IPHONE VIRTUAL REALITY TRAINING MODEL FOR MICROSURGICAL PRACTICE

University of Wisconsin Madison - Department of Biomedical Engineering
Team: Nicholas Jacobson, Haochen Wang, Henry Plamondon, Emma Kupitz, Frida Benitez
Clients: Dr. Ellen Shaffrey, Dr. Weifeng Zeng, Dr. Samuel Poore
Advisor: Dr. Aviad Hai, Dr. Alireza Ashtiani

Abstract

Problem:
Currently, medical students have trouble gaining access to locations where microsurgical practice is available due to the scarcity and cost of the large microscopes.

Purpose:
To design a prototype that is compatible with a single smartphone camera lens to reduce the cost and expand the availability of training to virtually any location across the globe. The video should be available to livestream to another computer/phone with minimal lag for immediate feedback from microsurgical trainers. The prototype must provide stereoscopic vision which will allow users to utilize their depth perception to determine the distance between their hands and the workbench.

Final Results:
The final design is a small housing containing angled mirrors capable of being attached to a phone's back camera. This attachment is significantly smaller, cheaper, and more mobile than the surgical microscopes that are currently used. The mirrors work to split the field of view into two images and feed the images into the camera lens simultaneously. This splitting of the image creates binocular vision, thereby creating depth perception with a single lens. This image is then streamed to a second phone in a Google Cardboard virtual reality headset. The student wears the headset while practicing to see a zoomed view of the workbench with depth perception capabilities.

Background

- Microsurgery allows for the treatment of numerous health conditions to extend and improve quality of life.
- Limited availability of microscopes creates a barrier for medical students in various locations to conveniently practice microsurgery often
- Smartphone cameras provide adequate zoom, but lack depth perception, making them difficult to utilize for precise movements vertically
- Humans are capable of perceiving depth due to the angle of light hitting each eye independently, which is mimicked with this prototype

Design Specifications

- Lightweight; < 4.5 kg
- Adequate zoom and resolution to see sutures (0.07mm in diameter) [1]
- Stream delay < 0.5 seconds
- Capable of providing depth perception

Motivation

- Microscopes required for training microsurgeons are expensive, inaccessible, and hard to relocate.
  - This leads to a large barrier to entry when attempting to train various medical students across the globe
- Using a smartphone as a microscope for practice would lower this barrier to entry.
  - Good magnification capabilities, inexpensive, portable, remote (during COVID)
  - Many students have access to a smartphone from any location
- The drawback to using a smartphone camera alone is the lack of depth perception.
- This device seeks to improve upon the depth perception when viewing through the smartphone camera.
  - This will allow our device to more closely mimic and replicate the results of larger microscopes.

Competing Designs

Mitaka MM51 microscope
- High resolution at 160 line-pairs per millimeter
- 42x magnification
- 8:1 Zoom

Orbeye 4K 3D Orbital Camera System
- 4K 3D monitor for shared viewing. Real-life color gamut and depth perception.
- 26x magnification
- No image latency

<u>Drawbacks of Existing Designs</u>
- Expensive: ~$300,000
- Inaccessible: Have to travel to hospital or lab to use
- Hard to transport: Large, heavy, and bulky

Figure 1: Mitaka MM51 Microscope currently used in operating rooms. [2]

Materials

Table 1: Materials and Costs

Component	Use	Cost
3D Printed Material, Grey Pro Resin	Housing	$4
1x1 inch Mirrors	Reflect image	$7.99
Google Cardboard	Stereoscopic display	Provided by client
Phone Boom Arm	Hold imaging device	Provided by client

