

Note-Taker 2.0: The Next Step Toward Enabling Students who are Legally Blind to Take Notes in Class

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ABSTRACT

In-class note-taking is a vital learning activity in secondary and post-secondary classrooms. The process of note-taking helps students stay focused on the instruction, forces them to cognitively process what is being presented, and better retain what has been taught, even if they never refer to their notes after the class. However, note-taking is difficult for students with low vision, or who are legally blind for two reasons. First, they are less able to see what is being presented at the front of the room, and second, they must repeatedly switch between the far-sight task of viewing the front of the room, and the near-sight task of taking notes. This paper describes ongoing research aimed at developing a portable assistive device (called the Note-Taker) that a student can take to class, to assist in the process of taking notes. It describes the principles that have guided the development of the proof-of-concept Note-Taker prototype and the Note-Taker 2.0 prototype. Initial testing of those prototypes has been encouraging, but some significant problems remain to be solved. Proposed solutions are currently being implemented, and appear to be effective. If ongoing usability testing confirms their effectiveness, they will be implemented on the planned Note-Taker 3.0 prototype.

Categories and Subject Descriptors

H.1.2 [Models and Principles] User/Machine Systems; I.4.1 [Image Processing and Computer Vision] Digitization and Image Capture K.3.1 [Computers in Education] Computer Uses in Education

General Terms

Design, Experimentation, Human Factors

Keywords

Note-Taker, note-taking, lecture notes, legal blindness, low vision

1. INTRODUCTION

Note-taking is a vital factor in the process of secondary and post-secondary education. The act of note-taking forces a student to mentally assimilate what is being presented in the classroom in order to extract and record new information being

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ASSETS'10, October 25 - 27, 2010, Orlando, Florida, USA.

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presented [1] [2]. As a consequence of this active process, students retain information better, even if they never subsequently review their notes [3].

During the process of note-taking, students rapidly switch between a near-sight task (such as viewing and writing notes), and a far-sight task (such as viewing a distant board or PowerPoint slide). Fully-sighted students need only glance up and down to switch instantaneously. In contrast, students with low-vision, or who are legally blind, may require magnification for one or both of these tasks.

For a detailed discussion of the types of assistive technologies available to low-vision students, we refer the interested reader to our previous work [4]. The following is a high-level summary. Assistive technologies that provide magnification for near-sight tasks include handheld and desktop magnifiers, CCTVs, and screen magnification software. Assistive technologies that provide magnification for far-sight tasks include handheld and head-mounted monoculars [5] as well as some head-mounted camera systems. A select few camera-based systems provide magnification for both near and far-sight tasks but are slow in transitioning between the two [6]. They also either (1) require a setup that is not realistically portable, or (2) require users to wear a pair of goggles, which may obstruct social interactions between the wearer and their professor or peers.

Unfortunately, currently available assistive technologies typically provide magnification for either near-sight tasks, or far-sight tasks – but not both. So, when using these assistive technologies, low-vision users spend a significant amount of their note-taking time switching between a near-sight and a far-sight task. We call the time spent switching between viewing the board, viewing the notes, and then viewing the board again the *Board-Note-Board* (BNB) delay

Constant BNB delays can prevent low-vision students from taking notes fast enough to keep up with fast-paced class presentations. Science, Technology, Engineering and Math (STEM) classes present a particular challenge, due to their use of mathematical notation and diagrams, which preclude the use of typing to take notes.

Alternatives to note-taking exist, but they are not ideal. In the United States, the Americans with Disabilities Act mandates that universities supply low-vision students with a copy of classroom notes [7]. To satisfy this mandate, universities pay other students to make copies of their notes after each class. Some classrooms are equipped with lecture recording systems, where lecture material is recorded through classroom-installed cameras [8] or digital whiteboards [9] [10]. However, these alternatives to note-taking do not engage students with visual disabilities in the cognitive process of classroom note-taking. Indeed, they raise

the question of why the student should attend class at all. They also make the student dependent upon other people or technologies over which they have no control – technologies that are not likely to be available in other learning venues, such as conferences or meetings.

