



JOHNS HOPKINS
M E D I C I N E

Evaluating Colored VR Navigation for Laminectomy and Mastoidectomy

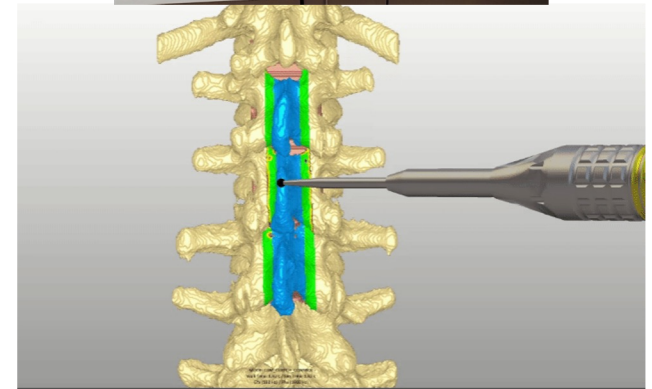
Team 19: Jonathan Wang, Kesavan Venkatesh, Yi Wang
Mentors: David Usevitch, Hisashi Ishida, Adnan Munawar

Project Background

- **Colored VR navigation** using signed-distance functions (SDF)
- Execute **user-study** on laminectomy
- Execute **feasibility-study** on mastoidectomy



[4]



Selected Literature

[1] A. Munawar et al., “Fully Immersive Virtual Reality for Skull-base Surgery: Surgical Training and Beyond”

Technical

[2] H. Ishida and J. A. Barragan et al., “Improving Surgical Situational Awareness with Signed Distance Field: A Pilot Study in Virtual Reality”

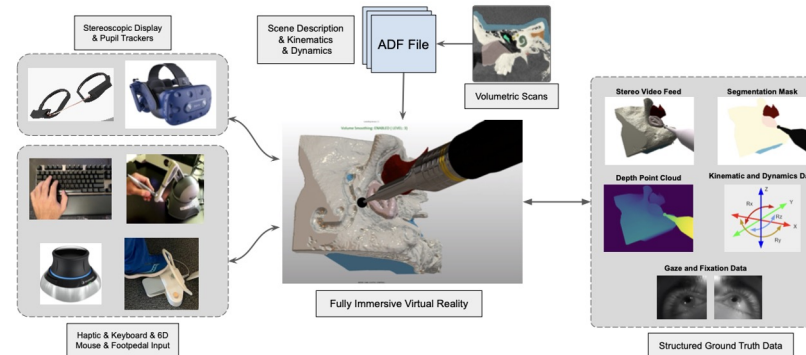
Technical

[3] F. Heinrich et al., “HoloPointer: a virtual augmented reality pointer for laparoscopic surgery training,” *Int J Comput Assist Radiol Surg*, vol. 16, no. 1, pp. 161–168, Jan. 2021, doi: [10.1007/s11548-020-02272-2](https://doi.org/10.1007/s11548-020-02272-2).

Clinical

FIVRS

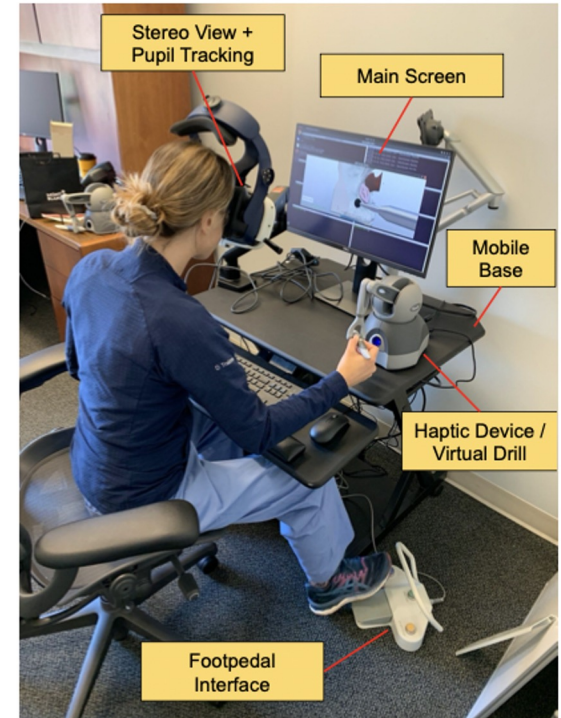
- **Title:** Fully Immersive Virtual Reality for Skull-base Surgery: Surgical Training and Beyond
- **First author:** Adnan Munawar
- **Relevance**
 - Technical outline for VR drilling simulator we will use



