Hochschule Karlsruhe (HSKA) – University of Applied Sciences

Geomatics Master (MSc.) **Faculty of Information Management and Media (IMM)**

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Master Thesis (Year 2013)

Development of an Android-Smartphone based GNSS/MEMS Autonomous Vehicle Navigation System and Evaluation on a Calibration Robot in cooperation with John Deere

Referee

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Key Words

Precise Farming, Navigation, MEMS Sensors, INS, Multisensory Navigation, Kalman Filter, DGNSS, Smartphones, Android, Java, C, JNI, Android Bluetooth, Magnetometer Calibration

Summary

Specific tasks in agriculture, such as growing vegetables, require precise and repeatable positioning using differential GNSS services in real time. Through the use of additional sensors not only position and velocity, but also orientation of the vehicle can be computed. The topic of the thesis has been built in collaboration with John Deere. It is based on the integration of a smartphone, to be used as a low cost multi-sensor platform for vehicle navigation and wireless data transmission, with the John Deere's GNSS receivers to support its positioning and orientation. The aim is to extend those NAVKA algorithms developed by the University of Applied Sciences of Karlsruhe (www.navka.de), and adapt them for agricultural operations. The multi-sensor platform (acceleration, rotation and magnetometer sensors) is used on a smartphone (with Android OS). By integrating GNSS and sensor data with the Navka algorithms a highest measurement frequency can be provided, highest accuracy on position and velocity and orientation of the vehicle. The wireless data transmission method used has been Bluetooth, allowing cableless operability between the smartphone and the GNSS receiver. For the configuration of the adjustment parameters of NAVKA and for proving the quality of the results, the smartphone has been fixed to a robotic arm for compare the results with the accurate data which it provides. Finally, the smartphone has been integrated in a bracket in a tractor for realizing tests under real circumstances to check whether the result obtained from the previous tests was valid.

For the data collection from the GNSS receiver and the smartphone sensors an Android App has been created. This App is responsible of connecting the smartphone with the Bluetooth receiver, for retrieve the receiver data regarding position and velocity, the retrieved data comes in an array of bytes so a parsing function has been also created for transform this information into human readable format. The App collects, as well, the data from the gyroscopes, accelerometers and magnetometers of the smartphone and makes the time synchronization between receiver and sensor measurements. The collected data will be treated in post-processing with the Navka software to find out the best configuration and adjustment parameters for obtaining the best navigation solution available.

Regarding the integration of the collected data with the NAVKA algorithms, our primary goal was to obtain the 0.02 m position accuracy provided by the GNSS receiver, good velocity accuracy and a good orientation solution. The position solution (figure 1) was different depending on the GNSS measurement frequency. In the case of the 1Hz measurement frequency, drift errors coming from the INS system where found. That is why it was assumed, for an optimal position solution the correction of the drift effect from the INS system by the GNSS measurement has to be with a frequency of 10Hz. After this assumption, all the datasets presented a position accuracy of 2cm or better in the most of the cases. A second assumption was, for a large GNSS outage, smartphones are not able to handle the system alone. As regards the velocity (figure 2), the filter solution provides a very accurate velocity solution, more than the provided by the GNSS receiver. The velocity and position solution from the filter, when the vehicle stops, were presenting irregularities. The Navka algorithms should be adapted for this type of trajectories, maybe a threshold for very slow velocities. Because of the Smartphone sensors quality, the solution of the orientation angles roll and pitch (figure 3) was well computed but, sometimes, the noise from the sensors has been transmitted. The noise is more present on measurements where the roll and pitch angles are kept on zero, being the solution fuzzier than when they do vary. It has been also found, there is an internal calibration of the smartphone when it comes to rotation rates raw data, when the rotation rates in general where very noisy an interval of all 0.000001 measurements has been found. The magnetic sensors solution appeared too problematic due to calibration and accuracy issues. A lot of disturbances where affecting the magnetometer both internal and external of the smartphone. For this purpose, a very big investigation is needed, checking the disturbances of the different vehicles on the magnetic field sensors, of the robotic arm on the case of robot tests and of the different smartphones itself. Also the positioning frequency has been

improved. With the GNSS receiver, the highest measurement frequency is at 10Hz while, when integrating the INS system, the measurement frequency is much higher, of about 100Hz.