2. Design Principles

Given the importance of note-taking to secondary and post-secondary education, a much more satisfactory solution to this problem is to equip students with their own portable device that (1) gives them access to classroom presentations, and (2) facilitates the process of classroom note-taking. To guide our own research toward this end, we have developed the following principles:

1. The solution should not rely upon the presence of previously installed equipment in the classroom.
2. The solution should not make users dependent on others (including other students, the lecturer, or a member of the technical staff).
3. The solution should not interfere with their interactions with lecturers and peers, as might be the case with an obtrusive, head-mounted camera system.
4. The solution should not require lecturers to change their presentations in any way. Ideally, lecturers should not even need to be aware that a special solution is being employed.
5. The solution should not disrupt the classroom environment. For example, it should not obstruct the views of other students, and it should not be noisy.
6. The solution should not be significantly more expensive than other types of assistive technology. This sets a ceiling cost of \$3000.
7. The solution should provide users with real-time access to all aspects of the classroom presentation, including the lecturer, the chalkboard/whiteboard, and any projected images.
8. The solution should be portable, should not take more than a couple of minutes to set up, and should fit within the footprint of a student's classroom desk or table.
9. In accordance with our BATE (Beyond Accessibility To Efficiency) principle, the solution should allow users to access information during class as readily as sighted students. In other words, users should not be required to spend extra time outside of class listening to recorded lectures, in order to learn the same information that fully sighted students can absorb during class.

3. The Proof-of-Concept Note-Taker

Figure 1 shows an early proof-of-concept prototype of a device that we call the *Note-Taker*. It was comprised of a 13-inch Lenovo X61 Tablet PC with a 1280x768 screen, an off-the-shelf servo-operated pan/tilt mechanism (Eagletron PowerPod), and a consumer digital video camcorder (Sony TRV-22) with 10x optical zoom that could be remotely controlled (by the Tablet PC) through a LANC port. This entire Note-Taker system could be carried in a student backpack, and was battery-powered. Upon arriving in the classroom, the student clamped the pan/tilt mechanism to the desk, installed the video camera onto the pan/tilt mechanism, and connected both to the Tablet PC through USB cables.

As shown in Figure 2, the proof-of-concept Note-Taker user interface consisted of 3 windows: (1) a window that displayed 720x480, 30FPS live video from the camera, (2) a window that was used as a digital notepad, and (3) a small window that provided up/down/left/right/zoom controls for the pan/tilt mechanism that aimed the camera.

During lectures, the student viewed the live video of the front of the classroom in one window, and took notes by writing into the digital notepad window. The fact that both windows were on a single display surface allowed low-vision students to view both their notes and the board without a delay, and it obviated the need for a far-sight assistive device, such as a monocular.



Figure 1: The proof-of-concept Note-Taker in use

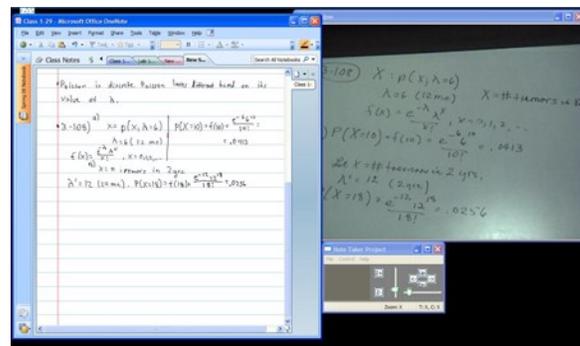


Figure 2: The Proof-of-Concept Note-Taker user interface

4. Usability studies with the proof-of-concept Note-Taker prototype

The proof-of-concept Note-Taker prototype was developed during the Summer and Fall of 2007, and was then used in a 3-month case study by a senior-level undergraduate (D) who is legally blind, during the Spring 2008 semester. Midway through that semester, a second prototype was constructed, and was provided to a sophomore-level undergraduate (M) who was also legally blind.

