A Farm Information Model for Development and Configuration of Interoperable ICT Components to support Collaborative Business Processes – a case of late blight protection

Jan Willem Kruize[a,c,1], Daan Goense[b], Sjaak Wolfert[a,c], Cor N. Verdouw[a,c], Huub Scholten[a], Adrie J.M. Beulens[a]

[a] *Information Technology group, Wageningen University, Hollandseweg 1, 6706 KN, the Netherlands*
[b] *Wageningen UR, Livestock Research*
[c] *Wageningen UR, Agricultural Economics Research Institute*

Abstract

Farm enterprises[2] need to collaborate with numerous actors that are part of Agri-Food Supply Chain Networks (AFSCNs) such as governments, advisory services, contractors, processors, input providers and certification bodies. This collaboration is required to produce food in a more sustainable, safe and transparent manner. To collaborate efficiently and effectively, information needs to be shared within collaborative Business Processes. The information sharing within such collaborative Business Processes should be supported by an ICT infrastructure consisting of interoperable ICT Components. Currently, most of the available ICT Components are not interoperable, hindering data exchange between ICT Components of various vendors. Consequently, this situation is hindering optimization of farm production processes and collaboration in AFSCNs. Therefore, a platform, called FIspace, is being established for multiple domains that support the development and configuration of interoperable ICT Components into a system that is able to support collaborative farm Business Processes. To develop interoperable ICT Components and configure these in an easy and flexible manner to support farm enterprises, a farm information model is, amongst other models, required.

The objective of this paper is to describe a farm information model and a proof of concept that demonstrates how a collaborative Business Process for farming can be configured using this farm information model. Knowledge to develop this model and a proof of concept is obtained by case study research focusing on the collaborative Business Processes of spraying and crop protection of potatoes against late blight disease.

The presented farm information reference model is able to describe the relations between a farm enterprise and its collaborators, the Business Processes related to the supporting ICT Components and the data messages for data exchange between ICT Components.

1 Introduction

Due to the increasing world population and demands regarding sustainable, safe and transparent food production, farm enterprises are part of collaborative Business Processes. In these collaborative Business Processes they interact with numerous actors that are part of Agri-Food Supply Chains. A first example of such collaboration is the sharing of the farm's crop production plans and the usage of minerals with the government to ensure sustainable production. A second example is the recording of crop related activities and the sharing of these crop records with farm customers (e.g. processors, retail) and certification bodies to guarantee a safe

[1] Corresponding author, Information Technology, Wageningen University, Hollandseweg 1, PO Box 8130, 6700 EW Wageningen, the Netherlands, telephone: +31 70 3358177, fax +31 317 485646, janwillem.kruize@wur.nl

[2] A farm enterprise can be an arable farm, livestock farm or horticultural farm. In our research we focus on arable farm enterprises

and transparent food production. A third example is the collaboration between a farm and advisors to strive for optimal yields.

Information and Communication Technologies (ICT) can support these collaborations and making them more efficient. Nowadays, numerous vendors offer a variety of farm ICT Components[3] that can support farmers in their operations, collect information and share this information within Agri-Food Supply Chain Networks. Some examples of such ICT Components are Farm Management Information Systems (FMIS), Terminals, Sensors and Advisory Modules. Although these ICT Components are available, farms experience problems in using them. One of the main issues that hinder utilization is the lack of the integrating capabilities which should be improved (e.g. improving compatibility and usefulness of the technology) (McBratney et al., 2005; Sørensen et al., 2010; Wolfert et al., 2010, Aubert et al., 2012, Kaloxylos et al., 2012; Kaloxylos et al., 2014; Kruize et al., 2013).

To improve the integrating capabilities and usefulness of current and to be developed ICT Components, Kruize et al. (*forthcoming*) suggested setting up farm Software Ecosystems (SECOs). In farm Software Ecosystems a set of Actors collaborate on a Platform, aiming to support farm Business Processes with coherent functionality (Application Services and Business Services). The Actors that collaborate within a Software Ecosystem operate through the exchange of information, resources or Artefacts (Jansen et al., 2009). Currently, several Software Ecosystems are set-up that can have, amongst others, farm enterprises as end-users (e.g. AgroSense[4], Crop-R[5], FIspace[6]).However, these Software Ecosystems are lacking farm-specific reference information models that can guide a more coherent development of interoperable ICT Components (Kruize et al., *forthcoming*).

Based on a case study and current literature we developed a Farm Information Model that can support the development of interoperable ICT Components. These ICT Components can be developed and used within SECOs and support collaborative farm Business Processes in an integrated manner. The farm information model contains three types of models which are an Actor Model, A Reference Architecture of Agricultural Enterprises Model and a Data Model.

