COMPATIBLE ISOBUS APPLICATIONS USING A COMPUTATIONAL TOOL FOR SUPPORT THE PHASES OF THE PRECISION AGRICULTURE CYCLE

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ABSTRACT

The Precision Agriculture (PA) cycle is composed of phases like mapping the spatial variability of the culture parameters, data analyses and treatment of the field. The multidisciplinary practices on this phases use embedded electronic and remote sensing in agricultural machinery. This practices demand researches of sensors and communication networks for data acquisition and control of Mobile Implement Control System (MICS) in the farm field to exchange with Farm Management Information System (FMIS). The MICS composed with CAN-Based Distributed Control System (DCS) according to ISO 11783 (or ISOBUS) standard. The ISO 1173 standard provides the interconnection of electronic devices embedded in agricultural machinery and implements through a control and serial data communication network. The IsoAgLib is an Object Oriented C++ library that has the communication services and needed management systems according with the ISO 11783 standard. This library allows building ISOBUS compatible equipment without the protocols implementation contained in this standard. This work presents the parameters of compatible ISOBUS application with IsoAgLib computational tool to support phases of PA cycle. This work also carries out the Information and Communication Technology (ICT) among MICS and FMIS, through eXtensible Markup Language (XML) format of data. The CAN-Based DCS (or MICS) consists in two parts, one on the tractor and other on the implement. The tractor composed of Universal Terminal (UT), Task Controller (TC) and Global Navigation Satellite Systems (GNSS) receiver. The implement composed of IsoAgLib installed on portable industrial Personal Computers (PC) integrated with agricultural sensors or actuators. The third part is Geographic Information System (GIS) software installed on FMIS. The evaluation of the connection was done by analyzing the CAN messages thorough ISO 11783-bus among PC, UT, TC and GNSS during the agricultural process. After agricultural process, the XML data was transfer to GIS software to data analyses. The ISO 11783 standard fully supports the PA phases. This work could be a reference to compatible ISOBUS applications providing expertise of ISO 11783 extensive standard, PA and ICT applications for researchers and professionals.

Keywords: Distributed Control Systems, CAN networks, embedded network communication, communication standard, file standard.

INTRODUCTION

The most common use of the embedded electronic and remote sensing in agricultural machinery demands adoption of Precision Agriculture (PA). PA is management strategy for the agricultural production and involves multidisciplinary practices (Gozdowsk and Samborski, 2007). It's became necessary the researches of sensors and communication networks for data acquisition and control in the farm field works. The ISO 11783 (also known as ISOBUS) provides a standard for the interconnection of electronic devices, or Electronics Control Units (ECU), embedded in agricultural machinery and implements through a control network (CAN – Controller Area Network) (ISO 11898, 1993) and serial data communication (Auernhammer and Speckmann, 2006). The IsoAgLib is a library that has the communication services and management systems needed to be compatible with the ISO 11783 standard (IsoAgLib, 2012; Spangler, 2001; Spangler, 2008). This library allows building ISOBUS compatible equipment without the protocols implementation contained in this standard. This work also carries out the Information and Communication Technology (ICT) among MICS and FMIS, through eXtensible Markup Language (XML) format of data. The CAN-Based DCS (or MICS) consists in two parts, one on the tractor and other on the implement. The tractor composed of Universal Terminal (UT), Task Controller (TC) and Global Navigation Satellite Systems (GNSS) receiver. The implement composed of IsoAgLib installed on portable industrial Personal Computers (PC) integrated with agricultural sensors or actuators. The third part is Geographic Information System (GIS) software installed on FMIS. This work presents a IsoAgLib study and implementation to support learning of ISO 11783 standard parts, PA and Information and Communication Technology (ICT) (Steinberger et al., 2009). In the next sections will expose the enabling technologies of PA, the ISO 11783 and the IsoAgLib characteristics, the materials and methods, the results and the conclusion of this work.

ENABLING TECHNOLOGIES OF PRECISION AGRICULTURE

The basic principle of Precision Agriculture (PA) is handling the variability of soil and crops in space and time. This variability are of the soil, the climate, the diversity of cultures, the performance of agricultural machinery and natural or synthetic inputs used in agricultural production. Based on these principles are given some definitions of the term PA:

- “A management strategy that uses Information Technology (IT) to collect data from multiple sources to support decision making system of the agricultural production.” (National Research Council: Board on Agriculture, 1997);
- “A set of techniques that allows the management of localized cultures.” (Balastreire et al., 1998);
- “Precision agriculture is the application of principles and technologies to manage the spatial and temporal variability, associated with all aspects of agricultural production to increase agricultural productivity and environmental quality.” (Pierce and Nowak, 1999);
- “A set of techniques and crop management actions taking into account the variability of soil parameters and the behavior of the crop in the plot.” (Menegatti and Molin, 2004);
- “PA is defined as a holistic strategy and protective of the environment in which agricultural producers may change the use of materials and methods of cultivation to match the variation of soil and cultural conditions across the country. There are still other definitions and all these suggest that there are at least three critical elements to the success of PA: information, technology and management.” (Srinivasan, 2006).

