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Modeling Knowledge Flow and Learning Strategy in Multi-agent System

Steven K.C. Lo
Department of Information Management, Jinwen University of Science and Technology,
New Taipei City 231, Taiwan, Republic of China

Abstract: This study proposed an integral concept and methodology of knowledge management with procedural methods to enhance the efficiency and productivity of managing knowledge-Knowledge State Transition. It provides flexible treatments for promoting the feasibilities of knowledge management. This article also proposes a suitable model for managing and presenting knowledge by using computer aspect and shows the important of learning mechanism. At first, the knowledge map architecture is proposed to achieve knowledge navigation, knowledge dissemination and knowledge sharing in this study. In learning model, this study constructed the models by information technology, it not only could quantify these extract data and infer some formulas. It can help us to use the right method to learning and choose the useful knowledge to management. It will focus on that, major is that let learner achieve auxiliary effect during learning process by information technology and can quantify and modularize, not infer automatically.

Key words: Multi-agent, knowledge agent, knowledge map, knowledge selection, learning model

INTRODUCTION

The efficiency of managing knowledge affects much on the competition and productivity of economics (Chang, 2000). Although knowledge management comes from the sphere of business administration, knowledge management (Lau and Tsui, 2009; Becerra-Fernandez, 2000; Kingston and Macintosh, 2000; Han and Park, 2009) can be practical to levels of the entire society for the concepts of business administration can be widely defined. From the usage of a government to the learning and working of a person, knowledge management is a not only an issue but a fulfillment of each level of the world. A person is an atomic unit of an organization. Capabilities of a person will be important elements whether an organization will take one into consideration or not. With learning and the accumulation of knowledge, a person will be capable of professional skills.

The twenty-first century is an era of post-industrial society or intelligent society wherein intellectual power decides a country's competitiveness. Therefore, the more the creativity, intelligence and analytic capacity a country has, the stronger its competitiveness will be in the world's knowledge economy (Kaku, 1998). Michio Kaku claims that "Knowledge and technology" will become the only determining factor in a nation's competitiveness. In the industrial society, the scales of the business systems kept on expanding. With knowledge economy, the economic benefits created by employing the knowledge can be called Knowledge Productivity (KP). Knowledge productivity affects the strength of competitiveness. The more efficient knowledge management, the higher knowledge productivity it will be. In the knowledge economy era, economy created mainly by knowledge system (Gu *et al*., 2012; Lau *et al*., 2003; Chang, 2008) and knowledge gained from the learning. This article proposed some models and functions to explain the important of learning and relationship between learning and knowledge by information technology.

In the multi-agent (Ellis and Wainer, 1994; Chen *et al*., 2011; Wu, 2001; He *et al*., 2009; Kotz and Gray, 1999; Shah *et al*., 2009; Ilarri *et al*., 2008; Yau *et al*., 2003; Park and Sugumaran, 2005) communication and coordination mechanism, this article provide an integrity aspect and methodology of knowledge management, with procedural methods to enhance the efficiency and productivity of managing knowledge. It is a methodology refers to the concept of software life cycle . If knowledge management is not good enough, the crisis would be caused the same as software crisis. Knowledge representation (Garcia-Crespo *et al*., 2011; Chen and Rao, 2008; Huang, 2009; Ma *et al*., 2010; Perrin and Petry, 2003; Wang *et al*., 2008) and dissemination (Huang and Lin, 2010; Liu and Ke, 2007; Lopez-Juarez and Howarth, 2002; Hatzilygeroudis and Prentzas, 2004; Wang and Shao, 2012; Liu *et al*., 2011; Tseng and Huang, 2011; Walczak, 1998; Rybakov, 2009) is now an important topic in research of knowledge management and business application. This study propose a suitable model for managing and presenting knowledge by using computer aspect and show the

