Implementations of FroboMind
using the Robot Operating System framework

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Introduction

Several different architectures has been suggested for agricultural robotic vehicles like Agriture (Nebot *et al.* 2011), The Hortibot and AgroBot linux shared memory based architecture (Jørgensen *et al.* 2007), or the FroboMind (Jensen *et al.* 2011). Implementing the different architectures across universities and platforms is complicated. Science of robotics suffers because it can be difficult to replicate the results of other researchers. Barriers to evaluating each other's work include incompatible hardware platforms, closed or proprietary software, and intellectual property concerns that lead to secrecy. Willow Garage claims to have an approach that overcomes these barriers (Oyama *et al.* 2009). ROS (Robot Operating System) is an open source robotics framework designed to take advantage of networked computing infrastructures. It can manage many different process written in different languages across many computers, which enables large, diverse robotics systems that fully take advantage of the available computing resources (Oyama *et al.* 2009). According to Oyama (2009) ROS has dual design goals: take advantage of networked computing infrastructures and encourage sharing of software. Hence in the future ROS may lead to a Robot App Store similar to the iPhone App Store (Orca 2010). As an example Libby & Kantor (2011) used ROS on a perception-based GPS-free approach for localizing a mobile robot demonstrated in over 20km of online operation in a variety of real orchard environments.

Jensen *et al.* (2011) proposed a flexible system architecture *Field Robot Cognitive System Architecture (FroboMind)* which provides the base for further research and development within cognition based navigation of plant nursing robots. This work present the implementation of the latter conceptual architecture FroboMind utilising the open-source cross language robotic framework ROS. Secondly a rugged hardware platform FroboBox is presented. FroboBox will have the most common interfaces often involved when working with sensors and actuators used on agricultural plant and animal nursing robots.

Vehicle mechanical platform

The existing agricultural research vehicle ASuBot was chosen for the implementation of FroboMind. ASuBot is a modified AGCO Massey Ferguson garden tractor and is a joint project between the University of Southern Denmark and Aarhus University. This modifications includes a Topcon AES25 electrical steering system, which makes the ASubot able to steer by sending steering commands, Sick LMS111 Lidars, which is the primary navigation sensors and a ADIS16345 inertial measurement unit from Analog devices which may be used as a pose information source.
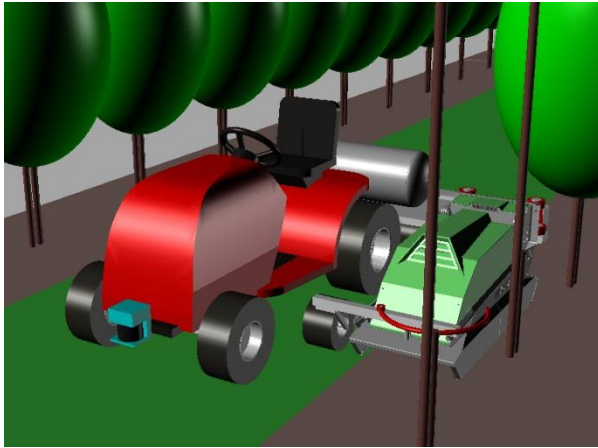
Figure 1: Left: Illustration of domain in which the FroboBox system is used the control the ASuBot equipped with a prototype natural gas burner from EnvoDan ApS (www.envodan.dk) for weeding with orchards. Right: The FroboBox prototype.

Hardware architecture

The FroboBox has been developed to handle the low level processes listed in the conceptual architecture of FroboMind (Jensen *et al.* 2011). The Frobobox provides a wide range of interfaces which is often used when communicating between sensors, implements and actuators. Hence, FroboBox will be suitable for other vehicle-platforms than the ASuBot as it may easily be adapted to different sensor/implement/actuator configurations.

Furthermore the FroboBox provides a wired/wireless network which may be connected to the Internet using a 3G uplink as well serve as a link to an *Autonomous Task Computer* which handles the high level processes also proposed in the conceptual architecture of FroboMind (Jensen *et al.* 2011) .

Software architecture

The FroboMind software architecture is implemented on the FroboBox hardware platform, running a Debian Linux with the ROS framework on-top.

