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Knowledge Engineering and Capitalization for Injection Mold Design

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Abstract. The process of Knowledge Engineering plays an important role in the management of industrial knowledge. By its nature, industrial knowledge is combined and linked together as a chain. Industrial knowledge that is considered "good", i.e., knowledge that is ensured to be complete and usable, must be validated by human experts prior to both its initial and recurring use. This paper proposes the concept of knowledge capitalization associated by PCA method and validated by shop floor experts. Injection mold design is used for testing.

Keywords: Knowledge Management, Knowledge Engineering and Capitalization, Case-Based Reasoning, Injection Mold Design

1. Introduction

The process of knowledge engineering (KE) plays an important role in management of industrial knowledge and building an expert system. It means an engineering discipline that involves integrating knowledge into computer systems in order to solve complex problems normally requiring a high level of human expertise [1]. The KE involves various activities; assessment problem, acquiring and structuring the general and specific knowledge, testing and validating of the stored knowledge, integration and maintenance of the system, revision and evaluation of the system. The KE principles have been developed in order to manage different types of knowledge, different types of experts and expertise, different ways of representing knowledge which can support validation and re-use of knowledge, different way of using knowledge. Knowledge is a set of precise and concise information that could induce a change or arouse more effective actions in a boarder context capable of triggering a new learning and new knowledge. The knowledge of an organization can be classified into two parts; explicit knowledge and tacit knowledge. The former refers the expressed knowledge in a document form, whereas the later refers to an unwritten know-how and keep in deep worker's mind. Knowledge management is presently well-known in anywhere. However, knowledge sharing and transferring is still a question for many people and organizations in order to use knowledge effectively. Knowledge management can be divided into four steps; knowledge formulation, knowledge capitalization, knowledge re-textualization and knowledge sharing. Nowadays, Industrial knowledge is managed by a capitalization concept and become more and more important. To capitalize knowledge means to reuse the knowledge of a given domain previously stored and modelled in order to perform a new task. The knowledge is stored in the database called corporate memory to the industrial experience in a given domain [2]. Knowledge capitalization aims to build a capital from existing information or knowledge in an organization in order to enhance them through their dissemination to other institutions or stakeholders as well as to serve he group in a context of knowledge sharing [3], [4], [5]. The capitalization method can be used by several ways. However, case-based reasoning (CBR) seems to be very relevant. The CBR performs a knowledge base containing cases which are collected from existing knowledge and experience of already solved problems. The similar problems can be solved by similar solutions. Aamodt and Plaza [6] presented that the CBR was a problem solving process containing four phases; retrieve phase, reuse phase, revise phase and retain phase. The retrieve phase finds the most similar cases, matches and executes the cases and their details of solving problems. The reuse phase uses the solutions of the similar cases in order to solve the new problem. The differences between the reminded case and the new case are taken into account and the previous solution is adapted to the new situation. The revise phase proposes the solution and evaluates such solution to the real world. The retain phase stores a new case in the case base. Case-based reasoning derives from a view of understanding as an explanation process of human problem solving process [7]. Cognitive model or memory organization is crucial aspects to a capitalization methodology. The memory organization packages (MOPs) proposed by Kolodner [8] contains two functions. They hold general knowledge, and they organize, in a complex hierarchy, specific experiences or cases of the general knowledge. MOPs store instances in which extant expectations were inadequate for understanding the situation. Cases are indexed primarily by anomalies. If a similar anomaly is encountered, the previous encountered case can be recalled and provide its expectations. Reminding, learning and understanding go along together. The retrieval specification requires purposes, needs and descriptions as input from users and provides target, description and verification criteria. The match receives target description as input and gets memory records as the output. The evaluation receives memory records and verification criteria and returns two choices; the success and failure. If the success is encountered, the output is terminated, otherwise it is revised the retrieval specification. The CBR applications are widely used in many domains such as in design [9], [10] in service help desk [11], [12], in injection moulding [13]. This paper proposes the capitalization model which reuses exploit knowledge in industry. The existing knowledge is the common knowledge which the domain experts and operators use every day together with the knowledge from the electronic documents from the project reports. Case-based reasoning (CBR) is employed to support the capitalization. The CBR is formerly created by individual module. The problem is difficult to share the knowledge chain effectively. Therefore, the research develops a link and updates knowledge automatically and immediately after the context of knowledge is verified and changed. The case study of injection moulding is illustrated. There are more than 50 cases of plastic product design is studied in order to installed as the basis and generic knowledge. The knowledge is verified in a Thai company where it operates the whole processes of plastic products. It begins with product design, mould design, mould making, product manufacturing and assembly.

