Knowledge structuring and evaluation based on grey theory

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Abstract. It is important nowadays to provide guidance for individuals or organizations to improve their knowledge according to their objectives, especially in the case of incomplete cognition. Based on grey system theory, a knowledge architecture which consists of grey elements including knowledge fields and knowledge units is built. The method to calculate the weightiness of each knowledge unit, with regard to the user's objectives, is detailed. The knowledge possessed by the user is also evaluated with grey clustering method by whitenization weight function.

1 Introduction

Knowledge is a very important factor to knowledge workers and knowledge-intensive organizations. Guidance, which points out what the most important knowledge is according to user's objectives and gives the evaluation of current knowledge possessions, is required to improve one's knowledge more efficiently. However, the existing knowledge management technology[1, 2] can not resolve this problem since the cognition and evaluation of knowledge is indefinite and difficult.

To resolve this problem, this paper introduces grey theory[3, 4] into the knowledge management. The grey theory was founded by Prof. Julong Deng in 1982 and caused intense attention because of its original thought and broad applicability. Grey means the information is incomplete. This theory intended to use extremely limited known information to forecast unknown information. By far, it has already developed a set of technologies including system modeling, analysis, evaluation, optimization, forecasting and decision-making, and has been applied in many fields such as agriculture, environment and mechanical engineering.

To knowledge workers and knowledge-intensive organizations, the objectives are usually indefinite and changing, while the cognition of its own knowledge is incomplete. Though the cognition will be continually improved along with the accumulation of knowledge, the characteristic of grey will always exist. Therefore, it is more suitable to use grey system theory, instead of other traditional theories and methods, to model and evaluate one's knowledge.

In this paper, the knowledge architecture based on grey theory is given firstly. Then it provides a method to calculate the weightiness of each knowledge unit in the architecture, with regard to the user's objectives. Finally it presents how to evaluate the knowledge with grey clustering method.

2 Knowledge architecture based on grey theory

Since the pursuing of knowledge should be objective-driven, in this knowledge architecture, we should first define the system objective, which could change with time. The knowledge architecture mainly consists of knowledge fields (KF) and knowledge units (KU), both of which are grey elements. A knowledge field is the field that the knowledge belongs to. Each knowledge field could be divided into many sub-fields. The knowledge fields that can not be divided any more are called knowledge units. The knowledge architecture defined above is shown as Fig. 1. Here KF refers to knowledge field, while KU refers to knowledge unit.

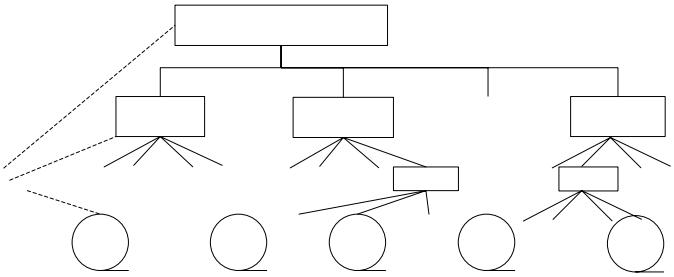

Fig. 1. Knowledge architecture

Because of the incomplete cognition, each element in this knowledge architecture is a grey element, which means the element has not been cognized completely. We use grey degree to represent the extent of grey for grey elements. Grey degree describes the grey extent of a knowledge unit. The value range is $(0,1]$. 0 represents completely known, while 1 represents totally unknown.

According to grey theory, the knowledge units will never turn 'white', in other words, the grey degree will never reach 0. But users can define that when the grey degree is less than a certain value (such as 0.1), the knowledge unit can be regarded as white approximately. What's more, since the grey degree is very hard to be measured precisely, we can define several grey clusters in $(0,1]$, thus the grey degree could be estimated by judging which grey cluster the knowledge unit belongs to.

3 The weightiness of knowledge units

The weightiness of a knowledge unit is a quantitative parameter used to indicate the importance of a knowledge unit, with regard to the user's objective. The basic principle to determine the weightiness of a knowledge unit is the analysis hierarchy process. The process is detailed as following.

