ARtEYE: Augmented Reality Text & Eye-Enhancer

A pioneering medical approach for myopia, synergizing Augmented Reality with artificial intelligence.

Zhaohan Yan
Department of Electrical and Computer Engineering
Johns Hopkins University
Baltimore, MD, US
zyan36@jh.edu

Haochen Wang
Department of Biomedical Engineering
Johns Hopkins University
Baltimore, MD, US
hwang292@jh.edu

Sijun Wang
Department of Biomedical Engineering
Johns Hopkins University
Baltimore, MD, US
swang365@jh.edu

Abstract - Myopia, more commonly known as nearsightedness, is a prevalent global health concern projected to affect approximately 3.36 billion individuals by 2030. This condition necessitates regular optical assessments and updates in prescription eyewear, typically every two to three years, imposing significant financial and logistical burdens on those affected. In response to these challenges, a novel augmented reality (AR) device, ARtEYE, has been developed. This device leverages a combination of augmented reality technology, optical character recognition (OCR), and artificial intelligence (AI) to enhance the visual experience of users. ARtEYE is designed not only to improve sight but also to facilitate real-world interactions through advanced computational tools. Featuring various input modalities such as cameras and microphones, the device offers a dynamic and interactive user experience. A key innovation of ARtEYE is its focus on text projection, which simplifies the optical complexities typically associated with AR technologies, thereby reducing production and retail costs. This breakthrough makes ARtEYE an accessible and cost-effective alternative for individuals with visual impairments, providing a contemporary solution that blends functionality with affordability.

Keywords - Myopia, Augmented reality (AR), Artificial Intelligence (AI), Optical Character Recognition (OCR)

I. Introduction

Myopia, or nearsightedness, is one of the leading causes of impaired vision globally, escalating at a rate that resembles an epidemic. As of now, the predominant solutions for managing this condition include progressive ophthalmic lenses and single-vision glasses, which correct refractive errors by adjusting the focus of light onto the retina. Typically, acquiring these prescriptions entails a visit to an ophthalmologist, adding financial burdens and inconvenience for those affected.

Amid these challenges, augmented reality (AR) technology emerges as a potential adjunct to traditional eyewear. AR's core capability is to enhance the real world with digital overlays, making them appear as integral parts of our surrounding environment. AR technology is diverse, encompassing types such as projection-based, marker-based, markerless, GPS/location-based, superimposition-based, and simultaneous localization and mapping (SLAM). These technologies enrich our interaction with the real world by placing virtual elements in live settings.

Although many AR devices, like Microsoft's HoloLens, are designed for complex tasks-ranging from medical education to aiding in surgical procedures-their sophisticated features can make them bulky and costly, thus limiting their daily use. In contrast, ARtEYE is designed to seamlessly integrate into the daily lives of users. This device focuses on enhancing visual experiences for myopia patients through features like text-only projection, modular design, and ease of use. It connects to an AR platform integrated with technologies like Google AI and ChatGPT, allowing for interactive, text-based engagements in real-world scenarios.

