

Computer-assisted, Stereoscopic-based Surgical Navigation



Ananya Rajan, Darin Tsui, Capalina Melentyev, Rohan Kumar, Frank E. Talke

University of California, San Diego, Center for Memory and Recording Research

Background

Navigation systems are being increasingly used during minimally invasive surgeries. They prioritize

- Real-time guidance
 - High precision
 - Improved clinical outcome
- Existing technologies have limitations:
- High-cost due to use of IR cameras
 - Inaccessible to smaller healthcare institutions

Systems utilizing stereoscopic, videometric tracking with fiducial markers can be made low-cost cameras.

Objectives

Design an optical tracking system that is:

- Cost-effective
- Radiation exposure limiting
- Accurate

Stereoscopic Vision

The ability to perceive depth using two or more image sensors

- Camera parameters: focal length (f), optical centers ($x_{l/r}$)
 - Disparity (d)
 - 3D Position (x, y, z)

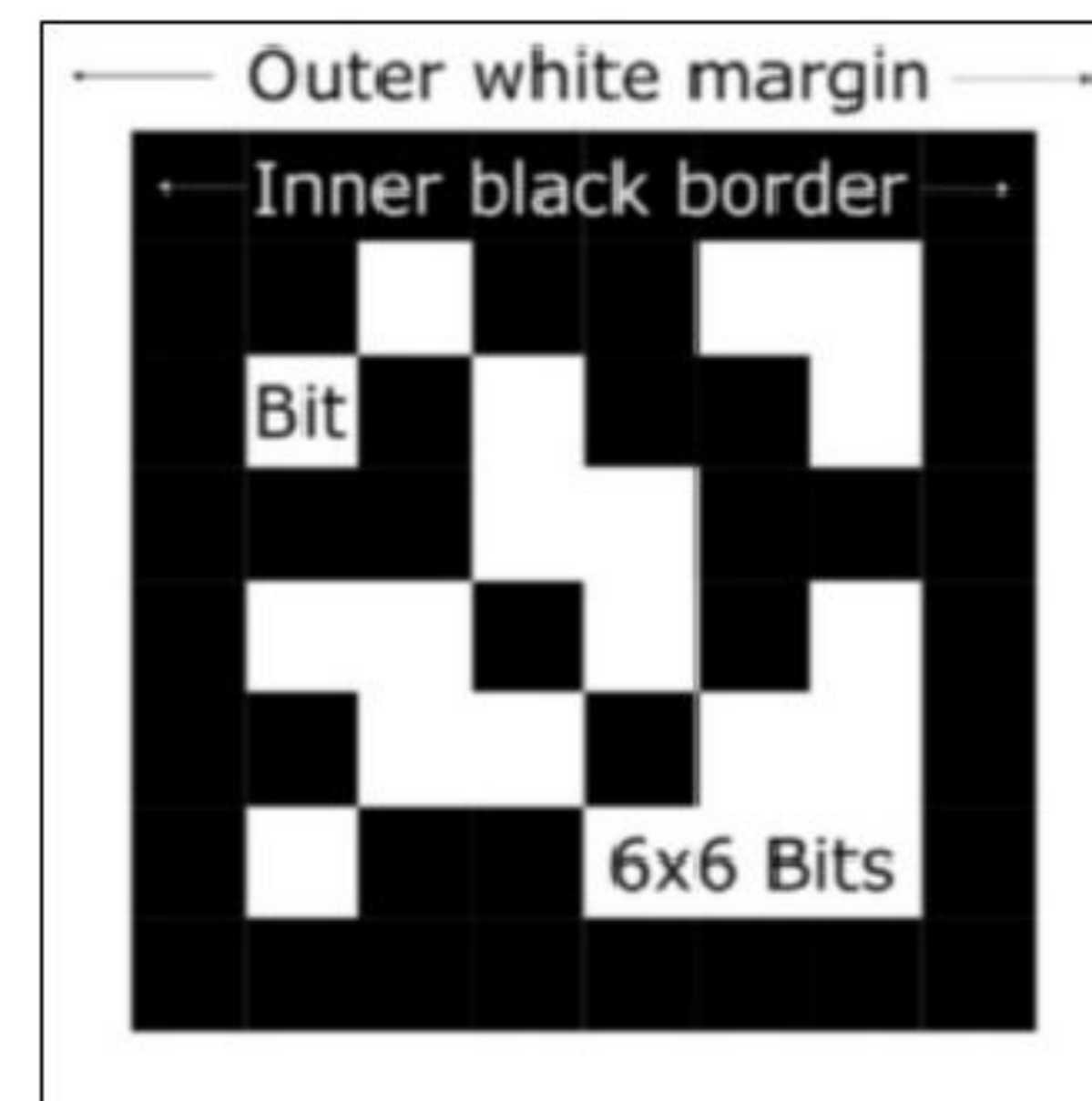


