iPhone Virtual Reality Model for Microsurgery

BME 400

Team Members: Haochen Wang, Alex Vazquez, Sam Neuman

Advisor: Professor Wally Block

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

Presenting: Haochen

Overview

1. Motivation and problem statement
2. Background
3. Previous work
4. Product Design Specifications (PDS)
5. Proposed designs
6. Design matrix
7. Future Work
8. References

Commercial gap in portable microsurgery training solution.

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- Cost $200,000 to 1 million[1]

- Huge and heavy

- Hard to stream the practice

Figure 1: The client Dr. Shaffery is using microscope from Zeiss to perform a neurosurgery on mice. Team member Alex (in grey) is viewing the process from one pair of eyepieces.

Smartphones are better in terms of portability, accessibility, and cost than competing designs.

Figure 2: Orbeye 4K 3D Orbital Camera System

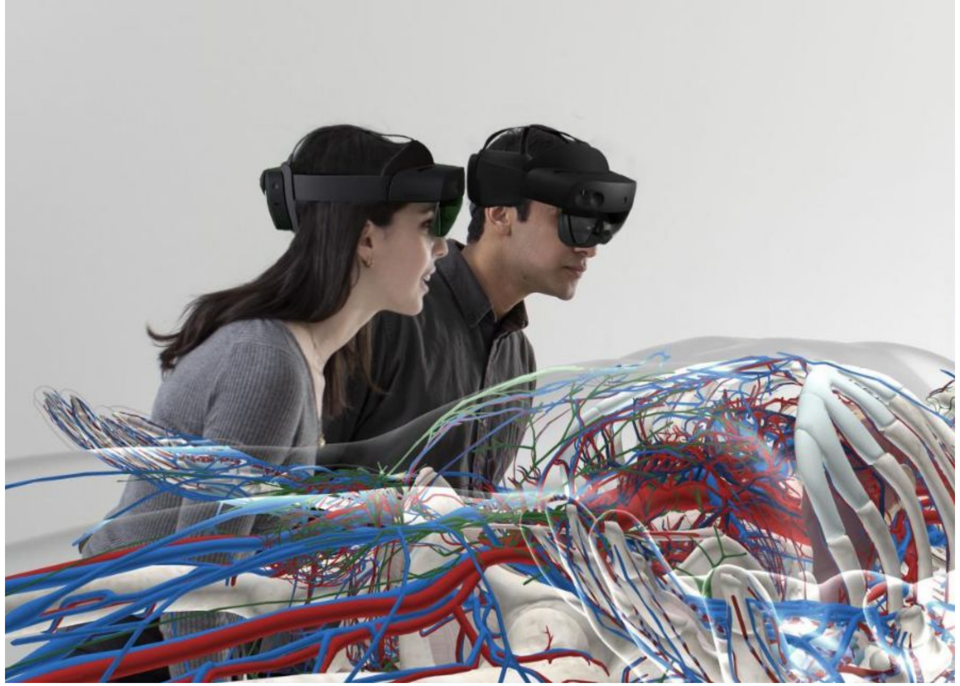
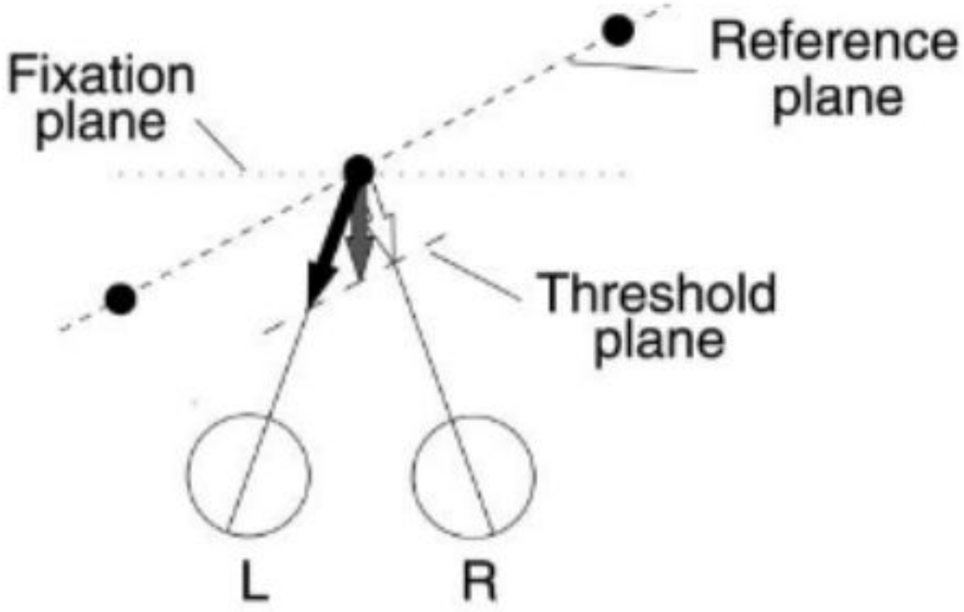