2. Research Methodology

This section presents the research methodology. First, the case-based formulation model is proposed. The aim is to a model of knowledge capitalization and evaluation, memory organization, knowledge evaluation and integration. The main components are case representation, case indexing and case storage. Then, the knowledge is organized by capitalization

2.1. Knowledge Capitalization and Validation

The knowledge capitalization and validation are a process to use the created knowledge or reuse exploit knowledge. In mould design domain, for example, they are five steps to make decision; study of part description or drawing, basic calculation, selection a mould base (type and size), design core and cavity (including gate and runner system), ejection system, and design cooling system. All processes are time consuming and need a lot of experience. By using the concept of knowledge capitalization, mould designing time is shorter and it can ensure that the designed mould is practical based on the previous design. The capitalization model development for injection moulding process is illustrated in the Figure 1.

The model is divided into three parts; the knowledge capitalization, the knowledge based system, and the product &requirement. The knowledge based system is primarily crated before the product & requirements can be performed. Afterwards, the knowledge based system is integrated to the knowledge capitalization in order to reformat and reuse the existing and exploiting knowledge. Case-based reasoning is employed combining with the formula based system. The main task for the injection molding is to create product model on CAD, analyze the model on CAE, design the mould on CAD, analyze the mould on CAE, plan the making process by the mould maker, simulate the process by CAM, make the mould at the shop floor, test and correct the mould before using, inject the product by the made mould.

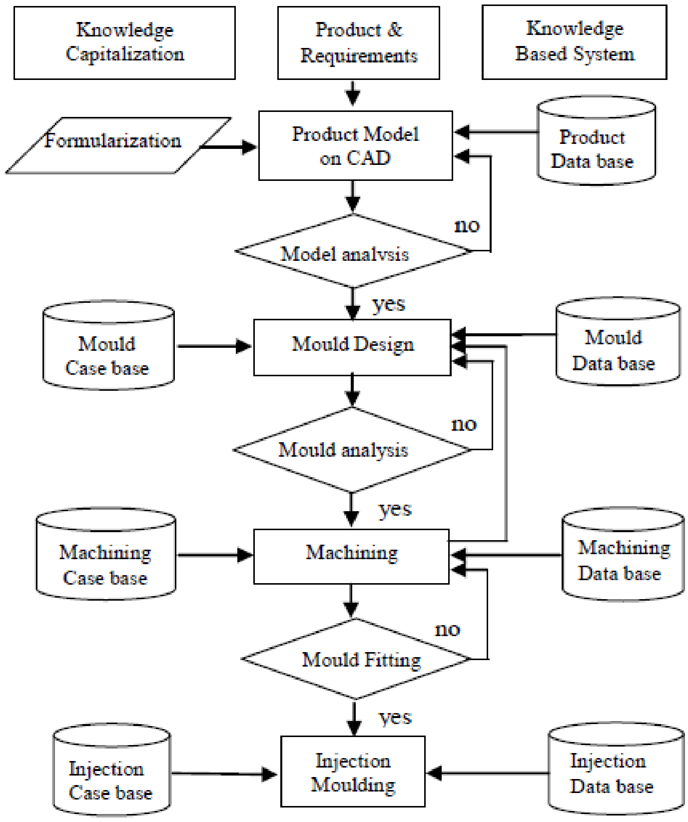

Fig. 1: Knowledge Capitalization Model for Injection Moulding Design.

2.2. Case Representation

The case representation is the primarily step to a capitalization system design. It requires a suitable format to serve the problem descriptions. In case of the domain which is linked like a knowledge chain combining with several processes, frame representation is an effective method. The case combined with sub-frame in order to represent different functions as shown in the Figure 2.

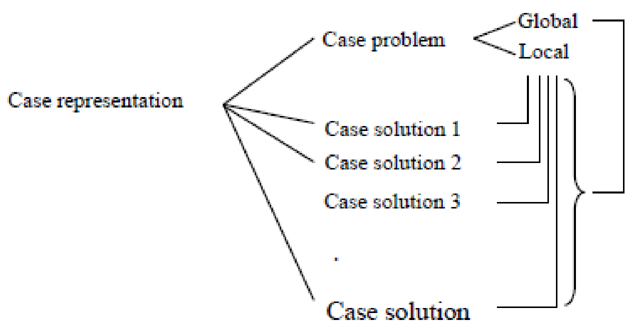

Fig. 2: Case Representation Structure.

The case problem contains global and local problems. The global asks for the ultimate goal, whereas the local ask for a problem component. The local case problem is supposed to get a solution 1 which is recorded in the case solution 1. Similarly, the local case problem 2, 3, 4, until n are matched and linked to the case solutions 2, 3, 4, until n respectively.

