JOHNS HOPKINS
WHITING SCHOOL of ENGINEERING

LABORATORY FOR Computational Sensing + Robotics

CIS II Spring 2019 Project 11

Augmented Reality Magnifying Loupe for Surgery

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Background

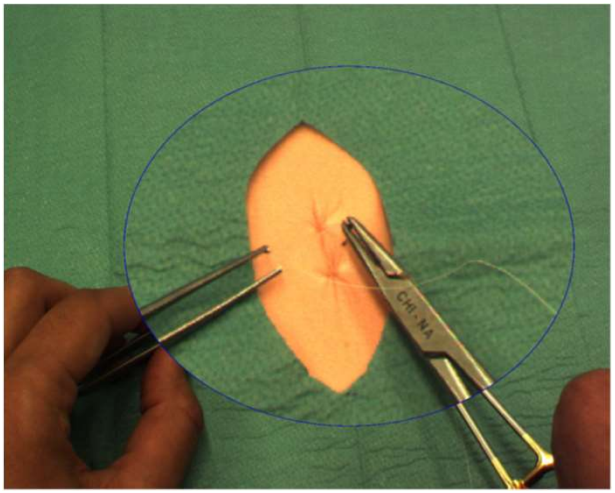
- A magnifying loupe is often used in surgical procedures, including neurosurgery and dentistry, in order to enhance the vision of fine detail [1].

- Augmented Reality (AR) guidance in the loupe can potentially help the practitioner in navigation and operation.[2]

[1] James, Teresa, and Alan SM Gilmour. "Magnifying loupes in modern dental practice: an update." Dental update 37.9 (2010): 633-636.
[2] Ho-Beom Kwon, Young-Seok Park & Jung-Suk Han (2018) Augmented reality in dentistry: a current perspective, Acta Odontologica Scandinavica, 76:7, 497-503

Previous work

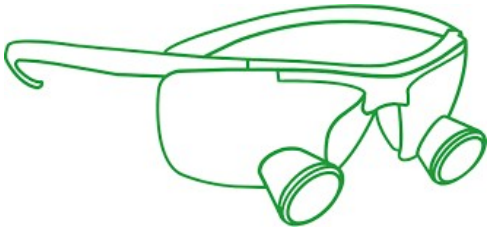
Method	Limitations
Video see-through	Latency
Digital magnification	Low Resolution

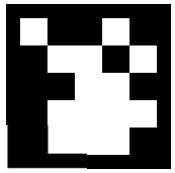


[1] Martin-Gonzalez, Anabel, et al. “Head-Mounted Virtual Loupe with Sight-Based Activation for Surgical Applications.” *2009 8th IEEE International Symposium on Mixed and Augmented Reality*, 2009,

Objectives

- Design a surgical loupe mount for optical see-through head-mounted display (HMD)
- Develop a calibration method to associate the field-of-magnified-vision, the HMD screen space and the task workspace
- Evaluate the proposed system