Figure 3: Microsoft Hololens 2

Single lens smartphone does not provide depth perception.

- Depth perception requires a reference plane for the object
- 2D image does not provide depth cues



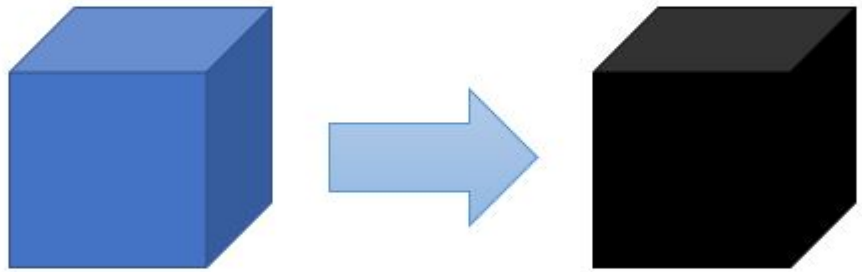


Figure 4(top): illustration of how binocular disparity (depth perception) is formed from a reference plane to the object being observed [3].
Figure 5(bottom): a demo on how 2D image captured by a single lens camera fails to provide depth cues.

Previous team developed algorithm with anaglyph filter for real-time video processing.

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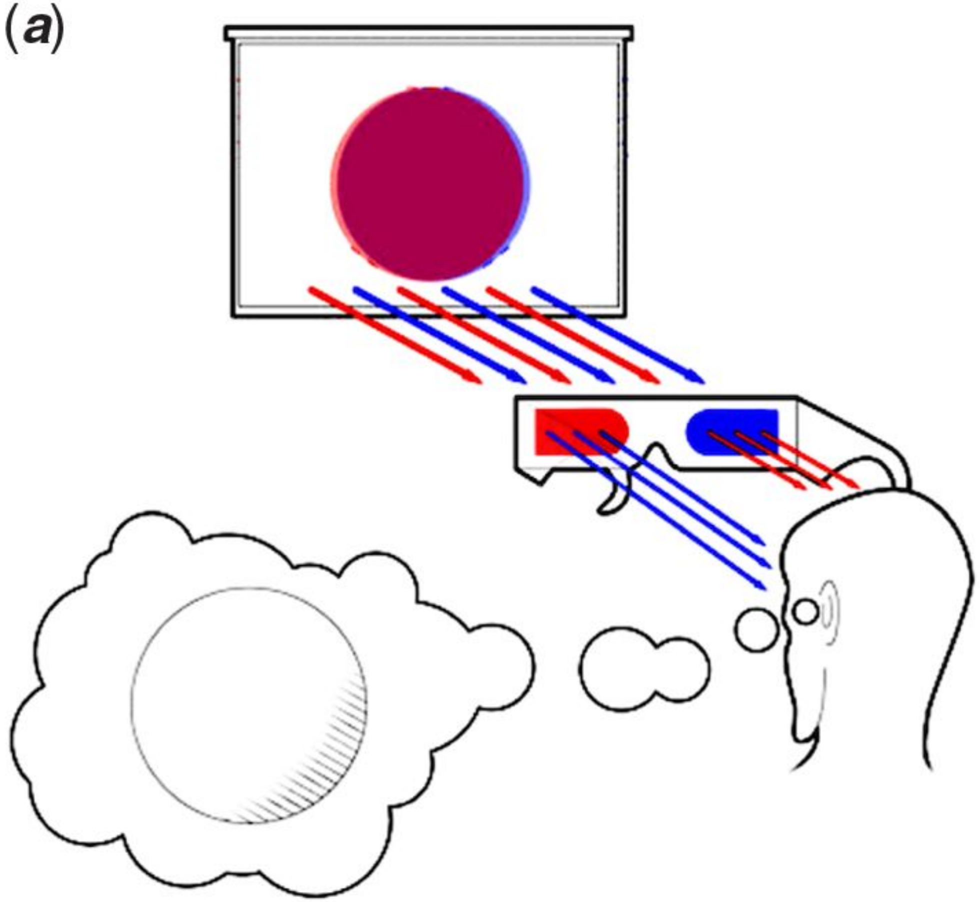

