Accuracy of the Hololens 2's infrared cameras in the context of surgical navigation

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1 Background

- **Surgical navigation technology** allows surgeons to precisely track the location and orientation of surgical instruments throughout a procedure.
- This technology serves as a **guidance system** during operations.
- The need for a fixed screen in **conventional surgical navigation systems** requires the surgeon to continuously switch focus between the surgical site and the screen, **increasing mental load**[1].


Fig 1: AR Surgical Navigation


Fig 2: HoloLens 2

- **There is still room for improvement in the field of surgical navigation.**
- **Augmented reality (AR)** can extend surgical navigation capabilities by allowing the superimposition of hidden structure onto the visible surface.

References

[1] Pierre Ambrosini, Abdullah Thabit, and Mohamed Benmahdjoub. Holonav: Hololens as a surgical navigation system, 2022.

[2]J. Kaplan, AR Surgical Navigation. 2022

[3] Turbosquid, Microsoft Hololens 2 -Device. 2021.

[4] Romuald Bedzinski, Polaris NDI Tracking Navigation System with passive Rigid Bodies . 2009.

2 Reseach Q

What is the distance error between a state-of-the art optical tracker, and our optical tracking method using the HoloLens2?

- Should IR cameras be used solely or as a basis for tracking with other sensors or cameras?
- What factors influence the accuracy of the tracking algorithm and to what extent?

3 Tools Used

In addition to the use of the HoloLens 2, **other tools are used in this research**.

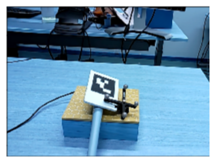


Fig 3: Infrared Markers

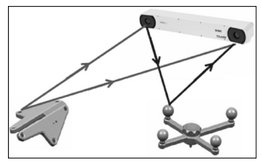
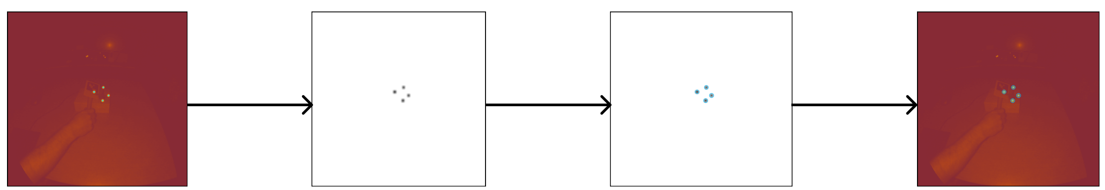


Fig 4: Infrared Tracker

Infrared markers:
- Shown in figure 3, are used to track movements.

Optical tracker:
- Shown in figure 4, The optical tracker provides the ground truth positions of the IR markers.

4 Processing Pipeline



IR Input Frame → Binarization → Blob Detection → 2D to 3D Transformation

5 Depth Detection

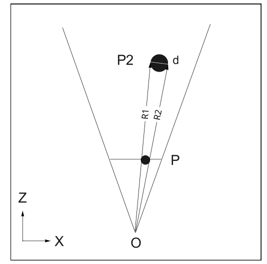


Fig 5: Finding the correct position P2 using sphere diameter d

Depth Sensors are not Accurate enough for depth detection.

Depth Detection method based on the **known measure of the sphere** and **binary search**

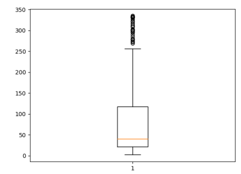


Fig 6: Box-Plot of 11.5mm Expected diameter search

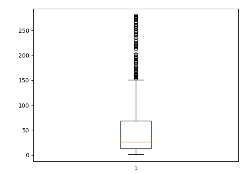


Fig 7: Box-Plot of 13mm Expected diameter search

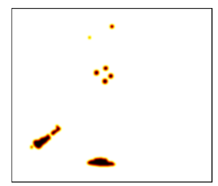


Fig 8: Lower threshold on image causes IR artifacts to show on binarized image

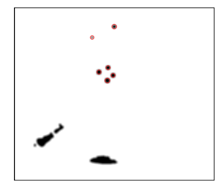


Fig 8: Lower threshold causes artifacts to be picked up during blob detection (Red)

6 Results

This method was found to be less accurate than state of the art technologies

At **25mm median distance error,** and **minimum distance error of 1.04mm**, as seen in Figure 7.

Most Influential factors are:

- **Depth** of object from screen (Due to screen reolution)
- **Threshold** used for Binarization
- **Expected Diameter of sphere** during search
- Use of **interpolation** during unprojection

The significance of a change in these parameters was calculated using **The Wilcoxon sign test**

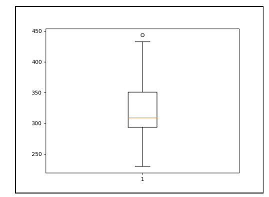


Fig 9: Depth of spheres with distance error less than median

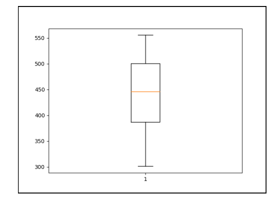


Fig 10: Depth of spheres with distance error greater than median

7 Limitations

*The **main limitation** of this research is the **localization of the ground truth positions:***
- **Frame rates are not synchronized**
- **Using QR code detection to Transform to same coordinate system**

*Commercial **AR technology has room for improvement:***
- **Low Resolution cameras**
- **Inaccurate depth sensors**

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