Seminar – Fall 2023

Robot_Assisted CT_Guided percutaneous procedures to Improve in Accuracy of Navigation system

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Contents

Recap : Dual Sensor

What is Dual sensor?

The dual sensor is designed with:

- Optical localizer
  - detects and tracks 6-DoF poses of medical instruments

- Two RGB-D sensors
  - equipped with a Tof depth sensor and a visible light camera that provides both 3D surface data and the corresponding RGB color information

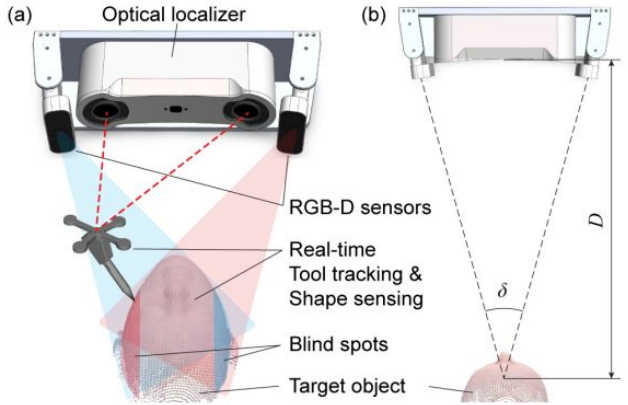
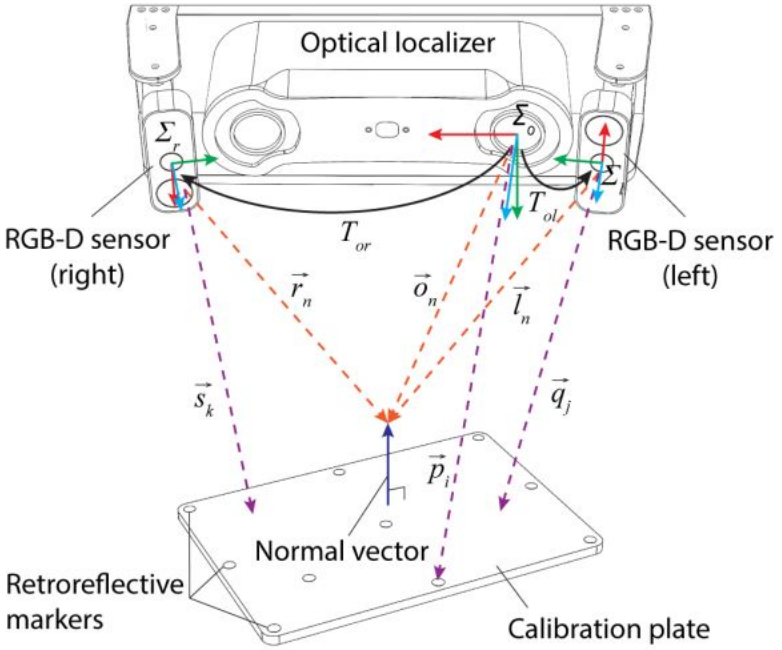


Fig. 1. Dual sensor design: (a) configuration and (b) working distance; Integrating an optical localizer and two RGB-D sensors enables simultaneous sensing of real-time 3D surface shape and 6-DoF tool pose. Two RGB-D sensors mitigate mutual blind spots.

Recap: Calibration of Dual Sensor

The proposed one-time calibration method are introduced in the following sub-sections