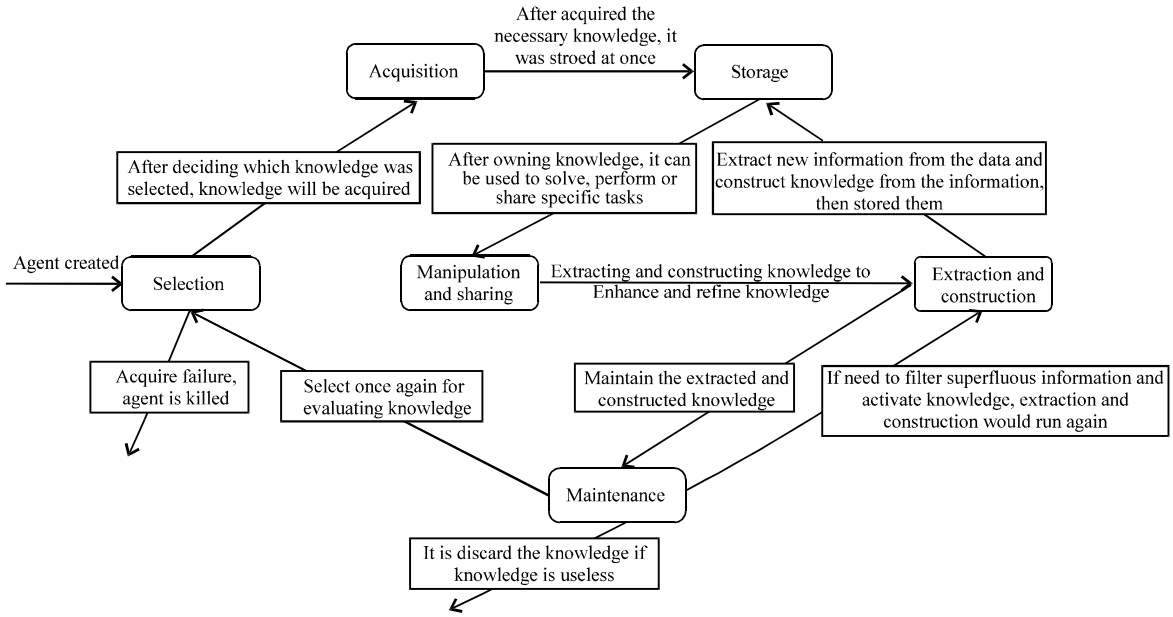

Fig. 1: Knowledge agent state transition diagram

important of learning mechanism. As to the learning evaluation parts, it will focus on three major topics: learning model, learning method evaluation and knowledge selection. In learning model, it is constructed by information technology, it not only could quantify these extract data and infer some formulas. This article also proposes the evaluation mechanism of learning method, included learning evaluation mechanism and knowledge selection, they can help us to use the right method to learning and choose the useful knowledge to management. This study will focus on that, major is that let learner achieve auxiliary effect during learning process by information technology and can quantify and modularize, not infer automatically.

ESTABLISHED KNOWLEDGE AGENT STATE TRANSITION

By introducing the idea of knowledge user group, this article design an efficient knowledge agent to search knowledge on the internet when a learner is trying to solve a problem. The aim of the knowledge agent is not to retrieve the knowledge from raw information on the internet but to search those organized knowledge information by employing different searching algorithm and standard knowledge exchange format. As a result, a methodology of knowledge management "Knowledge Agent State Transition" in Fig. 1 was proposed. It shows six states to transit by knowledge agent: Selection, Acquisition, Storage, Manipulation and Sharing, Extraction and Construction and Maintenance.

The state transition provides a sequential route as well as a flexible route. The sequential route starts from the "Selection" phase and going through the phases step-by-step. It is expected to be a complete implementation of knowledge management. The flexible route of state transition is a practical mechanism for implementation in accordance with the situation and environment. More specifically, the requirement of storage will be triggered if some new knowledge was created from "Extraction and Construction" and "Maintenance". In addition, in order to activate and refine knowledge, the mechanism of the "Maintenance" state will trigger another state like "Selection", "Manipulation and Sharing", or "Extraction and Construction".

These states represent that the possible states of the knowledge management process. Now it will explain the significance of each state.

Selection: people have to realize what the value they can require to measure and evaluate the productivity of knowledge when they select knowledge.

Acquisition: After deciding which knowledge was selected, the next step is to acquire this knowledge.

