agriOpenLink: Towards Adaptive Agricultural Processes Enabled by Open Interfaces, Linked Data and Services

Slobodanka D. Kathrin Tomic[1], Anna Fensel[1], Christian Aschauer[2], Klemens Gregor Schulmeister[2], Thomas Riegler[3], Franz Handler[3], Marcel Otte[4], Wolfgang Auer[4]

[1] The Telecommunications Research Center Vienna (FTW), Vienna, Austria
{tomic,fensel}@ftw.at
[2] University of Natural Resources and Life Sciences, Division of Agricultural Engineering (BOKU), Vienna, Austria
{christian.aschauer,klemens.schulmeister}@boku.ac.at
[3] Josephinum Research (JR), Wieselburg, Austria
{thomas.riegler, franz.handler}@josephinum.at
[4] MKW Electronics GesmbH (MKWE) Weibern, Austria
{marcel.otte,wolfgang.auer}@mkw.at

Abstract. Today, users involved in agricultural production processes increasingly rely on advanced agricultural machines and specialized applications utilizing the latest advances in information and communication technology (ICT). Robots and machines host numerous specialized sensors and measurement devices and generate large amounts of data that combined with data coming from external sources, could provide a basis for better process understanding and process optimization. One serious roadblock to this vision is a lack of interoperability between the equipment of different vendors; another pitfall of current solutions is that the process knowledge is not modelled in a standardized machine readable form. On the other hand, such process model can be flexibly used to support process-specific integration of machines, and enable context-sensitive automatic process optimization. This paper presents an approach and preliminary results regarding architecture for adaptive optimization of agricultural processes via open interfaces, linked data and semantic services that is being developed within the project agriOpenLink; its goal is to provide a novel methodology and tools for semantic proces orchestraion and dynamic context-based adaptation, significantly reducing the effort needed to create new ICT-controlled agricultural applications involving machines and users.

Keywords: Semantic Services, Semantic Processes, Ontology, Open Interfaces

1 Introduction

Precision farming is a new paradigm in agricultural production motivated by the need to optimize the use of production resources, and to reduce costs and environmental impacts of production. It is a synonym for in-house robotics, field robotics and intelligent agricultural machines, and their ability to detect their context, e.g. a location, and perform highly localized actions within a production process in a timely manner.

While the precision farming market is growing, the awareness that ***interoperable*** equipment can bring large benefits, is still low. The i*nteroperable* equipment can be seamlessly plugged-in within the system, and have their data easily collected and flexibly interlinked with other available data, aiding to flexible creation and control of agricultural process. The vision of flexible plug-and-play of devices or processes is currently far from being reached. The approach of the *agriOpenLink* initiative, which we present in this paper, is to contribute open interfaces and open process models for agriculture, offering methodology and tools for automated creation of new processes over plug-and-play process infrastructure. We extensively use service and semantic technology: the system functions map into dynamically combinable semantic services enabling the system to flexibly grow as new devices and services are plugged in. An ultimate goal is to offer efficient technology to the developers of applications for agriculture, and to stimulate creation of new applications.

The paper is structured as follows. The challenges are described in Section 2. Section 3 presents the approach within the context of related work. Section 4 outlines the architecture of the semantic process management, and Section 5 concludes the paper.

2 Problem Description

Two severe obstacles must be surmounted to reach the full benefits of the precision farming vision: closed data interfaces and closed process implementations.

Closed Data Interfaces: One major trend we are witnessing today in the precision farming market is an emergence of process applications which use integrated equipment of a single vendor, and generate data that cannot be used for integration with other systems. Contrary to this practice, *agriOpenLink* aims at integration of the heterogeneous equipment of different vendors, by means of a simple extensible open source library (Data Interface API), which may establish itself as a de facto standard.

Closed Process Implementation: Although emerging applications instrument specific agricultural processes and offer user-friendly interaction over portable devices and the Internet, the process optimization model is hidden within specific application code. The process knowledge is not formally captured and the process implementations are closed; hence different processes cannot exchange internal data or impact each other. Accordingly, they cannot flexibly react on external context, and there is no support for dynamic creation of new processes based on combination of existing ones. To address this problem *agriOpenLink* makes use of **service and semantic** paradigms. Semantic technology offers means to interlink data and services based on their semantic meaning and use this interlinked structure as a base for reasoning, and triggering of control actions. It is an aim of *agriOpenLink* to establish formal machine readable semantic models of several agriculture processes and to develop a semantic service based process platform - agriOpenLink Process Tool-box - to support flexible process creation, monitoring and optimization, as well as flexible creation of new processes as new atomic functions and new equipment are made available.

3 agriOpenLink Approach

In this section we describe taken approach in the context of the relevant related work.

Open Data and Ontologies for Agriculture: In this field there is already a significant body of knowledge, and a strong semantic community behind it. Semantic approaches in agriculture aim at solving lexical interoperability, data interoperability, knowledge model interoperability and object interoperability [1]. An organization with a significant role in designing ontologies for agriculture is Food and Agriculture Organization of the United Nations (FAO; http://aims.fao.org). FAO is developing agriculture management information standards such as AGROVOC thesaurus, Agris and openAgris. Further research work focuses on agricultural ontologies and information systems approaches, e.g., as presented in [2]. *agriOpenLink* aims at using existing semantic models, while innovation is in the production process modelling.

