

Introduction

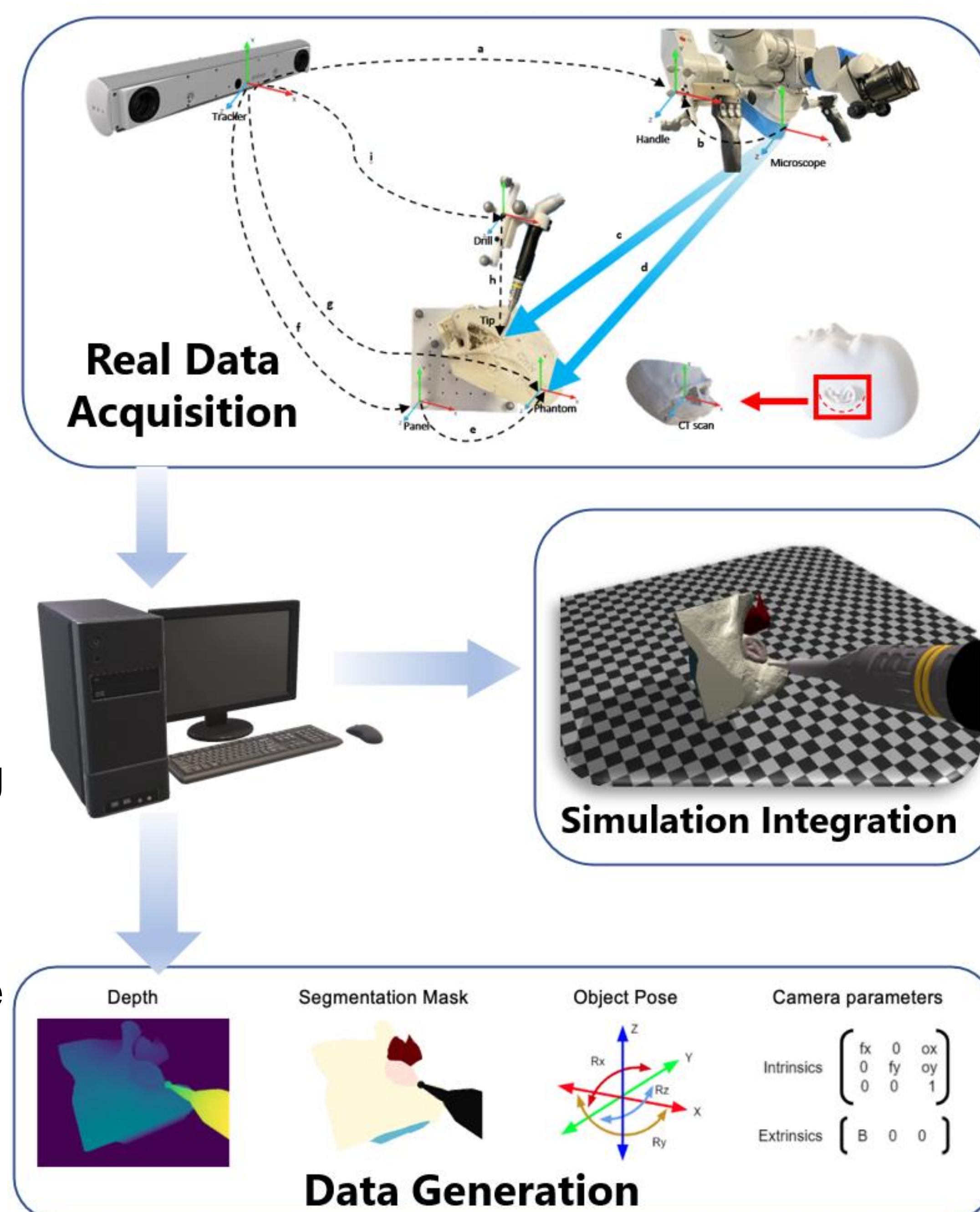
Surgical simulators have been recently exploited not only as a platform to plan and train surgery preoperatively but also as a tool for data generation. However, attempts to develop algorithm in virtual simulation when placed in real scenario tended to perform worse than expected. While efforts has been made to either get more accurate real world data or more natural simulated data, using partly from both has not been investigated. Real Data alone involves cascaded calculations and transformations which intuitively amplify the error throughout each step. Picking either way is problematic.

