VIRTUAL REALITY TRAINING MODEL FOR MICROSURGICAL PRACTICE

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Abstract

Problem:
Currently, medical students and surgical residents have difficulty gaining access to locations of microsurgical practice due to the scarcity and expense of large microscopes.

Purpose:
To produce a final design concept that can recreate the experience of a commercial surgical microscope at a low cost that can expand the availability of training to virtually any location across the globe. The video should be accessible via stream to a VR headset with minimal lag for immediate feedback for microsurgical trainees. The design concept must provide stereoscopic vision to allow users to utilize depth perception to determine the distance between their hands and the surgical specimen as well as navigate the surgical field.

Final Results:
The final design consists of two webcams fixed in place by a 3D printed chassis and angled downward towards the surgical field. A Raspberry Pi microcomputer receives the input of the two cameras and sends the images over a local server to an Oculus VR headset. The user views each of the images in each eye, and disparities between the two images in each eye allows for depth perception. The software of our final design was stable and provided minimal latency over long durations of use. This design is the first reported self-contained digital microscope VR system capable of stereoscopic vision.

Background

- Microsurgery allows for the treatment of numerous health conditions.
- Microscopes required for training microsurgeons are expensive, inaccessible, and hard to relocate.
  - This leads to a large barrier to to training for various types of physicians across the globe [1].
- Modern webcams have good magnification capabilities and are inexpensive, portable, and can operate anywhere with internet.
  - The affordability of webcams is ideal for at-home training systems
- Individual webcams lack depth perception.
- This device seeks to provide the user with depth perception when viewing the surgical field [2].
  - Achieve a comparable experience to the use of commercial microscopes.

Design Specifications

- Lightweight; < 4.5 kg
- Adequate zoom and resolution to see sutures (at 0.07mm diameter) [3]
- Stream delay < 0.5 seconds
- Capable of providing stereoscopic vision

Competing Designs

Mitaka MM51 microscope [4]
- 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. [4]

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

Materials

Table 1: Materials and Costs

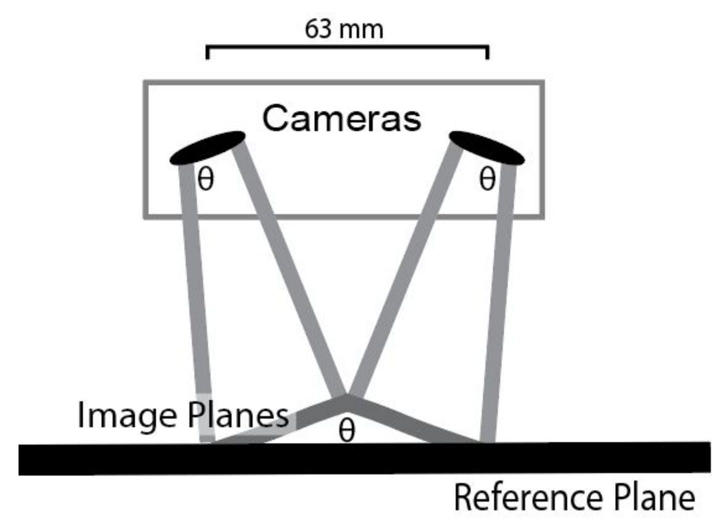
Component	Use	Cost
Logitech C920 Webcam	Image Acquisition	$100 each, 2 units
3D printed chassis	Hold webcams	$53
Oculus Quest 2	Stereoscopic display	$320
Phone Boom Arm	Hold chassis	$30
Total		$573

Figure 2: Early proof-of-concept prototype design utilizing a double-mirror array fabricated from cardboard.

Final Design

A.

B.



C.

