UC San Diego
JACOBS SCHOOL OF ENGINEERING

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

Darin Tsui[1], Capalina Melentyev[1], Ananya Rajan[1],
Rohan Kumar[1], Farshad Ahadian[2], and Frank E. Talke[1]

[1]Center for Memory and Recording Research
[2]Center for Pain Medicine
University of California San Diego

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

Maltham and Wells-Quinn, *Journal of Spine Surgery*, 2019

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

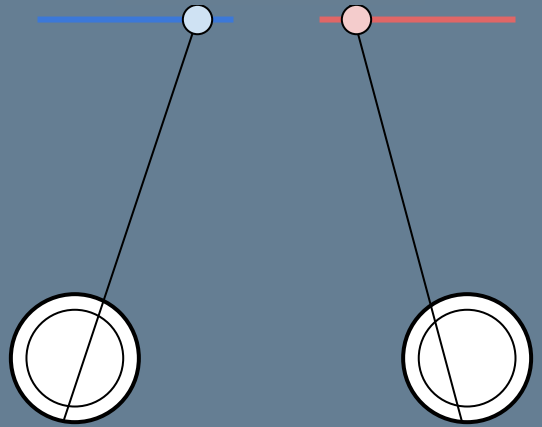
Objective

Current Proposition:

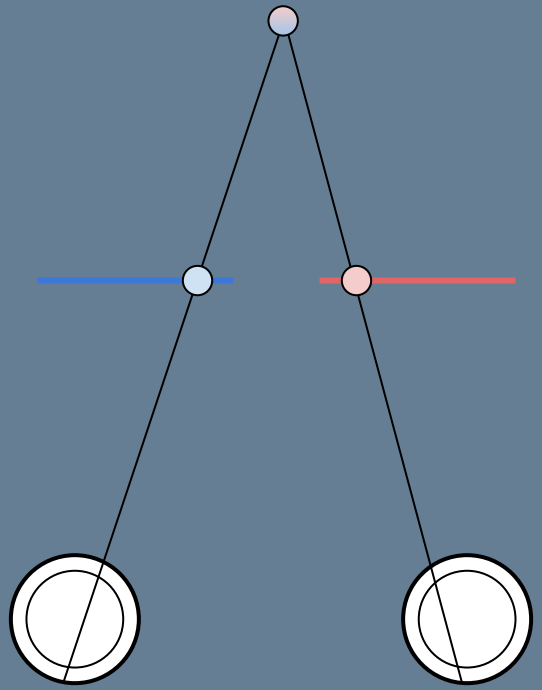
- Optical tracking
- AR navigation
- Design-validation