A PA system should have the ability to relate the measures of the field and interpretation of spatial and temporal variability, generating information for the management of variability by the application of inputs. These applications should be located and made by machines and devices for the correct application of different inputs in a specific location. The PA system should be able to register the data of the applications for review by a specialist team, and after examination, should be generated action plans for future management of the variability. The following process “field data acquisition” → “data analysis” → “planning of the management field” → “management of the field” of the PA is cyclical, and this feature is called cycle of PA or PA phases, and Figure 1 show according to Molin (2003).

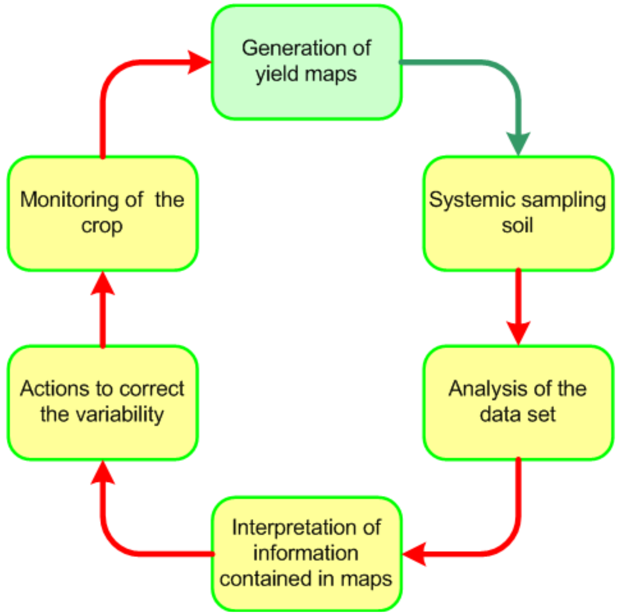
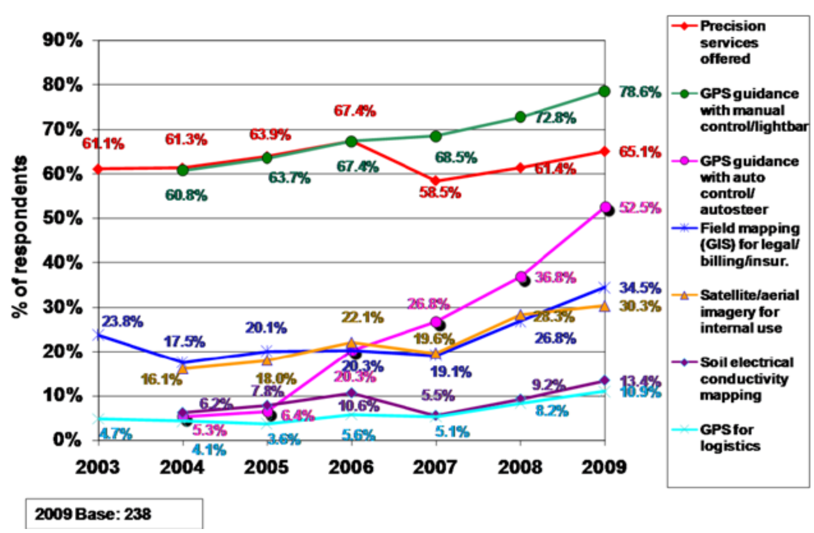
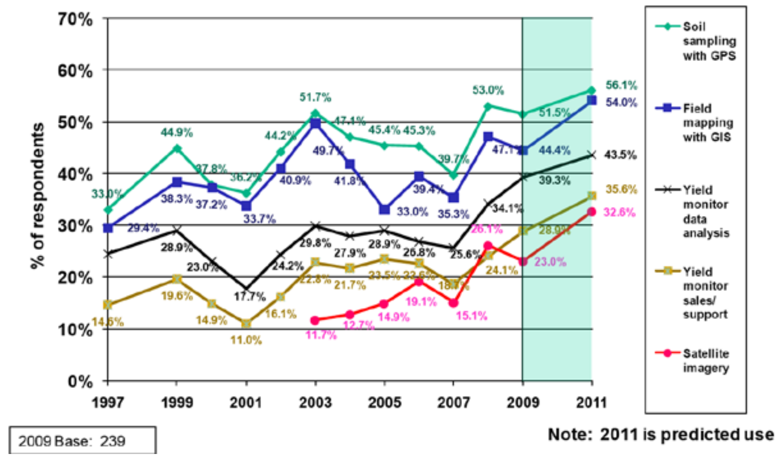


