

UC San Diego

JACOBS SCHOOL OF ENGINEERING



An Optical Tracking Approach to Computer-assisted Surgical Navigation via Stereoscopic Vision

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Background



- Real-time guidance to surgeons during operational procedures
 - See instrument positions relative to preoperative imaging
 - High precision → improves success of surgery

Background



- Augmentation of traditional procedures
 - Neurosurgery
 - Orthopedic surgery
 - Maxillofacial surgery

Current Solutions

7D Surgical

Uses machine vision to match real-time images of patients to pre-existing imaging

- Does not directly track instruments
- Cost: \$400,000 - \$600,000

Stryker

Navigation is dependent on infrared markers mounted on instruments

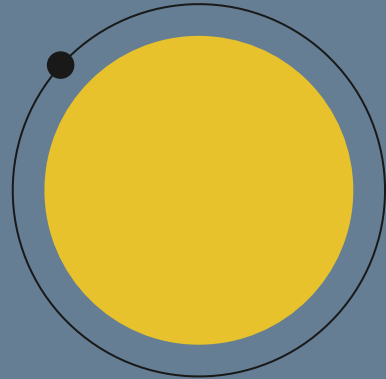
- Cost: \$250,000 - \$500,000

Medtronic Stealth	BrainLab	7D Surgical	Stryker
<ul style="list-style-type: none"> • \$500,000-\$700,000 • Most common for spine in ANZ • Often used in conjunction with O-arm • First to offer integrated pedicle screw instruments • Recommended for use with Medtronic prosthesis by manufacturer 	<ul style="list-style-type: none"> • \$500,000-\$700,000 • Has universal registration mechanism for intraoperative imaging • Wide range of compatible instruments from different implant manufacturers • Open navigation platform not owned by an implant manufacturer 	<ul style="list-style-type: none"> • \$400,000 - \$600,000 • Uses Machine Vision to register the patient rapidly • Ability to rapidly re-register • Basic spine instrumentation • Open navigation platform not linked to an implant manufacturer 	<ul style="list-style-type: none"> • \$250,000 - \$450,000 • Has universal registration mechanism for intraoperative imaging • Cutaneous non-bone anchored tracker • Optimised for use with Stryker prosthesis
<p>Passive Instrument Tracking</p>		<p>Active Instrument Tracking</p>	



Objective

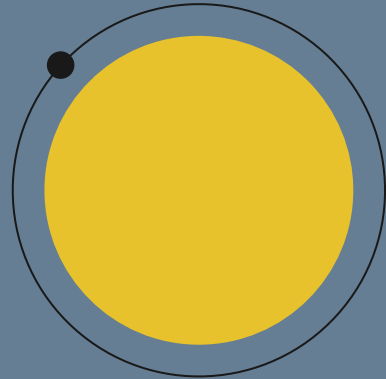
We aim to design a surgical navigation system that is:
Cost-effective
Radiation-exposure limiting
Accurate





Objective

Current Proposition:
Optical tracking
AR navigation
Design-validation





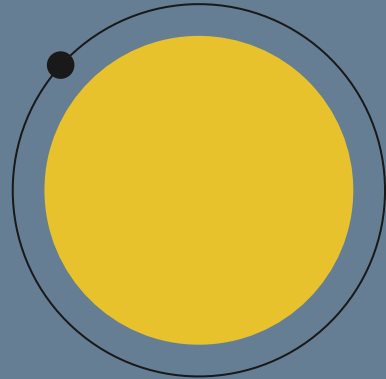
Objective

Current Proposition:

