ARCHITECTURE AND MODEL OF DATA INTEGRATION BETWEEN MANAGEMENT SYSTEMS AND AGRICULTURAL MACHINES FOR PRECISION AGRICULTURE

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ABSTRACT

The development of robotic systems has challenges as the high degree of interdisciplinarity, the difficulty of integration between the various robotic control systems and lack of standardization in the definition of electronics and control systems that will be used to build the robots. Recent lines of research intend to define the standards for the development of electronic systems and applications to facilitate integration and interoperability between agricultural systems, for example, the standard ISO11783 for agricultural machines. The development of agricultural robots implies the same needs and is also expected to provide integration with geographic information systems, due to its wide potential application in agriculture. Thus, this project presents a hierarchical architecture of the systems involved in the process for precision agriculture, and development of algorithms for interoperability between robotic control systems and decision making support system, with applications in agriculture. Based on the results of integrations, such systems can generate specific robotic missions to be inserted in an autonomous agricultural robot, designed according to the ISO11783 standard.

Keywords: Robotic Systems, Systems Integration, precision agriculture, autonomous vehicles.

INTRODUCTION

Researches on Precision Agriculture aimed at supporting the processes of decision making in agriculture, but still face many challenges, among them are: the high degree of interdisciplinarity, the difficulty of integration between systems and the lack of standardization used in the definition of electronic and navigation systems, and managing large amounts of information.

Projects in this line of research requiring a high degree of interdisciplinarity and knowledge in various areas, including: Mechanical Engineering, Electrical Engineering, Computer Science, and knowledge of the specific area of application, the Agricultural Engineering. Researchers highlight the more than a decade that these challenges are limiting to further spread the concept and implementation of operational processes using precision agriculture (PA), among them stands out the work (BOA, 1997).Given the aforementioned context, there are several research opportunities in the areas of (PA), especially with the goal of integration of information and systems used in agricultural production process, and efforts to standardize the embedded electronic systems. The research presented by (SAKAI, 2008) presents a result of these efforts that have as their main focus the standard electronic ISOBUS.

Currently research projects in robotics, regardless of application area, or of different types of robots, face challenges related to multidisciplinary projects structures, definition of equipment to be used (cameras, sensors, actuators, motors), and especially developing systems for control, and communication with the robot. These systems require the creation of complex algorithms, nontrivial, and currently do not have any kind of standardization.

The need to develop these systems, and lack of standardization that exists today, bring significant losses for the projects, mainly related to developments in research. This difficulty is due to the need to use complex algorithms and not trivial to control the robot, and the lack of standardization of equipment (hardware) used for construction of robotic systems. In this current scenario, the development of control systems time-consuming research, and the results are hardly reused by other groups. To meet the challenges in building robotic systems many researchers work to create frameworks in order to deal with complexity and facilitate prototyping software, resulting in many robotic software systems currently used in research and industry (Kramer, 2007) .

The work of (Nader Mohamed, 2008) presents challenges in developing this new generation of autonomous robots, highlights the amount of hardware modules and software from different manufacturers that are embedded in robots and gives the requirements regarding the integration and interoperability of communication between these modules . These issues are addressed by the integration of the development of an intermediate layer of software, known as middleware.

In general middleware system are used to reduce time and cost of developing distributed systems.

Some recent studies presents studies on the use of middleware in robotic systems with different application areas, the functions of a middleware system as well as evaluation criteria, including: (Wienke, 2011) (Nader Mohamed, 2009) .

Despite great efforts in developing electronic systems and computational applied to robotics, there are still many opportunities for research in the areas of integration of these systems applied to the agricultural area. Besides the first efforts regarding standardization of electronic systems embedded in agricultural machines, there are still many operational limitations that hinder the creation of agricultural tasks ("missions") and integration of decision support systems and geographic information systems, with control systems in agricultural machines. We stand out as one of the first difficulties: lack of standardization in the form of maps with the definitions of tasks to be performed, and how to ship them to the robot control systems in agriculture.