2 Materials and Method

2.1 Design Oriented Research

This paper is based on Design Oriented Research. Design Oriented Research aims is to produce an innovative design and applies typical concepts from design methodology (Hartog, 2012). The purpose of Design Oriented Research is to create innovative artefacts that extend the boundaries of human and organizational capabilities (Hevner et al., 2004). These artefacts are developed through a design process. In this research a (reference) model is created. The application of reference models is motivated by the "Design by Reuse" paradigm and in that way most of the dominant ERP vendors use reference models to make enterprise specific information systems (van der Aalst et al., 2006). In this research we aim to create specific (parts of) farm information systems making reference models a natural choice. To design and test our Reference Model (Farm Information Model) we used an case study named the FIspace Crop Protection and Information Sharing Trial.

2.2 Case Study: late blight protection

The EU-funded Future Internet Public-Private Partnership Programme (FI-PPP) aims to accelerate the development and adoption of Future Internet technologies in Europe, advance the European market for smart infrastructures and increase the effectiveness of Business Processes through the Internet. Within this program,

[3] An ICT Component is a Atomic or Composite Application Component that is deployed on a Node (Hardware and System Software).
[4] http://www.agrosense.eu/
[5] https://www.crop-r.com/
[6] http://www.agrosense.eu/

the FIspace project is developing a cloud platform that supports business-to-business collaboration and enterprise integration the development of integrated and extensible collaboration services together with an initial set of domain applications. FIspace aims to enable the formation of domain-specific Software Ecosystems. To test the FIspace platform in different domains, trials are started. In this research we use the trial 'Crop Protection and Information Sharing' as a case study to develop and test our models. In this trial software is developed which can support farmers in a collaborative farm Business Process related to late blight protection. Based on this case study we created a more generic Farm Information Model that should be able to describe and develop applications able to support other collaborative farm Business Processes as well.

3 The Farm Information Model

The Farm Information Model is a Reference Model that can be used to develop Atomic Application Components[7] and to configure these into Composite[8] Application Components that can support (parts of) collaborative farm Business Processes. The Farm Information Model can support this by describing collaborative farm Business Processes. This description includes the involved Actor(s), the collaborative Business Processes, the resources (Atomic of Composite Application Components) to support these Business Processes and the messages including data object that can be exchanged between the Atomic Application Components. In this section we provide an Actor Model, a Reference Architecture of Agricultural Enterprises able to describe collaborative farm Business Processes and a first version of a Data model that is able to describe messages between Atomic Application Components in order to configure a Composite Application Component.

3.1 Actor Model

In a collaborative Business Process two or more Business Entities collaborate to produce a product. In this collaboration the Business Entities provide (Atomic) Application Components, including Application Functions, which support these collaborative Business Processes. In Table 1 Actors[9] are presented that can be used to model the Business Entities that can collaborate within collaborative farm Business Processes.

Table 1: Actors of Agri-Food Supply Chain Networks (Kruize et al., forthcoming)

Actors	Description
Accountancy Organisation	supports the systematic and comprehensive recording of financial transactions of an enterprise
Advisory Service	has as one of its main activities to advise farmers or provide information (data)
Contractor	executes activities, i.e. Operation's and Task's on behalf of another actor.
Farm Enterprise	has agricultural production as main activity
Government	used for controlling a country or state
Input Supplier	provides inputs (e.g. fertilizers, seed, pesticides) to a farm enterprise
Maintenance Organisation	provides a maintenance Service to an enterprise
Processor	processes produce (e.g. potatoes) from a farm enterprise
Software Provider	provides ICT Components (Software) that can be used by other actors
Technology Providers	develops technologies (Hardware and Software such as sensors, terminals) for other actors
Transporter/Collector	transports the produce from a farm enterprise to another actor

[7] An Atomic Application Component, deployed on a Device, is part of an Information System however not able to share data automatically with other Application Components.
[8] A composition of Atomic Application Components, which is created by ICT Customization using a configuration process (Verdouw et al., 2010), that performs collective behaviour by exchanging data automatically between the Atomic Application Components and which can be deployed on a Device.
[9] One or more Actors can represent a single real world Business Entity

3.2 A reference Architecture of Agricultural Enterprises

In this research we extended the Reference Architecture of Agricultural Enterprises (RAAgE) (Kruize et al., 2013). RAAgE is a Reference Model that supports the development of enterprise architectures for farm enterprises. In such an architecture, farm Business Processes and the ICT Components supporting farm Business Processes are described. This description is made using the architectural language ArchiMate vs. 2.1[10]. ArchiMate is an open and independent modelling language that can be used to develop architectural descriptions.

