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Approach for a Simplified Meshing Network as Monitoring Solution in Farming Applications

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Abstract

In this paper an approach for transferring complex and demanding ICT from industrial production to agricultural infrastructure requirements will be presented. This will enable SME farming businesses to tap the full growing potential of their arable land. The overall goal is to increase yields, crop-quality, efficiency of fertilizer and resource deployment with real-time growing-related data.

Core aspect will be a meshed network of single sensing nodes, that monitor growth-relevant parameters on arable fields. The underlying technique has been approved in manufacturing SME that already utilize production data for controlling and optimizing their production processes, flow of material and machining steps via a thorough ICT-system. Therefore, a qualitative and explorative research design was conducted under 70 German SMEs.

Hereof, a frugalization inspired process led to a microcontroller-operated sensor network that is based on a long-range communication and low-power set up. The system uses specific data rates and is able to permanently cover broad monitoring areas. The respective prototype was empirically examined and provides a reasonable solution space that needs to be further elaborated in long-term field studies.

Besides potent companies that can afford to develop, test and run respective systems, as for instance smart- or precision farming, there is a huge gap to small and medium sized enterprises (SME) that are not able to deploy such technology but count for the majority of companies. That provides the impetus for further research on how to utilize the data for a decision support model

Key words

condition-based-monitoring, cultivating, decision, measuring, smart-farming

1. INTRODUCTION

Persistent transformation processes in the industry and economy drive technological progress and affect value creation in most businesses and branches. Technological progress acts as an accelerating catalyst in manyfold ways and offers, in result, new procedures of solution [1]. An intelligent and smart control of processes positively affects resource deployment and its efficiency and is pertinent to quality. Thus, data itself and the velocity of information processing advanced to crucial competitive factors for most businesses. Besides potent companies with highly elaborated production facilities that can afford to develop, test and run respective technologies, there is a huge gap to especially SME, that are not able to deploy such complex systems yet. Whereas, speaking of numbers of scale this kind of enterprises has the potential to disseminate such key technologies for a broader range of users.

The pervasion of powerful technologies from prototypal demonstration to a broad and resilient application is already examined in literature and depicted in product life cycle models. It states that new technologies are primarily available to a closed circle of early adopters at typically higher costs [2]. Thus, most enterprises and especially SME cannot afford such high-tech applications besides the fact, that there is no sophisticated machine park available, that would allow digitized operations and enhancing efficiency anyway.

In fact, there is already an increasingly dissemination of data driven production solutions in manufacturing companies to be recognized and includes condition-based monitoring solutions for many applications. So, in terms of technical progress, there is both the need to develop new solutions in the first place and facilitate such concepts later for a broader application and market penetration.

Data technology concepts have been adapted to farming needs and brought up so called smart farming technology (SF), that utilizes modern information and communication solutions. After plant breeding and genetic modelling this technique is referred to the third green revolution and considered as the next milestone in bio-economy and agricultural research [4]. It combines information and communication technologies (ICT), the internet of things, sensors and actuators, geo-positioning, big data, drones, robotic etc. to level up resource efficiency in the field of food production. The technology is said to contribute to a secured food supply, too [3].

The concept of SF is, until now, only common in industrialized countries and enables for cultivating vast landscapes. From a farmer´s point of view, the technology provides sufficient data to support decision making and optimize processes that even allow growing on difficult terrain.

In numbers this means there are in total 266.000 farming companies in Germany that produce goods with a value of 58 bil. EUR on total arable land space of about 17 mil. ha [3]. Indeed, more than 90 % of the farmers already make use of assisting technological solutions, whereas this refers to rather low-tec applications and the extend of automatization of mechanical devices.

Regarding this, it requires at the same time further development of the technology itself and carefully selected simplifications in order to ensure applicability along the value chain and price sensitive users. By this, the research contributes to overcome food supply shortage and resource scarcity.

2. MATERIALS AND METHODS

This paper is based on an explorative research design in the first place, focusing on understanding dependencies and market demands of operators in the farming business regarding monitoring technologies for growth relevant tasks. In addition, a literature study complements the observation with current publications and general market trends on solutions for precision and smart farming technology set-ups, that can be applied even with low technological infrastructure and consider the current technology-related challenges in for small farming businesses.

In order to narrow down these results on a specific research field, a complementary qualitative research design was planned. After the explorative phase with several generic talks with companies and customers who supply agriculture farming tools, in total eight guideline-based expert interviews were conducted. The data were evaluated and benchmarked with literature findings, using pairwise comparison on the identified key parameters. This prioritization enabled for a definitive solution space. Besides interview result from German companies, that represent rather developed market players, an additional research journey to Cuba was conducted as part of the explorative phase.