Despite the fact that D and M were both legally blind (i.e. they had visual acuities worse than 20/200) they were both able focus at very short distances. This allowed them to view the display surface of the Tablet PC from only a few inches away and handwrite their notes. So, the proof-of-concept Note-Taker served their needs fairly well.

D used the prototype for a total of 150 hours in the classroom and, aside from bugs, found the prototype to be very beneficial. One problem that D cited was that, when he panned the camera a significant distance to the left or right, the camera's aim would tend to droop downward, requiring an upward adjustment at the end of the pan. Another problem was the distraction of having to adjust the direction of the camera incrementally, using the up/down/left/right buttons on the touch-sensitive surface of the Tablet PC, which often required multiple increments. In addition, depending on the particular classroom situation, factors such as lighting, viewing angle, and poor contrast (particularly on dusty green chalkboards) made the boards difficult to read.

M used the prototype for one month. His evaluation was somewhat mixed. M was not accustomed to taking notes in the classroom. He indicated that he had usually found it too difficult to simultaneously take notes and keep up with the lecture through his monocular. M had relied on university-supplied note-takers, but was struggling with his courses – perhaps due to the lack of active note-taking.

Unlike D, M had no prior experience with using Tablet PCs and digital ink to take notes, and this made his use of the Note-Taker in the classroom more difficult. Although he felt that the *Note-Taker* had overall been more of a hindrance than a help during his one-month case study, he was still optimistic about its potential. He felt that his problems were due more to the interface learning curve than to the *Note-Taker* itself.

The four most important problems that M experienced when using the prototype Note-Taker in class were (1) using the up/down/left/right interface to aim the camera, (2) correcting for camera droop during panning which was particularly noticeable at high zoom, (3) organizing and managing the files created as he took notes in class, (4) lack of calibration between the tablet pen and the tablet surface. Despite these problems, M felt that the *Note-Taker* had allowed him to better appreciate the benefits of taking notes, and he felt that it would be useful if the problems listed above could be resolved.

5. The Note-Taker 2.0 Prototype

In 2009 (based on the preliminary work described above) the National Science Foundation awarded a grant to further develop the Note-Taker, and to perform further classroom usability testing. Based on the results of the early usability testing, CUBiC researchers at Arizona State University began to develop a second generation Note-Taker prototype to address the primary complaints voiced by users of the proof-of-concept prototype, and they began usability testing on that prototype.

5.1 The Note-Taker 2.0 Pan/Tilt/Zoom Camera

One complaint voiced during the usability testing of the proof-of-concept prototype was that, when a user panned the camera a significant distance to the left or right, the camera's aim would tend to droop downward, requiring an upward adjustment at the end of the pan. We concluded that this was an inherent problem with the low-cost, off-the-shelf pan/tilt mechanism that was used in the proof-of-concept prototype. With a lack of commercial alternatives, this problem could only be resolved by designing a custom pan/tilt mechanism for the Note-Taker.

The resulting Note-Taker 2.0 pan/tilt/zoom (PTZ) camera is shown in Figure 3. This prototype is a USB peripheral, and is considerably more rugged and precise, than the proof-of-concept prototype. It employs a Sony industrial video camera with 36x zoom, two titanium-gear servo motors, an internal USB hub,

and a lithium battery that provides more than 5 hours of operation per charge. Compared to the multiple physical connections required by the proof-of-concept camera prototype, this requires a single USB to mini-USB connection. Figure 4 shows it in use with a Tablet PC and Note-Taker software. A view of the front of the classroom is seen in the top half of the Tablet PC display, and the digital notepad is at the bottom.