MOTIVATION

This work aims to provide an interface for decision making in agriculture, ie, building requirements to enable the implementation of data exchange system for agricultural management systems and operation of farm machinery including navigation of autonomous systems;

It aims to present all systems (hardware and software) exist in an autonomous agricultural robot, and development of algorithms for integration of a system to support decision making and agricultural equipment control and navigation of agricultural machines, including execution of missions for autonomous robots;

Assess and develop methods of integrating all control systems embedded in an autonomous robot for agriculture.

MATERIALS AND METHODS

Aiming to replace the man in activities with high risk, or even in activities that require great efforts, and improve the efficiency of field operations, intensified research and development of autonomous robots for use in various areas , including area oil, industrial. Current literature presents the results of the work and efforts in robotic research groups, applied in various areas.(Incze, 2009) as shown by (Sousa, 2007) (Slaughter, 2008) and (Tabile, 2012), research is being carried out in order to enable the use of autonomous robots in activities in agriculture. There are several tasks that are currently performed by men and that, through the results of current research, may be replaced by autonomous robots, among these are:

- Mappings of the planting areas;
- Sampling the soil;
- The analysis and identification of areas with infestations;
- The analysis and estimation of production;
- The fertilizer application and/or pesticides;

The Figure 1 shows the hierarchical architecture for the integration of systems used, the flow of information from the system from the creation of the mission to his execution in the field, and return the data stored during its execution.

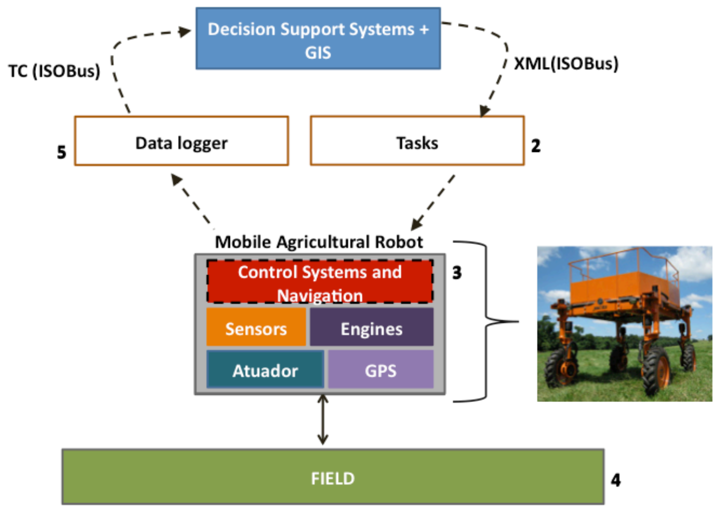

Figure 1. Hierarchical architecture of a robotic system agricultural

Each agricultural operation, which can be called "mission" to be performed by a robot farm is the result of a series of processing and analysis of agronomic data spatial-temporal . After processing the data (geographic and agronomic), is defined a map of recommendation containing information about the mission, which is embedded in agricultural mobile robot with an autonomous navigation system, and used as reference for the implementation. The operating cycle of the robot shown in Figure 1 is divided into five steps:

1. Support System for decision making / GIS: Manage information about field operations, such as productivity, costs, machine maintenance, among other information, has generated research opportunities. The integration proposal envisages the creation of an algorithm that can export the geographic databases in default XML file maps of ISO 11783. That way can use GIS market with integrated farming systems that use the standard ISOBUS. (ISO, 2007).

2.Missions: Maps containing information about the operations to perform on the field. These maps contain geographical information such as: boundary area to be used, known obstacles (trees, buildings), planting rows that need to be followed by the navigation system of the robot, and agronomic informations specific about the "mission" that will be performed, such as: sequence of operations (capturing an image of the area, collect soil samples), sampling rates, the speed that operation must be performed, among others.

3.Autonomous agricultural robot: the robot agricultural has a series of devices (sensors and actuators), and motors, GPS and other electronic equipment. All these facilities are managed by autonomous systems of navigation, guidance and responsible for the tasks execution in the field. The robot has an electronic system that is in accordance with ISO 11783, which provides a standard for interconnecting electronic devices embedded and agricultural implements through a control network and serial communication (ISO, 2007). In Brazil, the ISO 11783 standard is supported by the Task Force ISOBUS Brazil (Brasil, 2008)

4.Field: Areas planted with various crops (perennial and/or non-perennial), including: citrus and grains.