Optical tracking

AR navigation

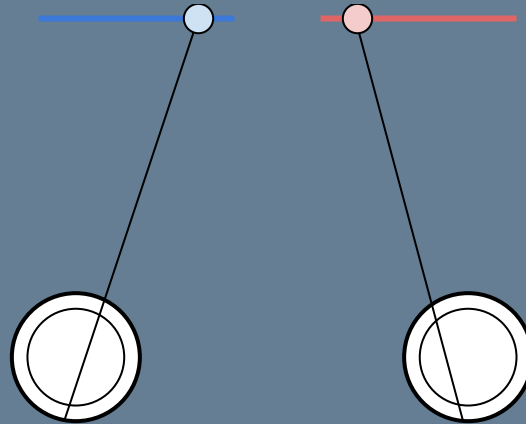
Design-validation



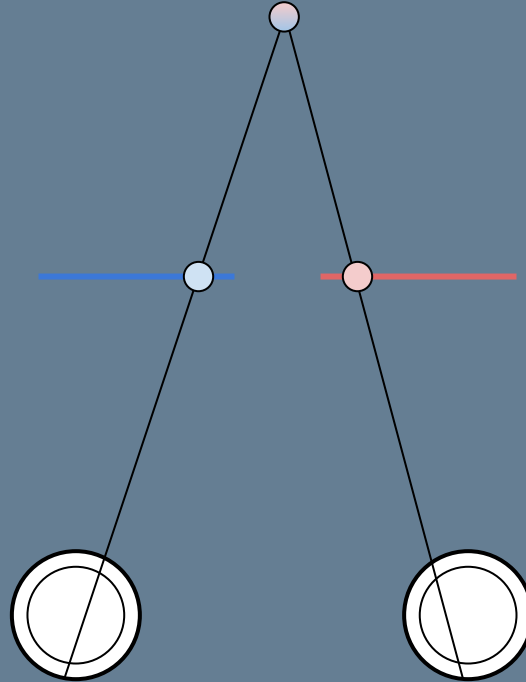
Stereoscopic Vision - In Concept



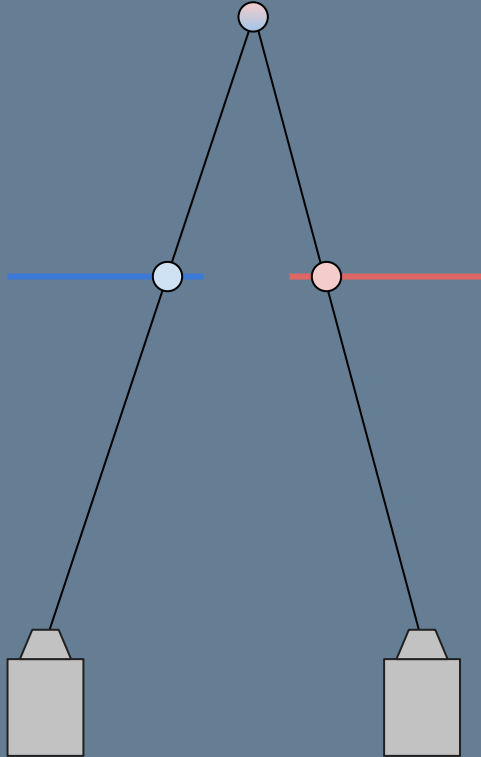
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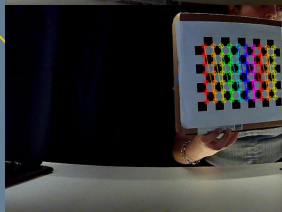
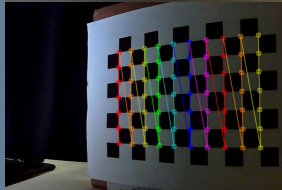
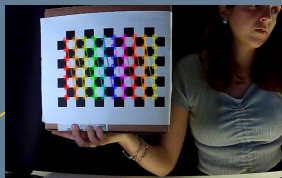
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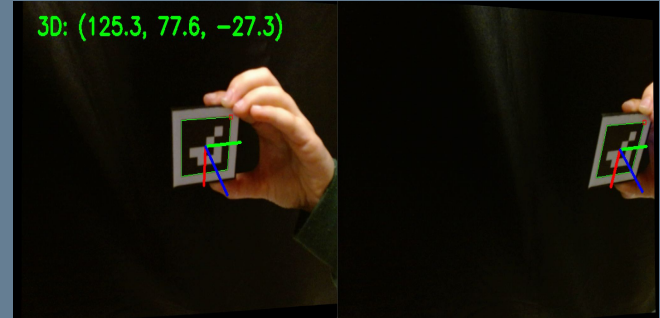
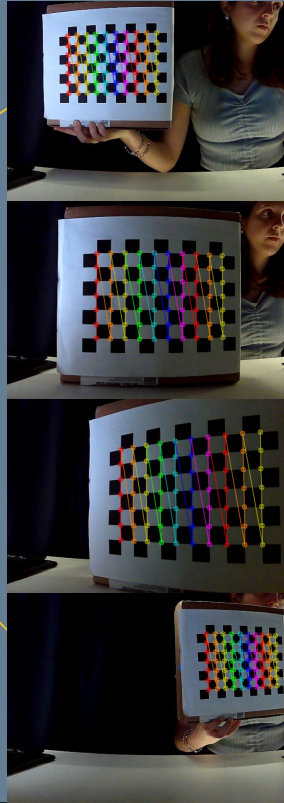
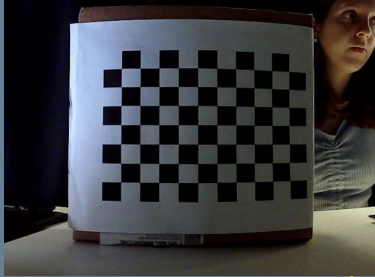
Stereoscopic Vision - In Practice



