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Tobias Pauli
FAU Erlangen-Nurnberg, tobias.pauli@fau.edu

Yanpei Lin
University of Queensland, yanpei.lin@uq.net.au

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The Generativity of Industrial IoT Platforms: Beyond Predictive Maintenance?

Paper-a-thon

Tobias Pauli
FAU Erlangen-Nürnberg
Nürnberg, Germany
tobias.pauli@fau.de

Yanpei Lin
The University of Queensland
Brisbane, Australia
yanpei.lin@uq.net.au

Abstract

As the Industrial Internet of Things (IIoT) increasingly connects various assets, firms are establishing platforms to harness the data and make it available to third parties to create complementary offerings. As a result, IIoT platforms possess high generativity, i.e. the potential of triggering a variety of innovations. However, little is known to date about how this generative potential is leveraged. Therefore, in this study, we analyzed the solutions provided via the IIoT platform of a large European industrial firm along two dimensions: the diversity of solution scenarios they address, and the diversity of capabilities they display. Our preliminary results indicate that the diversity of scenarios addressed by IIoT solutions is quite high, whereas the diversity of capabilities is mainly limited to monitoring. Our study provides empirical insights on the generativity of IIoT platforms and extends the literature on digital platforms by indicating that generativity might require a more differentiated analysis.

Keywords: IIoT Platform, Digital Platform, Generativity, Industrial Internet of Things.

Introduction

In line with the advent of the *Industrial Internet of Things* (IIoT), many firms are creating platforms to collect data from industrial assets and make it available to third parties. Viewed from a technological perspective, platforms enable the creation of solutions by others (Gawer 2014). Thus, it is at the heart of platform business models to leverage the innovation capabilities of complementors (Parker et al. 2017; Thomas et al. 2014). As a result, digital platforms and their surrounding ecosystems are often associated with the notion of *Generativity* (Hein et al. 2019), defined as "a technology's overall capacity to produce unprompted change driven by large, varied, and uncoordinated audiences" (Zittrain 2006, p. 1980). Generativity is not only linked to digital platforms, but digital innovation in general, as the nature of digital or smart products allows for the creation of new value propositions without having to physically change the product (Yoo et al. 2010).

IIoT platforms enable the collection and use of data from various kinds of assets and devices from wearables to ships and power plants. The most frequently mentioned example for new market offerings enabled by this is predictive maintenance (e.g., Kiel et al. 2017; Weking et al. 2018; Wortmann and Flüchter 2015). However, various other ways of using the capabilities of smart machines and the IIoT are conceivable (Atzori et al. 2010; Sisinni et al. 2018). As the generativity of a digital platform is increased by the heterogeneity of components that can be integrated with and added to it (Yoo et al. 2010), IIoT platforms possess high generative potential. Nevertheless, research on how this generative potential manifests in practice is still scarce. Therefore, in this paper, we conducted a single case study using online data to answer the research question "How do actors leverage the generative potential of IIoT platforms?". In this process, we analyzed a total number of 102 application solutions provided on a large European industrial firm's IIoT platform. To operationalize the construct of generativity, we assessed the application solutions regarding two dimensions: diversity of solution scenarios and diversity of products capabilities. First, we assessed the diversity of solution scenarios to see if they go beyond the field of maintenance. Second, we assessed the diversity in terms of the capabilities of smart products from simple monitoring to full autonomy as defined by Porter and Heppelmann (2014).

Our preliminary results indicate that the generativity of IIoT platforms might currently not be leveraged to its full potential. While the diversity of scenarios and domains addressed by IIoT solutions is quite high, the diversity of capabilities is rather low and primarily limited to monitoring. This study entails two contributions. First, we provide empirical insights on the generativity of IIoT platforms and an approach for an operationalization of the generativity construct in this context. Second, we extend the literature on the generativity of digital platforms by showing that generativity might be domain specific. As such, our study responds to the call for a consideration of technological aspects of different digital platforms (De Reuver et al. 2018), as the variety of digital platforms necessitates a differentiated analysis.

