What are Students Seeing? Insights from Real-Time Eye and Face Tracking in Special Education

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ABSTRACT

Special needs is an encompassing term, referring to a broad range of impairments and many other disorders marked by learning problems [4]. Students with special educational needs often experience difficulty maintaining their focus or processing information during school lessons. In small group or one-on-one settings, teachers and special educators must interpret subtle behavioural cues to adapt their teaching methods, for the benefit of their students. However, when teachers rely solely on their own observations, the results may be subjective and in group settings, they might overlook key behavioural cues as their attention is divided among multiple students. This poster presents a non-intrusive, AI-powered system that utilizes facial-detection and eye-tracking computer vision techniques to provide special education (SPED) teachers with real-time, interpretable feedback on their students' shifts in focus, understanding and engagement.

1 INTRODUCTION AND MOTIVATION

Special education aims to support disabled students, whose disability adversely affects their learning, with specially designed instruction, an instruction built to maximize their learning and functioning [2]. Despite the support provided by various guidelines, policies and programs over time to strengthen efforts in special education, regular schools providing inclusive orientation continue to face numerous obstacles and challenges. A recent study conducted in Ilagan, Isabela, Philippines, aiming to investigate the issues and challenges faced by SPED teachers in teaching children with learning disabilities, discovered that these teachers lacked updated teaching and curriculum guides, Instructional Materials as well as access to seminars on how to effectively handle SPED instruction [1]. In light of these findings and the rapid development of AI and computer vision tools designed to support the field of special education, it is vital to leverage technology to assist SPED teachers in meeting their students' needs.

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2 RELATED WORK

Building on these challenges, a growing body of research explored how eye-tracking and facial-detection technologies can equip SPED teachers with real-time, interpretable insights into students' shifts in focus and engagement. These insights provide teachers with a strong foundation to confidently develop teaching strategies tailored to their students' learning styles.

Shilaskar et al. [5], proposed an approach for analysing students' attention patterns in online classes by tracking their eye gaze using computer vision techniques. The recommended approach used Haar Cascade Classifiers and Dlib-based facial analysis to classify students' eye movements into nine directional states, ultimately classifying attention as either attentive or non-attentive. While effective in gaze tracking, the system's accuracy was limited by environmental factors such as varying lightnings and head movements, emphasizing the need for further improvements like image registration.

Additionally, another study [6] introduced the Average Feature Point method, combined with the First Valley method for threshold selection, to improve iris centre localization using standard notebook cameras instead of infrared cameras. Experimental results showed a significant improvement in accuracy over the traditional Hough transform, achieving a 98.8% success rate in iris localization and providing a strong foundation for more accurate eye gaze tracking.

Last but not least, Kainz et al. [3] proposed a system capable of measuring, and potentially improving human attention using eye-tracking techniques. The system uses the Dlib face detector, followed by the Timm and Barth algorithm for pupil detection. Additionally, it includes an original implementation for gaze direction and calibration. Despite relying on low-resolution cameras operating in visible spectrum, the system has been shown to be capable of calibrating, measuring and displaying attention patterns in humans.

3 PROPOSED IMPLEMENTATION

The proposed system leverages standard webcam input to monitor students' behaviour during lessons in real time. Face and eye regions are initially detected using Haar Cascade classifiers, then refined using tools such as Dlib's frontal face detector or Mediapipe's face detection model to enhance robustness under variable lighting conditions and head orientations.

For iris and pupil detection, the system integrates multiple techniques; including the Timm and Barth algorithm, centroid and blob detection, and the Hough Circular Transform, to improve detection accuracy and robustness across different face angles and illumination levels [3, 5, 6]. In order to estimate the direction of the gaze, a geometric model, inspired by [5], maps the pupil position to a number of different distinct visual regions in the video frame to keep track of where the student is looking.

To interpret engagement, student attention states are then classified into different engagement levels, such as focused, distracted, confused, drowsy and fatigued using a trained machine learning model. This model learns from patterns in gaze direction, blink frequency, and behavioural cues such as yawning, frequent gaze shifts or prolonged off-screen focus, in order to make data-driven predictions. Furthermore, constant fixation on a single point may suggest confusion or difficulty processing a piece of information. These thresholds can be dynamically adjusted using machine learning models that combine contextual data, historical student behaviour, and SPED teacher feedback to personalize engagement analysis for each student.

Captured data is visualised through a dashboard, aimed at SPED teachers, highlighting key engagement insights. This includes real-time alerts during moments of inattentiveness or difficulty, visualization of how each student's attention shifts throughout the lesson and simplified, interpretable observations to support well-informed decision-making. Each student has an individual profile that tracks their behaviour across different subjects (e.g. separate profiles for math, music, etc.) enabling SPED teachers to improve their teaching strategies to suit each individual's unique needs. The main priority of the interface is interpretability, providing clear, user-friendly feedback and explanations for all insights the system provides the teachers with.

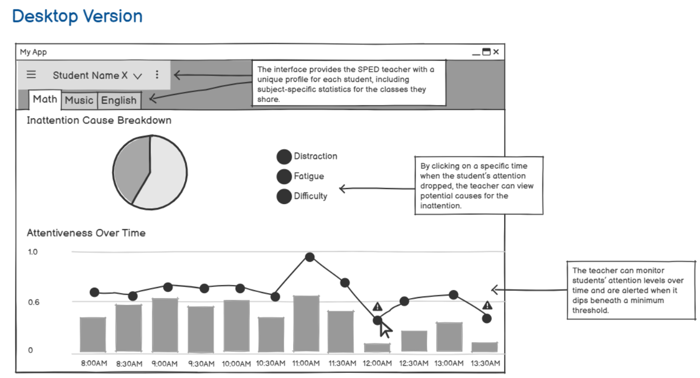

Figure 1: Proposed dashboard design (Desktop Version)

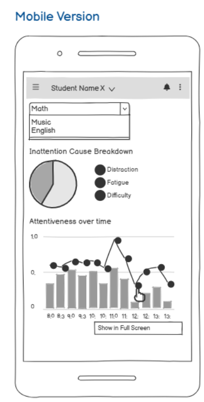

Figure 2: Proposed dashboard design (Mobile Version)

4 FUTURE WORK

Future work will involve implementing the system, testing the system in real classroom environments, improving the accuracy of attention pattern detection using deep learning techniques, and expanding behavioural analysis beyond eye and facial cues to include additional signals such as body posture or fidgeting patterns. The system aims to give teachers a comprehensive understanding of student engagement, allowing them to offer targeted support without needing to disrupt the students' focus and space through constant check-ins.

5 CONCLUSION

This poster combines machine learning, human-computer interaction, classical computer vision and inclusive education all into a unified system for behaviour interpretation and personalised attention tracking. It empowers SPED educators to better support their students through real-time visual analytics they can engage with. By addressing limitations in existing gaze-tracking approaches, such as sensitivity to lighting and lack of personalization, this system offers a more teacher-friendly, classroom-ready solution. Future works aims to secure the necessary ethical and financial support to bring the system to life, evaluate its effectiveness in real classroom environments, and potentially introduce additional behavioural cues to enrich engagement analysis.

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