engineering proceedings

Proceeding Paper

NEVONEX—The Importance of Middleware and Interfaces for the Digital Transformation of Agriculture †

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† Presented at the 13th EFITA International Conference, online, 25–26 May 2021.

Abstract: For a "system of systems" approach in agriculture, agricultural machinery is facing the challenge of bringing tractor-implement combinations and harvesting machinery to the IoT (Internet of Things). While standards such as the ISO 11783 (ISOBUS) have enabled seamless tractor-implement communications, the manufacturer-independent communication of tractors, implements and harvesting machinery with external sensors and different Cloud systems/services are still lacking. IoT ecosystems for agricultural machinery are gaining ground in the market to solve these problems. In this regard, an overview is given about the role of interfaces and middleware and how they can help to improve data flow, improve connectivity, compatibility and interoperability of digital products that farmers use.

Keywords: IoT; cloud; ISOBUS; connectivity; interoperability

Citation: Treiber, M.; Bernhardt, H. NEVONEX—The Importance of Middleware and Interfaces for the Digital Transformation of Agriculture. *Eng. Proc.* **2021**, *9*, 3. https://doi.org/10.3390/engproc2021009003

Academic Editors: Dimitrios Kateris and Maria Lampridi

Published: 19 November 2021

1. Introduction

The adoption of digital agriculture technology is rising [1] and is estimated to double in the next 5 years for German farmers. With this rise, farmers start to collect bigger and more diverse datasets from their daily operations. The tools used to gather and manage this information have seen a vast improvement over the last few years with FMIS (Farm Management Information Systems), ISOBUS and government documentation systems, where farmers provide their documentation for receiving subsidies and standalone decision support systems for growers focused on finding the right time, amount and products to do applications on their crops. However, this leads to many different complex workflows that cost a farmer's time, and the decision whether or not to adopt digital technology for a certain application on a farm often involves a tedious search of combining the right digital tools to an efficient workflow to achieve the desired solution. The challenge of agricultural engineering in this regard is to bring together all the different digital tools, increase compatibility, connectivity, and interoperability so that it is easier for farmers to create seamless workflows for the digital processes/process management on their farms. Solutions to this problem can be found in standards, interfaces, and middleware.

This paper gives an overview of the systems that farmers use, the adoption of these systems, data formats, existing middleware and interfaces and shows how IoT ecosystems can improve the situation for agricultural machinery.

2. Materials and Methods

This study first provides definitions of the terms interface, standard and middleware in an agricultural context. Further, an overview of the state-of-the-art possibilities in those categories is given for the livestock farming and crop farming sectors.

3. Results and Discussion

3.1. Definitions and Examples in Agriculture

A Standard is "something set up and established by authority, custom, or general consent as a model or example" [2]. In an agricultural context, examples for standards can be found in regulations concerning the qualities of products (e.g., Regulation (EU) 1308/2013) or production processes and are set by government authorities but can also be derived from market pressure (e.g., food retailer labels). Regarding agricultural machinery, the most important standard by far is the ISO 11783 (ISOBUS) that standardizes tractor-implement communications.

An Interface is "the place at which independent and often unrelated systems meet and act on or communicate with each other" [2]. To stick with the above-mentioned examples, interfaces are necessary to provide documentation about agricultural production processes and the quality of goods to authorities or control bodies, that document the standards. In practice, these interfaces come to farmers in the form of paper documentation that needs to be filled in and slowly transitions to providing documentation in web-based frontends (e.g., application for subsidies from the European Union CAP), where software interfaces (in this case cloud APIs) to farm management information systems (FMIS) become more and more common to save farmers time and improve on the available documentation. On the side of agricultural machinery, an interface would be the control access to certain functions, sensors, or actuators in the tractor-implement combination. Examples are controlling engine speed, engine fuel rate, sections, or variable rates of an implement, etc.

"Middleware is software that lies between an operating system and the applications running on it. Essentially functioning as hidden translation layer, middleware enables communication and data management for distributed applications" [3]. As an intermediary between systems, middleware in an agricultural context can overcome the challenges of many (often proprietary) interfaces, data formats and historically grown standards by providing a layer that generates compatibility between two or more individual systems. A middleware can therefore broker data in between different cloud systems that farmers use (e.g., FMIS to government systems) or make sure that a machine can receive different data formats from the cloud to accomplish its tasks (e.g., application maps, direct control commands or messages).

Therefore, if the "system of systems" approach for agriculture [4] is taken seriously, there is no way around employing different kinds of middleware in the agricultural sector to overcome the challenges of connectivity, compatibility, and interoperability of systems. However, middleware is an often-overlooked topic, as a good middleware is not seen by the user and is hardly marketable, and with the opportunities a good middleware offers, there is the risk of companies not being able to protect their differentiation by innovation strategies long enough to recover development costs.

3.2. Situation in Livestock Farming

The adoption of Precision Livestock Farming technologies is on the rise [3]. Automatic milking systems, slat cleaning robots, autonomous feed mixers, Herd Management Systems (compare "FMIS for animal husbandry"), and sensor systems for the surveillance of animals and feedstock help farmers to focus their interests and efforts to those areas of the farm where it matters most. However, a standard such as the ISOBUS for the communication between those different systems is lacking. There are different tools and software solutions available that offer workarounds (e.g., Middleware from the home-automation sector as seen in [5].) However, a commercial and manufacturer-independent ecosystem for the integration of all precision livestock farming information from robots, wireless sensor systems and cloud documentation is still lacking. Therefore, in practice, systems either remain manufacturer-dependent (full-liner approach), farming operations must resort to software engineering providers to cover their needs, or systems simply remain incompatible. The results for farmers entail a lot of unnecessary labor and time spent on documentation.