Stereoscopic Vision - In Concept

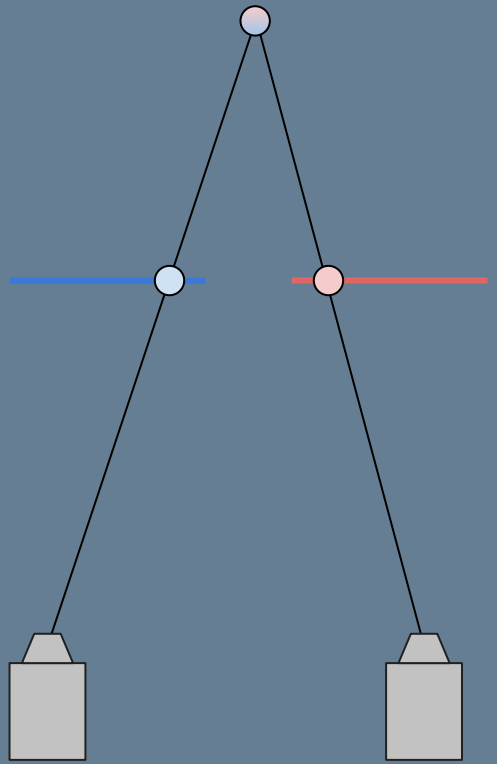
Stereoscopic Vision - In Concept



Stereoscopic Vision - In Concept

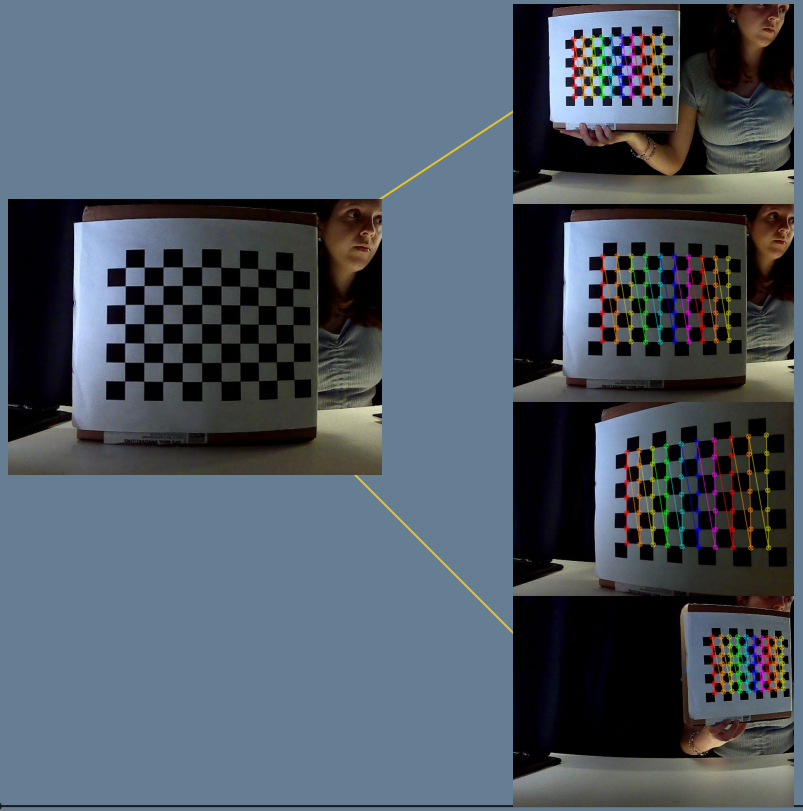


Stereoscopic Vision - In Concept

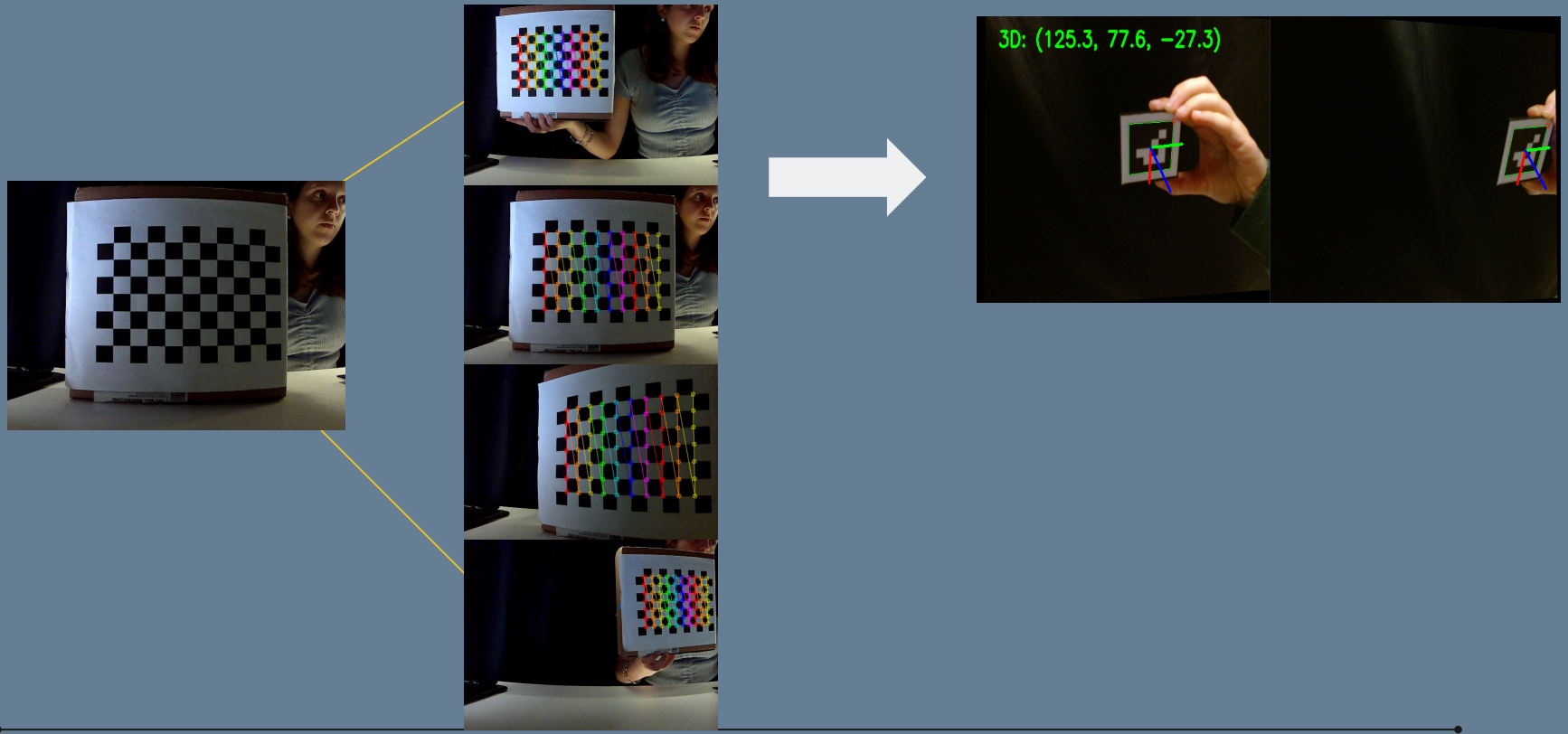


Stereoscopic Vision - In Practice

