InnoServPro: Innovative Service Products for individual and availability-oriented business models in capital goods industry

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1. Introduction

Although GRIMME is one of the worldwide market leaders, producing a complete product line of potato equipment, the number of competitors is increasing, both regionally operating ones and internationally working companies.

Their daily work consists of the delivery of worldwide service, but in future with an extreme pressure concerning the activities involved, as life is going to change and to become more strenuous every day – especially owing to crimes, crises and environmental disasters. [6] Today usually not only the machines are sold "as a product", but also the service products have to be defined and the first use of the machine has to be accompanied. In order to operate in a prompt and effective way as well as on a high grade level, 3 aspects nowadays have to be taken into consideration:

1. well educated personnel with clear responsibility;
2. in time parts availability;
3. up-to-date systems of communication, organization as well as documentation.

Farming and Agribusiness will change rapidly in the next few years. The growing world population must feed by the same amount of farming land in the future. Databased Services enable increasing the productivity of the farmer by the harvest and give him treatment recommendation. [7]

The publication is structure as follows. The second chapter contains the motivation of GRIMME to develop Product Service Systems (PSS) and availability oriented business models. The third chapter gives an overview of the Use case in the potato harvester with sensor, data handling and condition estimation. The chapter 3 ends with the value network map. The paper ends with a conclusion and an outlook of future work for developing the business model.

2. Motivation

2.1. Product-Service Systems (PSS) in Farming and capital goods industry

The growing demand for innovative services forces traditional product-oriented companies to perceive the potential and strategic importance of service. Innovative services enable these companies to ensure their market positions and to achieve economic success. Due to this, it becomes necessary to systemize service design, development and management processes as well as to tightly integrate products and services.[4]

For this economic success methods and important fields of action regarding the systematization of services is done by service engineering for integration of products and services. The successes full integrated Product-Service Systems are integrated solution and required from the customer.

2.2. Development of Business models

To identify and select innovative services, an analysis on interactions among partners of the extended value-added network is helpful and will be considered. To achieve the overarching objective, three sub goals are defined:

1. development of customized, availability-oriented business models;
2. development and integration of smart components with the ability to communicate;
3. design and configuration of an information management platform to provide and exchange service relevant data. [5]

Derived from the use-cases and identified services, customized, availability-oriented business models have to be developed for each enterprise. This activity takes place in close coordination with the specific enterprise using business model canvases. Thereafter, different business models have to be assessed and prioritized. In doing so, company-specific criteria will be identified in different workshops with suitable experts. After the assessment, the most promising business models will be selected. In the next step, further and innovative service-ideas have to be identified to fulfil the requirements derived from the assessed business-models. Therefore, different workshops and idea-finding processes need to be conducted with the companies and their partners in the extended value-added network. The innovative services have to be assessed with the service assessment concept.

2.3. Services to realize availability-oriented business models

In general business models can be elaborated and visualized with the nine elements of the business model canvas. But each definition must be proofed with a typical customer of the target group.
PSS enable innovative function-, availability- or result oriented business models and new business models with the aim to fulfil customer´s needs. In this paper, only availability-oriented business models are in focus and described. Availability-oriented business models use PSS to guarantee the usability and availability of products for the customer. The PSS-provider takes responsibility of the Business processes of the customer and takes a part of the production risk. [5]

Services for availability oriented business models develop machine manufacturer to Provider of Product-Service Systems in a network. The network also enclosed the pre supplier, dealer and sales and service companies.

3. Use case description

As potatoes can only be harvested for a short period of time in a year, a failure during the harvest season is critical. For this work, a smart sensor is defined as the physical sensor combined with signal processing for condition-estimation and monitoring and a communication system.

3.1. Machine and system description

In an internal process, the agricultural machinery manufacturer GRIMME has identified the drive belt, which moves the conveyor system of the pick-up unit of the Varitron 470 potato harvester as service-relevant. The potato stems, which were previously cleared by a sieve, are sieved with beaters and transported into the machine via this conveyor system. The potatoes are then cleaned, sorted and collected. The pick-up unit consists of a drive, a gearbox, various sensors and the drive belt. In addition, metal bars are attached to the belt via positive-locking connections. The bars have a defined spacing, which varies depending on the type of conveyor. The drive is provided by a hydraulic motor, which transmits the rotation via a gear unit to a toothed wheel, which in turn drives the conveyor system via the engagement with the metal bars. Harvesting requires specific, weather-dependent boundary conditions over a certain period of time. If these requirements are met, it is important to harvest the crop as quickly as possible in order to prevent a change in the weather. During machine operation, the belt is subjected to an irregular tension and shear load. These can ultimately lead to a demolition. If the belt tears during field operation, a large quantity of soil, potatoes and stones remains inside the machine. Repairs now require a previous, time-consuming emptying or cleaning. In the event of an emergency, the standing time during harvesting can lead to devastating economic damage to the farm. [2]