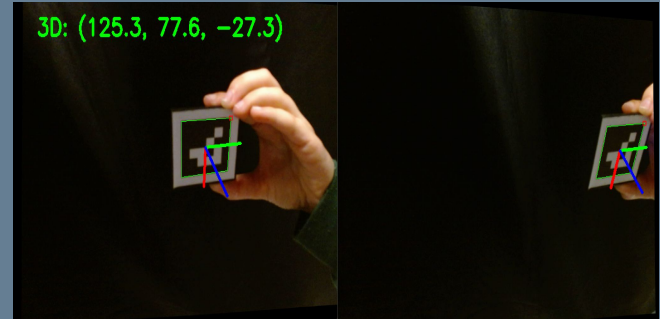
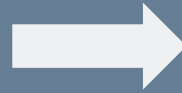
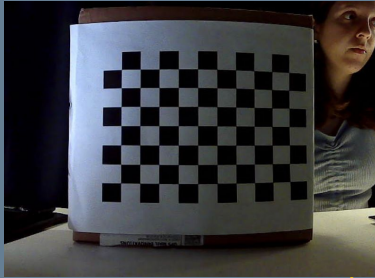
Stereoscopic Vision - In Practice



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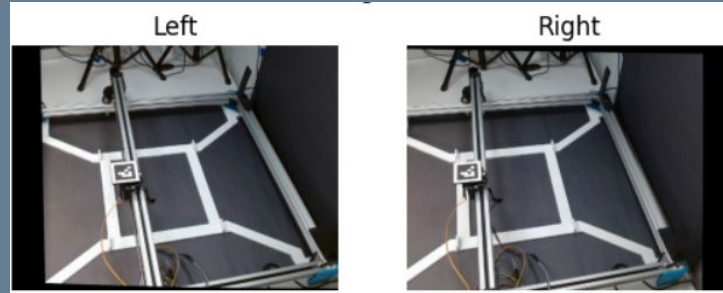
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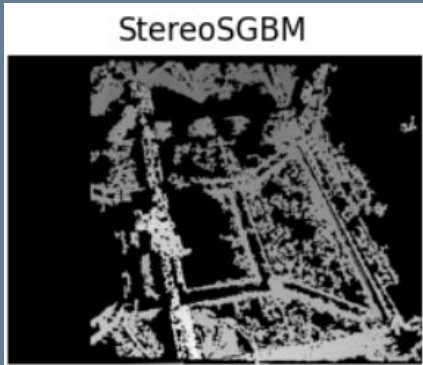
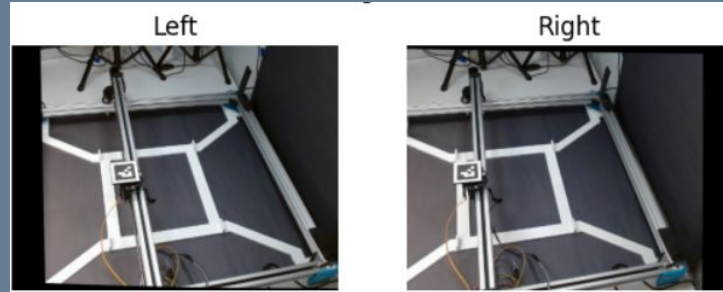
Disparity - difference in image location



