Service engineering in the domain of precision farming

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Abstract

Due to the growing complexity of agricultural services the structured development and management of those services becomes more and more important. The following article shows how the concepts and methods of service engineering can be applied to the agricultural domain using nutrient mapping as an exemplary precision farming service.

Keywords: Service Engineering, Precision Farming Services, Agricultural Services

Introduction

Recent years have brought tremendous innovations for precision farming (PF). However, most of these innovations have focused on technical aspects, e.g. developing new equipment (Primicerio, et al., 2012) or increasing performance of existing equipment (Mahmood, et al., 2012) These achievements increase efficiency of used resources and allow for capturing of various data. However, new challenges emerge in the context of a broad application of the methods and processes of PF. One example would be the growing number of actors necessary for the provision of services in the domain of PF, which is basically the result of two factors. Due to high acquisition costs, the purchase of hardware required for PF is often not economically feasible for single organisations. Likewise, the high level of knowledge of other domains required for certain tasks of PF is often not available on farms. Thus, a variety of external service providers, specialised in the provision of hardware or knowledge, are integrated in the overall process of precision farming. As one example, the nutrient mapping can be determined here as a field for the service provider.

Despite the growing importance and complexity of services, the authors are not aware of any current approach that focuses on the services side of precision agriculture. Since services represent a permanently growing share of companies' turnovers, a productive provision of complex services is of essential importance. Therefore, structured approaches for managing services are necessary. On the one hand, services are not only provided by one organisation anymore but rather by a co-operative process of different organisations. On the other hand, agriculture has its own specifics that need to be considered in service development and provision. Therefore, analysis and improvement of services using methods of service engineering is a feasible approach.

The aim of this contribution is to identify and classify domain specifics of PF regarding service engineering. The findings were gathered using a two-stage approach. First, a literature review gave an overview of the generic challenges of the agricultural domain. As a second step, expert interviews of various stakeholders were conducted. A close co-operation with a provider of base fertilisation services ensured the practical applicability of the findings.

Service Engineering

Due to increasing challenges in service development, service engineering is widely used in the domains of industrial and technical services. Service engineering describes the systematic conception, development and management of services by the use of adequate models, methods and tools (Bullinger et al., 2003).

Service engineering was developed because of the increased importance of services in organisations. Increased market pressure adds to the necessity of service engineering. As Fähnrich & Meiren (2007) stated, two aspects are fundamental for successful service development. First, a model for developing services is necessary, i.e. organisations need to establish a structured approach. Second, organisations need to establish operational support in terms of methods and tools. As shown below, PF services share specific characteristics. Therefore, it is possible to establish suitable and domain-dependent approaches for service development.

The further deliberations will apply an understanding of services as described by Böttcher & Fähnrich (2009). The basic idea is the division of service models into four basic aspects, which are the product, process, resource and component model. The subsequently described challenges and specifics of PF services are clarified by illustrating the corresponding effects on those four aspects.

Use Case

The following explanations of service engineering approaches for PF are based on an existing use case. In co-operation with an industry partner, the process of Global Navigation Satellite Systems (GNSS) supported nutrient mapping was analysed. This process roughly consists of the following high-level activities.

First, order and customer details are gathered. Field engineers schedule various orders according to given priorities. These orders are executed, i.e. soil samples are collected and a protocol is created. Collected soil samples are sent to laboratories and protocols are sent to the operational headquarters. Based on the results of the laboratory analysis, nutrient maps are generated. Figure 1 gives an overview of the map generation process using the well-known language BPMN (Business Process Model and Notation). Based on the use case and literature, the following section highlights some key characteristics of PF services.

Precision Farming Services

Many factors influence the planning and provision of services in the domain of precision farming. In the following, a selection of these factors is presented. Based on the identified specifics for service processes, the challenges for service engineering in the domain of PF were deduced.