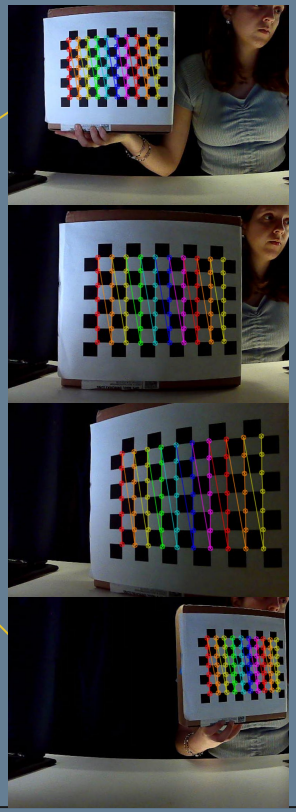
Stereoscopic Vision - In Practice

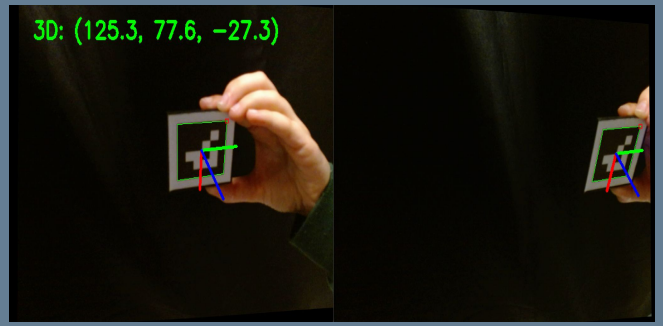


Stereoscopic Vision - In Practice



Stereoscopic Vision - In Practice

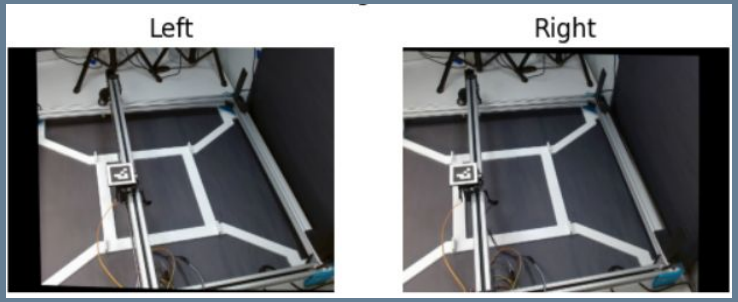




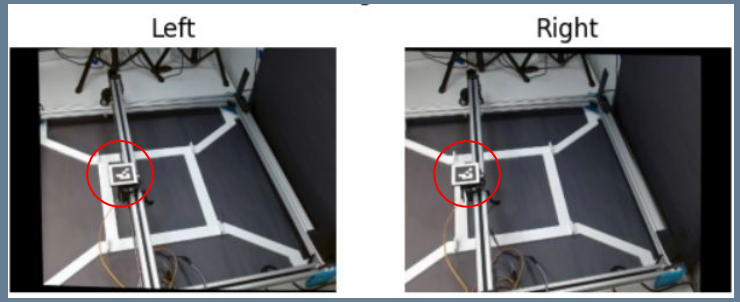
Disparity - difference in image location

