RESEARCH ON THE GENERATION METHOD OF MANUFACTURING KNOWLEDGE CAPABILITY GRAPH

by

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Manufacturing knowledge can be preserved through knowledge accumulation and continuous integration. In order to improve the using efficiency of manufacturing knowledge, these knowledges are stored and used in the way of Knowledge graph. This paper will study the construction of Knowledge graph based on manufacturing process methods and the ability of Knowledge graph to provide services. This kind of manufacturing knowledge capability not only provides the manufacturing realization method of processing technology, but also can correspond to the design realization method of design graphics, providing theoretical support for the integrated realization of design and manufacturing process.

Key words: *manufacturing knowledge capability graph, Knowledge graph, knowledge accumulation, manufacturing knowledge, design realization*

Introduction

Knowledge graph is a semantic based on knowledge representation and reasoning, which represents entities, relationships, attributes and other knowledge in a graphical manner. At present, it is one of the research hotspots in the field of artificial intelligence. The research in the field of Knowledge graph mainly focuses on knowledge representation and reasoning learning, Knowledge graph construction. Hu [1] took the design calculation of pressure vessels as the research object and designed a recommended algorithm for design calculation services. Ma [2] took the industrial Cloud robotics as the research object, and proposed an onlogy-based Knowledge graph construction architecture of industrial Cloud robotics manufacturing capability. Yuan [3] has established a Knowledge graph for manufacturing industry, which integrates quantitative knowledge attribute. Duan [4] has developed a B/S structure of metal cutting Knowledge graph, which provides a new smart brain method for metal cutting. Gong [5] has developed a product assembly knowledge recommendation system based on Knowledge graph and scene awareness. Wang [6] studied the integration and characterization of steel production process data using Knowledge graph technology. Han [7] explored the application of Knowledge graph in assisting aeroengine design and development. Xu [8] has reorganized industrial design data, established correlation relationships between data, and solved the problem of low efficiency in industrial knowledge inference.

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Knowledge transfer in manufacturing and design process

Accumulation of manufacturing knowledge

Manufacturing knowledge (MK) refers to the knowledge accumulated, summarized, and created through practice, learning, and communication in the manufacturing history process. The manufacturing knowledge MK can be expressed:

$$\text{MK} = \{x_1, \text{x}_2, \text{x}_3 \cdots x_n\} \tag{1}$$

where $x_1, x_2, x_3 \ldots x_n$ are the elements that make up knowledge.

The elements that make up knowledge include resource usage methods, parameter calculation methods, logical operation methods, and so on. The accumulation of manufacturing knowledge refers to the process of continuously supplementing and improving the set of manufacturing knowledge.

Let us give the derivative accumulation of manufacturing knowledge. Manufacturing knowledge derivation model P1 can be given:

$$\text{MK}\{x_1, x_2, x_3\} \to \text{P}_1 \to \text{MK}\{f(x_1), f(x_2), f(x_3)\} \tag{2}$$

where MK$\{f(x_1), f(x_2), f(x_3)\}$ is the manufacturing knowledge derived from MK.

Through the manufacturing knowledge derivation model P1, new manufacturing knowledge element variables can be derived from the element variables of the original manufacturing knowledge MK. At the same time, the new derived variables are expanded into the variable set of the original manufacturing knowledge MK, completing the derivation and accumulation of manufacturing knowledge, as shown in fig. 1.

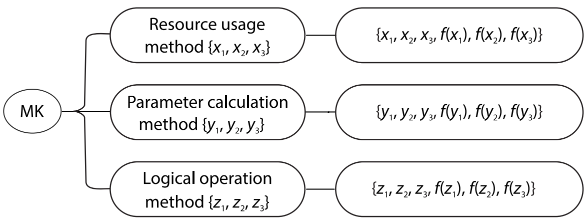

Figure 1. Thev MK accumulation model

Let us consider the innovative accumulation of manufacturing knowledge. The integration and reconstruction model of manufacturing knowledge element variables is shown:

$$\text{MK}\{x_1, x_2 \ldots x_n\} \to \text{MKIM} \to \text{MK}\{x_1', \text{x}_2' \ldots x_n'\} \tag{3}$$

where MK$\{x_1, x_2, x_3\}$ is the original manufacturing knowledge MK, MK$\{x_1', x_2' \ldots x_n'\}$ – the manufacturing knowledge created by MK, and MKIM – the innovative method for manufacturing knowledge.