Fig. 1. PA phases. Source: Molin (2003)

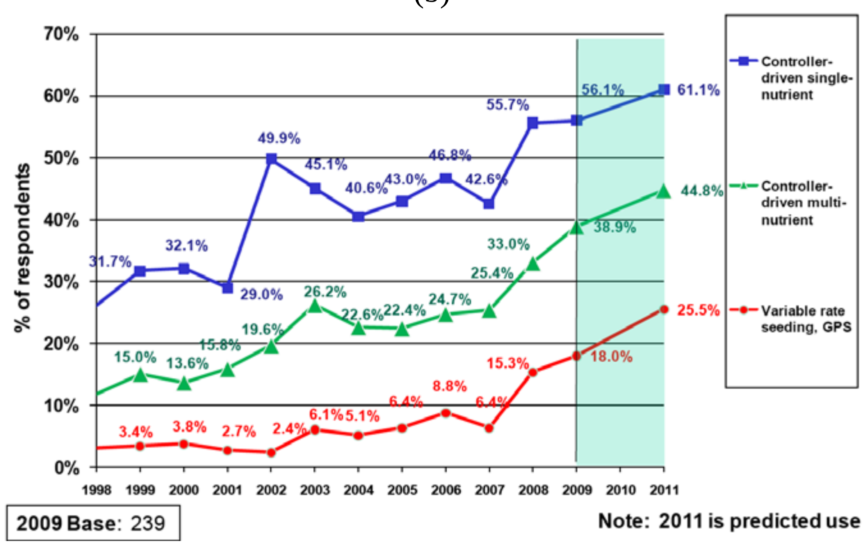
Those phases enabling a large number of technologies, for example, the Global Positioning System (GPS) guidance, field mapping by Geographic Information System (GIS), satellite or aerial imagery, soil electrical conductivity mapping, remote sensing, soil sampling techniques, Variable Rate Technology (VRT) and others. The adoption of PA along of eleven years ago is demonstrated in Whipker and Akridge (2009). The Figure 2 (a) shows the graph of the usage of PA technologies between 2003 to 2009 years, Figure 2 (b) show the graphs of the usage of PA services between 1996 to 2009 years with predicted use for 2011 year, and Figure 2 (c) show the growth of variable rate application using VRT between 1997 to 2009 years with predicted use for 2011 year.



(a)



(b)



(c)

Fig. 2. (a)Use of enabling technologies of PA over time (b)Use of PA services over time (c) Use of the variable rate seeding + GPS, controller driver for a single nutrient and for multi nutrient. Source: Whipker and Akridge (2009)

According to the Figure 2 (a), Figure 2 (b) and Figure 2 (c), it notices since 2007 year only the satellite/aerial imagery didn't follow the use of the other technologies and services, which increased linearly, showing the acceptance of PA.

LIBRARY FOR THE COMMUNICATION NETWORKS

The ISO 11783 Standard

ISO 11783 is the standard that specifies a communications system for agricultural equipment. The main task of ISO 11783 is to provide an open and interconnected system for embedded electronic systems and serial data communication in agriculture and forestry machinery, in other words, to provide the communication among the ECU via standardized network (ISO 11783-1, 2007).

The importance of electronics and ICT in the agricultural sector was also recognized internationally by the development and foreign adoption of ISO 11783, with the following definitions:

- Use of the CAN 2.0B protocol (ISO 11898, 1993), with an extended 29-bit identifier;
- Bus speed to 250 kbit/s;
- Adjusting according to ISO/Open System Interconnect Basic Reference Model (ISO/OSI Basic Reference Model);
- Definition of a standard interoperable with SAE J1939 (2012);
- Defining the tasks of the tractor (Tractor ECU) for different classes;
- Permission to proprietary message types.

