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Technology lifecycle-oriented search for production technologies

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ABSTRACT

The adoption of production technologies is a major challenge for manufacturing companies. Despite the long term impact of decisions on production technologies, companies are often unaware how to search for alternative production technologies. We developed a method that focusses on the systematic search for production technologies for fulfilling future manufacturing tasks. The method consists of three steps including the selection of information sources, information search and information evaluation. It takes advantages of the concept of technology lifecycles. The method provides a useful tool for producing companies and has been applied exemplary in the automotive industry.

Introduction

The contemporary literature stresses that producing companies face challenges of dynamic environments and increased competition (e.g., [1–3]). Such dynamics are partly driven by customer demands for high quality and low-price products in a shorter time [4]. One important aspect to meet these challenges is the adoption of production technologies.[1]

Companies often lack awareness of available technologies as they are primarily searching inside their own industry. However, effective technologies can also be found in remote domains, also referred to as analogous markets [6]. Analogous markets share similar characteristics. Interestingly, such technologies often provide a high potential. According to that, Ashton and Stacey [7, p. 81] state that technologies outside the company "hold important potential for creating economic value more rapidly and at less cost than traditional internally-developed advances."

However, the identification of unknown technologies is resource-intensive since companies often cannot specify their prospective technology need. Moreover, a large amount of information and a variety of information sources can be an obstacle rather than an aid for searching for adequate technologies [8]. Companies do not have a systematic way to structure the available information and its sources and thus often fail to identify suitable technologies [7,9,10]. A systematic search for technologies is necessary to identify appropriate technology-related information and use them for deciding about the adoption.

This paper develops a method to systematically search and identify production technologies. Available technologies follow a lifecycle [11] and thus differ in their maturity [12]. Maturity partly reflects a technology's potential as well as its risk. The utilization of information sources depends strongly on the technology lifecycle [8,13]. Based on suitable information sources, search paths can be used to reach these sources and extract relevant information before information on technologies identified are summarized in technology profiles. In this context, technology search is defined as a systematic search for adequate information on technologies at different stages of their lifecycle using suitable information sources.

Technology search is part of technology intelligence that contributes to the registration of technological threats and opportunities resulting from a company's environment [14,15] by capturing, evaluating and delivering relevant technology related information based on defined information needs [8,15–17]. However, shortcomings in the current practice of technology intelligence are identified. This comprises the missing differentiation between technology types, e.g., product technologies and production technologies. Current technology intelligence processes are further too generic to be applicable within industrial practice (e.g., [7–10,18–22]). Moreover, these processes focus on different objectives including the identification of mostly emergent technologies, their respective development in future and the

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[1] We define production technologies (referred to as "technology" in the following) as emerging and established production processes needed to produce current and future products (based on [5]).

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resulting threats and opportunities belonging to the company (e.g., [7,9]) rather than the identification of technologies for a specific manufacturing task. To support technology intelligence, there are approaches dealing with manual (e.g., [23–26]) and automatic (e.g., [27–31]) search for information in the context of information management. However, a metamodel for searching for information on technologies in multiple sources is lacking as well as search paths to access these sources.

Thus, we add to the literature on technology intelligence. We develop a method, which is domain-spanning and applicable to producing companies to systematically search for production technologies depending on their lifecycle.

This article is structured as follows. "Sources for technology search" section addresses the principles for selecting adequate information sources. "Dimensions for information evaluation" section provides a common understanding for evaluating the quality of information on technologies. In "Method for technology search" section, the method for technology search is developed and applied in an industry case. "Discussion and conclusion" section serves to discuss the developed method and concludes the paper.

Sources for technology search

The objective of searching for technologies is to capture useful technology-related information in adequate information sources. Therefore, we collected information sources from literature ("Collection of information sources" section) and classified them ("Classification of information sources" section). According to Brenner [13] and Lichtenthaler [8], the use of information sources also depends on the corresponding phase of the technology lifecycle for which a company searches for a technology. The relevance of the information sources correlates with the phases of this lifecycle. For that reason, we estimated the relevance of these sources to find information on production technologies in an empirical investigation by carrying out a questionnaire-based study ("Relevance of information sources depending on the technology lifecycle" section).

