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An Independent Innovative Knowledge Service Model

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Abstract: Aiming at the most of the knowledge service system only providing information query and the lack of knowledge integration and innovation, a generally adaptive knowledge service model based on independent innovation is proposed, which can bring the deep integration and innovation by dealing with intelligent knowledge processing. The model can integrate multi-sources heterogeneous data, combining and mining measurement data from related information provided by associated databases, to build knowledge tree and can realize knowledge navigation, knowledge recommendation and knowledge visualization with the real knowledge service requirements. It mainly focuses on the fundamental knowledge service model and it's supporting techniques in this study. Moreover, the experimental results indicate that the independent innovative knowledge service has higher rationality, accuracy and visibility than previously published studies. It can automatically structure knowledge tree according to user interest. The completeness of knowledge recommendation is gradually improved and satisfaction of knowledge navigation is improved by 5%.

Key words: Knowledge engineering, knowledge service, knowledge navigation, knowledge recommendation

INTRODUCTION

Knowledge services are programs that provide content-based (data, information, knowledge) organizational outputs (e.g., advice, answers, facilitation), to meet external user wants or needs. Knowledge service is the highest form of information service. It is the set of knowledge system and related service means, techniques and environmental facilities. Knowledge service is also the procedure to resolve user issues by refining knowledge through various explicit and implicit knowledge resources. It is targeted knowledge content and solutions-orientated services (Mentzas *et al*., 2007). In knowledge economy era, user's requirements are turning towards knowledge, personalization, diversity and internetization. This change requests researcher must explore the innovative knowledge service models and establish the entire service system by making the knowledge integration and innovation as the core capability.

Knowledge service can promote national economic growth and social development and it keeps drawing both domestic and overseas researchers' attention. The oversea research started from the late 90s in the 20th century. It emphasis on the industrial research, relationship between knowledge service business and knowledge innovation and focuses on knowledge management within the organization in the micro level research of knowledge service (Gray, 2007). In 1999, Junwei Ren brought knowledge service into domestic library and information industry. It becomes hotspot and most of research is to focus on such specific field. In recent years, some domestic researchers continue overseas hotspot and pay attention to knowledge service and innovation (Xia *et al*., 2008; You, 2004). Though, the existing service models don't integrate the knowledge deeply enough and the service platforms lack of the unified planning and regulation, so it is hard to fulfill the unified service standards and resource sharing and further promote knowledge discovery (Shi, 2002), propagation and innovation.

A generally adaptive knowledge service model based on independent innovation is proposed. It combines the information technology, computer network technology with the real service requirements, which try to break through the application and category limitations of service and promote the efficient use of resources on knowledge innovation.

RELATED WORK ON KNOWLEDGE SERVICE MODEL

The knowledge service model aims at making knowledge integration and delivery through all kinds of advanced technology integration, providing relative knowledge for resolving users' problems and technology innovations, fulfilling knowledge sharing, new knowledge innovation and value increase. This model consists of five

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parts: Acquisition, access, classification, process and storage and service engine.

Knowledge acquisition: Recognizes innovative and effective knowledge, primarily through processing different sources, different platforms and different forms of massive, heterogeneous information and using advanced mining technology to find and excavate abundant knowledge. Furthermore, the implicit knowledge is acquired by analysis, extraction, restructuring, consolidation and other means. A unified standard platform acquires a unified standard of knowledge. Its related technologies include search, Web 2.0, knowledge agent, knowledge discovery and machine learning (Wang *et al.*, 2006).

Knowledge classification: Aims at fulfilling specialized knowledge services in order to provide service for the subject-oriented professional service. For different user groups, different knowledge classification is deployed according to their actual demands. For example, knowledge can be classified by discipline of teaching, while also can be classified by industrial fields or domains for entrepreneurs. Its related technologies include decision-making trees, association rules, Bayesian network, neural networks, genetic algorithms, rough sets and fuzzy logic techniques, etc.

