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IPS – An Information Production System for Precision Farming

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To optimize the process of base fertilisation in the context of Precision Farming, IT support for the corresponding service processes was developed as part of a research project. Applying the methods of service engineering, a software system that supports an efficient and transparent service provision was developed in the IPS project (Information Production System for Precision Farming). The paper shows the methodological approach of the project, the potential for innovation of the developed software system and discusses the results. Thereby, the findings presented in this paper can be regarded as an exemplary application of service engineering which may also be advantageous for similar service-orientated agricultural sectors.

Keywords
Precision Farming services, service engineering, nutrient mapping, Information Production System

Today, site-specific farming that allows for efficient field cultivation is used as a response to the increasing global demand for food. However, due to the limited availability of arable land and the growing necessity of environmentally friendly cultivation, the optimization of agricultural production must not stop at individual economic interests. In the past three decades, significant technical progress has been made in the field of site-specific farm management (Mulla 2013). A precondition is an efficient and highly detailed data acquisition. Sensors are available for various areas of Precision Farming (PF) (e.g. nitrogen fertilisation, plant protection). Although initial approaches for sensor-based analysis exist for single nutrients, no solution for a comprehensive and reliable sensor-based detection can be expected in the medium term (Kim et al. 2009). Thus, soil samples are used to determine nutrient content.

IPS – as an Information Production System, which is explicitly tailored to the processes of site-specific nutrient mapping – is contributing to the optimization of the underlying service processes. The system focuses the area of basic nutrient mapping (phosphorus, potassium, magnesium and pH). The expertise of different stakeholders is required to perform the necessary measures (for example, field technicians take soil samples, laboratories analyse them and consultants evaluate the results and give recommendations). Therefore, this application can be seen as exemplary for collaborative service provision in precision farming. Extensive data exchange and coordination processes between the large numbers of participants may cause inefficiencies, non-transparent processes and erroneous data transfer. Due to these factors, service provision can be delayed, posing problems for the customer as well as for the service provider. An online-based information systems can be used to enable data exchange between the different users with respect to their requirements (Nikkilä et al. 2012).

The approach, the contents and the results of the research project IPS may bring new perspectives to services in the agricultural domain, suggesting starting points for improvement processes and showing various potential for optimization.

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Methodology

In the following, the approach for the development of IPS is described in detail. An overview of the performed steps provides Figure 1.

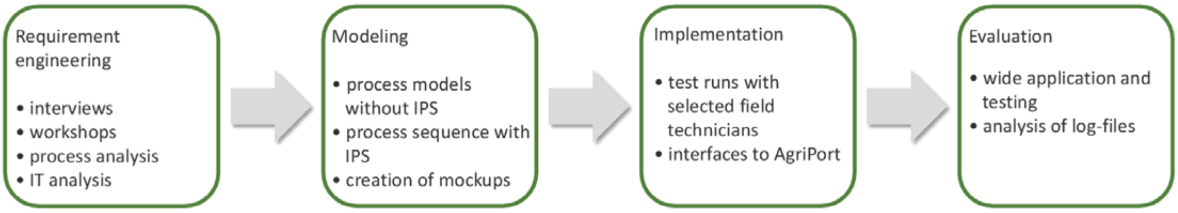

Figure 1: Procedure for the development of IPS

The first step conducted by the two project partners (Agricon GmbH and the University of Leipzig), was to model the current nutrient mapping process (see Klingner et al. 2013). For this purpose, all participating stakeholders, including service provider employees, laboratories, field engineers and consultants, were interviewed about work tasks and processes. To gather information, five sessions of semis-structured interviews with several representatives of the addressed groups were conducted.

The modeling focus was twofold. First, the regular workflow was focused. Second, error handling, e. g. in the context of data transfer, was documented. In addition to as-is modelling, to-be models for the use case site specific nutrient mapping were developed. Thereby, the requirements of the service provider as well as those of customers and further stakeholders were considered.

Due to the fact that the future software system should be integrated into the existing, highly heterogeneous system infrastructure (Steinberger et al. 2009), the IT infrastructure was analysed additionally. Besides the used hard- and software, information about the variety of used data formats were gathered. To achieve a high efficiency and to avoid re-entering data, existing interfaces between the stakeholders were documented and corresponding data formats were deduced.

