



Assessment of corporate innovation capability with a data-mining approach: industrial case studies



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ABSTRACT

The interest in assessment of innovation capability of manufacturing systems is fueled by the growing competition. At this time, there is no generally accepted model to evaluate innovation capability of manufacturing systems. In this paper, a fuzzy-logic based data-mining approach is proposed to assess innovation capability of manufacturing systems. The proposed algorithm is illustrated with two industrial case studies representing two different industry sectors. The results derived from these case studies demonstrate advantages of the proposed algorithm in assessing corporate innovation capability.

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1. Introduction

Assessing innovation capability of a corporation is important to remain competitive. Although the interest in assessment of innovation capability of organizations is growing, the literature on innovation capability is not extensive. This could be due to the lack of understanding of innovation. The need to create innovation science was outlined in Kusiak (2007a). The research related to innovation is interdisciplinary and has attracted numerous science and practice communities (Kusiak, 2007e). Due to its interdisciplinary nature, numerous definitions of innovation have appeared in the literature (e.g., see Martínez-Román, Gamero, & Tamayo, 2011). According to Kusiak (2009), innovation aims at the creation of new products, processes, services by the use of new and existing knowledge. Productivity and efficiency can be improved by application of methods and tools, such as: trial and error approach, lead user study, and innovation networks cited in Kusiak (2007c).

The literature offers different definitions of innovation capability. In this paper, innovation capability is defined as the ability to support and sustain innovation by using resources from diverse business areas ranging from marketing, research and development

(R&D) and manufacturing to logistics, and human factors. An organization's capability is vital for sustaining its competitive advantage and implementation of new strategies (Guan & Ma, 2003). The innovation capability of an organization indicates its innovation potential and future technological power. Higher innovation capability implies stronger competitive power and long-term survival in a competitive environment. There is no widely agreed upon model for comprehensive assessment of innovation capability. The reason behind the latter is that the factors impacting innovation capability change from sector to sector and technology to technology. In addition, measuring such factors is difficult due to their imprecision and vagueness. However, assessing innovation capability of any organization is important.

Assessing innovation capability of any organization requires the considerations of multiple capabilities, such as organization innovation capability, process innovation capability, product innovation capability, marketing innovation capability etc. Considerations and evaluation of such capabilities needs the usage of data-mining driven methods to find out unknown pattern and meaningful results. Previous studies do not focus on associations among corporate innovation capabilities. No previous work also applies a fuzzy-logic based data-mining approach to assessment of innovation capability of corporations.

In this paper, a fuzzy-logic based data-mining approach is applied to assess innovation capability of organizations and to address imprecision and vagueness. The classic association rules

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cannot capture meaningful relationships among different types of innovation capabilities. To address this limitation, fuzzy association rules are used. The fuzzy rules are derived with data-mining algorithms, and they constitute a fuzzy-rule algorithm proposed in this paper. The fuzzy rules capture perceptions for decision makers. Knowing associations among different innovation capabilities offers great value to any organization in two ways: (1) making innovation capability of the competitive environment transparent and (2) organization's priorities become apparent. The major contribution of this paper is threefold. First, it proposes a fuzzy-logic based data-mining approach to assess corporate innovation capability in practice. Second, the study demonstrates a successful application of FGBRMA with industrial case studies. Third, a fuzzy-logic based data-mining approach is applied in this study to overcome the limitation of the classic association rule-based data mining algorithms and to address imprecision and vagueness in practice.

The remainder of this paper is organized as follows. The literature on innovation capability is presented in Section 2. The proposed approach for assessment of innovation capability is introduced in Section 3. To validate the proposed approach, applications in two different sectors are provided in Section 4. The final section offers future research directions and conclusions.

2. Literature review

The number of applications of formal methods in innovation science is rather limited. Engler and Kusiak (2010) proposed a novel text-mining approach to determine the authoritative entities involved in collaborative innovation. Engler and Kusiak (2008) proposed web mining for innovation. In addition, Kusiak (2007b) and Kusiak (2007d) discussed data mining in industrial applications and innovation. Guan and Ma (2003) conducted an empirical study to explore the relationship between innovation capability and export performance of Chinese exporting firms. The results demonstrated a relationship between the total improvement of innovation capability and export growth. It was determined that learning orientation impacts innovation capability of a corporation. In addition, organization's innovation capability and learning orientation affect firm performance (Calantone, Cavusgil, & Zhao, 2002). A range of internal and external factors may impact innovative performance of corporations. Details on these factors analyzed for electronics and software development firms are presented in Romijn and Albaladejo (2002). R&D positively affects innovation potential of a company. Higher R&D intensity and higher R&D manpower are important predictors of corporate performance (Sher & Yang, 2005). In addition, different types of technology sourcing impact innovative capability of corporations (Zhao, Tong, Wong, & Zhu, 2005). Koc and Ceylan (2007) documented factors impacting innovative capacity of large corporations.