Storage: After acquired the necessary knowledge, it was stored at once. These knowledge needs to be stored into brains or into the database via software system in order to be retrieved and utilized afterwards. Knowing the knack of storing knowledge well will improve the quality of stored knowledge and the usage of the knowledge will be more responsive.

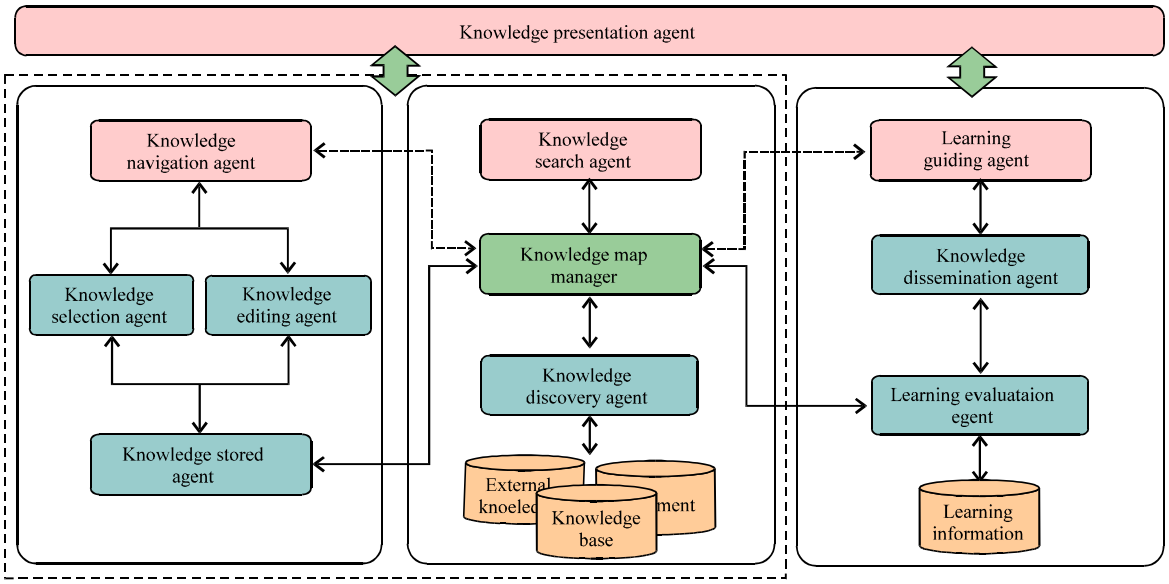

Fig. 2: Using Multi-agents coordination to construct knowledge map architectur

Manipulation and Sharing: After owning knowledge, it can be used to solve problems or to perform specific tasks. The transmission is to share or present knowledge to a potential recipient. If knowledge is not absorbed, it has not been transferred.

Extraction and Construction: extracting and constructing knowledge is centered on how to enhance and refine knowledge. People "extract" new information from the data and consequently and "construct" knowledge from the information to obtain high quality knowledge productivity.

Maintenance: It is possible for stored knowledge to be the condition of insufficient, weak, incorrect and idle. It is necessary to maintain the activation and renew the insufficiency of knowledge as well as re-supply and adjust incorrect knowledge.

KNOWLEDGE MAP ARCHITECTURE

As people know, knowledge is different from document and it does not exist independently. If knowledge wants to exists, it needs to depend on other knowledge and with a specific structure for a specific task. In the field of decision-making, knowledge map is a method designed not only to elicit information complexity that the decision makers faced but also to combine the probabilities associated with each factor to obtain a final probability. The knowledge map model helps us to achieve the goal (Fig. 2). It integrates multi-agent interaction and knowledge flow into this knowledge map. In the education field, the important aspect is on the relationship of knowledge classification. In the learning process, learner can see the presentation result from the presentation interface and learn some knowledge from the knowledge map database via knowledge map manager. It also can gain some advises from the learning guiding module. Many researches in education have proved that knowledge structure has significant effect on learner's construction of cognitive map.