Technical approach
HMD Choice

Microsoft HoloLens

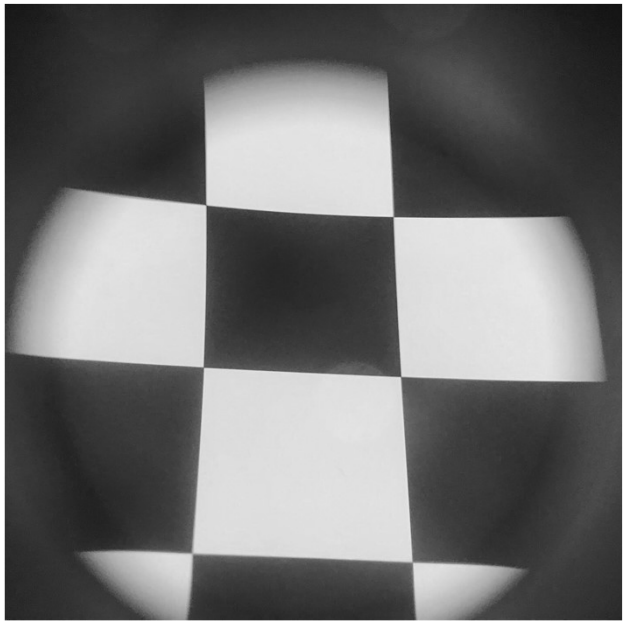
Magic Leap One

Epson BT-300

Technical approach
Mechanical Design

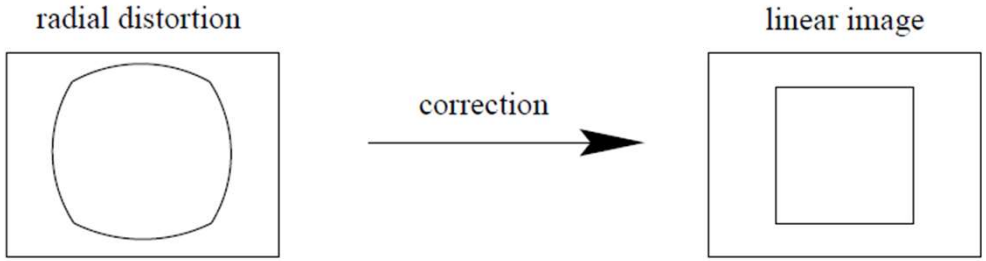
- Interchangeable lens for different magnification (x2 – x3.5)
- Able to flip
- Adjustable distance for different users

Technical approach
Distortion Correction

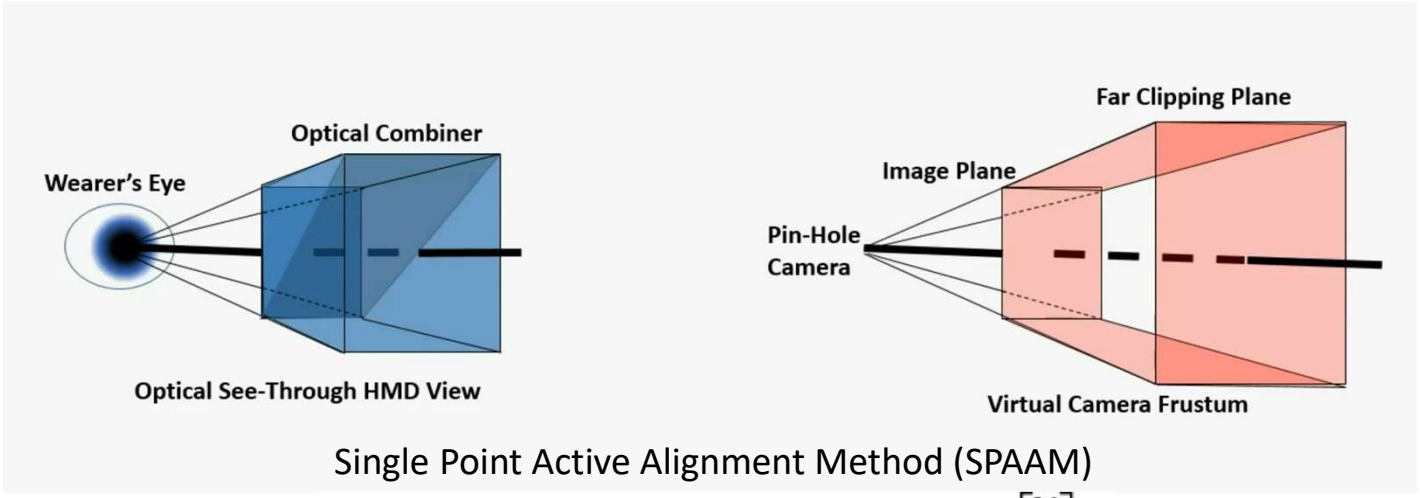


Radial Distortion

$$x_{corrected} = x(1 + k_1 r^2 + k_2 r^4 + k_3 r^6)$$
$$y_{corrected} = y(1 + k_1 r^2 + k_2 r^4 + k_3 r^6)$$