Hence, the work aims to provide a simplified solution space for further design of a sensing and communication technology for agricultural businesses, a suitable starting point needed to be selected. This approach is considered frugalization and was be applied on a surveillance system for growing-related operations. The underlying technique has already been approved in small and medium-sized manufacturing companies, that use relevant production data via a comprehensive and practical ICT-system in order to control and optimize their production processes.

However, a quantitative study to underline the importance of current processes in the farming business is already being planned to test assumptions derived from the solution path. Considering the total population size, i.e. 266.000 farming enterprises, a sound confidence level of 95 %, which equals 5 % error margin, this leads to a sample size of 384 enterprises to be surveyed from now on. Hence, the goal is to analyze cause and effect relationships within this first instance and secondly establish a comprehensive proposal of the described solution, based on actual customer needs.

3. RESULTS AND DISCUSSION

3.1. Results

The field study revealed the very basic requirements of farmers on the infrastructure. Besides proper tools and machinery (both considered as most important) another 70 % states that ICT support is inevitable to deal with increasing calculation tasks.

Generally, the vast majority (93 %) strives for technological assistance but is not capable to operate such complex solutions. The reasons are missing infrastructure (42 %), high investment and running costs (41 %), time (9 %; for implementation and learning) and minor other factors. Especially the tight supply of reasonable systems seems to be the most important impediment. This is true for both, developed (Germany) and less developed (Cuba) countries.

3.2. State of the art

Latest manufacturing technologies apply cyber physical systems that use data as additional resource for process design, steering and decision-making in production facilities. Characteristic feature of such systems are small areas that are monitored by high frequency communication devices with high data-rates. In addition, steady power supply and ambient conditions isolate this certain use case from farming applications, where wide-area production grounds with versatile surrounding conditions are typic.

There are multiple solutions to transfer data between a data link which comes with different characteristics to handle. First, there are different restrictions about the usable frequency on most continents. That means, a multilayer hardware-layout, which is able to exchange different radiofrequency modules without modifying the software, is a prerequisite for international usecases. Common frequencies for European and north- /south American application are 433, 868, 915 MHz and 2,4 or 5 GHz. Due to the limit of physics, a higher frequency is linked to a higher rate of transmission but induces lower coverage. There already exist various concepts to transmit specific data, even via huge distances, i. e. 25 km, and aggregate them in a networked system [5].

Generally speaking, there is a strong correlation between a stable connection over wide areas and the sampling rate (samples per seconds). For instance, agriculture use cases typically require relatively low sampling rates (1/15 min.). Due to a higher path of transmission to a Server/Datahub lower frequencies with a lower bandwidth are deployed.

Typically, it is based on Long Range (LoRa) or a similar narrowband application (see given frequencies before) in different meshed clusters.

Furthermore, there is an additional technology deployed which uses the 4G-IoT-Narrowband. The advantage of this technology is that multiple measurement-tasks can be run at the same time, only requiring 4G-connection. Afterwards, the data will be transmitted to a web-based API, which processes the Data to useful information. Indeed, even with this technology the described dependency between a high reach and small sampling rate of the data still exists.

Along with the second mayor trend in the agricultural business, precision farming (PF), there arises a huge economic potential [6]. Focusing on a precise cultivation, this approach includes especially digital process technology, that will be examined in this paper. The term itself refers to a farming management concept, based on observing, measuring and responding to inter and intra-field variability in crops. It aims at the targeted deployment of growth relevant factors and separates the fields accordingly into identifiable units. In contrast to common manners, the identified areas are not based on property lines or on the expected average yearly crop yield but on their true potential of bringing up plants in an ecological way. Thus, this approach enables farmers to manage their fields based on the spatial variability, such as the availability of nutrients and expected crop yield [7].

To a much greater extent than ever before, plant protection is guided by the pressurized expectation to avoid damage and economic efficiency. The precision farming method involves measures of small-scale soil cultivation, sowing, fertilization, application of pesticides and other operations.

Prerequisite for this technology is an elaborated and mostly expensive IT infrastructure, that can cope with the amount of data and offer the required computing power. Subsequently, certain barriers to entry arise that leave less developed economies and/or farmers behind and moreover interfere the pervasion of a future technology.

3.3. Approach

3.3.1. System design

In the following the systematic approach, on how to establish resilient, reasonable ICT-systems to professionalize farming tasks with low infrastructure requirements will be introduced. The solution is inspired by SF technology and offers a straight potential for resource efficient and sustainable farming with a centralized and condition-based cultivation.

It uses the combination of empirical and experience-based knowledge with data-driven process information to support decision making processes about growth-relevant parameters. The aim is to raise agricultural yields in terms of harvest and returns along the value chain by using mostly given resources by taking advantage of sustainable movements.

The solution is thought to be a platform, enabling a linked sensor network over agriculture surfaces. This platform-architecture includes sensor-nodes that enables a continuous monitoring of growth relevant parameters (see Figure 1).

