iPhone Virtual Reality Model for Microsurgery

BME 402

Team Members: Haochen Wang, Samuel Neuman

Advisor: Professor Wally Block

Clients: Dr. Ellen Shaffrey, Dr. Samuel Poore and Dr. Weifeng Zeng

Overview

1. Motivation and problem statement
2. Background
3. Product Design Specifications (PDS)
4. Previous work
5. Current design
6. Calibration and testing
7. Final prototype and cost
8. References

Commercial gap in portable microsurgery training solution.

Figure 1: The client Dr. Shaffery is using a Zeiss microscope to perform an animal surgery.

- Client: Poore lab focuses on developing novel strategies for peripheral nerve regeneration
- Surgical microscopes: $200k to 1m [1]
- Shortage of microscopes
- Challenges to livestream the practice

Competing concepts fall short in accessibility and similarity

Figure 2: Omano Stereo Boom dissecting microscope

- $700 USD
- Fixed aperture requires external lighting
- Incompatible with a camera

Figure 3: Jianmongkol et al. used a simple smartphone setup [2]

- Lack of stereoscopic vision
- Not intended for training simulations

Technical Constraints and Quantitative Specs

- Stereoscopic display for video output
- Resolution high enough to see 7-0 sutures (0.070 mm in diameter)
- Minimal 30 fps; maximum 0.1 s display latency
- Portability and minimal reliance on external infrastructure

Summary of Previous Work

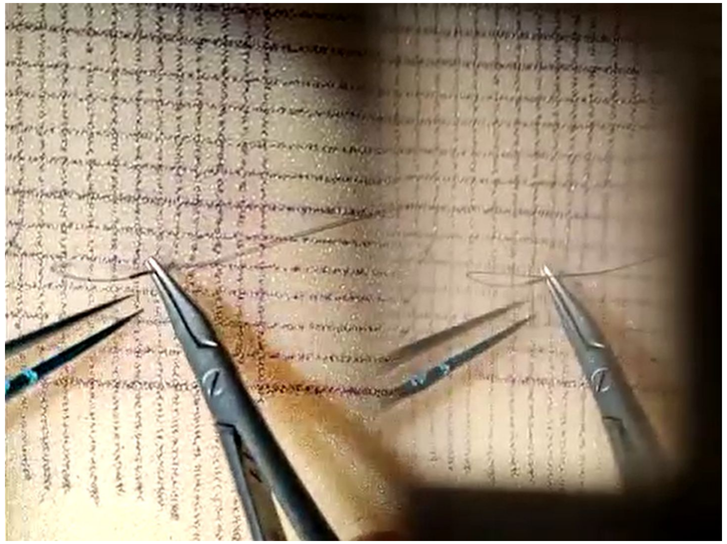


Figure 4. Visual output of concept.

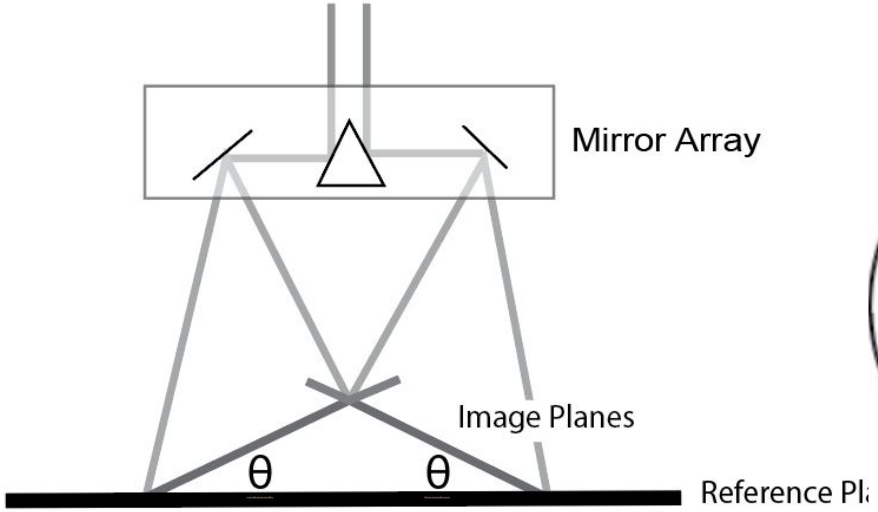


Figure 5. Ray tracing diagram of mirror array

- Computational approach: image transformations performed in silico
- Close resemblance to surgical theater
- Poor use of resources