The Table 1 shows the 14 parts and the status of ISO 11783:

Table 1. 14 parts and the status of ISO 11783. Source: ISO (2012)

PART	EDITION	STAGE	STATUS ISO/TC23/SC19/WG1 – ISO 11783	Year
Part 1: General standard for mobile data communication	1	90.20	International Standard under periodical review	2007
	2	30.99	Approved Committee Draft (CD) to DIS	2012
Part 2: Physical layer	1	90.20	International Standard under periodical review	2002
	2	60.60	International Standard published	2012
Part 3: Data link layer	1	95.99	Withdrawal of International Standard	2007
	2	90.20	International Standard under periodical review	2007
	3	30.99	Committee Draft (CD) approved for registration of DIS	2012
Part 4: Network layer	1	90.20	International Standard under periodical review	2001
	2	60.60	International Standard published	2012
Part 5: Network management	1	95.99	Withdrawal of International Standard	2011
	2	60.60	International Standard published	2012
Part 6: Virtual terminal	1	95.99	Withdrawal of International Standard	2010
	2	90.92	International Standard to be revised	2012
Part 7: Implement messages application layer	1	95.99	Withdrawal of International Standard	2009
	2	90.92	International Standard to be revised	2009
	3	20.20	Working Draft Study Initiated	2012
Part 8: Power train messages	1	90.93	International Standard confirmed	2012
Part 9: Tractor ECU	1	90.92	International Standard to be revised	2002
	2	60.60	International Standard published	2012
Part 10: Task controller and management information system data interchange	1	60.60	International Standard published	2009
	2	30.99	Approved Committee Draft (CD) to DIS	2012
Part 11: Mobile data element dictionary	1	90.92	International Standard to be revised	2007
	2	60.60	International Standard published	2012
Part 12: Diagnostics services	1	90.92	International Standard to be revised	2009
	2	20.20	Working Draft Study Initiated	2012
Part 13: File server	1	90.92	International Standard to be revised	2007
	2	60.00	International Standard under publication	2012
Part 14: Sequence control	1	50.92	FDIS referred back to TC or SC	2012

However, the ISO 11783 standard is not yet widely adopted by the Brazilian companies like the foreign companies. By the global trend, it is important to initiate projects for implementation of the standard based on the information needed systematized. The investments in the agribusiness engineering in Brazil are necessary to reach the international standard. Only in this way can participate in the process of global innovation in an area so important to Brazil.

IsoAgLib

The IsoAgLib is a C++ library to development of ISO 11783 standard applications in an Object Oriented way (IsoAgLib, 2012; Spangler, 2008). The library provides resources to program and to simulate the software of implement ECU or of another client device of the Universal Terminal (UT), Task Controller (TC) and File Server (FS). The author of IsoAgLib library, Dipl.-Inform. Achim Spangler, licensed with exceptions under the terms of the GNU General Public License (GPL). The GPL grants users of the library the right to use, to modify and to distribute it. This library allows building ISOBUS compatible equipment without the protocols implementation contained in this standard. Nowadays, hosting and maintaining IsoAgLib are carried out by OSB (OSB, 2012). The business model IsoAgLib contains engineering services, tools, and support and maintenance contracts. The IsoAgLib software is open source and thus source code open to every user. Using IsoAgLib is generally free; there are available two different types of licenses:

- GNU GPL, Version 2, with Exceptions;
- Commercial (OEM) License.

In case of using the open source license GPL, the implementation of IsoAgLib in your products can be protected by support and maintenance contracts with OSB, however it is not mandatory. The commercial licensing is particularly suitable for implementations of IsoAgLib within complex software architectures and along with specific enhancements (OSB, 2012).

The IsoAgLib has a modular design according to the different functional components of the standard ISO 11783. The library has modular design to ensure the minimal use of IsoAgLib in program memory of Implement ECU. The IsoAgLib presents the layered design to be easily adapted to new hardware platforms. Most of the software can be used without modification on all platforms. The layered structure is described by the diagram in Figure 3.

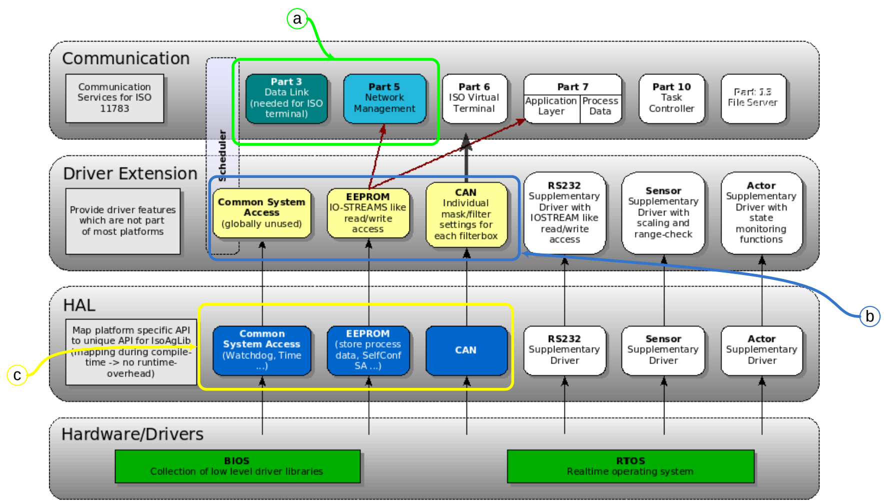


Fig. 3. Structure view of IsoAgLib modular design. Source: IsoAgLib (2012).

