Sensor Fusion using IMU Data for 3D Orientation

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Introduction

- Gyroscope, accelerometer, and magnetometer can be used to find the 3D orientation of a system
- The sensors inside an iPhone 12 were used to record the data for this project
- Each sensor experiences disturbances which can distorted and inaccurate orientation
- Sensor fusion is used reject the disturbance and obtain the accurate orientation.
- The system maps the device's coordinate and the coordinates created by the gravitational vector and magnet vector

Figure 1: Input signals from MARG

Conclusion

- The system uses quaternions which prevents gimbal lock and ensures numerical stability in the system
- The average error in orientation was higher than desired
- Further research will be conduct to lower the average error from 7 degrees to 3 degrees or lower
- The high average error comes from rapid linear movement of the iPhone
- Other tests were conducted with slow moving data and the average error was around 3 degree

Design

- The project implemented a Kalman filter using MATLAB as the simulation tool
- Around 30 seconds of data was recorded from the sensors on the iPhone
- To better translate the orientation, the coordinates were transformed from quaternions to Euler angles or x-y-z coordinates.
- From these three graphs, the filter matches the ground truth very, except in the roll angles around 10 seconds.
- At 10 seconds, the phone moves rapidly and the filter mistakes the linear movement in the roll angles as a disturbance and smooths them out.

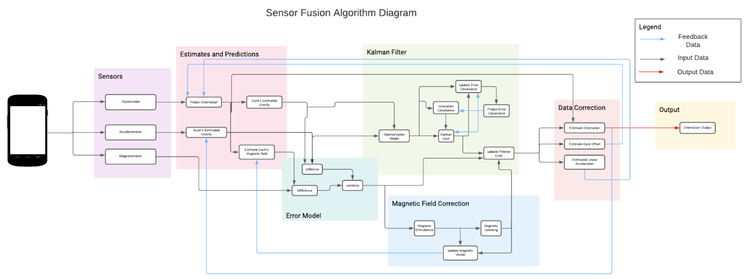

Figure 2: Sensor Fusion Diagram

Sensor	Advantage	Disadvantage
Gyroscope	• Rapid changes in orientation	• Drifts over time • Only relative orientation
Accelerometer	• Absolute measurement of gravity	• Corrupted by rotation and rapid movements
Magnetometer	• Measures Earth's magnetic fields	• Corrupted by other magnetic fields

Figure 5: Table of sensor's advantages and disadvantages

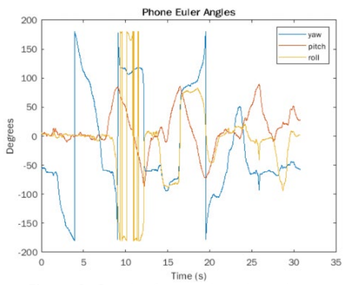

Figure 8: Graph of ground truth angles

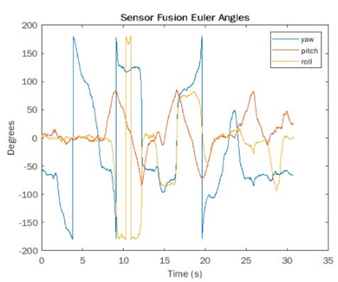

Figure 9: Graph of sensor fusion angles

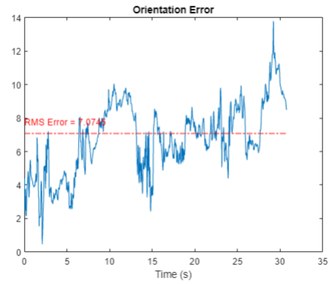

Figure 10: Graph of error in orientation and the average error in red

Results

- The sensor fusion algorithm used is a Kalman filter
- A Kalman filter predicts a value then corrects it
- Gyroscope predicts orientation
- Accelerometer and magnetometer correct the orientation
- The Kalman filter is extended using covariance matrices to remove the reliance of linearization
- Algorithm accepts parameters to reduce disturbances

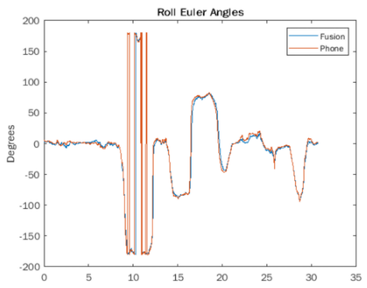

Figure 3: Graph of roll angles

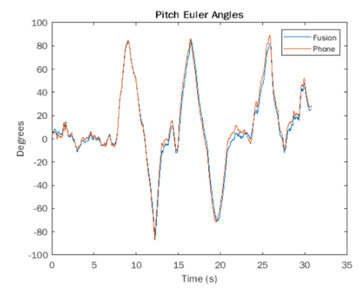

Figure 4: Graph of pitch angles

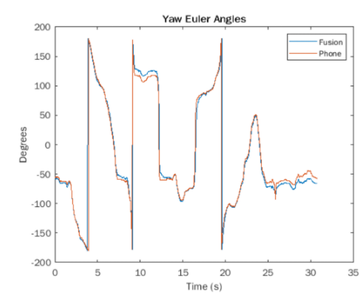

Figure 6: Graph of yaw angles

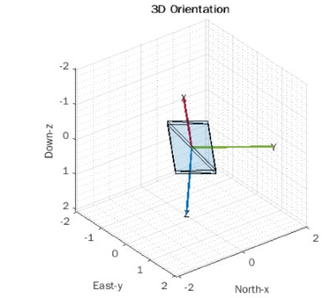

Figure 7: 3D graph of orientation

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