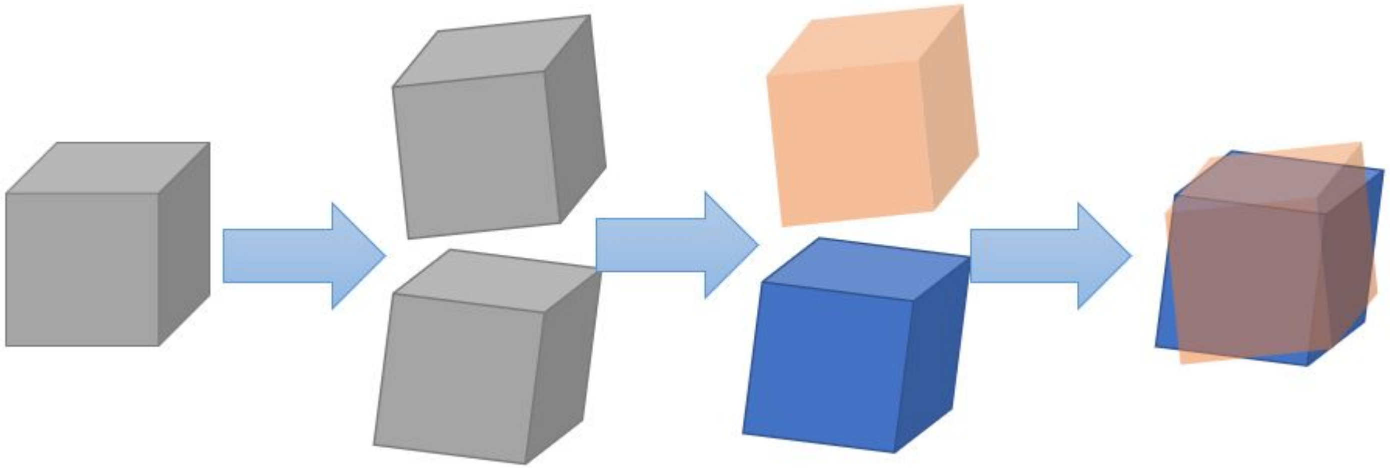

- Figure 6(left): mechanism of anaglyph 3D
- Figure 7(right): illustration of the algorithm

Previous team developed smartphone attachment to reduce running time.