In the Figure 3are listed all the elements needed by layers for all projects:

- HAL (Hardware Abstraction Layer) - Figure 3 (c);
- Extensions - Figure 3 (b);
- Communication - Figure 3 (a).

The other elements listed in the Figure 3 are not necessary for all projects. For example, drivers in the HAL layer as RS232 input sensors and control actuators (mainly PWM) were developed for a research project at the Technische Universität München (TUM - Technical University of Munich).

The IsoAgLib was developed to be compatible with various systems, and these systems can be composed of processor, memory, Human Machine Interface (HMI) and interface with the CAN bus. Because of this, the IsoAgLib is divided into two parts: the library itself and HAL. The HAL is responsible for communicating with the operating system (OS) or BIOS device that is running the application, as can be seen in Figure 3.

The library provides the Address Claim negotiation of an ECU to the CAN bus ISO 11783. It also implements the transport protocols that are used in the initialization with UT and TC. Due to the object orientation code design, the IsoAgLib was implemented in C + + language, and the library makes use of templates and namespaces. It also uses some objects on the STD (Standard Template Library), for example, lists, queues, vectors, etc. You can use the IsoAgLib in embedded devices that use Linux OS (Linux, 2012) or Microsoft Window OS (Microsoft, 2012). In addition, you can use the library in the Personal Computer (PC) running Linux or Microsoft Windows with CAN interfaces which have the HAL of the IsoAgLib.

An ISO 11783 tractor must have a UT, a TC, a FS and a Diagnostics Service Tool as shows in the Figure 4 "Server ECUs".

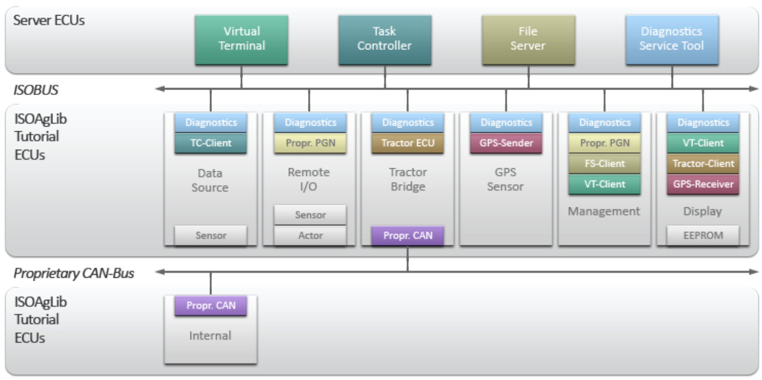


Fig. 4. ISO 11783 Network whit IsoAgLib. Source: IsoAgLib (2012).

The Figure 4 presents an ISO 11783 network which the "IsoAgLib Tutorial ECUs" are the ECUs that are implemented using necessary elements in the Figure 3.

MATERIALS AND METHODS

This section will describe the hardware and software used in the ISO 11783 workbench.

Vector CANoe, CAN Interfaces and Universal Terminal ISOBUS

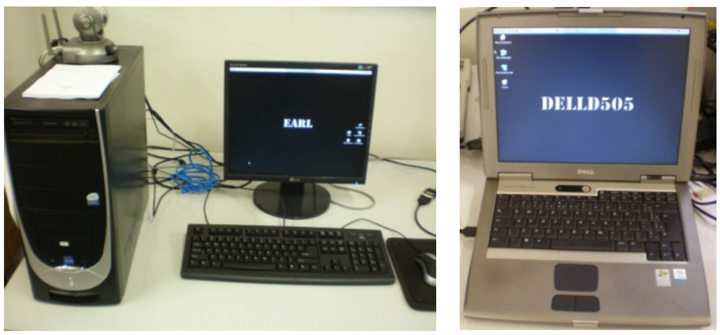
The environment of testing and monitoring is used Vector Canoe, which can be used with two types of interfaces CAN: CANCardXL and CANBoardXL (Vector, 2012). The difference between these interfaces is that the CANCardXL is a PCMCIA card, ideal for use in notebooks. And CANBoardXL is a PCI card ideal for desktop computers.

The devices CANCardXL and CANBoardXL are interfaces between the CAN bus and the environment Vector Canoe, where the connection to the CAN bus is done via two CAN channels, CH1 and CH2. There are a large number of tools to aid the development of ISO 11783, but the most complete tool is the Vector CANoe with libraries for ISO 11783 interpretation. The general characteristics of the tool are:

- Message traffic on the bus - all messages sent on the network can be viewed in the software;

- Analysis of functionality - you can check the performance of procedures by analyzing the messages and the proper functionality of a controller;
- Performance analysis - verifying that the times and delays of messages on the bus;
- Simulation of a network layout - the software has a simulator of a UT to interact with Virtual and Real ECUs.

