Supporting Precision Agriculture by Technology Integration on a Inter and Intra Enterprise Level

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Abstract

Dutch agri-food supply chain network actors can use technologies, (web) services and tools to increase sustainable production and chain transparency in agriculture. Adoption of these (web) services and tools in arable farming is still low. Therefore, the Dutch ministry of agriculture started a public-private project to support more sustainable crop production: the Program Precision Agriculture. In this program, technologies, tools and (web) services are developed. Integrating new tools and (web) services into farm management is difficult and involves different disciplines. Research is involved for supporting integration. This paper provides a brief description of current projects in the Program Precision Agriculture, related to information integration. The projects are classified based on their integration levels and scope.

Keywords: information intensive agriculture, information integration framework, service-oriented approach

Introduction

Dutch Agri-Food Supply Chain Networks (AFSCNs) face challenges fulfilling consumer's demands related to sustainable food production and chain transparency. To meet these demands, ICT specific communication within AFSCNs and farm business processes should improve. The farm, as a place of primary production, plays a central role. All kind of (web) services (e.g. field measurements, crop simulation, decision support) and tools (e.g. variable rate implements, Global Positioning Systems, software applications, sensors) can support or significantly improve current farm business processes. At farm level, collection, processing and integration of data into farm management is needed to get high quality information for better farmers' decision making (Fountas *et al.*, 2006, Kitchen, 2008)

Dutch AFSCNs can be characterized as 'high-tech'. Various farms are supported site-specifically by using satellite images, crop scans, yield measurements, etc. Machines are able to operate precisely using advanced positioning systems (e.g. Global Positioning Systems, Real-time kinematic, etc.). These technological developments and tools are accompanied by all kinds of innovative (web) services.

Adoption of Precision Agriculture (PA) can contribute to higher yields and quality while reducing environmental impact. PA should be seen as a management process (Blackmore, 2003). Therefore, farmers should change their current business processes to adopt PA.

Currently, few farmers have adopted PA and use the available technologies and tools in farm management on a daily basis. Researchers have found multiple reasons why PA is not widely adopted (Pedersen *et al.*, 2004, McBratney *et al.*, 2005, Jochinke *et al.*, 2007, Lamb *et al.*, 2008, Reichardt & Jürgens, 2009). One of the main reasons is that the actual business processes are not well or not at all supported by decision support tools (McBratney *et al.*, 2005). In addition, compatibility between applications is lacking (Pedersen *et al.*, 2004). Our research focuses on dealing with these shortcomings by creating interoperability between different tools in order to support farm business processes.

A farmer's goal is to manage his (sub)fields, crops, farm, etc. Control can be achieved by closing the control cycle. This control cycle includes planning of recourses, executing the plan, monitoring the controlled objects (e.g. fields, crops, farm), analysing the results and improving the process. Various tools and (web) services provided by different AFSCN actors can support parts of this control cycle. To support this control cycle tools and (web) services should be in integrated. Mainly due to the poor standardization, current applications are isolated packages that poorly communicate with each other (Wolfert *et al.*, 2010). A lack of compatibility between different technical systems is a barrier to use new technologies (Pedersen *et al.*, 2004). Integrating these state-of-the-art technologies and tools in farm management and control processes is difficult (Lamb *et al.*, 2008, Wolfert *et al.*, 2010). In the paper of Wolfert *et al.* (2010) a method for technology integration in enterprises is described. In this paper, parts of the method of Wolfert *et al.* (2010) are used to analyse current projects in the Program Precision Agriculture, related to information integration.

First, this paper provides a description of projects that will support farmers in their business processes by developing new tools or data standards. Then a framework showing different dimensions of integration in enterprises is presented. Finally, these projects are analysed and classified on the level and scope of integration followed by a discussion, conclusion and future work.

