Improved board vision: Improved visualization of classroom board for visually impaired students

Hugo Raskin
Robin Delvaux
Mallory Bouchard
Simon Karler
hugo.raskin@student.unamur.be
robin.delvaux@student.unamur.be
mallory.bouchard@student.unamur.be
simon.karler@student.unamur.be
University of Namur, Namur Digital Institute (NaDI)
Namur, Belgium

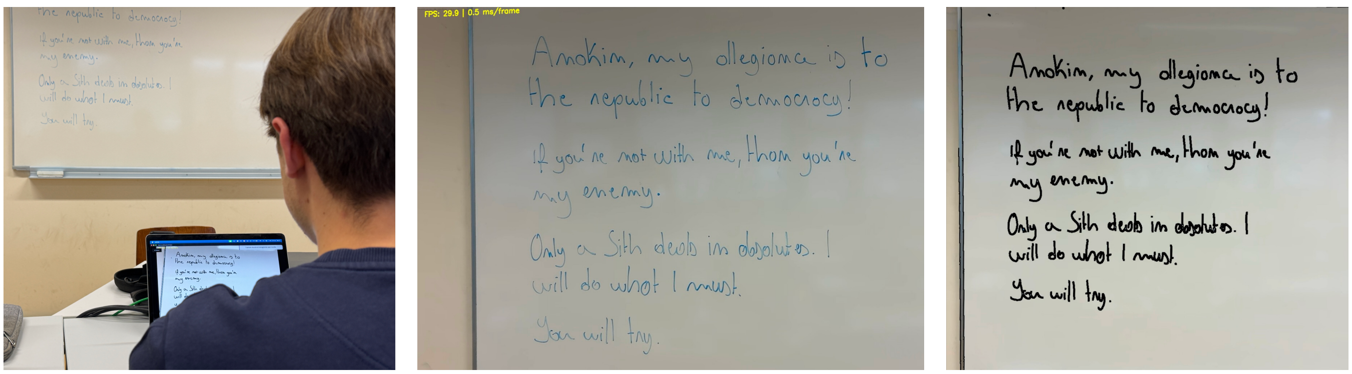

Figure 1: Illustration of the use case of Improved board vision (left); processing the original board (middle), and the enhanced board (right).

ABSTRACT

The equity of learning for students with vision loss has been studied for the past few decades. Several approaches, such as note-taking devices or head-mounted displays, have provided improved visibility of whiteboards or blackboards to visually impaired students. However, these approaches often require the student, the professor, or even the classroom environment to adapt to new devices, which increases friction. Additionally, the quality of the image is often problematic, as low-light classrooms reduce the visibility of the board. In this paper, we present Improved board vision, an application that takes advantage of students' own devices—laptops and smartphones—to increase visibility by enhancing the image of the board through a processing pipeline. We plan to evaluate the approach through a user study involving task completion in a classroom context and answering questionnaires, including the User Experience Questionnaire (UEQ). Even though Improved board vision has not yet been evaluated, we believe it will improve accessibility for visually impaired students, thereby enhancing equity among learners.

CCS CONCEPTS

• **Human-centered computing → Mixed / augmented reality**; Graphical user interfaces; User interface programming; *Interaction devices.*

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1 INTRODUCTION

The Convention on the Rights of Persons with Disabilities (CRPD), adopted by the EU in 2010, emphasizes the rights of people with visual impairments, including equitable access to education, which requires appropriate aids or the usage of accessibility devices.

Prior research has explored various approaches to improve equity for students with visual impairments in classroom settings. For example, Hayden et al. [3] highlighted the importance of note-taking for learning and proposed a tablet-based accessibility device

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that retransmits the content of the blackboard or whiteboard. Other solutions [5, 6] similarly rely on dedicated devices to broadcast board information to students. However, these approaches often require students, instructors, or even classroom infrastructure to adapt to yet another accessibility system. In addition, image quality remains a persistent challenge, as low-light environments and reflections on the board frequently degrade visibility.

Following this line of work, we present Improved board vision, an accessible application designed to enhance the visibility of blackboards and whiteboards for students with visual impairments. The system operates on students' existing devices, which connect wirelessly to a camera, either the student's smartphone or a classroom camera. The camera captures the classroom board and transmits it to the student's laptop application. Once received, the video stream is processed through an enhancement pipeline that applies several operations, including hand detection, lighting correction, edge detection, and board-reading techniques.

The remainder of this paper is structured as follows: Section 2 reviews related work; Section 3 presents Improved board vision 's architecture and workflow; Section 4 describes the planned evaluation; Section 5 discusses potential applications of Improved board vision; and Section 6 concludes the paper.