The challenge is therefore to enable monitoring of belt wear under the typically harsh agricultural conditions in order to make sufficiently reliable estimates of the remaining service life of the belt. The position of the conveyor belt in a self-propelled potato harvester is shown in **Figure 1.**

3.2. Smart sensor concept and failure causing condition

First, a sensor concept, which is able to robustly deliver information in rough environments, is presented. The sensor is robust by concept against wear causing influences of the component. Then, smart and robust signal processing and interpretation is discussed. The harvester uses conveyor belts to move the harvested potatoes through the machine and to separate them from the earth of the mounds, in which the potatoes are grown in, and other parts of the plant . The conveyor belts consist of three belts made of hard rubber, which connect bars orthogonal to the con-veying direction to build the conveying surface for the potatoes. The three belts are closed by locks. Both bars and locks are made of ferromagnetic metal.

The conveyor belts were identified as the component most likely causing failures, since they suffer from wear due to the operating conditions. The belts are already designed and optimized to resist the rough environmental conditions under which they operate, but wear nevertheless occurs and leads to failures when preventive service is lacking. As their wear strongly depends on individual usage and operation conditions, time-based services are not optimal. To prevent failure of the conveyor belts in the harvester, and to avoid unnecessary maintenance, the condition of the belts has to be monitored to trigger services just before a failure occurs. Investigations by the manufacturer of the conveyor belts identified the source of break-down as related to the elongation of the conveyor belts. Condition monitoring enables failure-pre-venting services only if the change of the condition is detectable and predictable with an adequate certainty. The process of the elongation was investigated in test bench trials. Results showed that the elongation increased slowly with the applied stress, and can be predicted. The sensor used for the potato harvester combines an anisotropic magneto-resistive-sensor (AMR) and a permanent magnet with the purpose to magnetize the bars as they pass the sensor. The AMR-sensor choice, size of the magnet, and the position of the sensor relative to the magnet are dependent on the geometrical conditions of the actual problem. Laboratory test have been carried out to investigate different combinations. As result, an AMR-sensor (fieldsensor by Sensitec) build on a ceramic circuit with a hard ferrite magnet of the size. The robust sensor concept has a environmental acceptance for field condition. How it is mounted at the intake unit below the intake conveyer see **Figure 2.**

3.3. Signal interpretation and condition estimation

For sensor connection and data handling was developed an electronic Subsystem **Figure 3.** This subsystem is connected to the harvester can-bus system to get the machine data, which are necessary for data, analyse and pre-processing.

Aim of the pre-processing is to convert and divide the analogue stream of continuous data into smaller, discrete parts associated with the movement of one bar in front of the sensor. The signal interpretation aims to reconstruct the movement of the bar in front of the sensor from the pre-processed signal. This is especially difficult since an at least two-dimensional movement has to be recon-structed from a one-dimensional signal. To relate the movement signal of individual bars and to the elon-gation of the conveyor belt, we further have to interpret the signal (post-processing step). By the combined interpretation of the observations of all bars, the condition of the conveyor belt can be extracted as the vector of distances between each belt element, at time. Changes in this can be used to calculate an estimate for the time to failure and a probability. [3]

3.4. Business model and value network map

In the time of developing the sensor concept, the service team also developed the business model. To show the data and monetary flow there was created a value network map, which is shown in **Figure 4.** Manufacturers of industrial goods integrate several components from different component suppliers into their specific machines or manufacturing lines. Component suppliers also have sub-suppliers for products. For the cross-company process "exchange of data" the need for a central cloud platform arises. External data analysts and other service providers can be integrated into the value network. Component suppliers have detailed knowledge about their own products and can offer them to machine owners as well as manufacturers. This could go along with the product engineering, supporting the design of the machine, or during operation to ensure product quality and productivity while keeping machine downtimes low. Machine operators can provide information regarding current usage of machines and components as well as failures. This information can be used for product improvements of manufacturers and component suppliers and is essential to monitor availability. Production optimization or condition-based maintenance becomes possible. Several partners of the value network can conduct the maintenance of components. Consulting of external service provider is possible as well. Depending on the size and technology experience of the partners in the value network, tasks can be realized by different partners.[1] The value network map also shows the possibility of the monetary flow and the system boundary which is based by the customer. The customer every time has the chance to make decisions for input into the system.

4. Conclusion and outlook of Future Work

As far as the next 2 – 3 years are concerned, one major advantage will consist of the fact that the delivery and the identification of the parts could be effected more rapidly than 24 hours after the "first call". For this purpose we are in the process of developing worldwide logistic structures, intelligent interfaces of machines in order to predict the frequency of maintenance. Resulting from the above mentioned point of view, the future European production of agricultural machinery about the year 2020 will depend on dynamic and effective aftersales organizations. The main reason for this thesis is the fact that products respectively machines could be copied, but that there does not exist any possibility of copying aftersales organizations and its qualified staff.