[1]

Technical Approach

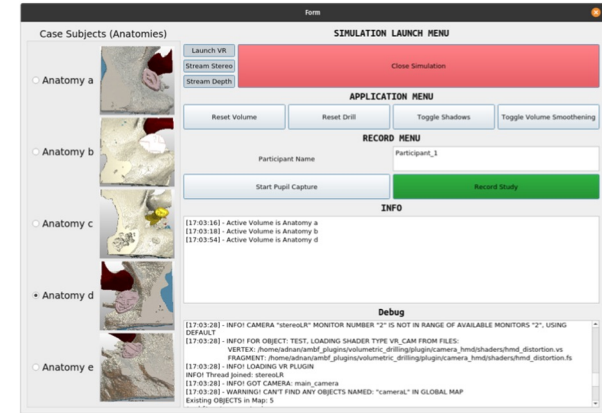
- **Hardware**
 - Linux OS
 - HTC Vive Pro (VR headset)
 - Phantom Omni (haptic device)
 - Model 4 burr types
 - Keyboard, 6D mouse, foot pedal



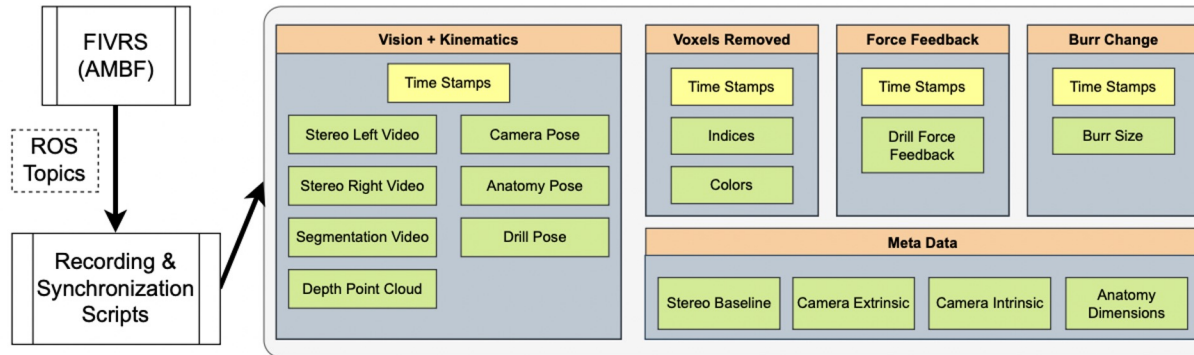
[1]

Technical Approach

- **Software**
 - AMBF plugin
 - GUI
 - ROS/Python data extraction



[1]



[1]

Technical Approach

- Focused on **haptic** and **audio feedback**
- **Haptic force**

$$\vec{F}_{\text{haptic}} = \vec{F}_{\text{collision}} + \vec{1} \cdot A_{\text{drill}} \cdot \sin(ft)$$

[1]

- **Audio drilling pitch**

$$p_{\text{pitch}} = A_{\text{audio}} - \|\vec{F}_{\text{collision}}\| / \|\vec{F}_{\text{max}}\|$$

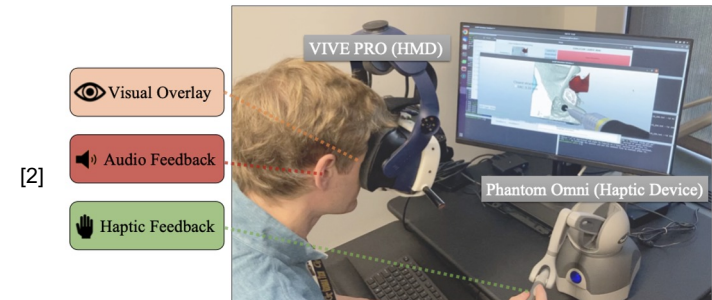
- **Visual feedback** via text overlays when user drilled near sensitive anatomy
 - Shadowing and online smoothing for visual fidelity