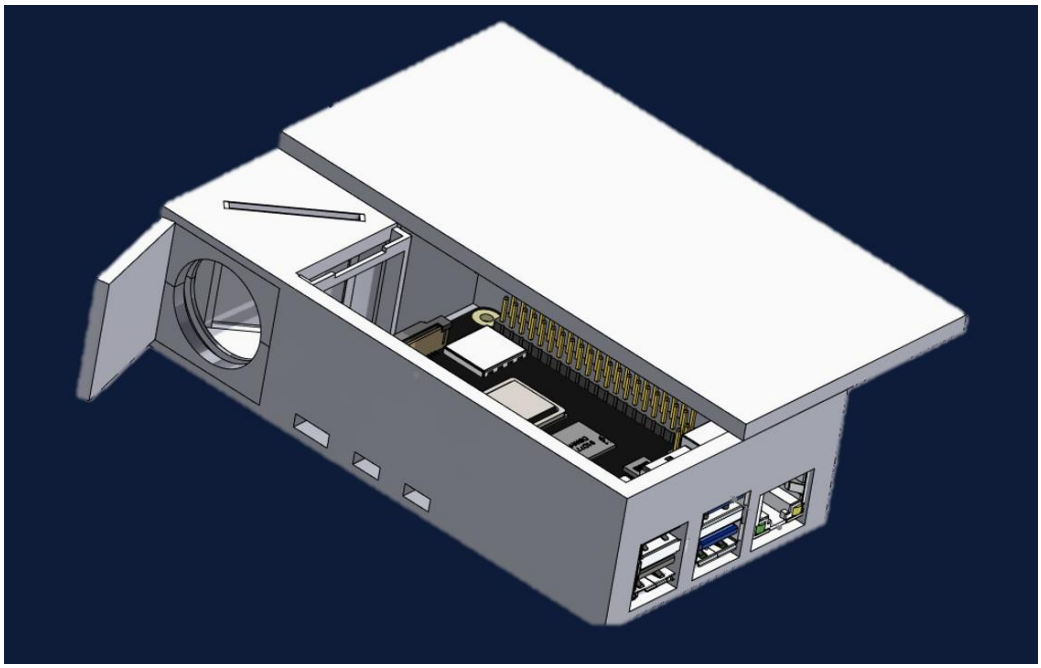


Fig. 1. ARtEYE 1.0 CAD

Unlike other AR products such as Google Glass, which often prioritize high-end features over user-friendliness and cost, ARtEYE is crafted with an emphasis on affordability, simplicity, and functionality. Its design is not only geared towards individuals with nearsightedness but also extends to professionals like field engineers who need real-time access to textual data or schematics. Furthermore, ARtEYE's modular design invites customization, akin to building with LEGO, enabling users to personalize their devices according to their specific needs and preferences.

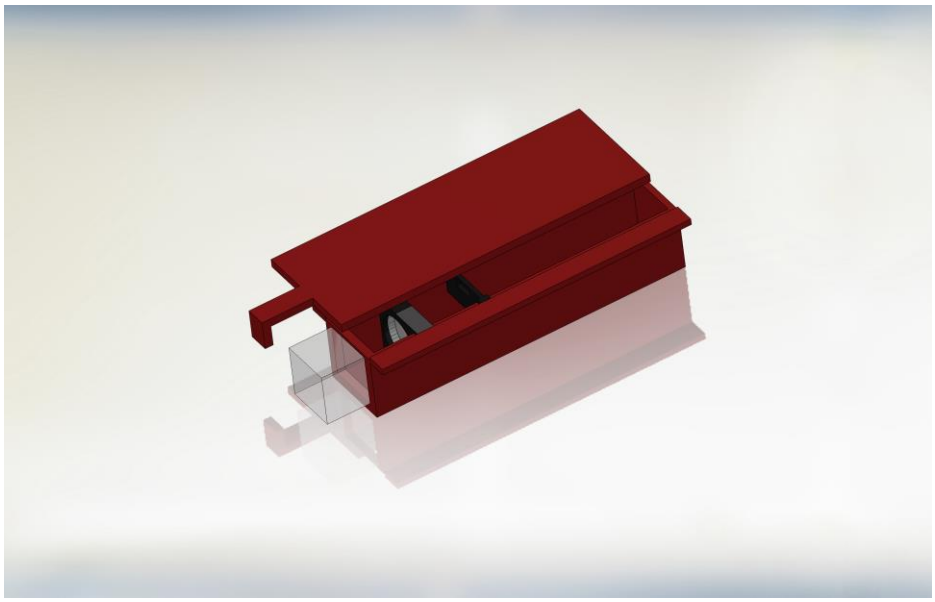


Fig. 2. ARtEYE 2.0 CAD

Thus, ARtEYE positions itself as not only a complementary option to conventional eyewear for myopia correction but also as a versatile tool for everyday practical applications, promising to redefine our interaction with technology and our environment.