Projects in the Program Precision Agriculture

To support a more sustainable production of Dutch AFSCN the government has started a public-private project 'Program Precision Agriculture' (in Dutch: Programma Precisie Landbouw (PPL)). PPL includes 35 projects. Participants are farmers, food processing companies, service providers, manufacturers and universities. Together they invest 6 million euro. The Dutch government invests another 6 million euro in different projects related to PA. Research is involved to align current projects and integrate developed tools in farm management. Currently several projects are started. Projects related to technology integration are briefly explained.

<u>Upgrade of EDI-teelt+ standardization</u>

This project documents and publishes current Dutch standards for Geo-Information and electronic data exchange (EDI teelt+) for crops cultivated in the Netherlands. The EDI teelt standard was used for inter-enterprise exchange about cultivation. EDI teelt+ needs to be updated with Geo-information in order to match fields with the crops cultivated on that field and to support PA-technologies.

Map based Controlled Traffic Farming (CTF)
This project will provide an application that can represent, modify and develop CTF maps. These maps can be used in all cultivation practices. The application will be accessible as a web-service. CTF maps can be made, modified and used within the enterprise, supporting different navigation equipment.

Online Quality Management System (QMS)
A Dutch advisory agency for arable farming developed an on-line Quality Management System (QMS). This QMS presents remote sensing data derived from satellite images made of agricultural fields. The QMS system shows differences in crop growth status within and between fields. Why differences occur, cannot be analysed based on current data. This project will extend the current application to realize that additional information about fields can be added. Based on this additional information fields from different farmers can be benchmarked more accurately using this application.

Development web-services to represent and modify geo-data
Goal of this project is to develop an application that is able to manage geo-data provided by vehicle mounted sensors and to develop an online database to store the geo-data. This online database will be owned by individual farmers. The application can be used to represent and modify geo-data with different formats from different sensors. The online database will be accessible for other applications using web-services.

Sustainability and benchmarking report of sugar beet production
At this moment, farmers can register their cultivation practices about sugar beet production on-line. Based on these data reports about sugar beet cultivation practices, the financial balance and advice can be generated. This application will be extended. Additional data can be added to calculate a sustainability mark. This mark is calculated based on energy consumption and environmental impact. The mark can be used by farmers to benchmark their cultivation practices with others from their region. The data format is based on EDI teelt+.

Alert by violation of Global Gap procedures in Imhotep (custom made ERP system for arable farming)
One of the biggest farms in the Netherlands has developed a custom made kind of ERP package (Imhotep). An application will be developed that will give an alert when Global Gap procedures will be violated based on a pesticide spraying plan made in Imhotep. The project focuses on support of the planning of pesticides and checks regulations. The application will be accessible as a web-service.

Methods

Integration of technologies within and between enterprises can be divided in different dimensions of integration. A definition of integration can be that all systems are connected, data is shared in the organisation, the applications can interoperate, and the business processes are coordinated with the information system in relation with other processes (Giachetti, 2004). Integration can be achieved by *coordination of* processes, *interoperability* between applications, *standardization* of data and *connectivity* between devices and systems (Giachetti, 2004). Figure 1 shows how these aspects are related.

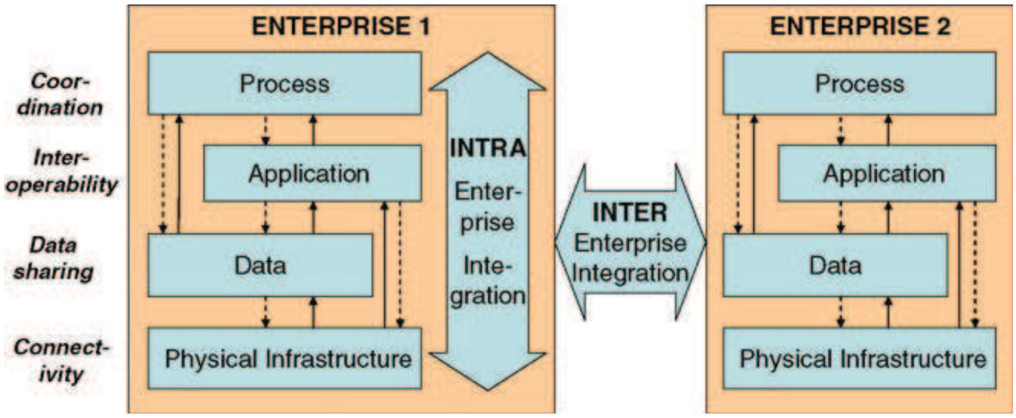

Figure 1. Integration framework (Wolfert et al., 2010, based on Giachetti 2004)

