Hochschule Karlsruhe (HSKA) – University of Applied Sciences	
Geomatics Master (M. Sc.)	**Faculty of Information Management and Media (IMM)**

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Integration of Wide-area Differential GNSS Receivers into Multi-sensor Navigation-algorithms for Precision Agriculture Applications

Referee

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Key Words

Integrated Navigation, Loosely-coupled Architecture, GNSS/INS, MEMS Sensors, C, Raspberry Pi, Vim, Quaternion-based Kalman Filter, MATLAB, Land Vehicle Guidance

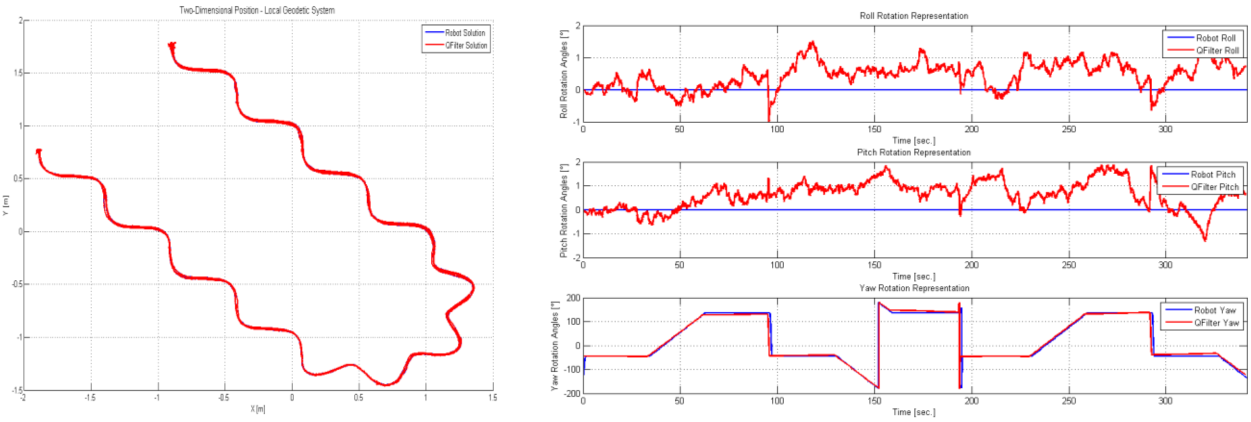
Summary

The particular integration of Global Navigation Satellite Systems (GNSS) and Inertial Navigation Systems (INS) is currently being considered as a solution proposal for land vehicles autonomous navigation. This technologies unification, under certain conditions, is able to provide with the consistency and accuracy necessary for most of the applications associated to the agricultural sector. These days, the farming precinct talks about Precision Farming, term involving the employment of position, velocity and heading information for autonomous guidance, in order the land vehicles to precisely automate agricultural duties such as plowing, tilling, disking, harrowing and planting with a sub-decimeter quality level.

Figure 1: *John Deere's Agrar-Management System Solution (Source: www.deere.de/wps/dcom/de_DE/products/equipment)*

Taking into consideration the notable interest of John Deere enterprise to incur within this integrated-navigation concept, a working relationship between John Deere's Intelligent Solutions Group (ISG) and the Karlsruhe University of Applied Sciences has been established. The cooperation possessed the aim of performing a GNSS-aided inertial navigation integration, yielding a compatible and reliable system for agricultural appliance. A loosely-coupled GNSS/INS architecture has been implemented, using the John Deere SF3000 GNSS receiver and the sensors box known as Robinette GM1 from teXXmo sensor systems. The receiver provided with the satellite navigation solution (position, velocity and time) and the Robinette GM1 contributed with the sensed accelerations, rotation rates, magnetic readings and barometric pressure, all of those magnitudes relative to the inertial-Frame.

Pursuing both navigation principles to be fused, the use of a GNSS/INS integration algorithm has been materialized, known as the QFilter [Zwiener, Aug. 2012], mathematical set of applications based on a Quaternion Kalman Filter for the navigation state vector estimation under a GNSS deep-coupling integration notion. With the support of the Raspberry Pi credit-card micro-computer as the computation unit, four (4) performance tests on an industrial robotic arm have been carried out, collecting Real Time Kinematic (RTK) satellite navigation solutions (2.5 cm exactitude) and each quoted observation yielded by the mini-sensors box. The position, velocity and time information out of the receiver was acquired at a working frequency of 10 Hz, while the Robinette GM1 was set to acquire 750 observations every second (750 Hz). The corresponding robotic arm navigation results have been meticulously compared with each generated QFilter solution, computed results being the direct outcomes of a post-processing phase executed on a laptop personal computer. The upcoming figures express the direct results from Test N° 3, carried out at John Deere Intelligent Group facilities.



(a) (b)

Figure 2: (a) Two-Dimensional Positioning Solution (b) Roll-Pitch-Yaw Angles Comparison

All the way across the current work, it has been determined that the implemented system can reliably provide with an accurate positioning solution in the order of 0.01 m of exactitude, competent quality considering the stable 0.025 m supplied by the RTK satellite solution signal. Correspondingly, satisfactory orientation parameters have been also computed, characterized by a roll middle error in the magnitude of 0.332°, a pitch middle error of 0.509° and a heading middle angular difference of 3.637° (best obtained results). It is important to note that during the observation time on the robotic arm, the raw measurements have been pronouncedly disturbed by several factors such as the presence of harsh artificial magnetic anomalies, inertial sensors temperature fluctuations and moderate vibrations on Robinette GM1 holder. These undesirable side effects were presented during each of the performance tests but, their respective quantification and modeling has not been carried out so that the exposed orientation middle differences have been strongly perturbed by these influences, affecting the most the heading angle result. As possible alternatives to aim for a better yaw angle determination are the use of the multi-antenna GNSS-derived heading or the trajectory-derived heading, methods which could offer stable solutions when there is a minimal presence of GNSS outages [Groves, Apr. 2013].