The paper is structured as follows: First, we provide a short overview of (IIoT) platforms and how they are linked to generativity. Next, we describe how we collected and analyzed our data, including our operationalization of the generativity construct. Afterwards, we present the preliminary insights from this study before providing some concluding remarks and an outlook on future research.

Theoretical Background

Research in Information Systems studies platforms primarily from two perspectives: a market-oriented perspective, and a technology-oriented perspective (Schreieck et al. 2016). While the former focuses on the role of platforms as an intermediary between different groups of actors (Rochet and Tirole 2006), the latter emphasizes platforms' characteristic of serving as a foundation for complementary solutions provided by an ecosystem of third-parties (Gawer and Cusumano 2014). This technology-oriented perspective is adopted in the study at hand.

As physical products are increasingly equipped with sensors, actuators, connectivity, and software, digital platforms have become a major trajectory of innovation (Yoo et al. 2012). The extension of physical products with digital capabilities does not only allow for the collection and analysis of increasing amounts of data. Instead, it allows for the enhancement or re-definition of a product's or device's use along its lifecycle without the necessity of physical changes (Yoo et al. 2010). As a result, digital platforms are often associated with *Generativity* in the sense of triggering complementary innovation by third parties. In short, this means that different actors can use the platform as a basis to create a variety of different offerings and value propositions, enabled by the provision of boundary resources by the platform owner (Ghazawneh and Henfridsson 2013).

The term *Industrial Internet of Things* describes the connection of various kinds of industrial assets such as machines with each other, and with information systems (Sisinni et al. 2018). This is enabled by the equipment of machines with sensors, actuators, connectivity, and data storage and processing functions (Atzori et al. 2010). As a result, these machines become "smart", which enables new potentials for their use. Porter and Heppelmann (2014) classify the capabilities of such smart products or machines into four levels that build on each other: monitoring, control, optimization, and autonomy. Monitoring refers to the possibility of collecting real-time information about a machine's operation. Control defines the capability of remotely controlling smart machines because of their connected nature. Subsequently, intelligent algorithms can adjust and optimize performance. The most advanced capability of smart machines is completely autonomous operation by self-optimization and interaction with the environment and other machines. Consequently, in the case of IIoT platforms, with a heterogeneous set of such smart assets as well as a diverse ecosystem of third-party actors providing complementary solutions by drawing on the capabilities of smart machines, it stands to reason that they possess high generative potential (Yoo et al. 2010).

Method

To answer our research question, we conducted a single case study (Yin 2018) using online data from the website as well as the application store of an IIoT platform established by a large European industrial firm. The platform allows for the collection of data from industrial assets irrespective of the manufacturer and provides cloud- and edge-computing functionalities. Furthermore, boundary resources such as software development kits and application programming interfaces provide third parties with the means to create complementary solutions in the form of applications that use the asset data.

The case was selected by convenience sampling based on the large amount of data that was readily accessible. In total, we collected 54 use cases and 60 applications including descriptions of their functionality and the benefits offered by their use. We chose to look at these two units of analysis instead of focusing on one because of conceivable differences in their innovativeness. While applications are available for a generic set of customers, similar to applications on mobile platforms such as Android, use cases describe solutions that have been realized or can potentially be realized for single customers. Thus, use cases might display more advanced solutions that are difficult to provide in the form of a generic application. After a first check, we removed three use cases and nine applications from our dataset, as they did not leverage or offer any smart capabilities but focused, for example, on the support of application development itself. This left us with a final set of 102 solutions for our analysis.

Subsequently, we analyzed the collected data to gain insights on the manifestation of generativity on IIoT platforms. Generativity in the context of digital platforms describes their potential to drive the creation of a variety of different innovations by a multitude of actors. Subsequently, we propose that generativity manifests in the variety of solutions that are created on a platform. To operationalize the construct of generativity as defined above, we therefore chose to look at two dimensions. First, we looked at the different solution scenarios such as predictive maintenance or fleet management. Second, we assessed the level and diversity of smart machine capabilities leveraged by the solutions.