II. ARtEYE Modular Design

The ARtEYE device is architected with a modular design that includes three primary components: a camera module, a display module, and an optical module, along with integrated cloud services powered by Google Cloud Platform (GCP). Each module is designed to operate cohesively yet maintains the ability to function independently, enhancing both flexibility and customization for users. The camera module utilizes an ESP32-CAM to capture real-world images. These images are then transmitted to a server hosted on GCP via REST API, enabling robust and scalable cloud processing. The display module is powered by an ESP-32 processor and connects wirelessly to the cloud server. It subscribes to image upload statuses and, upon receiving notifications, displays the text extracted from the images on an OLED screen. This allows for real-time text updates that are crucial for seamless AR experiences. The optical module is intricately designed with lenses, mirrors, and a beam splitter to create an augmented reality display, projecting digital information directly into the user's field of vision. The entire system is wirelessly interconnected using REST API protocols and Bluetooth SPP (Serial Port Profile), ensuring a fluid and responsive user interface. This modular design not only facilitates easy upgrades and maintenance but also allows users to customize their ARtEYE system according to their specific needs, leveraging advanced AR capabilities in daily activities

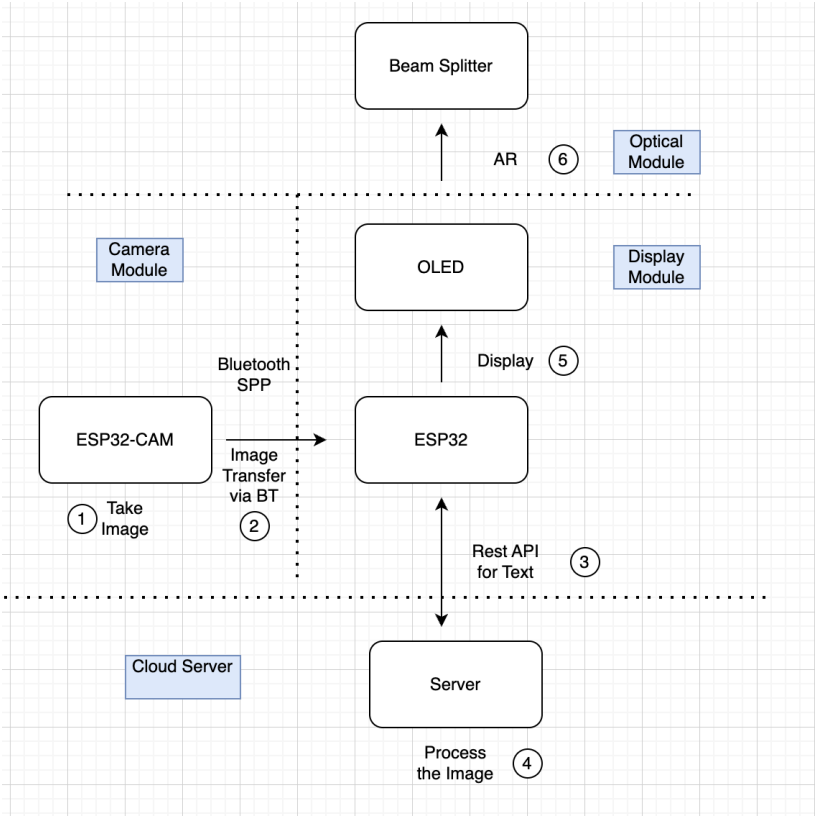


Fig. 3. ARtEYE Modular Design

III. ARtEYE API Design

The ARtEYE system's API design employs a straightforward yet powerful pattern to facilitate the integration and management of the various modules within the device, as well as their interaction with cloud services. The API allows for the uploading of images, checking their processing status, and communicating updates to the display module,

which are critical operations for the ARtEYE's functionality. The design promotes ease of use and scalability, ensuring that developers can efficiently build on and customize the AR experience according to specific needs.

arteye.yaml

```yaml
paths:
  /images/upload:
    post:
      summary: "Uploads captured image from the camera module."
      responses:
        200:
          description: "Image uploaded successfully."

  /images/status:
    get:
      summary: "Checks the status of image processing."
      responses:
        200:
          description: "Processing status returned."

  /display/update:
    post:
      summary: "Sends text to be displayed on the OLED screen."
      responses:
        200:
          description: "Text updated successfully."
```

Fig. 4. Outline of the key API requests

In support of fostering innovation and community engagement, the documentation for these APIs is made available in an open-source format. This approach not only encourages the creative use of ARtEYE in various applications but also supports ongoing development by the broader community. By providing clear, open documentation, we empower developers and enthusiasts to explore new use cases and contribute to the evolution of the ARtEYE platform, enhancing its value and utility in everyday scenarios.