Based on the insights from the interviews, the business processes as currently applied were modeled using Business Process Model and Notation (BPMN), a notation for modeling and visualising business processes (White 2004). Thereby, single process steps within the business process are displayed in a structured way through graphical symbols. On this basis, the weak points of the process itself, but also interdependencies between preceding processes or stakeholders and weak points of the business process become visible.

Afterwards, the conception, development and implementation of the IPS were conducted. Based on the captured processes and requirements, optimised processes tailored to the specific requirements where modeled as a preliminary work for the later system specification. The aim was to map the entire “information production process” incorporating also domain-specific restrictions such as environmental influences, need for cooperativeness and flexibility. In this context, redundancies had to be avoided and possible parallelisation of process steps were analysed. Additionally, mock-ups were built to visualise the later user interface of the software.

After system implementation, testing and real-world use of IPS started. In this context, an evaluation was conducted. Based on a quantitative analysis, an increase in efficiency could be proven in detail with figures.

The following sections provide an in-depth look at the above-mentioned steps. After illustrating the as-is process (without IPS), the to-be process of nutrient mapping based on IPS is presented.

Process flow without IPS

In the first phase of the project, the business process of nutrient mapping was modelled. Nutrient mapping is a complex, collaborative process, which means that the expertise of various stakeholders is required. In the beginning, based on the evaluation of the semi-structured interviews, the entire business process of nutrient mapping was modelled (Figure 2). The model comprises the following eight steps: 1. order acceptance, 2. planning of processing, 3. processing on the field, 4. feedback of results from fieldwork, 5. feedback from laboratory, 6. generation of nutrient maps, 7. processing and shipment, 8. controlling.

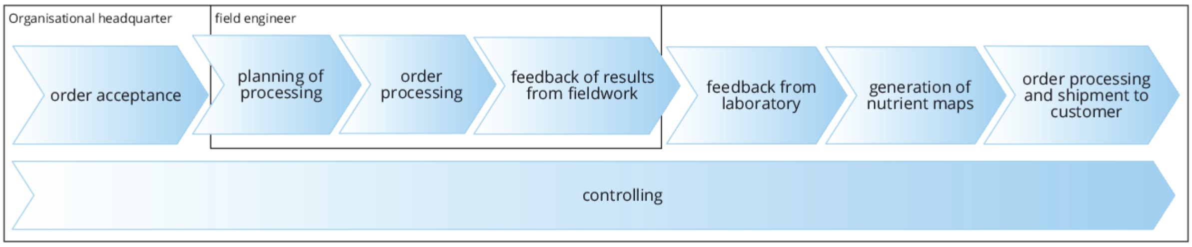

Figure 2: Process flow of nutrient mapping

During modelling, it came clear that the process lacks transparency and several participants needed to re-enter existing data. For example, after receiving the order acceptance a customer had no insights about the status of his/her order until he/she got the final results. Also the service provider did not have any information about outsourced process steps (e.g. analysis of soil samples in laboratory). Thus, automated controlling was not possible, since the status of single process steps as well as of the process itself was not transparent.

Additionally, visualising the entire process revealed usages of different types of media. One example was the completely paper-based documentation of the soil sampling by the field engineer. First of all, manual generation of these protocols was time-consuming. In addition, processing in the laboratory sometimes was hampered due to unreadable or incomplete recordings of soil samples. Besides this, diffused communication channels prevented a fluent correction of mistakes, which unnecesarily prolonged the order processing.

Multiple software systems were required to perform the nutrient mapping process. For example, laboratories used different applications for analysing soil samples and for communicating the results to Agricon. Since there was no defined data exchange interface, data were usually sent via Excel-file or PDF. Additional software was necessary to perform supporting process steps, e.g. customer management, processing planning, controlling and the central processing of GIS data. Caused by this diversity of used software tools, several transformation processes were necessary during the process (e.g. manual export and import of data from different systems). Every manual transformation caused a delay and was a potential source for mistakes and inconsistencies. The great effort became particularly obvious during soil sampling by the field engineer. Figure 3 shows the sampling process from the perspective of the field engineer.