Figure 3: The Note-Taker 2.0 PTZ Camera

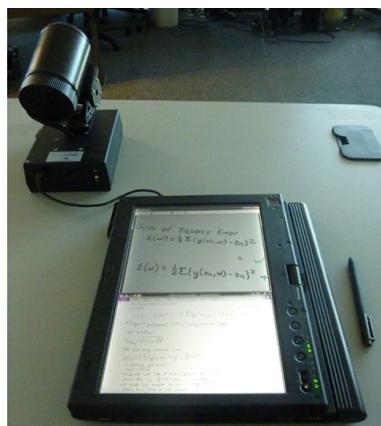


Figure 4: The Note-Taker 2.0 Prototype in Operation

5.2 The touch-driven camera control interface

Another complaint voiced during the usability testing of the proof-of-concept prototype was the distraction of having to incrementally adjust the aim of the camera, using the up/down/left/right buttons on the display surface of the Tablet PC, which often required multiple activations to move the camera to the desired position.

In response to this complaint, three methods have been developed for controlling the camera. The first method allows the student to center the camera view on any feature visible in the video window (such as the professor) by simply tapping that feature with their finger. The camera quickly centers on that feature, which then becomes the focal point for subsequent zooms. Alternatively, the user can touch any feature in the image and drag that feature to another location in the window. The camera will keep that feature under the user's finger by panning and tilting accordingly. Third, students can use multitouch pinch and unpinch gestures to make the camera zoom in or out, respectively.

5.3 Notes

The Note-Taker software allows users to take notes and view live video in a split-screen interface, in either a vertical or horizontal window tiling, depending on tablet orientation. This split-screen interface was fundamental to the Note-Taker's design. Normally, viewing notes is a near-sight task whereas viewing a distant whiteboard is a far-sight task. By providing users with a means of taking notes and viewing the board on the same screen, we have obviated the need for far-sight tasks.

5.4 File Management

Another complaint voiced during the usability testing of the proof-of-concept prototype was that there was no structured way to handle archiving and retrieval of class notes and related screenshots. Now, the software automatically archives all recorded material (notes, video, audio, screenshots) based on "note-taking sessions" which are categorized by class. A typical user might have 5 classes, each with 2-4 note-taking sessions per week. When they wish to review their notes, students can browse note-taking sessions by date and/or class.

5.5 Look-Back

Lecturers will sometimes occlude material on the board that students are trying to copy. To deal with this problem the Note-Taker extracts and caches one video frame per second over the previous 10 seconds. When the instructor obscures the board, the student can quickly "look back" through these cached frames to find one that was captured before the board content was occluded. When ready, the student can then resume with the live video.

5.6 Real-Time Image Processing

Users cannot be assumed to have complete control over the classroom environments in which they are taking notes. Factors that often affect visibility include low contrast caused by limited ambient lighting, poorly maintained chalk or whiteboards, low-quality image projection systems, or the use of colored chalk or markers. In addition to zoom, Note-Taker users can employ adaptive histogram equalization and color inversion to improve board visibility, as shown in Figure 5.

6. Usability testing of the Note-Taker 2.0 pan/tilt/zoom (PTZ) camera

The development of the Note-Taker 2.0 PTZ camera has largely been completed, and usability testing has recently begun. To date, three students (2 males and 1 female) have participated in the usability testing. Ages ranged from 21 to 33, and their majors were Chemistry, English, and Business. Two participants said that they took notes in 50% of their classes, and one took notes in 80% of his classes.

The purpose of this testing is to measure how effective this PTZ camera is in providing students who have visual disabilities with good visibility of the front of a classroom. The usability test is being conducted under controlled classroom conditions by two investigators.

The test instruments include the Note-Taker 2.0 PTZ camera, which is connected to a Tablet PC with a USB cable. Participants are asked to perform five tasks, aimed at determining how readily the camera affords them access to typical visual stimuli at the front of a simulated classroom. Since students with visual disabilities typically sit in the front row of their classes, the visual stimuli are placed ten feet in front of them during the testing. When authorized by the participant, a

video recorder and an audio recorder are used to record the interactions between the investigators and the participants during usability testing.

