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Publication date:
2014

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Jæger, C. L. D., Jensen, K., Larsen, M., Hundevadt, S., Griepentrog, H. W., & Jørgensen, R. N. (2014). *Evaluating the PORTABILITY of the FROBOMIND ROBOT SOFTWARE architecture to new AUTONOMOUS PLATFORM*. Poster session presented at 9th European Conference on Precision Agriculture , Lleida, Spain.

Evaluating the PORTABILITY of the FROBOMIND ROBOT SOFTWARE architecture to new AUTONOMOUS PLATFORM

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9th European Conference on Precision Agriculture — Facing new challenges, providing new solutions
Lleida, Catalonia, Spain
July 7th-11th 2013

Introduction

The University of Hohenheim (UniHoh) is conducting research in novel precision agriculture production methods which involve crop scouting and organic weeding applications etc. and are collaborating with the University of Southern Denmark on utilizing autonomous field robots in these projects. UniHoh has a field robot platform Autonomous Mechanisation System (AMS) based on a Hako tractor retrofitted with sensors, actuators and the MobotWare framework (Reske-Nielsen et. al., 2006), (Griepentrog et al., 2011), (Griepentrog et al., 2009) allowing autonomous navigation in the field. Recently UniHoh acquired a new robot platform called Armadillo Scout which is a modular platform designed for precision agriculture research. Armadillo Scout runs MobotWare (Beck et. al., 2010) and the open source FroboMind architecture (Jensen et. al., 2012) based on Robot Operating System (ROS) (Quigley et al., 2009). MobotWare has successfully been ported to both the AMS and the Armadillo Scout. To be able to use the same software solution on both platforms UniHoh set out to implement FroboMind on the AMS in this project. The purpose is to have FroboMind and Mobotware coexisting on both platforms which makes it possible to choose the best suitable solution for a given research project based on the qualities of Mobotware and FroboMind. The aim of this work is to evaluate the portability of FroboMind to a new platform with respect to both the implementation process and performance of the robot when operating autonomously in a precision agriculture environment.

Materials and methods

Autonomous Mechanisation System - The Hako tractor
The AMS (Fig.1) or the Hako tractor that was used as the target platform is a part of an advanced robotic crop establishment and control system based on Precision Agriculture principles, and was developed by University of Copenhagen in cooperation with the Department of Automation of the Technical University of Denmark (DTU). The AMS is currently being further developed at the Department of Instrumentation and Test Engineering at University of Hohenheim. AMS is based on a conventional 20 kW tractor (Hakotrac 3000) which was retrofitted with several sensors for navigation along with the controller system MobotWare (Beck et al., 2010) for autonomous operation. All actions on the AMS were achieved by using an electronic controller unit (ECU) (fig. 2) it is a ESX-3XL from Sensortechnik Wiedemann. The safety interlocks and emergency shutdown were achieved with a combination of stamp computers (with PIC microcontrollers), radio links, and hardwired relays. The safety circuit was developed as a result of the Safe and reliable project (Griepentrog et al., 2009). The tractor navigation controller was designed to follow a predetermined route plan accurately and repeatedly across a field with planned action points for implement control (Blackmore et al, 2007), (Blackmore et. al., 2004, Griepentrog et. al., 2009)

Figure 1. Autonomous Mechanisation System((AMS).

FroboMind
FroboMind is a conceptual architecture for field robot control software. The FroboMind architecture fig. 3 is optimized for precision agriculture and similar field robotics research projects with respect to the parameters modularity, reliability, extensibility, scalability and code reuse between different robot platforms and applications. At the current development state FroboMind is not considered to be stable or reliable enough for production use. In this project we have used the latest software submitted to the FroboMind repository at 2012-09-23. In this project FroboMind interfaces to the AMS through the ECU. The FroboMind computer communicates with the ECU through a CAN bus.

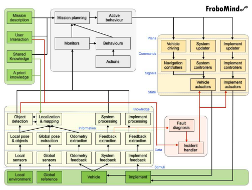

Figure 3. FroboMind archtecture.

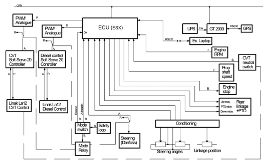

Figure 2. AMS Electronic Controller UNIT (ECU) interfaces.