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Disparity - difference in image location



$$\underline{d = x_l - x_r} \quad (1)$$

$$z = \frac{fb}{d} \quad (2)$$

$$x = \frac{x_l z}{f} \quad (3)$$

$$y = \frac{y_l z}{f} \quad (4)$$

Disparity - difference in image location



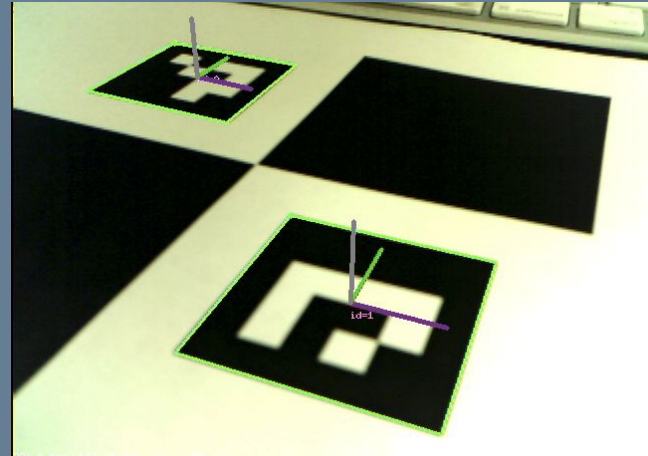
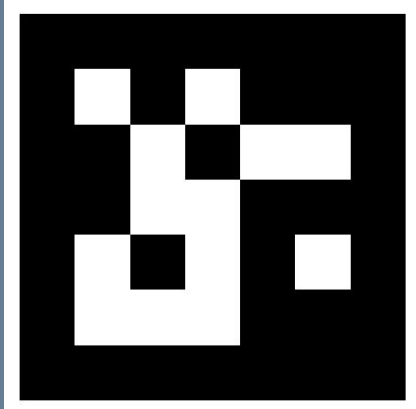
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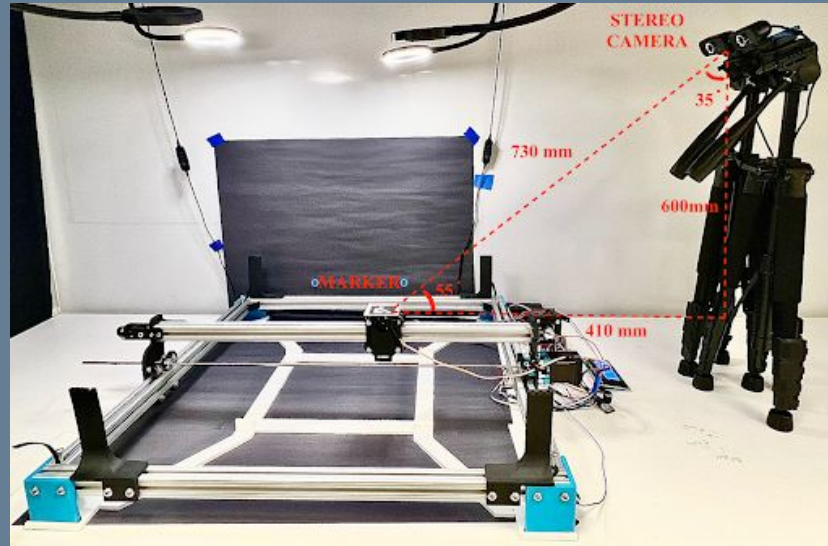
ArUco Markers