Technical approach
HMD Calibration



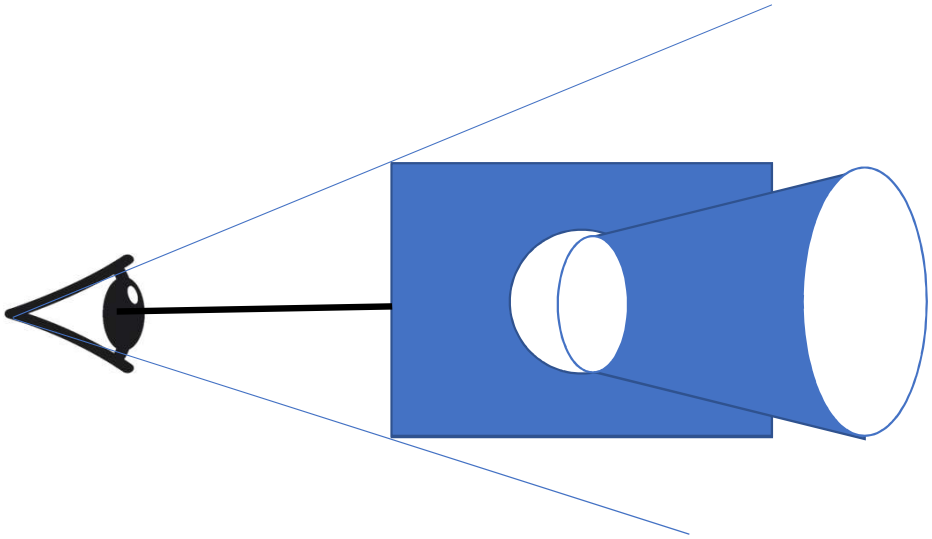
Single Point Active Alignment Method (SPAAM)

$$s\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} f_x & s & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} r_{11} & r_{12} & r_{13} & t_1 \\ r_{21} & r_{22} & r_{23} & t_2 \\ r_{31} & r_{32} & r_{33} & t_3 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

2D Image Coordinates | Intrinsic properties (Optical Centre, scaling) | Extrinsic properties (Camera Rotation and translation) | 3D World Coordinates

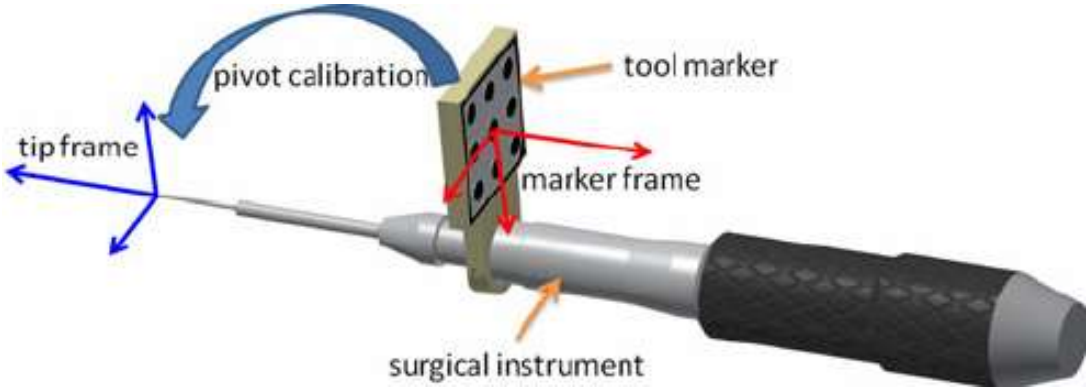
[1] K. R. Moser and J. E. Swan, "Evaluating optical see-through head-mounted display calibration via frustum visualization," 2015 IEEE Virtual Reality (VR), Arles, 2015, pp. 371-371.