Results

AMS position and orientation estimation
The FroboMind components which are required to perform simple navigation through row crop environments like orchards and maize fields were implemented on the AMS. Fig.4 shows a ROS-RVIZ simulation of this estimation with respect to the rows. The estimation is based on output from the IMU and LIDAR mounted on the AMS. The green rectangle defines the boundaries from within LIDAR data is used for a RANSAC based algorithm to estimate the rows. The blue lines visualize the estimated rows. An extended Kalman filter fuses the estimated output with the IMU data.

AMS Autonomy
During this project the design of the decision making layer were improved, and new components for mission control and behaviours and actions for in-row driving and headland turns were developed.

FroboMind portability
To test the FroboMind portability with respect to modularity, extensibility and code reuse a plan was made for implementing FroboMind on the AMS. The following table shows the predicted assignments and time consumption. The estimation was based on a team of four persons implementing the new architecture.

Task	Hours
Understanding existing software interfaces	10
Creating FroboMind interface to the ESX over CAN-bus	6
Prepare hardware on the AMS for connecting a FroboBox computer	2
Implementing Wiimote control for the AMS	3
Creating tutorial for adding new nodes to FroboMind	2
Update documentation for AMS	5
Implementing Behavior for the AMS in FroboMind	50
Testing Behavior in an orchard	50

Table 1

AMS and FroboMind performance in an orchard environment
In order to test the FroboMind portability with respect to reliability and precision agriculture applications it was decided to perform a field test in an apple tree orchard at UniHoh. fig.5 shows the approximate orchard tree sizes. The tree rows are 100 meter long and interspaced by 4 meter. In some rows a few trees are missing and/or replaced by younger and smaller trees. During the FroboMind integration and the first tests it was discovered that when requesting the AMS to drive straight it would drift slowly to the left. It is unknown what the cause of this problem is, however based on the performed tests it is likely that the problem is with the steering hardware

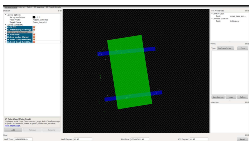

Figure 4. Simulation of robot orientation and offset in a row crop environment

Figure 5. Apple tree orchard used for implementation and testing.

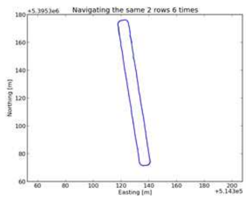

Figure 6. Navigating through the same route between two orchards rows six times.

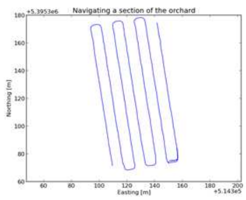

Figure 7. Navigation through a section of the orchard.

Testing FroboMind portability
FroboMind was ported to the Hako tractor during a one week long workshop. The duration of individual working tasks were estimated.

Testing AMS and FroboMind performance in an orchard environment
Fig.6 shows the GPS track from the first trial where the AMS navigates 6 full rounds driving the same path. Before the trial began a test round was completed. During the trial the following observations and comments were made:
1. round was completed successfully. 2. round was completed successfully. During this round a video recording was made while walking behind the robot to document the orchard environment. During the 3. round the robot navigation failed one time causing the robot to drive into the trees. This happened at a location where the apple trees were replanted by much younger trees at the left row. During the 4. round the robot navigation failed one time causing the robot to drive into the trees. This happened at another location where apple trees were missing for more than 6 meters at the right row. 5. round was completed successfully. During the 6. round the robot navigation failed one time causing the robot to drive into the trees. This happened at the same location was the fail during the 3. round. The navigation failures occurred at locations where the apple trees did not provide sufficient data for the implemented laser range scanner row detecting algorithm. Aside from the described problems the robot navigated reliably through the orchard.

Fig.7 shows the GPS track from the second trial where the AMS mission is to navigate autonomously through a section of the orchard.

During the trial the following observations and comments were made:
- Due to the problems with Turning to the right was achieved by hard coding a maximum turn.
- The robot failed a right turn two times. One time due to poor matching of the inter-row width and another time because one row was longer than the rest.
- Aside from these to fails the robot performed very reliable autonomous navigation through the orchard.
- The test was stopped after completing 7 rows.

Conclusion

For a 4 man team it is possible to implement and test FroboMind with 5 working days, though the days are longer than normal working days. The implementation is only possible as long as the hardware interfaces are well documented. It is not possible to optimize the behavior algorithms or low level control algorithms nor is it possible to debug and troubleshoot small problems on the platform within the time frame.

Acknowledgements

This research is linked to and partially funded from the Danish Ministry for Food, Agriculture and Fisheries project: FruitGrowth and the Danish National Advanced Technology Foundation project: The Intelligent Sprayer Boom.

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