Firstly, construct judgement matrixes including Objective-KF/KU matrix and KF-KF/KU matrixes. Each node in the architecture can have a judgement matrix with its sub-nodes. Suppose node A has n sub-nodes. Then the judgement matrix is $\Delta = \{\delta_{ij}\}, i, j = 1, \cdots, n.$, which means it is n-rank. Compare every two sub-nodes:

sub-node i and sub-node j. If they are the same important, we have $\delta_{ij} = 1$. If i is more important than j, $\delta_{ij} = 5$. If i is extremely more important than j, $\delta_{ij} = 9$.

Secondly, we can calculate the weightiness of every mono-layer according to the judgement matrixes. In other words, for a node that has sub-nodes, calculate the weightiness of its sub-nodes. It can be given by calculating the latent root $\lambda_{\max}$ and eigenvector W of the judgement matrix Δ, where

$$\Delta W = \lambda_{\max} W \qquad (1)$$

Finally, we calculate the overall weightiness, making use of the weightiness of every mono-layer.

Suppose the layer 1 has m elements: $A_1,...,A_m$, and the weightiness of A_i to layer 0 is a_0^i, i=1,2,…,m. The layer 2 has k elements: $B_1,...,B_k$, and the weightiness of B_j to A_i is b_i^j, $j = 1,2,...,k$. Here if B_j is independent of A_i, we have $b_i^j = 0$. Then the weightiness of B_j to layer 0 is

$$w_0^j = \sum_{i=1}^{m} a_0^i b_i^j,\ j = 1,2,...k \qquad (2)$$

. Actually, since B_j only has one father node, supposing its father node is A_i, then the weightiness of B_j to layer 0 is

$$w_0^j = a_0^l b_l^j \qquad (3)$$

.

If there are several objectives, the weightiness of each knowledge unit to each objective can be calculated in the similar way.

4 Knowledge evaluation with grey clustering method

Since knowledge is very hard to evaluate, we use grey clustering method to classify knowledge units with whitenization weight function according to how they are mastered.

Definition: Suppose there are n objects to be clustered, m clustering criterion, s different grey clusters. According to sampling $x_{ij}(i = 1,2,...,n;\ j = 1,2,...,m)$ of object i (i=1,2,…,n) regarding criterion j (j=1,2,…,m), classify object i into grey cluster k ($k \in \{1,2,...,s\}$). We call it grey clustering.[3]

In the knowledge architecture, each knowledge unit is an object to be clustered. Clustering criterions are observation criterions used to judge how the knowledge unit is mastered. Grey clusters refer to the grey classes defined based on the extent of knowledge mastery such as ‘bad’, ‘medium’ and ’excellent’.

In grey theory, whitenization weight function is frequently used to describe the preference extent when a grey element takes different value in its value field. Frequently used whitenization weight functions are shown in Fig. 3.

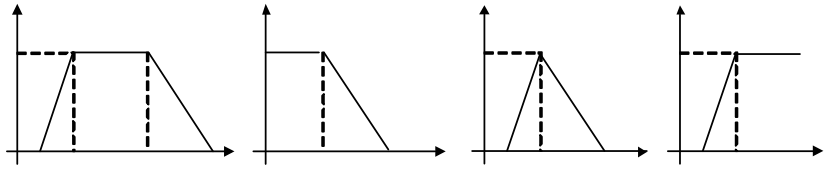

Fig. 3. Whitenization weight function

The whitenization weight function is represented as $f_j^k(\bullet)$. If $f_j^k(\bullet)$ is as shown in Fig. 3(a), Fig. 3(b), Fig. 3(c) or Fig. 3(d), then it is represented as $f_j^k[x_j^k(1), x_j^k(2), x_j^k(3), x_j^k(4)]$, $f_j^k[-,-, x_j^k(3), x_j^k(4)]$, $f_j^k[x_j^k(1), x_j^k(2),-, x_j^k(4)]$ or $f_j^k[x_j^k(1), x_j^k(2),-,-]$ separately. In the knowledge architecture, generally speaking, the whitenization weight function of 'bad' grey cluster should be like $f_j^k[-,-, x_j^k(3), x_j^k(4)]$; that of 'medium' grey cluster should be like $f_j^k[x_j^k(1), x_j^k(2),-, x_j^k(4)]$; and that of 'excellent' grey cluster should be like $f_j^k[x_j^k(1), x_j^k(2),-,-]$.