Knowledge presentation agent: This agent is responsible for knowledge navigation?knowledge searching and learning. It communicates with knowledge navigation agent knowledge search agent and learning guiding agent. After communicated with them, it would show the results on the presentation layer.

Knowledge navigation agent: It is used for guiding knowledge object (ex. documents) discovery according to knowledge structure generated in advance by the knowledge map manager. It is useful for learners to obtain knowledge scope and categories existing in the current community.

Knowledge search agent: It is used for identify knowledge object from the document base according to the user's requests.

Learning guiding agent: It is responsible for suggesting required knowledge according to the learning information database generalized by learning information recorder.

Knowledge map manager: It is mainly to coordinate the knowledge map navigation, knowledge search and learning guiding according to user's requests. It also needs to integrate the knowledge stored unit and some learning history information to access the correct information from multiple database via knowledge search agent.

Knowledge selection agent: Under people can only assimilate limited knowledge, this agent is responsible for selection of useful knowledge and understanding of what knowledge is assimilated in order to obtain high efficiency and excellent results.

Knowledge editing agent: This agent is responsible for common and standard knowledge exchange format. It is also used for starting to navigate the document or knowledge after knowledge presentation agent shows knowledge on some presentation devices.

Knowledge stored agent: This agent is responsible for knowledge stored of different types from human beings.

Knowledge discovery agent: This agent is responsible to give a proper solution from solution database and keep on to solve that. It will interact with Knowledge Map Manager to help the learners to surmount the impasse point.

Knowledge dissemination agent: It is responsible for knowledge dissemination with Petri-Net.

Learning evaluation agent: This agent is responsible for learning evaluated include some parameters like as learning method and learning time.

This article will introduce these agents in later sections. It will acquaint us with each component in this architecture.

Knowledge stored mechanism: First of all, Knowledge Stored Agent (KSA) is defined as the handler for knowledge stored of human beings. After input devices receive data which store in a human's brain, by means of KSA, its formation relates much to the input devices and the stored data types. A memory unit takes down not only the input data but the input devices and data types; moreover, it takes down the association with other memory units as well (Alavi and Leidner, 2001). As shown in Fig. 3, this article proposed two kinds of learning channel for a knowledge memory to store it, one is Sense channel and another one is Association channel.

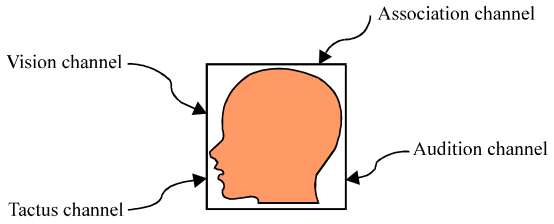

Fig. 3: Sense channel (vision, tactus, or audition) and association channel

Sense channel: It mainly learns from the sense of human. For example, you can learn or memorize some information from your vision, tactus, or audition.

Association channel: This channel comes from other knowledge association, you can learn or store (memorize) some knowledge from other knowledge memory.

Associated knowledge stored unit: The knowledge stored agent cooperatives every Knowledge Stored Unit (KSU) and each KSU has the structure as following:

- $V = \{V_n | n \in N\}$, every vertex *v* has one attribute which contains a payload
- $E = \{e_{ij} | i, j \in N\}$, e_{ij} represents a linkage built from V_i to V_j
- LM (V_s, V_n, A, S, W), LM is represented as "Learning Method" structure. It would be defined "Learning Method" included five parameters V_s, V_n, A, S and W

The definitions of these parameters are as following:

- V_S: V_S represents payload of source
- V_D: V_D represents payload of destination
- $A = \{d_i | d_i \in \text{Apparatus}, i \in N\}$, Apparatus = {eye, ear, mouse, nose, skin, finger}
- $S = \{s_i | s_i \in \text{Shape}, i \in N\}$, Shape = {text, voice, pronunciation, melody, picture, taste, material , position}

W is the weight of e_{ij}, it represented the different strength when learners use the different channel. Then, the article also defines two kinds of matrix as following.