Objectives

Therefore, we proposed a novel compositional paradigm along with AMBF++ of real world data and generation of virtual reality annotations to refine and expedite the data generation process both in favor of better surgical training and preoperative plan but more importantly for overcoming the data scarcity issue existed widespread in Deep Neural Networks (DNNs) training.

Overview of Pipeline

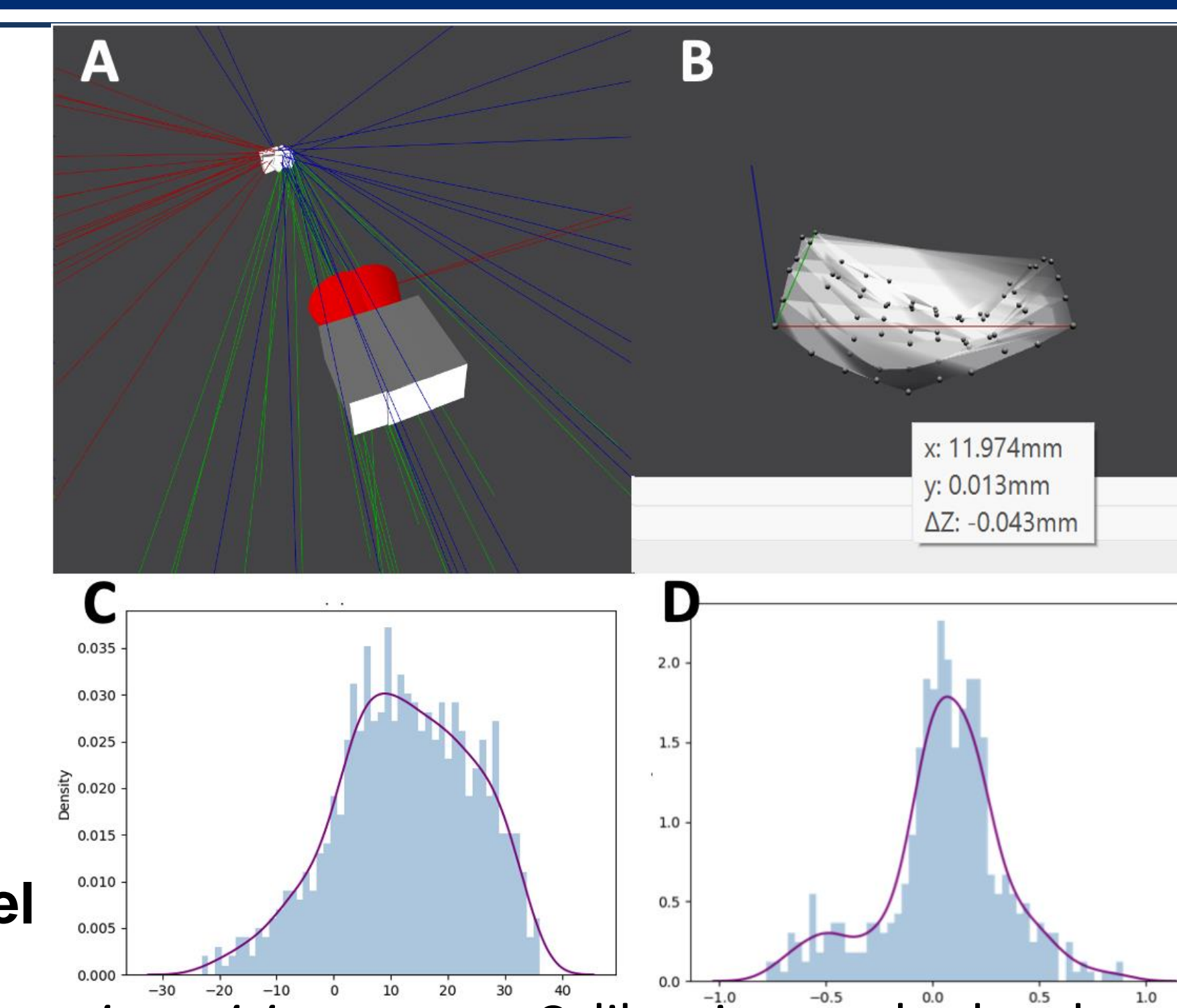
- Use surgical navigation setup to get 3D poses in real time including Microscope, Optical Tracker.
- Poses will be transmitted to PC and it will produce the corresponding VR scene meanwhile generate data of significance to pose estimation training.



