IPHONE VIRTUAL REALITY TRAINING MODEL FOR MICROSURGICAL PRACTICE

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Abstract

Problem:
Currently, it is difficult for students to gain access from various locations to microsurgical training due to cost and availability.

Purpose:
To design a prototype that is compatible with a single smartphone camera to reduce cost of training and increase availability from any location. The video should be able to be livestreamed for immediate instructor feedback. The prototype also needs to produce depth perception similar to a microscope.

Final Results:
The final design is a small housing of angled mirrors that attaches to a phone. This attachment is significantly smaller, cheaper, and more mobile than the surgical microscopes that are currently use This phone is supported above the practice site by a stand. The mirrors split the view into two images and feed it into the camera lens simultaneously. This splitting of the image creates binocular vision, thereby creating depth perception with a singular camera.
Finally, this image is streamed to a secondary phone in a virtual reality headset. The student wears the headset while practicing to see depth and a detailed image while practicing.

Background

- Microsurgery allows for the treatment of numerous health conditions to extend and improve quality of life.
- Limited availability of microscopes makes training microsurgeons more difficult and limits the amount of trainees possible.
- Smartphone cameras provide decent zoom, but lack depth perception, making them difficult to use as a microscope.
- Binocular view of the same object enables depth perception of human beings.

Design Specifications

- Lightweight; < 4.5 kg
- Ability to clearly see sutures (0.07mm in diameter) [1]
- Stream delay < 0.5 seconds
- Possesses depth perception

Motivation

- Microscopes required for training microsurgeons are expensive, inaccessible, and hard to relocate.
  - This leads to a large barrier to entry when trying to practice microsurgery.
- Using a smartphone as a microscope for practice would lower this barrier to entry.
  - Good magnification capabilities, inexpensive, portable, remote (during COVID)
- The largest drawback with using a smartphone camera is the lack of depth perception.
- Our device looks to improve upon the depth perception when viewing a subject through the smartphone camera.
  - This will allow our device to more closely resemble 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

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

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

Materials

Table 1: Materials and Costs

Component	Use	Cost
Cardboard	Housing	Recycled
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], previous team's design (middle), and the mirror attachment design (right). Speculated processes highlighted in yellow; future work in blue.

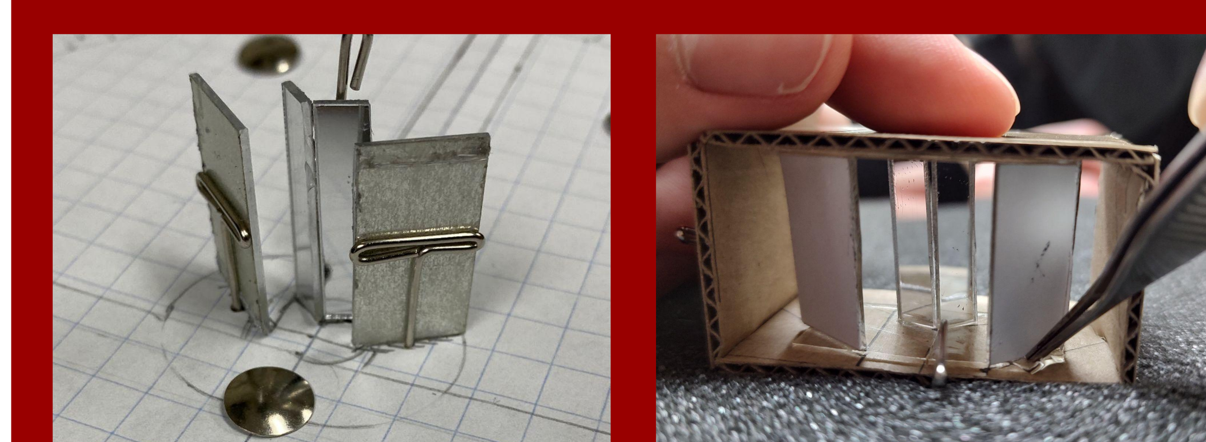

Figure 4: (Left) Determination of the most optimal parameters. (Right) Adjusting mirrors for Prototype Mark II.