The iterative model of manufacturing knowledge is suggested:

$$\text{MK}(x_{\text{n}+1}) = \text{MK}(x_n) - \frac{f(\text{MK}(x_n))}{f'(\text{MK}(x_n))} \tag{4}$$

where MK(x_n) is element variable x_n of original manufacturing knowledge MK, MK(x_{n+1}) – the MK element variable x_{n+1} obtained through iterative operation, and f'(MK(x_n)) – the derivative of f'(MK(x_n)).

Through the accumulation of manufacturing knowledge, a certain knowledge reserve can be formed, providing an important basis for the inheritance, reuse, and standardization of manufacturing knowledge.

The transmission process of manufacturing knowledge

The transmission process of manufacturing knowledge is the process of generating, storing, using, and exchanging in the collaborative process of design and manufacturing, which includes two processes: the generation process of manufacturing knowledge and the transmission process of design requirements for manufacturing knowledge. The process of generating manufacturing knowledge is a static process of knowledge generation, as shown in fig. 2.

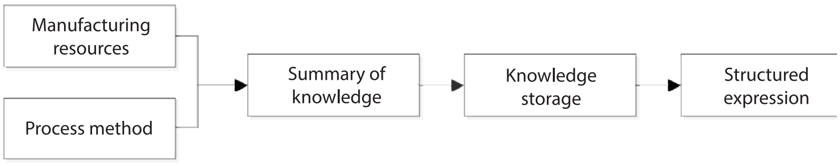

Figure 2. The MK generation process

The design requirement transfer process of manufacturing knowledge is a dynamic knowledge transfer process initiated by manufacturing knowledge in response to design requirements, as shown in fig. 3.

Manufacturing knowledge is used in the transmission of design requirements to determine the manufacturing feasibility of design graphics. It is transmitted to the matching results of a design graphic and to the results of a manufacturing driven method.

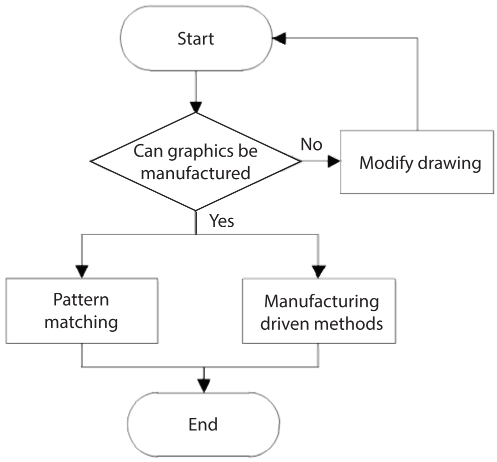

Figure 3. Design requirements transfer process

Structure of manufacturing knowledge capability units

Let us study the manufacturing knowledge capability graph. The set of MKCD in the manufacturing capability model (MCM) that have been structured and relational processed is called the manufacturing Knowledge capability map (MKCM) by using:

$$\text{MKC} = \text{MKCD}(i) = \{\text{MKCD}(i)\} \quad (5)$$

The manufacturing knowledge capability unit (MKCU) is composed of manufacturing entity manufacturing entity (ME), design entity (DE), and their relationships. The internal relationship between manufacturing knowledge capability units MKCU (1) and MKCU (2), as well as the combination relationship between MKCU (1) and MKCU (2), are shown in fig. 4.

The manufacturing knowledge capability units MKCU (1) and MKCU (2) are connected through their respective manufacturing entities to form the relationship MDDR of the design entity. Figure 4 is represented by a thick line with an arrow, with the manufacturing entity pointing towards the direction of the design entity. The manufacturing knowledge capability units MKCU (1) and MKCU (2) are connected through the combination relationship of manufacturing knowledge capability units. Between MKCU (1) and MKCU (2), manufacturing entities ME (1) and ME (2), and design entities DE (1) and DE (2) are connected through entity attributes. Figure 4 is represented by a thin curve with a bidirectional arrow.