Results

From comprehensive review on industry and academia, Charuco Target has been selected and Improved calibration pipeline has been adopted for best possible calibration result for later overall accuracy between virtual and real target. For instance, still snapshot tool for better stability and environment light control are some of the crucial components for our results.

Figure 1—Microscope Calibration Results
A) Stereo Calibration Result B) Target Optimization
C-D) Optimization from 11.4 ± 11.9 pixels to 0.05 ± 0.28 pixel



Ref_1: Hong Chen, Huiyang Liao, and Xianmin Zhang. *Telecentric stereo micro-vision system: Calibration method and experiments*. 57:82–92.

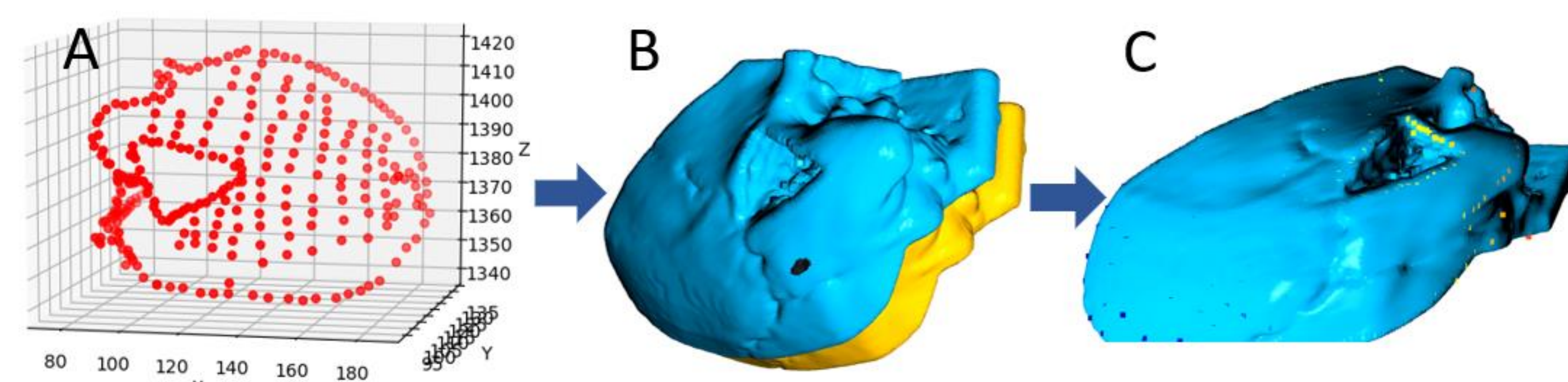


Figure 2—Phantom Registration
A) Sampled Point-cloud B) Registration Process C) Registration Result

280 points were sampled on phantom surface by a calibrated pivot. Then ICP algorithm is performed to register the phantom to tracker coordinate.

