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Structuring engineers' implicit knowledge of forming process design by using a graph model

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Abstract

Forming Process Design needs simultaneous consideration of multiple factors, accuracy of products, costs and cycle time. Consequently, its design knowledge is based on personal experience and tends to be implicit and untransferable in general. To represent and transfer such implicit and personal design knowledge of forming process, we propose a novel knowledge mining method based on graph theory. Experienced engineers' knowledge is transcribed as a set of statements through a series of interviews. Then, the interrelationship among these statements is clarified by translating them to a graph-based knowledge representation model. Implicit knowledge is extracted as structural characteristics of the graph.

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Keywords: Implicit knowledge, Graph model, Knowledge transfer, Process design, Expert

1. Introduction

1.1 "Tacit knowledge" and "Explicit knowledge"

There has already been a lot of discussion on "Tacit knowledge" and "Explicit knowledge". Polanyi [1] argued that "Tacit knowledge" is generally unconscious and cannot be expressed in detail and transferred to others. (ex. How to ride a bicycle or recognize a face of a certain person is unexpressible and untransferable.) On the other hand, "Tacit knowledge" in current business science and engineering was argued differently from Polanyi. Nonaka [2] said that "Tacit knowledge" is subjective, experiential, simultaneous and analog. It contains not only intuition and insight based on subject but also personal experience and sense of values, so it tends to be personal and implicit and difficult to communicate to others. On the other hand, "Explicit knowledge" is said to be objective, rational, ordered and digital, so that easily expressible by means of words or equations. Interaction between the tacit and the explicit knowledge, which is called knowledge conversion, expands human knowledge. Externalization, one kind of knowledge conversion in which change knowledge from implicit to explicit, is the essence of knowledge creation, but it is often highly personal and ambiguous because of its dependence on linguistic representation.

1.2 Previous studies to improve knowledge or skills transfer

Expert system has been studied since 1970s, which makes deduction based on acquired knowledge of expert. The beginning of this study aims to structure elucidation in organic chemistry [3], and this system was applied to clinical decision criteria of experts in early stage of development [4]. Though expert system was practically used in industry, it was abandoned in many cases because of lack of capability to cope with new issues arouse from change of surroundings condition.

Then, "Socialization, Externalization, Combination and Internalization model" (SECI model) [2], which was proposed in middle of 1990s, triggered for growing interest in "knowledge management" to deal with loss of knowledge with retirements of the core generation in Japanese industry. Fujita et al [5] studied the effectiveness of knowledge management, and Takahashi et al [6] studied real applications. In knowledge management system, knowledge has been accumulated enormously, however, is often hard to retrieve. It is necessary to archive complicated knowledge in an easily retrievable form.

On the other hand, development of devices which enables recording of human operation and sensors which enables

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measuring of machine and tool status helps study on skill transfer to expand available information.

1.3 Knowledge and skills transfer in plastic working

Plastic working has higher yield than machining and lower energy consumption than additive manufacturing. Machining and additive manufacturing need only drawings of products to form out, while plastic working needs not only drawings but process design including a series of forming process such as bending, swaging or bulging.

The following three points are reasons why it is difficult to transfer knowledge and skills in plastic working.

- There is no way to describe forming process apparently in drawings.
- Knowledge of intermediate shapes and criteria for choice of forming process tends to be implicit.
- Knowledge of experts themselves is fragmented and not systemized, because of the above two matters.

Knowledge and skills transfer in a field of plastic working is divided into two fields, visible and invisible. One hand, in visible issues, knowledge and skills are mainly based on somatic sensation, and the information related to these can be recorded or measured [7]. On the other hand, for the above three reasons, it is difficult to transfer knowledge in invisible issues. There was not so much progress in knowledge transfer for invisible issues including ideation of drawings and intention of processing operation.

1.4 Objectives

In this paper, the method of visualizing and organizing is mainly discussed to solve problems in transferring implicit knowledge to explicit and in making good use of accumulated knowledge in industry. The following two points are main advantages of that.

- Expression of implicit knowledge
  Knowledge which is not consciously given words that often is expressed to natural language with some ambiguity.
- Structuring by a graph-based model
  Giving a graph structure to massive and fragmented pieces of knowledge and semantics owing to combination of computer and engineers help viewers to understand experts' knowledge.

In addition, this method is applied to knowledge of forming process design in plastic working to check applicability to real issues.

2. Knowledge Description on Graph Model

2.1 Comparing some methods of semantics

To make use of enormous fragmented knowledge of experts, it is necessary to analyze statements in natural language and process them into understandable forms.

In recent years, semantic analysis has advanced greatly. Semantic analysis is to derive semantics from documents. The method called "Latent Semantic Analysis" (LSA) becomes popular. This method uses singular value decomposition and improves the detection of relevant documents, and introduction of Baysian inference to LSA, "Latent Dirichlet Allocation" (LDA), becomes powerful tool for topic analysis [8][9]. In addition, powerful methodology to derive thought and knowledge from a person was proposed. "Grounded theory" proposed by Glaser et al [10] is often used as the method of quantitative research when trying to extract knowledge and give meanings.

In this study, however, the objective is application to knowledge of expert of process design. So, methods developed in social investigation such as the above are not suitable because of high degree of specialization and smallness of data quantity of itself.

Parameter network model has been proposed by Kondoh et al [11]. This model describes relations between parameters including functions and attributes by using graph representation, and to use in recording thinking processes. Graph Model in this report is based on parameter network model.

2.2 Graph Model (a graph-based knowledge representation model)

Graph Model consists of three kinds of node (Entity, Attribute, Relation), and edges between nodes are undirected and non-weighted. Figure 1 shows an example of this model.

In this example, there are three statements about forming process. A graph in Figure 1 represents the information which these statements contain. In this example, a hexagonal-shaped node represents the relation between the prescribed strength, which is one of important properties of Torsion spring (Entity), and two parameters (outside diameter and thickness) of original tubes which determine the strength after deformation.

2.2.1 Entity

Entity is a concept corresponding to a physical object which can exist in the past, the present and the future [12]. Fixing the scope of Attributes is a main function of it. In this model, square-shaped nodes represent Entity.

2.2.2 Attribute

All parameters can be classified into a function parameter, design parameter and intermediate parameter, while the rule of distinction between them is not clearly defined by experts. In this model, Attribute nodes which are elliptical-shaped represent three kinds of parameter without distinction.

2.2.3 Relation

Relation can represent all kinds of relations which experts recognize quantitatively or qualitatively, and can connect Attributes in Graph Model. In this model, hexagonal-shaped nodes represent Relation.

2.2.4 Rules of connection

All edges which connect two of nodes in Graph Model are undirected and non-weighted. The combinations which can be connected are these following three kinds.

- Entity - Attribute
  To focus on an Entity which some Attributes belong to.
- Attribute - Relation