Conform ArchiMate, RAAgE distinguishes between the business layer, the application layer and the technology layer, and is able to describe the interrelations between these layers. The business layer offers products and services to external customers, which are realized in the organization by Business Processes performed by business actors (Group, 2012). The application layer supports the business layer with application services that are realized by (software) applications (Group, 2012). The technology layer offers infrastructure services (e.g. processing, storage, and communication services) needed to run applications, realized by computer and communication hardware and system software (Group, 2012).

RAAgE is able to represent the architecture of a farm enterprise by modelling the business, application and technology layer. RAAgE is mainly a reference to describe generic farm Business Processes (part of the Business Layer) and generic Application Services and Functions (Part of the Application Layer) relevant for farm Business Processes. The Business Processes are divided into a Management Control and an Operating Control layer. In this research RAAgE is extended with detailed Business Processes that are related to crop protection (part of the operating control layer). This extension can be used to represent different collaborative crop protection Business Processes. In the case study a collaborative Business Process model related to crop protection is presented.

3.3 Data Model

The data reference model Crop (drmCrop) that is developed and used in The Netherlands, specifies farm data, the messages sent between ICT Components and is aligned with the ISO 11783[11] standard. This current version describes the farm enterprise using class diagrams including attributes. The drmCrop Model is used as a reference to develop and describe messages that can be sent between different Atomic Application Components that form a Composite Application Component. The drmCrop Model will be made publicly available soon.

4 The configuration of ICT components to support different farming styles of late blight protection – a use case

4.1 Textual description

In European agriculture, multiple crops are often cultivated within a single farm enterprise such as potatoes, grain, sugar beets and onions. Protecting these crops with pesticides against various diseases is important to reduce yield losses. In the FIspace project trial ‘Crop Protection and Information Sharing’ the focus is on protecting potatoes against the disease ‘late blight’, also well-known under it scientific name *Phytophthora* . To protect potatoes against late blight, the leaves of the potatoes need to be sprayed with specific pesticides. For this protection it is important to spray on a regular basis with a frequency of approximately one time a week for the duration of almost 10 weeks. The spraying frequency is dependent on weather conditions and disease outbreaks in the region. Because pesticides are expensive it is both for environmental and economic reasons beneficial to have a low frequency for spraying in which the potatoes are well protected. Therefore

[10] http://www.opengroup.org/subjectareas/enterprise/archimate

[11] http://www.iso.org/iso/home.html

optimization of the spraying frequency, the pesticide type selection and the spraying execution is a Business Process that can be supported by smart technologies such as decision support systems (DSSs). These spraying DSSs require local weather data and data about the last spraying operation. These data are present in various data repositories belonging to software applications of various vendors. To support farmers in their spraying processes, data exchange between these different applications is required within a collaborative Business Process. Currently, automatic data exchange within a collaborative Business Process is troublesome. Therefore Composite Application Components will be configured, based on the FIspace Platform, which can enable automatic data exchange between some of these (adapted) Atomic Application Components.

4.1.1 Developed/Adapted Atomic Application Components

In the Crop Protection and Information Sharing Trial different Atomic Application Components are developed or adapted in order to configure a Composite Application Component that is able to support a collaborative Business Process. The developed or adapted Atomic Application Components are:

- *Farm Management Information System* - supports farms in managing their farm (sensor) data and provide functionalities for creation farm tasks and jobs, precision maps and task registrations. The Farm Management Information System is created by LimeTri and is named AgroSense.
- *Weather Application* - delivers weather scenarios for each requested location in the Netherlands in a high spatial resolution and a temporal resolution of one hour. The time range is up to maximal one year before the actual date and 8 days after the actual date. Available data includes the following variables: temperature, relative humidity, rainfall, pressure, specific humidity, incoming shortwave radiation - direct + diffuse, sensible heat flux, height of boundary layer, wind speed at 10 m, ET0 following Penman-Monteith, ET0 following Makking. The Weather Application is created by the Bo-Mo weather bureau.
- *Phytophthora Advisory Application* - supports farm enterprises with the timing of the pesticide application and the pesticide type. These are advanced DSSs that are made available by specialized vendors. In this trial the Phytophthora Advisory Application of Plant Research International (DLO-PRI) is adapted and used.
- *Terminal* - is mounted within the cabin of a tractor and used to control the implement(s) that are mounted to the tractor. Examples of implements are sprayers, seeders or planters. Advanced terminals can use GPS and control an implement to apply inputs at a variable rate. These terminals are an important component to enable smart spraying. In this trial a terminal of Kverneland Group Mechatronics is used.
- *Workability Data Application* - the Workability Data App helps the farmers to decide the most suitable period for their spraying activities. It warns its users about unforeseen and unfavourable weather conditions with respect to spraying. The Workability Data Application is developed by DLO-ASG.
- *Scheduling Application* - The Scheduling application collects the required farm operations from the Farm Management Information System (FMIS) each time a new farm operation is planned or one of the planned farm operations is executed. It collects also the availability of resources (men and machinery) as specified by the FMIS. After each update of Workability Data from the Workability Data App an optimal schedule for the farm operations is calculated. The cost of the operation, including additional labor cost in overtime, the cost of inputs of which the quantity may vary by the time of application, and the effect on the yield level by the time of the operation (the timeliness cost) are factors determining the optimal schedule. The Scheduling Application is developed by DLO-ASG.