Figure 1 displays two different integration scopes (Wolfert *et al.*, 2010):

- Intra-enterprise: within enterprises to overcome fragmentation between organizational units (functional silos) and systems;
- Inter-enterprise: between enterprises to move from operating as an isolated company towards a virtual enterprise that is integrated in multi-dimensional networks.

Further, four different integration types are presented (Wolfert *et al.*, 2010):

- Process Integration: alignment of tasks by coordination mechanisms (coordination);
- Application Integration: alignment of software systems so that one system online can use data generated by another one (interoperability);
- Data Integration: alignment of data definitions in order to be able to share data (data sharing);
- Physical Integration: technical infrastructure to enable communication between hardware components (connectivity).

The different integration types are interdependent in two ways (Wolfert *et al.*, 2010):

- Conditional (solid lines in Fig. 1): to share data and couple applications, the physical infrastructure must be connected; to integrate applications, there must be common data definitions; for effective process coordination it must be possible to share data or to integrate applications.
- Requiring (dotted lines in Fig. 1): a starting point is the need for integrated processes which defines the requirements for data exchange and application integration; application integration implies specific requirements for data to be exchanged; data exchange and application integration both require a supporting technical infrastructure.

Expected results

Current projects are analysed concerning to what extend they contribute to technology integration.
(A) Upgrade of EDI-teelt+ standardization: Developing a standard to improve data exchange within and between enterprises.
(B) Map based Controlled Traffic Farming (CTF): Designing an application for intra-enterprise integration by supporting farmers in creating and exchanging data formats for controlled traffic farming
(C) Online Quality Management System: Adapting an application for inter-enterprise integration by providing a tool to benchmark crop growth.
(D) Development of web-services to represent and modify geo-data: Development of an application for intra-enterprise integration by providing a tool to represent and modify geo-data from sensors.
(E) Sustainability and benchmarking report of sugar beet production: Adapting an application for inter-enterprise integration by providing a tool to benchmark the sustainability of sugar beet production
(F) Alert by violation of Global Gap procedures in Imhotep: Development of an application for intra-enterprise integration by supporting famers in their pesticide planning.

Table 1. PPL projects classified based on contribution to information integration

Integration Type:	Integration Scope:	
	Intra-Enterprise	Inter-Enterprise
Process		
Application	B, D, F	C, E
Data	A	A
Physical infrastructure		

As can be seen in table 1, current projects focus on developing applications to support farm processes or on the data exchange between the applications based on standardization. Currently, there are no projects within PPL focussing on extending the physical infrastructure. Moreover, there are not any projects focussing on describing agricultural processes and their coordination mechanisms.

Discussion

Most projects focus on the development of applications. We suggest that these projects use the data standard provided by the EDI teelt+ upgrade project. Some of the applications are accessible as web-services which enhances the interoperability between different applications.
The projects are not focusing on describing process models. Reference models can be used for modelling farm management styles, involved processes and available technologies and can improve current business processes. These reference models can be used to specify the needed functionality for supporting specific processes. Business Process Modelling Notation can be

used for developing reference models (Verdouw *et al.*, 2010). So far, several researchers have provided methods, modelling approaches, conceptual models for software applications in agriculture (Janssen, 2009, Nikkilä *et al.*, 2009, Sørensen *et al.*, 2010a, Sørensen *et al.*, 2010b, Wolfert *et al.*, 2010) based on previous and current research projects e.g. SEAMLESS, Future Farm, KODA, agriXchange. However, at this moment, a framework that integrates tools and (web) services to support agricultural business processes using reference models is not available.