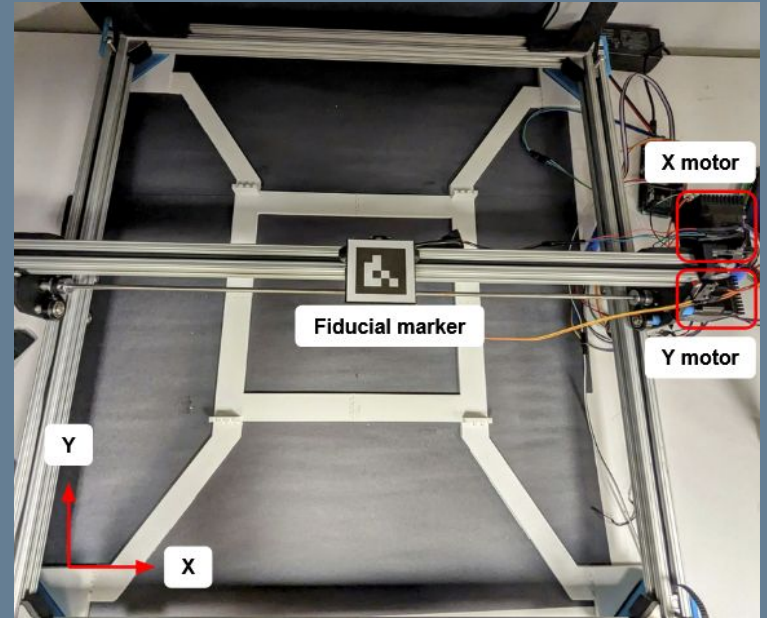
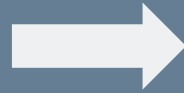
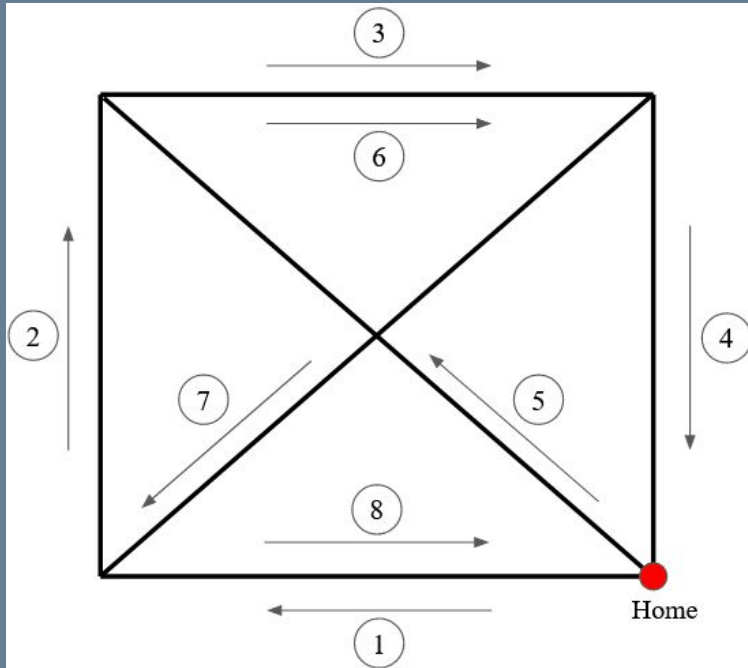
Tracking Demo



