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iGreen: A ubiquitous dynamic network to enable manufacturer independent data exchange in future precision farming

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ABSTRACT

In order to master the future challenges concerning increased demand for food and energy it is obvious that new methods are needed to boost productivity in a sustainable way. One key aspect to optimize agricultural processes and decision making is to derive effective means to acquire and share information along the value chain. In the past, data management in agriculture was dominated by proprietary, mostly Original Equipment Manufacturer (OEM) driven solutions with limited scope. To overcome the shortcomings associated with this, the German national joint research project iGreen was initiated in 2009 to enable convenient and efficient data sharing in a holistic and OEM independent way. As a project partner, John Deere focused on developing concepts and components for interconnecting machines among each other and with infrastructure nodes. In this paper the achieved results such as the infrastructure component referred to as the machine connector, the onboard data management and integration of mobile devices will be presented and evaluated through experiments focusing on data sharing in wheat and forage harvesting. The overall promising results indicate that in the future new applications focusing on optimizing processes can be enabled that will greatly improve the effectiveness and ease of agricultural production, especially fleet management and resource planning.

1. Introduction

To fulfill the steadily rising demand for agricultural products due to increasing world population and living standards as described in FAO (2009), new means are required to make current agricultural processes more efficient. Other effects such as intensified generation of renewable energy in form of ethanol and bio diesel based aggravate this trend even more.

Besides changes in the agricultural practices as well as enhanced irrigation and the availability of superior seed material and fertilizers, one central aspect to help this effort is to enable more effective information sharing and processing. If the available data is used and combined more efficiently this allows for better decision making and a higher degree of process automation. One major roadblock for these efforts is the lack of a universal and manufacturer independent approach for sharing data with different stakeholders along the agricultural value chain. Other potentially troublesome aspects regarding pervasive data sharing are the limited coverage, reduced quality of service as well as excessive cost of wireless telecommunication services in rural areas and absence of an integrated mean for public/private data combination.

In order to foster related activities in public institutions and industry partners, the research project iGreen was initiated by the German Federal Ministry of Education and Research (BMBF) in 2009.

In the following pages a retrospective overview of the achieved R&D insights from the perspective of a participating OEM will be given. The paper is structured into four main parts. At first, an introduction summarizing the state-of-the-art in related fields and identifying the shortcomings of currently available solutions will be given. The adjacent section introduces the approach in more detail and outlines the main components. In the following passage, some experiments will be presented to illustrate the concepts , prove feasibility of the realized systems and discuss the transferability into current farming practices. To conclude this article, a short summary is given.

1.1. State-of-the-art

Over the last decade(s) data management has become a topic of high interest in the field of agricultural engineering. The initial focus of the research efforts was mainly laid on machine to implement data exchange. The Agricultural Bus System (German: Landwirtschaftliches Bus-System, LBS) described in DIN (xxxx)

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can be seen as a first nationally driven norming initiative in Germany. In the following, this concept was internationally discussed and lead to the standard known as ISOBUS (ISO, xxxx).

Largely in parallel, first intra-farm data management approaches appeared that enabled exchange and structured processing of data between the so-called *mobile implement control system (MICS)* and the *farm management information system (FMIS)*. According details can be found in Auernhammer and Speckmann (2006). In this approach targeted at arable farming applications, the emphasis was laid on the interface standardization while aspects like the specification of transmission details and the required infrastructure remained intentionally largely untouched. A second branch for the intra-farm level communication for livestock operations was drafted in ISO (2007).

Due to the fact that the agricultural production process can be no longer regarded as an isolated effort but involves a large number of stakeholders such as suppliers and customers, extensions to these initiatives were inevitable. Thus, several national and international standardization efforts were driven by different groups to extend the scope in order to enable full data exchange along the whole production process in agriculture. In Germany, *agroXML* can be named as a typical example that fostered a web-technology-centric approach to interface between a farm (FMIS system) and outside stakeholders. In a similar way an international standard known as *AgXML* emerged that mainly focuses on the necessities of grain production. In North America, a non-profit consortium called *AgGateway* formed to establish eBusiness on a wide basis in the field of agriculture by means of developing common standards for data exchange.