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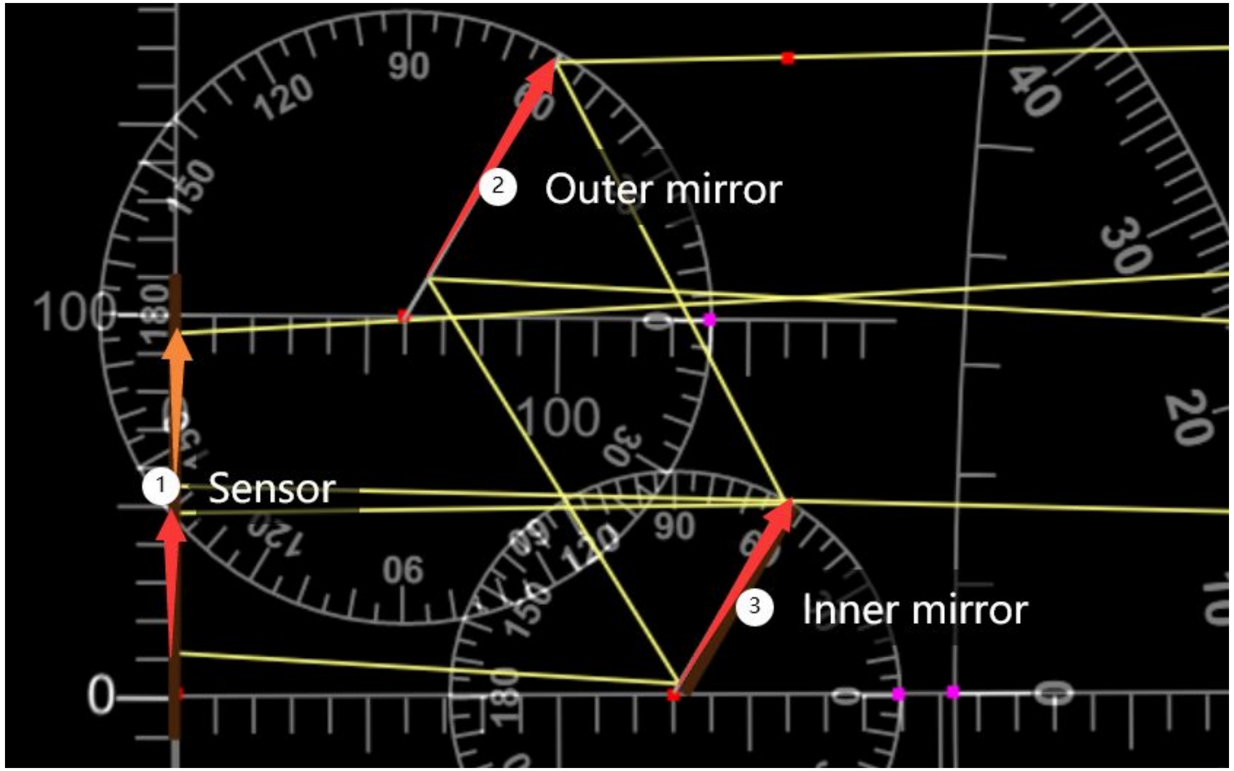