Collection of information sources

Information sources build the basis of any search method for production technology. To capture as many of these sources, the literature is reviewed.

In the field of technology intelligence, and beyond, within competitive intelligence, 18 literature sources were gathered. They include a list of 283 information sources in total that are potentially applicable to find information on technologies. However, these sources may be present on various *levels of aggregation*. For instance, Lichtenthaler [8,16,20] and Dully [32] mention "publications", while Mortara et al. [21] differ between "field publications" and "non-field publications". Information sources are further characterized by their *heterogeneity*. Wolfrum [33] cites research and development magazines. By contrast, Reger [9] distinguishes between magazines, newspapers and conference proceedings. In order to ensure a consistent list of available information sources to search for information on technologies, the sources quoted in literature are consolidated. These information sources are listed and defined in Table 1.

Classification of information sources

Kerr et al. [17] differentiate between three main classes of information sources named white, gray and black. These can be characterized according to their accessibility in general, whereby this paper focuses on white and gray information sources that are available legally. According to Kerr et al. [17], *white* information sources contain information that are publicly accessible, while gray information sources cover information not formally published. Each of the two main classes considered is further divided into subclasses.

There are information sources within and outside the focal company. Further, they can either be formal or informal. Formal means that the information is available in written form, e.g., conference proceedings, and patents. In contrast, informal sources denote information embedded in people's minds, e.g., undocumented discussions at conferences with experts. According to this

Table 1
Information sources from literature.

Information source	Definition	Literature sources
Internet	Information on websites and newsfeeds, which are freely available (websites of suppliers, etc.)	e.g., [9,21,22,35–38]
Intranet, internal reports and database	Information in the intranet or internal reports that are not accessible to people outside the company	e.g., [7,9,18,32,37,38]
Patents	Information from patent databases (patent offices, etc.) that permit an accurate access on patent specifications	e.g., [7,8,18,33,35–38]
Written publications	Information in literature (journals etc.) or literature databases, that permit an accurate access to this (Google scholar, etc.)	e.g., [7–9,16,20,34–38]
Technology studies	Information on technology studies and reports, which are worked out by governments, consulting, associations, etc.	e.g., [8,16,20,33–35]
Public research programs	Information on research projects in databases of research sponsors (German research foundation, etc.)	e.g., [7,9,18,36,37]
Scientific events	Information on novel scientific findings, which are accessible by participating at the event (conferences, seminars, etc.)	e.g., [7–9,16,18,20,22]
Commercial events	Information on the latest technologies for serial production available by joining the event (trade fairs, etc.)	e.g., [16,20–22,34–38]
Personal contacts	Conversations and voting meetings with personal contacts first-hand, by telephone or email, etc.	e.g., [16,20–22,34–38]
Internal experts	Conversations and voting meetings with specialists, R&D employees, gatekeepers first-hand, by telephone or email, etc.	e.g., [7–9,16,33–38]
External experts and stakeholders	Conversations and voting meetings with employees of suppliers, competitors, consultants, etc. by telephone, etc.	e.g., [7–9,16,20–22,35]
Research institutes and universities	Conversations and voting meetings with PhD students, research assistants and professors by telephone, etc.	e.g., [7–9,20,21,33–38]
Cooperations with companies	Information on cooperative arrangements and through intensive cooperation (joint-ventures, alliances etc.)	e.g., [8,9,16,20,21,38]
Committees and associations	Conversations and voting meetings with members of industry and standardization committees, etc. by telephone, etc.	e.g., [7,8,16,18,20,21]
Capital market	Information that can be gathered from capital market or flow of funds from venture capital fonds, etc.	e.g., [8,9,16,20,21]

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