Figure 2: Prototype design

Methodology and Prototyping

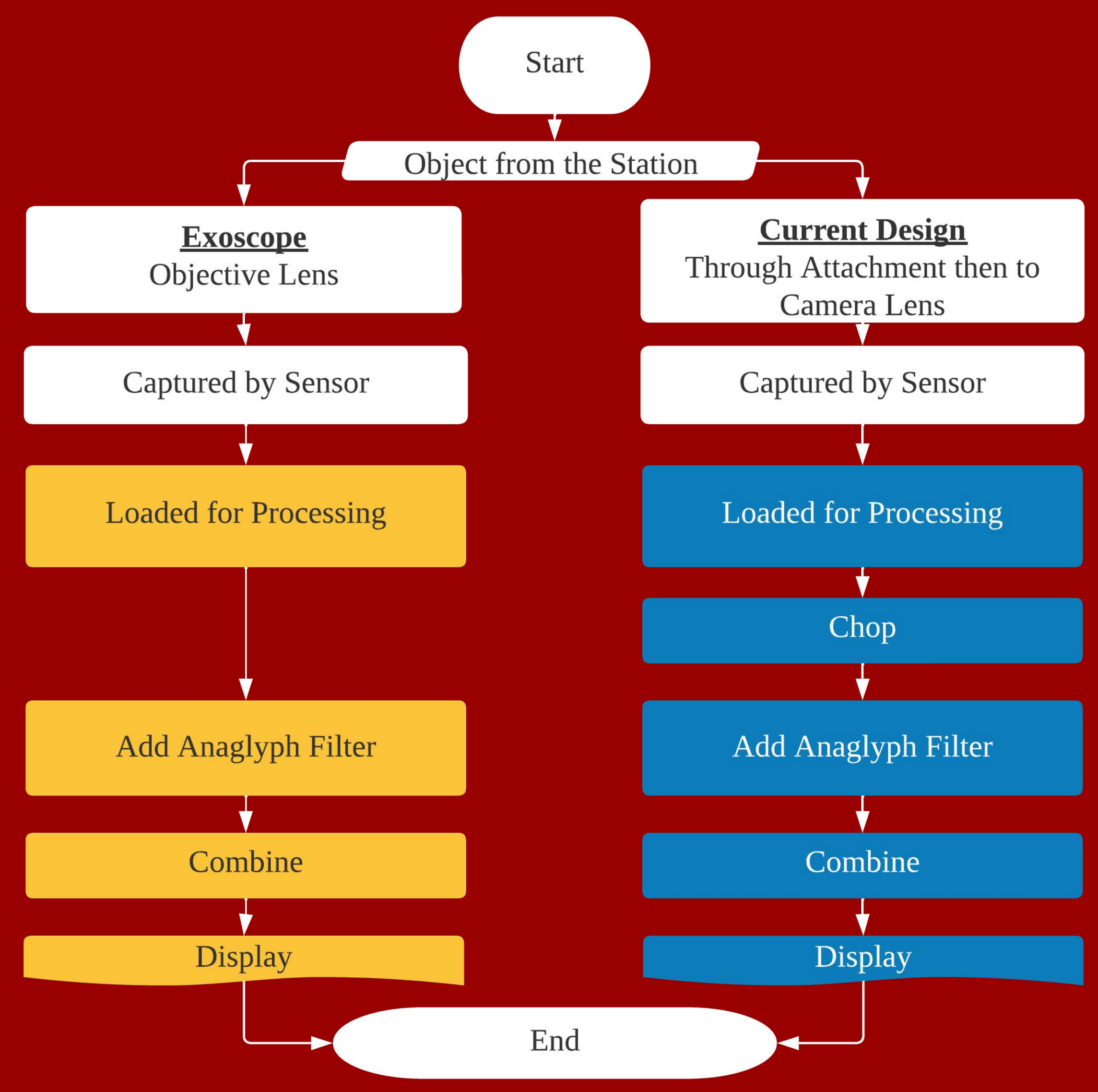

Figure 3: Workflow for exoscope (left) [3], and the mirror attachment design (right). Speculated processes highlighted in yellow; future work in blue.

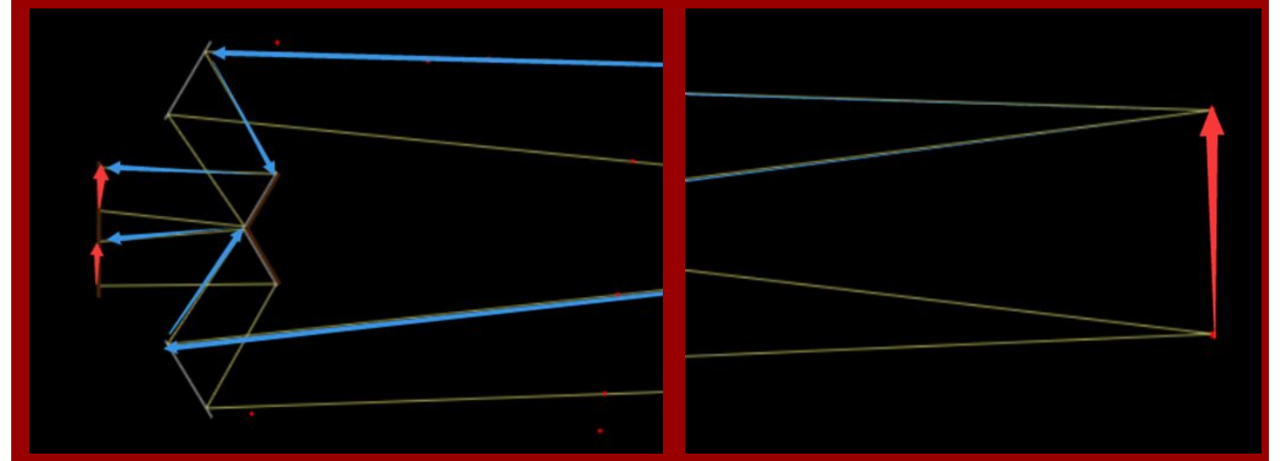

Figure 4: Left - Image forming on the sensor (two red arrows). Right - Light emitted from the object (red arrow). Ray tracing between the images is omitted.