Figure 8: ray tracing diagram

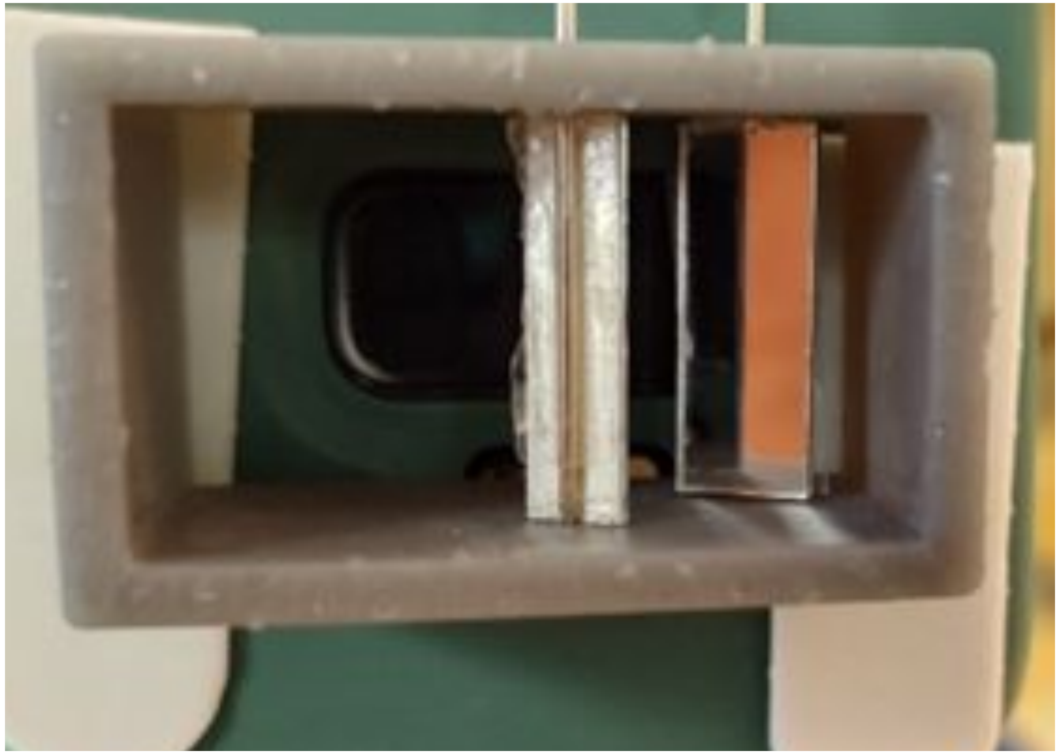

Figure 9: 3D-printed prototype

The primary goal of this semester is to combine the designs.

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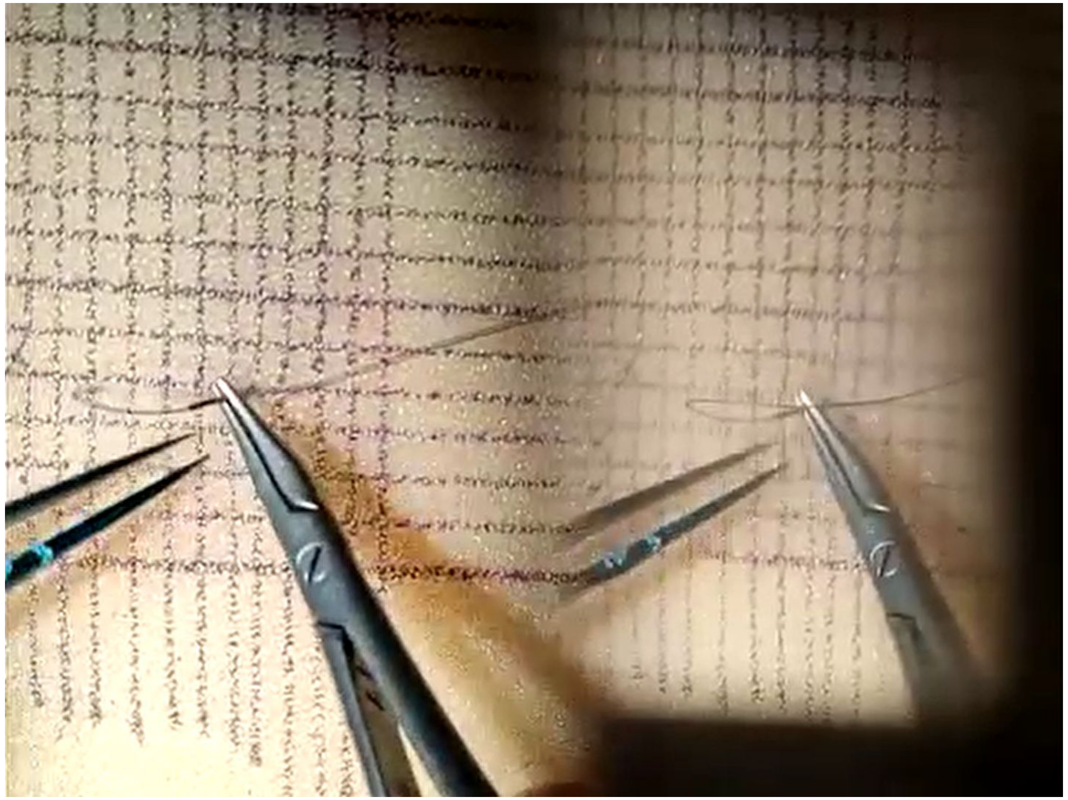

Figure 10 (left): image processed with anaglyph filter

Figure 11 (right): screenshot from smartphone attachment

Additional requirements are specified in PDS since last semester.