2 RELATED WORK

Hayden et al. developed Note-Taker [1–3], a tablet-based device equipped with a camera oriented toward the classroom board, highlighting the critical role of note-taking for students with visual impairments. Their system provided an accessible means for capturing lecture content in real time. Early iterations revealed recurring challenges related to low image contrast and suboptimal lighting conditions, which the authors mitigated through color inversion and contrast enhancement techniques.

Our work complements this prior research. Although Improved board vision places less emphasis on note-taking itself, it focuses on reducing the adverse effects of poor contrast and lighting through more advanced image-processing methods, such as edge detection. Moreover, Improved board vision extends beyond the functionality of Note-Taker by offering additional features that support visual accessibility in classroom settings.

Other tablet-based approaches [5, 8] have explored the use of accessible tools for students with visual impairments. However, many of these systems require adaptations from the instructor or modifications to the classroom environment to accommodate students' needs. For instance, Ludi et al. [5] employed a Mimio Capture system, which digitally retransmits the instructor's writing using specialized markers.

In contrast, our approach places no additional burden on either the instructor or the classroom infrastructure. Improved board vision is designed to be lightweight and easy to deploy, requiring only that the student position their device's camera toward the board to access visual information.

Finally, several studies have explored the use of vision-enhancement technologies for people with visual impairments [10]. However, these approaches often require additional hardware, such as head-mounted displays, which can increase the friction and discomfort for students. In contrast, our approach is lightweight and designed to provide vision enhancement using devices students already have, without requiring any extra equipment.

3 APPROACH

Figure 2 presents the architecture of Improved board vision. Conceptually, a student with visual loss uses Improved board vision while attending a lecture. A camera is placed in front of the blackboard or whiteboard—either the student's own camera or one provided by the classroom—in such a way that it captures the entire board.

The student then sits in the classroom and uses the Improved board vision app wirelessly to connect to the camera. The camera transmits the video stream to the app, which processes it through a pipeline that enhances the image, improving the student's ability to see the board.

3.1 Components

3.1.1 Hardware. Improved board vision is designed to be as easy to use as possible, leveraging students' own devices, without requiring yet another accessible device.

For the camera, students can use their smartphone cameras, either through Apple ecosystem connectivity (iPhone to Mac) or through IP-based connections (for Android devices or non-native devices). Additionally, the IP connection allows multiple students to connect to a single camera, such as in classrooms equipped with a central camera.

3.1.2 Software. The Improved board vision application is designed to be installed on any student computer, whether macOS or Windows, and to connect easily to the camera. Additionally, with a focus on accessibility, the app interface uses large buttons with bright colors, and the Luciole font is employed—a font specifically designed for visually impaired users.

3.2 Image Pipeline

Once the video stream enters the Improved board vision application, it is processed through a multi-stage pipeline designed to enhance image quality. Consistent with our emphasis on ease of use, a settings page allows students to select from predefined presets—each corresponding to a specific combination of activated pipeline steps—that best suit the requirements of a given lecture. For example, a student might enable light enhancement and edge detection during a literature lecture.

The following sections describe the steps that can be enabled in the pipeline.

3.2.1 Hand Recognizer. The hand recognizer step consists of tracking the instructor's index finger during the lecture. The rationale is that instructors use multiple modalities to convey information—speech, tone, and pointing gestures. By tracking the position of the instructor's pointing finger, Improved board vision can isolate the portion of the board the instructor is referring to while speaking. By zooming in on that region, Improved board vision aims to provide students with additional visual context that helps them follow the lecture in real time. When the instructor is outside the camera frame or is not pointing at the board, the zoom resets to its initial value and the entire board is displayed.

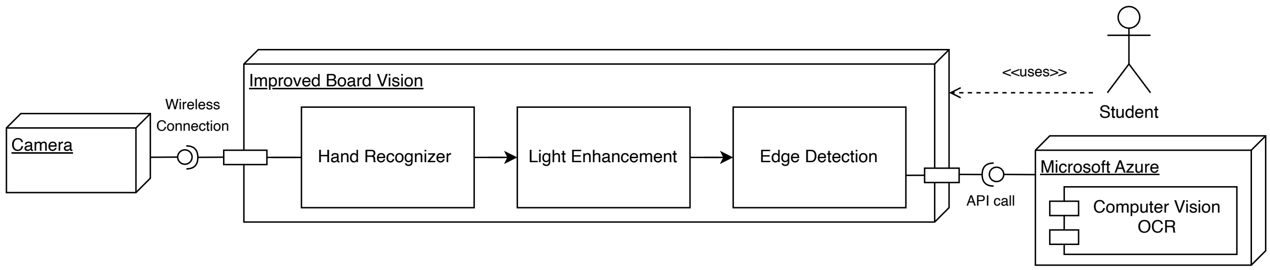

Figure 2: Architecture and workflow of Improved board vision

Index-finger tracking is implemented using Google's MediaPipe Hand Landmarks model, trained on approximately 30K real-world images. After processing an image, the model returns an array of 21 hand landmark coordinates. When a hand is detected (i.e., the returned array is not empty), a magnifier is applied to zoom into the board, using the index-finger coordinates as the center of the zoomed region.