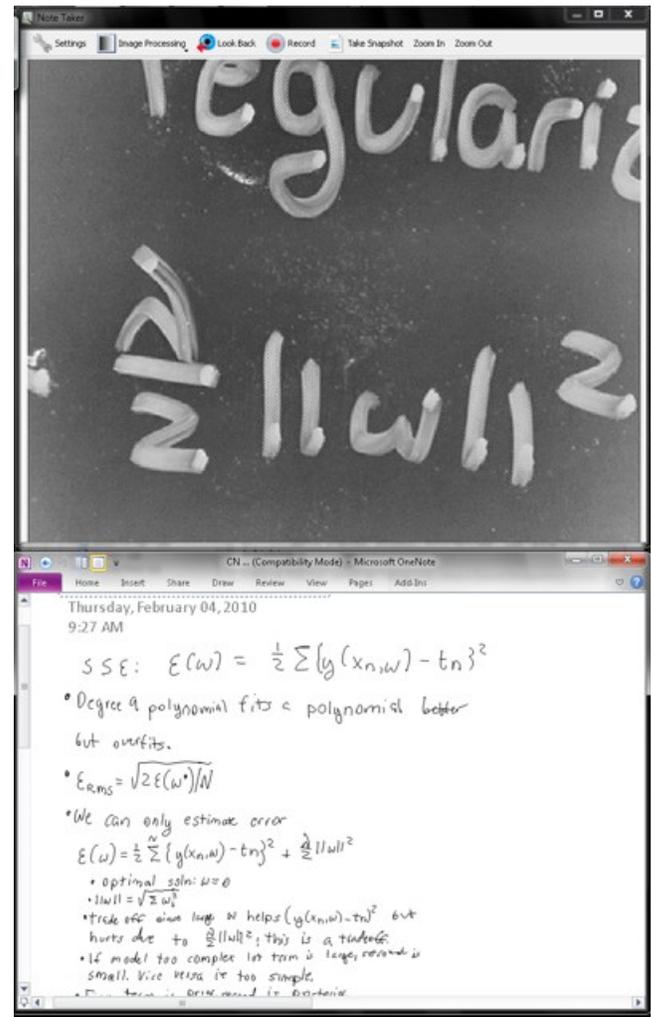


Figure 5. An example of histogram equalization and inversion

The entire usability test lasts about 40 minutes, including a pre-test survey, the five tasks, and a post-test survey. The pre-test survey is used to collect information about the participants' visual acuity, their note-taking habits, and their video watching habits. The post-test survey is used to collect their overall opinions about the usability and effectiveness of the PTZ camera.

The five tasks are designed to test the usability of the PTZ camera by challenging the participants to use it to view visual stimuli at the front of the room, which requires them to aim the camera and zoom it in and out. No time limits are imposed on the performance of the five tasks.

The participants are first shown how to use both the tapping method and the dragging method for adjusting the aim of the camera. Then they are shown how to use pinching and unpinching motions, to zoom the camera out and in, respectively. After a practice period, they are asked to perform the following tasks, which require them to use these actions to adjust the pan, tilt, and zoom of the camera.

Task 1 employs a Snellen eye chart (10ft) as a visual stimulus, and is designed to cause the participants to progressively zoom the camera, as they go down the chart, line by line. The participants are asked to read the letters on the eye chart, from the top to the bottom, first without using the pan/tilt/zoom camera, and then again using the camera. The bottom line on the eye chart represents a visual acuity of 20/10 (i.e. better than normal). Table 1 shows their visual acuity, as measured by this chart, with and without the camera.

Part. No.	Visual acuity with camera	Visual acuity without camera	Normal reading distance
1	20/10	20/80	1-2 inches
2	20/10	20/30	20 inches
3	20/10	Worse than 20/200	1-2 inches

Table 1. Effective visual acuity, with and without the camera

As shown in the Table 1, all three of the participants were able to read with an effective visual acuity of 20/10 when using the PTZ camera.

