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Software architecture for farm management information systems in precision agriculture

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ABSTRACT

Farm management information systems (FMIS) have steadily increased in their level of sophistication as they have included new technologies with Internet connectivity being the latest addition. However, few FMIS have used the full capabilities of the Internet, and the emerging concept of precision agriculture has little or no support in the current commercially available FMIS. FMIS for precision agriculture have certain additional requirements to traditional FMIS, which makes the implementation of these systems technically more complicated in several aspects. Our research aimed to identify the requirements posed by precision agriculture on FMIS and then evaluate a modern Web-based approach to the implementation of an FMIS that fulfilled these additional requirements.

1. Introduction

1.1. Background information

An information management system is required to unite all the parts of precision agriculture as described by Stafford (2000). This system has to be able to store the sensor data and operation documents generated by farming implements during their operation. The same system is also used either directly or indirectly (using an external service) to create the operation plans implemented with the ISOBUS (ISO 11783) enabled tractor-implement combination. For the generation of these plans, not only are considerable amounts of data required, but to create an accurate plan, working biological models, such as those described in Kropff et al. (2001) are required. The information system must be able to manage various data formats, both standardised as well as proprietary and be able to exchange data with services that provide computation for precision agriculture. Besides the features required by precision agriculture, the information system must also act as a traditional FMIS and provide the same record keeping and planning functions as traditional agricultural information systems.

Our research aims to identify the requirements of an FMIS for precision agriculture and then proposes a software architecture that fulfills these requirements. This architecture is to be based on the popular Web Application approach[1] and is evaluated together with a partial proof-of-concept implementation that was used in a practical demonstration involving a chosen field operation of precision agriculture. The importance of information technology and communication in precision agriculture is well established in research with studies such as Munack and Speckmann (2001) and Santana et al. (2007) supporting it.

1.2. Outline of this article

This article is organised so that following this introductory section there is a brief review of related research into modern FMIS and other information systems in agriculture. The review is followed by a set of identified requirements that precision agriculture poses for FMIS, which are then used as the foundation for specifying a software architecture for an FMIS for precision agriculture. Section 5 describes a test case for the specified architecture, which is then used together with a partial implementation to evaluate the architecture.

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[1] An approach anticipated a decade ago by T. Lewis. He notes "It is anticipated that the next innovation added to the model will be the use of the Information Superhighway and the World Wide Web (Internet)."(Lewis, 1998).

2. Related research

2.1. Research on FMIS

Since the implementation of a fully functional FMIS is an arduous task that cannot be accomplished without the backing of a large software development project, most academic research on FMIS restrict their scope to just some individual component of an FMIS. The parts of an FMIS that would appear to be particularly popular in research, are those related to decision support, the computational biological models, such as those predicting crop yield (Mo et al., 2004), and the usability of an FMIS. Usability has been identified as an important factor in the adoption of information systems, especially in agriculture (Nuthall and Alvarez, 2005), and there have been studies of usability in precision agriculture such as Haapala et al. (2006). Information systems of agriculture, especially those not intended for local farm computers, are similar to the information systems of other industry. Due to the considerable economic interests, the information systems of industry have been extensively studied (O'Brien, 1998) and despite the differences and smaller scale, the information systems of agriculture can be expected to benefit from this research and further approach these systems in similarity.

Most tasks of an FMIS, such as those related to record keeping, accounting and the printing of documents, are arguably of low academic interest as they differ only slightly from similar features found in other, unrelated commercially available systems. Due to their restricted scope and resources, academic research projects usually produce working prototypes that implement some particular feature of an FMIS in a novel way. FMIS related research is covered by, for example, McCown (2001,2002) with an emphasis on the decision support features. Since most of the FMIS available today are commercial systems, much of FMIS development occurs as ordinary commercial product development for existing systems.