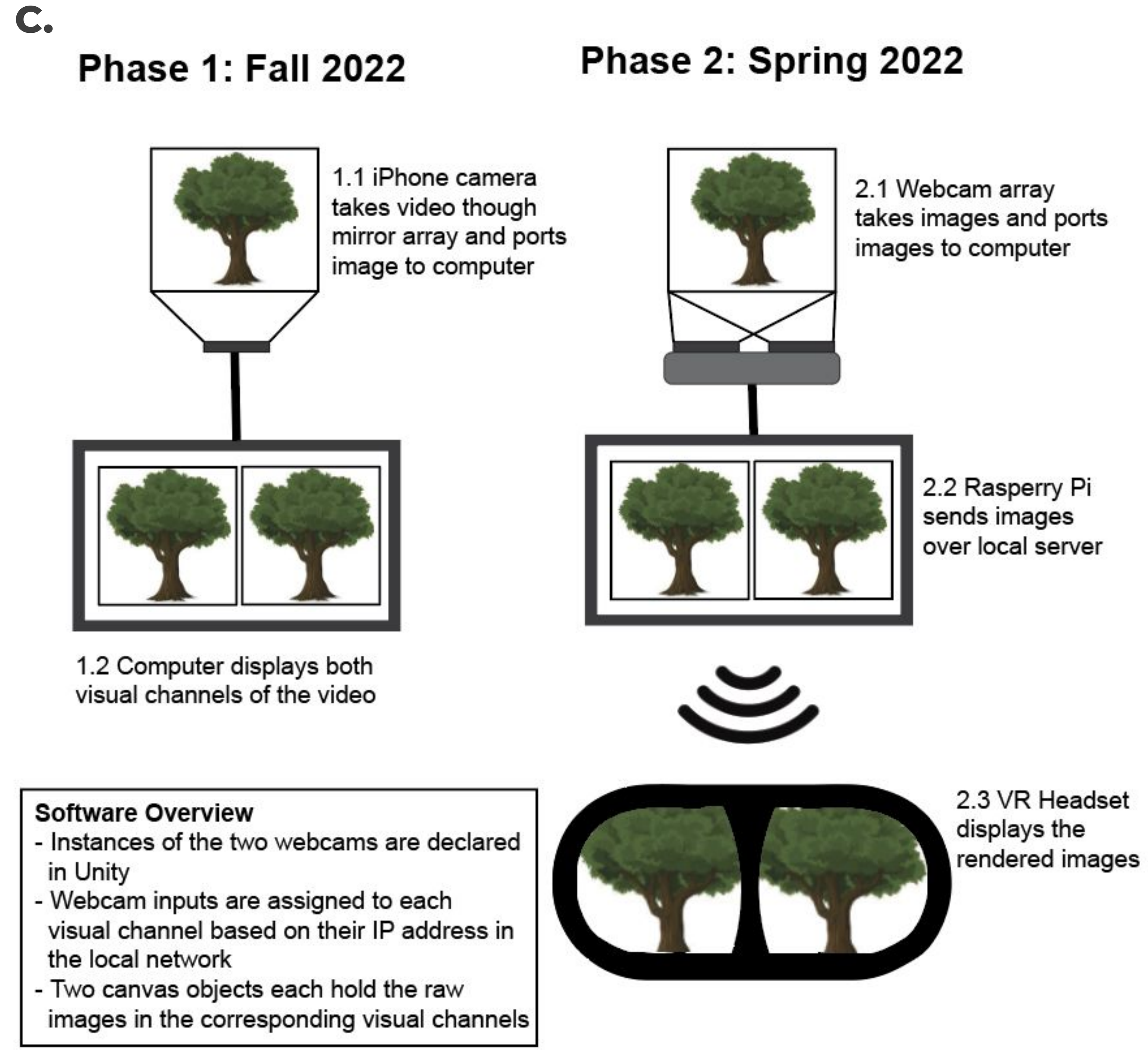


Figure 3: (A) The two phases of the design's progress. Phase 1 was defined by software development for video acquisition and local image streaming; Phase 2 was defined by the implementation of VR for video display. The general workflow of the software used for image streaming and presentation is shown. (B) Image of the design in-use. (C) Schematic of the final design of the webcam array. Both webcams are placed at focal disparity of 63 mm, the distance between human pupils. The angle θ can be modulated by adjusting the configuration of the webcam array. The disparities between two inclined image planes allow for stereoscopic vision.

Methodologies of Testing

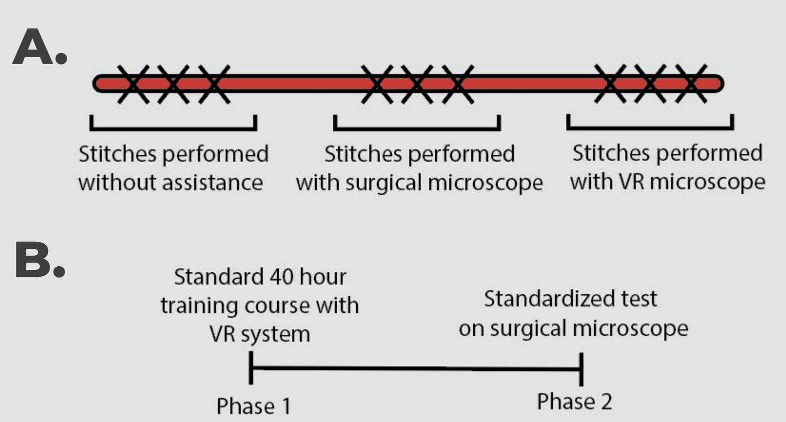


Figure 4. Methodologies to be used for evaluating the VR Microsurgery system. (A) Schematic of the assay to compare unassisted, surgical microscope-, and VR system-assisted suturing. The order that each regime is completed will be randomized. Suturing will be performed using a practice pad with 10 medical student or resident participants of varying levels of experience. The user experience of each trial will be evaluated using the SMaRT scale [3]. (B) Schematic of evaluating the system as a training tool. A sample of 10 untrained medical student volunteers will undergo a standardized 40 hour training course with the VR system prior to performing suturing on a surgical microscope.