Interface Data Models for Agriculture: Currently, several initiatives develop standards for the data interfaces for agricultural applications. One example is ISO Standard ISOagriNET [3], a standard for the communication between agricultural equipment in the livestock farming. Its level of adoption is relatively low and an open source implementation of the standard is not available. For grassland management and crop farming the XML based markup language agroXML (http://www.agroxml.org) is state of the art. For the data exchange between machines and personal computers (e.g. farm computer) the ISO-XML Standard is the current standard. agroRDF is an accompanying semantic model that is at the moment still under heavy development. It is built using Resource Description Framework (RDF) of W3C. ISO11783 also called ISOBUS, specifies the interfaces and data network for control and communication on agricultural machines like tractors. This standard is well established and there are commercial and open source implementations available. *agriOpenLink* aims at developing and open source realization of the interface data model (*agriOpenLink* Data Interface API) and the process for extending it based on semantic schema paradigm.

Semantic Services: Semantic services are atoms of process functionality that can be flexibly linked together. Service-oriented architectures (SOA) today have significant limitations because of the heavyweight WS-* specifications stack and lack of semantics in descriptions of service. Web APIs based on so-called REST (Representational State Transfer) principles provide a lightweight, increasingly popular alternative and allow for accessing data and functionality in an automated manner. Semantic Web Services add ontology and rule-based service descriptions [4], e.g. OWL-S ontology applies to SOAP (Simple Object Access Protocol) services represented with WSDL (Web Service Description Language). The Web Services Modeling Ontology (WSMO) [5] is a broader scoped extension. WSML (Web Service Modeling Language) [6] includes the ability to define rules. SAWSDL (Semantic Annotations for WSDL and XML Schema) is the only W3C recommendation in the area of Semantic Web Services. It enables referencing from WSDL service schema into arbitrary ontological models. The WSMO-Lite [7] service ontology fills the SAWSDL annotations with concrete semantic service descriptions. Semantically enabled RESTful services [8] leverage the advantages coming from the combination of Linked Data and service technologies [9]. *agriOpenLink* develops methods for exposing agricultural process data as Linked Data, and services as Linked Services and appropriate ontologies. The project applies the principles of WSMO as the semantic service framework with the most elaborated mediation part, and uses SPARQL *(*SPARQL Protocol And RDF Query Language*)* query in service discovery and matching.

Agriculture Process Modelling and Optimization: Theoretical mathematical analysis of agricultural processes is commonly based on model simulator tools. Some examples include APSIM (Agricultural Production Systems Simulator) [10] and IBSAL (Integrated Biomass Supply Analysis and Logistics Model [11]. Often used for applications in the agricultural sector is GASP IV a FORTRAN-based simulation language which provides the framework for modelling systems involving both continuous and discrete phenomena [12]. *agriOpenLink* uses existing simulation and optimization process models to establish their mapping into ontology for extensible adaptive processes. The aim is to enable developers to build process models and model and instrument their context-based optimization.

Semantic process composition and enablers for service activation: Composing processes by flexibly chaining services significantly reduces development costs and increases operational agility. Service composition paradigm addresses dynamic user needs and dynamic changes in service functionality. Service composition technologies try to separate processes and rules [13]. Among them, the hybrid service composition based on WSMO framework may be the most flexible one: while stable parts of a composition are specified using processes, the parts likely to change are specified using rules. Enablers for dynamic composition and activation of services are notification services and access control. Currently prevailing notification services lack standard mechanisms for the semantics of the notifications. Some emerging approaches like sparqlPuSH [14] combine the power of semantic representations with a pull/push notification system. Access control manages who gets access to what data or data producing services in which context and with which degree of detail e.g. by specifying privacy policies. The *agriOpenLink* process creation approach extends the hybrid service composition approach based on WSMO with capabilities to modify the processes and rules independently and reuse rules and decision logic. The goal is to link together the rules, processes and context sources during the composition process, and to take advantage of reasoning on linked data where a monitoring service subscribes to particular conditions/rules on data, as well as of filtering rules based on graph patterns as simple as SPARQL queries.

4 agriOpenLink Semantic Process Management Architecture

The key aspects of our approach related to process creation and control are depicted in Figure 1. The functionality of the process infrastructure is mapped into semantic services, which dynamically register, hence are discovered and dynamically invoked. Service developers implement and deploy services, and on the other hand, annotate and publish service descriptions in the semantic service repository. Data coming from the agricultural platforms (with *agriOpenLink* Data Interface) is subject to analytics and is stored into the knowledgebase. Application developers create process-based applications using goal-oriented process and service models. Invocation of concrete services is based on service ranking; process of ranking and filtering utilizes dynamic requirements, ranking algorithms and SPARQL queries.

