furthermore, notes entered after a live event tend to be more summative and may not be easily associated to any particular point in the captured notes. Thus StuAccess, therefore, provides a separate region where students can type in additional commentary that is associated to the entire lecture as a whole.

This information produced after the live capture phase is not timestamped and does not provide any indexing into the captured experience. It will be the subject of further research to demonstrate effective ways to timestamp access phase activities or otherwise associate access phase activities to prior or future captured activity.

PRELIMINARY EVALUATION

The previous sections discussed some general research issues for capture and access when we attempt to personalize the capture in a public setting. These issues were discussed in the context of the specific application of student note-taking during lectures. Recall from the introduction that we have clear motivation for providing personalized capture in the classroom setting. Our stated hypothesis of this research is that personalized capture will provide for a more effective engagement on the part of the students during lectures. One downside of the exclusive capture of public lecture information is that some students take no notes at all and admit that the mind has a tendency to wander. We have used StuPad in a handful of classes for the past two months, and though it is still too early to establish whether engagement is improved, we can begin to

operationalize this definition of engagement and present some preliminary results based on actual use.

A crude measure we can use is to observe note-taking trends. As we mentioned earlier, in our initial attempts to provide personalized capture, student notes looked very similar to the instructor's notes. Figure 5 demonstrates this observation. The left column shows captured student notes and the right column shows the corresponding instructor notes. Annotations in the left column were written by a student, since there was no live integration of public and personal streams in that version of the student note-taking system. Note the close correspondence with what the instructor wrote in the right column. In Figure 6, we see the same comparison of student versus instructor notes when the StuPad system was used. Now, with live integration of public and personal streams, any differences between the two columns reflect what additional note-taking the student performed.

What we see in Figure 6 is promising. Student notes contain more content than the lecturer notes and reflect student engagement in lecture material. The student did not need to copy what was already written by the instructor and could focus on adding relevant personal interpretation. These results also confirm our suspicions on problems of

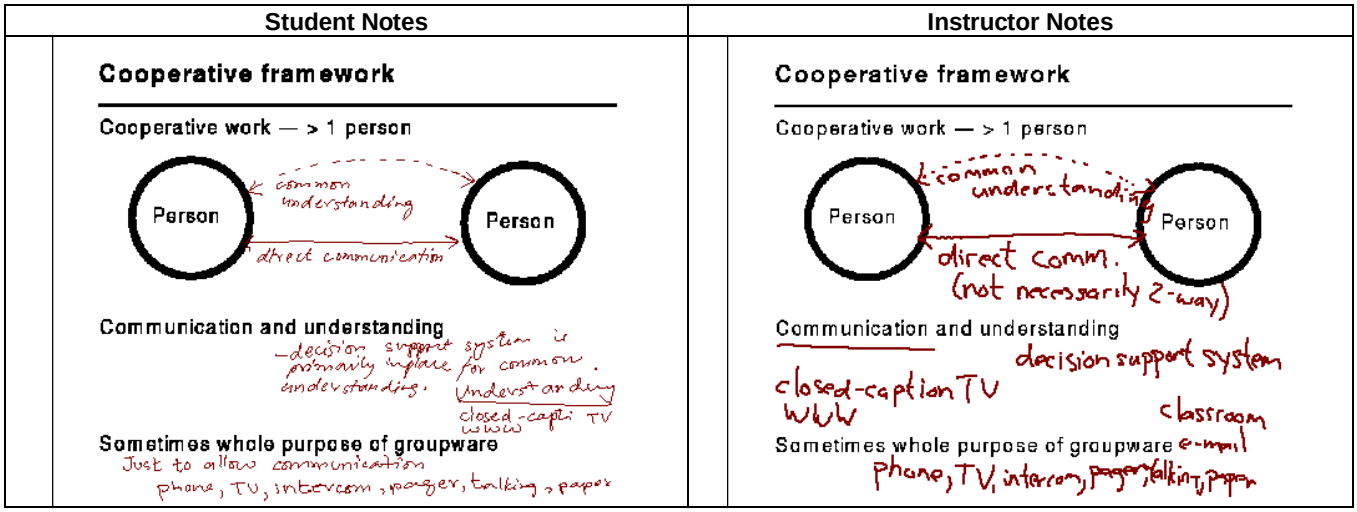

Figure 5: A comparison of student notes (left column) to instructor notes (right column) in the first attempt to add student capture shows the student notes tend to be exact copies of what the instructor writes on his/her slides.