Final Design

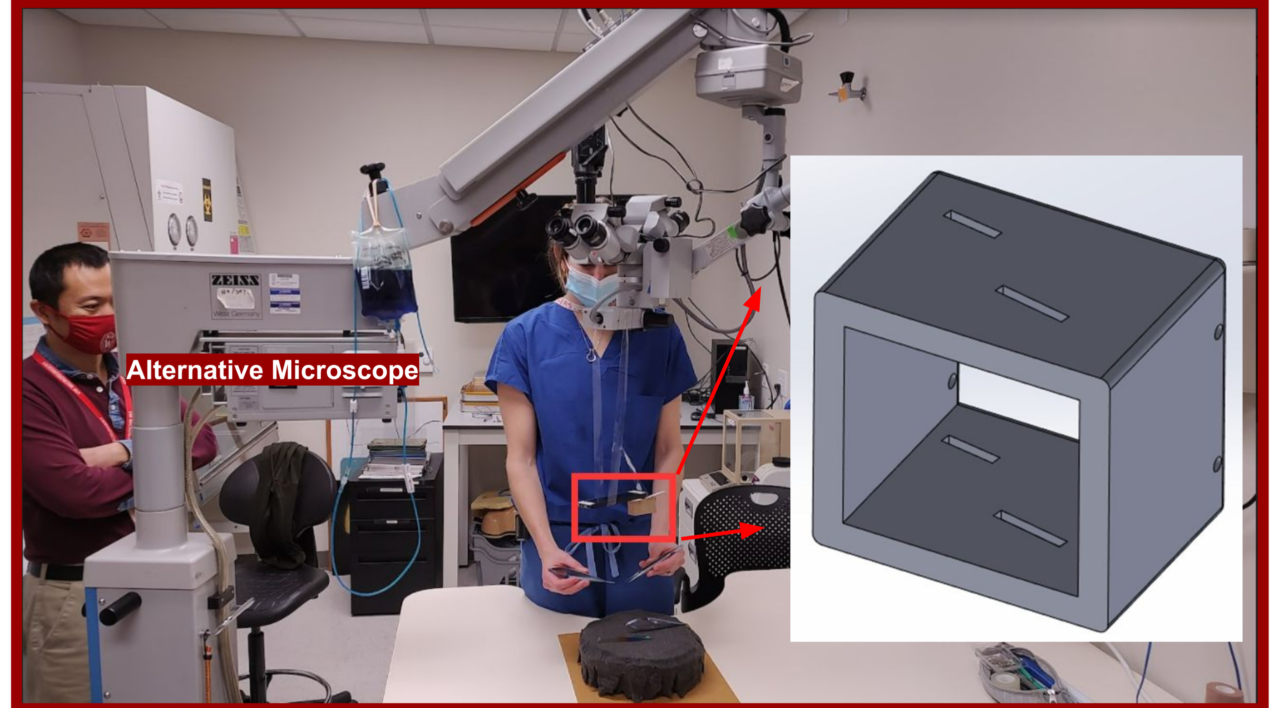

Figure 5: (Left) Prototype being used by the clients for testing, comparing to the size of the microscope currently used by the clients. (Right) CAD drawing of the design.