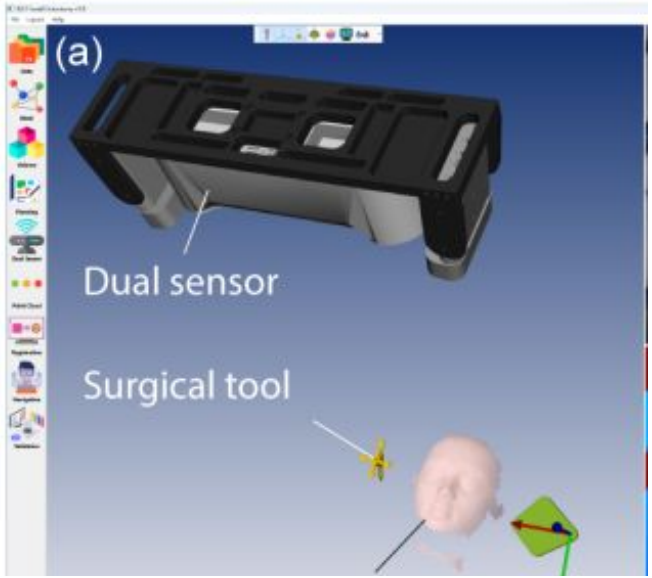
1. Calibration Plate
2. Estimation of Normal Vector
3. Estimation of Rotation Matrix
4. Estimation of Translation Vector



Software Implementation

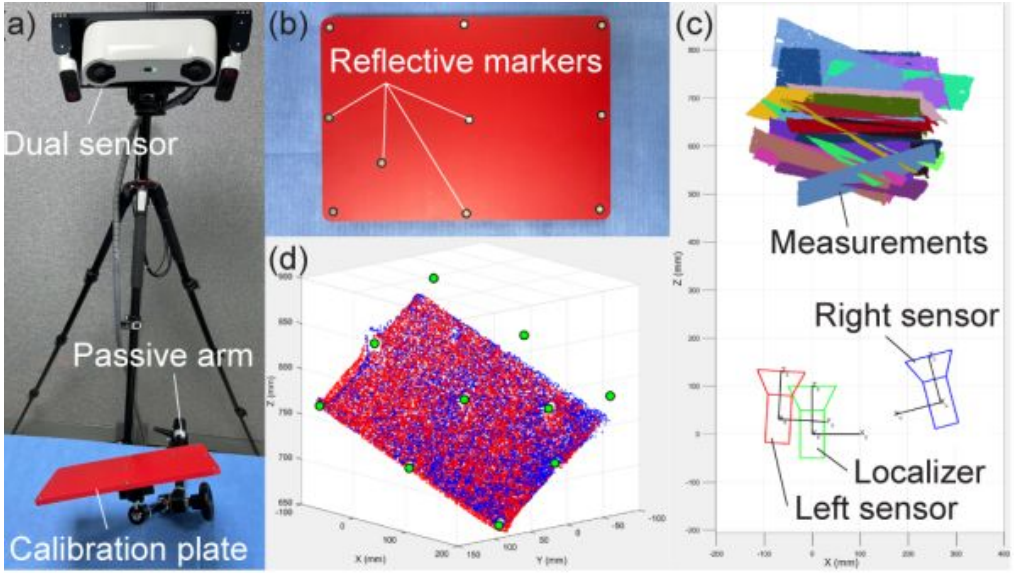
Core functions implement in software program

- Down sampling
- Edge Noise Reduction
- Point cloud Fusion
- Tool Tracking



Dual sensor software program: (a) 3D virtual space that shows 3D models of the dual sensor, surgical tools, and a shape measurement of the target object

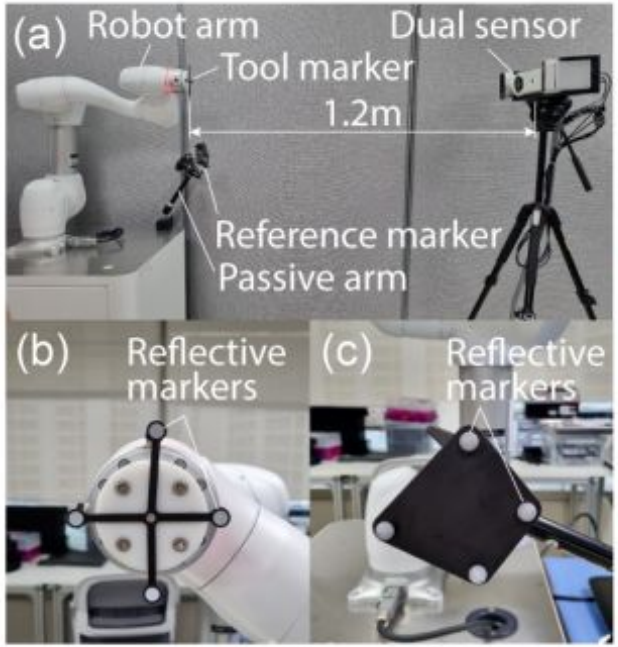
Evaluation of Sensor Calibration Accuracy