4.1.2 Composite Application Component Configurations

Farm enterprises execute different Business Processes to control their crops. Each farm has (partly) specific Business Processes and supports these with different ICT Components. Hence there is a need for different Composite Application Component configurations (deployed on a single or multiple Nodes) that are able to support such a wide variety of Business Processes. To form different types of Composite Application

Components the abovementioned Atomic Application Components are developed that can be configured. Through this development the Farm Information Model we redesigned and tested. This development, as part of the Crop Protection and Information Sharing Trial, resulted in two types of Composite Application Components able to support two scenarios. These scenarios are named the Basic Farm Configuration and a Smart Farm Configuration. The Basic Farm Configuration support farmers in the timing and type of pesticide selection, the creation of spray task and jobs, sending it to a terminal, its execution and the registration of the tasks. The Smart Farm Configuration supports additionally the scheduling of the job in an advanced manner. Not only advice is given regarding the most suitable time. It schedules the job, taking other jobs (e.g. fertilization, selection) into account, as well. In the following section we used the Farm Information Model to describe these configurations in detail.

4.2 Basic Farm Configuration description

The End-Users of this Composite Application Component are Farm Enterprises that require a Basic Configuration to spray against late blight. The Actors that participate in this collaborative Business Process are:

- Farm Enterprise
- Advisory Service (DLO-PRI and Bo-Mo weather bureau)
- Software Provider (LimeTri)
- Technology Provider (Kverneland Mechatronics)

These actors provide Application Components including Application Functions to enable collaboration in a farm Business Process that protects potatoes against Late Blight. These farm Business Processes are supported by the Atomic Application Components:

- Farm Management Information System
- Weather Application
- Terminal
- Phytophthora Advisory Application

Data messages sent between these Application Components are:

- Weather Message
- Phytophthora Advice Message
- Task Data Message (Planned)
- Task Data Message (Executed)

The specification of these messages, based on the drmCrop model, will be published later.

A description of this configuration can be found in Figure 1.

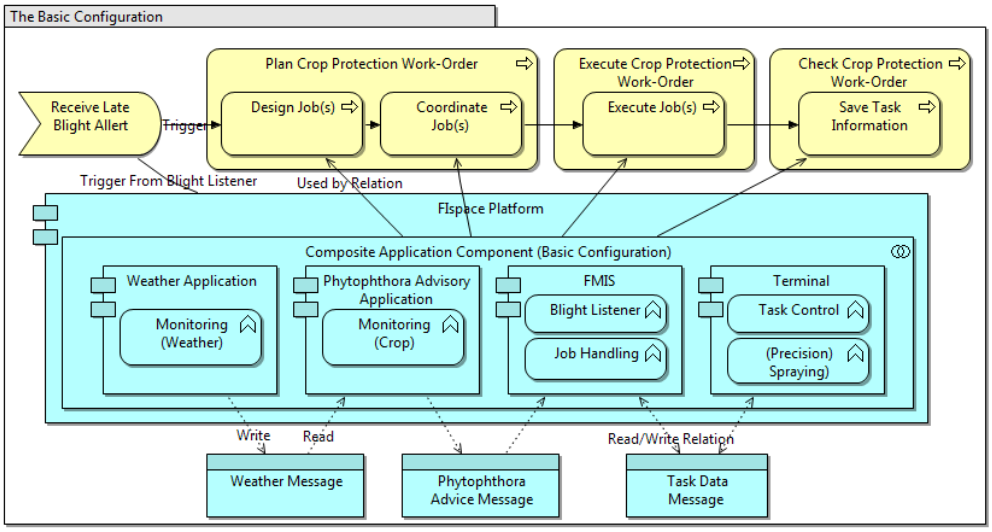

Figure 1: A Basic Farm Configuration in which the farm Business Processes, Application Components and Messages are depicted.