Technical approach
Rendering



Screen Loupe

Technical approach
Tracking



[1] Wang, Junchen & Suenaga, Hideyuki & Hoshi, Kazuto & Yang, Liangjing & Kobayashi, Etsuko & Sakuma, Ichiro & Liao, Hongen. (2014). Augmented Reality Navigation With Automatic Marker-Free Image Registration Using 3-D Image Overlay for Dental Surgery. IEEE transactions on bio-medical engineering. 61. 1295-304.

Dependencies

Dependencies	Solution	Alternative	Estimated Date
Access to Magic Leap One	Ask Dr. Navab for access	Ask Ehsan for Epson BT-300	Feb 25
Access to surgical loupe	Ask Long for access		Resolved
Access to CAD Software (SolidWorks or PTC Creo)	Download from JHU software catalog		Resolved
Access to 3D printer	Access to LCSR 3D printer	Use DMC 3D printer	Resolved

Key dates and milestones

- Mar 4: Finish Hardware prototype, begin calibration
- Mar 25: Finish calibration for single eye
- Apr 8: Finish stereo calibration, begin evaluation
- May 6: Finish evaluation
- May 9: Finish project report

Schedule

	Feb 11	Feb 18	Feb 25	Mar 4	Mar 11	Mar 18	Mar 25	Apr 1	Apr 8	Apr 15	Apr 22	Apr 29	May 6
Literature review													
Plan proposal and presentation													
Design and manufacture HMD mount for loupes													
Develop HMD calibration methods for single eye													
Develop stereo HMD calibration methods													
Identify a practical sub-task in surgery													
Conduct a comparative phantom study													

Deliverables

- Minimum: A hardware prototype to integrate Magic Leap One with magnifying loupe, a calibration process for single eye
- Expected: A user-friendly stereo calibration process to associate the field-of-magnified-vision, the HMD screen space and the task workspace
- Maximum: Evaluation results of proposed system with a comparative phantom study

Management Plan

- Weekly meeting with Long, Prof. Unberath, and Prof. Kazanzides
- Code on GitHub private repository
- Design document, project report on JH Box

Reading list

- [1] James, Teresa, and Alan SM Gilmour. "Magnifying loupes in modern dental practice: an update." Dental update 37.9 (2010): 633-636.
- [2] Martin-Gonzalez, Anabel, et al. “Head-Mounted Virtual Loupe with Sight-Based Activation for Surgical Applications.” *2009 8th IEEE International Symposium on Mixed and Augmented Reality*, 2009.
- [3]Tuceryan, Mihran, Yakup Genc, and Nassir Navab. "Single-Point active alignment method (SPAAM) for optical see-through HMD calibration for augmented reality." Presence: Teleoperators & Virtual Environments 11.3 (2002): 259-276.
- [4] L. Qian, A. Winkler, B. Fuerst, P. Kazanzides and N. Navab, "Reduction of Interaction Space in Single Point Active Alignment Method for Optical See-Through Head-Mounted Display Calibration," 2016 IEEE International Symposium on Mixed and Augmented Reality (ISMAR-Adjunct), Merida, 2016, pp. 156-157.
- [5] L. Qian, E. Azimi, P. Kazanzides et al., "Comprehensive tracker based display calibration for holographic optical see-through head-mounted display", 2017.
- [6] C. B. Owen, Ji Zhou, A. Tang and Fan Xiao, "Display-relative calibration for optical see-through head-mounted displays," *Third IEEE and ACM International Symposium on Mixed and Augmented Reality*, Arlington, VA, USA, 2004, pp. 70-78.
- [7] Y. Itoh and G. Klinker, "Interaction-free calibration for optical see-through head-mounted displays based on 3D Eye localization," *2014 IEEE Symposium on 3D User Interfaces (3DUI)*, Minneapolis, MN, 2014, pp. 75-82.
- [8] E. Azimi, L. Qian, P. Kazanzides, and N. Navab. Robust optical see-through head-mounted display calibration: Taking anisotropic nature of user interaction errors into account. In Virtual Reality (VR). IEEE, 2017.