2.3. Case Indexing and Matching

The case indexing method employs the Nearest Neighbour (NN) method and applies to add significant weight for each product characteristics. In addition, the relation by pair of the product characteristics is given the significant weight. The weight is provided by industrial experts. The product characteristics are surface, feature, shape, thickness, assembly and mechanism and difficulty like undercut or snap. The retrieval method uses the similarity matrix which is divided into two categories: numeric retrieval using equation (1), text retrieval using equation (2). The similarity comparison is calculated using equation (3).

$$\beta_i = \sum_{k=1}^{n_\beta} w_k \times \left[1 - \left| \frac{X_k - Case_{i,k}}{Range_k} \right| \right] \quad (1)$$

$$\gamma_i = 1 - \left[\sum_{i=1}^{N} \sum_{k=1}^{n_\gamma} w_k R_{i,k} \right] \quad (2)$$

$$similarity\left(X_k, Case_{i,k}\right) = \frac{\beta_i + \gamma_i}{\sum w} \quad (3)$$

Given parameters are as the followings:

βi = numeric similarity between the case i and inputted data
nβ = lists of numeric data
Xk = expected value of the characteristic k
Casei,k = value of case ith of the characteristic k from searched value
Rangek = different value between the maximum of the characteristic kth and searched value
i = case order
k = characteristic order
γi = text similarity between the case i and inputted data
nγ = lists of text data
N = quantity of cases
Ri,k = relation between Xk and case i of the characteristic k

2.4. Memory Organization Package

The most important part of the knowledge capitalization model is memory organization package. It is a dynamic memory. Once the cases are already existed in the case base, the capitalization process can be performed. The new case is defined into the model and compared with the case base (case comparison) as shown in the Figure 3. The result can be similar parts (Sim part) or un- similar parts (not Sim part). The unsimilar parts are then modified by knowledge experts (case modification), whereas the similar parts are adapted as adaptation case (Adapt case). This adapted case is not completed yet. It needs to combine with the modification parts to become a competed new case. The new case is further to integrate to the case base (integration) as a knowledge re-contexualization. The adaptation case is reused and validated in the real world (capitalization and validation).

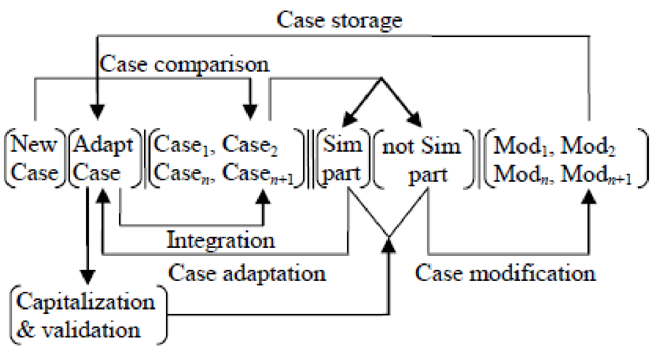

Fig. 3: Matrix of Case Memory Organization Package

3. Case Study

This section presents the case study of knowledge capitalization process for plastic injection molding domain as shown in the Fig.4. There are 52 projects that are collected from electronic documents. The precise problem is that they are collected in different format and ill-structure. Firstly, knowledge model in a well-structure format is designed. It is also classified types of knowledge in terms of general and instance knowledge. The general knowledge can be generated by a standard formula. The instance requires a knowledge engineer to translate into knowledge rules or rule base representation. The domain consists of the knowledge chain such as product knowledge, mold design knowledge, mold analysis, mold fitting, injection molding knowledge (including machine knowledge, material knowledge, processing knowledge and so on).

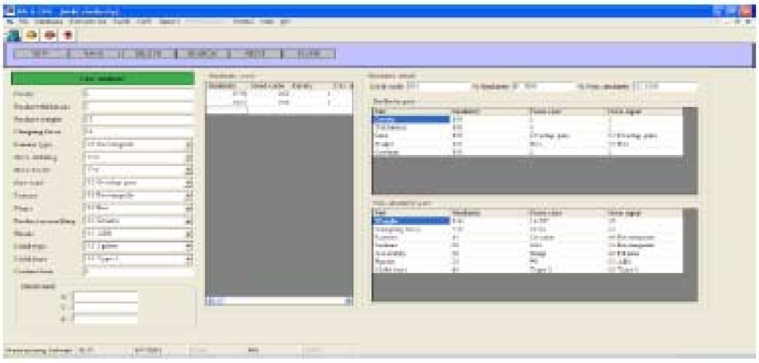

Fig. 4: The Case Comparison showed in the MOP

4. Conclusion

This paper has presented the knowledge engineering process, the revolution of using case-based reasoning combining with rule-based reasoning. The model of case representation for a knowledge chain is proposed following with the case problem representation as the product characteristics and requirements. Then, the model of capitalization for injection molding is purposed and developed. The case indexing and matching are created for both numeric and text matching.

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