The requirements for the implementation of this work are present in the following sections. The ISO 11783 workbench consists in two Personal Computers (PC), one desktop called “EARL” (Figure 5 (a)) and one notebook called “DELLD505” (Figure 5 (b)). The ISO 11783 connection between two PCs is by CAN hardware CANCardXL from Vector CANtech Inc. (Vector, 2008) embedded on notebook and CANBoardXL embedded on desktop.



(a) (b)

Fig. 5. ISO 11783 Network whit IsoAgLib.

There are a set of Universal Terminal (UT) ISOBUS of different agricultural industries, cited below:

- GTA 2 e C1000 from AGCO (2010);
- CCI 100 from CCI (2012) and (Kuhn, 2012);
- GS 1800 from John Deere (2012);
- UT from CNH (2012).

The IsoAgLib library is implemented, compiled and executed on the desktop. In the notebook, there are a sniffer CAN/ISO 11783 and a Universal Terminal (UT) simulator of Vector CANtech Inc. software CANoe 5.2 (Vector, 2012) and UT ISOBUS, which allows the visualization of the IsoAgLib executable from desktop.

RESULTS

PA Phases According to Technologies

The Figure 6 represents the agricultural cycle with e PA cycle:

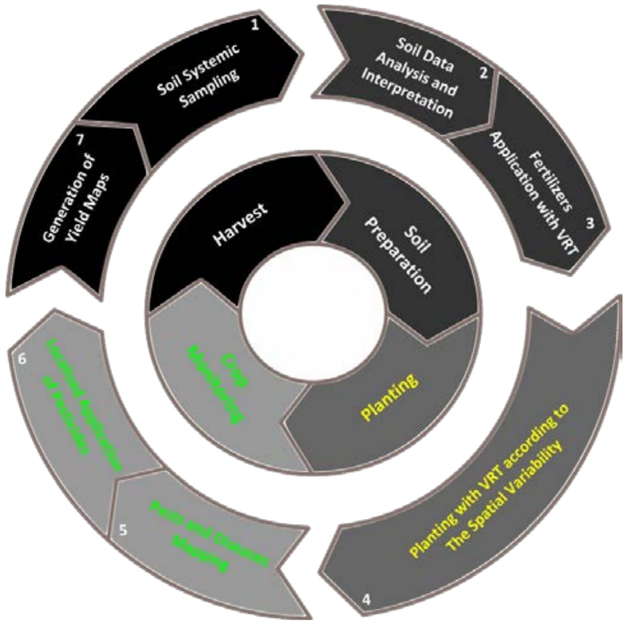


Fig. 6. PA cycle with agricultural cycle

The relationship between the PA cycle of the Figure 6 with the technologies and services of the Figure 2 is shown in Table 2.

Table 2. Relationship between the Figure 6 with the Figure 2.

Technologies and Services	Phases of PA
GPS guidance with manual control	(1)(3)(4)(5)(7)
GPS guidance with auto control	(1)(3)(4)(5)(6)(7)
Field mapping (GIS)	(1)(5)(7)
Satellite/ aerial imagery	(2)(5)
Soil electrical conductivity mapping	(1)(2)(3)
Soil sampling with GPS	(1)(2)(3)
Field mapping with GPS	(1)(3)(4)(5)(6)(7)
Yield monitor	(7)
Data analysis	(2)(5)
GPS for logistics	(1)(2)(3)(4)(5)(6)(7)
Variable rate applications (VRT)	(3)(4)(6)

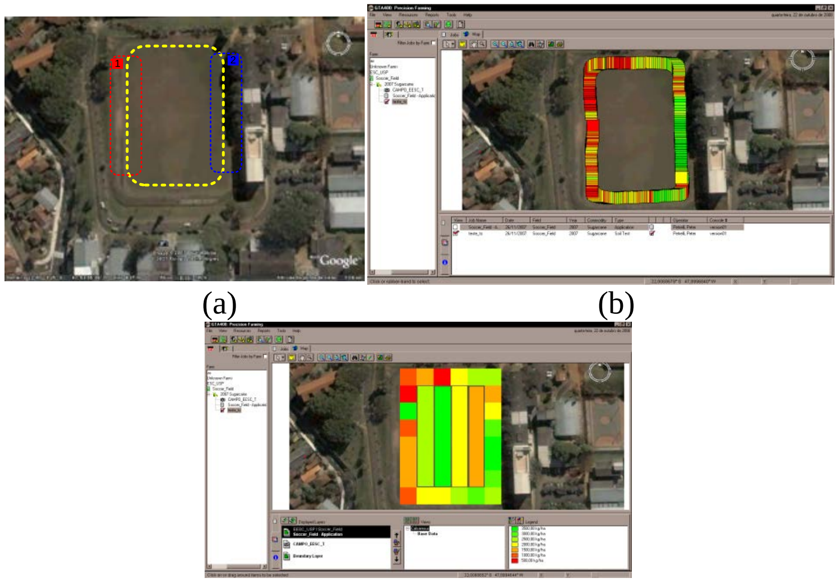
Based on Table 2, in practical way, we can associate those technologies and services with the agricultural applications of the PA.