Disparity - difference in image location

Disparity - difference in image location



Disparity - difference in image location



Disparity - difference in image location

$$d = x_l - x_r \quad (1)$$

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

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

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

Disparity - difference in image location

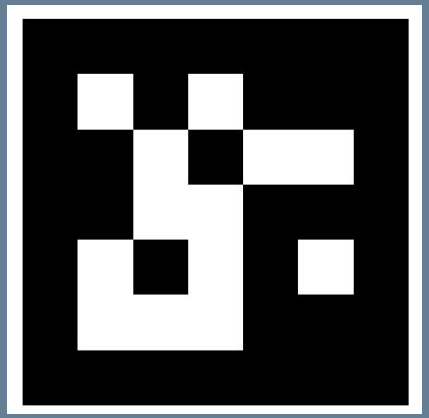
$$d = x_l - x_r \quad (1)$$

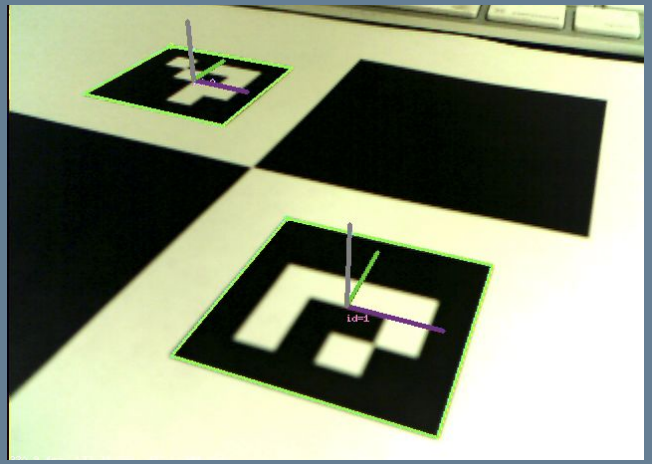
$$z = \frac{fb}{d} \quad (2)$$

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

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

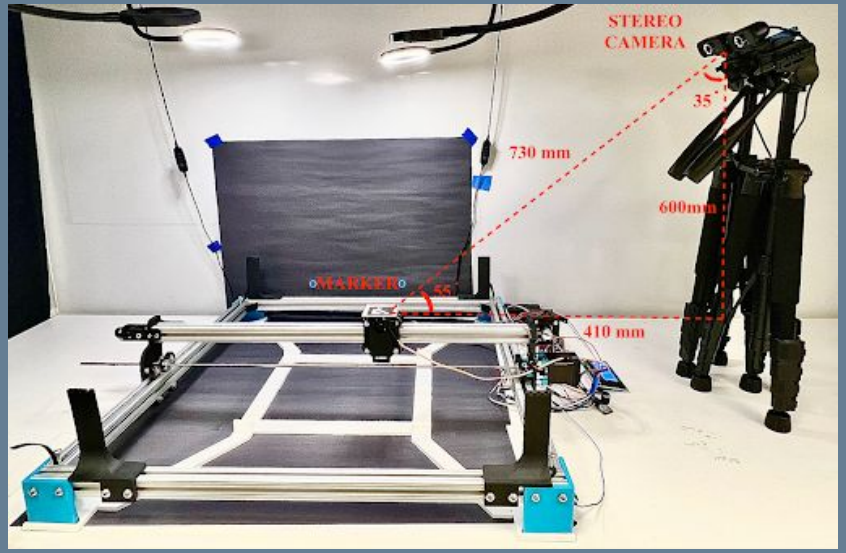
ArUco Markers