To determine the variety of solution scenarios we inductively assigned the solutions to categories emerging from the data, adding a category every time a solution could not be assigned to an existing category. While we initially assessed the diversity of capabilities deductively by assigning the solutions to the pre-defined categories monitoring, control, optimization, and autonomy as defined by Porter and Heppelmann (2014), we inductively added an additional category that emerged from the data. Our understanding of the different levels of capabilities is provided later on in Table 2. In addition, we noted whether the solutions are provided by the platform owner or by complementary actors to identify potential differences in the exhaustion of generativity.

Preliminary Results

Table 1 shows our results with regard to the diversity of solution scenarios we found in our data. Besides the expected scenarios like condition monitoring and predictive maintenance, there are various other value propositions provided via the platform. While some solutions enable capacity forecasting or are used in inventory management, others address innovative areas such as worker safety by tracking worker's position and detecting problems such as fatigue via wearables. Another innovative example are solutions that track the position and condition of assets and goods in order to assure compliance with standards and guidelines. In conclusion, the diversity of solution scenarios on IIoT platforms is rather high, especially considering the variety of industries we additionally found in our data, ranging from aerospace over electronics to the marine industry. Nevertheless, the majority of solutions focuses on the three areas of performance monitoring, condition monitoring, and predictive maintenance.

Table 1. Summary of Diversity of Solution Scenarios

Diversity of Solution Scenarios		No. of Solutions			Examples
		Developed by Platform Owner	Developed by Third Party Complementor	Total	
1	Condition monitoring	17 (Apps) 1 (Use cases)	11 (Apps) 28 (Use cases)	57	Monitoring machine parameters to assess the machine's condition.
2	Performance monitoring	17 (Apps) 3 (Use cases)	13 (Apps) 17 (Use cases)	50	Tracking the efficiency of machines and production processes.
3	Predictive maintenance	7 (Apps) 1 (Use cases)	10 (Apps) 21 (Use cases)	39	Predicting the failure of machine parts and providing recommendations for maintenance.
4	Traceability	0 (Apps) 1 (Use cases)	4 (Apps) 14 (Use cases)	19	Tracking goods along the supply chain to increase transparency.

5	Quality control	0 (Apps) 0 (Use cases)	2 (Apps) 6 (Use cases)	8	Using artificial intelligence to support quality control of produced goods.
6	Compliance	0 (Apps) 0 (Use cases)	2 (Apps) 6 (Use cases)	8	Tracking products along the production process with unique identifiers to prove compliance.
7	Safety	0 (Apps) 0 (Use cases)	0 (Apps) 8 (Use cases)	8	Tracking worker location and environmental conditions to prevent hazards.
8	Inventory management	0 (Apps) 0 (Use cases)	1 (Apps) 4 (Use cases)	5	Tracking material inventory in real time and sharing data with suppliers.
9	Energy monitoring	1 (Apps) 0 (Use cases)	0 (Apps) 1 (Use cases)	2	Monitoring energy consumption or energy savings.
10	Capacity forecasting	0 (Apps) 1 (Use cases)	0 (Apps) 0 (Use cases)	1	Forecasting of passenger numbers on trains to predict necessary train capacity.
11	Pay-per-use	0 (Apps) 0 (Use cases)	0 (Apps) 1 (Use cases)	1	Charging for the usage of a machine instead of selling it by monitoring its operation.
12	Automated transactions	0 (Apps) 0 (Use cases)	0 (Apps) 1 (Use cases)	1	Automatic billing of customers depending on their resource consumption.

Table 2 shows our results regarding the diversity of capabilities used by the solutions provided on the studied IIoT platform. Based on our findings, the diversity of capabilities can be regarded as rather low. Naturally, the monitoring capability is inherent to all solutions as it forms the basis for the subsequent levels. However, the majority of applications and use cases does not go beyond monitoring. Control capabilities are used by only 10 solutions in our sample. With regard to optimization as a capability, we had to divert to some extent from our pre-defined understanding and split it into two slightly different categories: optimization with recommendations provided to a human actor, and automatic optimization. While we found 24 solutions displaying the former capability, we did not find any evidence for the latter. This partially relaxes the assumption of Porter and Heppelmann (2014) that each capability is the prerequisite for the following, more advanced capability, as recommendations for optimization do not require control capabilities.

