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Data-based identification of knowledge transfer needs in global production networks

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Abstract

Manufacturing companies' value chains are increasingly distributed globally, which presents companies with the challenge of coordinating complex production networks. In general, these production networks grew historically rather than having been continuously planned, leading to heterogeneous production structures with many tangible and intangible flows to be coordinated. Thereby, many authors claim that the knowledge flow is one of the most important flows and the source of competitive advantage. However, today's managers face major challenges in transferring production knowledge, especially across globally distributed production sites. The first obstacle to a successful knowledge transfer is to identify what kind of knowledge should be transferred between whom and at what time. This process can take months of information collection and evaluation and is often too time-consuming and costly. Thus, this paper presents an approach to automatically identify at what point knowledge should be transferred. In order to achieve this, the company's raw data is being used to identify which employees work on similar production processes and how these processes perform. Therefore, production processes, which can be compared with each other, need to be formed, even though these processes may be performed at different production sites. Still, not every defined cluster of production processes necessarily requires the initiation of knowledge transfer since performing a knowledge transfer always entails considerable effort and some processes might already be aligned with each other. Consequently, in a next step it is analyzed how these comparable production processes differ from each other by taking into account their performances by means of feedback data. As a result, trigger points for knowledge transfer initiation can be determined.

Keywords

Knowledge transfer; Production network; Network coordination

1. Introduction

In the last decades, production has spread globally and value chains are becoming more and more fragmented leading to growing and complex production networks [1]. One consequence of this development is the often rapid and partially unstructured growth of the globally distributed production sites. The coordination and synchronization of these sites among each other is a major challenge. [2] As a result, global production networks are considered among the most complex man-made systems with many tangible and intangible flows to be coordinated [3]. One of the most important flows is probably the knowledge flow, yet very difficult to manage [4]. Many authors agree that the cross-site knowledge transfer of methods and best practices is a major challenge and an unsolved problem in practice [4,5]. However, at the same time the transfer of globally distributed knowledge in a production network is considered as a significant competitive advantage [6–9]. Knowledge transfer enables the alignment of performance differences between existing processes and supports employees to learn from each other by bringing them together in a context-specific way [7].

In general, knowledge transfer is defined as a process in which one organizational unit passes experiences, information and skills to another [10,11]. Thus, the elements of a knowledge transfer are the sender, the receiver, the transferred knowledge and the organizational context as for the relationship between sender and receiver (cf. Figure 1) [12]. In terms of knowledge transfer in production networks, production knowledge is particularly important, including manufacturing technologies as well as the operational knowledge as a recipe for action [4,5].

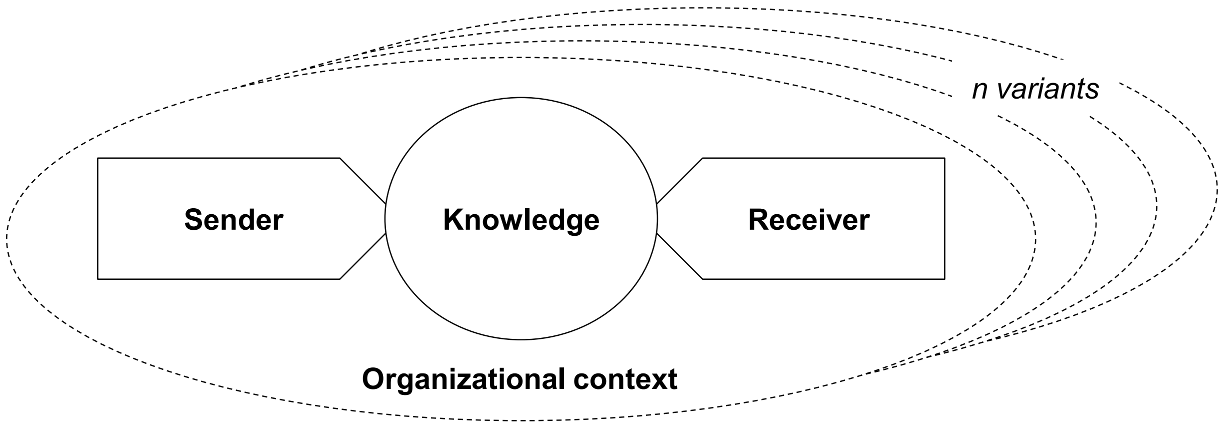


Figure 1: Elements of knowledge transfer [12]

Considering these different elements of knowledge transfer and the complex structure of production networks, an almost infinite number of potential knowledge transfer opportunities exists. Hence, it is difficult to identify where knowledge transfer is necessary in production networks and how the elements of a transfer need to be defined. Some companies try to address this challenge by operating a knowledge data bank like a knowledge “yellow pages”. However, such knowledge data banks serves rather as provisioning for operational information than connecting the right employees for an actual transfer of production know-how. [5] In order to address this problem, this paper aims to present an approach to systematically identify the need for knowledge transfer with the corresponding transfer participants within a production network.