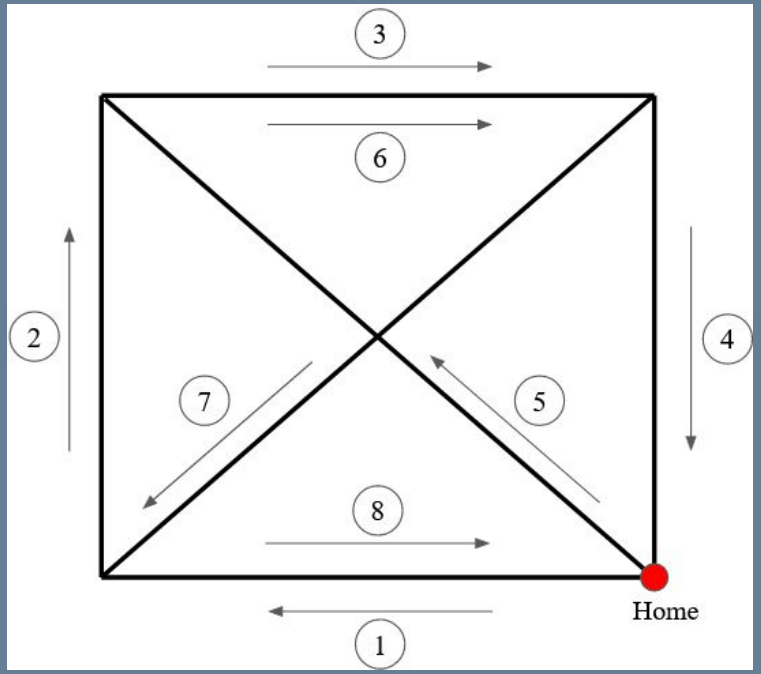


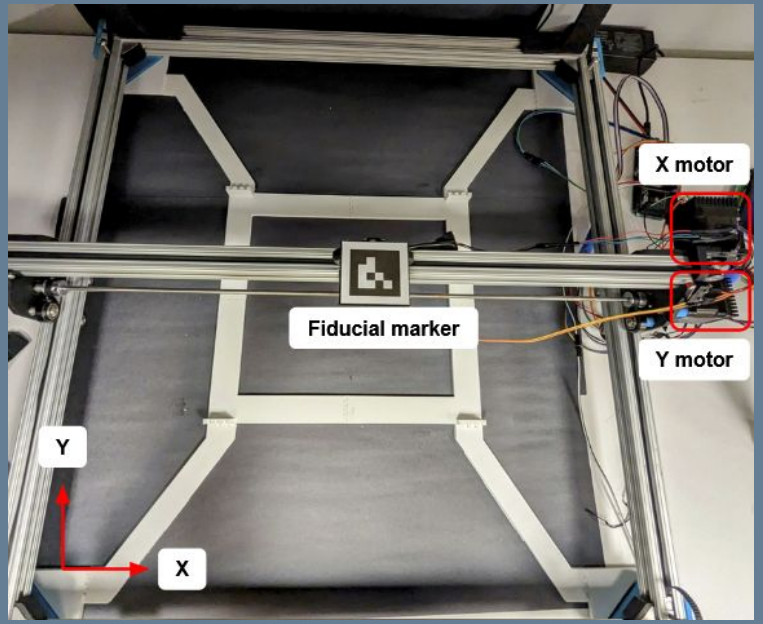
Tracking Demo

Positioning Platform



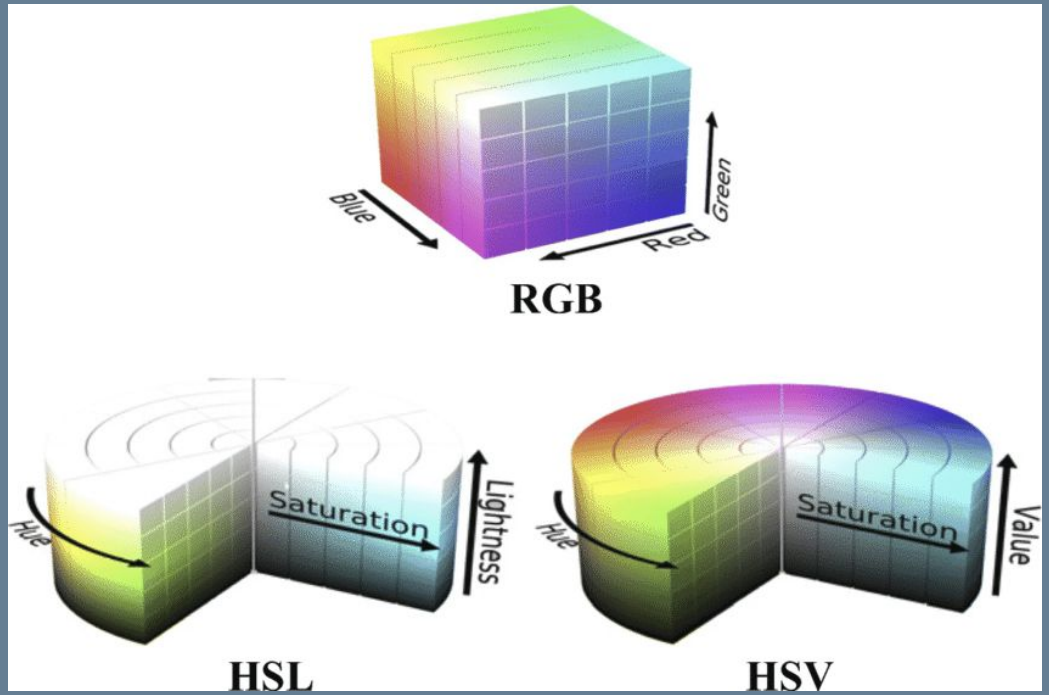
Validation





Tsui et al., *EMBC* 2023

Experiments



Experiments

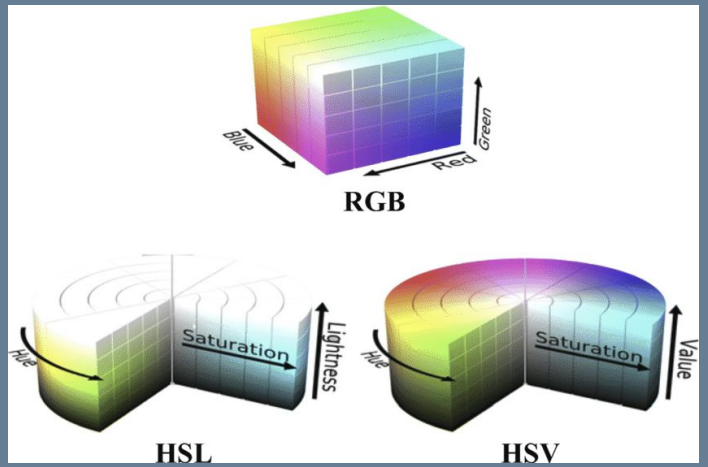


TABLE 1: DETECTION PERCENTAGE (%) OF FOUR COLORED MARKERS IN RGB, HSL AND HSV COLOR SPACES.