Relational matrix: It represents the connected relation network between every node (Knowledge Stored Unit), where, a_{ij}:

$$\begin{cases} = 0, \text{ no linkage from } V_i \text{ to } V_j \\ = n, \text{ has a linkage from } V_i \text{ to } V_j, \text{ n is strenght weight} \end{cases}$$

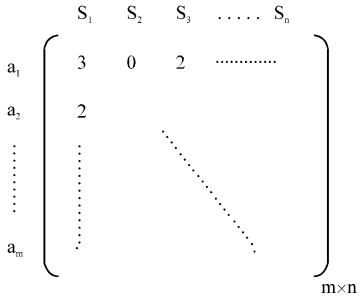

Fig. 4: A sample of mapping matrix

Strength weight matrix: It represents the strength weight from Apparatus and Shape mapping.

Storage prescription: We can follow some steps below to represent the storage prescription:

- Assume x is input, y is our output, then weight w_{ij} acquired from $W_{ij} = \alpha x_i y_j$
- It can be represented by matrix as following
- $W = \alpha y(x)^T$, α is a proportionality or normalizing, so for any pattern, it has one input pattern x^p, output pattern y^p, then will gain the formula $W = \alpha y^p (x^p)^T$
- If W_{ij} does not equal to null, it represents x_i has a connection to y_j
- Store all patterns, namely sum the weight of all patterns, it can gain the formula:

$$W = \sum_{p=1}^{P} W^p$$

When it has not started the memory procedure yet, all the values of weight are set to null. According to step 1 to 3, it can acquire the following formula:

$$W_{ij}^{new} = W_{ij}^{old} + \alpha x_i^p y_j^p$$

Weight mapping matrix: Define the set:

$$X = A \times S = \{(a_i, s_j) | \forall (a_i, s_j), a_i \in A, s_j \in S, i, j \in N\}$$

Weight Mapping Matrix $W_{m \times n}$, w_{ij} is the element of $W_{m \times n}$ where i=1 to m, j = 1 to n:

$$W_{m \times n} = \alpha_{A(S)}{}^T \Rightarrow \forall (a_i, s_j) \in Z \underrightarrow{inject} w_{ij}, \forall w_{ij} \in W_{m \times n}$$

According to the definition, we can find the example of weight mapping matrix in Fig. 4.

Associated memory network: Associated Memory Network (AMN) is mainly to the use of each Knowledge

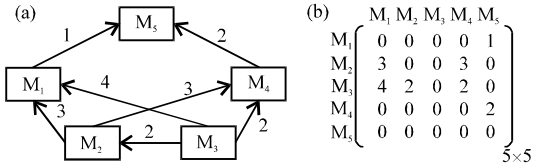

Fig. 5(a-b): (a) A sample of associated memory network, (b) AMN matrix

Stored Unit as defined above banded together into a network diagram. In Fig. 5a, there are five KSUs connected by their memory relation. The weight is on the arrow and the direction represents learning memory flow. In Fig. 5b, this matrix constructs from AMN. It is helpful to represent and infer from a network graph. "Zero" is represented no connection.

The AMN (Associated Memory Network, in Fig. 5a) can transform into an efficient graphic (Fig. 6) accord to the definition and algorithm as following. It will be a reference of learning path.

AMN definition:

- **path pattern:** Composed by nodes and edges
- **effective path:** No redundance node in the path pattern
- **Depth:** (node # -1) same as edge # in effective path
- **Distance:** Sum of weight in every effective path

Effective path generate algorithm

```
Procedure EffPathGen()
{   VD: Target Node
    for each row                    row as leave-string;
    process_row (row_number, leave-string);
    if temp-stack is not empty then
        process_temp_stack(node number);
}
Process_row (start_row_number, leave_string)
{   for each column as end node in this row;
    if a( start_row_number, end_node) = 0 go to next
    if a( start_row_number, end_node) ? 0 and end_node = VD
        if find pattern then retrieve this node, append leave-string and
        replace to result_array
        insert(start_row_number, end_node) to result_array
    if a( start_row_number, end_node) ? 0 and end_node ?VD
        if find pattern
        insert(start_row_number, end_node) to temp_stack
}
Process_temp_stack()
{   which (temp_stack is not empty)
    {   pop(node number)
        retrieve last node number as start_row_number
        process_row(last_node_number, leave string)
    }
}
```