2. State of the Art

In recent years, many researchers have increasingly focused on the topic of knowledge transfer in inter-organizational networks. Thereby, a lot of scientific work is based on the work of TSAI from 2001. [13] TSAI studies how the network position as well as the absorptive capacity effect the ability to create and capture knowledge. He argues that social interaction can foster knowledge transfer across business units. For stressing out his statement, he analyzed data from two companies with a total of 60 business units with the result that by obtaining a central network position, an organizational unit can benefit more from knowledge transfer and sharing. With his work, TSAI presents first impulses to strengthen knowledge transfer. [9] However, a more detailed approach with a guidance for improving knowledge transfer in production networks is delivered by FERDOWS. He presents a framework for choosing the appropriate transfer mechanism depending on the type of knowledge. Therefore, FERDOWS differentiates between tacit and codified as well as slow and fast changing knowledge, leading to four different knowledge transfer mechanisms. Thus, he distinguishes between transferring production know-how via manuals and systems, joint developments, projects and moving people. [5]

CHENG et al. go one step further by not only discussing how knowledge should be transferred, but also where and when the transfer should take place. In this context, they propose a time-place matrix for coordinating knowledge transfer. The authors point out that, for an efficient knowledge transfer, the right sequence between know-where, know-which, know-when and know-how is important. Hence, CHENG et al. point out that, before performing a knowledge transfer, the transfer initiation with defining the knowledge that should be transferred and the transfer participants is crucial. [14] Based on the approach of CHENG et al., FRIEDLI et al. develop a framework for managing knowledge flows with an orientation guide to enabling knowledge transfer. They discuss as well what kind of knowledge should be transferred between whom, at what time and with what kind of transfer mechanism. Furthermore, FRIEDLI et al. analyze different exchange structures and the degree of transparency for improving knowledge transfer. [7]

As described above, some approaches exist on the topic of knowledge transfer in production networks. Most research has been done in developing frameworks for coordinating knowledge transfer and defining the correct transfer mechanism. In addition, CHENG et al. and FRIEDLI et al. point out that determining the right time and the right transfer participants is important for an efficient knowledge transfer. Still, an approach to systematically identify knowledge transfer needs and the required transfer participants is missing. At the same time, researchers such as SZULANSKI point out that the procedure of identifying knowledge transfer needs could take months of information collection and evaluation [15]. This is especially critical with regards to global production networks with a wide range and distribution of different production processes and experts. Thus, a high number of potential knowledge transfer opportunities exist. In this context, LEYER et al. claim that connecting employees for a knowledge transfer should be based on indicating their process-related areas of expertise [16]. Consequently, determining what production processes are comparable within a production network serves for identifying which employees work in similar fields and could potentially learn from each other. Therefore, approaches for analyzing similarities of production processes are relevant for this topic, although these approaches are not directly categorized in the research area of knowledge transfer.

For example, approaches that identify comparable production processes to improve production planning and manufacturing process design can be used for orientation. Therefore, LI et al. use publicly available and general information about manufacturing processes and technologies to identify similarities based on the process capabilities such as achievable tolerances and machinable materials. A pairwise comparison of each process based on its capabilities serves as a basis for the subsequent application of a hierarchical cluster algorithm and graphical evaluation. The systematic approach and the data-based analysis of process characteristics and capabilities serve as a good orientation for identifying comparable production processes. [17] In a similar way, AHN AND CHANG and ZHANG et al. analyze production processes based on two aspects: the attributes of involved machines and other resources as well as the order of process steps. AHN AND CHANG focus on using graphical modelling methods like the BPMN (business process model and notation) to compare the processes based on a standardized metric [18]. Next to that, ZHANG et al.'s approach is based on the description and subsequent comparison of production processes using process graphs [19]. The individual units of such a process graph, which are displayed in the processing sequence, contain information about the type of operation, the position of the individual process in the process chain and characteristics of the operation. Hence, the comparison of the sequence and properties of the individual process units gives a detailed picture of the composition and comparability of production processes.