Since the significance and the dimension of each criterion are very different with each other, we adopt fixed weightiness to cluster. We call η_j the clustering weightiness of criterion j.

The steps of grey fixed-weightiness clustering are:

(1) Give the whitenization weight function of sub-cluster k of criterion j $f_j^k(\bullet)(j = 1,2,...,m; k = 1,2,...,s)$.

(2) Give the clustering weightiness of each criterion $\eta_j\,(j = 1,2,...,m)$ by qualitative analysis or using the method given in Section 3.

(3) Given $f_j^k(\bullet)$, η_j and $x_{ij}(i = 1,2,...,n; j = 1,2,...,m)$ which are samplings of object i regarding criterion j, calculate grey fixed-weightiness clustering quotieties $\sigma_i^k = \sum_{j=1}^{m} f_j^k(x_{ij}) \cdot \eta_j$ $(i = 1,2,...,n; k = 1,2,...,s)$.

(4) If $\sigma_i^{k^*} = \max_{1 \le k \le s} \{\sigma_i^k\}$, we can conclude that object i belongs to grey cluster $k^* f_{\cdot j}^k$

For example, suppose there are 4 knowledge units a, b, c, d. Establishing criterion set as { Ⅰ: number of literatures have been read; Ⅱ: number of published papers; Ⅲ: number of giving lectures}, we classify the four units into three clusters which are 'excellent', 'medium' and 'bad'. The samplings are shown in table 6.

Table 1. Samplings of each knowledge unit regarding criterions

0 $x_j^k(1)$ $x_j^k(2)$ $x_j^k($

(a)

	criterion I	criterion II	criterion III
KU a	5	1	0
KU b	44	4	3
KU c	20	3	1
KU d	25	5	2

Firstly, give the whitenization weight functions: $f_1^1[0,40,-,-]$, $f_1^2[0,20,-,40]$, $f_1^3[-,-,5,10]$, $f_2^1[0,10,-,-]$, $f_2^2[0,5,-,10]$, $f_2^3[-,-,4,8]$, $f_3^1[0,4,-,-]$, $f_3^2[0,2,-,4]$, $f_3^3[-,-,1,2]$. Assume the clustering weightiness of each criterion is $\eta_1 = 0.2, \eta_2 = 0.5, \eta_3 = 0.3$. Then it can be given:

$\sigma_1 = (\sigma_1^1, \sigma_1^2, \sigma_1^{3*}) = (0.075, 0.15, 1.0)$, $\sigma_2 = (\sigma_2^{1*}, \sigma_2^2, \sigma_2^3) = (0.625, 0.55, 0.5)$,

$\sigma_3 = (\sigma_3^1, \sigma_3^2, \sigma_3^{3*}) = (0.385, 0.65, 0.8)$, $\sigma_4 = (\sigma_4^1, \sigma_4^{2*}, \sigma_4^3) = (0.525, 0.95, 0.375)$

The results indicate that knowledge unit b2 belongs to 'excellent' grey cluster, b4 belongs to 'medium' grey cluster, b1 and b3 belongs to 'bad' grey cluster. Combining the evaluation result with the weightiness of knowledge units, the foremost learning and developing directions can be known.

6 Conclusion

This paper gives the knowledge architecture based on grey theory. It provides the method to calculate the weightiness of knowledge and to evaluate them. This method can not only help users to establish their knowledge architecture, but also inform them which are the most important knowledge and which are the foremost learning directions. It also provides the existing knowledge management technology a new idea, which is human-oriented since the user's objective and the expansibility of cognition are well considered. Furthermore, since the method provided in this paper is just objective-oriented, the process-based knowledge modeling and evaluation will be studied in our future work.

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