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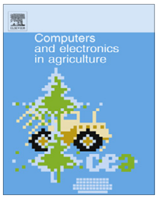

Automatic control of farming operations based on spatial web services

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ABSTRACT

Field operations relating to arable farming are often very data intensive tasks. An increasing number of regulations have been set to ensure food safety and environmental aspects. Also, the number of tools for the best practice management applied in precision agriculture is growing. However, there are yet no standardized, automated methods for a compliance management used in situations where circumstances change and are dependent on the specific location. Therefore compliance checks during the work progress online or on demand are difficult to achieve and the temporal accuracy can be very poor. In this work, we have developed a task controller (TC) prototype with an ISOBUS-compatible process data messages to be able to utilize multiple external services such as WFS (Web Feature Service) during a spraying operation. The WFS was set up in Germany to provide geodata while the actual task execution was performed in Finland. We developed a possibility to use and integrate external data from different sources in the TC on the tractor. Methods presented in this article serve as the basis for the development of multiple tools that can be used for improving farming system development, the environmental risk reduction of agricultural production and compliance checks. Existing information sources such as on board sensors, weather and forecast information, disease pressure, spatial environmental risks and real time remote sensing can be combined for new solutions of this kind. The development of technical standards for the seamless data exchange in the agricultural domain is therefore crucial. In this work, we are focussing on spatial data exchange between heterogeneous IT systems as a component of on-field machinery used in precision management.

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1. Introduction

Field operations on arable farming often require very data intensive and thorough planning. Changing conditions may cause various difficulties even when the operational plan is made with proper preparations. One of the key concerns of the farm managers as summarized by Sørensen et al. (2010) is that monitoring of field operations is time consuming and that there is a need for additional information and advanced technologies to manage monitoring and data acquisition online in the field.

In the last two decades there has been an increase in the number of legal regulations to confirm. Guidelines concerning food safety and environmental acts like fertilization of nutrients, the use of pesticides and seed types affect all farmers. There are also voluntary standards to show compliance to stricter requirements for products (Jahn et al., 2005; Fulponi, 2006) such as the EU Organic standard (EU Regulation 834/2007) or privately-run industry standards e.g. GlobalGAP (2007). A higher price level for specialized production and better food quality can be a driving factor for compliance to stricter standards. According to Nash et al. (2011), these agricultural standards are composed of a set of rules including metadata describing the publisher, the intention of the publisher, the spatiotemporal validity, the target audience, procedures in the event of non-compliance, a definition of terms used and how compliance to the rule is to be assessed. Integration of these rules into an automated management procedure is required to provide a better spatial and temporal response.

FMIS (Farm Management Information Systems) are developed to support management decision making and compliance to management standards by means of storing and processing of strategic,

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Abbreviations: CAN, controller area network; FMIS, Farm Management Information System; FTP, File Transfer Protocol; GDB, geodatabase; GeoRIF, Geographic Rule Interchange Format; GML, Geography Markup Language; HTTPS, Hypertext Transfer Protocol Secure; I-ECU, Electronic Control Unit of the Implement; LBS, location based service; MBR, Minimum Bounding Rectangle; MICS, mobile implement control system; NDVI, Normalized Difference Vegetation Index; OGC, Open Geospatial Consortium, Inc.; PDM, process data message; R-TC, prototype research task controller; SDI, Spatial Data Infrastructure; SOA, Service-Oriented Architecture; SSL, Secure Sockets Layer; TC, task controller; WFS, Web Feature Service; WFS-T, Transactional Web Feature Service; WMS, Web Map Service; WPS, Web Processing Service.

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tactical, operational and evaluation data. Typically many of the agricultural production standards are already hard-coded in the FMIS instead of obtaining that data from external sources. However, this approach is unsuitable in the long term due to the dynamic nature of agricultural production standards which are replaced and revised in irregular intervals (Nikkilä et al., 2012). They may only be valid for a limited group of farmers (e.g. country-wise, crop-wise). Therefore, more effort is needed for transferring regulations between IT systems and to provide means for an integration and interpretation of such rules in decision- and management support tools. A conceptual model of a modern FMIS suitable for automated compliance control is given by Sørensen et al. (2010).

Nikkilä et al. (2012) presented an evaluation web-service exploiting a spatial GeoRIF (Geographic Rule Interchange Format) interpreter for the automated compliance control. The application task was exposed to the automated compliance control before the field operation. After the field operation, the constructed operational document was checked again. Their work was further developed to present a design for spatial inference using an interchangeable rule format (Nikkilä et al., 2013). However, there are neither standardized methods nor technical implementations for managing compliance to standards, regulations or best practices during the work progress online or on demand. The lack of these methods leads inaccurate, inefficient and generalized decisions during the farming operation. Changing conditions like current rain and wind, pesticide alarms, weather forecasts, applicable matter content changes, working schedules, work applied by other working units, different risk analysis, information from aerial systems or advisory recommendations require a rapid update for the optimization of the operational plan and the adaption of the task in the field. When such changes occur, it would be profitable to be able to check and update automatically whether and how the relevant rules, regulations and best practices are still fulfilled. IT systems are the key component for such automated procedures, including, but not limited to FMIS.

