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Farm machinery management information system

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ABSTRACT

Management of farming operations is currently rapidly changing toward a systems perspective integrating the surroundings in terms of environmental impact, public entities and documentation of quality and growing conditions. The latest developments in Information and Communication Technologies (ICT) and the prevailing lack of interoperability between agricultural tractors, implements and on-board computers has led to the development of ISO 11783 (ISOBUS) international standard for securing a more effective communication between these entities. Precision agriculture requires an increasing amount of information in order to be sufficiently managed and the abilities of the ISOBUS protocol is a significant step toward this goal as it will provide a wealth of automated data acquisition for improving the management of crop production. However, there is an urgent need to organize and specify the pathways of this large amount of information as prerequisites for subsequently turning it into knowledge and decision support. The aim of this study was to analyze and design a future farm machinery management information system to handle tractor and implement data together with the interactions with their surroundings. Soft systems methodology was used to analyze the human activities and to identify user requirements in relation to the use of farm machinery and the management of the information generated and pertaining to the tractor and the farm implements. The empirical data to extract this information was gathered from 30 targeted interviews with tractor operators and farm managers located in Greece and Denmark, and pertaining to questions about the optimal use of farm machinery data and tractor-implement performance. A rich picture of the whole system was developed and from that a conceptual model that infers to daily operations with the tractor, implement and the interactions with the surroundings. The conceptual models were developed for both conventional farm machinery and agricultural robots. The conceptual model function will serve as a blueprint for further development of required sensors, communication technology, and information processing capabilities. The developed conceptual models were tested and validated with 15 farm managers from the initial reviewing panel in order to reveal supplemental additions and concerns.

1. Introduction

The introduction of precision agriculture technologies into common farm activities has provided farmers the opportunity to cope with in-field variability and to handle and manage efficiently a vast amount of available information (Fountas et al., 2006; Aubert et al., 2012). The technological innovations of on-board tractor performance monitoring systems and the recent advances in tractor technology, enables the acquisition of tractor and implement status data through the ISOBUS (International Organization for Standardization (ISO), 1997), and provide useful information to optimize the overall operations and field productivity (Scarlett, 2001; Backman et al., 2013). Combined with the Differential Global Positioning System (DGPS), the system could be used for spatial mapping of tractor-implement field performances (Taylor et al., 2002). Such technologies emerge as standard features on contemporary tractors with the aim to provide enhanced farm and operations management through the use of extensive databases as the basis for decision support and control actions. Additionally, on-the-go sensors mounted on agricultural machinery provide site-specific analytical information of soil and crop conditions (i.e. Adamchuk et al., 2004). Moreover, the development of autonomous vehicles adopted to field tasks will gradually change the role of the tractor operator toward monitoring and strategic management as

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this development will require an explicit management information system capable of managing interactive information flows and provide useful guidelines in real-time for operations execution. The interconnection between the ISOBUS and precision agriculture innovations will meet the farm manager's demands by open up a wealth of information for improved management of crop production.

The ISOBUS protocol plays an important role in the development of precision agriculture by helping information to be exchanged and stored more efficiently between sensors, processors, controllers and software packages from different manufacturers within the same tractor and/or vehicle (Stafford, 2000). The challenge is to integrate the data captured by these new technologies into a coherent farm management system. The main problem arises from the heterogeneous nature of these data resulting in a variety of data formats and interfaces. Incompatibility of different data formats are usually a fundamental problem and considerably manual efforts is required just to convert data from one format to another. Therefore, there is an imperative need for continuous data exchange either between the farm's computer and the computing devices mounted on the farm machinery or between the farm's computer and the external farming systems such as contractors, suppliers and advisory services. Nowadays, ISOBUS is considered as a standard within the agricultural industry and consisting of fourteen parts (such as data link layer, network layer, task controller and management information system data interchange), providing functionalities and other targeted options to FMIS developers. Steinberger et al. (2009) presented a prototype implementation of an agricultural process-data service that enables flexible data networking, where data recorded through the ISOBUS port were transferred to a server for further processing via a web portal and a web service interface. Iftikhar and Pedersen (2011) proposed an easy-to-use and flexible solution for ISOBUS based bi-directional data exchange as well as efficient requirements change management. The system utilizes an XML-based graphical user interface generating high-level data exchange specifications that can be simply used by farmers/farm managers.