$$d = x_l - x_r \quad (1)$$

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

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

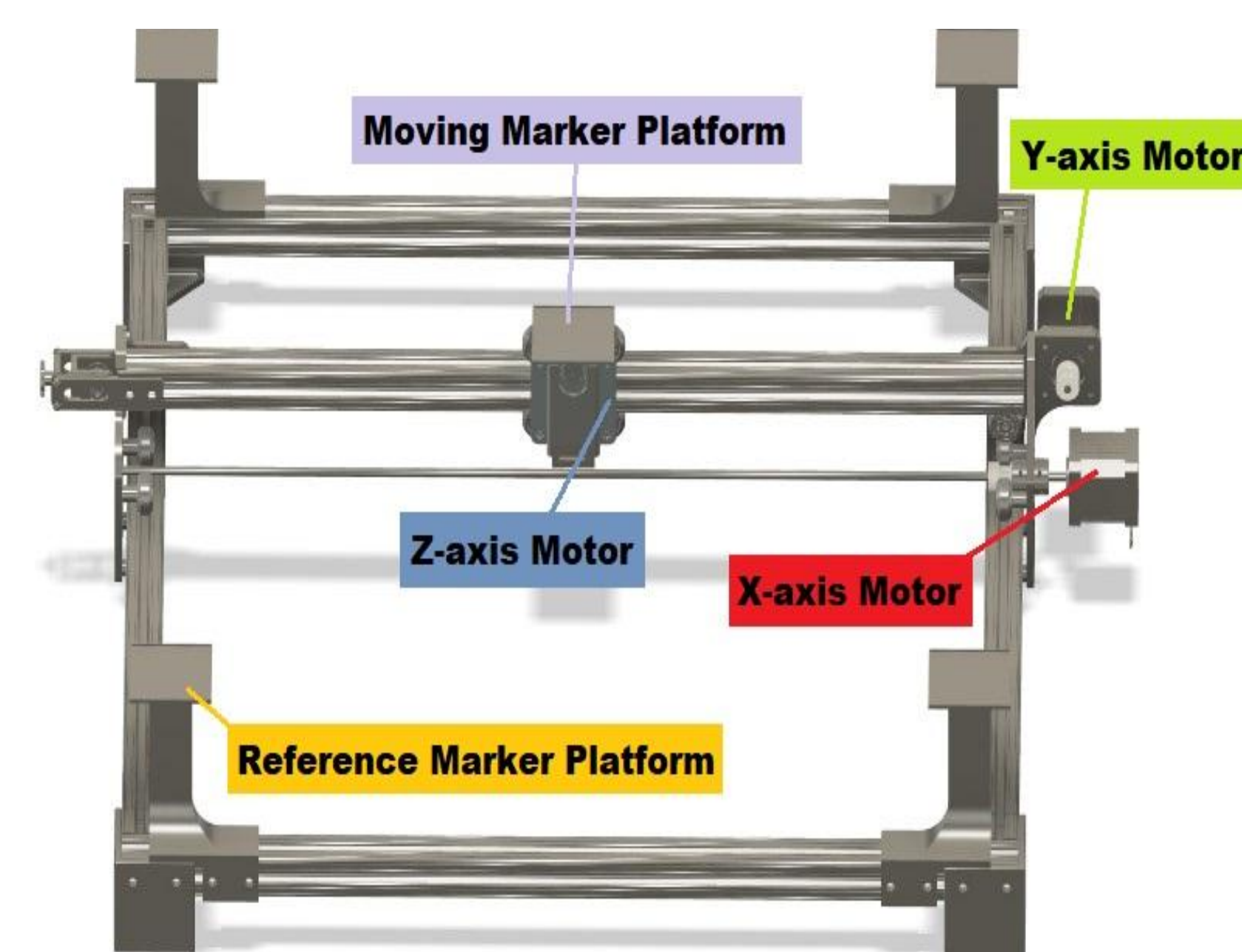
$$y = \frac{y_l z}{f} \quad (4)$$



ArUco Marker

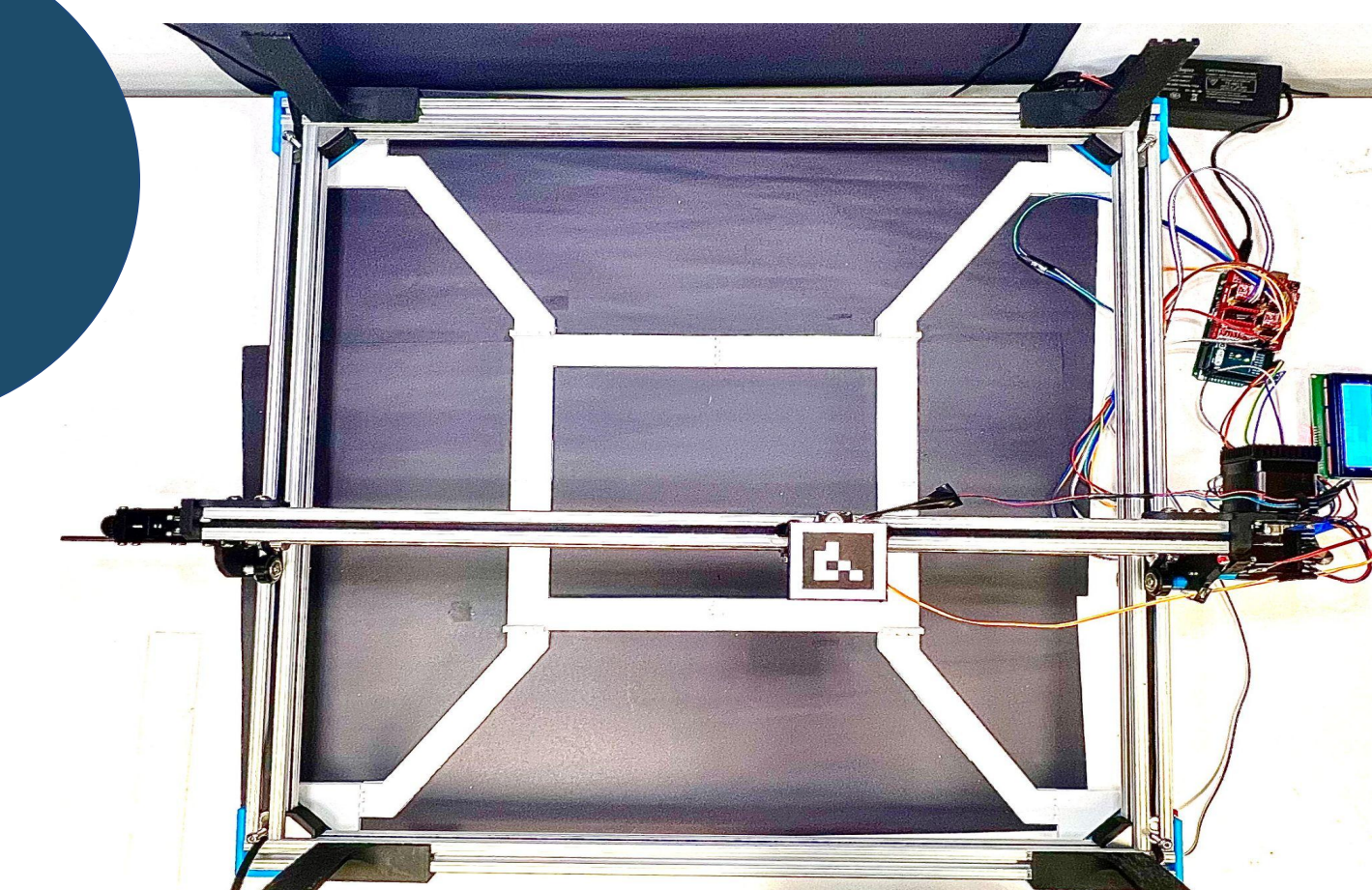
1 Fiducial Markers

Our implementation makes use of ArUco markers, open-source fiducial markers dedicated to positional tracking in real time. We implement the ArUco package using Python and OpenCV.