Knowledge processing: It is the core procedure to fulfill intelligent processing and achieve innovation. Firstly, knowledge is classified as different elements. Knowledge element is an indivisible unit with complete representation units, with data, formulas, facts, conclusions, etc. Some elements constitute knowledge unit. Through intelligent processing, the knowledge that is acquired and stored in repository will be integrated and semantically interconnected. Connection and combination of units achieved to produce new knowledge and then efficient use and value-added service can be achieved. Its related technologies include uncertainty information processing, fuzzy set and rough set theory, artificial neural networks (Zhang *et al.*, 2005), vector machines support (Lee and Huang, 2007), genetic algorithm (Zhou and Sun, 2005), swarm intelligence, artificial immune system (Timmis and Neal, 2001), quantum algorithms and information fusion (Kak, 1995), etc.

Knowledge storage: Aims at building a repository. The key is representation and organization model. Currently, three main kinds of representation model include:

- **Logic notation:** For example, first-order predicate logic denotation is usually used
- **Production rules or rule-based representation:** The heuristic or experience knowledge in professional field is usually rule-based representation
- **Semantic network:** It is a kind of pattern that is constituted by nodes and connections between nodes with arcs
- **Framework representations:** It constitutes the relevant object, event, condition and other entities' semantic knowledge according to project field. The main storage modes are self-bodies, knowledge trees and topic trees (Lu *et al.*, 2010)

Knowledge service engine: It is based on repository. It provides characteristic services according to user's requirements. It includes visualization, architecture reasoning, navigation, recommendation, etc.

- **Knowledge visualization:** To organize, present resources and the results are searched according to users' interests that are dynamic obtained. It provides users with an easily understandable visual interface
- **Knowledge architecture reasoning:** The user's interest point is used as the center, to return to certain elements within a radius of knowledge that are associated with users' interest. It provides user with knowledge of the system structure
- **Knowledge navigation:** It provides learners with a compiled and personalized navigation path, which fits their cognitive modes
- **Knowledge recommendation:** Analyze the access sequences of resource recommendation by resource entity, predict the most likely resource sets and provide knowledge to users after sorting by user's interest and resource quality

At present, most of service systems only provide information query and the lack of integration and innovation. Aiming at capturing good quality of service, a great diversity and volume of data have to be combined, integrated and fused. The independent innovative service model can integrate multi-sources heterogeneous data, combining and mining measurement data from related information provided by associated databases, to build knowledge tree.

SYSTEM ARCHITECTURE AND KEY TECHNOLOGIES

To build an independent innovation service platform, knowledge fusion and mining, knowledge tree, navigation and recommendation, visualization, etc., are to be used. The system shown in Fig. 1 includes following parts: Resources organization and management, building and

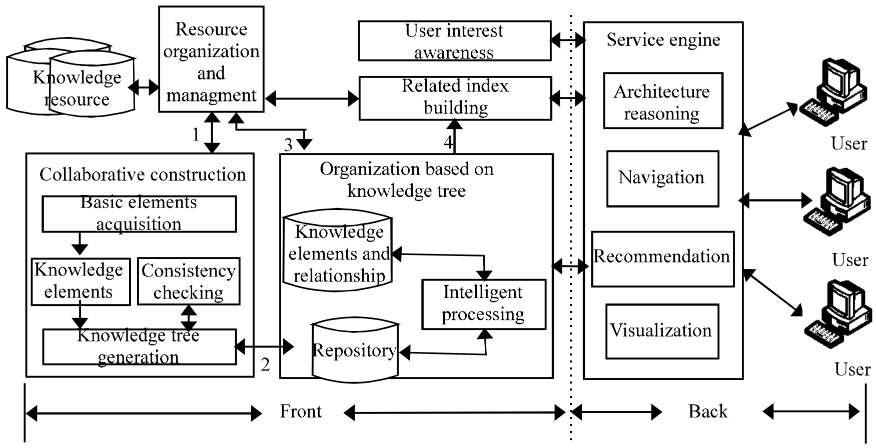

Fig. 1: System architecture of independent innovative knowledge service model

collaboration. Organization and service engine are based on knowledge tree.

Knowledge organization and management: Access to third-party resource entities, resource directories and repositories and manage knowledge tree in implementation centralized way. This module also provides resource access interface for heterogeneous collaborative construction (step 1).