Final Design

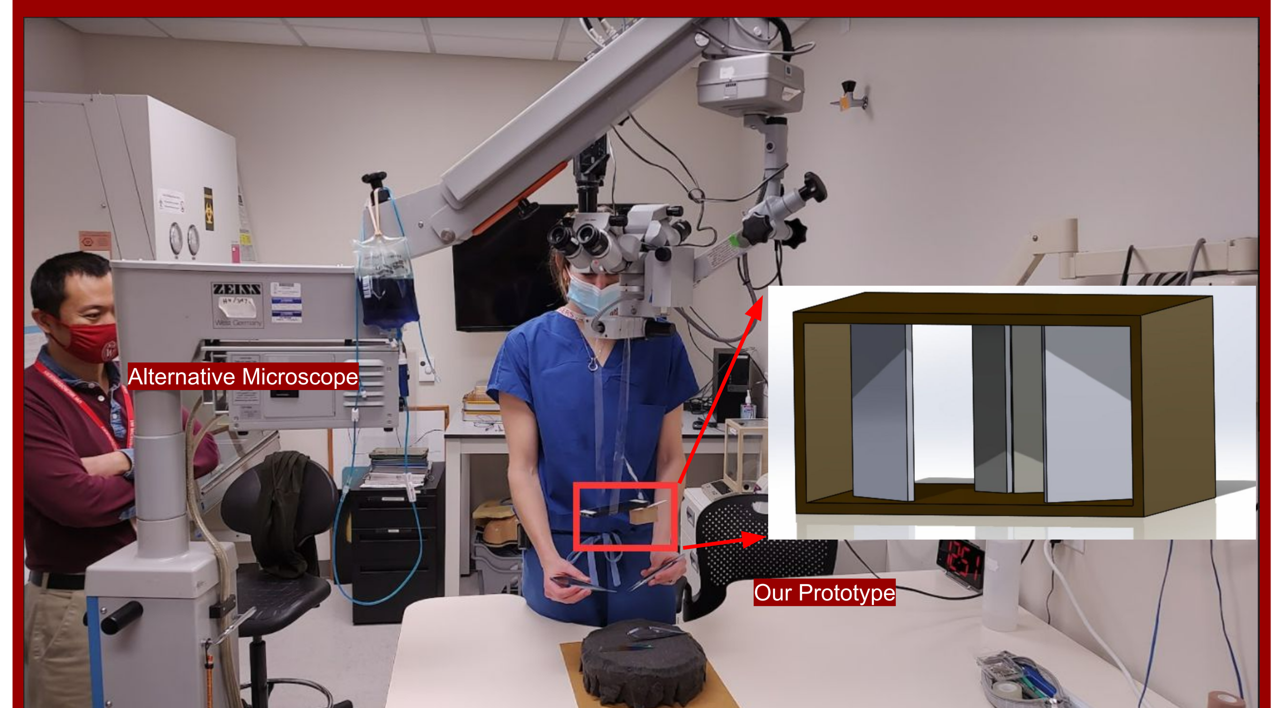

Figure 5: (Left) Prototype being used by the clients for testing, comparing to the size of the microscope currently used by the clients. (Right) CAD drawing of the design.

Testing and Results

Figure 6: (Left) Sample image produced by the design (Right) Testing on depth of perception by a team member. With Google Cardboard on, the member is trying to move sutures with a tweezer via the video streamlined from a smartphone with the attachment.

Depth perception and image quality
- FOV of 6 cm x 7.5 cm
- Acceptable image quality
  - Hard to distinguish sutures from the background
- Depth difference is perceived
  - Cannot be quantified with unstable prototype