ISOBUS to Support The PA Phases

To demonstrate the ISOBUS support, was developed the ISOBUS compatible applications listed in the next section.

Soil Conductivity Sensor and Crop Normalized Difference Vegetation Index (NDVI)

To support the PA phases 1, 2 and 5 (see Figure 6) was developed the ISOBUS interface to generate the XML with data field to check the spatial variability with GIS software according to the Figure 7.



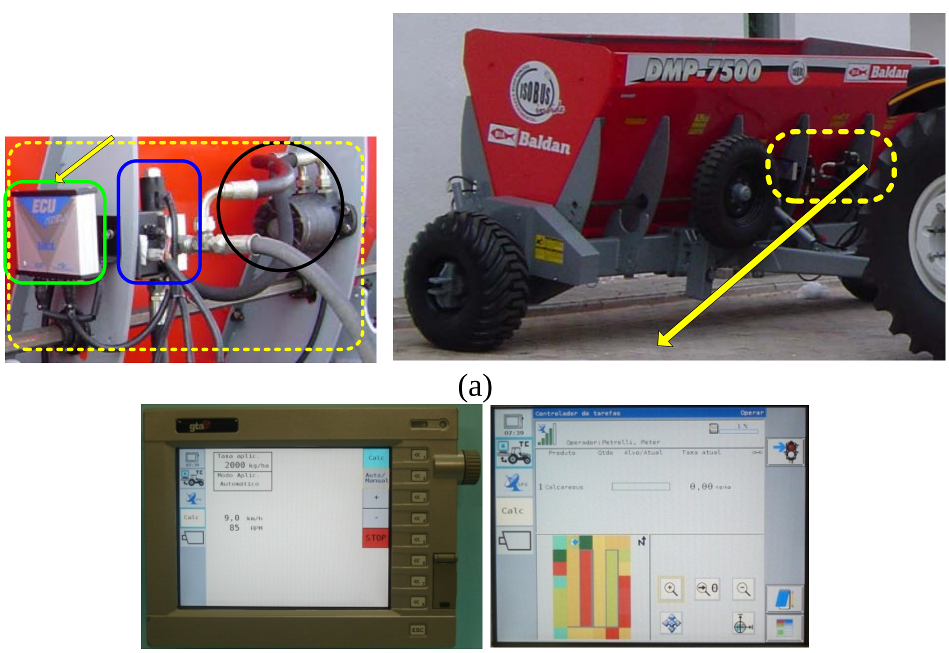
(a) (b)

(c)

Fig. 7. (a)Experimental field (b) XML file analysis and interpretation using GIS software (c) Generating the prescription maps

Limestone Application

Using the prescription map generated based on the sensors of the soil and/or crop, a Implement ECU of a limestone applicator from BALDAN (2010) was developed according to the Figure 8 (a).



(a)

(b) (c)

Fig. 8. (a)ISOBUS compatible limestone applicator. (b)IHM on UT to configure and control de the implement (c)VRT application according to the prescription map

According to the Figure 6, this prescription maps could be used in PA phases 3, 4 and 6, and the limestone applicator ISOBUS could be used in phase 3.

CONCLUSION

Was did the correlation with the PA, enabling technologies, IsoAgLib computational tool and ISOBUS to create a standard applications according to ISO 11783.

Mainly, the ISOBUS was creating to standardize the electronics and data management on agricultural machinery. In this work, the usability of ISOBUS was showed with the development the ISOBUS interface with sensor, applicator and management software, providing a holistic management of the field applications.

REFERENCES

AGCO. (2010) AGCO Corporation is one of the world's largest manufacturers and distributors of agricultural equipment, Available in: <http://www.agcocorp.com/>.

Auernhammer H., Speckmann H. (2006) Dedicated communication systems and standards for agricultural applications, Chapter 7 Communication Issues and Internet Use, CIGR Handbook of Agricultural Engineering. pp. 435-452.