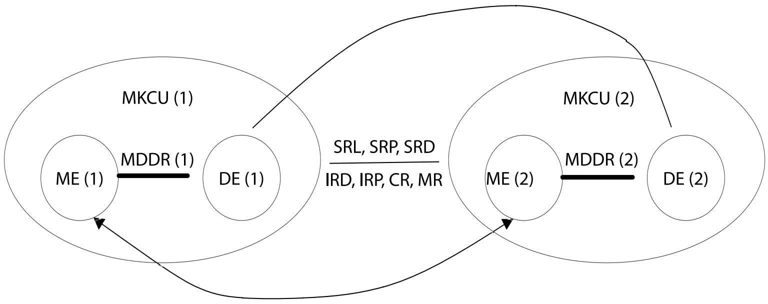

Figure 4. The MKCU combination relationship

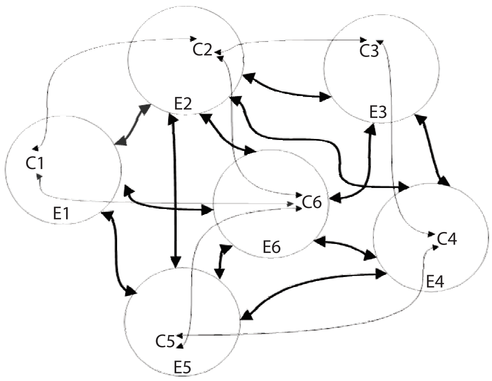

Figure 5. Complex MKC diagram

Principles of manufacturing knowledge capability map architecture

The complex manufacturing knowledge capability relationships are shown in fig. 5. Here, E1, E2, E3, E4, E5, and E6 represent entities. C1, C2, C3, C4, C5, and C6 represent attributes of entities, thick solid lines with bidirectional arrows represent relationships between entities, and thin solid lines with bidirectional arrows across entities represent connections between internal attributes of entities. The relationship between entities and the relationship between their internal attributes form a network connection diagram of multiple entities together.

Implementation of manufacturing knowledge capability map

The hierarchical structure of the manufacturing knowledge capability map is composed of graph layer, roll layer, page layer, and bar layer, and the storage and implementation of knowledge are also expanded at the aforementioned four levels, as shown in fig. 6.

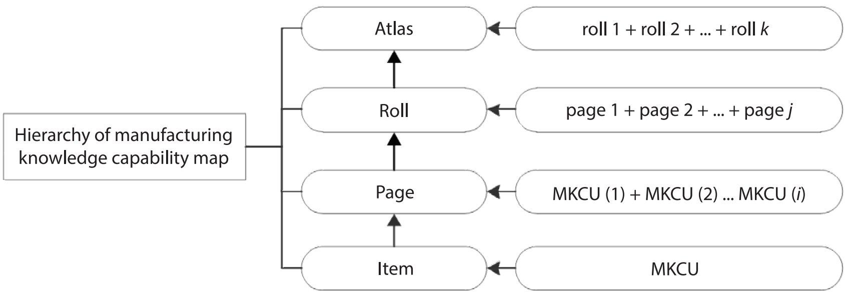

Figure 6. The MKCM hierarchy

Manufacturing knowledge capability map can be stored in many forms, including relational database, graph database, and phenotype database. Here, 2-D table structure is used. When storing, items are stored in the form of entities, relationships, and attributes to facilitate knowledge management and query. There is the storage of manufacturing knowledge capability map. For example, the ability graph of turning an outer circle is stored in a 2-D table structure, as shown in tab. 1.

Table 1. MKCM turning out

Level	Name	Entity	Relationship	Properties
Atlas	Turning	X1	R1	Y1
Roll	Outer contour			
Page	Cylindrical			
Item	Cylinder			

The implementation of the manufacturing knowledge capability map also requires continuous iteration and updating, in order to improve its capabilities gradually.

Conclusion

This paper explores the establishment of a manufacturing knowledge capability map, the expression of manufacturing knowledge, and the structural system. The basic units of the manufacturing knowledge capability map were analyzed and constructed. The expression, accumulation, and transfer processes of manufacturing knowledge were studied. By analyzing the working relationship between manufacturing knowledge and manufacturing knowledge capability, the structure of manufacturing knowledge capability units was presented. The unit form of *Manufacturing Entity – Relationship – Design Entity* was analyzed, as well as the attributes of manufacturing entity and design entity, this provides a theoretical basis for the establishment of a manufacturing knowledge capability map.

Nomenclature

MK – manufacturing knowledge, [–]
MKCU – manufacturing knowledge capability units, [–]
MKCM – manufacturing knowledge capability map, [–]

Acronyms

MK – manufacturing knowledge, [–]
MKCU – manufacturing knowledge capability units, [-]
MKCM – manufacturing knowledge capability map, [–]
MKIM – manufacturing knowledge innovative methods, [–]
MKCD – manufacturing knowledge capability domain, [–]
MDDR – manufacturing drive design relation, [–]
SRL – sequential relation location, [–]
SRP – sequential relation precision, [–]
SRD – sequential relation dimensions, [–]
IRD – inclusion relationship dimension, [–]
IRP – inclusion relationship precision, [–]
CR – cross relationship, [–]
MR – multiple relationship, [–]

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