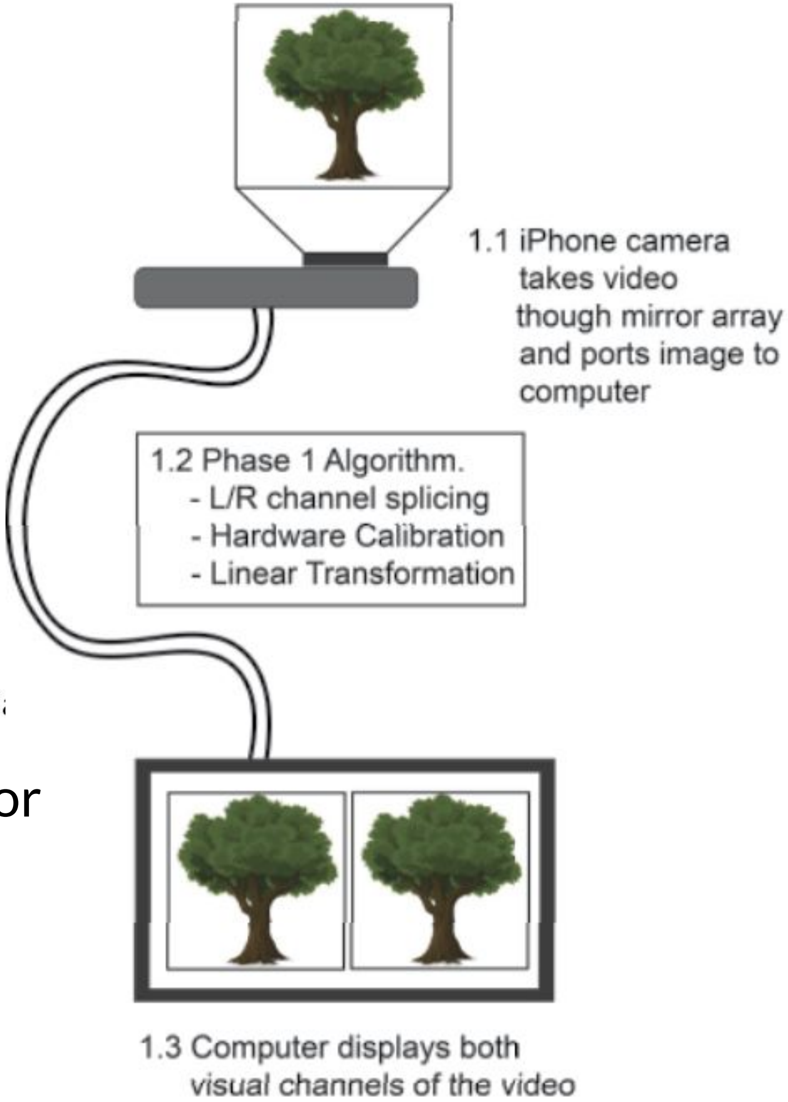
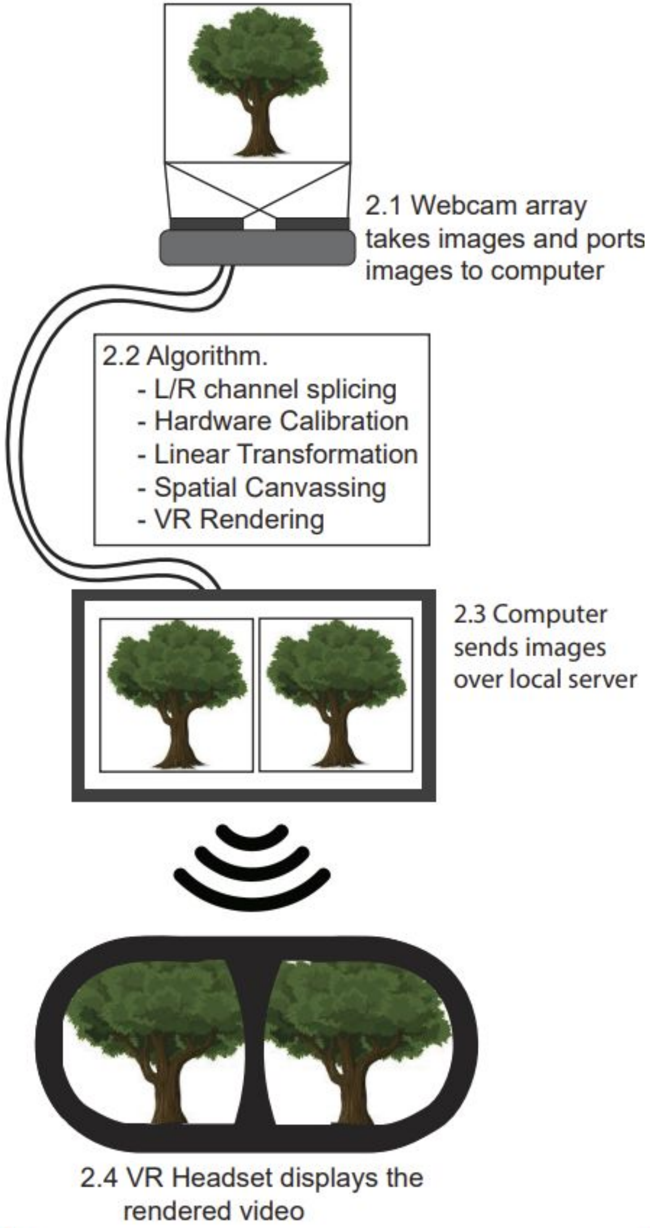


Figure 6. Schematic of previous concept.