Effective path diagram

Knowledge editing agent and knowledge dissemination agent: In this section, this article will discuss with Petri-

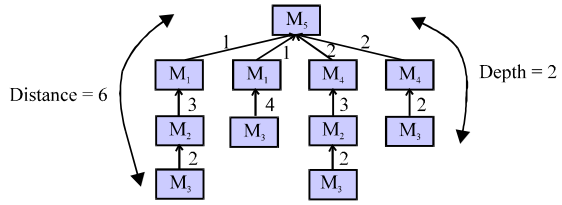

Fig. 6: Generated an effective path from associated memory network

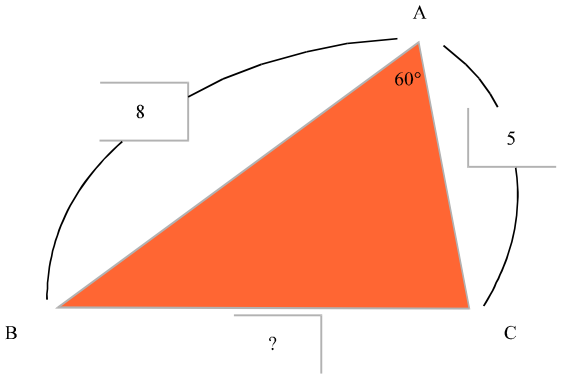

Fig. 7: A example of triangle question

Net Graph to solve the problem. Many people learn knowledge from solving a given problem. Therefore, this section will introduce the solving step can be represented by Petri-Net Graph and people will learn the knowledge from them. It can also evaluate the learning result by this way and then give the score to test and practice solving a given problem. As we have described the Petri-Net representation model previously. This section tries to introduce the solving a given question by Petri-Net Graph as following. The question sample is a Trigonometric function to solve the opposite side when it gives the values of two sides and included angle (Fig. 7).

The question statement:

$$\Delta ABC, \overline{AB} = 8, \overline{AC} = 5, \angle BAC = 60°, \text{calculate the value of } \overline{BC}?$$

The petri-net solution: A Petri net consists of places, transitions and arcs. P is a set of states, called places and T is a set of transitions. It describes the places and transitions (Table 1, 2) from triangle samples above mentioned. Based on the definition, it will build the solving step by Petri-Net Graph (Fig. 8) to evaluate the learning result and give the testing score.

Knowledge discovery agent: When people want to solve a problem and meet the step is broken, they can rely on the partial Petri-Net Graph to assist us to solve the given problem. Based on the knowledge discovery model in Fig. 8, it can give a proper solution from solution database and keep on to solve that. Due to a leaner usually occurs an impasse when he learned some knowledge and solved some problems. The knowledge discovery would be useful to help the learners to surmount the impasse point. This article can design more than one solution in the solution database based on Petri-Net. Then it can also construct the knowledge discovery and scoring model in Fig. 9. It would be stored in the database by structured form. The system knows what solution the learner will use and can provide suitable suggestions or hints to learner. And it can give the score to the learner depend on what steps he had finished.

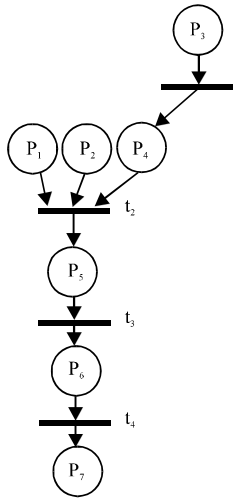

Fig. 8: The solution of sample question by Petri-net graph

Table 1: The places of petri net from Fig. 7 sample

Place	Description
P_1	$\overline{AB} = 8$
P_2	$\overline{AC} = 5$
P_3	$<BAC = 60°$
P_4	$\cos 60° = 1/2$
P_5	$\overline{BC}^2$
P_6	$\overline{BC} = \pm\sqrt{\overline{BC}^2}$
P_7	The value of $\overline{BC}$ is 7 (the value of each edge in triangle is positive)