IV. ARtEYE Virtual Status Management

The ARtEYE Virtual Status Management system depicted in the diagram orchestrates the workflow between various hardware components and the Raspberry Pi backend server to efficiently manage tasks related to image capturing and display updating. Here's a breakdown of the process:

1. Actor Interaction: The system begins with an actor (user) initiating the process by updating the system's status on the backend server to indicate readiness for operation.
2. Status Monitoring: The Raspberry Pi backend server continuously monitors this status and, upon recognizing that the system is ready (status 'I'), it signals the ESP-32 Cam module to capture an image.
3. Image Capturing and Upload: The ESP-32 Cam takes the image and uploads it to the server, subsequently updating the server's status to 'U', indicating that an image upload has occurred.
4. Display Module Interaction: Concurrently, the ESP-32 Display Module polls the server every 5 seconds to check for any status update. Once it detects the 'U' status, it triggers the display of the text extracted from the image.
5. Cycle Completion: After displaying the text, the display module updates the server's status back to 'W', signaling that it is ready for a new cycle to begin.

This workflow ensures smooth and continuous operation within the ARtEYE system, allowing for real-time interaction and display updates based on the images captured by the camera module. The use of REST APIs for communication between modules and the server ensures that the system is responsive and scalable.

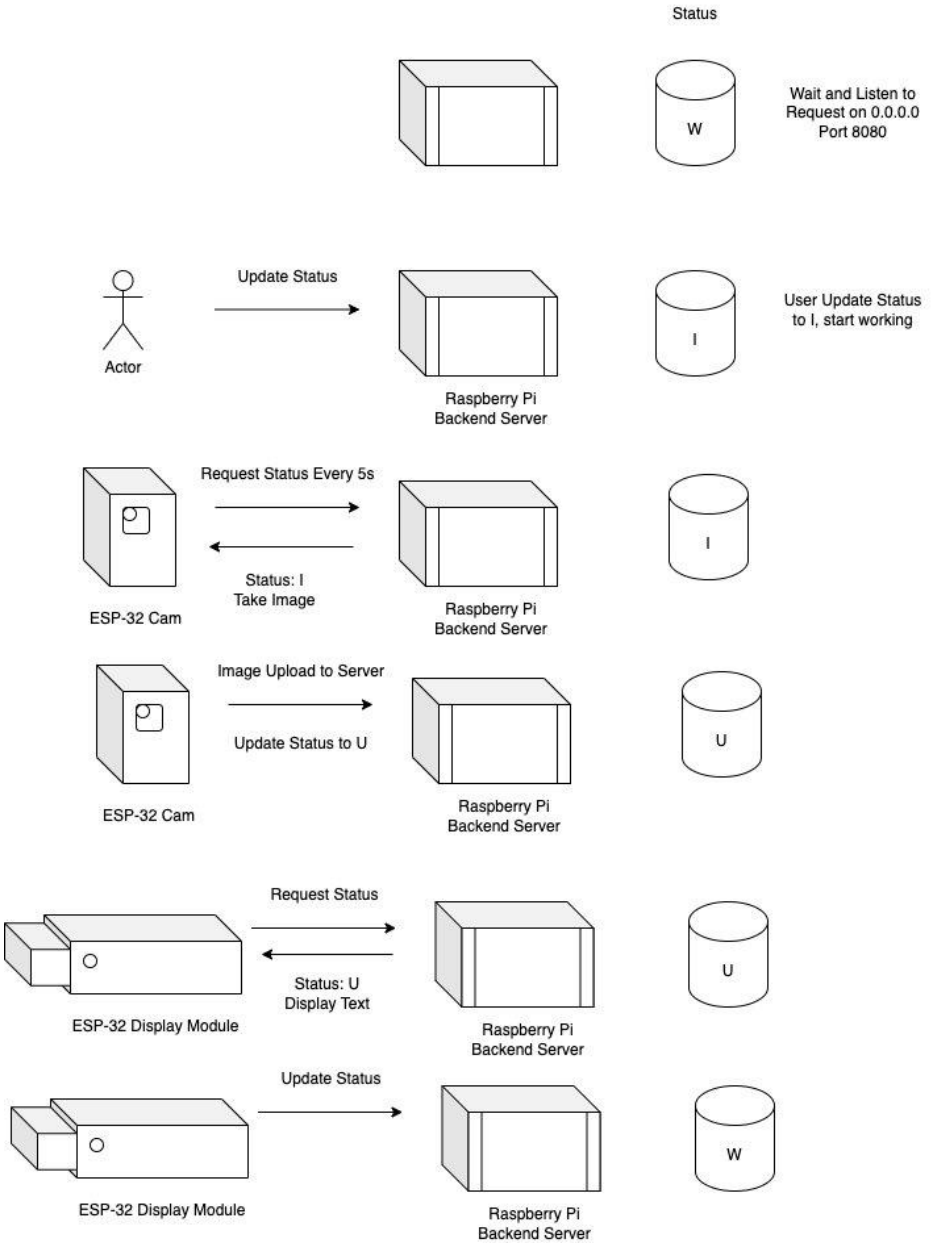


Fig. 5. Outline of the key API requests