In terms of implementing these methods, initially file-based exchange was adopted as the state-of-the-art. In order to overcome some of the shortcomings associated with this first approach the research community laid emphasis on a transition towards service-oriented architecture (SOA) paradigms combined with open and standardized interfaces by adopting web service technology. Examples for this can be found in the agricultural process-data service (APDS) published in Steinberger et al. (2009) and open geospatial web services introduced by Nash et al. (2009).

As a recent trend in this field semantic network approaches start to get adopted. They rely on the concept that information becomes associated with a specific basis for interpretation in form of ontologies. This allows for a broader range of applications and solutions to be delivered.

The need for a systematic approach towards data exchange is obviously not limited to the field of agricultural applications. One example of this in the on-highway domain is the development of intelligent traffic/transport systems featuring passenger cars and infrastructure components as nodes. The scope of these systems is to improve overall safety, optimize traffic flow through intelligent vehicle routing and enable new business models such as automated billing or toll applications. Again, these efforts are driven mainly with a national scope in the European Union (EU), North America, and Asia (see Hill and Garrett, 2011; Sawaji, 2012). The transfer of these concepts to the agricultural sector is everything but straight forward. This is mainly due to the generally less sophisticated communication infrastructure in rural areas, differences in the regulatory system (e.g. permissible frequency bands), and other application conditions such as inter-node distances, general node density, or data payload volume.

1.2. Identified shortcomings

In summary, it can be stated that a fair selection of approaches for data exchange with various scopes in the field of agricultural engineering exist. However, they tend to have a rather partial scope, typically assume permanent availability of network coverage, or do not scale with operation size. So far solutions seem to be largely OEM driven with an in general limited scope concerning the considered target applications as stated in Fountas et al. (2006). This makes them largely incompatible and unsuited to support the full agricultural production cycle. On a more technical level, the challenges associated with operations in infrastructure sparse environments such as robustness towards loss of coverage and low bandwidths remain largely unsolved.

As a last aspect to be mentioned, the seamless exchange between the stakeholders involved in a farming operation (suppliers, customers, public agencies) needs to be enabled with less effort and in a transparent and safe way.

Therefore, the main contributions to overcome the listed shortcomings involve:

- An innovative approach for linking agricultural machines into an integrated public-private data sharing network in a dependable way using state-of-the-art web-based technologies.
- Enabling machine data consolidation using a new approach towards model-free sensor data fusion.
- Performance assessment of the prototypical components in a series of field tests under typical application conditions.
- Manufacturer-independent way of exchanging machine and operation related data using wireless technology as a starting point for standardization.

2. The iGreen approach

In 2009 the three year national research project iGreen was initiated by a group of 23 partners with public R&D (universities, government agencies, research institutes) and industry (OEMs, service providers) background. The common vision was to investigate the ways for future cloud-based pervasive data sharing and location-based services in the agricultural sector to provide all means required to improve productivity, increase sustainability and allow for easier product traceability in modern agricultural production processes. Special emphasis was put on the combination of private and publicly owned data.

An example for such an activity is the use of field boundary maps based on public geo-data for field information sharing between e.g. a contractor and a farmer. Other examples would be the generation of pesticide application maps based on product information provided by a chemical company and soil property maps as well as publicly defined water protection areas to comply with legislative requirements. In order to make this truly useful, another focus area was the implementation of manufacturer independent solutions that allow for open data exchange. Concerning the outcome of these activities from an OEM perspective, the interested reader may be referred to Bartolein et al. (2011).

2.1. Infrastructure components

To realize the described data cloud functionality several components are needed to implement aspects of the overall approach. An overview of this concept is provided in Fig. 1.

As shown, two main components that enable different entities to exchange data on the levels below and above are the machine connector (MC) and the online box (OB).

The OB represents the main off-board entity of the network that is formed in a distributed fashion. The main responsibility of each OB incarnation is to encompass all means for data storage, alignment and synchronization for a given stakeholder in the data cloud. In order to fulfill this task, it relies on a permanent internet-based connection to the other entities. Thus, as a whole, the OBs form the backbone infrastructure of the iGreen network.