Collaborative knowledge construction: The main function is the acquisition of basic elements, knowledge tree generation and consistency checking. Discovery and analysis is carried out to acquire elements and their association. The knowledge tree is generated based on elements and their connections (step 2). Resource organization and management is applied according to generated knowledge tree in resource organization and management modules (step 3).

Knowledge tree based on organization: It integrates knowledge and associate the semantics using acquired elements and knowledge in repository, to achieve automatic innovation and update knowledge in repository (step 4).

Knowledge service engine: It is constituted by a number of loosely coupled business components and provides user-oriented personalization, interactive, navigational, visual resource service functions, mostly including user's dynamic interest apperception, personalized resources filtering and sorting, architecture reasoning, navigation, authoritative or hot resource discovery, resource recommendation, etc.

- **Knowledge tree structure building:** Since, knowledge is highly correlated with each other, in order to acquire the complete structure, the semantic implication extension, the semantic relevance extension and the semantic class belonging confirmation should be implemented. According to the characteristics of knowledge tree, an extended algorithm based on knowledge unit circle is proposed. Knowledge tree is a kind of network technology for fulfilling knowledge management, which connects the various knowledge nodes. Each node is an element that includes the related knowledge. All knowledge contained in the node is different, but they are relative each other. According to the characteristics of knowledge tree, an extended algorithm based on unit circle is proposed. The algorithm for knowledge tree structure building based on the method of knowledge radius and with knowledge target as root is defined as follows:

Algorithm 1: Knowledge tree structure building:

```
Step 1:   r =1, set _T000⇐g//r is knowledge radius
Step 2:   while r≤R do
Step 3:     for (i = 0; i<|set_Tri|; i++) do
Step 4:       for (j = 0; j<|set_Tri|; j++) do
Step 5:         for ∀ku∈KU_LTM do//ku is knowledge unit
Step 6:           for ∀sg∈ku do // sg is sub-target of knowledge unit ku
Step 7:             if parentOf (g, sg) = true then
Step 8:               set _Trij⇐sg
Step 9:             end
Step 10:          end
Step 11:        end
Step 12:      end
Step 13:    r = r+1
Step 14:  end
```

- **Knowledge recommendation:** The core of information recommendation research is how to accurately and effectively provide the information that the users need. The elements and the relationships between elements are recommended for user within a certain radius and the node of users' interest as the center. The sequence of users' interesting nodes is ordered based on trend degree of interest, which is defined as the following expression:

$$T_{s^i}(i) = \text{Trend}_{access}(i) + \text{Trend}_{KT}(i) \quad (1)$$

where, T_s^i (i) is trend degree of users' interest Trend_{access} (i) is interest trend degree based on access logs, it is defined as follows:

$$\text{Trend}_{access}(i) = \sum_{i \in s_j}^{1\le j\le m} f(\text{Spt}(s_j), \text{Sim}(s_i, s_j), \text{pos}(i, s_j')) \quad (2)$$

where, f is harmonic function, which adjusts the weight of three parameters in trend degree calculation, Spt (s'_j) represents the support of frequent sequences, Sim (s_i, s_j) stands for the similarity between the frequent sequence s_i and s_j, pos (i, s'_j) represents i's position in matched frequent sequence s'_j, Trend_{KT} (i) is interest trend degree based on knowledge tree, it is defined as follows:

$$\text{Trend}_{KT}(i) = g_{a \in s^j, i \in N_{kt}, (a,i) \in E}(\text{weight}(a,i)) \quad (3)$$

where, N_{kt} is the set of all nodes which are associated with the sequence of interesting nodes accessed lately in knowledge tree, it is defined as follows:

$$N_{kt} = \{i \mid \forall a \exists i (a \in s^i, (a,i) \in E\} \quad (4)$$

where, weight (a,i) is the weight of association in knowledge tree. E represents the set of associations