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

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

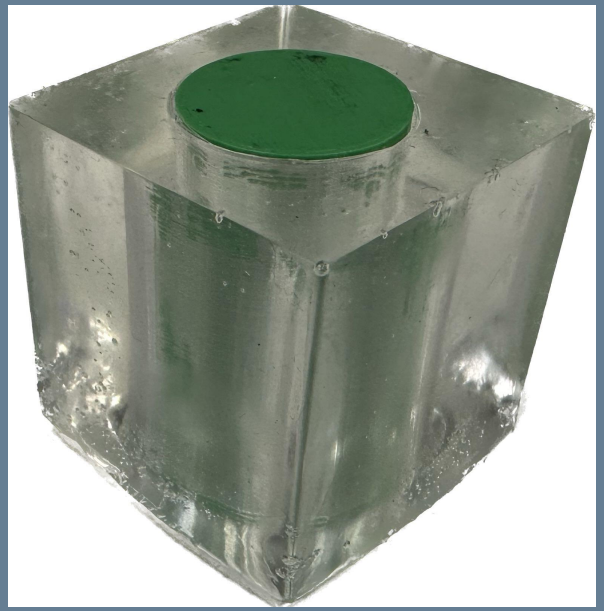
TABLE 2: MARKER TRACKING AVERAGE ERROR (MM) OF FOUR COLORED MARKERS IN RGB, HSL, AND HSV.

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

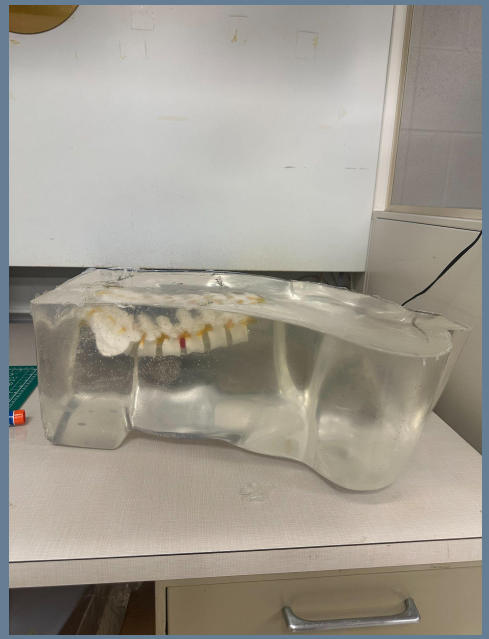
Discussion

- 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)

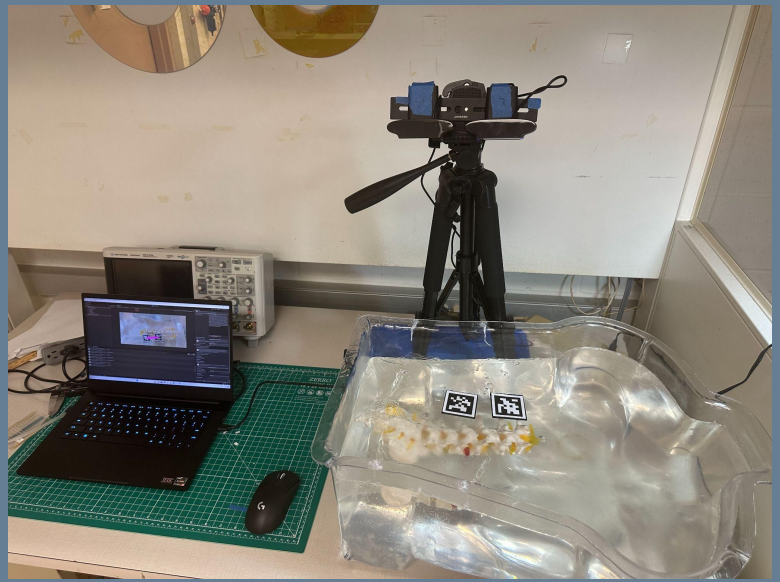


Physical Models (Body Shape)



AR Application (Cube)

AR Application (Body Shape Model)



Thank you!

Darin Tsui
dtsui@ucsd.edu