Current PPL projects are contributing to technology integration in Dutch AFSCN. However, not all relevant dimensions of integration are covered. No attention is paid at the process layer. Describing processes in agriculture is a key step to information integration.
In future work a framework should be developed that support inter and intra-enterprise integration of technologies in agriculture. Some of current PPL projects are ready to be integrated into a framework by exchanging data using web services.

In future research, focusing on information and technology intensive agriculture at farm level, a framework that finds and binds existing web-services and data to custom-made end-user applications to support farm management and control processes needs, to be developed. This framework should consist of:

- Reference models describing current and improved farm business processes (planning, execution, registration, analysis)
- An architecture integrating existing tools, data and models into end-user applications to support farm management.
- A methodology to extend the framework to build other custom-made end-user applications for agriculture or other application domains.

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References

Blackmore, S. (2003). The role of yield maps in Precision Farming. Cranfield University, Silsoe.

Fountas, S., Wulfsohn, D., Blackmore, B.S., Jacobsen, H.L., & Pedersen, S.M. (2006). A model of decision-making and information flows for information-intensive agriculture. Agricultural Systems, 87(2), 192-210.

Giachetti, R.E. (2004). A Framework to Review the Information Integration of the Enterprise. International Journal of Production Research, 42(6), 1147-1166.

Janssen, S.J.C. (2009). Managing the Hydra in integration: developing an integrated assessment tool for agricultural systems. Unpublished Proefschrift Wageningen

Jochinke, D.C., Noonon, B.J., Wachsmann, N.G., & Norton, R.M. (2007). The adoption of precision agriculture in an Australian broadacre cropping system--Challenges and opportunities. Field Crops Research, 104(1-3), 68-76.

Kitchen, N. R. (2008). "Emerging technologies for real-time and integrated agriculture decisions." Computers and Electronics in Agriculture 61(1): 1-3.

Lamb, D.W., Frazier, P., & Adams, P. (2008). Improving pathways to adoption: Putting the right P's in precision agriculture. Computers and Electronics in Agriculture, 61(1), 4-9.

McBratney, A., Whelan, B., Ancev, T., & Bouma, J. (2005). Future Directions of Precision Agriculture. Precision agriculture, 6(1), 7-23.

Nikkilä, R., Seilonen, I., & Koskinen, K. (2009). Software architecture for farm management information systems in precision agriculture. Computers and Electronics in Agriculture, 70(2), 328-336.

Pedersen, S.M., Fountas, S., Blackmore, B.S., Gylling, M., & Pedersen, J.L. (2004). Adoption and perspectives of precision farming in Denmark. Acta Agriculturae Scandinavica, Section B - Plant Soil Science, 54(1), 2 - 8.

Reichardt, M., & Jürgens, C. (2009). Adoption and future perspective of precision farming in Germany: results of several surveys among different agricultural target groups. Precision Agriculture, 10(1), 73-94.

Sørensen, C.G., Fountas, S., Nash, E., Pesonen, L., Bochtis, D., Pedersen, S.M., *et al.* (2010a). Conceptual model of a future farm management information system. Computers and Electronics in Agriculture, 72(1), 37-47.

Sørensen, C.G., Pesonen, L., Fountas, S., Suomi, P., Bochtis, D., Bildsøe, P., *et al.* (2010b). A user-centric approach for information modelling in arable farming. Computers and Electronics in Agriculture, 73(1), 44-55.

Verdouw, C.N., Beulens, A.J.M., Trienekens, J.H., & Verwaart, T. (2010). Towards dynamic reference information models: Readiness for ICT mass customisation. Computers in Industry, 61(9), 833-844.

Wolfert, J., Verdouw, C.N., Verloop, C.M., & Beulens, A.J.M. (2010). Organizing information integration in agri-food--A method based on a service-oriented architecture and living lab approach. Computers and Electronics in Agriculture, 70(2), 389-405.