By utilising the ROS method of structuring a project, each level of abstraction listed in the conceptual architecture of FroboMind is created as a ROS-package which is the main unit for organising software in ROS. Each package contains ROS processes (nodes) as well as source-code and other ROS specific files.

 - fmSystemEnvironment - package
 - fmSensorFeedback - package
 - fmPredefinedKnowledge - package
 - fmKnowledgeProcessingPlanning - package
 - fmNavigationActuation - package

Besides the packages defined by the architecture, listed above, two packages containing ROS-core functionalities and one package containing interface drivers (CANbus and serial communication) is implemented.

 - *fmCore* - package
 - *fmMsgs* - package
 - *fmInterfaces* - package

The above listed packages is collected in a ROS-stack called FroboMind. ROS-stacks are collections of packages that provide aggregate functionality, in this case the abstraction levels of the FroboMind architecture as well as low-level interface drivers.

Data exchange between the nodes in the FroboMind stack is accomplished by publishing messages to ROS-topics. ROS-messages is data-structures, much like C-structs, standard primitive types such as integer, floating point and boolean are supported and may contain data corresponding to a given abstraction level.
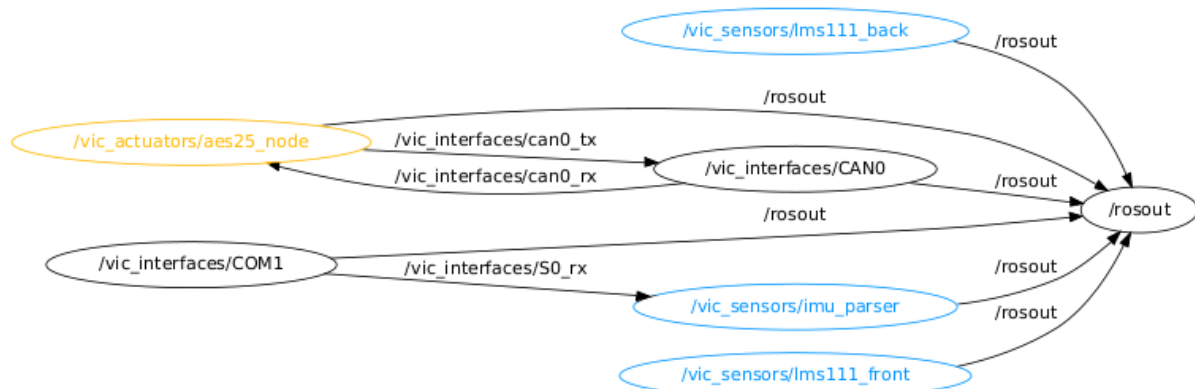

Figure 2: A ROS-rxgraph plot of nodes from an early version of the implementation of FromoMind. Black: fmInterfaces, Blue: fmSensorFeedback, Yellow: fmNavigationActuation.

As an example the *imu_parser* node (blue) shown in figure 2 is receiving raw data from the *COM1* serial interface node (black) which is handeling the interface driver. Raw data is parsed and measured accelerations is convertet to m/s^2 and angular velocities to rad/sec. The parsed and converted imu-data is published to a new topic, and made available to other nodes for further processing.

Conclusion

The work provides a highly domain specific architecture in form of the field robotic vehicle conceptual architecture FroboMind (Jensen *et al.* 2011). This architecture is currently, as a work in progress, being implemented in ROS to evaluate how well FroboMind maps into ROS.

A prominent feature in both ROS and the conceptual architecture FroboMind is the well defined interfaces/relations between components (topics and nodes in ROS). As ROS encourages well defined dataflows through ROS-topics, one of the major tasks has indeed been to define these interfaces.

Since ROS imposes no architectural constraints ROS has shown well suited for implementation of the proposed FroboMind architecture, which as a conceptual architecture provides a logical functional-decomposition and serves to identify and modularize key functionality and the relation between these modules.

AES25 electrical steering system; TopCon Precision Agriculture Europe for the Topcon AES25 electrical steering system and granting access to its CANbus protocol; and finally Sick Denmark for the four Sick LMS111 Lidars.

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