3.2.2 Light Enhancement. This step applies a transformation to increase the image's contrast and brightness. The implementation uses the OpenCV (Open Computer Vision) library for image enhancement. Specifically, it relies on the `convertScaleAbs` method, which applies a lightweight pixel-wise linear transformation and normalizes the result to an 8-bit range. Adjusting the parameters `alpha` (contrast) and `beta` (brightness) enhances the visual clarity of the board.

3.2.3 Edge Detection. The edge detection step consists of applying an edge detection filter to the image to increase the visibility of the information written on the board. The implementation is based on the work of Wolffsohn et al.[9], who showed in their study on real-time enhancement that simple generic edge detectors, such as the Prewitt or Sobel filters, can significantly improve board visibility for people with vision loss.

For Improved board vision, a simple Canny edge detector is applied to the image using the OpenCV library. The edge detected by the filter is then applied onto the original image to provide additional visibility to the students. Using a lightweight edge detection filter has the advantage of enabling real-time enhancement without compromising rendering performance.

3.2.4 Board Reading. As it uses AI models, the reading of the board is performed on demand (via a shortcut) to minimize the impact on Improved board vision's performance. In addition, we implemented wake-word detection—triggering specific actions through spoken commands—to provide a more natural and accessible interaction with Improved board vision. In this implementation, words such as "screen" (or "capture" in French) trigger a screenshot of the board and automatically read its contents aloud to the user.

The feature operates in two sequential phases. In the first phase, the enhanced image produced at the end of the pipeline is sent to an Optical Character Recognition (OCR) model, which extracts the text written on the board. This implementation uses an OCR service from the Azure Computer Vision API suite. On one hand, this offloads the computation from the student's device; on the other hand, it introduces a dependency on network connectivity. Azure's OCR is also multilingual and trained to recognize both handwritten and printed text, making it a comprehensive choice for Improved board vision.

In the second phase, the text extracted by the Azure API is passed to a Text-to-Speech (TTS) model, which generates an MP3 file containing the spoken version of the text. This MP3 file is then played to the student to help them understand what is written on the board.

An additional advantage of processing the board through screenshots and MP3 files is that students can replay the audio and review the captured board later, supporting their learning and note-taking.

3.2.5 Board to Braille. During preliminary discussions with visually impaired students, an additional use case for Improved board vision emerged. Once the board image has been converted to text by the Azure API, the output can be translated into Braille and transmitted to a refreshable Braille display. Incorporating a tactile modality offers visually impaired students a more natural and accessible means of interacting with Improved board vision.

4 EVALUATION

This section outlines the planned user evaluation of Improved board vision.

4.1 Participant Recruitment

Participants with visual impairments will be recruited through convenience sampling. As Improved board vision is not intended for learners with total blindness, individuals who are completely blind will not be included in this study. To ensure that participants have recent and relevant academic experience, they must currently be enrolled in courses; however, graduates from the past five years will also be considered, as their experience as students remains sufficiently recent. Recruitment will be conducted by contacting specialized schools and institutions supporting learners with visual impairments. In total, we aim for 5-10 participants, which is similar to related work [6].

With participants' consent, information about their visual condition and functional vision level will be collected. This will allow us to examine potential relationships between user experience outcomes and degree of vision impairment. Additionally, once the participant has agreed, the evaluation will be recorded to capture how the participants will interact with the application.

4.2 User evaluation

Improved board vision will be evaluated following the user evaluation defined in Hayden et al. [3]. The goal of this evaluation is to assess how effectively the application improves classroom board visibility for students with vision loss.

Before the evaluation, participants will receive a demonstration of Improved board vision 's functionalities. Background information will then be collected, including demographic data, prior experience with accessibility tools, and previous classroom experiences, in order to contextualize participants' profiles.

The evaluation will be conducted in controlled classroom conditions with a single investigator. Participants will be distributed so as to ensure balanced testing of Improved board vision with both blackboards and whiteboards, as well as an equitable distribution of visual impairment levels across conditions. The application's camera will be positioned in front of the board so that the entire writing surface is centered within the frame. Participants will be asked to sit in the row that best corresponds to where they usually position themselves in a classroom.

