Improving Tracking Accuracy via Fusion of Electromagnetic and Inertial Sensing

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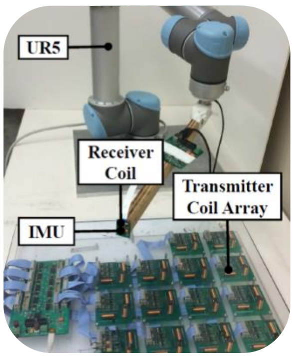
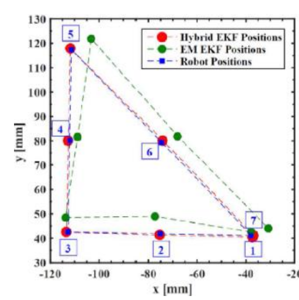
Tracking systems are essential for many computer assisted medical interventions because they allow the doctor to understand their position in the actual patient anatomy with respect to preoperative or intraoperative images. This study presents a hybrid electromagnetic (EM) and inertial (IMU) tracking system that maintains its accuracy even when the EM measurements are disturbed by metal. Experiments with and without metal were performed to demonstrate that the proposed method provides good static tracking for position and orientation. The long term goal is to extend hybrid tracking method to the dynamic case.



The EM Tracking system consisted of a 3x3 array of +z direction aligned coils, excited sequentially, and a receiver coil mounted on a UR5 robot's end effector. The receiver coil measured the magnitude of the magnetic field generated by the transmitter coils. The dipole field approximation is used for the coil magnetic field. The IMU tracking system consisted of a tri-axis accelerometer mounted on the UR5's end effector. The z-axis of the accelerometer is aligned with the coil axis of the receiver coil.

The Hybrid Tracking Extended Kalman Filter "predicts" and "updates" 5DOF position and orientation from each EM measurement. If metal is detected the EM measurements are not used to update state predictions. Metal is detected by comparing azimuth angle estimations with and without accelerometer data. When the EM measurements are not corrupted by metal the two estimations of ø agree. When the EM data is corrupted by metal the estimations are dramatically different. This difference is detected and used to reject inaccurate EM measurements. It is assumed that the initial data is not corrupted by metal. Additional calculations are performed so the system is 6 DOF. The last DOF is lost if the coil axis is aligned with gravity.

To test the performance of the Hybrid Tracking EKF, the robot was stopped every 37.5mm along a triangular path. Metal was introduced at each point. The robot's recorded position was taken as ground truth and a traditional EM EKF and our novel Hybrid Tracking EKF were both used to track the position of the robot. Error was defined as the distance between the estimated position and the robot position. The EM EKF had an error of 7.06mm and the Hybrid Tracking EKF had an accuracy of 0.75mm. The Hybrid EKF tracking accuracy was essentially unaffected by the presence of metal.



The contribution of this study is to show that EM and IMU measurements can be used together to increase static tracking accuracy in the presence of metal. The results show that the Hybrid EKF tracking accuracy is nearly independent of metal. The overall accuracy of our system is on the order of 0.7-0.8mm. The main direction of our future work is to extend this algorithm to the dynamic case. Our approach fuses coil, accelerometer and gyroscope measurements in a Kalman Filter.