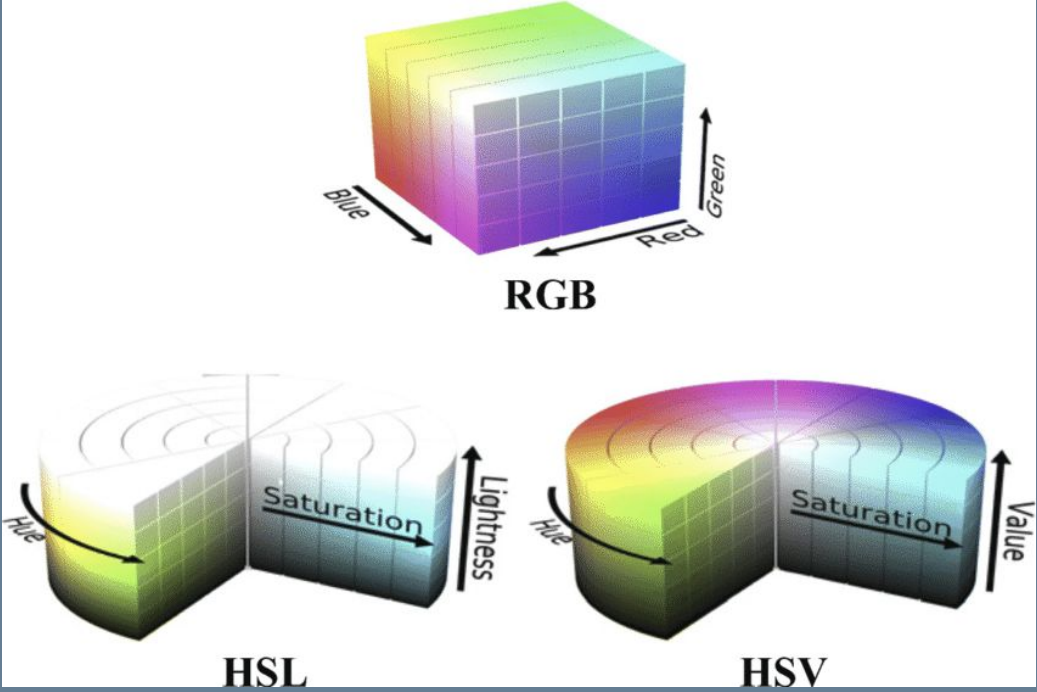
Positioning Platform



Validation



Experiments



Experiments

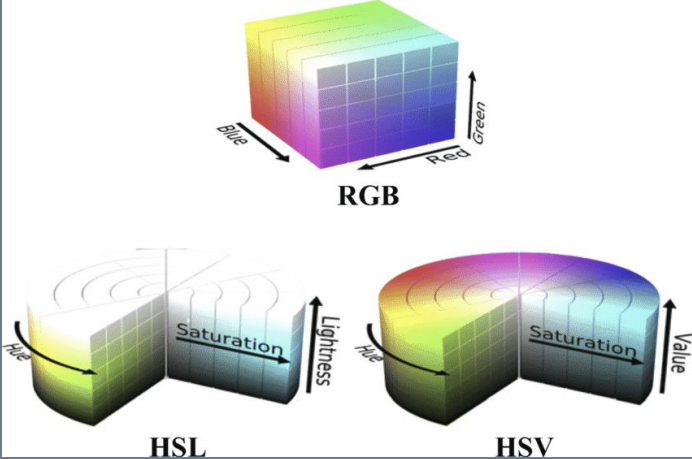


TABLE 1: DETECTION PERCENTAGE (%) OF FOUR COLORED MARKERS IN RGB, HSL AND HSV COLOR SPACES.

Color Space	Color			
	White	Pink	Yellow	Orange
RGB	99.7	98.1	97.1	99.5
HSL	99.5	81.3	89.7	87.0
HSV	97.5	73.5	78.4	80.6

TABLE 2: MARKER TRACKING AVERAGE ERROR (MM) OF FOUR COLORED MARKERS IN RGB, HSL, AND HSV.