Participants will complete five tasks, without any time constraint, using whatever Improved board vision functionalities they find most helpful:

- **Task 1:** Read aloud a Snellen eye chart.
- **Task 2:** Read aloud three equations.
- **Task 3:** Read aloud eleven uncommon words.
- **Task 4:** Read aloud entries from a periodic table of elements.
- **Task 5:** Read aloud nine sentences written across the full width of the board.

After completing all tasks, participants will be invited to fill out a questionnaire using a 7-point Likert scale (e.g., "Improved board vision helped me read the board?").

4.3 User Experience Questionnaire

At the end of the user evaluation, the participants will be asked to answer to a User Experience Questionnaire (UES) [4, 7], a heavily validated, state-of-the-art questionnaire that measures user experience based on established scales: Attractiveness (do users like or dislike the product?), Perspicuity (is it easy to familiarize oneself with the product?), Efficiency (can users complete their tasks without unnecessary effort?), Dependability (does the user feel in control of the interaction?), Stimulation (is it exciting and motivating to use the product?), and Novelty (is the product innovative and creative?).

4.4 Results Analysis

The results from the user evaluation will be analyzed using standard statistical methods including the mean, standard deviation, and score distribution. For the UEQ questionnaire, we will employ the UEQ Data Analysis Tool[4], which computes scores across six user experience dimensions and compares them against established benchmarks. These results will help us better understand Improved board vision 's capabilities, students' willingness to use it in their day-to-day academic activities, and the tool's strengths and weaknesses, which may inform directions for future work.

5 DISCUSSION

5.1 Improved board vision Evaluation

This preliminary work lacks evaluation. Future work will focus on evaluating Improved board vision, which will reveal additional strengths and weaknesses and help guide future development directions.

Additionally, The planned user evaluation of Improved board vision focuses on assessing the tool using only five simple tasks related to reading information on a blackboard or whiteboard. For a preliminary study, this approach can yield meaningful insights; however, future work should aim to evaluate Improved board vision using more comprehensive use cases and within real classroom situation.

5.2 Improved board vision Implementation

The main challenge in implementing Improved board vision was running sufficient AI models and techniques to effectively support students with vision loss. Because Improved board vision is designed to operate in real time and on students' own devices, selecting appropriate models was essential to minimize performance impact across a wide range of hardware.

Despite these efforts, Improved board vision relies on multiple AI techniques—such as hand detection, edge detection and text-to-speech—which means performance ultimately depends on the capabilities of each student's device. As a result, older devices may be unable to run Improved board vision at full performance. For the image-to-text step, a decentralized model (Azure's) was used. Although this approach reduces local hardware requirements, it introduces a dependency on network connectivity, which may not be suitable for all classroom environments.

Future work will focus on reducing the computational demands of Improved board vision, enabling it to run on a broader range of devices. Additionally, as more students attend class using tablets—which often have more limited hardware capabilities—future development will emphasize adapting Improved board vision to tablet environments, further highlighting the need to reduce performance requirements.

Early in development, we experimented with applying image-upscaling techniques—methods that improve image resolution by generating additional pixels. However, performing upscaling in real time placed too high a demand on device performance, making it impractical for students' devices. As a result, this approach was abandoned.

Regarding the order of steps in the processing pipeline, it was designed with performance in mind (e.g., applying edge detection only to the cropped image rather than the full frame). Nevertheless, future work should investigate whether alternative step ordering could yield better performance.

Furthermore, the current pipeline consists of relatively few steps. When designing the preset feature, this simplicity motivated the use of predefined presets only. As more processing steps are added to the pipeline, the value of allowing students to save custom presets—with different combinations of steps enabled or disabled—will increase considerably.

6 CONCLUSION

In this paper, we presented Improved board vision, an accessible application designed to enhance the visibility of blackboards and whiteboards for students with visual impairments. It operates on students' own devices, which wirelessly connect to a camera, whether students' smartphone or classroom central camera. The camera captures the classroom board and transmits it to the application on the student's laptop application. Once received, the video stream is processed through a pipeline that enhances visibility using several steps, including hand detection, lighting enhancement, edge detection, and board-reading techniques.

Improved board vision has not yet undergone evaluation, but we plan to conduct a preliminary user study by recruiting students with vision loss and asking them to complete five classroom tasks using the application. Participants will also complete a questionnaire and an UEQ to assess Improved board vision 's user experience.

Although evaluation has not yet been carried out, we have already identified several directions for future work, including customizable presets, improvements to the processing pipeline, and enhancements to individual steps. Additionally, future implementation efforts should focus on improving performance and adapting Improved board vision for tablet devices.

OPEN SCIENCE

Our GitHub repository with code is accessible at https://github.com/hraskin/ImprovedBoardVision. A demonstration video is also visible at https://www.youtube.com/watch?v=z2mYK1BogWs

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