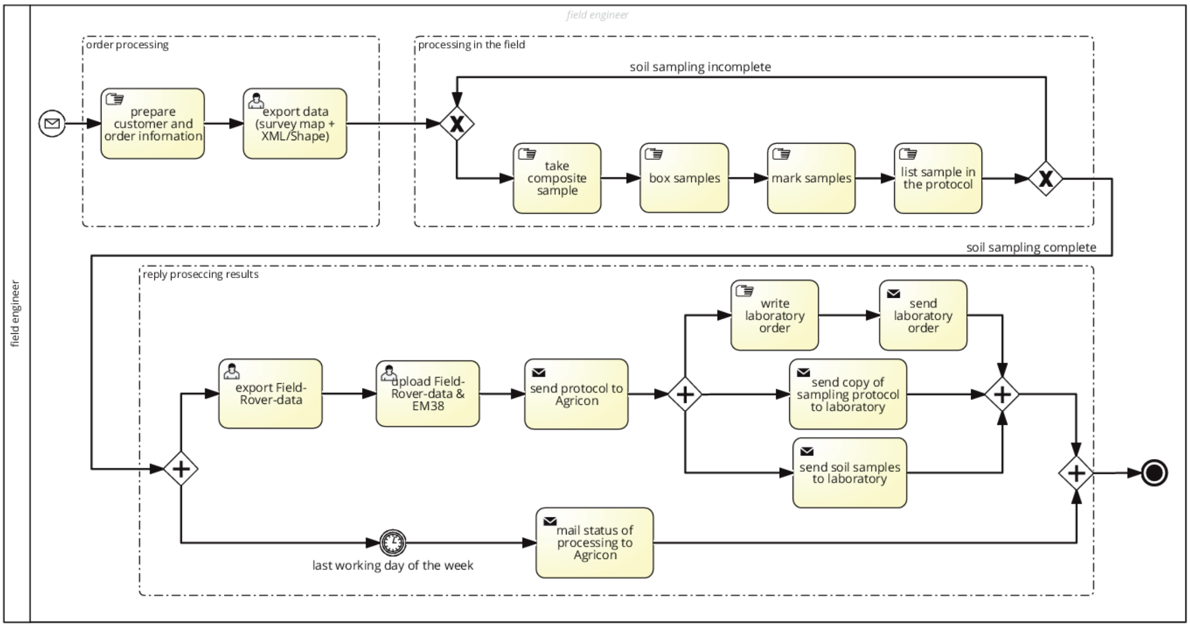

Figure 3: Soil sampling without IPSmobil

To perform order processing, first it was necessary to transmit order data by paper or telephone to the field technicians. Subsequently, prior survey and application data from the internal GIS system of the company had to be exported so that the new soil sampling could be planned on that basis.

The subsequent soil sampling was carried out manually. Therefore, the field engineer drove on the field and, with the support of a car-attached soil-sampler, took composite samples. Afterwards, these composite samples had to be packed and labelled manually. In the same way the paper-based protocol had to be filled with the required information (field name, sample number, GPS-data). After all samples had been taken, the field engineer had to transfer the GIS-data generated by the soil-sampler and the order information to the company. Furthermore, all required documents (protocols and laboratory orders), had to be filled out and sent by postal mailing.

The objective of IPS was to achieve a much higher level of automation by digitising process steps and creating appropriate interfaces. Thus, a mobile component (IPSmobil) was developed. Due to diverging requirements between field and office, a corresponding counterpart for administration tasks was developed (IPShq).

Process flow with IPS

Due to the diverse requirements of the different stakeholders, IPS consists of several components. While IPShq is used for order administration, mapping and controlling of the entire process, IPSmobil was created for processing on the field (soil sampling, reporting). Additionally, IPShq is linked to AgriPort, a cloud-based data management system for Precision Farming. This allows the farmer to track the status of his order and to access the results of nutrient mapping right after completion and release. Besides, the results are directly linked to the field data of the stored farm data, creating a high level of transparency for the user.

In order to present the benefits of the new system in detail, the following section describes the optimisation focusing the sub-process of soil sampling (Figure 4). Except for planning the initial order processing in AgriPort, IPSmobil covers the entire process, starting with the import of order data up to the transmission of raw sampling data to the laboratory. Since IPSmobil is installed on a ruggedised notebook, the field engineer can perform these steps independently of a computer workstation directly on the field. Besides, the also installed GIS module allows the field engineer to navigate his car with the connected soil-sampler precisely on the field, along the pre-determined grid. A mobile data connection is only necessary for exchanging data with AgriPort, i. e. at the process beginning and end. However, this is not bound to workdays and, thus, allows for deferred data transfer.