V. ARtEYE 1.0

The ARtEYE 1.0 system showcases significant advancements in augmented reality for visual aid through its carefully engineered features and practical demonstrations. Firstly, the device includes a 3D-printed housing that encapsulates both the optical and electronic components, ensuring a compact and user-friendly form factor. This integration not only aids in durability but also enhances the aesthetic appeal of the device.



Fig. 5. ARtEYE 1.0 Prototype

In terms of functionality, ARtEYE 1.0 excels in text capture and display capabilities. It successfully captures, recognizes, magnifies, and displays text from distances as great as 4 meters. For instance, it can clearly display the phrase “ARtEYE Johns Hopkins” from 2 cm-sized letters located 4 meters away, demonstrating its powerful optical performance. Additionally, the device adeptly manages the contrast between the displayed text and the background. For example, when it projects the word “Hello,” it does so with minimal interference, allowing users to easily read the text while still being fully aware of their surroundings. This feature is crucial for ensuring that ARtEYE can be used seamlessly in a variety of environments without disrupting the user's natural interaction with the real world.

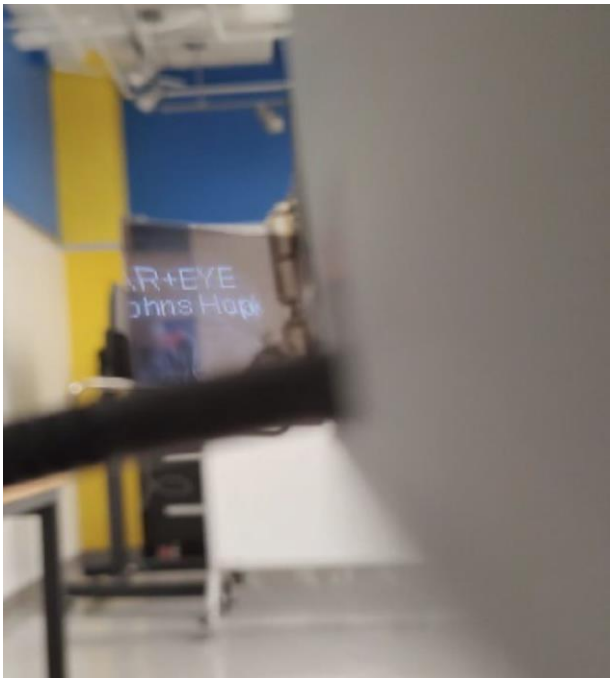


Fig. 6. ARtEYE 1.0 Experiment Result

Overall, ARtEYE 1.0's results illustrate a promising leap forward in using augmented reality technology to enhance visual perception, especially for individuals with visual impairments, offering them a new level of independence and interaction with their environment.

