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10.6 Sustainable increase of overhead productivity due to cyber-physical-systems

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Abstract
The amount of information is increasing constantly because of a growing automation in manufacturing processes and an increasing application of sensors. To handle this information in order to ensure sustainable decisions is the challenge in the future. Concurrently, the amount of decisions made by the management are increasing, which demands for an improvement of overhead productivity. This requires both the existing practical knowledge new technologies, which must be linked by matching software systems. The growing complexity of business processes will be configurable and controllable by the use of new assistance systems. Cyber-physical systems having characteristics such as ad-hoc networking, self-configuration and intelligent data processing will play a decisive role. This paper presents how current innovations can make an essential contribution to a further increase of overhead productivity by the support of collaboration and communication through cyber-physical systems.
Keywords:
Cyber-physical-systems, Optimization, Productivity, Sustainability

1 INTRODUCTION

Producing companies are facing the challenge to offer products matching individual customer demands at competitive prices [1]. At the same time the production is characterized by increasing market dynamics [2]. Hence, an adaptability of production systems is required, while assuring an efficient use of resources. Therefore, the effort and the complexity of planning, development and administration along the order fulfillment process increases. Indirect processes of manufacturing companies have been growing constantly and the need for knowledge workers and management staff rises. Today the support of these overhead functions must be focused to improve the overhead productivity. Thus, manufacturing processes will be more efficient in supporting producing companies to succeed on a global market.

Within the Cluster of Excellence "Integrative Production Technology for High-Wage Countries" current innovations are regarded to make a contribution to a further increase of overhead productivity by the support of collaboration and communication through cyber-physical systems.

2 INCREASING LABOUR PRODUCTIVITY IS THE CORE OF INDUSTRIAL DEVELOPMENT

The continuous increase in labor productivity is not only essential to high-wage countries it is the core of our industrial development and economic growth. In the last 20 years the annual increment of productivity (measured as gross domestic product GDP per person employed) in the countries of the OECD averaged 1,6 percent with tendency to sink, as shown in figure1 [3].

In the path of the industrialization three milestones of industrial revolution had a substantial impact on the increase of productivity.

- Availability of energy enables utilization of machines
- Economies of scale through division of labour
- Exponential growth in computing power enables automation of production

The development of the steam machine in the late 18th century marked the beginning of the first industrial revolution. As result the textile industry moved away from a decentralized production to a single production facility. The success was not driven by the plain revolutionary design, in fact it was the economic usability combined with a demand for a higher productivity. Due to the decentralization of production, many workers left their villages and moved to the city to find work at a factory. A former agrarian society changed to an industrial urbanized society [4].

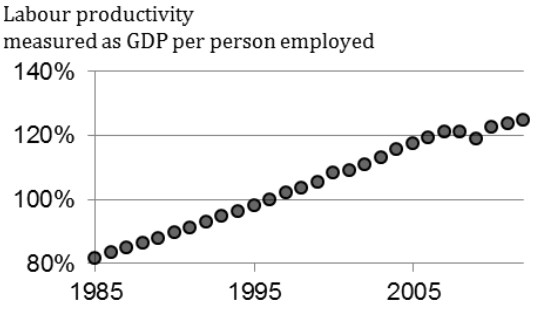


Figure 1: The development of labor productivity (OECD) [3].

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In the early 20th century the upcoming second industrial revolution laid the ground for a further increase in productivity. Henry Ford's introduction of the assembly line and Charles Taylor's scientific management enabled mass production of standardized goods, such as the Ford Model T [5]. Falling product prices and rising income lead to a rising consumption. Governmental regulations were passed to improve the working conditions and social issues. The second industrial revolution was enabled by the recognition that costs decrease if quantity rises.

The third industrial revolution was essentially a shift from mechanical and analogue electronic technologies towards digital technologies and is therefore sometimes also called the digital revolution. It began around 1980. One of its main results has been the automation of the production. The third industrial revolution has been enabled by the invention of digital computers. Their increase in processing power can be described by Moore's Law, which dates back to 1965. As it is displayed in figure 2, Moore's Law states that the number of transistors on a given chip can be doubled every two years [6].

Although the period is frequently quoted as 18 month in present times the law has been accepted until today. The improving chip performance is ensured by a higher number of transistors on integrated circuits. The increasing performance goes hand in hand with a simultaneous reduction in price. Moreover the increase in performance allows to solve problems, that couldn't be solved before. Today for example the implementation of data mining in web search engines is no longer a problem. At the same time the price reduction and performance improvement ensure that the application of such systems is possible in new areas. With the use of these systems additional data is created, which form a digital infrastructure that enables the step in further innovation [9].