Critical Review

Pros	Cons	Takeaways
<p>Technical outline for VR drilling simulator.</p> <p>Open-source code for research/public use.</p>	<ul style="list-style-type: none">• Asynchronous data extraction• Underdeveloped visual feedback• Lacked explanation of how gazing data was analyzed	<p>VR simulator is effective and next-steps include</p> <ol style="list-style-type: none">1) robust clinical testing2) development of feedback systems

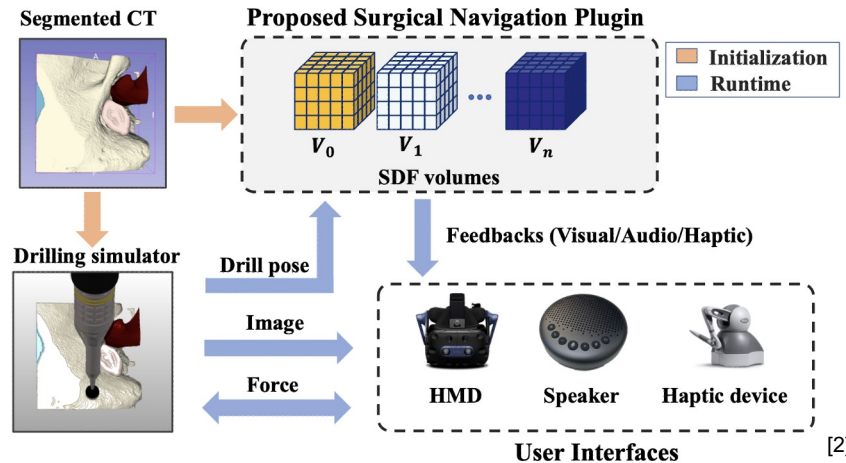
SDF Pilot Study

- **Title:** Improving Surgical Situational Awareness with Signed Distance Field: A Pilot Study in Virtual Reality
- **First authors:** Hisashi Ishida, Juan Antonio Barragan
- **Relevance**
 - Description of SDF-based VR simulator used in our project
 - Models data collection and analysis



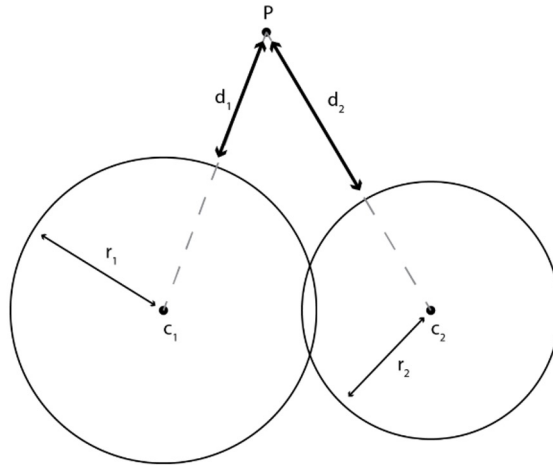
Technical Approach

- Input segmented CT/MRI scans
- Compute Signed Distance Field (SDF) volumes and query distances for user feedback

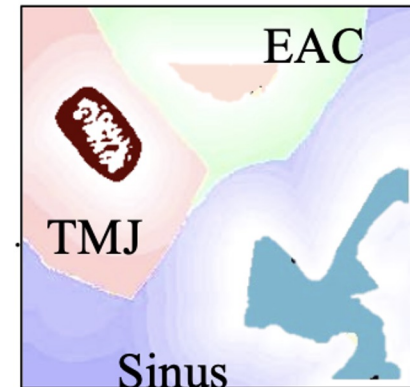


Technical Approach

- Signed Distance Field (SDF) is a function to compute distance from drilling tool to closest anatomy



