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A robust optical/inertial data fusion system for motion tracking of the robot manipulator

Key words: Data fusion, Optical tracking, Inertial measurement unit, Kalman filter

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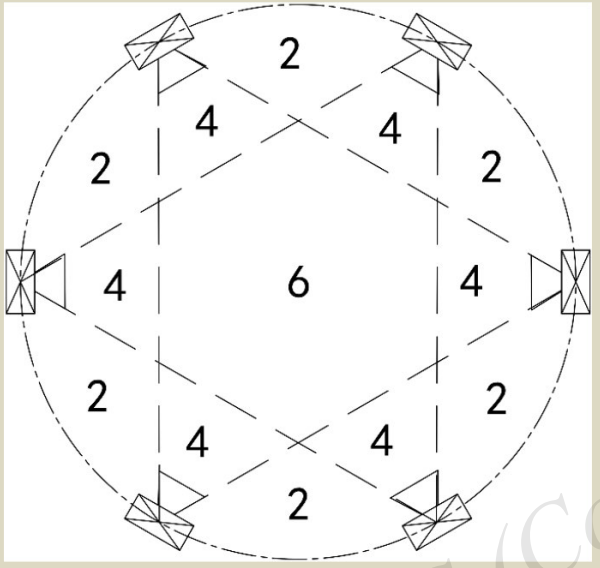
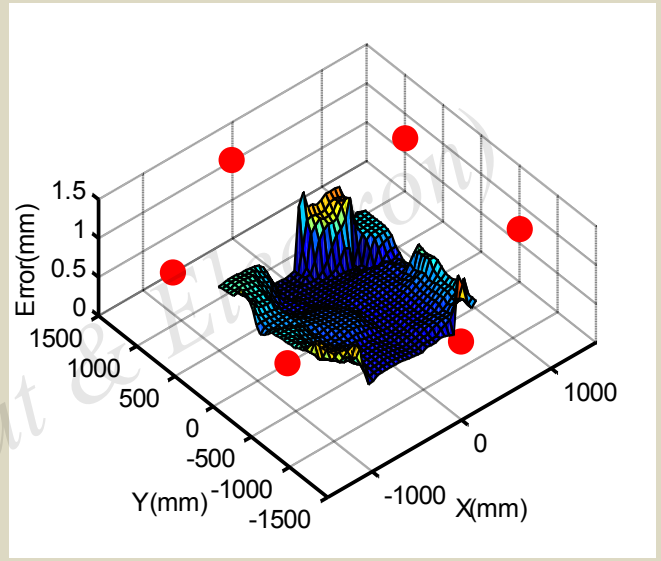
Introduction

- Motion tracking of robot manipulators, which is needed for kinematic calibration or real-time motion control, requires high accuracy and robustness.
- The optical tracking system (OTS) has high-accuracy position and orientation tracking ability, but suffers from the marker-missing problem and uneven error distribution in the workspace.
- A method for improving a low-cost OTS in terms of accuracy and robustness is developed using data fusion with an inertial measurement unit (IMU).

Design method (I)



Positioning of the six cameras (the number in each area indicates the number of cameras that can cover the area)

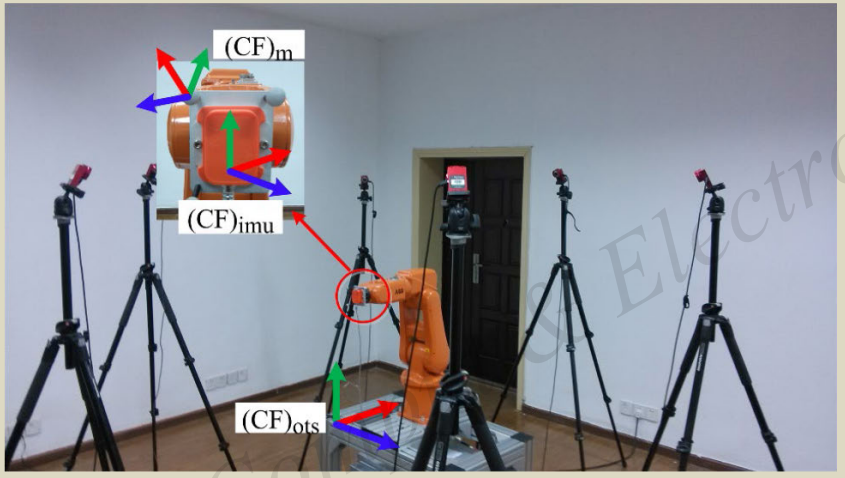


Error distribution of OTS (● denotes the position of each camera)

Performance evaluation of OTS shows an uneven error distribution in the workspace of OTS.