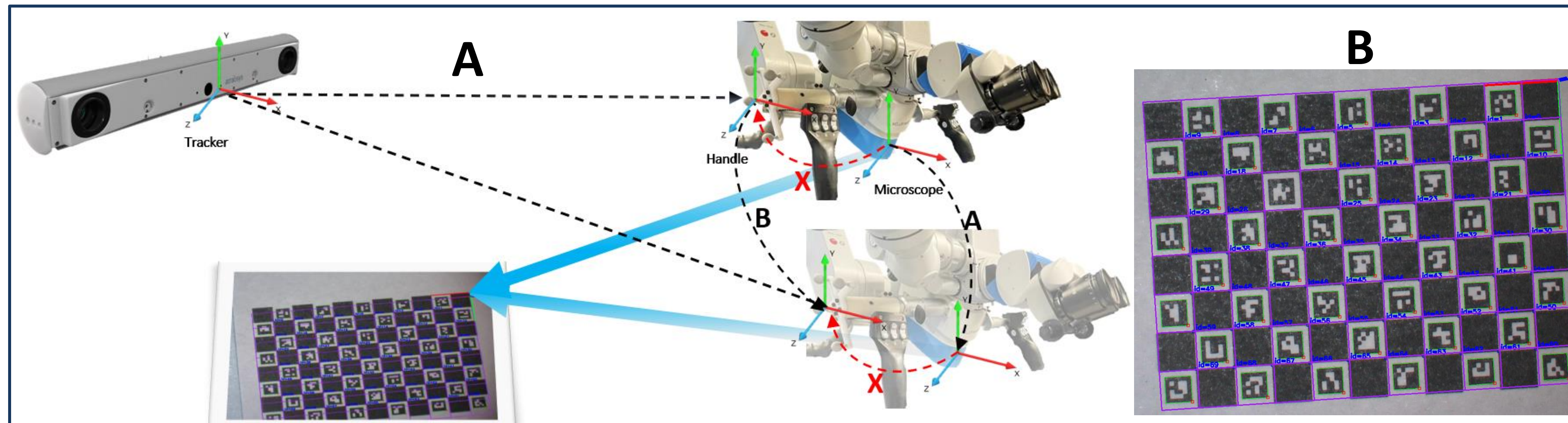


Figure 3—Hand-eye Calibration
A) Hand-eye calibration setup B) reprojected grid (purple) on original frame

The hand-eye calibration was set up as an $AX=XB$ problem. We then refer a toolbox for hand-eye calibration (Furrer et al.) using dual-quaternion. This method optimize whole process including target extraction, time alignment, data pre-filtering, and nonlinear optimization refinement. Hand-eye calibration was evaluated by reprojection error.