An Australian project that focused on the decision support features related to the cultivation of wheat crops, implemented a DSS (decision support system) called WHEATMAN that was then evaluated with the local farmers in North-Eastern Australia (Hayman and Easdown, 2002). The project dated from a period when the amount of computers in households was increasing rapidly and the expectations for computer-based systems were high. The project was successful in the sense that the use of the system did show a positive correlation with increased farm efficiency. However, the adoption rates for the system were considerably lower than expected and the increased availability of computers on farms did not automatically result in the use of the computer for farm management. The project also observed the importance of involving the end-users in the development of the system and – as with any information system for agriculture – localisation and usability are critical issues for the overall success of the system.

While not a technology per se, precision agriculture is a management concept which is technologically more complicated than traditional farming and has hence generated a variety of new fields for agriculture related technical research. Consequently, many of the numerous requirements of precision agriculture listed in Stafford (2000) have been subject to academic research. Currently, information systems for precision agriculture, known also as precision farming information systems (PFIS), are a branch with very few academic or commercial systems available. One prototype of an FMIS for precision agriculture is presented by Linseisen (2001), with emphasis on the processing of GIS (geographic information system) data. A framework for service-oriented FMIS is also presented by Murakami et al. (2007) that emphasises the communication and transfer of data between all the elements of modern agriculture. Such architectural proposals and considerations are the prerequisite for a fully functional FMIS for precision agriculture. However, they are still far from an FMIS that could be used by the majority of farmers. Most of the future academic research on FMIS can be expected to focus on features somehow related to precision agriculture.

The current state of FMIS research would seem to indicate that some of the biological models and models for decision support are well known, allowing limited simulation and prediction of yields and growth as in Mo et al. (2004). Also known are the underlying reasons behind FMIS usage among farmers and many of the special user requirements that exist for FMIS. Research is, however, somewhat lacking on information systems for precision agriculture with no large-scale prototype in existence and only a few publications on the possible architectures for an FMIS for precision agriculture.

2.2. Existing FMIS

Most of the FMIS in daily use today are commercial on-site software running on an ordinary PC with some version of the Microsoft Windows operating system. The features of these FMIS are usually intended for some particular form of agriculture such as arable farming or husbandry. Regardless of any specialisation, however, the record keeping and financial planning functions are usually identical. Chaudhary et al. (2004) present an architecture for a Web application based DSS with emphasis on integrated sensor inputs. While Web applications are considered by many as the platform of future FMIS, they are still very rare compared to the FMIS implemented as traditional on-site software.

Besides the FMIS, there are also specialised DSS for agriculture that usually focus on some very specific task. An example of such a system is presented by Lewis who describes a practical system for the eco-management of a farm (Lewis and Bardon, 1998). The system aims to assist in the eco-management of a farm by evaluating the farming practices on a positive–negative scale with high positive numbers representing ecologically sound farming. There are also various services available for both traditional agriculture as well as precision agriculture. For traditional agriculture such services include, for example, soil analyses for which the results can be inputted either automatically or manually to the FMIS. Services for precision agriculture are inherently more complicated, one such service is the Kemira LORIS[2] which uses aerial imaging to estimate levels of biomass on fields. The biomass estimates can then be used to calculate the amount of chemicals, such as fertilisers, to apply to the field.

In Finland, there are a few major commercial providers of FMIS; namely Wisu[3] and Agrineuvos,[4] both of which have plugins or related software available for the various specialities of farm management. The developer of the former, ProAgria, also has a new WebWisu FMIS available that bears architectural similarity to the FMIS presented in this article. WebWisu is essentially a Web application with a normal browser interface as well as an interface meant for mobile devices. Both Wisu and Agrineuvos are traditional on-site software implemented for the Microsoft Windows operating system.

2.3. Limitations of existing FMIS

For the duration of their existence, FMIS have faced certain difficulties. Particularly the early FMIS suffered from low adoption rates during times when computers were still relatively rare and the utilisation of an FMIS would have to have been the reason for many to purchase a computer. At the time, there were studies

[2] Product of Kemira, http://www.kemiraloris.com.
[3] Product of ProAgria, http://www.proagria.fi (in Finnish).
[4] Product of Suonentieto, http://www.suonentieto.fi (in Finnish).