5.Results of mission: After execution of the tasks in the field, all operational data are exported agricultural machinery, imported and analyzed by Geographic Information System. The data must be exported in standard ISO 11783 has conversion algorithms for reading through Geographic Information Systems (GIS) market available.

Using the architecture presented above it becomes possible integration between the management systems and geographic information systems (GIS) with the control systems and agricultural mobile robot navigation for execution of specific operations in the field.

ROBOTIC ARCHITECTURE AND AGRICULTURAL ROBOT

As shown by (Tabile, 2012) has developed a modular robotic platform able to move in environments typical of the agricultural area for the purpose of data acquisition and research of new technologies for remote sensing for agriculture. Among the main features are: robustness, mobility, low weight, high operational capacity and autonomy consistent with agricultural needs. The robotic platform base presents a multifunctional feature to allow the coupling module data acquisition field for spatial variability and by means of sensors considered portable equipment. The development of this robotic platform was directed to work in perennial crops, semi-annual and perennial.

The mobile robot has several agricultural systems of perception and action.Among the systems of perception include: Computer vision, inertial and GPS systems, scanner and Agronomic Data to be shipped, such as: maps of infestations, routes of operations. The actuation systems include: guidance and propulsion control, platform stabilization, robotic arm.

The robot has a farm CAN bus for data communication and control that follows the pattern ISOBUS which was developed specifically for the agricultural área (ISO, 2007). The figure shows the agricultural robot.

Figure 2. Autonomous Agricultural robot

All components were developed by different manufacturers, are controlled by software developed in different programming languages. To reduce the complexity of integration between the various control modules and communication with the bus ISOBUS, designed a software architecture that uses a middleware between the layers of perception and action, as the following figure:

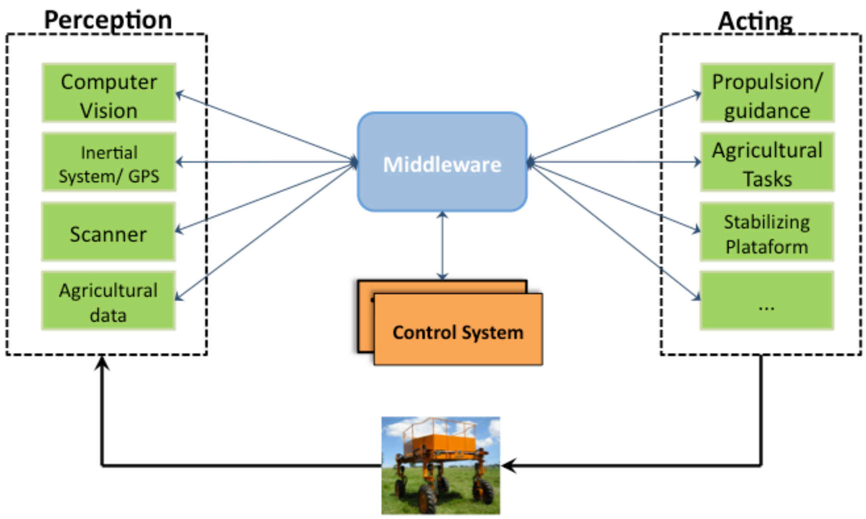

Figure 3. Integration of robotic architecture systems using middleware

The table below shows the module embedded in the robot and its associated programming language that was used in development.

Table1. Embedded Systems and their development environments.

Embedded Systems	Development Environment
Computer Vision	Matlab
Inertial System and GPS	C/C++
Scanner laser	C++
Robotic Arm	C/C++
Propulsion and Guidance	Labview
Stabilizing Plataform	Labview

Currently different research groups are working on the agricultural robot applying different areas of knowledge such as: robotic control, computer vision, among others.