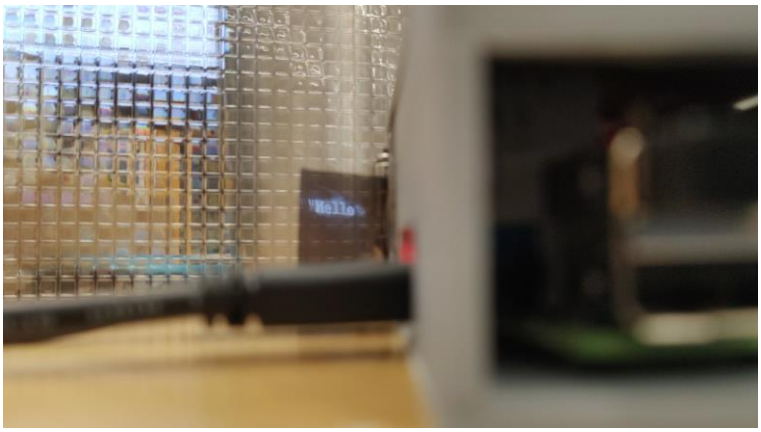


Fig. 7. ARtEYE 1.0 Display Module

VI. ARtEYE 2.0

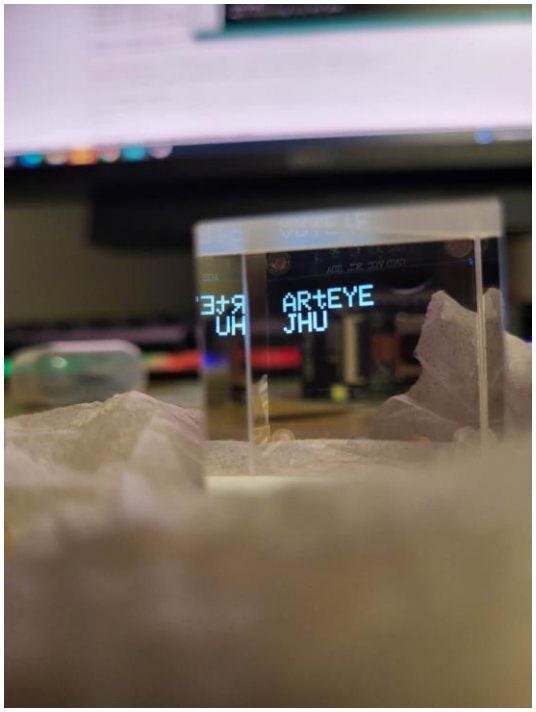


Fig. 8. ARtEYE 2.0 Display Module

The ARtEYE 2.0 represents a monumental leap forward in the evolution of augmented reality visual aids, marking significant improvements in display technology and device architecture. This new version boasts an enhanced display system that provides true augmented reality experiences. Key improvements include increased transparency and superior display quality, which allow for sharp, vibrant images that blend seamlessly with the real world. The contrast has also been finely tuned to ensure that text and images stand out against various backgrounds without overshadowing the environment. Additionally, ARtEYE 2.0 introduces focus adjustment capabilities, enabling users to fine-tune their viewing experiences based on their specific visual needs and the distances at which objects or texts are located.