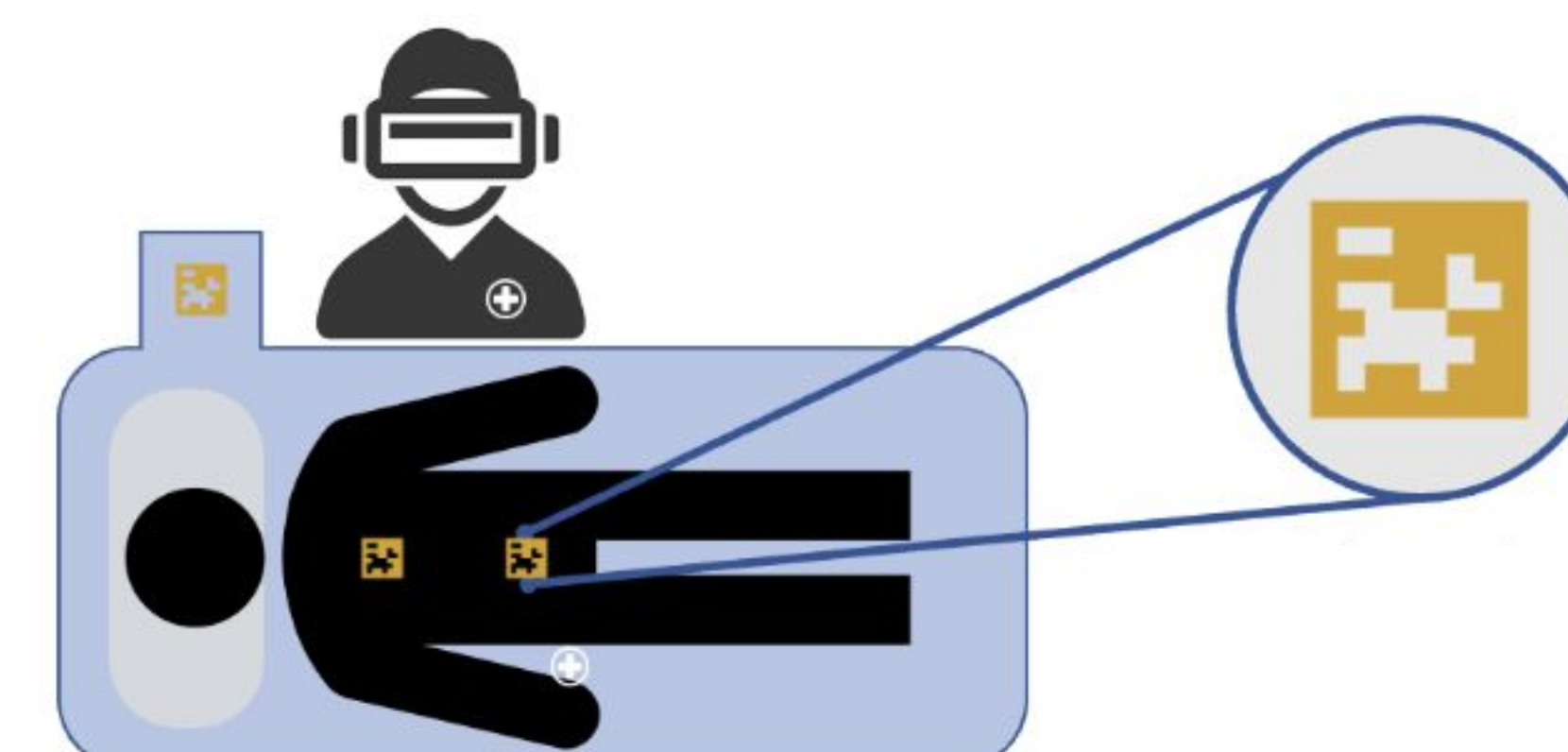
