Demo Abstract: Edge-based Augmented Reality Guidance System for Retinal Laser Therapy via Feature Matching

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ABSTRACT

In ophthalmology, retinal laser therapy is a treatment for retinopathy that requires the use of magnifying lens to treat damaged regions of retinal landmarks, hence creating challenges of inverted magnified images and requiring prolonged training. Augmented Reality (AR) can benefit clinicians during retinal laser therapy by guiding them with retinal landmark holograms and contextual information. Though recent developments in AR magnification show that a direct overlay of the magnified scenes can be achieved, retinal laser therapy requires high precision and visual acuity while maintaining the visual perception of the rest of the environment. Therefore, we demonstrate an AR-based selective magnification system that provides contextual and visualization-based guidance to clinicians. An edge-computing architecture is developed for detecting and matching the feature points between the magnified image and color fundus image of the retina to identify the magnified region of retinal landmarks. We showcase how our AR guidance system can assist clinicians during retinal laser therapy.

CCS CONCEPTS

• **Applied computing → Health care information systems**; • **Human-centered computing → Mixed / augmented reality**.

KEYWORDS

Augmented reality, retinal laser therapy, edge computing, magnification, feature matching

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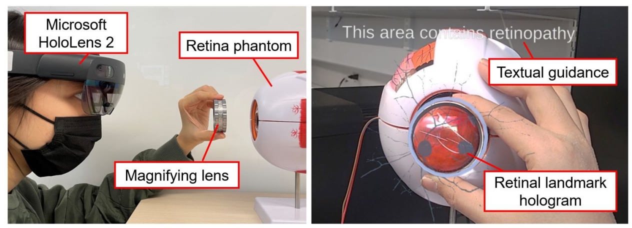

Figure 1: The setup of our AR guidance system includes a Microsoft HoloLens 2, a magnifying lens, and a retina phantom model to simulate retinal laser therapy.

1 INTRODUCTION

Retinal laser therapy, an ophthalmologic procedure that seals or destroys leaking blood vessels in the retina, is an example that can benefit from selective magnification using Augmented Reality (AR). This treatment is commonly performed on patients with various retinal pathologies (e.g., proliferative diabetic retinopathy, diabetic macular edema, and retinal tears) [3]. A common approach used for retinal laser therapy is the laser indirect ophthalmoscope (LIO) which requires the magnifying lenses to be used to examine the fundus (i.e., backside of the retina) of an eye to determine the areas to be treated by the laser, avoiding anatomical landmarks (e.g., macula, optical disc, and blood vessels). However, the use of magnified lenses in LIO produces an inverted image and navigation of the retina requires prolonged training.

Recent developments of AR magnification show that direct magnification can be achieved through the attachment of the head-mounted loupe to the AR headset [4] or the additional external cameras feeding magnified images in real-time [2]. While these approaches directly overlay the visualization of the entire magnified scenes in AR, retinal laser therapy requires selective magnification with the use of magnifying lenses, which is more computationally intensive. The task of treating patients during retinal laser therapy demands high precision and visual acuity for clinicians while maintaining the visual perception of the whole environment. This requires the AR system to selectively magnify a region of interest in real-time [1] and offload the computation of image processing to the edge to optimize the AR experience with minimal latency [5].

To address these challenges of retinal laser therapy with LIO, we propose an edge-based real-time AR magnification system that overlays a hologram of magnified retinal landmarks providing guidance to clinicians during retinal laser therapy. We developed a pipeline of feature matching between the magnified image and color fundus photo (CFP) to identify the location and scale of the magnified region of retinal landmarks on the edge server. The AR app obtains the results of the feature matching and visualizes the hologram of magnified retinal landmarks on a magnifying lens (shown in Figure 1). This selective magnification allows clinicians to be guided on the magnified region (i.e., region of interest) by AR, while maintaining the visual perception of the rest of the environment. To the best of our knowledge, our work is first to integrate AR into retinal laser therapy to selectively magnify the hologram and provide guidance intra-operatively.