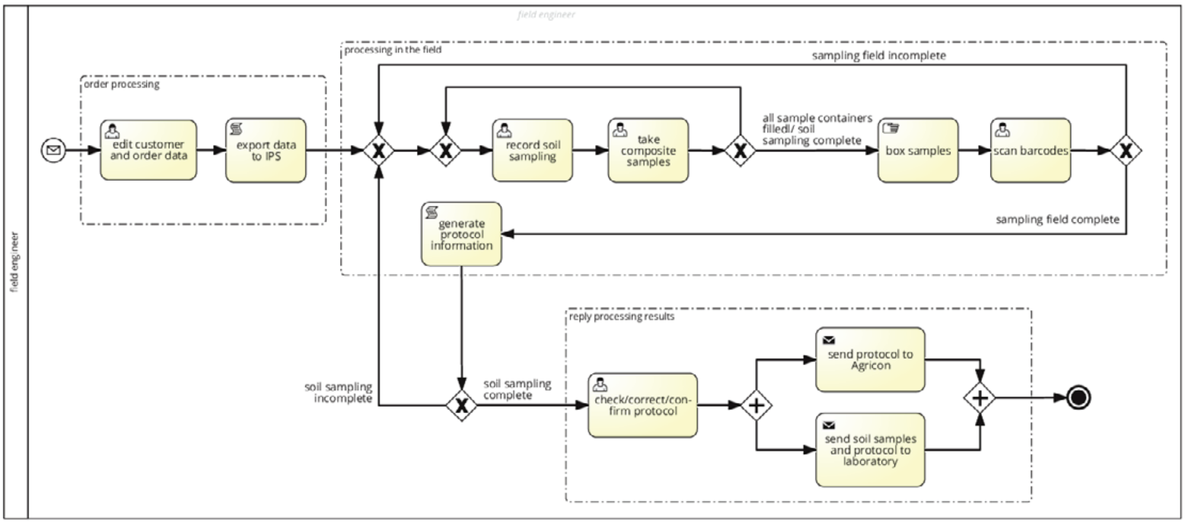

Figure 4: Soil sampling with IPSmobil

During protocol generation, the field engineer benefits from an integrated validity check. By using a barcode system, it is possible to identify soil samples during the entire succeeding order processing. Another benefit of using barcodes is that former mistakes, resulting from the manual labelling, can be prevented since barcodes are scanned and thus automatically connected to the protocol data of the soil sample. Coupling the soil sampler and IPSmobil allows for fully automated protocol generation. This helps to save time and to avoid mistakes that may appear during manually protocolling.

To avoid using different media types, the connectivity and compatibility between the software of associated stakeholders were improved. As the technical basis an extension of agroXML, a standardised data format for the transmission of agricultural data (Kunisch et al. 2007) was developed. Thereby, the order information (from IPS to the field engineer) as well as the accompanying soil sampling documentation (from field engineer to the laboratory) and the laboratory analysis (from laboratory to IPS) can be transferred in a standardised way. Therefore, validity checks can be conducted, which lead to an easier and more accurate detection of missing or erroneous data. In the process, the data are transferred by the field engineer to IPShq via mail. IPS carries out an automated completeness check on the server, so that errors (e. g. fewer samples taken than planned) can be detected early. The complete data are checked by the GIS-centre (IPShq) with regard to validity and quality and linked with the sampling raw data afterwards. These steps are supported by various automatic test routines, so that possible outliers can be detected and corrected automatically and the consistency with the existing customer database is guaranteed. Afterwards, the resulting nutrient maps are integrated into Agriport and made available for the customer. Additionally, application maps for phosphorus, potassium, magnesium and lime are provided. Due to electronic data transfer, delays are avoided.