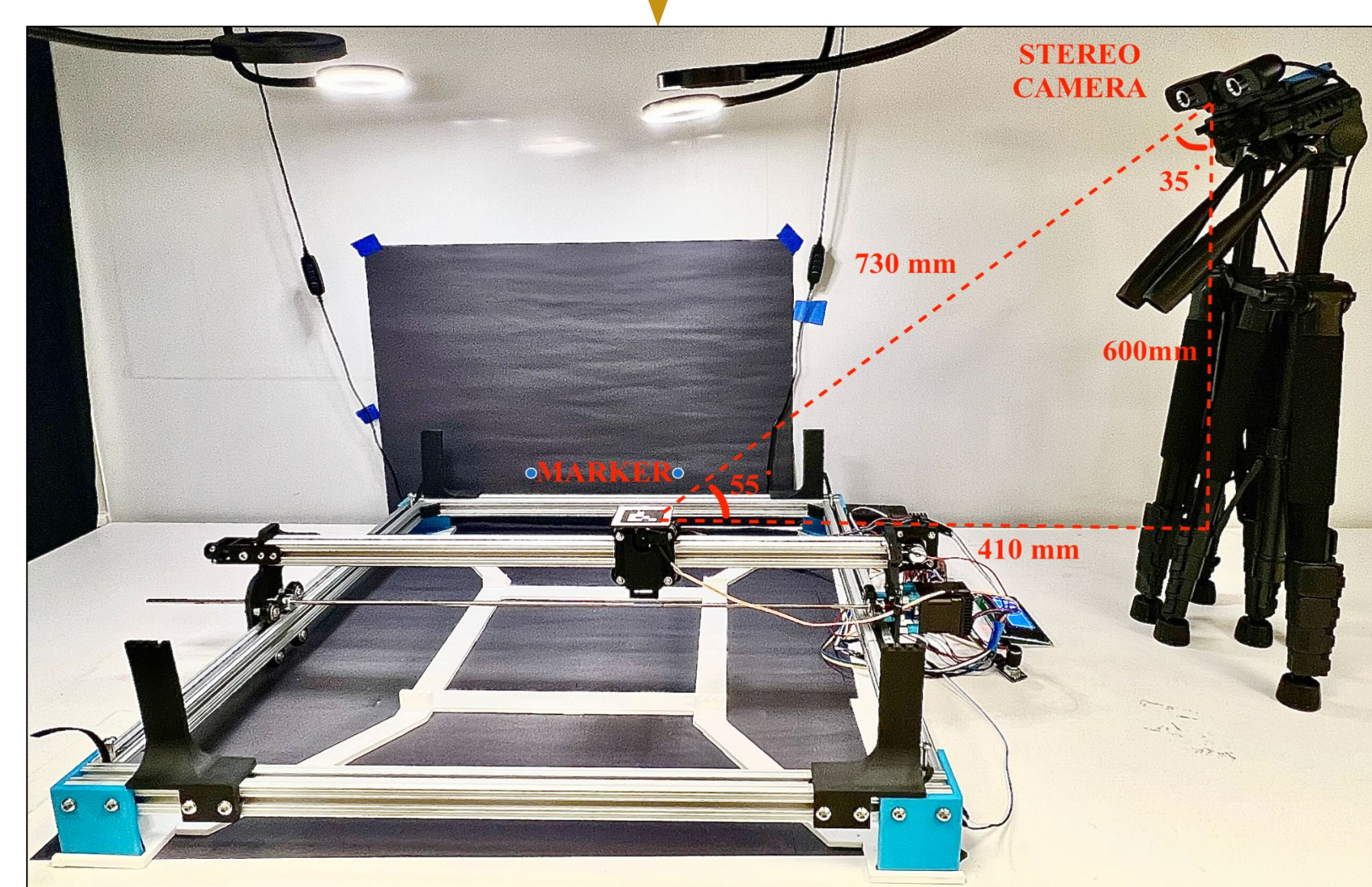
2 XYZ Platform