Figure 1: Network with nodes and master hub (left)

3.3.2. Resource monitoring

The solution provides a high-performance low-power measuring set-up for arable land. It is based on a scalable amount of meshed sensing nodes. These can easily be modified and adapted to variable scenarios in order to be implemented for different agricultural applications and are operated with a variable set of input parameters.

Instead of intense capital expenditure for enhancing the technological base and time-consuming efforts for the initial operating as well as maintenance, a smart work-around based on Long Range meshing communication technology is used.

By this, farmers will be provided with a reasonable solution that can be scaled easily. As data will take on a core resource in the set-up, a profound and especially interdisciplinary know-ledge base will be established that will provide an impetus for fostering agricultural business concepts.

By this, practical knowledge and empirical data, as they are already considered as crucial input in manufacturing applications, are transferred to a new application. For different measuring tasks the central hub will be enriched by a scalable CAN-BUS API. This will allow for modification of the used measuring set-up and installed sensors, even in the working environment. As solution, the active transmission of signals of a single entity can be realized via microcontrollers, e.g., type AP2921 by Siemens. Although this type is primarily designed for high-data rates, it provides further advantage regarding scalability (see Figure 2).

This layout can be run with a raspberry-pi infrastructure that enables for an inexpensive and performing approach. Besides, the gathered data of a masterhub can easily be interpreted on the Pi and be forwarded to a WebSocket API. Especially a WebSocket application promotes the intended usability because it enables for a direct transfer of data to a browser. By means of design, the API can even be directly integrated on the hub. Via a separate control panel, that interface can be used to control external further application, for example data retrieval form a browser.

Regarding the actual sensing tasks, precision will be favoured over resolution. This seems to be appropriate because of the rather raw case of application and a generally lower meaning of resolution on the field. This alignment supports a possibly low cost solution. Nonetheless, both are required for metering tasks, which are not part of the paper.

A distinctive control routine will ensure the long-term applicability of every respective entity in the field. That means, a dynamic battery management will be employed to control sensing intensity depending of the actual power level (i. e. electric potential). With lower power level, the device will prolong its measuring and sending intervals.

According to this, further research will be conducted to determine power limits and respectively timed intervals. In order to even expand on ultra-low-power operation an extension with photovoltaic powering could be realized, indeed causing additional costs and maintenance efforts.

3.3.3. Resource monitoring

The generated data-streams get linked via a 433MHz/868MHz/LoRA to a masterhub, which collects all data und send them online to a custom endpoint, like an API, web-dashboard or a cloud-based data storage. The API/dashboard is run by various analysis/graphs, so the user can evaluate the detailed condition of the monitored area. There are various technology of communications existing. If the use case is to create a local network, which even can work offline, a LoRa- or other ISM-Band (free to use) is recommend. If there is need to send the data immediately to a remote web-based server, the IoT-Narrowband on 4G/LTE-base can be used. For a migration of the data by a remote masterhub, LoRa is a data protocol dedicated for low-latency transmission of single data packages.

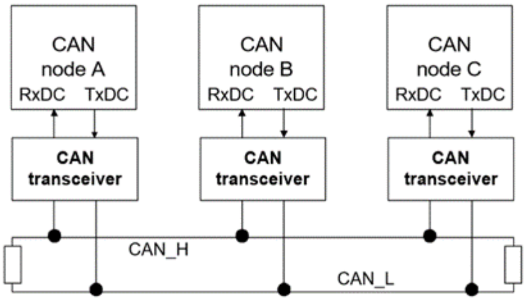

Figure 2. API-layout on the hub to integrate sensors

In contrast to high-frequency production solutions it covers up to 35 km distance between transmitter and receiver. By this it qualifies especially for the application in agriculture with vast landscapes and partly low internet coverage, such as the 3G standard or even lower.

Typical for measuring tasks in agricultural surrounding lower sampling rates are sufficient. A continuous sampling rate of e.g. 0,02 Hz can easily be operated via LoRa-protocol and prepare the technology to inform even about unexpected conditions and changes with less latency – which by means increasingly happens as a matter of short-term climate changes.

So, the distinctive advantage is its independency from network coverage. In case there is no local internet-connection, the 4G-IoT-Narrowband shall be used to send the data to an online-endpoint, even on outlying geographical areas. This would create a reliable entry point for smart farming even in developing countries with low infrastructure and limited resources to make use of high-end precision farming technologies.

With respect to interoperability and security matters, it seems adequate to use the popular MQTT network protocol that transports massages between devices – in this case a masterhub and several APIs. This technology as well supports the intended meshing for enlarging the potential measuring area.

3.3.4. Security

The security of the collected and processed data gets a high place value. In this concept, all data are heavily secured by a strong AES256 encryption. This kind of encryption seems slightly to be overpowered for agriculture use cases, but due to the frugaliziation of technology, which can be integrated deeply into many industry-processes, it is already developed within the “privacy by design” rule and prepares for potential scale-up operations later on.