Within this context, the middleware layer is used to exchange information and data between programs developed in different communication protocols, operating systems and platforms. All software modules, regardless of programming language was developed, using an API to perform messaging with data from sensors and control and performance.

The integration of embedded systems can increase the efficiency of the control system because it allow exchanges of messages between modules of perception, generating redundant information. An example is the possibility of the Computer Vision System to receive information from laser scanner module to check a reading done. If the camera's computer vision systems makes an data acquisition and identify a obstacle, can used the information generated by the scanner to confirm or discard this information. Thus information was restricted only to specific systems are available for use by other modules of the robot.

The figure below shows the architecture of an exchange of messages between the modules loaded by the middleware.

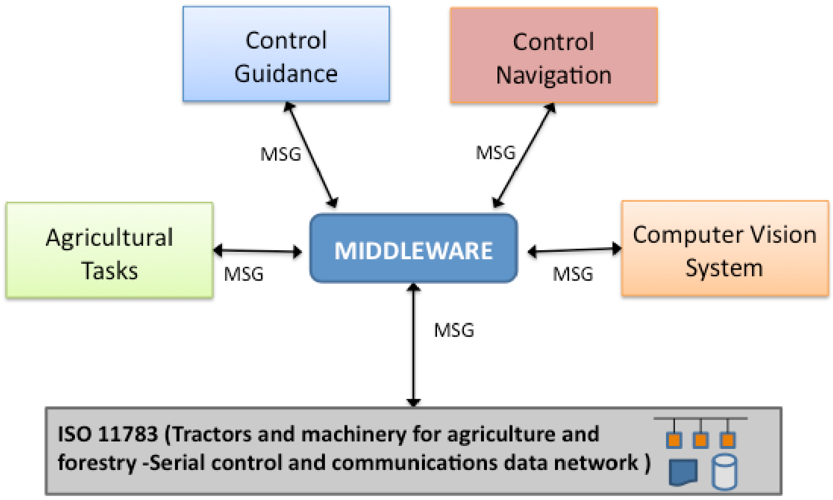

Figure 4. integration of embedded systems and messaging with middleware

As can be seen, all messaging (MSG) on the CAN bus of the robot are sent to the middleware and are available for embedded modules, as well as the messages generated by these modules are sent to the bus. In the validation tests of the proposed architecture was used middleware OpenMQ which is free and is available on the market with uses in integration of distributed systems for many areas.

RESULTS AND DISCUSSIONS

The paper presented an integration architecture for an autonomous agricultural robot developed order to perform tasks using the concept of precision agriculture. In this line of research was necessary to create an architecture to integrate data generated from geographic information systems (GIS), or systems of agricultural decision support, with embedded control systems in agricultural robot. In order to maintain compatibility of architecture created, and the robot agriculture, with industry-standard farm machinery, such integration was done using XML files in the format defined in ISO 11783.

The model architecture and integration of data on the systems of perception and acting that was proposed, is consistent with the desirable requirements for distributed robotic systems, as presented by (Wienke, 2011). Among the needs requirements that are met by the proposed architecture are:

Portability: This property allows the control system is capable of functioning in different execution environments without changes. This is possible because the messages used by the control system are read in the middleware layer and are independent of architecture or platform that is generating this information.

Flexibility: is the ability with which the structure of a system of embedded software can be changed by inserting new software modules without the need to rewrite the control software.

Interoperability: Ability to run a set of systems for common purpose or domain, regardless of programming language , platform, or hardware manufacturers. The Table 1 shows all embedded modules on the agricultural robot and their development platforms.

The integration architecture through a middleware enables systems to sharing information, and increases efficiency in the process of decision-making information by different sensors that are available to being consulted and compared to their readings.

CONCLUSION

Was presented a hierarchical architecture of the systems modules of existing in an autonomous agricultural robot, identifying the flow of information and the interactions between different systems to support agricultural operations.

Despite efforts at standardization of bus, data and eletronic through ISO 11783, discussed the solutions for the development of standardization between systems of support decision systems and control operations (missions) agricultural embedded on agricultural robot.

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