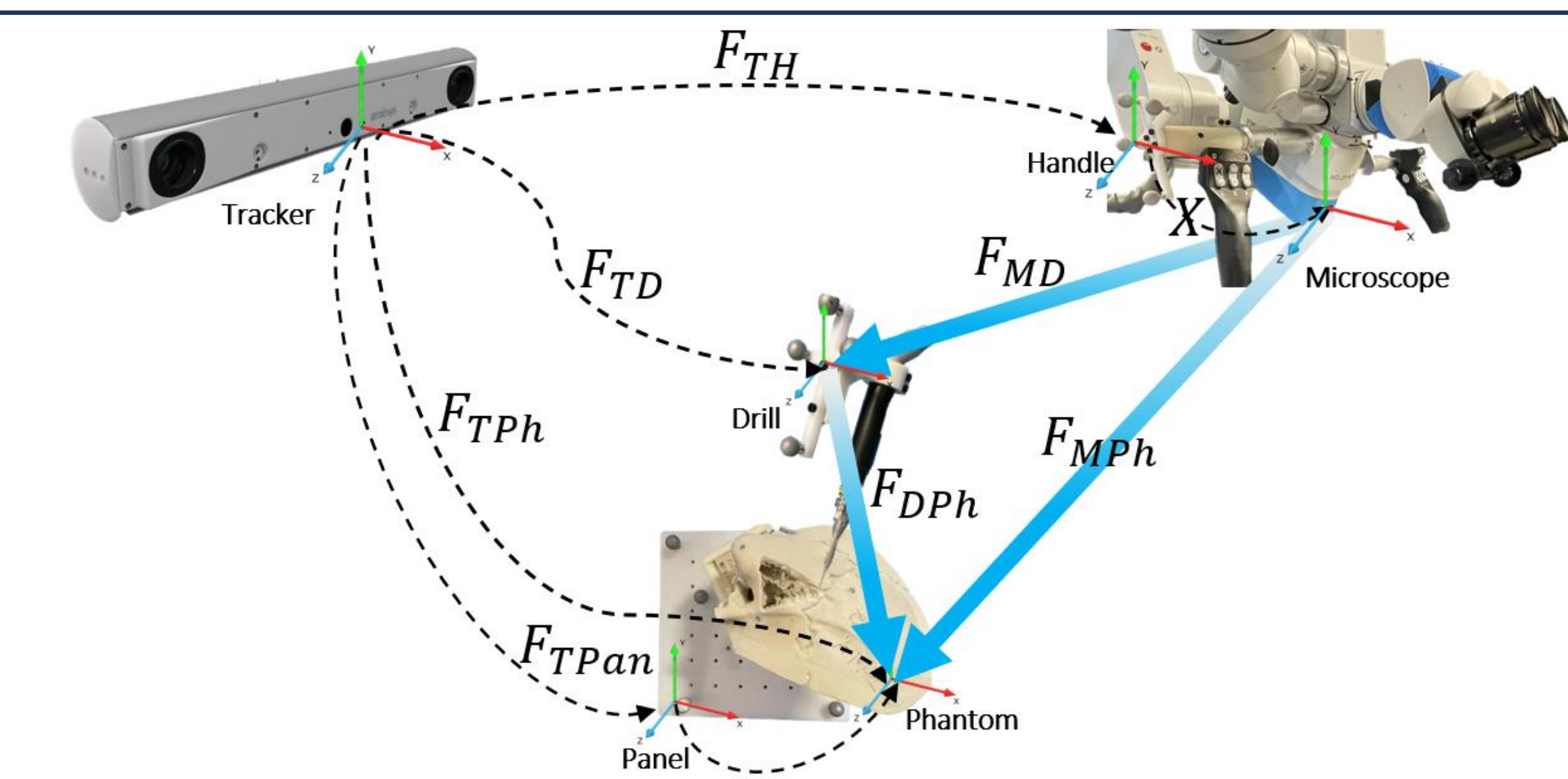


Figure 4 – Sensitivity Analysis

For quantitatively analyze the errors and determine the decisive part that affects the overall errors.

The rotation error for microscope to drill about 0.1 rad, and translation error is about 3 mm.

The projection error is about 100 pixels, mostly determined by X and camera intrinsic parameters. This can be optimized to 10 pixels.

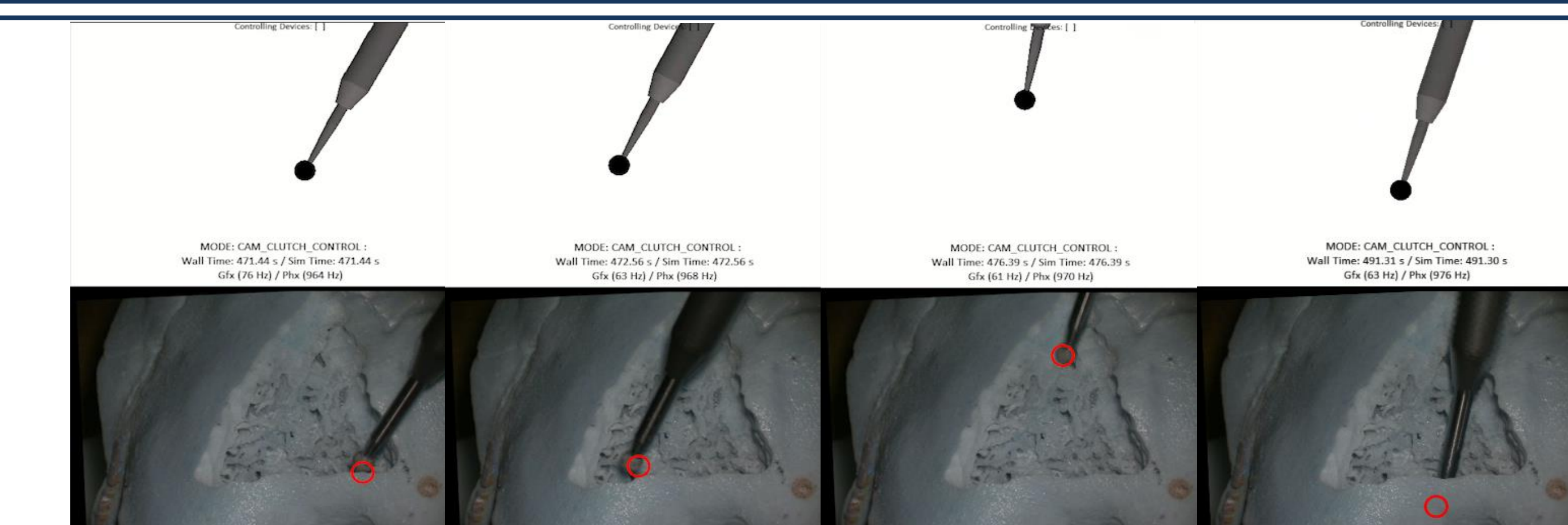


Figure 5 – VR Integration

Integrate motion track into VR environment. Generate depth and masks for real scenes.

Conclusion

In particular our framework is demonstrated to achieve down to 0.6mm in surgical tool translation error furthermore with down to 1 mm and 1° error in pose tracking to achieve the state-of-the-art performance in this specific task. Our code and sample data are released at <https://github.com/Rxliang/RoboMaster>

Future Work

- Integrate phantom into VR environment.
- Generate Segmentation masks into real scenes.
- Benchmark DNN performance on synthetic data and our data.
- Frame-to-model pose estimation.