Final Design Concept

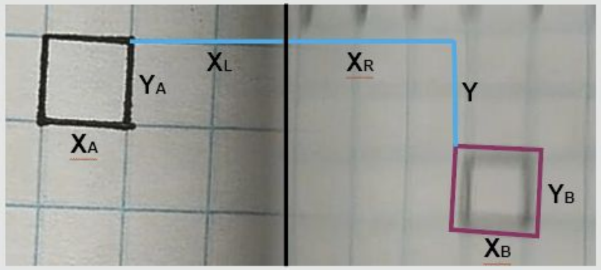
- Two webcams fixed 60mm apart focus on the object of interest
- Hardware connection feeds images from both webcams into reference in Unity program
- Necessary calibrations are made for rendering
- Videos are simultaneously streamed to the VR headset and displayed on a computer

Figure 6. Schematic of final design concept. Stereoscopic vision is achieved through disparity between two webcams; images from each webcam are presented separately to each eye. Final design requires wireless connection for streaming between computer and VR headset.



Plans for Calibration and Testing

- Establish functional distance of use range (Feb.)
- Write methods for real-time adjustments to focal distance (Feb. - Mar.)
- Write methods for calibration of image position in 2D vector space (Feb. - Mar.)
- Perform live testing with medical students and residents (by Mar. 31st)
    - Timed test of chicken breast anastomosis vs. microscope
    - Exit survey on ease of use, feasibility, practicality



Calibration Angles

$$\Delta\phi_x = F \times arcsin(X_L - X_R)$$

$$\Delta\phi_y = F \times arcsin(Y)$$

Normalization

$$\mathbf{A} = \begin{bmatrix} X_A & 0 \\ 0 & Y_A \end{bmatrix} \quad \mathbf{B} = \begin{bmatrix} X_B & 0 \\ 0 & Y_B \end{bmatrix}$$

$$define \;\; \mathbf{S} \in \mathbb{R} = \begin{bmatrix} \cos(\theta) & 0 \\ 0 & 1 \end{bmatrix}$$

$$det(\mathbf{A}) = det(\mathbf{B} \times \mathbf{S}) = Area = xycos(\theta)$$

Figure 6. Calculations relevant to positioning of images in 2D plane.

Final Prototype and Cost

- Apk file to install Unity project
- User manual
- Cardboard packaging for the following components (provided by clients)
  - Oculus Quest 2 ($ 425)
  - Logitech C920 webcam (2 x $ 65)
  - Raspberry Pi 4 ($ 45)
  - Camera stand ($ 15)

Estimated total: $ 615

Acknowledgements

We would like to thank Prof. Block for his assistance advising us this semester in continuing to improve our prototype and guiding us through the design process.

We would also like to thank Dr. John Puccinelli for planning and setting up this class to allow us to work as a BME design team.

And of course, we would like to thank Dr. Ellen Schaffrey, Dr. Samuel Poore, Sahand Eftekari and Dr. Weifeng Zeng for the opportunity to work with them on designing this prototype to help the future of microsurgery trainees!

References

[1] D. Grady, “Orbeye 3-D system turns surgery into dizzying, immersive experience,” *The Columbus Dispatch*, 12-Jan-2018. [Online]. Available: https://www.dispatch.com/news/20180114/orbeye-3-d-system-turns-surgery-into-dizzying-immersive-experience#:~:text=Mark%20Miller%2C%20a%20spokesman%20for,cost%20about%20%24400%2C000%2C%20Langer%20said. [Accessed: 15-Oct-2021].

[2] “ORBEYE 4K 3D Digital Video Microscope | Olympus Medical Systems,” *www.olympus.co.uk*. https://www.olympus.co.uk/medical/en/Products-and-solutions/Medical-specialities/Neurosurgery/ORBEYE.html [accessed Oct. 15, 2021].

[3] A. Glennerster, S. P. McKee, and M. D. Birch, “Evidence for surface-based processing of binocular disparity,” vol. 12, no. 10, pp. 825–828, May 2002, doi: S0960-9822(02)00817-5 [pii].

[4]

S. K. Gupta and P. Gupta, “Anaglyph stereo virtual dissection: a novel inexpensive method for stereoscopic visualisation of intracardiac anatomy on CT angiogram,” vol. 31, no. 12, pp. 1958–1961, Dec. 2021, doi: 10.1017/S1047951121001323 [doi].