Results

With the help of the project IPS, the number of used software tools was reduced, electronic data transfer was introduced and a software tool satisfying the requirements of different stakeholders was developed. As a result, it was possible to automate a majority of process steps resulting in a higher productivity. In addition, automated data transfer between IPSmobil and AgriPort in combination with instant data dissemination increases process transparency for both Agricon and customers. Up until now, customers did not have any information about the processing status of their orders. Contrary, IPS enables continuous status tracking within AgriPort and a promptly access to lab results and nutrient maps. By optimizing the communication between the involved stakeholders, it is now also possible to provide the service significantly faster than without IPS. Applying standardized data formats in particular, allows for an easy integration of the results, without any manual formatting or complex transformations for integration into existing databases.

The majority of order processing data is generated in digital form allowing for statistical analyses. Thereby, the order situation of a specific region can be evaluated, or critical orders can be identified quickly. Overall, a comprehensive controlling becomes feasible for the service provider. Furthermore, a central order management enables the digitalisation of the corresponding bookkeeping processes. It is no longer necessary to enter order data manually.

To quantify some of the positive effects that result from the implementation of IPS, electronic protocol data and log-files from soil sampling can be taken as a reference. Table 2 shows the amount of time saved, resulting from the application of IPSmobil during the sub-process of soil sampling (taking samples, labelling of samples, generate protocol). Log-files from about 6,000 soil samples, which contained the timestamp of the beginning and the end of a sampling process, where used as the basis for the calculation (Table 1). For calculation, the values were smoothed by 10 percent, i.e. minimum and maximum values have been removed in order to filter erroneous data resulting from GPS-failures. The data set contains two different soil samplers (Soil Sampler old/new). The particularity of the new soil sampler is its capability to take up to five composite soil samples (from 15 to 25 single sampling points). This significant increase in capacity results in a huge boost in efficiency, since the field engineer can collect up to five samples (instead of one sample) before having to get out of the car to bag and mark the samples.

Table 1: Evaluation of log files from soil sampling

Soil sampler	IPSmobil	Field engineer	Samples	Min [s]	Max [s]	Average [s]
Old	no	4	2993	291	754	470
Old	yes	3	737	287	476	375
New	no	2	1282	244	249	247
New	yes	1	922	200	200	200

Table 2: Time saving though IPSmobil (relative)

	Soil sampler old / without IPS	Soil sampler new / without IPS	Soil sampler old / with IPS
Soil sampler old / without IPS	0 %	/	/
Soil sampler new / without IPS	47.25 %	0 %	/
Soil sampler old / with IPS	**20.17 %**	/	0 %
Soil sampler new / with IPS	57.35 %	18.73 %	46.57 %

The results are shown in Table 2, segmented in groups using different combinations of the new and old soil samplers and with or without IPSmobil. The results indicate that the deployment of IPS can reduce the process throughput time for soil sampling with an old soil sampler by 20.17 %. Using the new soil sampler and IPS leads to a time saving of 18.73 % in conjunction with IPS. In addition to these quantifiable results, there are further improvements in other sections of the entire process. For instance, order preparation processes and data processing of lab results up to the generation of nutrient maps benefit as well. On the one hand processes can be automated and accelerated by defining and standardizing data formats and interfaces, on the other hand potential sources of errors can be eliminated also in these steps, whereby the overall quality of the process is increased.

To summarize, the development of a homogenous software system makes the entire process of nutrient mapping faster and more transparent. Time consuming steps, such as manual generation of the soil sampling protocol, the manual import of protocol data or lab results were automated. Since data is no longer exchanged by postal mail but electronically, considerable time savings can be realised here, too. Overall, the reduction of required software systems made the entire process more user-friendly.

Conclusion

The development of IPS shows how the application of a service engineering approach in agriculture leads to improvements in quality and effectiveness of a service provision. In connection with the cloud-based AgriPort, it offers farmers more traceability and transparency.

Taking IPS as an example, various effects of optimizing cooperative business processes through digitalisation were shown. Based on business processes modelling, weak points have been identified. Through standardization of data formats, reducing the number of used tools and the predefinition of error routines, the whole service became more efficient benefitting all stakeholders.

Based on the results of the project, further cooperation partners of Agricon can be efficiently integrated into the complex service networks in the future. Even though interfaces and protocols are company-specifically suited to the infrastructure of Agricon, the applied methods and principles are transferable to other fields of application. This exemplifies the potential of service engineering in the agricultural domain.

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