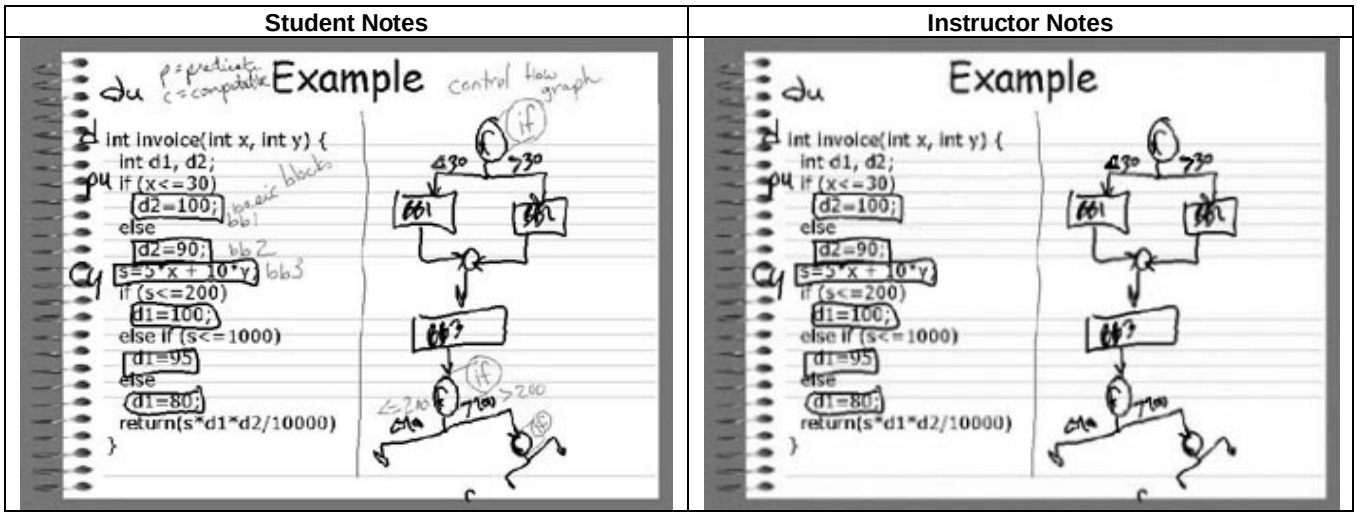

Figure 6: A comparison of student notes (left column) to instructor notes (right column) with the StuPad system shows that by providing the integration of the instructor's captured notes, students have the opportunity to take summary type notes that capture the essence of the lecture discussion.

annotation space. When the instructor presents a dense slide or annotates a slide a lot, less room is available for the student. Prior to having implemented a segmenting strategy discussed above, several students complained about the lecturer's annotations "stepping on" their own notes.

Further evaluation will be conducted to study the effectiveness and usefulness of the StuPad system in enabling students to personalize the lecture experience. The effectiveness of this particular system will continue to be measured through the notes created by the students; where experts will determine if the personal notes created have added value. The usefulness of the system will be measured by the students' repeated usage of the system; if students perceive value in having used the system, then they will continue to use the system over time.

CONCLUSIONS AND FUTURE WORK

Initial results of StuPad have shown that by enabling live integration of public streams of information, students are able to capture notes that are personally meaningful and summarizes the points being made in the lecture. This integration, however, leads to some capture and access issues that were not previously addressed in systems that either only captured public or personal streams of information. StuPad is a system used in real everyday situation in which we have explored some solutions to those issues.

We have not addressed the issues involved allowing the user to add timestamped information during the access phase. In such situations, the issue involves determining whether the user wants to insert absolute time stamps (what information added should be given the time stamp of when it was created) or if it should be relative to the duration of time into the session being reviewed. Furthermore how should access to previously captured sessions during a capture session be addressed. The challenge is to understand the user's implied intent and is the subject our future work, which will be reported on later.

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