Another approach for analyzing comparable production processes is to identify similar products. In this field, LENZ et al. and BRUNO analyze the manufacturing processes involved in the various products in order to identify comparable products. BRUNO uses a manufacturing process ontology and identifies similar products by comparing the manufacturing technologies that are used for the products. [20] LENZ et al. go into more detail by focusing on the analysis of the data from CNC machines with the G-code containing the various attributes of machine movements. Thus, the G-code serves as the basis for the analysis of the manufacturing processes and subsequent identification of similar products. [21]

Examining these approaches shows that analyzing product characteristics as well as resource characteristics can be used to identify comparable production processes. Furthermore, data-driven analysis supports this process and helps to automatically identify comparable production processes. This can be helpful to identify knowledge transfer needs based on comparable production processes, especially considering the high number of different potential knowledge transfer opportunities in production networks. However, data-driven approaches are currently missing in the research area of knowledge transfer in global production networks and should be focused more intensively in the future.

3. Approach

Based on the analyzed requirements for the identification of knowledge transfer needs and the examination of existing approaches in this field of research, a new approach is presented in Figure 2. This approach is divided into three steps beginning with the characterization of production processes in production networks, followed by the identification of comparable production processes and the identification of knowledge transfer needs.

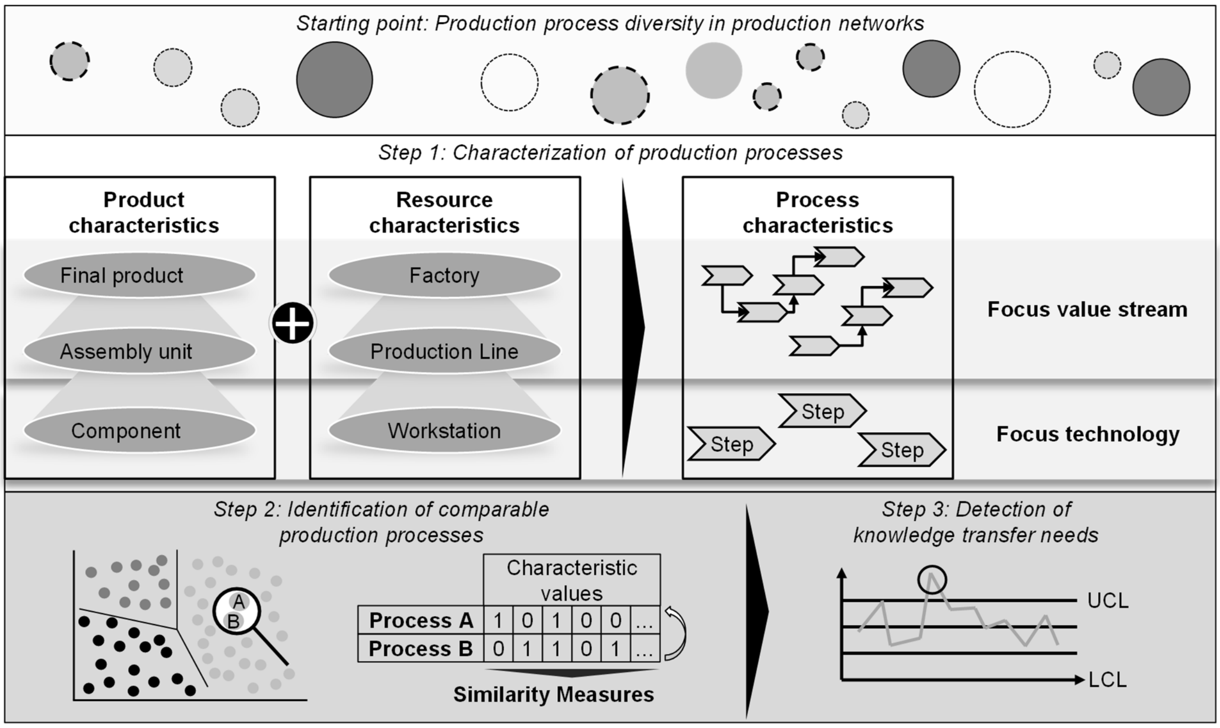
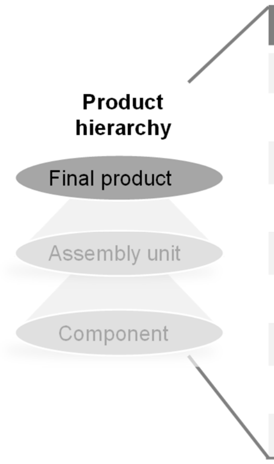