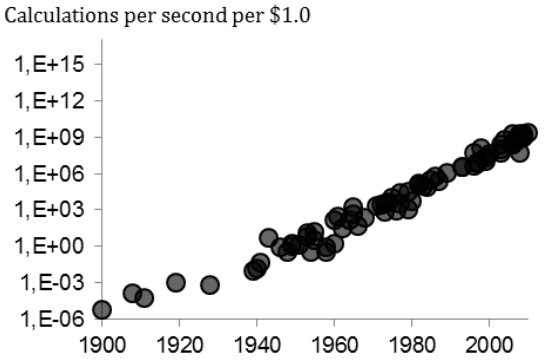


Figure 2: exponential growth of computing power: Moore's Law [7, 8].

According to Kagermann the fourth industrial revolution has just started [10]. New technologies enable a collaborative productivity, from which production and the whole economy might benefit in a way that new increases in productivity can be reached. In order to take advantage of this new development a description analogue to Moore's Law is essential. In the following chapter we deduce a trajectory, which describes the development of collaborative productivity as a result of this fourth revolution.

3 INDUSTRIALIZATION OF OVERHEAD THROUGH COLLABORATIVE PRODUCTIVITY

3.1 The 4th industrial revolution and industrialization of overhead

Collaborative productivity is defined by three types of collaboration and communication: between people, between people and smart devices (Human–computer Interaction, HCI) and between smart devices themselves (Machine to machine, M2M). The main prerequisite for these information exchanges is the internet. In 2008, the things connected to the internet exceeded the human population on earth [11]. This progress is partially driven by the rising popularity of smartphones and their ability to access the internet irrespective of the place and time. Therefore it's possible to instantly gain or provide information. Social networks like Facebook benefit from this development as they allow people to connect with each other. Consequently smart devices use the internet or local networks to communicate with one another, whether there's direct human interaction present or not. While the first three revolutions had a strong focus on the shop floor we are now facing the opportunity to industrialize business processes and overhead. Most companies focus on improving production and logistics while disregarding the potentials in their indirect departments (see figure 3).

In order to tap the potentials and increase the productivity in these areas, companies have to industrialize their business processes and overhead focusing on collaboration and communication. The improvement of the work performance, especially facilitating processes and assisting decisions can be supported by cyber-physical systems. Cyber-physical systems can be considered as a composition of embedded systems, real physical systems and sensor systems [12]. These objects can communicate via internet. An object can be both man and machine [13]. The real physical world and the virtual world, the "cyberspace", are completely connected with each other [10].

The impact of the current developments can be illustrated by three examples:

- Researchers at the University of Southern California took four years: 1986, 1993, 2000 and 2007 and extrapolated numbers from roughly 1,100 sources of information [14]. They discovered that in 2002, digital data storage surpassed non-digital for the first time and by 2007, 94 percent of all information on the planet was already in digital form.
- A study of Accenture shows how consumer technology is changing the modern workplace [15]. Employees are demanding the right to use their own smartphones and tablets. They feel more productive using their personal IT. Executives can not ignore this fundamental change anymore even though they have no adequate answer to manage this situation yet. 23% of employees use their personal devices at work regularly and about the same amount of employees would even be willing to defray the costs. 44% are dissatisfied with the devices and software applications provided by their company [15].
- In a freestyle chess tournament in 2005 hosted by Playchess.com anyone could compete, even teams of people or people with computer [16]. Surprisingly not the grandmaster with a state of the art computer or the super-computer won but a group of amateurs using three computers at the same time. They managed to combine

human strategic guidance with tactical acuity of a computer in the best way.

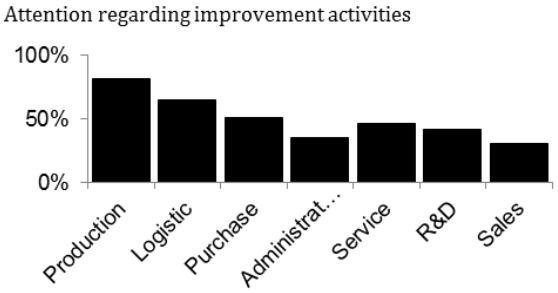


Figure 3: Results of a survey from 2011 of WZL RWTH Aachen University regarding production systems in over 80 companies.