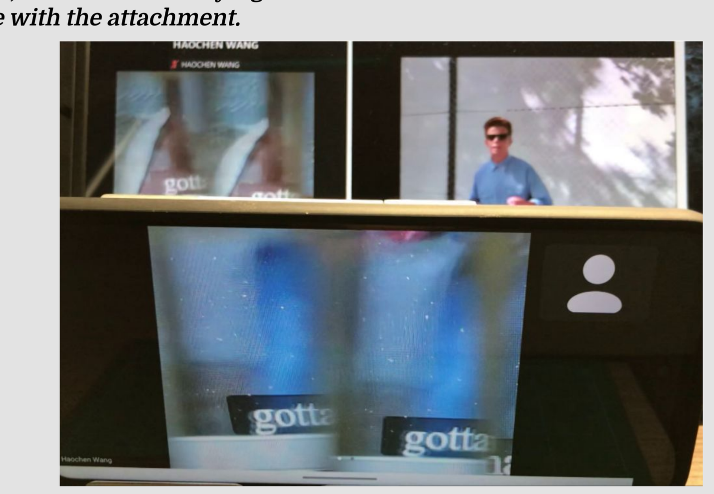

Figure 7 (Top): Measurement on the time delay between video recorded with the attachment and the streamed monitor via zoom. (Top left) Streamed video on a monitor via zoom (Top right) Music video being captured by the design (Bottom) Smartphone capturing the music video.

Delay and Compactness
- Dimension of the attachment:
  2.5 cm x 2.5 cm x 5 cm
- Average delay: 0.21s
  - 0.15s for non- real-time video from previous team
- Optical simulation shows that the surface area of the mirrors are not fully used

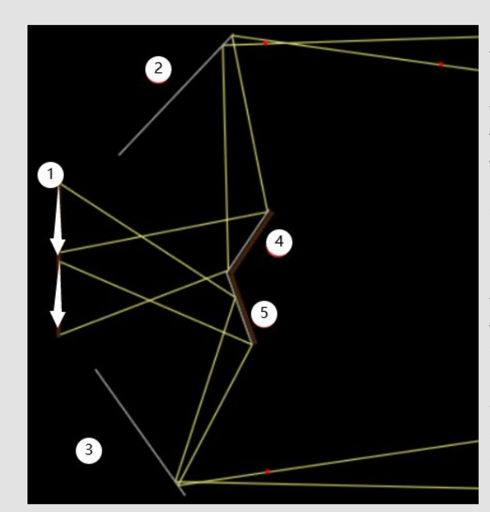

Figure 8 (Left): Optic simulation. Light from the subject gets reflected by the outer mirrors (2), (3) onto the inner mirrors (4), (5). Then, light will be directed through the camera lens (1), forming two identical views of the subject. (represented by two upside-down arrows). Arrows will be converted upright by the camera lens.

Discussion

- Need for better depth perception and image quality
- Time delay is high
- Compactness can be improved
- Need for a stable prototype

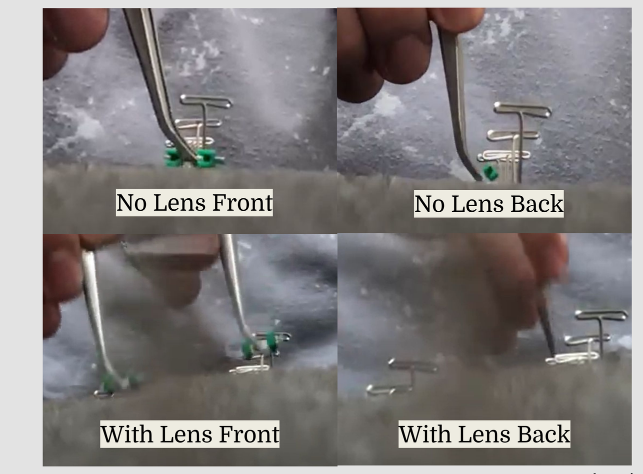

Figure 9: Comparison for depth perception without (top) and with (bottom) the attachment.

Conclusion

- The goal for the semester was to develop a prototype that allows medical students practicing microsurgery to visualize a small workspace 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
- Although not every aspect of the project is complete, the progress made during the semester has paved the way for future work to be planned and executed in coming semesters
- The scope of the topics regarding optics and ray patterns exceed the education of the team, however, this was overcome and depth perception was achieved nonetheless
- This prototype may even have implications beyond the scope of the medical field and into other fields of technology and virtual reality as a cheap, easy alternative to some of the more expensive and clunky virtual reality products currently on the market

Future Work

- Increase stability of mirrors in the housing, possible via 3D printing
- Devise a more precise fabrication technique
- 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
- Devise a more natural way to view the subject.

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

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