Balastreire L.A., Elias I.A., Amaral J.R. (1998) Precision Agriculture: Productivity mapping of the crop corn. Engenharia Rural, ESALQ/USP.

BALDAN. (2010) Agri - Tillage do Brasil (ATB): implement manufacture, Available in: <www.baldan.com.br/>.

CCI. (2012) Competence Center ISOBUS, Available in: <http://www.cc-isobus.com/>.

CNH. (2012) Manufacturer of agricultural and construction equipment, Available in: <www.cnh.com/>.

Gozdowsk D., Samborski S. (2007) Book Reviews - Precision agriculture. Journal: Communications in Biometry and Crop Science 2:90-94.

ISO 11783-1. (2007) Tractors and machinery for agriculture and forestry — Serial control and communications data network, Part 1: General standard for mobile data communication, International Organization for Standardization, Geneva, Switzerland.

ISO 11898. (1993) Road vehicles - Interchange of digital information - Controller area network (CAN) for high speed communication, Describes the general architecture of CAN in terms of hierarchical layers according to the ISO reference model for OSI specified in ISO 7498, International Organization for Standardization, Geneva, Switzerland.

ISO. (2012) ISO - International Standardization Organization, Available in: <http://www.iso.org/>.

IsoAgLib. (2012) Development of ISO 11783 applications in an Object Oriented way., Available in: <http://www.isoaglib.com/devzone/>.

John Deere. (2012) Manufacture of tractors, engines to construction, forestry and turf care equipment, and, provides equipment, tools, technology and services, Available in: <www.deere.com/>.

Kuhn. (2012) Agricultural machinery manufacturer, Available in: <www.kuhn.com/>.

Linux F. (2012) Linux.com is the name of a website owned by the Linux Foundation. The site is currently a central source for Linux information, software, documentation and answers across the server, desktop/netbook, mobile, and embedded areas. Linux.com offers free Linux tutorials, news and blogs, discussion forums and groups, a Linux software and hardware directory, and a job board., Availabel in: <http://www.linux.com/>.

Menegatti L.A.A., Molin J.P. (2004) The sugarcane and Precision Agriculture, IDEA NEWS 4. .

Microsoft. (2012) Microsoft Corporation (MS) is a multi-national U.S. software, developer of the Windows operating system, Availabel in: <http://www.microsoft.com/en/us/default.aspx>.

Molin J.P. (2003) Precision Agriculture: the variability management (in portuguese language), Piracicaba - SP, Brazil.

National Research Council: Board on Agriculture. (1997) Precision Agriculture in the 21st Century: Geospatial and information technologies in crop management Authors: COMMITTEE ON ASSESSING CROP YIELD: SITE-SPECIFIC FARMING, INFORMATION SYSTEMS, AND RESEARCH OPPORTUNITIES, NATIONAL RESEARCH COUNCIL: BOARD ON AGRICULTURE. National Academy Press, Washington - D.C., USA.

OSB A. (2012) The OSB is a leading engineering services for electrical, mechanical and IT. The main competence: technical services, particularly for the automotive industry, telecommunications, agricultural technology, machinery and equipment., Available in German: <http://www.osb-ag.de/>, Schwanthalerstraße 69, 80336 Munich, Germany.

Pierce F.J., Nowak P. (1999) Aspects of precision agriculture, Advances in Agronomy. pp. 1-85.

SAE J1939. (2012) Recommended practice for a serial control and communications vehicle network, 17 parts, published in different years, Society of Automotive Engineers (SAE), available in: <http://www.sae.org/standardsdev/groundvehicle/j1939a.htm>, Warrendale, PA, EUA.

Spangler A. (2001) Open Source Development: A suitable Method to introduce a standardized communication protocol?, 1st Workshop on Open Source Software, ICSE 2001.

Spangler A. (2008) Tools for interface development and diagnostics - Presentation in Workshop ISOBUS Brazil 2008 by Software Development Manager, Competence Center Embedded Systems, OSB AG employment, Available in: <http://www.isobus.org.br/ws2008/presentations/>, São Carlos, SP, Brazil.

Srinivasan A. (2006) Handbook of Precision Agriculture: Principles and applications The Hayworth Press New York, NY, USA.

Steinberger G., Rothmund M., Auernhammer H. (2009) Mobile farm equipment as a data source in an agricultural service architecture. Computers and Electronics in Agriculture 65:238-246.

Vector. (2012) The Vector Group is the manufacturer of software tools and software components for networking in electronic systems based on CAN, LIN, MOST, FlexRay. Available in: <http://www.vector-worldwide.com/>.

Whipker L.D., Akridge J.T. (2009) 2009 Precision Agricultural Services Dealership Survey Results, Purdue University, College of Agriculture, Department of Agricultural Economics.