- **Knowledge navigation:** Knowledge navigation extracts the most probable path as a new user's guide and this path could be learned from old user's a large number of interest paths. It is assumed that N users visited the knowledge tree of the specific area. The tree nodes set is:

$$E = \{E_i \mid 1 \le i \le p\}$$

where, m is arbitrary user in N users, visited the E sequence is:

$$\{N_{e1}^m, N_{e2}^m, ..., N_{ek}^m\} \ (1 \le k \le p)$$

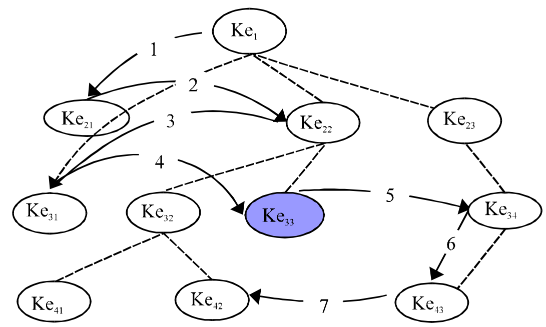

Fig. 2: An example of navigation path

Navigation path is defined as follows:

$$\{(E_1, E_2, ..., E_u, ..., E_p) \mid E_u = E_i, \text{if}(E_i \mid \max\{P_u(E_i)\})\}, (1 \le i \le p) \quad (5)$$

where, P_u (E_i) represents the probability of every tree node appears in the navigation path at the u place:

$$P_u(E_i) = \sum_{m=1}^{N} f_{ue}(m)/p \quad (6)$$

where, f_{ue} (m) is defined as follows:

$$f_{ue}(m) = \begin{cases} 1, & N_{eu}^m = E_i \\ 0, & N_{eu}^m \ne E_i \end{cases} \quad (7)$$

An example of navigation path is shown in Fig. 2. Ke_{33} is the users' interesting node.

EXPERIMENTAL RESULTS AND ANALYSES

To evaluate the effectiveness of the proposed independent innovative service model, it is applied to a part of the domain of "Computer network" which is evaluated from architecture reasoning, recommendation and navigation. An example of independent innovative service is shown in Fig. 3, assumed that the knowledge point is "IP."

Knowledge architecture reasoning: All the elements associated with "IP" within a certain radius are shown in the left. Resource entity list based on the order in accordance with hot degree and reliability are list out, making the top list of high-quality resources in the right. "IP" is selected as knowledge point and different radius to carry out the structure-based reasoning experiment.