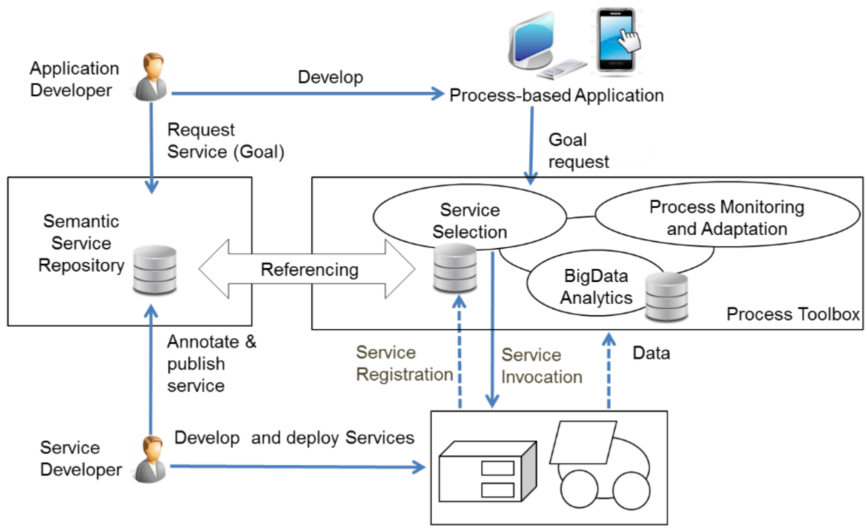

Figure 1. Semantic Process Management Architcture

With this approach we aim at: *extensibility and re-configurability* by assuring interoperability of data and of process models; *notification-based monitoring* of the context built by linking measurements and status data, providing the input for process optimization and service selection; *real-time optimization* by configuration of policies acting on the context for fast immediate process adaptations. (4) *pro-active optimization recommendations* based on analysis of the potential for process optimization.

5 Conclusions

In this paper we present an approach of an industrial research initiative *agriOpenLink* that develops methodology and designs tools for creating applications for control and optimization of farming processes. *agriOpenLink* common inter-disciplinary methodology spans mathematical process modelling, process ontology definition, interface data model realization, design of the infrastructure for semantics-enabled dynamic process control, and finally testing tools with users. This approach addresses many stakeholders in the agricultural sector: at the interface level the development of an open source interface standard may have high multiplication effect by involving many relevant data producers; at the system level the improvement of process modelling and optimization methodology and its implementation based on semantic services technology requires focused coordination of ICT and process expertise. In this process it is our goal to reach a broad community of users - the developers creating smart farming applications - who may join our efforts in establishing *agriOpenLink* open interface and process solution.

Acknowledgments

This work is supported within the project *agriOpenLink* partially funded by the Austrian Research Promotion Agency (FFG) within the program "Future ICT". The Telecommunications Research Center Vienna (FTW) is supported by the Austrian government and the City of Vienna within the competence center program COMET.

References

1. Roussey, C., et al. Ontologies in Agriculture, Ingénierie des Systèmes d'Information 16(3):55-84 (2011).
2. Goumopoulos, C. et al: An Ontology-Driven System Architecture for Precision Agriculture Applications, International Journal of Metadata, Semantics and Ontologies (IJMSO), p.72-84 (2009)
3. ISO17532: Stationary equipment for agriculture - Data communications network for livestock farming. Genf: Beuth Verlag.
4. Fensel, D., et al. Enabling Semantic Web Services: The Web Service Modeling Ontology. Springer (2006).
5. Roman, D. et al: Web Service Modeling Ontology. Applied Ontology 1(1), 77–106 (2005).
6. de Bruijn, et al: The web service modeling language WSML: An overview. In: ESWC. pp. 590–604 (2006).
7. Vitvar, T. et at: WSMO-Lite Annotations for Web Services. In: 5th European Semantic Web Conferences. pp. 674–689 (June 2008).
8. Verborgh, R., et al: Efficient Runtime Service Discovery and Consumption with Hyperlinked RESTdesc. 7th International Conference on Next Generation Web Services Practices (2011).
9. Pedrinaci, C. et al: Services and the Web of Data: An Unexploited Symbiosis. In: AAAI Spring Symposium (March 2010).
10. McCown et.al. APSIM: a novel software system for model development, model testing and simulation in agricultural systems research, Agricultural Systems Vol. 50, Issue 3, 1996, 255–271.
11. Ebadian, M. et al: A new simulation model for multi-agricultural biomass logistics system in bioenergy production, Biosystems Engineering, 2011, 110, 3, pp 280-290.
12. Alan A.: A combined continuous - discrete FORTRAN-based simulation language, School of Industrial Engineering Purdue University Lafayette.
13. Feldkamp, D,. and Singh. N. Making BPEL flexible. Technical Report SS-08-01, Association for the Advancement of Artificial Intelligence, 2008.
14. Passant, A., et al, sparqlPuSH: Proactive notification of data updates in RDF stores using PubSubHubbub, 6th Workshop on Scripting and Development for the Semantic Web, Crete, Greece, May 2010.