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Extraction of Principle Knowledge from Process Patents for Manufacturing Process Innovation

Gangfeng Wang^{a,b,*}, Xitian Tian^b, Junhao Geng^b, Richard Evans^c, Shengchuang Che^a

^a Key Laboratory of Road Construction Technology and Equipment of MOE, School of Construction Machinery, Chang'an University, Xi'an 710064, China

^b Institute of CAPP & Manufacturing Engineering Software, Northwestern Polytechnical University, Xi'an 710072, China

^c Westminster Business School, University of Westminster, London, NW1 5LS, UK

* Corresponding author. Tel.: +86-029-82334586. E-mail address: wanggf@chd.edu.cn; wanggf@mail.nwpu.edu.cn

Abstract

Process patents contain substantial knowledge of the principles behind manufacturing process problems-solving; however, this knowledge is implicit in lengthy texts and cannot be directly reused in innovation design. To effectively support systematic manufacturing process innovation, this paper presents an approach to extracting principle innovation knowledge from process patents. The proposed approach consists of (1) classifying process patents by taking process method, manufacturing object and manufacturing feature as the references; (2) extracting generalized process contradiction parameters and the principles behind solving such process contradictions based on patent mining and technology abstraction of TRIZ (the theory of inventive problem solving); and (3) constructing a domain process contradiction matrix and mapping the relationship between the matrix and the corresponding process patents. Finally, a case study is presented to illustrate the applicability of the proposed approach.

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1. Introduction

Innovation has always been regarded as an important factor in maintaining the competitive advantage and market position of manufacturing companies, especially in the face of fierce competition often present in global markets. In recent years, theoretical methods and the application of innovative design have gradually become the common concern of academia and industry [1]. With the development of information and communication technologies, Knowledge Management (KM) and theoretical approaches to innovation [2], a new category of tools known as Computer-Aided Innovation (CAI) is being developed; these offer an effective way to assist designers to achieve creative inspiration and improve the efficiency of technological innovation. The goal of CAI is to support enterprises in effectively implementing a complete innovation process throughout the entire product life cycle; this includes fuzzy front end, product development, manufacturing, service

and recycling, up to and including successful innovations in the marketplace [3]. Process innovation is a positive step in seeking to guarantee the delivery of product innovation and is also fundamental to the sustainable development of manufacturing [4-6]. As a branch of CAI, Computer-Aided Process Innovation (CAPI) can stimulate the creative thinking of process designers and help them to implement process innovation through the adoption of structured or systematic approaches [7].

Process innovation design is a structured innovative implementation process based on knowledge, and consequently formalized process innovation knowledge acquisition is crucial for CAPI. Process patents have become an important knowledge resource for process innovation design due to their innovative and practical features, but the inherent principle knowledge contained within patent text does not lend itself easily to the application of such knowledge in process innovation [8]. On the other hand, the contradiction

matrix of classical TRIZ (Theory of Inventive Problem Solving), formed through the analysis and extraction of several million technology patents, is used to point out the inventive principles that can be applied to solve technical contradiction of specific problems [9]. However the matrix is mainly suitable for product innovation due to the lack of specific process parameters and corresponding principles for innovation design.

In this research, we explore principle knowledge extraction from process patents for CAPI based on patent mining and knowledge management. An extraction framework of principle knowledge is described firstly. Then, we propose the methods of automatic classification of process patents and principle knowledge extraction based on patent mining. Finally, a case study of principle knowledge extraction from micro-cutting patents is illustrated.

2. Extraction framework of process innovation knowledge from process patents

From the systems thinking perspective, a specific problem-solving of process innovation mainly includes analysis and formulation of process problem, process conflict extraction and resolution, detailed design of process innovation scheme, evaluation and optimization of the scheme. Process innovation knowledge, which exists in the entire lifecycle of process innovation, is used to support process innovation activities correctly implemented and to produce new process knowledge. According to the knowledge demand and application of innovative design process, we divide process innovation knowledge into the following types: Problem Description Template, Process Contradiction Matrix (PCM), Manufacturing Scientific Effect, Innovative Scheme Instance, and Manufacturing Capability Description, etc [7]. Among them, PCM can provide the solution direction and innovative principle for technical conflict resolution of process problem-solving. And the process patents also contain innovative solutions and principles, so we can use the patent knowledge to build the PCM for CAPI. Here, we firstly establish a formal representation model of PCM, and then illustrate the PCM construction process based on patent mining.

2.1. Formal representation of process contradiction matrix

A technical contradiction arises when an attempt to improve certain attributes of a technical system leads to the deterioration of other attributes of that system [9]. Referring the classical TRIZ theory, we define the process contradiction as the phenomena of technical contradiction occurring in manufacturing systems. When the process contradiction hampers the realization of a process innovation goal, a process problem arises. In this paper, the parameters with contrary behavior characteristics are referred to as process contradiction parameters. The parameter which is expected to get enhanced or improved is called strengthening parameter, while the parameter which is expected to get reduced or downgraded is called weakening parameter. The combination composed of any one strengthening parameter and any one weakening parameter is called a process contradiction pair.

Generally, each process contradiction pair will have several corresponding basic solving directions, namely the solving principles for process contradiction. Solving principles are the general laws to resolve those process contradictions. Here, a process contradiction matrix is used to represent the relationships between process contradiction pairs and the corresponding solving principles, as shown in Table 1. And it is defined as:

$$PCM = \bigcup_{i,j=1}^n PCM_{ij} = \bigcup_{i,j=1}^n \left(\left(\overline{Par}_i, \overline{Par}_j \right), Sp_{ij} \right) \tag{1}$$

where $PCM_{ij} = \left(\left(\overline{Par}_i, \overline{Par}_j \right), Sp_{ij} \right)$ stands for process contradiction unit, and n is the total number of process contradiction parameters. \overline{Par}_i and \overline{Par}_j represent strengthening parameters and weakening parameters, respectively. $Sp_{ij} = \{Sp_{ij}^1, Sp_{ij}^2, \dots, Sp_{ij}^k\}$ is a set of solving principles for a process contradiction, and k is the number of solving principles.

Table 1. The form of process contradiction matrix.

Weakening parameters →				
↓ Strengthening parameters	Par_1	Par_2	Par_3	...
Par_1		Sp_{12}	Sp_{13}	
Par_2	Sp_{21}		Sp_{23}	
Par_3		Sp_{32}		...
...	

2.2. Construction process of process contradiction matrix

The process contradiction matrix construction based on patent mining is a knowledge conversion process that maps the unstructured patent text into the structural innovation knowledge by using Natural Language Processing (NLP) technology [10]. As can be seen in Fig. 1, process contradiction matrix construction should be based on the classified process patents in a specific way firstly, and then process contradiction parameters and contradiction solving principles can be extracted respectively from the patents under the support of knowledge base, finally principle knowledge will be associated by backtracking the mining process. Thus construction process mainly consists of the following parts: process patents classification, process contradiction parameters mining, contradiction solving principles mining and principle knowledge association for process contradiction matrix.

Process patent documents need to be pre-processed before the data mining. We store the required parts of the patents, and form a process patent database having unified data format. Patent text generally has a relatively uniform format, for example US patents mainly have Title, Abstract, Claims, Background of the Invention, Summary of the Invention, Description of the Invention, etc. It needs to deal with a lot of

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