Task 2 uses three equations, presented on the whiteboard as visual stimuli. This task is designed to cause the participants to trade off increasing zoom against decreasing field of view, in order to read mathematical equations efficiently. The participants were asked to read the equations aloud using the PTZ camera. All three were able to eventually select a zoom level that allowed them to read the equations correctly, without the need for any further zoom adjustments. Some camera tilting and panning were needed, and the participants expressed some frustration as the camera occasionally entered a vibration period when it was repositioned.

Task 3 uses 11 unusual words written on a white board as visual stimuli. The participants are asked to repeatedly find the target word (which is being pointed to by one of the investigators at the front of the room) and then read that word aloud. Two of the participants were able to find an intermediate level of zoom that provided a wide enough visual field to determine the target word, and enough zoom to read that word. The third participant zoomed out to determine the target word, and then moved that word to the center of the display by tapping, and zoomed in to read it. (He said that the touch-and-drag method was more useful for fine adjustments of the camera direction, after it was zoomed in.)

Task 4 uses a periodic table of elements as a stimulus with large font element symbols (e.g. Sn) and very small font atomic weight numeric values, which require extreme zoom. All three of the participants said that they needed to zoom in and out a lot to accomplish this task. All had difficulty precisely controlling the zoom level, and one participant almost gave up. One of the participants (who was a chemistry major) was able to accomplish this task relatively quickly. The other two participants had difficulty searching for the specified element symbols, since they had to zoom in so far to read the element symbols that they could not see a substantial portion of the table. All three participants felt that both the tapping and the touch-and-drag methods for moving the camera were about equally useful. Two said that the touch-and-drag method was useful for the finer adjustments, which were needed after zooming in all the way to read the tiny atomic weight numbers.

Task 5 uses nine phrases that run the entire width of a white board. This task is designed to cause the participants to use the

panning function of the camera to scan the phrases from left to right, while reading them aloud. All three participants completed this task very easily and quickly, reading each phrase correctly without needing to change zoom levels during the scanning. Two of the participants felt that the tapping method and the touch-and-drag methods were equally useful, while the other participant preferred the touch-and-drag method.

At the conclusion of each task the participants were asked to express their agreement or disagreement with statements such as “It is easy to aim the camera by tapping” on a Likert scale from 1 to 7. All three participants agreed at a level of 4 or higher that both the tapping and touch-and-drag methods for aiming the camera were easy to use. However, two of the participants strongly disagreed with the statement that the zoom was easy to control.

When asked during the post-test survey to identify problems that they had encountered in using the Note-Taker 2.0 PTZ camera for viewing the front of the room, the three participants listed the following problems:

1. The touch-and-drag method for moving the camera was sometimes slow to respond, and the video looked somewhat jittery during the dragging due to camera vibration – especially at high zoom.
2. When the tapping method was used, the tapped feature did not always move *exactly* to the center of the video frame.
3. It was difficult to precisely control the amount of zoom. Sometimes the camera zoomed too far. It was not clear to the participants how to better control it.
4. When zoomed in all the way, tapping and dragging seemed to cause overshoot in the camera movement.
5. The camera sometimes went into a prolonged jittering motion (due to camera vibration) when it was moved to a new position.

Despite these problems, all three of the participants strongly agreed with the statement that they would like to use the PTZ camera in their classrooms, given some refinements. The participants also offered the following suggestions for refining the Note-Taker:

1. If the video display could optimize the brightness and contrast, and could invert the contrast, it might make things easier to see.
2. It might be convenient to have buttons that could be used to select specific zoom levels.
3. There should be a visual indicator when the maximum zoom level has been reached.
4. There should be an alternative to the pinching motion to control the zoom. For example, a double-tap to zoom into the tapped area, or sweeping a finger clockwise (or counterclockwise) to zoom in (or out).
5. The pan/tilt mechanism should be totally quiet while moving the camera, in order to minimize disturbance of other students in the classroom.
6. The camera should be able to zoom in on any tapped point within the video frame, instead of always zooming in on the center.

