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# DEVELOPMENT AND TESTING OF A LIGHTWEIGHT, ALL-DAY GLASSES-MOUNTED WEARABLE: INVESTIGATING THE VISUAL ENVIRONMENT IN CHILDREN FOR MYOPIA RISK ASSESSMENT

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***Abstract*** – In recent years, the prevalence of myopia, caused by elongation of the eye, has increased dramatically. Researchers suggest that both light intensity and the range of viewing distances may influence myopia risk in children, but this remains unconfirmed. Investigating these environmental factors is therefore essential. While wearable devices have been used to gather relevant data, they often fall short, failing to measure spectral light content, estimate viewing distances across the central and near-peripheral visual field, or collect data at eye level. This study introduces a new solution: a lightweight, glasses-mounted system designed to improve comfort, usability, and recording duration. It is composed of a microcontroller-based system, providing a strong balance of computing power and energy efficiency, supporting full-day data collection.

**Keywords:** myopia, visual environment, wearable technology, light spectrum, natural-scene statistics

## 1. INTRODUCTION

Researchers are investigating how factors like illumination intensity and viewing distances experienced by children may influence eye growth [1–3], although definitive conclusions are still lacking. The main concern with myopia is not just the need for corrective lenses, but the structural changes that elevate the risk of serious vision-threatening conditions such as retinal detachment, myopic maculopathy, and glaucoma. This underscores the importance of studying environmental contributors to childhood myopia. Wearable devices have been introduced to gather data on children's visual environments (see [4] for a review). A pilot study with an head-mounted sensor rig successfully collected valuable, highly relevant data for investigating environmental risk factors for myopia in children [4]. However, the prototype had limitations. Technologically, its short measurement duration was constrained by bulky hardware and high power consumption. Ergonomically, the device's size and weight reduced comfort and potentially altered children's natural behavior during use. The aim of this work is to perform a preliminary evaluation of a new lightweight, glasses-mounted configuration integrating depth, spectral, and inertial sensing, minimizing movement restrictions, improve comfort, and extend recording duration—potentially to a full day. This setup is tested under laboratory conditions to verify feasibility, optimize calibration procedures, and assess its suitability for future studies on children's visual environments.

## 2. METHODS AND PROCEDURES

At the core of the device is an ESP32-S3 microcontroller (Espressif Systems, Shanghai, China), mounted on a module from Seeed Studio (Seeed Studio, Shenzhen, China) composed by a camera and a microSD card slot with reduced dimensions. Compared to the previously used Raspberry Pi, this platform offers a significant reduction in power consumption and weight, enabling a tenfold increase in measurement duration. All electronics are mounted on the glasses frame, as depicted in Figure 1, with only a single cable connecting to a compact power bank worn on the user's back. To reduce power and computational demands, the device is designed purely for data acquisition; all processing is performed offline after data collection.

Figure 1. Complete system with all the sensors mounted on the glasses frame

Due to the resource limitations of the microcontroller, high-speed serial stereo cameras, such as the one used in the previous project [4], were not suitable.

To extract depth information, we implemented a machine learning algorithm known as MiDas [5], which provides a relative depth map. Combining this information with sparse data from an 8×8 depth matrix allowed us to generate a dense high resolution depth estimation. For image acquisition, we selected the OV2640 (OmniVision Technologies, Santa Clara, CA, USA) image sensor, collecting frames at VGA resolution. For depth sensing, we chose the VL53L5CX module (STMicroelectronics, Geneva, Switzerland), a highly flexible and user-friendly 8x8 time-of-flight sensor with $I^2C$ communication protocol. The depth estimation system, made by the MiDaS model and the 8x8 sensor, has been calibrated using the Intel RealSense D435i (Intel, Santa Clara, CA, USA) as a reference.

To measure spectral composition and illuminance, we integrated the AS7341 (AMS OSRAM, Premstätten, Austria) 10-

channel spectral sensor, which communicates via $I^2C$ for simple integration. The sensor was calibrated in the [300,800] nm range using a Xenon arc lamp and a Hamamatsu PMA-11 (Hamamatsu Photonics, Japan) reference spectrometer. The calibration setup included a 99 % reflectance target (Labsphere, North Sutton, NH, USA) to ensure that both spectrometers received uniform and consistent illumination.