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Design requirement:

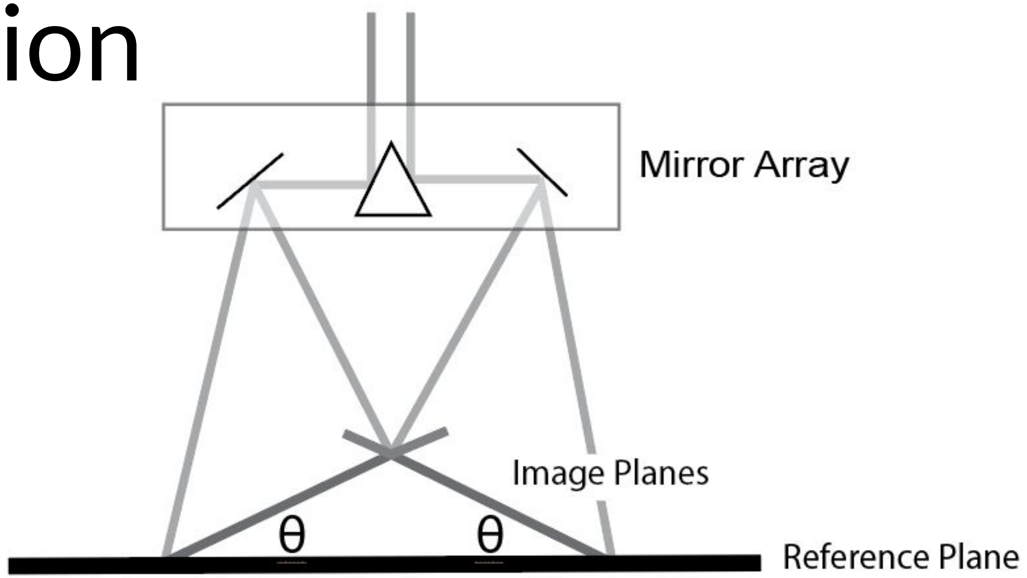
- Light weight: < 4.5 kg
- Stereoscopic display for video output
- User awareness of the surrounding environment

Performance requirement:

- Resolution high enough to see 7-0 sutures (0.070 mm in diameter)
- Minimal 30 fps; maximum 0.1 s display latency

Basis of Image Transformation

- Small amount of overlap with focussed image planes
  - Crop centers of each image
- Pixel grayscale averaging to combine contributions for 3D effect
- Linear transformation to 'flatten' images for 3D effect



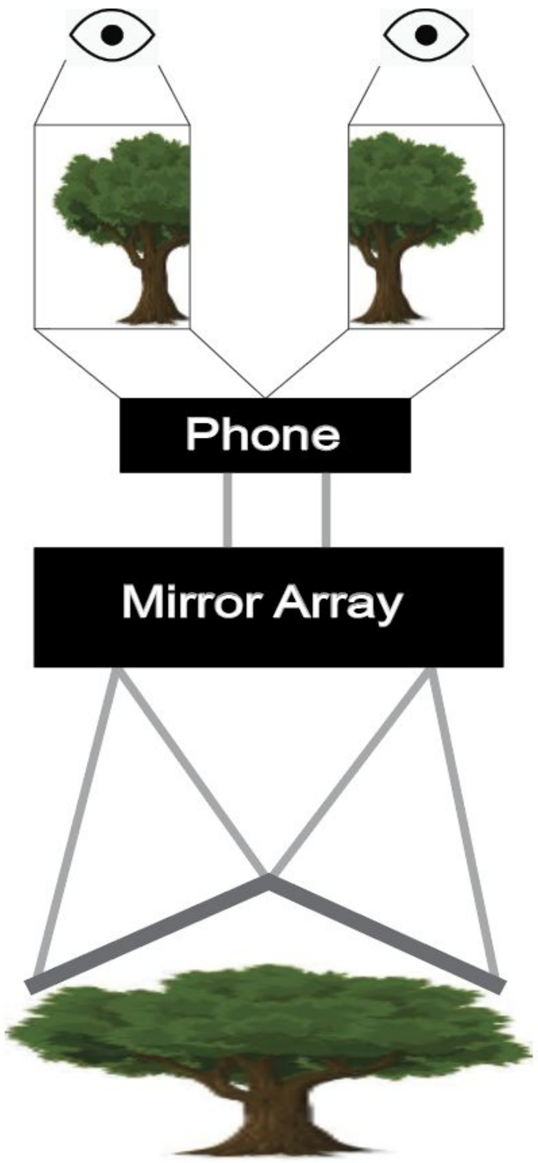
$$\{\mathbf{A} \in \mathbb{R}\} = \begin{bmatrix} \cos(\theta) & 0 \\ 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} x & 0 \\ 0 & y \end{bmatrix} \times \mathbf{A} = \begin{bmatrix} \mathrm{x}\cos(\theta) & 0 \\ 0 & y \end{bmatrix}$$