Lawson and Samson (2001) proposed an innovation capability based model to achieve effective performance of organizations. Koc (2007) determined organizational factors of innovation capacity in software development companies. Yang, Zhang, and Ding (2015) proposed a method based on uncertain linguistic variables and analytical hierarchy process to study innovation capability. In addition, the impact of intellectual capital on radical and incremental innovative capability (Subramaniam & Youndt, 2005), national innovation capability (Sun, 2009), R&D project assessment with respect to innovation capability (Elmqvist & Masson, 2009) has been reported in the literature. Martínez-Román et al. (2011) discussed innovation in small and medium enterprises, while Forsman (2011) analyzed innovation capacity and development of small enterprises. In addition, the impact of customer relationship management (Lin, Chen, & Chiu, 2010), tacit knowledge

transfer (Cavusgil, Calantone, & Zhao, 2003), knowledge management (Yang, Rui, & Wang, 2006), knowledge sharing (Lin, 2007) of innovation capability have been researched in the literature. Ahmed and Abdalla (1999) discussed the role of innovation process in crafting the vision of the future.

The relationship between innovation capability and corporate knowledge management (Tasmin & Woods, 2007), and the knowledge creation process (Numprasertchai, Kanchanasanpetch, & Numprasertchai, 2009) have been studied.

Fuzzy logic based studies have been conducted to analyze innovation capability (see Dereli, Durmusoglu, & Daim, 2011; Lin, Tseng, Chen, & Chiu, 2011; Lu, Chen, & Wang, 2007; Wang, Lu, & Chen, 2008).

Although data mining algorithms usually call for large data sets, fuzzy association rules can be derived based on small data sets, e.g., provided by a few decision makers. For example, Vinodh, Prakash, and Selvan (2011) used data from five different decision makers to evaluate leanness in manufacturing with fuzzy association rules. Similarly, Hu, Chen, and Tzeng (2003) used data from ten different resources, which can be considered decision makers, to utilize fuzzy association rules. Although a few decision makers are enough to employ fuzzy association rules, the number of rules derived by fuzzy association rules is generally high. Fuzzy association rules provides only meaningful results among these rules derived.

Fuzzy association rules express relationships among items under fuzziness. In this paper, the items are referred to as factors. The relationship among factors is expressed with association rules. The rules indicate that if condition "A" occurs, then condition "B" may also occur. Details on the association rules are provided in Hipp, Guntzer, and Nakhaeizadeh (2000), Zhao and Bhowmick (2003), Kotsiantis and Kanellopoulos (2006), Sowan, Dahal, Hossain, Zhang, and Spencer (2013), and Altuntas, Dereli, and Kusiak (2015).

Association rules are widely used tools in data mining. Jain, Benyoucef, and Deshmukh (2008) applied association rules to evaluate agility of supply chains. Vinodh et al. (2011) used fuzzy association rules based approach to evaluate leanness. We are not aware of any study using association rules to evaluate innovation capability.

Most publications related to the innovation capability report empirical research based on surveyed data. They focus on identification of factors impacting innovation capability, relationship between innovation capability and these factors, and validation of various hypothesis. This paper presents application of the fuzzy-grids based rule-mining algorithm (FGBRMA) to assess innovation capability of organizations. Details of the proposed approach introduced in the next section.

3. Fuzzy-grid based rule-mining algorithm (FGBRMA)

Hu et al. (2003) proposed fuzzy-grid based rule-mining algorithm (FGBRMA) to find associations in a relational database. The algorithm proposed in this paper is based on data mining. It includes two stages, generation of the large fuzzy grids and generation of fuzzy association rules (Hu et al., 2003).

Overview of the proposed methodology is illustrated in Fig. 1.

The steps of the FGBRM algorithm (Hu et al., 2003) applied to assess corporate innovation capability are presented next. The proposed FGBRMA application is new.

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| Step 1: | Determine factors impacting innovation capability. |
| Step 2: | Determine fuzzy partitioning of factors and fuzzy sets with membership functions. |
| Step 3: | Specify the minimum support value. |
| Step 4: | Specify decision makers. |

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