Design method (II)

System setup:

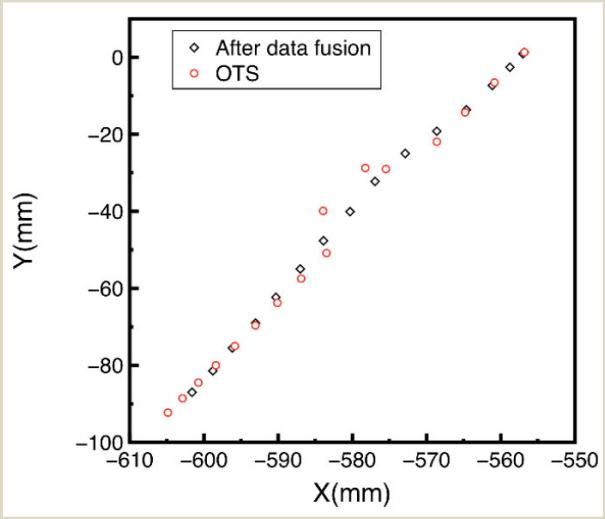


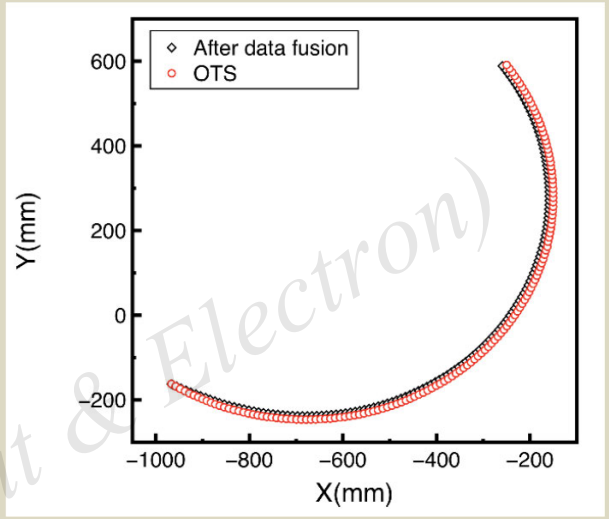
The data from OTS and IMU is used to estimate the position x_p and orientation x_o of the robot's end effector using the Kalman filter. The discretized transition equations of the state space models are

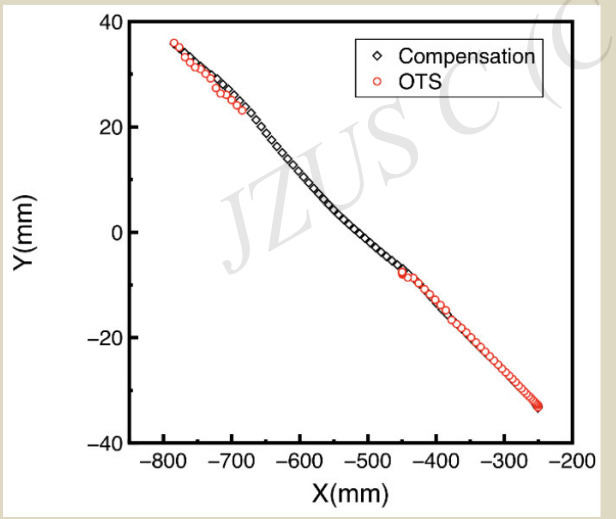
$$\begin{bmatrix} \boldsymbol{x}_p(k) \\ \boldsymbol{x}'_p(k) \\ \boldsymbol{x}''_p(k) \end{bmatrix} = \begin{bmatrix} 1 & \Delta T & \Delta T^2/2 \\ 0 & 1 & \Delta T \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \boldsymbol{x}_p(k-1) \\ \boldsymbol{x}'_p(k-1) \\ \boldsymbol{x}''_p(k-1) \end{bmatrix}, \quad \begin{bmatrix} \boldsymbol{x}_o(k) \\ \boldsymbol{x}'_o(k) \end{bmatrix} = \begin{bmatrix} 1 & \Delta T \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \boldsymbol{x}_o(k-1) \\ \boldsymbol{x}'_o(k-1) \end{bmatrix},$$

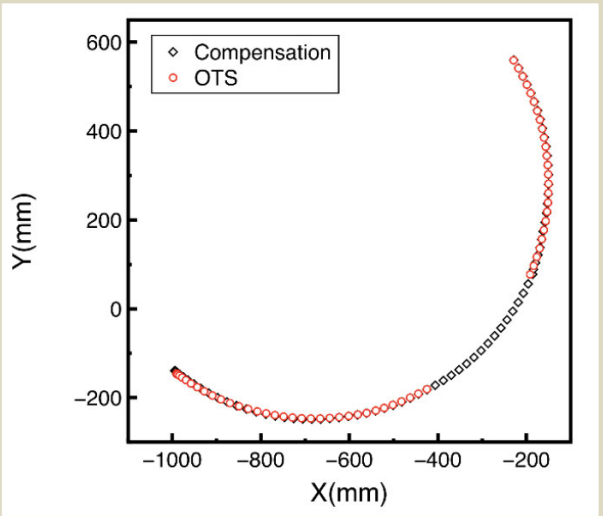
where ΔT is the sampling time of the discretization.

Experimental results









Conclusions

- A robust optical-inertial data fusion system is proposed for motion tracking of the robot manipulator.
- Based on the evaluation of error distribution of OTS, a Kalman filter with a dynamic covariance is developed for data fusion.
- The capability of the developed approach is proved by several experiments, and the performance of OTS is improved in terms of accuracy and reliability.