3.2 Approach of predicting the industrialization of overhead

Due to cyber-physical-systems and their impact on collaboration we expect the possibility of a strong increase of productivity in indirect departments that needs to be faced. In this chapter we will introduce an approach for predicting this industrialization of overhead. In the same time the presented approach gives details on how to face these changes.

The core idea of the approach is that in the future more and more management activities will be supported and consulted by information technology devices, which are cyber-physical-systems. Management, indirect employees and all kind of brain workers will spend less time with gathering information or doing routine activities. Instead they will be disburdened by smart devices that allow data access in real time and high resolution and autonomous execution of routine tasks.

To predict the industrialization of overhead, the presented approach takes four main aspects into account.

- The increasing performance of smart devices, software and hardware [17]
- The increasing number of smart devices including infrastructure [18]
- The friction or efficiency of the interfaces (data-software, software-software, human-software)
- The management qualifications of the employees, which we keep constant in this approach.

We choose to keep the management qualifications constant in this first approach in order to simplify the model and focus on the main implications. However we assume, that the qualifications of employees will rise due to the interaction the interaction with these smart devices and the systematic aggregation of information and the succeeding learning and experiencing.

As a conclusion of the chess tournament Geshe deduced an equation to explain the unexpected outcome [16]. This equation combined with an equation of Hilbert is used to calculate the increase of overhead productivity (see Table 1) [17].

Table 1: calculation of overhead productivity

$\Delta_a = \frac{a_i}{a_{i-1}} - 1$	
$a_i = h_i \frac{c_i}{(1+f_i)}$	$h_i = const.$
	$c_i = c_{i-1} + (c_{i-1} \times (p_h + p_s + n))$
	$f_i = f_{i-1} \times (1-r)$

Variables		
p_h	4%/a	incr. of performance of devices, hardware
p_s	2%/a	incr. of performance of devices, software
n	2%/a	incr. of number of devices, infrastructure
c	(p_n, p_s, n)	computer power
h	const.	Management power
f_0	0,5	friction of human-computer interaction
r	5%/a	reduction of friction per year
a	(h, c, f)	analytic management power
Δ_a	1/a	incr. of overhead productivity per yr.
i		year

As a result of the equation figure 4 displays the expected curve of the increase of overhead productivity in the following years. The development is based on the assumptions shown in the variable list (see Table 1).

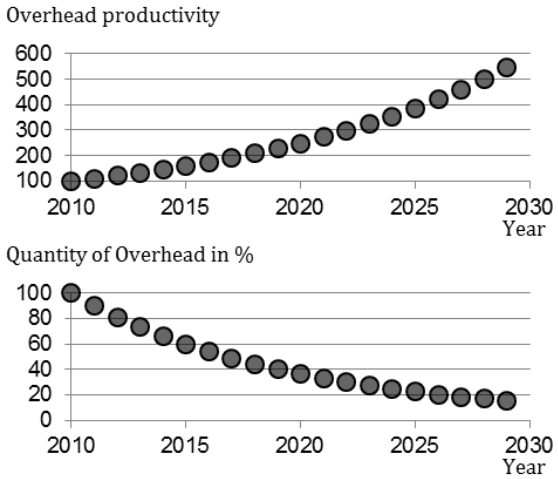


Figure 4: Increase of overhead productivity in the following years.

The assumptions from Hilbert (concerning the variables p_h, p_s and n), which are based on a static system state, have been adapted to meet the reality in companies. Furthermore Hilbert calculates with higher values [17]. We reduced these values according to the average life cycle of devices in companies. The result is a rather conservative gradient of the curve. The friction of human-computer interaction is a first assumption based on experiences and is currently being validated in an on-going research project.

3.3 Preconditions for the increase of productivity

To reach the described increase of productivity in indirect departments of a producing company, the following innovations are necessary:

- technological support for communication
- reduction of friction between management and IT
- semantic models to override the heterogeneous IT-world

In the Cluster of Excellence nine projects are inventing technologies to support the described development. One of them is AixViPMaP, a project that develops a platform to integrate material and process simulation to overcome semantic problems in the product and process development process [19].

4 CONCLUSION AND FURTHER RESEARCH

An increase of productivity of overhead is essential for companies in high-wage countries as well as emerging economies. The analytical skills of human management power will rise through the intense interaction with new hard- and software applications. Thus, the complexity in planning production processes can be handled more efficiently and reliably. The results are ideally planned manufacturing processes with reduced planning costs. Applied systems and their solutions will be more transparent and the trust in these systems will rise.

Nevertheless the described development and its implications will call for further research in production management as well as in human-machine-interaction to further increase the productivity of overhead.

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