Furthermore, the sensor nodes can create a hashvalue considering especially time and potentially geo-information of the collected data, so the receiver (masterhub) can compare the incoming data streams with the hashvalue as a kind of verification.

To prevent a processing of false/corrupted sensor signals, especially in pH, fertilizer or soil moisture measurements, all input-signals have to pass a galvanic isolation. Even though this isolation would result in slightly higher manufacturing costs, it increases the reliability of the system. Furthermore, the galvanic isolation protects the electronic on-chip-circuit against electric discharges.

To detect an incorrect wiring or a damage of the electric circuit between a sensor and the sensor-node, all inputs got a open circuit detection. This means, if a e. g. Negative Temperature Coefficient Thermistor shows an implausible value for the expected temperature-ranges, there must be an incorrect wiring or damage within the sensor itself. The sensor-node detects this error and extends the existing telegram structure with unique errorcodes, so the Graphical User Interface can display a warning sign and push-notifications to the user.

Another security-related task is the prevention of data-loss, which leads to white gaps in the measurement stream. The current approach to prevent this loss is a local, timestamp-based storage on each sensor node. After transmitting data to the masterhub, a checksum is transmitted, so the node and masterhub can identify incorrect transmissions of data. After a transmission is successfully completed, the masterhub saves the data on a timeseries database, like InfluxDB or Prometheus, which is hosted on the desired endpoint like API or cloud. Within the dashboard environment, which is connected to the encrypted timeseries database, the user can create different backup-tasks, like backup to a cloud, local storage or other servers.

For a continuous monitoring of all nodes, each telegram gets added relevant status-information about all connected sensors, battery-level, connection strength and the ratio of successfully vs. unsuccessful transmitted data-packages. So, the user can easily see, which node may need to be checked to prevent more failures.

4. CONCLUSION

High-end SF and PF technologies have the potential for enhancing efficiency. They use digitized arable landmarks that can digitally be managed in order to increase yields and lower resource deployment continuously. For executing such tasks, drones, autonomous harvesters. Accordingly, these can be found most of all are on vast farming areas with already digitized processes and well financed operators. Another prerequisite is an highly elaborated infrastructure with 5G-Networks for a bidirectional data-transmission.

As an effect, this kind of technology requires an already digitized staring point with ICT infrastructure. The full potential of such systems lays in a centralized control entity with high processing power, that can analyze and process the amount of data via artificial intelligence in order to control the machinery on the field. Any bettering and enhancement of such a set up regarding digitization, efficiency and yields require disproportional efforts and especially additional expenditures. Considering this, the technology is rather suitable for already digitized environments and inappropriate for small-scale farms and low-infrastructure landscapes.

In consequence, especially smaller farming-businesses cannot participate in this development and underachieve the growing potential of their arable land. Thus, there is the need for a low-tec application as enabling technology towards fully digitized manufacturing of farming goods.

So, it is evident, that transferring individual sub-technologies, like high performance sensor-meshing, into a more applicable context for regular farmers that could promote the pervasion of the respective technology. In the first place, farmers should gain insight into the actual conditions of their fields by monitoring key performance indicators, such as pH, density, humidity, atmospheric pressure, sun intensity, amount of irrigation water, temperature, fertilizer. This can be realized effectively by implementing meshed sensors across the measuring field. Moreover, large-scale benefits are expected as a result of scale effects.

The presented approach shall provide a basic and thus applicable method for science- and evidence-based farming, complementing to experience based decision. In concrete terms there will be given a solution for monitoring arable space regarding growth-related parameters and derive data-based actions to be taken. With specific data transmission set-ups it will be possible, to easily integrate specific sensor nodes in an agricultural environment to regularly gather at least data on soil, environment and plant conditions. These will be transformed into specific information for machinery and assisting technological entities. The added value will be an enhanced knowledge-base, regarding condition-based cultivating of arable land. By the use of such data, even re-cultivation will be possible, as irrigation water, fertilizer etc. can pointedly be deployed, relating to the actual nutrient concentration in the soil and/or water.

Further advantages, that come along is the predictability of some kinds of pest, which depend on the humidity, sun-intension or amount of fertilizer. The specific advantage will be the maximal scalability of the system by at the same time very low cost of approximately about 200 EUR per node. As a matter of fact, this leads to economic and ecological savings for the farmer resulting from lower expenditures for supplies and working hours.

Ultimately this has positive effects on the economy, too, regarding sustainable and efficient growing of agricultural products by using modern data-driven technologies.

For promoting this approach, further research in terms of empirical assessments will be conducted. This is intended to improve transparency on the actual demand-side, especially about the current state of digitalization, available machines and ICT facilities. In addition, there will be further technical research necessary on the node design and its power supply.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest