An Expert Recommendation System for Product Empirical Knowledge Consultation

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Abstract—**Product lifecycle, a knowledge intensive process, consists mainly of market analysis, product design and process development, product manufacturing, product distribution, product in use, post-sale service and product recycling. Performing and achieving each activity or its supply chain activities require product empirical knowledge at different levels to resolve product-related problems or make certain decisions. However, effective consultation and sharing of tacit product empirical knowledge would greatly enhance product market competitiveness. Therefore, effectively and correctly sharing product empirical knowledge from domain experts in different organizations require developing an expert recommendation system for product empirical knowledge consultation, which is priority concern for product knowledge management.**

This study develops an expert recommendation system for product empirical knowledge consultation by using ontology to matchmaking of the required consultative experts quickly and correctly for the product empirical knowledge requester, thus sharing required product empirical knowledge by interpersonal communication to resolve product-related problems efficiently. The tasks involved in this study include: (i) designing an expert recommendation process for product empirical knowledge consultation, (ii) developing an expert recommendation method for product empirical knowledge consultation, and (iii) implementing an expert recommendation mechanism for product empirical knowledge consultation.

Keywords-empirical knowledge; expert recommendation; tacit knowledge sharing; ontology; knowledge consultation

I. INTRODUCTION

Knowledge-based economies view knowledge as the most important asset for a knowledge worker in an organization. Organizational knowledge can be effectively captured, managed, and shared to create competitive advantage that other organizations could not imitate.

Product lifecycle, a knowledge intensive process, largely involves market analysis, product design and process development, product manufacturing, product distribution, product in use, post-sale service and product recycling [6]. Each activity and its supply chain activities encompass complex and professional product knowledge. Product knowledge can be divided into explicit product knowledge and tacit product knowledge, which can resolve product-related problems and perform related activities. Explicit product knowledge can be obtained by using information systems (systematic strategy); more valuable tacit product knowledge (product empirical knowledge) must be obtained through experts' consultation (personalization strategy). However, effectively and correctly sharing product empirical knowledge owned by domain experts requires developing an expert recommendation system for product empirical knowledge consultation, which is priority concern in product knowledge management.

Tacit knowledge sharing studies have developed various methods [4][7]. However, while recent studies have focused mainly on providing communicative environments, tools and methods for tacit knowledge, searching for appropriate empirical knowledge consultative experts has seldom been addressed, making it impossible to not only effectively and correctly share this valuable product empirical knowledge with empirical knowledge requesters, but also share tacit product knowledge.

Therefore, this study develops an ontology-based expert recommendation system for product empirical knowledge consultation to facilitate the matchmaking of required consultative experts rapidly and correctly for the product empirical knowledge requester. Subsequently, the empirical knowledge requester attempts to acquire product empirical knowledge of experts through an interactive method of empirical knowledge consultation. To achieve this purpose, the following tasks are performed: (i) designing the expert recommendation process for product empirical knowledge consultation, (ii) developing the expert recommendation method for product empirical knowledge consultation, and (iii) implementing the expert recommendation mechanism for product empirical knowledge consultation.

II. EXPERT RECOMMENDATION PROCESS DESIGN FOR PRODUCT EMPIRICAL KNOWLEDGE CONSULTATION

This section first introduces the expert recommendation framework for product empirical knowledge consultation. Subsequently, the expert recommendation process for product empirical knowledge consultation is designed to assist in system development.

A. Expert Recommendation Framework for Product Empirical Knowledge Consultation

Based on enterprise collaboration lifecycle and knowledge management techniques, this subsection presents an overview of expert recommendation framework for

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consulting of product empirical knowledge in product lifecycle and its supply chain, as shown in Fig. 1.

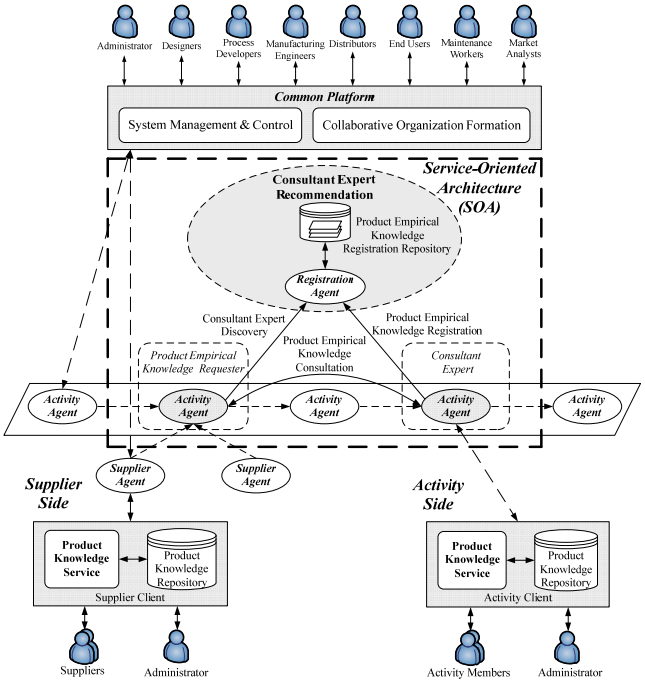

Figure 1. Expert recommendation framework for product empirical knowledge consultation.

B. *Expert Recommendation Process for Product Empirical Knowledge Consultation*

This subsection mainly designs the expert recommendation process for product empirical knowledge consultation to facilitate matchmaking of required consultative experts quickly and correctly for a requester of product empirical knowledge in activities of product lifecycle and its supply chain, as well as solve product development-related problems encountered by a knowledge requester, as shown in Fig. 2. This process includes registration/withdrawal of product empirical knowledge and consultative expert recommendation. Ontology is employed to establish experts' profile and sharable product empirical knowledge and, then, store them in the meta product empirical knowledge library via registration of product empirical knowledge to encourage consultative experts to share product empirical knowledge. Moreover, product empirical knowledge is withdrawn by product empirical knowledge withdrawal that provided from consultative experts. Ontology is utilized by consultative expert recommendation to achieve matchmaking of knowledge according to requirements of product empirical knowledge requester in order to search out appropriate consultative experts for consulting product empirical knowledge.

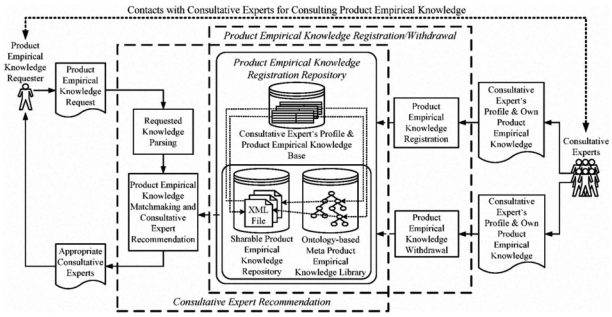

Figure 2. Ontology-based expert recommendation process for product empirical knowledge consultation.

III. PRODUCT EMPIRICAL KNOWLEDGE REGISTRATION AND WITHDRAWAL

Based on the designed process of ontology-based expert recommendation for product empirical knowledge consultation, this section details the registration and withdrawal of product empirical knowledge. Figure 3 shows the procedure for registration and withdrawal of product empirical knowledge, which includes four main steps of input of consultative expert's profile and sharable product empirical knowledge, registration of product empirical knowledge, withdrawal of consultative expert's profile and sharable product empirical knowledge, and withdrawal of product empirical knowledge.

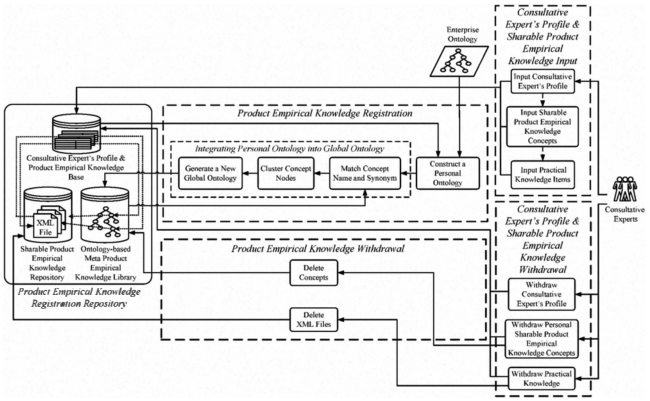

Figure 3. The procedure for registering and withdrawing product empirical knowledge.

A. *Definition of Consultative Expert's Profile and Sharable Product Empirical Knowledge*

This subsection defines the consultative expert's profile and sharable product empirical knowledge. The profile of consultative expert mainly records consultative expert-related information, including the name, ID, status, specialty, and enterprise ID. The sharable product empirical knowledge concept indicates the product empirical knowledge provided by a consultative expert can be sharable. The sharable product empirical knowledge concept includes the concept name and status. Each sharable product empirical knowledge concept has its practical knowledge item. Practical knowledge item can be divided into seven descriptions of

product empirical knowledge: know-what, know-why, know-how, know-when, know-where, know-who, and know-with.

B. Product Empirical Knowledge Registration

Registration of product empirical knowledge includes two phases, namely construction of personal ontology and integration of personal ontology and global ontology.

1) Personal Ontology Construction

Sharable product empirical knowledge concepts from consultative expert and the knowledge concepts from the enterprise they belong to are first matched by registration of product empirical knowledge. The relationships among sharable knowledge concepts are then constructed, which are discussed below:

Step 1. Match the concepts.

The name for sharable knowledge concepts and enterprise knowledge concepts are matched utilizing the concept similarity calculation method of Jaccard Coefficient [2]. If no matches occur for appropriate enterprise knowledge concept, synonym matching of enterprise knowledge concepts is executed. Equation (1) shows the calculational equation.

$$ConceptSim(SC_i, EC_j) = |SC_i \cap EC_j| / |SC_i \cup EC_j| \quad (1)$$

where SC_i is the i_{th} concept name term set from sharable knowledge concepts, i.e., $SC_i = \{SC_1, SC_2, \ldots, SC_i\}$, and EC_j is the j_{th} concept name term set from enterprise knowledge concepts, i.e., $EC_j = \{EC_1, EC_2, \ldots, EC_j\}$.

In concept similarity matching, concept names are first deconstructed as term sets of unit words, followed by calculating the similarity for term sets of two different concept names.

Step 2. Construct the concept relationship.

Based on the enterprise knowledge concepts matched in Step 1, relationships among sharable knowledge concepts are constructed using the OWL ontology reasoning rule [1]. The establishment rule is as shown below:

(?P rdf:type owl:TransitiveProperty) $\wedge$ (?A ?P ?B) $\wedge$ (?B ?P ?C) $\Rightarrow$ (?A ?P ?C)

where P denotes a transitive property, A, B, and C represent enterprise knowledge concepts, " $\wedge$ " is an intersection symbol.

2) Integration of Personal Ontology and Global Ontology

Following establishment of the personal ontology for consultative experts, the personal ontology and the global ontology from registration repository of product empirical knowledge are integrated. The global product empirical knowledge concepts of consultative experts are then established. The integration steps are described as follows:

Step 1. Match the concept name and synonym.

The name and synonym for personal product empirical knowledge concepts and global product empirical knowledge concepts are matched using the Jaccard Coefficient (1).

Step 2. Cluster the empirical knowledge concept nodes.

Clustering by level and relationship are performed for empirical knowledge concept nodes by employing Agglomerative Hierarchical Clustering (AHC) [5] (2).

$$S(C_i, C_j) = (\min_{p \in C_i, p' \in C_j} | p - p' |) \approx 0 \quad (2)$$

where S denotes two knowledge concepts of C_i, C_j belonging to the same cluster, and p is the parent knowledge concept of C.

Step 3. Generate a new global ontology.

Based on the above cluster results, the new global ontology is generated according to the levels located and the relationships among knowledge concepts from each level of every knowledge concept by registration of product empirical knowledge. The new global ontology is then stored into registration repository of product empirical knowledge.

C. Product Empirical Knowledge Registration Repository

The profile and sharable product empirical knowledge of a consultative expert, as defined above, are modeled to design the registration repository of product empirical knowledge (Fig. 4).

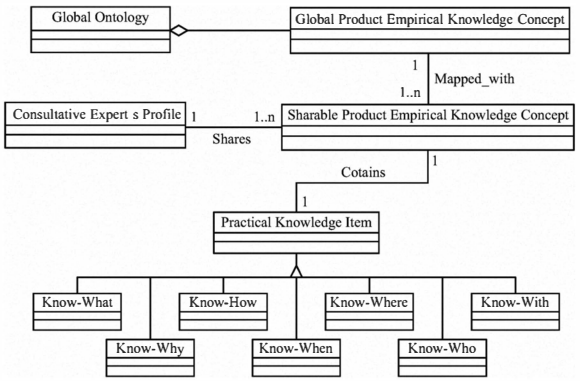

Figure 4. Knowledge model in product empirical knowledge registration repository.

D. Consultative Expert's Profile and Sharable Product Empirical Knowledge Withdrawal

During collaborative product development, allied enterprises can choose flexibly to join or withdraw from the product development team. Therefore, the expert recommendation system for product empirical knowledge consultation also provides consultative experts from allied enterprises to withdraw their profiles and sharable product empirical knowledge, as described below: (i) Withdrawal of Consultative Expert's Profile, and (ii) Withdrawal of Personal Sharable Product Empirical Knowledge Concepts and Practical Knowledge.

IV. CONSULTATIVE EXPERT RECOMMENDATION

Based on registration of product empirical knowledge by experts in Section III, this section describes the consultative expert recommendation. As shown in Fig. 5, consultative expert recommendation comprises three steps: requested knowledge parsing, concept matching of product empirical knowledge, and attribute name set matching of practical knowledge items – all of which are described below.

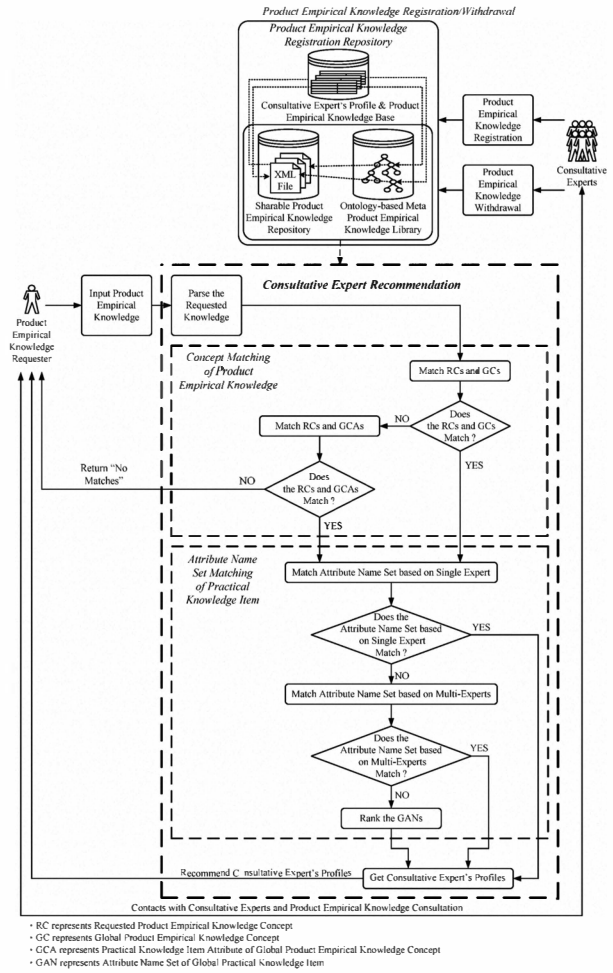

Figure 5. Procedure for consultative expert recommendation.

A. Requested Knowledge Parsing

When encountering product development problems, the requester of product empirical knowledge must first input the knowledge request by using natural language and, then, execute the requested knowledge parsing to obtain required knowledge concepts and their attributes. The requested knowledge parsing consists of sentence breaking, sentence classing, word tagging, and syntactic parsing.

B. Concept Matching of Product Empirical Knowledge

Based on the knowledge parsing results in Subsection IV.A, this subsection introduces the matching for requested product empirical knowledge concepts and global product empirical knowledge concepts. If no matches occur, then matching is executed for requested knowledge concepts and practical knowledge item attributes of global knowledge concepts. They are detailed as follows.

- Matching for Requested Product Empirical Knowledge Concepts and Global Product Empirical Knowledge Concepts: The concept name is first matched by this step. If no matches occur for an appropriate global knowledge concept, synonym matching of global knowledge concepts is performed. Equation (1) shows the concept similarity calculation equation of Jaccard Coefficient.
- Matching for Requested Product Empirical Knowledge Concepts and Practical Knowledge Item Attributes of Global Product Empirical Knowledge Concepts: In this step, the TF-IDF method is adopted to matchmaking of the most similar global knowledge concept for the requested knowledge concept, (3)~(5) show the calculational equation.

1) Term Frequency (TF): mainly to calculate the appearance frequency of requested knowledge concept r in the attribute of global practical knowledge item g.

$$tf_{gr} = n_r / n_{all} \tag{3}$$

where nr denotes the appearance amount of requested knowledge concept r in the attribute of global practical knowledge item g, and nall is the total amount of significant terms in the attribute of global practical knowledge item g.