7. Additional Features to be Implemented in the Note-Taker 2.0

While the Note-Taker 2.0 PTZ camera development is largely complete, the software development is ongoing. Below are the software features that are scheduled to be implemented in the Note-Taker 2.0.

7.1 Digital notepad magnification

Our highest priority software feature for the Note-Taker is magnification for the digital notepad (magnification is not needed for streaming video as users are well served by the camera's optical zoom). STEM students need to take at least some handwritten notes to handle mathematical notation and diagrams. However, those students who need large amounts of magnification are limited in their ability to take handwritten notes on the Note-Taker's digital notepad because none of the commercially available screen magnification software (including AI Squared's ZoomText [11], Freedom Scientific's Magic [12], and Dolphin's Lunar [13]) are compatible with pen input.

While these applications magnify the displayed content of a tablet PC's screen, they do not scale the stylus or touch input accordingly. As a result, the computer sees stylus and touch inputs in a very different region of the screen image than where the user touches the magnified image on the screen. Worse, the (x,y) offset is not the same at different points across the screen. Given the fact that Tablet PCs have been available for more than a decade, it is not clear that screen magnification software suppliers see this as a problem that needs to be addressed.

Given the closed software architecture of these magnifiers, there does not seem to be any way to adapt them for use with the Note-Taker's digital notepad. While Windows 7 provides a basic magnifier that works with touch and stylus input, it requires users to repeatedly tap "arrows" to slide their zoomed-in view around on the screen. This causes unacceptable delays for users who wish to take notes.

The alternative we are pursuing is to develop custom magnifier software for use with the Note-Taker that will maintain calibration with pen and touch inputs, and allow users to quickly slide their zoomed-in view around on the screen.

7.2 Hardware Calibration

Another important software feature for the Note-Taker 2.0 is a calibration mechanism for the camera control. During our usability testing (Section 6), we found that users want to see a very precise synchronism between their finger motions on the display surface and the resulting camera motions. For example, if a particular feature in the video is fingered and then dragged, that same feature should be under the finger at the end of the drag. Likewise, when the user taps a visual feature in the video window to aim the camera at it, that feature should move precisely to the center of the screen. When a pinch (or un-pinch) operation is used to zoom-out or zoom-in the camera, the shrinking or magnification of the displayed video should be in proportion of the movement of the fingers, and should stop as soon as the finger motions stop.

Given the fact that the pan/tilt/zoom camera is mechanical, its accuracy is subject to variances in mechanical tolerances, as well as wear over time. In order to ensure precise control, we are developing a calibration method for precisely synchronizing changes in finger positions on the surface of the Tablet PC display with changes in the direction and zoom-level of the camera.

7.3 Additional Real-Time Image Processing

When the writing on a board at the front of the classroom is viewed obliquely from a student's desk that is off center, there are distortions due to linear perspective. When the board is viewed directly by a person with normal binocular vision, these distortions are not a major problem. However, when viewed in a 2D video frame, it can be surprisingly difficult to read. Standard linear image warping techniques can be used correct for mild distortions, making it easier to read.

When a laser pointer is used by a presenter, students with low acuity can have difficulty in detecting it - especially in video, which has a low dynamic range, compared to the real world. Detection and enhancement of such laser pointer dots can make them much more visible to Note-Taker users.

Our current implementation of adaptive histogram equalization does not always provide visually pleasing results. We plan to implement an improved, domain-tested form of adaptive thresholding as specified by [14]. This moving average adaptive thresholding was used to good effect in retrieving image content from classroom whiteboards by [15].