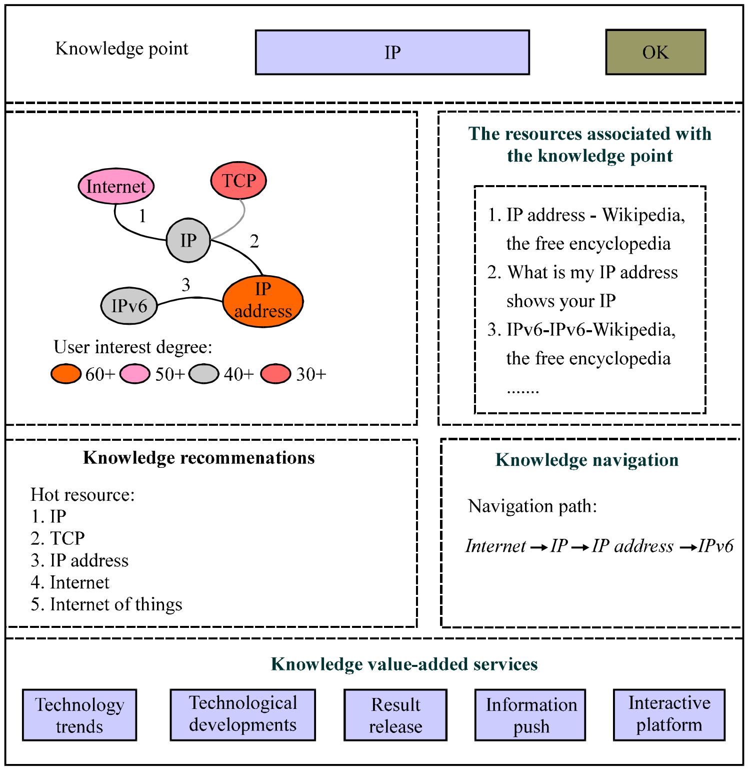

Fig. 3: Platform of independent innovative knowledge service

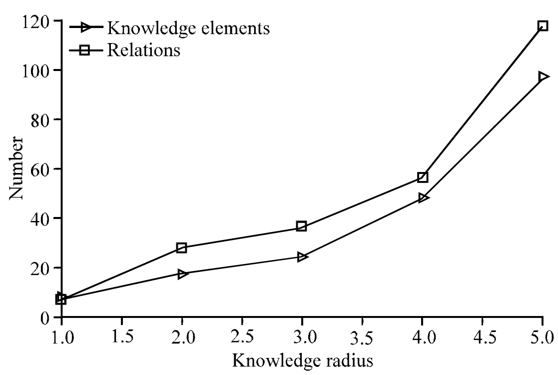

Fig. 4: Relationship between knowledge radius and the number of knowledge elements and relations

It returns all the elements, which are associated with the knowledge point within a certain radius. The structure-based reasoning results are shown in Fig. 4. With the radius increasing, the number of elements and relations continuously increase.

Knowledge recommendation: Different colors of element present the different hot degree and different colors of resource text present the different hot degree of resource. The right part is presentation of the user relative hot and interest degree. Different color portrait present the frequency of the node user accessed. When users click the knowledge point, resource entity list based on the ranking in accordance with hot and authoritative degree are list out, making the top list of high-quality knowledge point.

In this work, knowledge completeness is used for performance measurement. Knowledge completeness (Kc) is described as follows:

$$Kc=1-\frac{|ke_{no}|}{|ke_{\Omega}|} \tag{8}$$

where, $|ke_{no}|$ is the number of elements which are not recommended. $|ke_{\Omega}|$ is the number of elements which should be recommended. From the experimental results of recommendation, it can see that the threshold influences the completeness of recommendation. With the threshold increases, completeness is gradually improved.

Knowledge navigation: The black bold lines in the knowledge tree represent cognitive path tendency, the numbers on the black bold line indicate the sequence of cognitive steps. The navigation path in the knowledge tree is {ke1→ke21→ke22→ke31→ke33→ke34→ke43→ ke42}.

In this work, knowledge satisfaction is used for performance measurement. Knowledge satisfaction (Ks) is described as follows:

$$Ks = 1 - \frac{V_{ge} - V(Kp)}{V_{ge}} \quad (9)$$

where, V_{ge} is the expected value of navigation path, V (Kp) is the value of the knowledge path, it is defined as follows:

$$V(Kp) = w_1 V(kp(ke_1)) + w_2 V(kp(ke_2)) +, ..., + w_j V(kp(ke_j)) \quad (10)$$

where, w_i is weight, V $(kp(ke_j)$ is the value of the j-th element to achieve the overall goal on the path. “IP”, “TCP”, “TCP/IP protocol”, “IP Protocol” and “IP definition” is separately selected as knowledge point. The average satisfaction of navigation is 0.76.

The experimental results indicate that the independent innovative service has higher rationality, accuracy and visibility than previously published studies. It can automatically structure architecture according to user’s interest. The completeness of recommendation is gradually improved, but it has great relationship with threshold selection. Satisfaction of navigation is improved by 5%. Through interacting with these visual interfaces, learners are able to explore the information space with their interest.

CONCLUSION

Based on summary and analysis of the knowledge service models available now, an independent innovative service model has been proposed, which can bring the deep integration and innovation by dealing with intelligent processing. Service engine provides the personalized knowledge and the self-knowledge concept to implement service. It achieves management and sharing, semantic organization and convergence among knowledge. The knowledge is related and can be visited uniformly and transparently by view. It provides a unified pattern to query and search knowledge of heterogeneous data resources in order to achieve sharing and collaboration and has flexible scalability, reusability, etc. This model also aims to achieve semantic interoperability, uses structural and logical reasoning to mine the tacit knowledge and build system, then present to users in a graphical way in order to achieve high-quality service.

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