Evaluation of sensor calibration accuracy: (a) experimental setup, (b) calibration plate containing a red planar surface and ten retroreflective flat markers, (c) measurements of calibration plate in 20 varied poses in different colors, and (d) visualization of center points of the markers (green) and 3D points of the plate transformed by Tol (blue) and Tor (red)

Experiment: Tracking Accuracy

- Two rigid-body markers are designed and fabricated using aluminum.
- The first marker was intended for potential attachment to surgical tools, while the second marker was prepared to be used as a reference.



Evaluation of tool tracking accuracy: (a) experimental setup, (b) rigid-body tool marker attached to the robot's end-effector, (c) rigid-body reference marker attached to the robot's base,

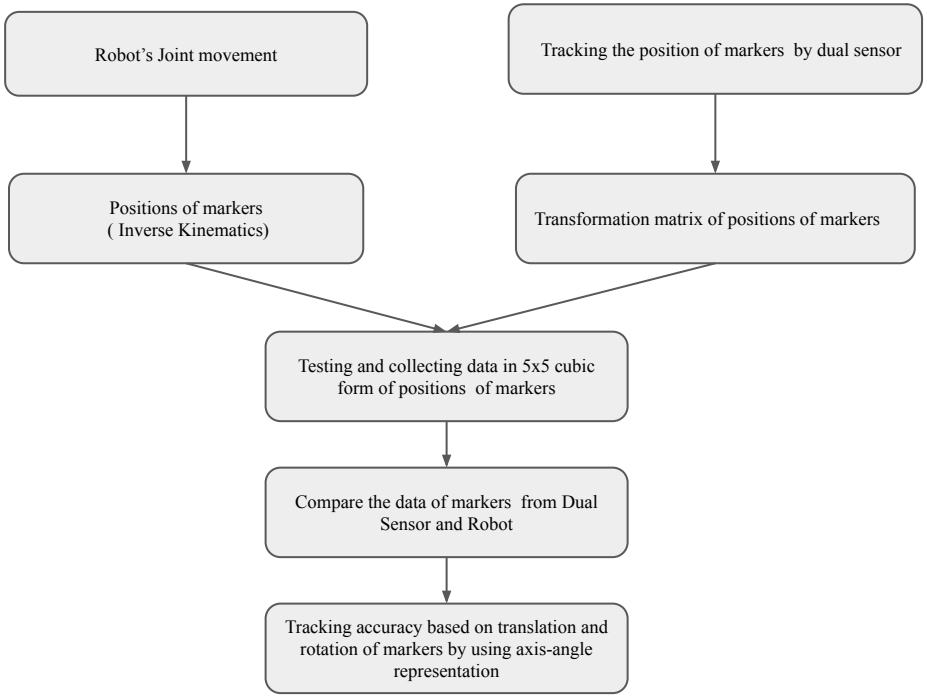
Robot’s Specification

Robotic arm

- Joints: 6
- Payload: 6 kg
- Range: 900 mm
- Speed: 1 m/s
- Repeatability: ± 0.1 mm
- Weight: 27 kg
- Accuracy:±0.05 to ±0.03 millimeters