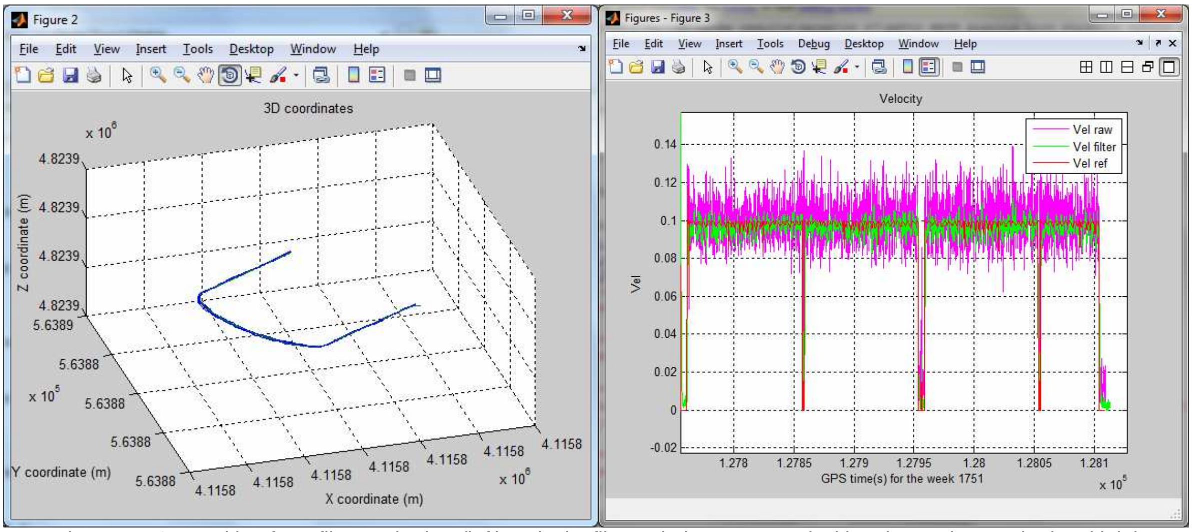

Figure 1 – 3D position from filter and robot (left), velocity filter solution compared with vel. raw data and robot (right)

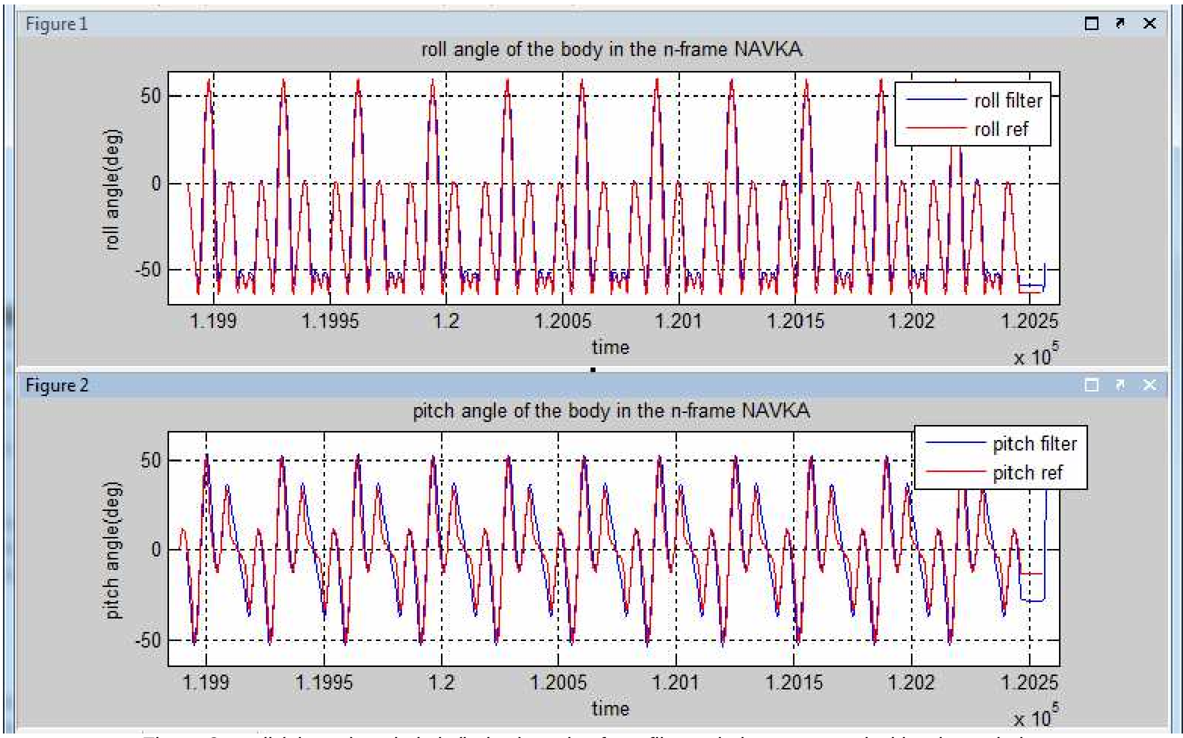

Figure 2 – roll (above) and pitch (below) angles from filter solution compared with robot solution

The multisensor-multiplatform NAVKA with the distributed sensors, consisting of 1 GNSS-sensors and 1 smartphone MEMS-platform could be proved to work very well and providing a high precise navigation solution on that sensor-design.

But the technical/physical problem caused by of the magnet disturbance field on the tractor, and on the robot, affected the quality of the navigation solution.

There are however several different possibilities to solve that problem. The first one could be to find a better location for the smartphone on the tractor, where the magnetic field is not disturbed (like it is possible e.g. on drones). Another option could be, to change the sensors configuration. For example to several MEMS platforms and to renounce on magnetometer data, or to use a low cost L1 GNSS receiver in addition to the existing two-frequency GNSS receiver. Either the DGNSS raw data (deep-coupling) or the two DGNSS moving-base positions (tight coupling) could be integrated in the NAVKA multisensor-multiplatform algorithm.