Especially tasks in precision farming field operations can be quite complex. Rather than constructing and evaluating a single complete task, it would be better to evaluate all the individual, separate spatial decisions which form the task in hand. These decisions can be made based on available spatial and rule-based data sets. Those data sets incorporate the actual, local situation of the farm and down to the scale of variations within each field. In this context, the web service standards for geospatial data exchange are important. They apply Service-Oriented Architecture (SOA) as a software architecture design.

1.1. Suitable spatial web services

SOA allows information exchange on-demand between distributed systems. Often only particular data values or information related to a particular object or spatial extent is required. This has also been one of the focuses of standardization based the work of the ISO/TC211 Geographic Information/Geomatics and the Open Geospatial Consortium, Inc. (OGC).

As a result of the INSPIRE directive 2007/2/EC, many of the spatial data sources have gained public availability often by providing a Web Map Service (WMS) or a Web Feature Service (WFS) e.g. German GDI-DE (IMAGI, 2009) and Finnish Paikkatietoikkuna (NLS, 2010). Including these services into the farming operation would make it possible to have beneficial up-to-date sources of data, which would also be following common standards. One example of this is the development of making customized agricultural services, such as local disease status as a WMS (Ronkainen et al., 2012).

The output of a WMS is mainly used for the presentation of geodata for a human user by mapping background imagery together with additional layers of information or to summarise data (Nash et al., 2009a). For a machine interpretation of a single object's information, more suitable output becomes from a feature-oriented WFS. The development of WFS made progress in the ISO 19142. WFS is a data query mechanism to access and retrieve data in real time over the web. The potential scopes of application in the agriculture domain are processes of reading free scalable vector data, documentation and controlling. In general a request to the WFS is answered in the Geography Markup Language (GML). GML is also a standard developed by the OGC and transferred to ISO 19136. It is a markup language developed to describe geographic objects. Korduan and Nash (2005) identified it as a suitable format for geographic data on precision agriculture. Based on a study of Nørremark and Sørensen (2012), there is an ongoing research on adapting transactional WFS (WFS-T) capabilities to a task controller in Denmark.

1.2. ISOBUS environment

To adapt possible changes caused by some external data in farming operation, it is necessary to be able to deliver a proper message to the Electronic Control Unit of the Implement (I-ECU). To control the implement in a standardized way, the idea of ISOBUS Task Controller (TC) has been introduced. ISOBUS has already gained a relatively large market share over the last decade and is implemented by many manufacturers. ISO/FDIS 11783-10 (ISO, 2007) is a standardized interface relating to communication at the software level between FMIS and mobile implement control system (MICS) using board computers (ISOBUS-TC). TC uses XML-based formats for communication with FMIS, and Process Data Messages (PDM) via controller area network (CAN) bus to communicate with the I-ECU. TC handles data setup and machine configurations and also takes care of the documentation of the work executed by the mobile system. For the spatial working rate changes of the implement, TC uses an ISOBUS task map. So far the ISOBUS task has been considered to be structured as one task per one work. In practice, a planned task is selected from a drop list at the beginning of the work. Then the entire work is done according to it.

Commercial systems that exploit external sensor information like special on-board cameras still have their own controllers when operating with ISOBUS-machinery. Earlier research related to ISOBUS-TC and data transfer has had its focus on an XML-based transfer of data from the FMIS to onboard devices and in a data dictionary of identifiers for process data variables and data elements (Nash et al., 2009b). Peets et al. (2012) studied collection and management of data acquired from ISO 11783 compliant and non-compliant on-the-go sensors, but their focus was also on data collection, not exploiting it during the work. The work by Iftikhar and Pedersen (2011) focused on the exchange of data between the farming devices also including climate control and production monitoring equipment, temperature monitoring sensor and the farming systems featuring agricultural advisory service, supplier, contractor and manufacturers. The solution focused on ISOBUS-available functions. However, there has not been research on exploiting multiple spatial web services during farming operation or implementing them into an ISOBUS environment.

1.3. Research focus

In this study, the focus is in the following scenario: a farmer wants to operate according to the new environmental rules which also contain spatial restrictions and are provided by different authors. The application task for precision spraying has been planned according to these rules, but in order for this plan to succeed, the weather needs to be suitable. There is also an accurate

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