2) Inverse Description Frequency (IDF): IDF represents the inverse of appearance frequency for requested knowledge concept r from all the practical knowledge item attributes in a certain global knowledge concept.

$$IDF_r = log_2 (N/df_r) \tag{4}$$

where N is the total amount of practical knowledge item attributes owned by the global knowledge concept, and df_r denotes the total amount of practical knowledge item attributes in which the requested knowledge concept r has appeared in all the practical knowledge item attributes owned by the global knowledge concept.

Equation (3) multiplied by (4) is weight, as shown in (5):

$$W_{gr} = (n_r / n_{all}) \times log_2 (N/df_r) \tag{5}$$

C. Attribute Name Set Matching of Practical Knowledge Item

Based on the results of concept matching in Subsection IV.B, the attribute name set is matched. The attribute name set matching model can be classified into two models (Fig. 6), as described below:

- Attribute Name Set Matching based on Single Expert: This step initially involves filtering the different attribute names. The attribute name set is then matched by using Jaccard Coefficient method to match the appropriate attribute name set of global practical knowledge item. Equation (6) shows the calculation equation.

$$AttributeNameSetSim(RAN_i, GAN_j) = (RAN_i \cap GAN_j) / (RAN_i + GAN_j - (RAN_i \cap GAN_j)) \tag{6}$$

where RAN_i is the i_{th} set for attribute name of requested practical knowledge item, i.e., $RAN_i = \{RAN_1, RAN_2, \ldots, RAN_i\}$, and GAN_j is the j_{th} set for attribute name of global practical knowledge item, i.e., $GAN_j = \{GAN_1, GAN_2, \ldots, GAN_j\}$.

- Attribute Name Set Matching based on Multi-Experts: This step involves executing the attribute name set matching based on multi-experts by employing the Power Set method [3].
- Attribute Name Set Ranking: According to above matching results of the attribute name set, this step initially involves ranking the similarity value from best to worst. The mapped to concepts and experts are then found out based on attribute name set to recommend them to a knowledge requester in order to facilitate consultation of product empirical knowledge.

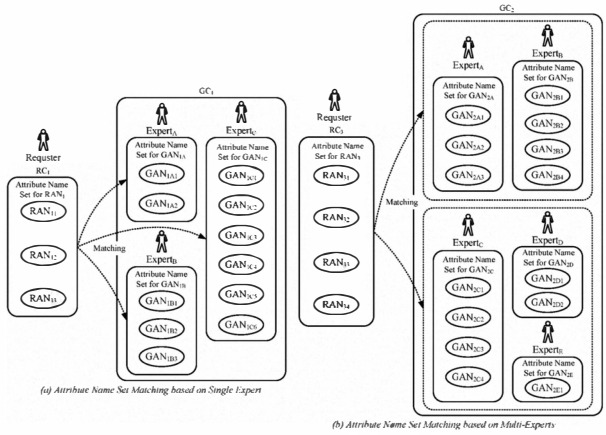

Figure 6. Attribute name set matching models.

V. Prototype Implementation

Based on the above proposed methods for registration/withdrawal of product empirical knowledge and consultative expert recommendation, this study implements a prototype of the expert recommendation for product empirical knowledge consultation. Figure 7 shows the interface for recommending consultative experts.

VI. Conclusions

This study developed an ontology-based expert recommendation process for product empirical knowledge consultation. Methods were then developed for registration/withdrawal of product empirical knowledge and consultative expert recommendation. Finally, the ontology-based expert recommendation system for product empirical knowledge consultation was implemented based on these proposed methods. The main results and contributions of this study are as follows: (i) the proposed method for registration/withdrawal of product empirical knowledge can assist consultative experts to establish profiles and sharable product empirical knowledge and, then, execute product tacit knowledge consulting and sharing in activities of product lifecycle and its supply chain, and (ii) consultative expert recommendation: In addition to supporting product empirical knowledge requesters to correctly match appropriate consultative experts, consultative expert recommendation can create product value by using interpersonal interaction method to share product empirical knowledge.

Results of this study can facilitate the capture and application of tacit product knowledge for knowledge workers involved with activities of product lifecycle and its supply chain, ultimately enhancing product development efficiency and quality in order to further strengthen market competitiveness.

Figure 7. Snapshot of recommending consultative experts.

Acknowledgment

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