2 SYSTEM DESIGN

Figure 2 shows our system architecture. In the pre-operative stage, we compute the retinopathy detection and extract a retinal landmark model from the CFP. This information is then used to provide contextual and visualization-based AR guidance to the users through feature matching during the intra-operative stage.

Pre-operative stage: Using CFP and optical coherence tomography (OCT) images, we computed the retinopathy detection to store information about which regions of retinal landmarks exhibit retinopathy. This information was later used as contextual guidance to alert users on the regions that need to be treated and avoided with the laser. For the creation of the retinal landmark hologram, we extracted a 3D model of retinal landmarks that include the macula, the optical disc, and the blood vessels from an anonymous patient's CFP through thresholding and smoothing. We imported this model to HoloLens 2 to visualize it as a hologram in the user's view.

Intra-operative stage: Due to the computational constraints of HoloLens 2, we offloaded the computation of image processing to the edge server and changed the AR guidance based on the edge processing results to optimize the latency.

Edge processing: The built-in camera sensor on HoloLens 2 captured the magnified image through the magnifying lens by lens detection. The images were then sent to the edge server over a wireless local area network for feature detection and matching. The images were first flipped and converted to a grayscale image. We used a contrast-limited adaptive histogram equalization, a common approach in ophthalmology to enhance feature detection on the CFP, to enable more feature points to be detected. This increased the average number of feature points available on the CFP from 69 to 9268 using the scale-invariant feature transform (SIFT) descriptor from OpenCV. We then matched the points using a fast library for approximate nearest neighbor (FLANN) matching and filtered out for good matching points by using a Lowe's ratio test to eliminate false matches. On average, the SIFT and FLANN-based approach matched 59.9 points (2.51%) and the latency was 147.5ms. The result of feature matching provided the location and scale of the magnified region in relation to the CFP.

AR guidance: HoloLens 2 obtained these results to reflect the magnification by scaling and positioning the hologram of the retinal landmarks. The hologram of the magnified region was overlaid on a magnifying lens, providing visualization-based guidance to the users. Based on the identified magnified region, the name of retinal landmarks and the presence of retinopathy were displayed as text in a hologram to provide contextual guidance to the users.

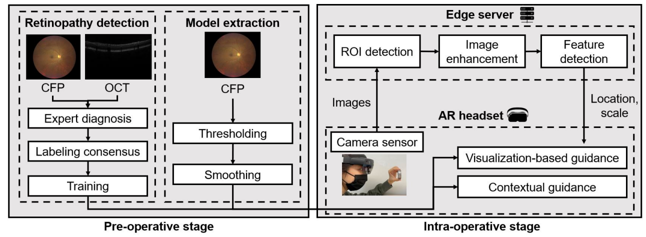

Figure 2: The overall architecture includes the pre-operative stage for retinopathy detection and model extraction using the CFP and OCT images and the intra-operative stage for feature matching and AR-based guidance.

3 INTERACTIVE DEMONSTRATION

We use the same architecture shown in Figure 2 for our demonstration. It allows the participants to develop an understanding of the AR guidance system for retinal laser therapy that benefits from both visualization-based and contextual guidance. We use a custom-designed retina phantom model and a 10x magnifying lens in this demo to simulate retinal laser therapy. The participants are allowed to hold the magnifying lens to inspect the retinal landmarks inside the phantom model. The participants wear the HoloLens 2 to initiate the AR app. A video of the demo is available online.[1]

During the demo, the participants are allowed to freely move the magnifying lens in different angles and directions to inspect different areas of retinal landmarks within the phantom model. Based on the regions of retinal landmarks that are being inspected by the participants, corresponding contextual guidance such as the presence of retinopathy or the name of landmarks is provided as a text hologram in their AR views. Moreover, the participants can understand the practicality and feasibility of the AR guidance system for retinal laser therapy. The participants can envision how the system can guide clinicians in inspecting retinal landmarks and treating the damaged areas (i.e., retinal tears or areas with retinopathy) during retinal laser therapy.

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[1]Link to the demo video: https://sites.duke.edu/sangjuneom/areyesurgery