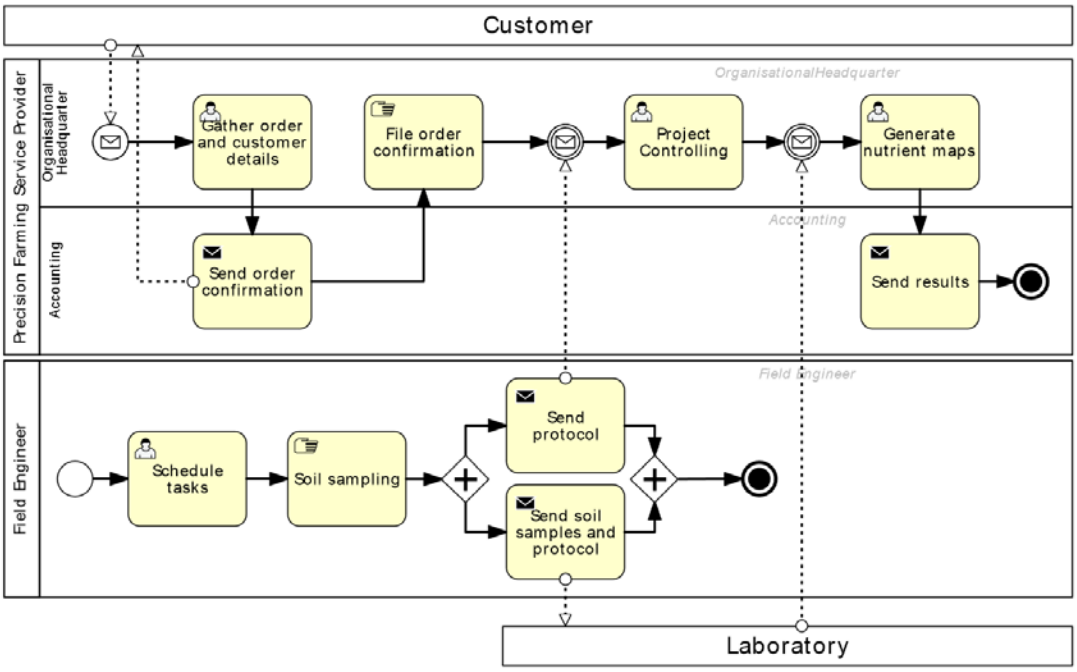

Figure 1. BPMN model of generating nutrient maps

Weather dependency

The provision of several PF services, e.g. geo-referenced soil sampling or fertilisation, depends on the weather condition. Therefore, the planning and provision of services have to consider various other data, in this case meteorological data. The weather dependency has several impacts on the use case given above. For example, soil samples can only be collected with appropriate soil moisture content. However, this is just a very obvious impact. Field engineers need to develop a plan for scheduling various orders. Due to improper weather conditions it might be necessary to continuously modify this plan. If not stated explicitly, this impact is not transparent.

With regard to the four dimensions of service modelling the weather dependency affects mainly the process as well the resource model. Resources are required to be provided in a flexible manner, to be able to adapt scheduling dynamically. Furthermore, service processes need to be flexible enough to react on changing conditions.

Seasonality

Although several services can only be provided in a specific season, necessary resources (cars, technical equipment, personnel, etc.) need to be held available throughout the whole year, although the workload varies considerably. This applies also for soil sampling. For effective provision of soil sampling services, an organisation needs to establish ways for optimal resource allocation. Therefore, it is amongst others necessary to harmonise the schedules of several field engineers.

Seasonality affects the resource model of services. Innovative approaches are needed to be able to use available resources efficiently. The dichotomy of economy and flexibility has to be dissolved, i.e. growing demand must not be hindered by resource shortages.

Dispersion

Agricultural structures are highly regional specific. Whereas some areas are dominated by a few key players, many regions are characterised by a high regional dispersion of a variety of smaller stakeholders. Therefore, it is important to create business structures which allow for the use of economies of scale even in scattered customer environments.

Dispersion affects the use case at several points. For example, the service provider needs to establish ways for integrating several small-scale customers. This is necessary because it is not possible at reasonable expense to serve all customers individually. In addition, field engineers should have the opportunity to schedule their tasks based on the regional specifics.

Co-operation

Increased technical requirements lead to a growing complexity regarding the provision of PF services. Thus, several highly specialised companies participate in service provision, i.e. services are provided in a co-operative manner. To ensure effective and efficient co-operation, interfaces and processes have to be defined and synchronised.

In the soil sampling use case, four parties are involved in the service provision process. For successful service provision, especially the service provider and the field engineer need to stay in close contact. In addition, the communication with the laboratory needs to be considered. It is necessary to establish data and message exchange interfaces.

How Service Engineering can help

Using service engineering approaches it was possible to identify several design flaws that decrease the productivity of the process. With a list of existing flaws and keeping the PF service characteristics in mind, it is planned to develop a system supporting service provision. Subsequently, it is shown how the concepts of service engineering can support the process of the structured development of services, using the example of the nutrient mapping service.