4.3 Smart Farm Configuration Description

The End-Users of this Composite Application Component are Farm Enterprises that require smart configurations. The Actors that participate in this collaborative Business Process are:

- Farm Enterprise
- Advisory Service (DLO-PRI, Bo-Mo weather bureau and DLO-ASG)
- Software Provider (LimeTri)
- Technology Provider (Kverneland Mechatronics)

These actors collaborate in a farm business to protect potatoes against Late Blight. These farm Business Processes are supported by the Atomic Application Components:

- Farm Management Information System
- Weather Application
- Terminal
- Phytophthora Advisory Application
- Workability Data Application
- Scheduling Application

Data messages sent between these Application Components are:

- Weather Message
- Phytophthora Advice Message
- Workability Message
- Capacity Message
- Task Data Message (Planned)
- Task Data Message (Executed)

A description of this configuration can be found in Figure 2. In this Figure we only depicted, related to the Basic Farm Configuration, the additional Business Processes, Application Components and Messages (in a light tint). The additional Business Processes are part of the Plan Crop Protection Work-Order. In the Smart Farm Configuration, the Business Processes of the Execute and Check Crop Protection Work-Order, and the Application Components supporting these processes, are the same as in the Basic Farm Configuration.

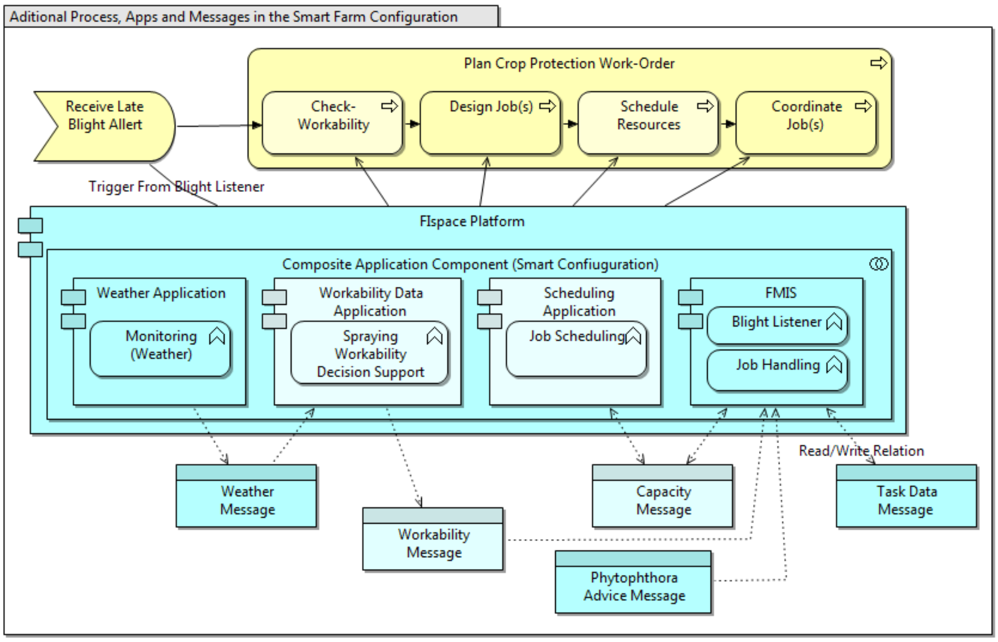

Figure 2: A Smart Farm Configuration depicting, related to the Basic Farm Configuration, the additional farm Business Processes, Application Components and Messages (in a light tint)

5 Conclusions

The Farm Information Model is a reference model and contains an Actor model, a Reference Architecture of Agricultural Enterprises and a Data model. This Farm Information Model is developed and used within the Crop Protection and Information Sharing Trial of the FIspace Project. In this FIspace trial two Composite Application Components are developed named the Basic Farm Configuration and the Smart Farm Configuration. These configurations are described in this paper using the Farm Information Model.

In future the Farm Information Model should be tested by creating new specific Composite Application Component configurations (instances) that support farmers in collaborative Business Processes. Based upon this further testing we can conclude if the Farm Information Model, in combination with other models, can support the development of Atomic Application Components that can be configured into Composite Application Components. We expect that the Farm Information Model enriches the FIspace and other farm Software Ecosystems and enables the integration of ICT Components.

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