Presenting: Sam

Design 1: Single Frame View

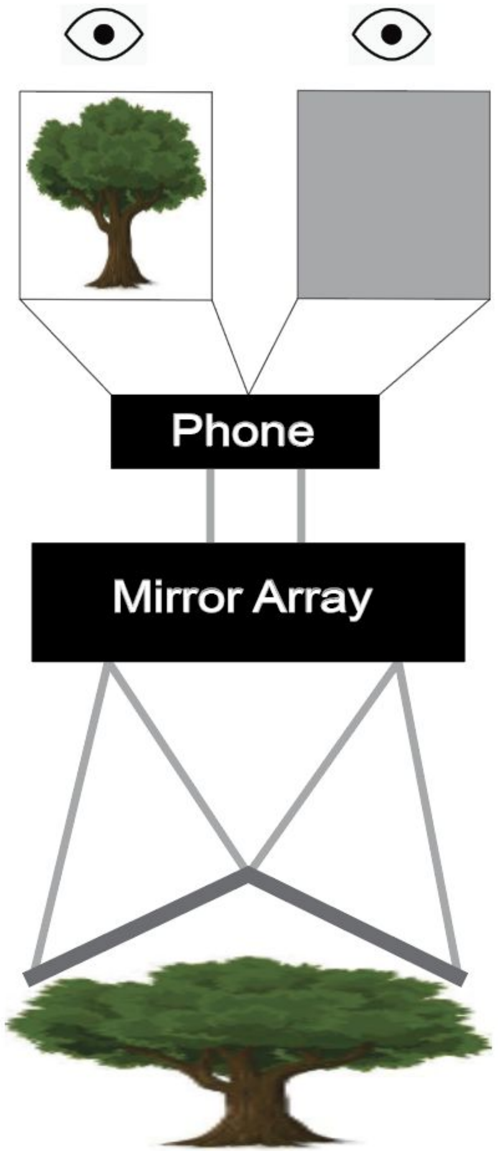
- Left and right images presented simultaneously
    - Operate at 60 fps
- Two perspectives stitched together at region of overlap
- Linear transformation to flatten image
- Both eyes are shown different sides of the image



Presenting: Sam

Design 2: Combined Frame View

- Left and right images presented in alternative fashion
  - Operate at 120 fps
- Two perspectives stitched together at region of overlap
- No flattening
- Both eyes are shown full image at different perspectives



Presenting: Alex

Design Matrix

Criteria		Combined Frame View		Single Frame View	
	Weight	Raw Score	Score	Raw Score	Score
Effectiveness (Latency)	25	3/5	15	5/5	25
Sensitivity (Depth Perception)	20	4/5	16	5/5	20
Ease of Use	20	5/5	20	4/5	16
Cost	15	3/5	9	2/5	6
Compatibility	10	4/5	8	2/5	4
Frame Rate	5	4/5	4	2/5	2
Durability	5	4/5	4	5/5	5
Total	100	27/35	76	25/35	78

Table 1: Design matrix of proposed materials. The criteria assigned with a full score are highlighted in yellow. And the highest total score is highlighted in green.

Presenting: Alex

Future Work

- Finalize software processing of image
- Rework physical mounting of mirrors

Figure 7: Visual of workspace through lens with rectangles outlining the slight blind spot in the middle of the image

Presenting: Alex

Acknowledgements

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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].