Figure 2: Approach for a data-based identification of knowledge transfer needs

In the first step of the presented approach, production processes are characterized in order to build a framework to automatically identify comparable production processes out of the diversity of production processes in global production networks. As analyzed in chapter 2, the description of production processes can be based on product and resource characteristics. This is consistent with the framework according to STEINWASSER who describes production processes as a combination of product and resource factors [22]. By distinguishing between these two areas, there is a clear separation between different production processes with simultaneously low complexity for further analysis. For defining both product and resource factors, a differentiation between different aggregation levels is necessary, since characteristic features differ depending on the structural level. At the product level, a distinction can be made between final products, assemblies and components [23]. The characteristic features used to describe a final product are for example the product structure, the product range and the production scale in terms of batch sizes (cf. Figure 3). In contrast, on the component level relevant characteristic features are for example the raw part geometry, the material used and requested tolerances. At the resource level, in a production network a distinction can be made between the factory, the production line and the workstation at the lowest level [24]. At the factory level, information on the factory type, the logistics structure and the number of workstations and machines are relevant. Whereas at the workstation level, other characteristic features, such as the manufacturing technology and the specification of tools are focused. Depending on the structural level of the product and resource type, the level of the production processes differs with focusing either on the value stream analyzing the process flow between different process steps or rather the technology within a process step.



Product characteristics	Description	Scale level
Structural level	Bill of material level of the product	Metric scale
Strategic positioning	Amount of the profit margin	Metric scale
Production costs	Costs for manufacturing a product	Metric scale
Direct production cost share	Percentage of costs of goods manufactured	Metric scale
Material cost share	Percentage of costs of goods manufactured	Metric scale
Product structure	Number of structural levels and items	Metric scale
Product range	Degree of standardization of product design	Ordinal scale
Production scale	Lot size in relation to repeatability	Metric scale
Stocking strategy	Level of the stockholding requirement item	Ordinal scale

Figure 3: Exemplary product characteristics on the level of a final product

In order to characterize production processes as described above, different data is needed to automatically identify comparable production processes in the following. Therefore, an UML data model is displayed in Figure 4 summarizing the information needs from different data sources. The product and resource information are typically stored in different information systems such as an ERP system (enterprise resource planning) or MDC system (machine data collection). However, these different kinds of data are typically connected with each other in a work plan for a specific process step. Thus, the work plan is the description of the process steps with an operation description and an associated process owner. This information primarily serves to identify comparable production processes and to identify which employees are working on these processes. Next to this information, performance characteristics by means of production feedback data are important in order to assess the production processes and to identify deviations. This information is needed to evaluate how comparable production processes differ from each other and in what dimensions employees should learn from each other. Feedback data is typically connected to a specific work order and in this way to a specific product and resource type.