The use case is demonstrated at a self-propelled machinery because this is a closed system. The developed business model can be transferred also to a towed potato harvester but in this case the system boundary must be define to the tractor.
For this, system concepts and robust smart sensors with the ability to communicate have to be developed with respect of challenging operational conditions of capital goods. As example, the conveyor belts of a potato harvester were investigated. In this context, a robust sensor concept and the concept for a robust signal processing were presented. The robust interpretation of the sensor signal was discussed in detail.

Maintenance services are in focus of the use case in order to avoid and reduce unscheduled downtimes of machines. The use case shows that the concept is valuable to achieve availability-oriented business models.Support for continuous improvement should be given to companies since the business models underlie a rapidly changing world due to new technologies and the digitization.

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FIGURES

Figure 1 - Potato Harvester with service relevant components

Figure 2 - Smart Sensor in the self-propelled potato harvester

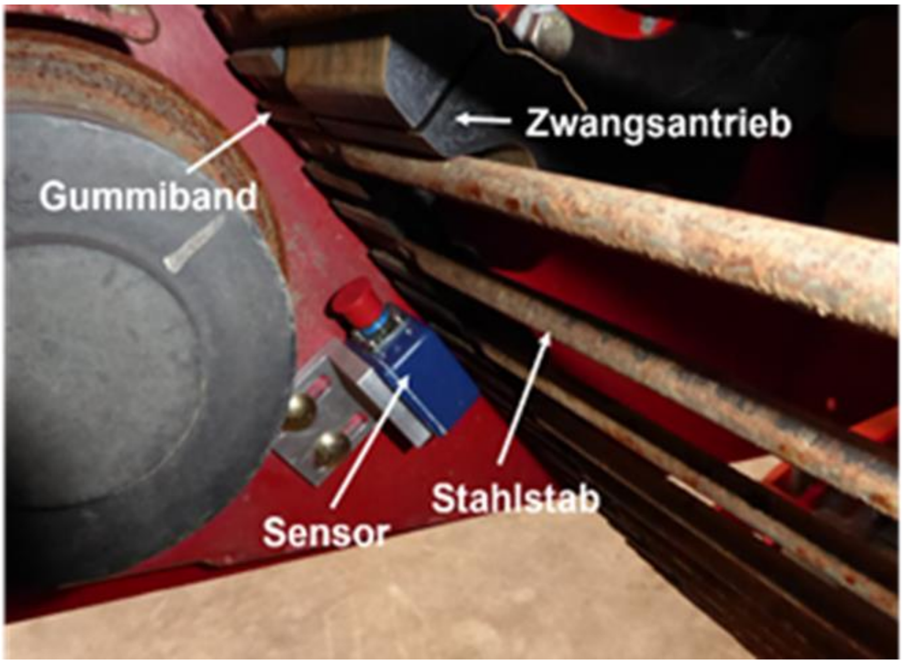

Figure 3 - Electronic Subsystem for data handling and communication

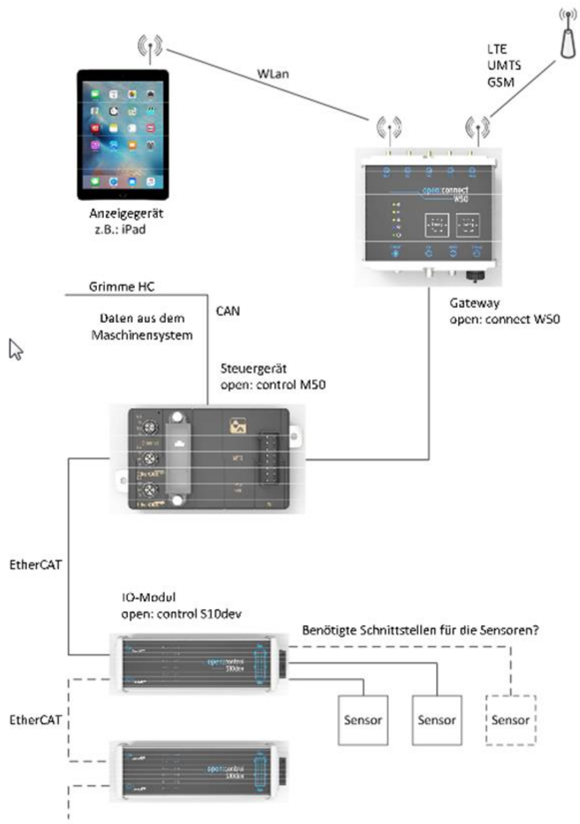

Figure 4 - Value network map for the Business Model