3.3. Situation in Crop Farming

The systems farmers use in crop farming can be categorized as follows: Government documentation systems, which help farmers to apply for subsidies and meet basic documentation required by law. These are usually provided by government agencies to farmers. An FMIS helps the farmer to document all agricultural processes on the farm and the modular services also offer a lot of additional functions such as buying application maps, managing stock, tracking machine hours and fleet management and basic cost/benefit analyses. Next to the FMIS, crop management systems arise that are based on scientific models and help make decisions on application times—rates and suitable products. As those systems are not complete FMIS, they fall into the category of decision support systems, of which different ones are often offered to farmers from numerous extension services of universities, government agencies and federations. In the last few years, wireless sensor networks, drones and autonomous robots were added to the game to further complicate investment decisions for farmers. While wireless sensor networks and Wi-Fi cameras have been a huge success for individual use cases, and drones find their way to agriculture as sensor carrier platforms to create near-real-time decision map layers, robots are still in the early stages of their technology readiness level. Further, some online marketplaces for agricultural goods (and, e.g., carbon farming) have found their way to the farms and sometimes are even integrated into FMIS. Some of those services grow into FMIS as modular services by different providers. However, the transfer of machinery data and control commands to tractor-implement combinations is still in the hands of proprietary telemetry solutions. In crop farming environments, there is one basic workflow that is important to farmers during the early stages of adoption: Creating or buying application maps, transferring them to the machine, executing the task and uploading the "as-applied" map back to their documentation system, to close the loop. Experience from practice shows that the transfer to the machine often still happens via flash drives and not wirelessly, posing a threat for error on large operations regarding the availability, compatibility of flash drives and user error (loss, breakage, long distances to travel if wrong application map is used). The application map is basically the gold standard of transferring information into machine-readable formats, where an ISOBUS task-controller translates the information to machinery control commands. Limitations arise when live sensor information or live information from cloud systems should be considered to create ground truth and adjust the map value to a sensor-validated environment in real-time. Further challenges arise when next to an application map, further optimization software needs to be run on the machine. Examples for this are data-logging in the background, live optimization of a fertilizer spreader pattern or the automated control of balancing and tire pressure control systems.

This is where complex middleware such as, e.g., the NEVONEX ecosystem [6] comes into play, offering these kinds of functionalities and enabling the machine to run those in parallel in the form of digital services that are enabled by the IoT ecosystem architecture of this technology.

4. Conclusions

Middleware is a powerful set of tools to overcome the problems of connectivity, compatibility and interoperability with the different digital products that farmers use. For a "system of systems" approach, this invisible component of digital farming systems is therefore of utmost importance for the future. In precision livestock farming, commercial middleware that integrates systems to manufacturer independently is still lacking. In crop farming, the first steps towards the use of middleware can be seen in the connection of different cloud services that farmers use (e.g., agrirouter [7] and data connect [8], which are supported by the ISOBUS on the machinery side). However, to reach the next level, full interoperability of agricultural machinery and cloud systems is necessary and the different service providers need better access to the individual interfaces and functionalities of the machines. IoT ecosystems for agricultural machinery such as, e.g., the NEVONEX

Ecosystem, can help to provide these functionalities. As multi-sided platforms, their market success and operating mechanisms have yet to be better understood.

Author Contributions: Conceptualization, M.T.; methodology, M.T.; formal analysis, M.T.; investigation, M.T.; writing—original draft preparation, M.T.; writing—review and editing, M.T. and H.B.; supervision, H.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Robert Bosch GmbH.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data sharing is not applicable. No new data were created or analyzed in this study.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. Gabriel, A.; Gandorfer, M. *Landwirte-Befragung 2020 Digitale Landwirtschaft Bayern*; Landesanstalt für Landwirtschaft: Ruhstorf, Germany, 2020.
2. Merriam-Webster. "Interface" and "Standard" Merriam-Webster.com Dictionary. Available online: https://www.merriam-webster.com/dictionary/interface (accessed on 25 July 2021).
3. Microsoft Azure—What Is Middleware? Available online: https://azure.microsoft.com/en-us/overview/what-is-middleware/ (accessed on 29 July 2021).
4. Porter, M.E.; Heppelmann, J.E. How Smart Connected Products are Transforming Competition. *Harv. Bus. Rev.* **2014**, *92*, 64–88.
5. Treiber, M.; Höhendinger, M.; Rupp, H.; Schlereth, N.; Bauerdick, J.; Bernhardt, H. Connectivity for IoT Solutions in Integrated Dairy Farming in Germany. In *2019 ASABE Annual International Meeting*; American Society of Agricultural and Biological Engineers: St. Joseph, MI, USA, 2019. [CrossRef]
6. Robert Bosch GmbH. NEVONEX Powered by Bosch: The Ecosystem for Smart, Digital Agriculture. Available online: https://www.bosch-presse.de/pressportal/de/en/nevonex-powered-by-bosch-the-ecosystem-for-smart-digital-agriculture-199552.html (accessed on 15 September 2019).
7. DKE-Data GmbH. Strong Basis—Strong Developer. 2017. Available online: https://my-agrirouter.com/en/news/archive/read/news/detail/News/strong-basis-strong-developer/ (accessed on 13 May 2019).
8. John Deere, CLAAS, CNH Industrial and 365FarmNet Form DataConnect. 2019. Available online: https://www.deere.com/en/our-company/news-and-announcements/news-releases/2019/agriculture/2019nov05-dataconnect/ (accessed on 5 July 2021).