Farm management information systems have to be able to comply with legal regulations and agricultural production standards to ensure food safety and environmental protection. Compliance with additional quality requirements usually gives the products an added value in the market. The rules and standards must be represented in a form understood by a computerized management system which will perform automated compliance checking. With that in mind, Nash et al. (2009) suggested a general structural model for an agricultural standard, while Nash et al. (2011) proposed an XML-based format for the formal representation of machine readable decision rules and standards to enable the automation of compliance checking.

Nikkilä et al. (2010) evaluated a web-based approach for the implementation of an FMIS that fulfils the new requirements posed by precision agriculture. As mentioned above, these new requirements must have increased connectivity capabilities with external services targeting precision agriculture and GIS data. Also, the communications with the ISOBUS tractor-implement combination are fundamental in scope. Farm data are stored off-site, communicated via Web services to well-backed-up central system considerably more secure than on a volatile local farm PC. Special care must be given to the design of user interfaces, as poor interfaces have often been identified as key reasons for low adoption of FMIS in agriculture or information systems in general (Seneler et al., 2009). Furthermore, Kaloxylos et al. (2012) pointed out that current Web network configurations face shortcomings especially in handling vast numbers of networked devices. There is still no standardized solution to enable a simple and cohesive interoperability among services and stakeholders. It was argued to introduce autonomic and cognitive elements in the overall management process to support and integrate different stakeholders and services, interworking with the networked infra-structures.

The innovation of this paper is the shift of the perspective from the farmer/farm manager as the core of the system, which was the focus on the previous papers by Sorensen et al. (2010a,b) to a tractor-centric approach leading to an innovative FMIS architecture where the information flows derive from an intelligent machinery entity that has an upgraded role as part of the decision making process. The term Farm Machinery Management Information System (FMMIS) is used in this paper to describe the above approach which relies on information-to-action decision processes for field operations. According to Kitchen (2008), an information-to-action decision process needs to be: (1) in situ sensor-based; (2) automated for real-time or near real-time computer processing and transformation into knowledge for decision making (3) packaged so that sensing and processing of information are a part of the equipment used to accomplish the required management action; and (4) transparent to the operator/manager for decision evaluation and confirmation.

Therefore, the overall objective of this study was to create a conceptual basic outline and structure for a Farm Machinery Management Information System (FMMIS) using the soft system methodology (SSM) as the deriving approach. This approach will establish the interrelationships between farm machinery and their surroundings through explicit formulation of the information flows, definition of the databases, guidance of knowledge encoding and extraction of requirements for the advanced FMMIS. Specifically, it is the objective to understand the soft-system and process-oriented activities of tractor operators and farm managers and to design a model of the individual FMMIS components, indicating where the FMMIS will be required to assist/enable information flows. Subsequently, this model will be adapted to conform with the concept of the future FMMIS using autonomous vehicles to replace the conventional tractors and identifying the potential changes required by the overall FMMIS design.

2. Material and methods

Generally, the Soft System Methodology is based on a participatory problem definition and structuring into a group of stakeholders dealing with complex situations. Such approaches come under the heading of Problem Structuring Methods (PSM) (Eden and Ackermann, 2006). As a specific part of PSM, Soft Systems Methodology (SSM) is used to analyze human activities, preferable management activities, and to identify user requirements and activity as the basis for subsequent system design (Checkland and Scholes, 1990). Previously, SSM has been used to describe complex agricultural systems, such as the conceptual framework of a general farm management information system (Sorensen et al., 2010b), as well as the use of precision agriculture activities in a university farm (Fountas et al., 2009). As a first step, a 'rich picture' to describe the problem situation was derived, which depicts a particular situation or issue of the system under study and depicts relationships, connections, influences and cause and effects. Rich pictures depict complicated situations and form the first step of the staged process. In order to be able to model the purposed changes to the current system, the proposed system needs to be clearly outlined and defined through a so called "root definition" defining the goal of the system and presenting different perspectives on the system and the inherent assumptions including guidelines on how to bring about transformations, enhancing change and improvement of the system under consideration. The root definition is devised in the form PQR. A system to do P, by means of Q to achieve R or "What to do (P), How to do it (Q), and Why to do it (R)". Special attention should be paid to the elements of