Marker tracking experiments are performed on the XYZ platform. Markers are classified as either moving or reference markers.



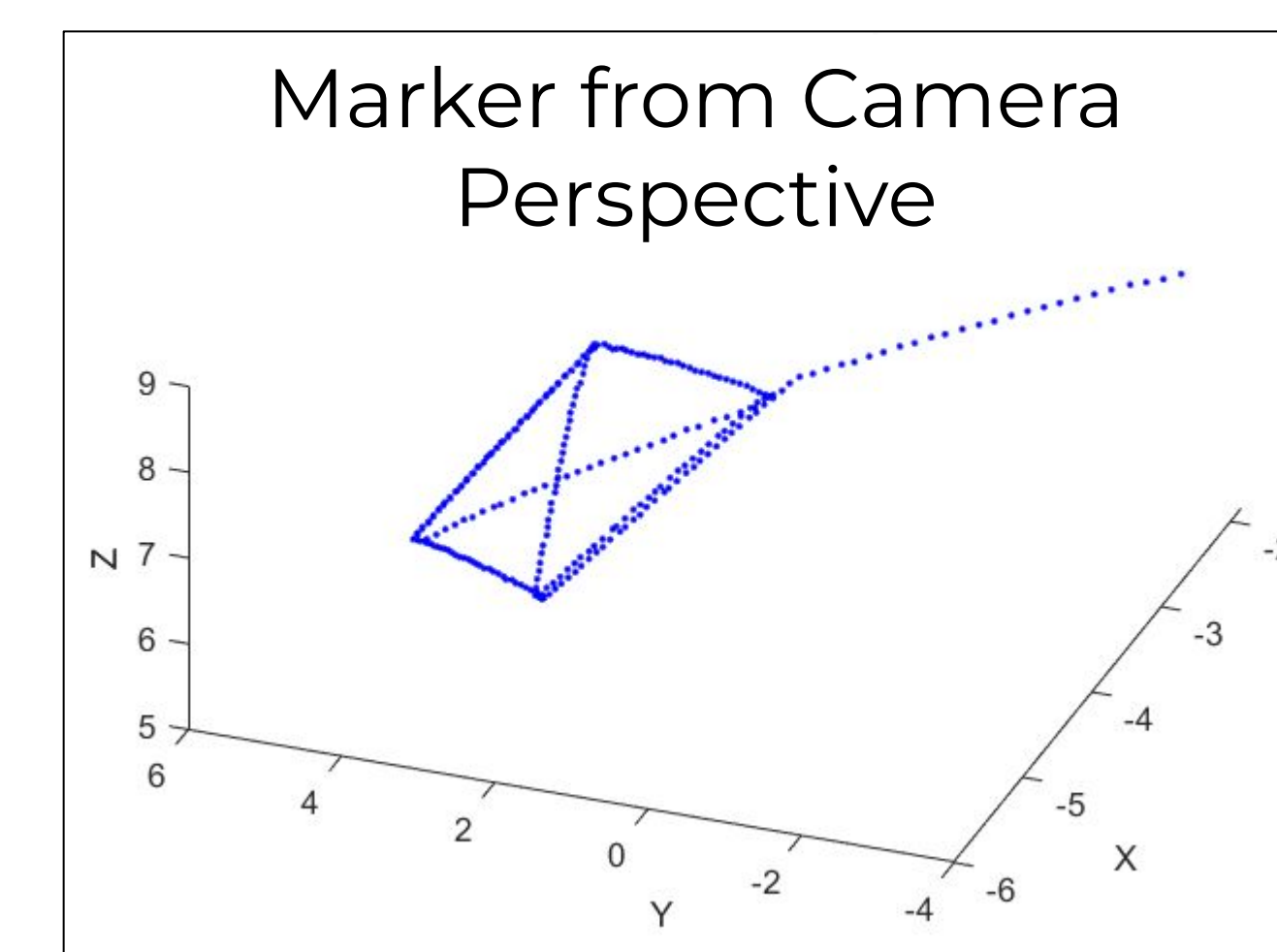
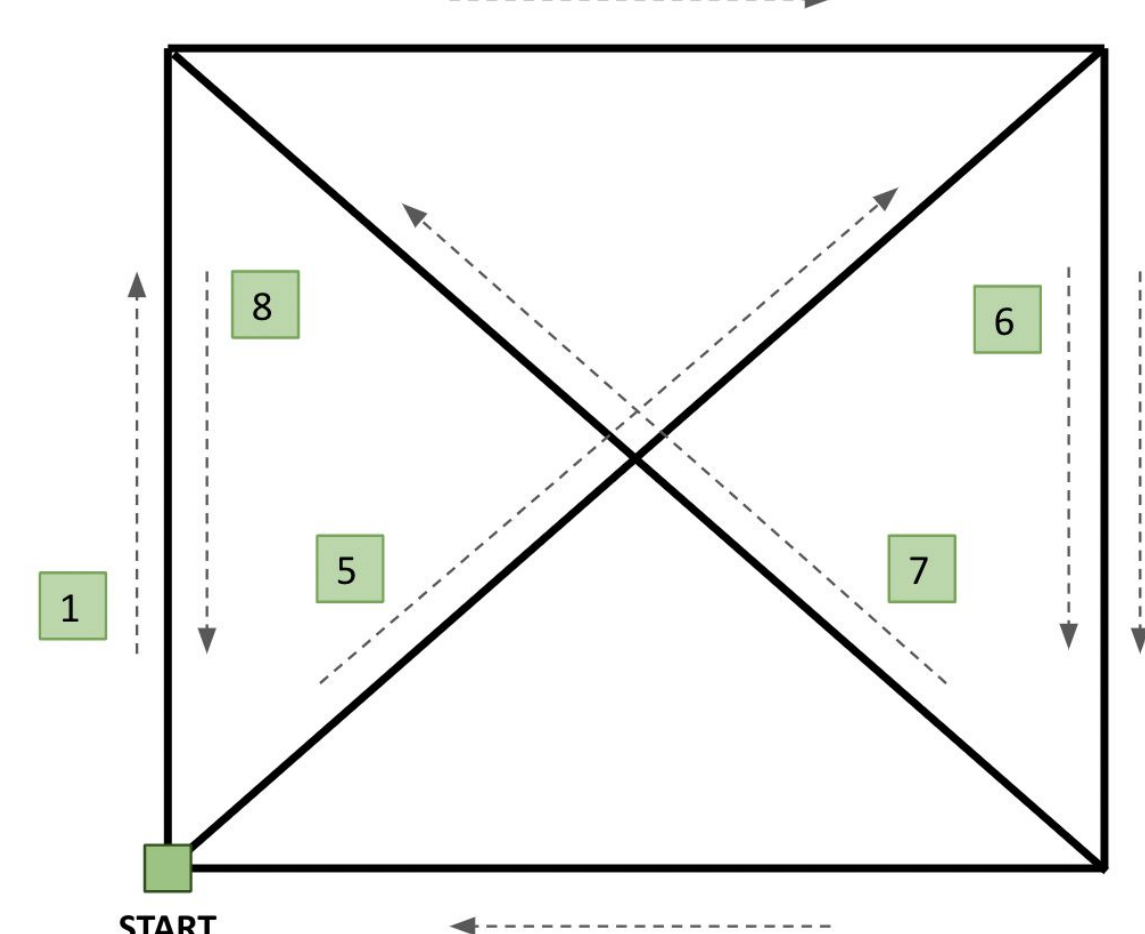
3 Stereoscopic Camera

For 3D positional tracking, a calibrated stereoscopic camera system was constructed using two low-cost web cameras.



4 Prototype

Our proposed system makes use of fiducial markers in tandem with augmented reality to provide positional assistance to surgeons.



Experimental Testing

ArUco Marker Colors

- White, Pink, Yellow, Orange

Color Spaces

- RGB
- HSV
- HSL



Algorithm Design

- Kalman Filtering

Conclusion

Our proposed technology is:

- Promising
 - ~5mm error
- Affordable
 - ~\$40 camera setup
- Minimally invasive
 - Only requires cameras and fiducial markers

Future directions:

- Increase camera quality
- Integrate dual stereocamera setup
- Marker adhesive design

Acknowledgements



UC San Diego

JACOBS SCHOOL OF ENGINEERING
Mechanical and Aerospace Engineering



We would like to thank our lab members at the Talke Biomedical Device Lab, as well as Dr. Farshad Ahadian, MD for their continued support and advice. Research supported by GEM grant #2020429.