(e) Combined



[2]

<https://jasmcole.com/2019/10/03/signed-distance-fields/>

[2] H. Ishida and J. A. Barragan et al.,
"Improving Surgical Situational Awareness
with Signed Distance Field: A Pilot Study in
Virtual Reality"

Technical Approach

- Basic EDT to compute a SDF

1	1	1	1
1	0	0	1
1	1	0	1
1	1	1	1
1	1	1	1



∞	∞	∞	∞
1	0	0	1
4	1	0	1
∞	∞	∞	∞
∞	∞	∞	∞



2	1	1	2
1	0	0	1
2	1	0	1
5	2	1	2
8	5	4	5

$$g_{ijk} = \min_x \{(i-x)^2; f_{xjk} = 0, 1 \leq x \leq L\}.$$

$$h_{ijk} = \min_y \{g_{iyk} + (j-y)^2; 1 \leq y \leq M\}.$$

Pilot Study

- **Goal:** evaluate the utility of audio, visual, and haptic feedback
- **Subjects:** three experienced surgeons, one medical student
- **Data:** quantitative (completion time, number of unintended voxels removed) and qualitative (NASA-TLX) on two CTs

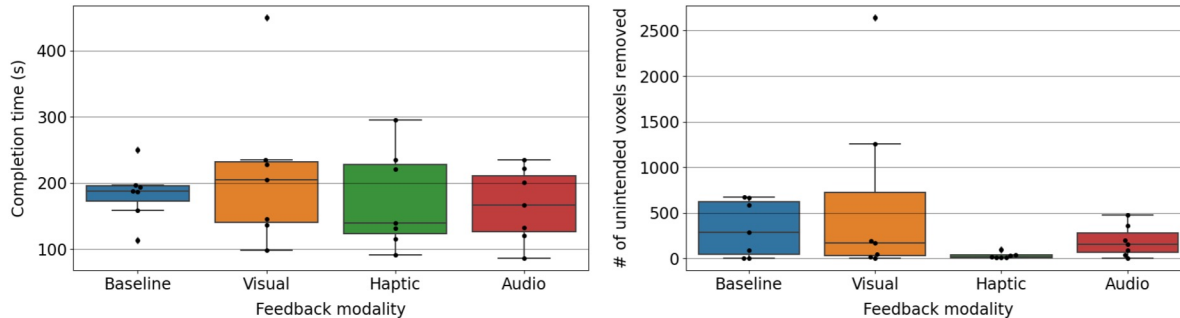


Fig. 6: User study objective metrics. (a) Completion time per anatomy and (b) number of unintended voxels removed.

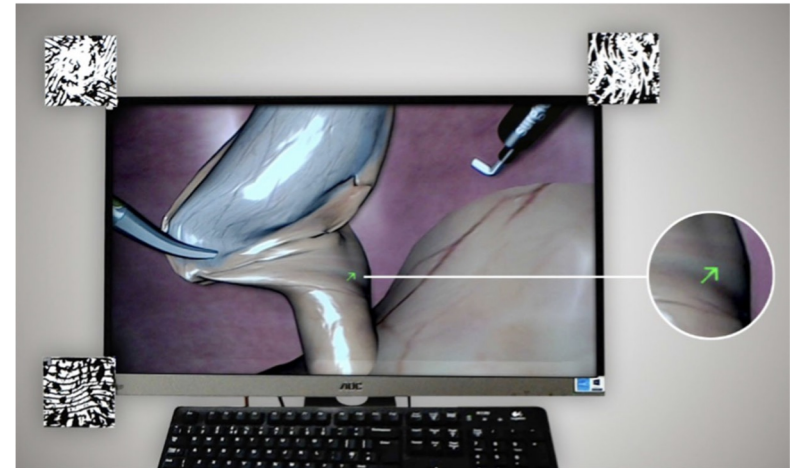
[2]