Testing and Results

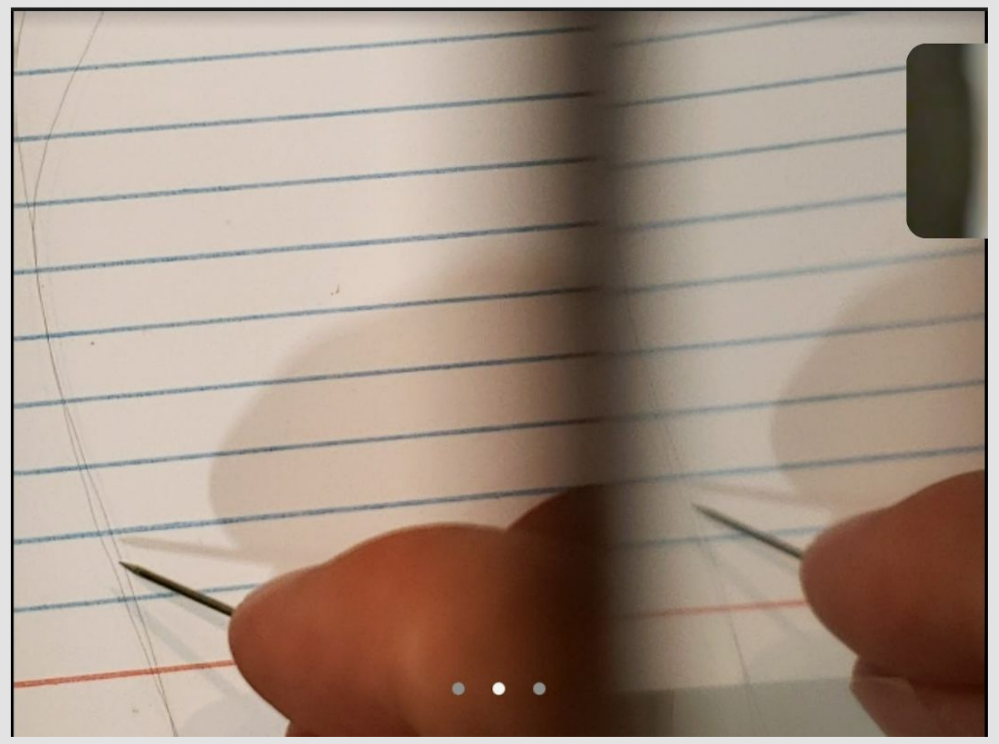

Figure 6: Sample screenshot during testing. The participant aimed to move the suture (thin black line) with a pin. Left-half: image formed between the mirrors (direct capture). Right-half: image formed on the mirrors (reflect capture).

- Improved image quality
- Dimension of the attachment:
  - 2.5 cm x 2.5 cm x 5 cm (Previous)
  - 2.87 cm x 2.34 cm x 3.14 cm (Current)
- FOV
  - 6 cm x 7.5 cm (Previous)
  - 4.7 cm x 7.0 cm (Current)
- Direct (Left) and reflect (Right) capture misalignment
  - x-direction: + 8.45 mm Left/ -9.22 mm Right, compared to FOV
  - y-direction: +5.37 mm Right, compared to Left view

Discussion

- The misalignment in the images undermines the quality and depth perception
- Need for better mirror quality
- Compactness can be improved
- Need for more accurate parameters
- 6-0 sutures are clearly visible on the direct capture, so feasibility of the design is proved

Conclusion

- The goal for the semester was to create a prototype that improved the previous one made last semester
- Ultimately the prototype should give medical students the access to practice microsurgery through a single lens that provides depth perception
- Some of the most important goals achieved are:
  - A small prototype that is immensely easier to transport than the current, alternative microscope
  - Stereoscopic vision, which gives a sense of depth perception
  - The ability for students to practice from any location, regardless of distance to the nearest laboratory
  - Compatibility with a smartphone, which virtually every student owns
  - A significant cost reduction from the current alternative microscope
  - Stable housing of the prototype to prevent movement of the mirrors
  - Improved image quality
  - Less blindspots in the image
- Although not every aspect of the project is complete, the progress made during the semester has provided new insight into the design as new challenges were presented that had not been considered before
- This prototype may also have implications beyond the medical field, providing alternative to virtual reality products that are currently available.

Future Work

- Improve depth perception
- Devise a more precise fabrication technique
- Devise a way to reduce delay created when the image is streamed
- Implement low-latency software to clean up the video
- Implement manual focus to increase clarity
- Perform testing with surgical trainees to assess the device's performance
- Implement a stable attachment to the phone

References

[1] B. M. A. A; "The surgical suture," Aesthetic surgery journal, Apr-2019. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/30869751/. [Accessed: 24-Sep-2021].
[2] "Highest Resolution Microsurgery Microscope | MM51," *Mitaka USA*. https://mitakausa.com/mm51/ [accessed Oct. 15, 2021].
[3] NSD Surgical Imaging, "NDS Surgical Imaging 4K 3D," *NDS Surgical Imaging*, 10-Jul-2020. [Online]. Available: https://www.ndssi.com/4k-3d/. [Accessed: 07-Dec-2021].

Acknowledgements

Dr. Ellen Shaffrey, Dr. Weifeng Zeng, Dr. Samuel Poore, Dr. Aviad Hai and Dr Alireza Ashtiani