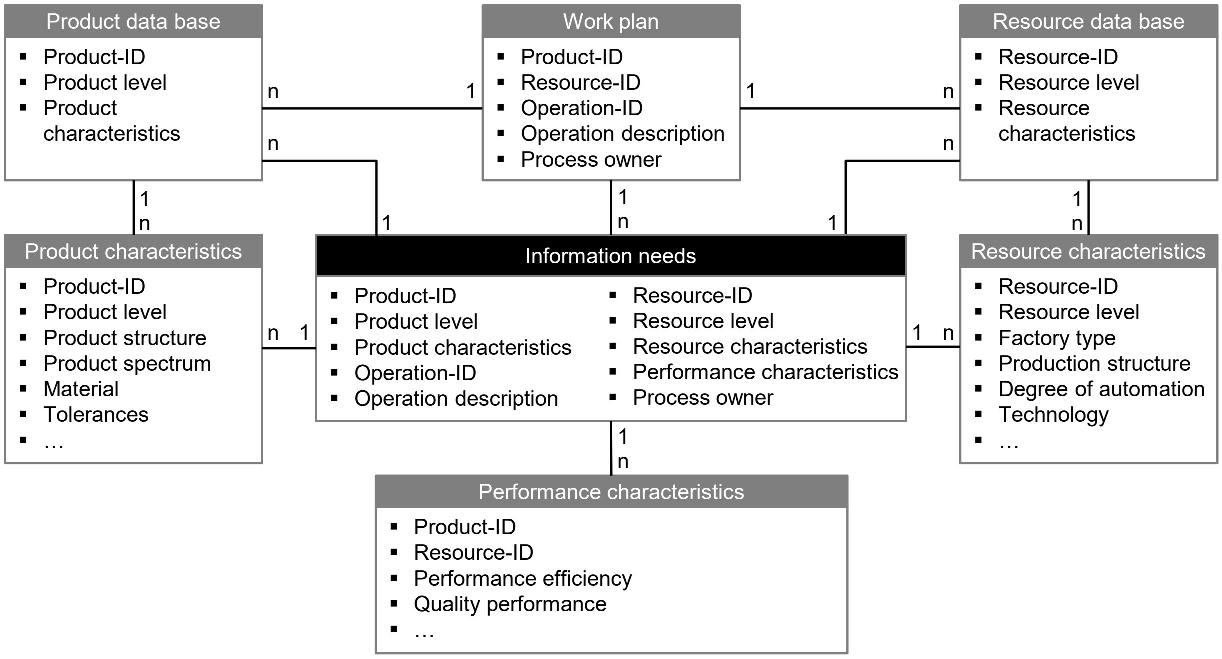


Figure 4: Information needs to characterize production processes

After characterizing the different production processes within a production network, the second step of the presented approach is the application of clustering and similarity analysis based on the described data model to identify comparable production processes. When selecting suitable data-based analysis methods, several criteria must be taken into account. On the one hand, the analysis of large amounts of data should be carried out as quickly and largely automatically as possible, so that manual steps for the user are only necessary for a qualitative evaluation of the results. In addition, it must be possible to analyze both metrically and non-metrically scaled values since some product and resource characteristics are categorized in a nominal or ordinal scale (cf. Figrue 3). Furthermore, the methods used should already have been tested in practice and thus be able to show a high user acceptance. Considering these prerequisites, the choice for the analysis of metrically scaled characteristics is a cluster analysis. The affiliation to a cluster is essentially determined by the distance of the characteristics between the individual objects. Objects that can be assigned to a cluster should therefore have a small distance to each other. This describes the homogeneity within the clusters. On the other hand, the different clusters should have objects with a high distance to each other, which describes the heterogeneity between the clusters. [25] Next to the cluster analysis, the analysis of comparability of non-metrically product and resource characteristics is determined using a similarity analysis. The pairwise calculated similarity values of two processes are the basis for the decision and are compared with a limit value defined by the user. If the similarity value is above the specified limit value, it can be assumed that the two processes are comparable. [26] The final decision on the comparability of the identified processes is made by the user within the framework of a qualitative evaluation of the results and a plausibility check.

The third step of the approach is finally the identification of knowledge transfer needs based on the determined cluster of comparable production processes in a production network. A cluster of comparable production processes does not automatically lead to a knowledge transfer need since these processes might already be aligned with each other. A knowledge transfer always entails considerable effort, which is why it should only be performed if a need exists. Hence, production feedback data to the production processes can be used to analyze the process performance as described in the data model in Figure 4. For automatically identifying process deviations, statistical process control (SPC) can be used. This is a widely used method for monitoring processes and detecting deviations. For this purpose, statistical control charts are the tools to implement SPC by systematically analyzing the output of processes. Therefore, upper and lower control limits (UCL, LCL) are defined depending on the mean value of the performances within a process cluster.

[27] For the purpose of process monitoring in production networks, an adaptive control chart is necessary since the design parameters need to vary over time. Thus, the width of the control limits needs to be adjusted company-specific depending on the processes' sensitivity. As a result of the SPC, process deviations within a cluster of comparable production processes can be determined and the upper and lower control limits can be used as trigger points for a knowledge transfer need.

4. Discussion and future research

In this paper, the main challenges for knowledge transfer in production networks and a three-step approach to systematically identify knowledge transfer needs are presented. Due to the high variety and amount of knowledge transfer opportunities in production networks, a data-based approach is chosen. In the first step, a framework has been developed to determine which production processes can be compared with each other. This step is necessary to identify which employees work on comparable production processes where a potential knowledge transfer need exists. For this purpose, production processes are described as a combination of product and resource factors with varying characteristics. In this context, an UML data model has been developed to show the information needs to characterize production processes. Based on this data model, the second step describes the application of clustering and similarity analysis to automatically identify clusters of comparable production processes. The third step of the presented approach focuses on the identification of knowledge transfer needs based on production feedback data. Therefore, statistical process control can be used by analyzing deviations within a cluster of comparable production processes and applying upper and lower control limits as trigger points for a knowledge transfer initiation.

Further research is required by detailing the needed feedback data for the statistical process control. Depending on the aggregation level of the cluster of comparable production processes, the target system for these production processes differs. Consequently, an adaptive target system with the corresponding production feedback data is needed. Moreover, further research aims to validate the developed approach and ensure its applicability in practices.

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Biography

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