It is important to note that applications as well as use cases can both address several scenarios as well as several capabilities. Therefore, the total numbers in the tables are higher than our dataset of 102 applications and use cases. On a side note, contrary to our expectations, we did not find evidence for a higher maturity of use cases compared to applications. However, the use cases in our sample showed a larger diversity in terms of solution scenarios than the applications. Furthermore, our results show that a large number of solutions, especially applications, are provided by the platform owner instead of complementors. Additionally, the third-party solutions display a higher variety of solution scenarios. This is, of course, linked to the prevalence of use cases on the third-party side.

Table 2. Summary of Diversity of Capabilities

Diversity of capabilities	No. of Solutions			Description
	Developed by Platform Owner	Developed by Third Party Complementor	Total	
Monitoring	25 (Apps) 3 (Use cases)	25 (Apps) 48 (Use cases)	102	Monitoring the status, performance or location of an asset.
Control	2 (Apps) 3 (Use cases)	2 (Apps) 3 (Use cases)	10	Controlling functions of an asset remotely.
Optimization (recommendation)	7 (Apps) 2 (Use cases)	8 (Apps) 7 (Use cases)	24	Providing recommendations for optimization of asset operation through data analysis.
Optimization (automatically)	0 (Apps) 0 (Use cases)	0 (Apps) 0 (Use cases)	0	Adjusting parameters for optimization of asset operation automatically.
Autonomy	0 (Apps) 0 (Use cases)	0 (Apps) 0 (Use cases)	0	Enabling autonomous operation of an asset without any human interference.

Concluding Remarks and Outlook

Similar to any research, this study is subject to some limitations. First, we only studied a single case, which might negatively affect the generalizability of our insights. Furthermore, we relied only on online data from the application store and website of the platform for this study. Data triangulation by conducting interviews with the solution providers could therefore be valuable for future research to create a more detailed picture. Third, the applications and use cases in our sample might not capture the full spectrum of solutions offered on the platform. However, it is very likely that the solutions published on the platform's website are among the most innovative for marketing purposes.

Concluding, our results indicate that to date, the generativity of IIoT platforms is either not leveraged to its full extent, especially regarding the realized capabilities of smart machines, or might be lower than typically assumed for digital platforms in general. Thus, our study extends the literature on the generativity of digital platforms by showing that generativity might be domain specific. While Zittrain's (2006) understanding of generativity is often applied to digital innovation in general, and digital platforms in particular, it might not be transferable unconditionally to the domain of IIoT platforms or even platforms in general. Whereas in the case of the Internet, Zittrain (2006) refers to "uncoordinated audiences" (p. 1980), the peripheral actors in platform ecosystems are usually subject to coordination and governance by the platform owner (Tiwana et al. 2010). Nevertheless, the heterogeneity of the connected assets as well as the different actors contributing to IIoT platforms create the potential for various innovations that should be used. It is therefore one of the key challenges for platform owners to balance control and autonomy (Tiwana et al. 2010), in order to reach the desired level of generativity and innovation.

To advance this preliminary study, we plan to conduct a multiple case study to identify potential barriers for the exhaustion of generativity that might be specific to the context of IIoT platforms such as governance mentioned above. The lack of control capabilities, for example, might be a deliberate choice by platform owners for security reasons. Furthermore, as most IIoT platforms have been established only recently, the rather low exhaustion of generativity might be associated with an early stage in the platform lifecycle. Additionally, we also see a need in identifying potential drivers of innovation in IIoT platforms. Studies in other fields, for example on mobile platforms, have shown that innovations by the platform owner can increase the innovativeness of complementors or push it to different directions because of attention spillovers and increased competition (Foerderer et al. 2018; Wen and Zhu 2019). As indicated by our data, the owner of the platform we studied in this paper already provides a substantial amount of applications. However, as these are generally less innovative and diverse than the solutions provided by third parties, the impetus for innovation may be limited in this case.

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