Color Space	Color			
	White	Pink	Yellow	Orange
RGB	5.48	5.62	12.35	5.39
HSL	5.38	6.80	5.96	6.26
HSV	5.61	6.98	6.17	5.88

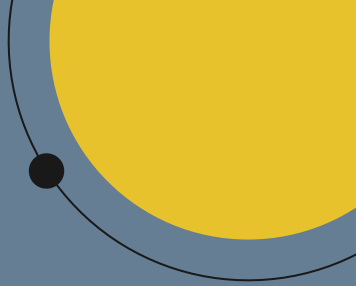
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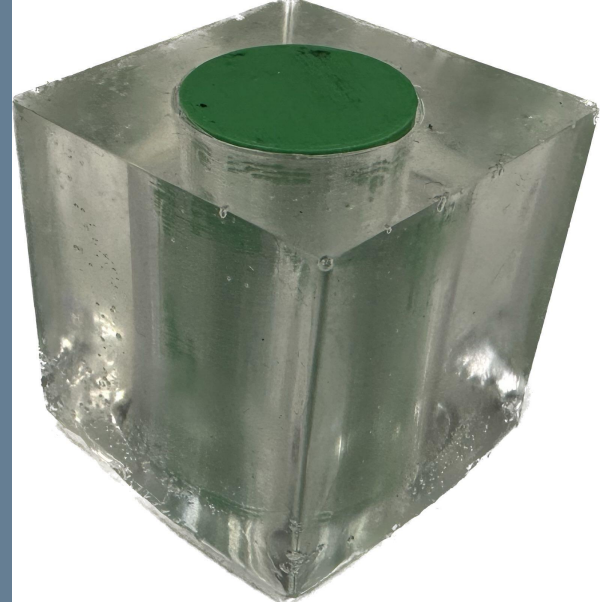
Discussion



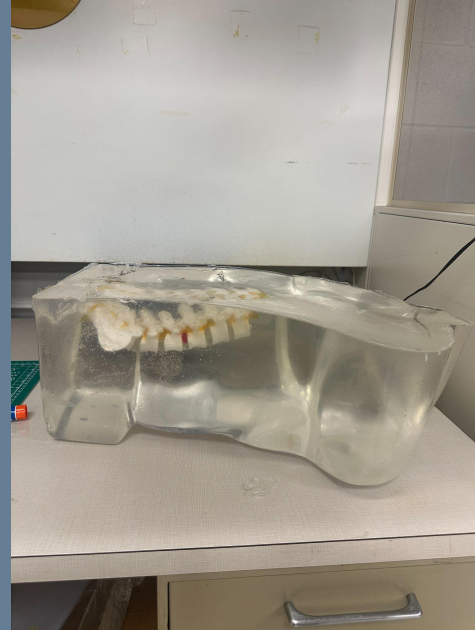
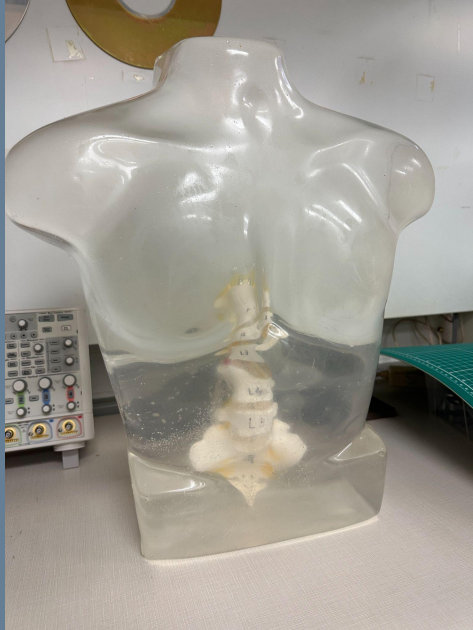
- Our surgical navigation system is promising:
 - 5 mm of error is higher than needed for clinical use but has potential to be reduced with higher quality cameras
- Affordable:
 - We spent around 60 dollars on two web cameras
- Minimally invasive:
 - Only requires external cameras and ArUco markers
- What's next?



Physical Models (Cube)



Physical Models (Body Shape)



AR Application (Cube)



AR Application (Body Shape Model)





Thank you!

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