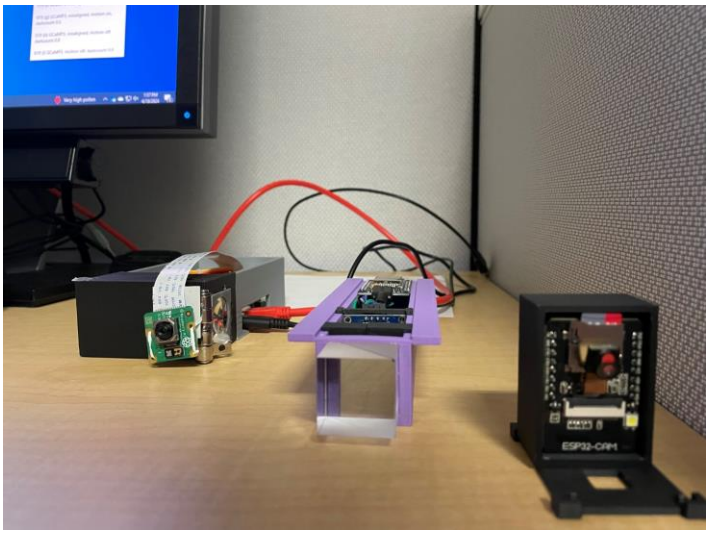


Fig. 9. ARtEYE 2.0 Prototype

In terms of design, ARtEYE 2.0 has achieved a significant reduction in size and weight through its innovative modular design. Components such as the camera, display, and processing units are now completely wirelessly connected, enhancing the flexibility and comfort of use. This modular approach not only makes the device lighter and more comfortable to wear but also allows for easy customization and upgrades by the user, catering to a wide array of needs and preferences.

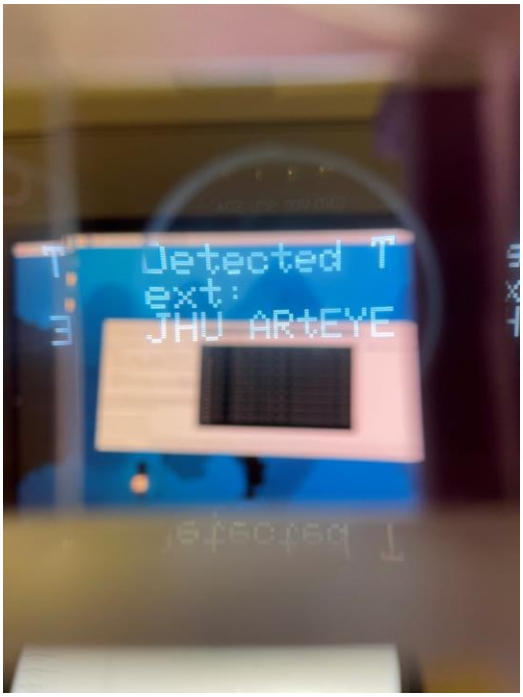


Fig. 10. ARtEYE 2.0 Experiment Result

These advancements collectively transform ARtEYE 2.0 into a more dynamic and adaptable tool, offering users a discreet, effective, and personalized way to enhance their visual perception. The device now not only aids those with visual impairments but also enriches the visual experience for a broader audience, pushing the boundaries of what can be achieved with augmented reality in everyday life.

VII. Conclusion

In conclusion, the development and refinement of the ARtEYE system represents a significant advancement in the field of augmented reality and its application to real-world visual impairments. Starting from ARtEYE 1.0, which introduced a functional and integrated solution for enhancing visual perception, the evolution to ARtEYE 2.0 has marked considerable progress, particularly in terms of display capabilities and device usability. The enhanced transparency, improved display quality, and focus adjustment features in ARtEYE 2.0 not only provide true augmented reality experiences but also ensure that users can interact with their environment in a more natural and intuitive manner. Additionally, the lightweight, modular design of the latest version emphasizes user comfort and customization, broadening the potential applications of the device.

The achievements of the ARtEYE project underscore the potential of augmented reality to transform the lives of individuals with visual impairments, offering them greater independence and a higher quality of life. This research also paves the way for future innovations where AR can be seamlessly integrated into various aspects of daily life, extending beyond medical applications to educational, professional, and recreational uses. The ARtEYE system sets a new benchmark in the field and suggests a future where technology and human experience converge in ways that were once imagined only in science fiction. The ongoing development of such technologies promises not only to enhance human capabilities but also to redefine our interaction with the digital world.

Acknowledgement

I would like to express my profound gratitude to Professor Sathappan Ramesh for his expert guidance and invaluable advice throughout this project.