Service Engineering as the methodical development and management of services offers various approaches to meet the described challenges of services in the domain of precision farming. The lifecycle of services can be divided into nine phases (Meyer, 2008). In the following, it is described how service engineering approaches can support the challenges in the domain of PF through these nine phases. To concretise the abstract descriptions of service engineering methods, each phase is illustrated by an example in regard to the nutrient mapping service.

The phases can be segregated into three separate groups, which focus on different goals. First, the modelling of the service takes place in the phases of *definition*, *requirements engineering* and *conception*. The goal is to develop the portfolio of a service provider in a consistent and standardised manner. Based on such a portfolio model, customer-individual service configurations can be created and assessed regarding productivity aspects (Klingner et al., 2011). This is conducted during the *realisation* and *test* phases. Finally, the phases *market launch*, *operation* and *retirement* also focus the provision of existing services. This includes marketing activities as well as a continuous improvement by monitoring and adaptation.

Definition

Planning and structuring services prior to service provision is a central idea of service engineering. During definition, basic steps for providing a service are specified. By visualising these steps, relevant influence factors on different activities can be identified at an early stage. Thus, determining those activities which depend on specific weather conditions becomes feasible. To increase productivity, highly weather-dependent activities and weather-independent activities can be segregated and ideally be provided separately. Beyond that, a structured planning of activities allows for the identification of optimisation potential, e.g. by paralleling of activities or altering their order.

The analysis of the exemplary process of GNSS-supported nutrient mapping showed that the service provision, in the current state, mixed dependent and independent activities. One example would be the creation of maps. It does not start before the results of the laboratory analysis are completed. This was considered necessary, since nutrient mapping is a part of the map creation process. However, the systematic analysis of the service showed that the division of the mapping process into two separate activities is feasible. The first map containing geographical data can be created immediately after the soil sampling process. After the results of the laboratory analysis are available, this map can be augmented with nutrient data.

In-depth analysis of single service components showed that only a small part of the service activities are influenced by the weather. The structured description of activities allows for unbundling complex services into small, independent and easily manageable service parts (Böttcher & Klingner, 2011). Furthermore, possible alternatives of weather-dependent activities could be identified. In the case of changing weather conditions, this allows for a dynamic assignment of alternatives to reduce costs of the service.

Requirements Engineering

With regard to the increasingly co-operative provision of services in the domain of precision farming, the structured gathering of requirements of all involved stakeholders is necessary. Besides customers and service provider, this includes laboratories and other subcontractors. By the requirements analysis, the alignment of expectations and requirements of process stakeholders and the provider’s plans can be conducted.

Nutrient map generation involves various stakeholders. E.g., laboratories analyse soil samples. To ensure effective and efficient service provision, clearly defined interfaces between companies have to be provided. To further improve the processes regarding productivity aspects, the subcontractors’ internal workflows should be analysed as well. Thus, special requirements could be integrated in the definition of the interfaces.

In addition to the involvement of laboratories, requirements engineering for PF services also needs to consider the dispersion of customers. Requirements of small-scale customers vary greatly from requirements of large agricultural organisations. These differences must be considered when designing services.

Conceptual Design

To finalise service development, the service has to be conceptualised. This includes specifying all single service parts, particularly which activities are to be conducted in each service part. Furthermore, the service parts can be augmented with key performance indicators (KPI) to measure each part’s productivity. Likewise, the detailed, competence-oriented allocation of staff members and subcontractors to the different service parts becomes feasible.

As a result of a thorough and precise conceptual specification, it is possible to gain various insights regarding a service, even before it is provided. The use of IT-tools can support an assessment of the expected productivity or the risk (e.g. in regards to the customer integration) of the service, prior to its application. Another important aspect is an increased transparency regarding processes, which is particularly relevant in the context of the increasing importance of co-operative services.

Using the modelled process, it is possible to identify different requirements regarding necessary qualification for the various activities for generating nutrient maps. Furthermore, activities requiring different qualifications can be distinguished from each other. This allows for a more appropriate employee allocation during business process reengineering. Thus, activities with the same or equal requirements can be identified and considered for employee planning.