Table 2: The SMaRT scale [3]

Category	Description
Instrument Handling	Fluid, concise movements
Respect for "Tissue"	Minimal tissue damage
Efficiency	No wasted movements or loss of needle
Suture Handling	Controlled and delicate sutures, no wasted movements
Suturing Technique	Accurate needle placement
Quality of Knot	Square, snug ends
Final Product	Smooth outer appearance
Operation Flow	Appropriate pace over planned course
Overall Performance	All aspects completed

Results

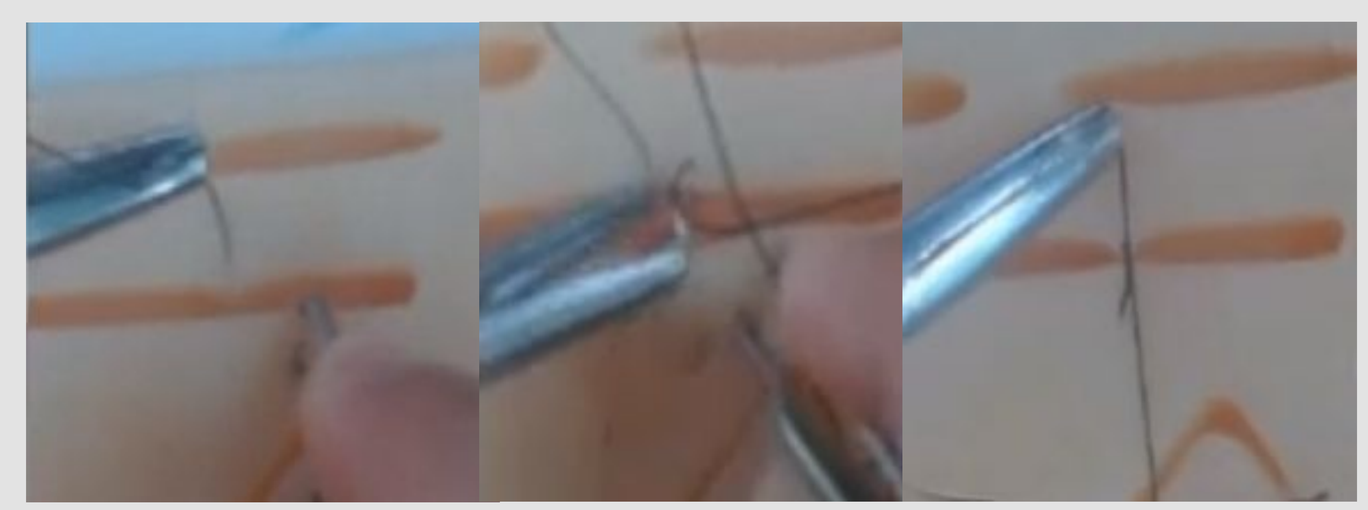


Figure 5: Screenshots for the left eye from the completion of a suture using the VR microsurgery system during Phase 1 testing. Multiple sutures were able to be completed in succession, starting with the passage of the needle into the incision, exit of the needle from the other side of the incision, and tying of the knot.

During proof-of-concept testing, multiple observations were made on the efficacy of the design
- Frame rate averaged 30 fps and never went below 15 fps, which is in alignment with established metrics of quality [3].
- The software build in Oculus was stable, though fluctuations in quality occurred.
- The autofocus feature of the webcams often corrupted view of the surgical field.
- Subjective user experience could be noticeably distinguished from the experience of a surgical microscope, yet showing potential as a training method.
- Adjustments in camera alignment could easily achieved to correct for horizontal and vertical disparities on the image plane.

Discussion

- Logitech webcams provide a 90° field of view.
  - Distortion arises near the edges of the field of view.
  - Solutions may exist in software.
- Autofocus feature in webcams often construed the image of the surgical field.
  - Hardware and software solutions are yet to be explored.
- Raspberry Pi may create bottleneck for image streaming.
  - Lower bound of 15 fps is manageable for surgical practice [2].

Conclusion

- The goal of the semester was to refine the final prototype in preparation for extensive testing in the clinical settings.
- Ultimately, the prototype should give medical students the access to practice microsurgery through a VR system that provides depth perception
- Some of the most important goals achieved are:
  - A significant cost reduction from commercial microscopes.
  - A compact design concept that is portable and easy and set up compared to commercial microscopes.
  - Stereoscopic vision, and therefore depth perception.
  - The ability for students to practice from any location, regardless of distance to the nearest laboratory.
  - Stable housing of the prototype to prevent movement of the mirrors.
  - Improved image quality.
  - Minimization of blind spots in the image.
- Among goals not maximally achieved, minimal conceptual modifications to the prototype are needed.
  - Most limitations lie in the hardware configuration of the prototype.
- This prototype may also have implications beyond the medical field, providing alternative to virtual reality products that are currently available.

Future Work

- Proceed to large-scale phases of testing to determine the design's potential as a replacement for current microscopes and as a training device.
- Create protocols for the calibration of camera angles for future development of automatic adjustment features.
- Invest in software and hardware to restrict the autofocus of the webcams.
- Continue software development to achieve a wrapped projection of the images onto the spatial canvas to mimic the surgical microscope.

References

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Acknowledgements

We would like to thank Dr. Block for his insights and advice, and we would like to thank our clients for the opportunity to explore microsurgery training.
We would like to acknowledge Alexander Vasquez and previous BME design teams for their intellectual contributions to this project.
Special thanks to Dr. Puccinelli for coordinating BME Design program.