Doosan M609

Flowchart for Tracking Accuracy of Dual Sensor



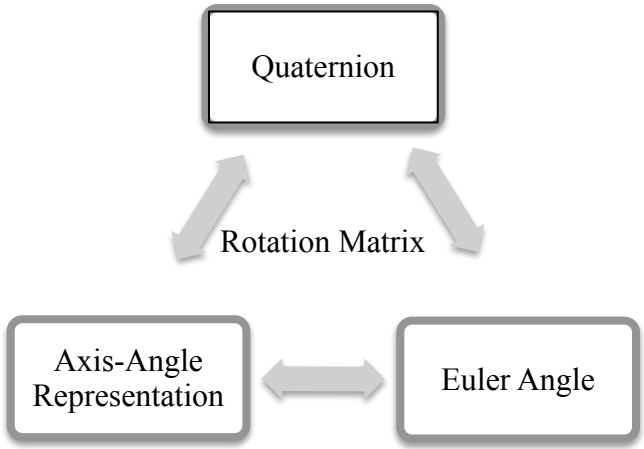
Transformation Matrix

$$T = \begin{bmatrix} R & Pos \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} \begin{bmatrix} X_x & Y_x & Z_x \\ X_y & Y_y & Z_y \\ X_z & Y_z & Z_z \end{bmatrix} & \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \\ \begin{matrix} 0 & 0 & 0 \end{matrix} & 1 \end{bmatrix}$$

Rotation

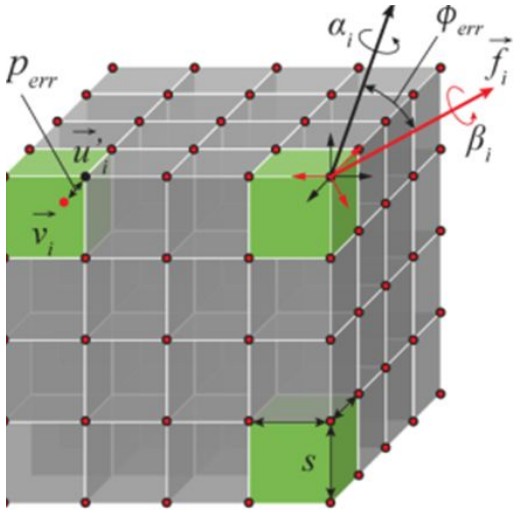
Translation

How to Find Rotation Matrix



Evaluation errors of Dual sensor

- The robotic arm moved its end-effector to each grid point within a 5×5×5 cubic grid, totaling K = 125 grid points
- At each grid point, two different rotations were applied to the robot's end-effector: a constant rotation for every grid points, Rc, and a random rotation for each grid point, Ri .
- A random rotation - range of -30° to 30°in roll, pitch, and yaw angles.
- The poses of the two markers taking 0.05sec (20fps)

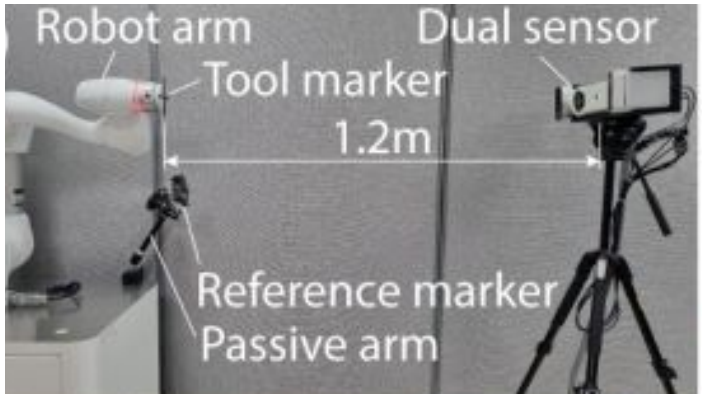


Tracking Accuracy

The translational and rotational errors for dual sensor in tool tracking:

$$p_{err} = 0.53 \pm 0.27mm$$

$$r_{err} = [0.23 \pm 0.089°, 0.040 \pm 0.024°].$$



Conclusion

- A hybrid sensor system that combines two RGB-D sensors with an optical localizer, enabling it to seamlessly and concurrently conduct real-time 3D shape sensing and 6-DoF tool pose tracking.

- Usage : Deformable registration, augmented reality-based guidance, robotic assistance, and automation

- Deploy the sensor system in specific medical applications, including image-guided facial surgery, needle intervention and breast biopsy.

Thank You