8. Planned features for Note-Taker 3.0

While Note-Taker 2.0 is still undergoing usability testing, plans are underway for the implementation of Note-Taker 3.0. The functionality of the Note-Taker 2.0 PTZ camera is greatly superior to the earlier proof-of-concept camera. However, it is still rather bulky, noisy, and vulnerable to damage if dropped. In the next phase of our research we will build multiple Note-Taker 3.0 units, and give them to students to carry with them to their classes. This will necessitate the development of a more rugged, compact PTZ camera.

Figure 6 shows a model of our proposed Note-Taker 3.0 PTZ camera. Figure 6(a) shows the PTZ camera unit in use, and Figure 6(b) shows the PTZ camera unit closed for transport.

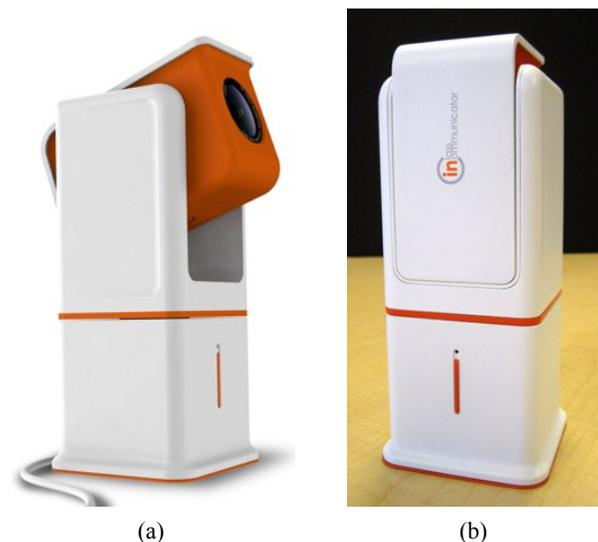


Figure 6. The Note-Taker 3.0 PTZ camera

The camera is mounted inside a protective shell, and its center of gravity is aligned with its horizontal pivot, to allow for precise servo control without vibration. When not in use, the camera is swiveled downward to protect its lens. The whole mechanism is then slipped into a protective case, for transport in the student's

backpack. In addition to this new camera mechanism, the following features are planned for Note-Taker 3.0.

- A means for capturing video frames and inserting them into the notes, to reduce the need for copying equations and other board text into the notes.
- Additional file management features, including a weekly schedule of classes that allows the system to suggest appropriate file names, and appropriate destination folders for newly created files, based on the clock and calendar date.
- Provisions for archiving Note-Taker files onto external media, to reduce the amount of hard disk space used in the Tablet PC.
- A comprehensive search facility with a scroll bar to help the student quickly search the video, keyword search for typed notes, and indexing symbol search (such as asterisks) in handwritten notes. This search facility will search across multiple note-taking sessions.
- A motion tracking feature that allows the Note-Taker Camera to stay centered on the professor, while allowing the student to take manual control of the camera as necessary.

9. Conclusion

Based on usability testing of the proof-of-concept Note-Taker and using the funding provided by the NSF, we are currently developing a Note-Taker 2.0 prototype. Initial testing of that prototype has been encouraging, but some significant problems remain to be solved. While the students who have performed usability testing on the PTZ camera have agreed that it would provide better access to classroom presentations, its zoom controls are not perceived to be easy to use, and camera vibration is a problem as zoom levels approach the maximum of 36x. On the note-taking side, some students need magnifier software that will work properly with the digital notepad, to allow them to take handwritten notes in their STEM classes.

Proposed solutions to the camera problems are currently being implemented, and appear to be effective. If ongoing usability testing confirms their effectiveness, they will be implemented on the planned Note-Taker 3.0 PTZ camera. We are working towards a magnifier solution to support note-taking for those students who are not able to take notes without it. When a solution is implemented, real-world, in-class usability testing with Note-Taker 3.0 will take place during the 2010-2011 academic year.

10. Acknowledgement

This material is based in part upon work supported by the National Science Foundation under Grant Number IIS-0931278. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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