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Pattern-based Business Model Development for Cyber-Physical Production Systems

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Abstract

The application of Cyber-Physical Systems (CPS) in production systems leads to Cyber-Physical Production Systems (CPPS) or the Smart Factory, respectively. In such an environment products, production resources as well as processes are each individually characterised by the special qualities of CPS. The current and future business potentials of production networks with decentralized coordination are enormous. However it is difficult for companies to keep track of the risks and chances of CPPS and develop appropriate business models. Therefore in this contribution a methodology for the pattern-based development and realization of business models in the context of Cyber-Physical Production Systems is presented. The methodology comprises three main modules that cover the most important aspects of business models for CPPS. In the first module patterns of established business models are gathered and their applicability in the context of CPPS is examined. The resulting library is then extended with patterns explicitly dedicated to CPPS and represents the base for a development procedure model. In the second module the developed business models are assessed with regard to their risks. For this purpose a method to analyse the risks of different business models and the perception of customers is elaborated. The focus of the third module is on the operationalization of abstract business models into company-specific business processes. It contains a design scheme to model value creation networks as well as typical configurations of these networks. The overall methodology is therefore supposed to make the opportunities of CPPS not only available to big corporations but also to small and medium-sized enterprises.

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1. Introduction

At the edge of the 4th industrial revolution manufacturing companies currently face a fundamental change in the nature of their value chains. By combining local information processing and global communication capabilities in products and production systems of tomorrow, new opportunities open up for the architecture of complex systems. With embedded software previously simple subsystems become intelligent objects that autonomously execute tasks, raise events and communicate with other objects via the internet. Already today, such interconnected systems enable improved or novel business processes within the value creation along the product life cycle.

The current and future business potentials of production networks with decentralized coordination are enormous. However it is difficult for companies to keep track of the risks and chances of these Cyber-Physical Production Systems (CPPS) and develop according business models. Accordingly companies require support in the development, risk assessment and implementation of innovative business models for CPPS [1] [2] [3].

Current research shows that most business models can be reduced to recurring patterns [4]. One example for such a pattern is the concept of “Remote Maintenance” of products or production systems. In this case web-based technologies or the “Internet of Things” are utilized to support maintenance processes via the internet and thus improve them.

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Hence a broad pattern knowledge base is the key to exploit the full potentials of CPPS. Based on this knowledge base companies can identify new business models or enhance established ones step-by-step with a structured approach of a pattern-based business model development. The success of such developed business models then strongly depends on the perceived risks of the involved stakeholders. Therefore a detailed analysis and assessment of the risk situation is of outmost importance. Finally it is necessary to implement the theoretical business model into company practice by identifying the required changes of the existing business processes.

For this purpose in this contribution a methodology for the pattern-based development and realization of business models in the context of Cyber-Physical Production Systems is proposed. This methodology addresses the five relevant action fields pattern library, business model development procedure, risk analysis, operationalization and IT tool support. To further specify the problem background, chapter two discusses the special characteristics of CPPS in particular as well as the issue of business model development and risk analysis in general. In chapter three our proposed methodology is introduced by a detailed description of the most important modules pattern library plus procedure model, risk analysis and operationalization. Chapter four concludes with a summary and an outlook to future work required.

2. Problem Background

In this chapter the theoretical foundations for the proposed methodology as well as previous work in the literature are reviewed. In the first section the concepts of Cyber-Physical Systems as well as Cyber-Physical Production Systems are introduced. Subsequently methods of general as well as pattern-based business model development and risk analysis are discussed in more detail and the particular challenges within the context of CPPS are outlined.

2.1. Cyber-Physical Production Systems

Embedded systems are major drivers of innovation for current high-tech products. Via the internet these systems are increasingly connected with each other to merge the physical world and the cyberspace within so-called Cyber-Physical System (CPS). Supported by sensors these systems obtain information from their physical surroundings and provide them to internet services, that in turn can directly affect the physical world by actuators. CPS are part of a globally connected world where products, devices and objects interact beyond classical application boundaries and form the internet of things, data and services [1].

The application of CPS in production systems leads to Cyber-Physical Production Systems (CPPS) or the Smart Factory, respectively. In such an environment products, production resources as well as processes are each individually characterised by the special qualities of CPS. The resulting potential benefits are manifold [2]:

- Optimization of production processes, where the individual units of a CPPS know their application areas, configuration possibilities as well as production constraints.
- Optimised product customization by an intelligent composition of individually suited production systems under consideration of objectives as product properties, costs, reliability, deliverability, etc.
- Resource-efficient production by minimizing overhead costs and flawed resource allocation.
- Human-centred production processes, where the machines follow the workers' speed and instructions.

This paradigm change associated with CPPS, which is also referred to by the term Fourth Industrial Revolution, thus not only includes a further increase in automation but also the development of intelligent observation and decision processes. It enables the management and optimization of companies and even whole value chains in almost real-time. For the first time the unfinished product takes over an active role during its production: not a central control system but each part for itself determines which manufacturing process steps need to be conducted next. The product thereby controls its own production process autonomously, observes the relevant environment as well as process parameters by its sensor systems and triggers the according countermeasures in case of any disturbances [3].

Due to these new and unprecedented characteristics of CPPS the decision makers in industry and politics are unsure of how to exploit the new potentials in the best way. As CPS interact with each other beyond any company borders and control their own production process, the resulting value of the product can no longer be assigned to one single owner. It is instead necessary to identify new forms of collaborative product development and production between companies of the same or different value chains. New business models are therefore required to widely facilitate the benefits of CPPS.

2.2. Business models and recurring patterns

A unified description of the structure and the content of a business model can hardly be found in literature. Various definitions take different aspects into account, e.g. the value proposition, the process for creation of goods etc. In comparison to a strategy, a business model encompasses single aspects that are crucial for the value add for the customer. Goal is a holistic characterization of the business and simultaneously the reduction to the essentials [4] [5] [6] [7] [8].

From the different definitions can be deduced, that business models encompass many facts. For reducing complexity and giving a sound overview, an approach for a clear structuring is needed. Therefore, Osterwalder and Pigneur developed the "Business Model Canvas", which comprises eight parts surrounding the value proposition (i.e. customer segments, customer relationship, distribution channels, key partner, key activities, key partnerships, revenue streams and cost structure). Chesbrough separates his