We also added an MPU6050 (TDK InvenSense, San Jose, CA, USA) inertial measurement unit (IMU) combining a 3-axis accelerometer and gyroscope. The IMU enables machine learning–based recognition of physical activities such as reading, using a smartphone, working at a monitor, or playing outside, offering important context for visual and lighting data. Data is stored on a microSD card, allowing for easy offline transfer.

## 3. RESULTS AND DISCUSSION

During testing, the use of a single ToF frame combined with an RGB image resulted in limited depth resolution and reduced confidence in the output. To mitigate this, a strategy based on acquiring multiple ToF frames and applying temporal filtering was adopted. This improved the quality and reliability of the model input, as shown in Figure 2.

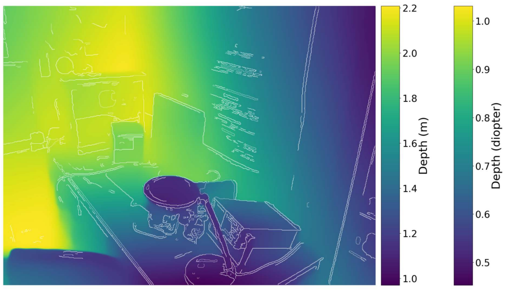

Figure 2. Depth estimation obtained from the RGB image and 8x8 ToF sensor as an output of the system, combined with edge-map of the original scene

Figure shows the depth map generated by the model, overlaid with the edge map of the original RGB image. The effective depth range is limited to approximately 3 meters, which corresponds to the maximum measurable distance of the current ToF sensor. Further improvements to this parameter are planned as part of ongoing work.

Each visible channel of the AS7341 was modeled as a Gaussian function, centered at the nominal peak wavelength of the channel and with the theoretical full width at half maximum (FWHM) specified in the datasheet. As shown in Figure 3, the Gaussian amplitudes were then optimized so that the weighted sum of the eight channels matched the PMA-11 reference spectrum under Xenon arc lamp illumination, resulting in an overall RMSE of 0.0476. To enhance the relevance of the measurement to human perception, the CIE photopic luminous efficiency function [6] will be applied to the calibrated spectrum. This weighting provided a representation of the light intensity that is more consistent with the photopic sensitivity of the human eye.

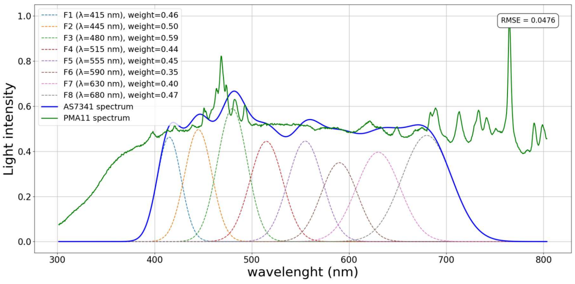

Figure 3. AS7341 spectrum calibration with Xenon arc lamp, fitting the PMA-11 spectrum. For each channel of the AS7341 it is also reported the weight used and the RMSE obtained

The complete system—including all sensors and the glass frame is expected to weigh approximately 50 grams. This represents a significant reduction in weight compared to our previous solution and offers extended measurement sessions with reduced user fatigue and improved overall usability.

## 4. CONCLUSIONS

The implemented device is comfortable, safe, and easy to use, allowing reliable operation by non-technical users, such as the child's parents, and enabling extended recordings. Moreover, it is able to provide a robust and compact representation of the key factors of the visual experience that have a potential correlation to myopia progression. The system will undergo pilot testing with a group of five adults and one child. The objective of this phase is to perform a stress-test of the device, pushing it to its operational limits and identify criticalities and areas for further improvement. This pilot test will allow us to evaluate the maximum sustainable measurement duration under typical usage conditions, taking into account factors such as comfort, reliability, and data quality. The device is expected to offer valuable insights about the relationship between environmental factors and the development of myopia, especially with modern lifestyle shifts that have increased the amount of time people spend indoors, near work and display use.

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