As Grönroos & Ojasalo (2004) state, identifying relevant influence factors is a huge problem for evaluating productivity of complex services. Among others this is caused by the multitude of activities necessary for service delivery. An approach to address this challenge is to decompose complex services into smaller components and to describe these components in more detail (Böttcher & Klingner, 2011). This allows for a simplified delineation of service components and, thus, for allocating more specific KPIs to components. This is of great relevance since generating nutrient maps consists of several different activities.

For example, the process of soil sampling in the field faces different productivity challenges in comparison to the generation of nutrient maps. The productivity of soil sampling might be highly influenced by external conditions like weather and geographic conditions. Contrary, nutrient map generation is independent from these conditions. Therefore, productivity of both service parts needs to be measured using different indicators.

Realisation

Increased demand for customer-individual offers is a phenomenon that can be observed in several domains including agricultural services. Service engineering tackles this challenge in the realisation phase. During realisation services are tailored for specific customer needs (configuration). Furthermore, preparing service description for operation is part of the realisation. For example, this can be achieved by transforming the description of service processes into executable processes, e.g. BPMN models enriched with technical details. These models can be passed to workflow management systems supporting the service provision.

Generating nutrient maps provides various possibilities for customer individualisation. For example, it is possible to assign different priorities to soil samples. Customers requiring fast results might increase their priority by paying a surcharge. In addition, soil sampling differs from small-scale to large-scale agricultural organisations.

Test

The structured definition of services simplifies the identification of prospects and limitations compared to monolithic service descriptions. Furthermore, service providers and customers can interactively evaluate different service variants. Through the use of component-specific KPIs, it is possible to identify service variants that cannot be provided at reasonable expense by the provider. Contrary to providers who focus on productivity, customers consider service quality as a very important aspect. Without any pre-definition of the service delivery process, it is difficult or even impossible to make predictions about expected service quality. A structured approach supports the identification of potential design flaws and detecting errors in early stages of the service development.

Interviews with PF consultants showed that quality is a factor with different interpretation from small-scale to large-scale customers. Large-scale customers usually want (and are able) to participate in the service provision process. Contrary, small-scale customers are rather focused on the service results, e.g. nutrient maps. Thus, during test it is necessary to recap the results of the requirements engineering.

The throughput time is a common measure to assess service productivity. Using this for generating nutrient maps, it is possible to identify deviation from target values of specific service components and to identify possible sources of errors. Based on these insights, service providers are able to intervene as necessary.

Market Launch

The previous sections dealt with activities for planning and defining services. In addition, service engineering supports service provision, too. The first step of provision is the market launch of new services. Up to now, pragmatic approaches are used quite frequently, i.e. innovative services are developed according to demands of specific customers without any additional planning steps (Böttcher & Meiren, 2012). However, this usually results in services meeting the needs of only a single customer. Furthermore, other customers are unaware of these services, since there is no structured marketing. An orderly market launch, accompanied by targeted information campaigns, allows for increased awareness about new services.

In PF with its seasonality it is of utmost importance to launch new services at the appropriate time. Especially small-scale customers do not have enough resources for dealing with service offers during harvest season. Due to the multitude of participating organisations, it is necessary to establish adapted strategies for market launch. Besides preparations regarding the launch, it is also necessary to establish basic conditions for providing new services. Without this, the success of new services cannot be guaranteed. For example, insufficient capacity counteracts success of well-defined and structured services. Finally, service employees need to be informed about service provision and trained in the treatment of customers.

Structured development of the nutrient map generation service leads to a detailed knowledge about necessary resources before the service is provided for the first time. Based on this information, it is possible to offer the service with appropriate conditions. By analysing the market environment of a new service, it is possible to anticipate its demand and to adjust its price resulting in an optimal resource utilisation.

Service Business and Retirement

Service engineering focuses not only on service planning and conceptual design but also on continuous monitoring and improvement based on customer feedback. These two activities are part of the service business phase. Monitoring and improvement are used to ensure consistent service quality, especially for long-term services. Among others, this can be achieved by using planning systems for identifying impending shortages of staff or physical resources. Therefore, increased degree of resource utilisation allows for better handling of seasonal fluctuations in demand.

Conclusion[1]

An overview of the characteristics of services in the domain of precision farming has been given. The benefits of the methodical approach of service engineering are shown through the various phases of the service-lifecycle and illustrated by the service of nutrient map creation.

As future work a supportive system for PF processes should be designed and implemented based on the findings. Furthermore, more specific challenges have to be identified and integrated in a specific service engineering approach for the domain of PF.

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