Critical Review

Pros	Cons	Takeaways
<p>Evaluated three distinct feedback mechanisms (visual, audio, haptic) independently in virtual-reality simulator.</p>	<ul style="list-style-type: none">• Few subjects (n=4) for study and small number of CTs (n=2)• Did not compare between surgeons	<p>Visual feedback could be improved with specific anatomical guidance and less confusing display.</p>

HoloPointer

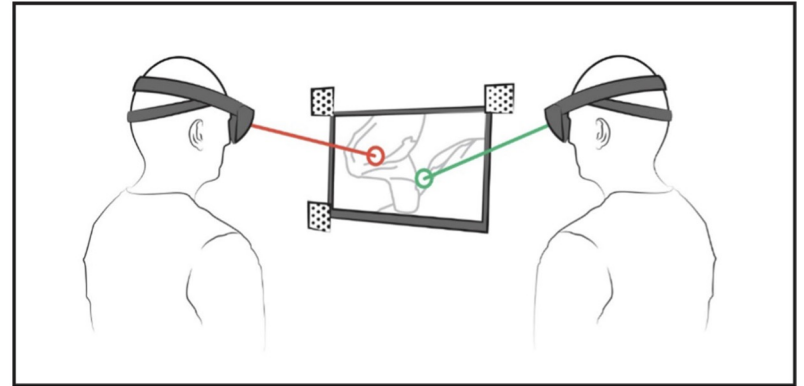
- **Title:** HoloPointer: a virtual augmented reality pointer for laparoscopic surgery training
- **First author:** Florian Heinrich
- **Journal:** IJCARS
- **Relevance**
 - Virtual technology for different surgical training
 - Outlines user study protocol



[3]

Technical Approach

- **Hardware**
 - Microsoft HoloLens
 - Laparoscopic monitor
- **Software**
 - Pointer application (Unity)
 - Vuforia AR SDK
- **Methods**
 - 2D image markers for registration
 - Ray casting to map pointer coordinates



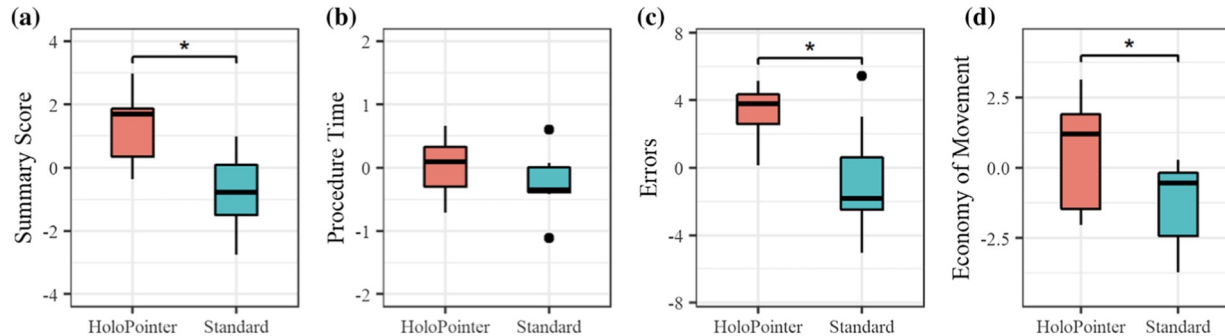
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User Study

- **Goal:** evaluate the utility of HoloLens as a training tool
- **Subjects:** one senior surgeon (trainer); seven junior residents, one senior resident, one consultant (trainees)
- **Data:** z-scores for procedure time, errors, economy of movement; subjective feedback questionnaire



[3]

Critical Review

Pros	Cons	Takeaways
<p>Similar study outline (two conditions per subject) to what we've proposed.</p>	<ul style="list-style-type: none">• Omission of experienced surgeon results• Lacked granularity in z-scores due to summation• Limited subjective feedback• Limited technical details	<p>Adaptable user study design that established efficacy of HoloLens AR training platform.</p>

Conclusion

- **FIVRS:**
 - Technical framework for VR Drilling simulator with feedback
- **SDF:**
 - More accurate tool-anatomy measurements using SDFs
- **HoloPointer:**
 - Adaptable user study design