Table 2: The transitions of petri net from Fig. 7 sample

Transition	Description
t_1	Get the value of cose 60° based on trigonometric function
t_2	Theorem: $\overline{BC}^2 = \overline{AB}^2 + \overline{AC}^2 - 2 \times \overline{AB} \times \overline{AC} \times \cos\angle BAC$
t_3	Calculate the square root of $\overline{BC}^2$
t_4	Calculate the value of $\overline{BC}$

Learning evaluation agent: The learning economy is a concept which is represented by the Learning Evaluation

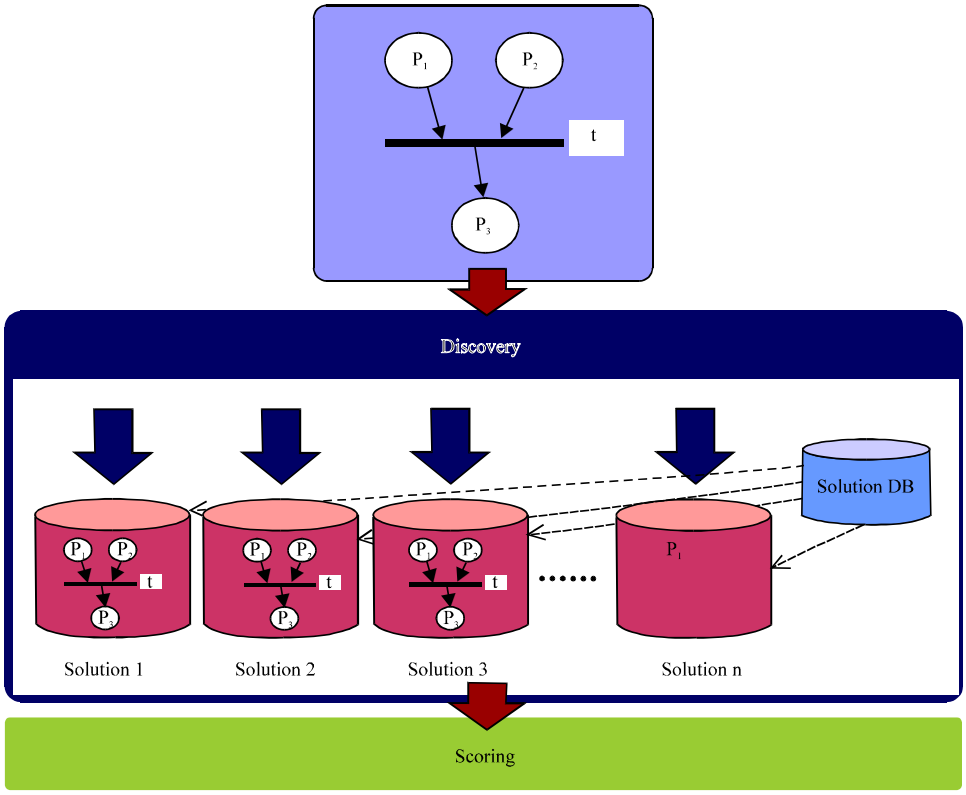

Fig. 9: Knowledge discovery and scoring model

Function (LEF). If there are two learning method, the efficiency of method A is double than method B, method A would gain the double knowledge capacity than Method B at the same time. It would also create the double economic benefits. So, this function is defined as following:

- $LEF(LM_n) = T_n$, where LM is learning method, T is learning time and n is from 1 to n

However, people can evaluate the learning result by different learning method. It is mainly purpose of LEF. For example, when people learn same thing, they can choose three methods: LM_1, LM_2 and LM_3 to learn it. So, they can ponder what time achieving the same learning result is by LM_1, LM_2 and LM_3.
Assume that:

- $LEF(LM_1) = 20$ h
- $LEF(LM_2) = 6$ h
- $LEF(LM_3) = 2$ h

If learner chooses LM_3, the learning efficiency is decuple than using LM_1, triple than LM_2. So, the learning economy of LM_3 is higher than using LM_1 and LM_2. Before learners discuss Knowledge Selection Function (KSF), they will define the Learning Profitability (LP) first. Because, select suitable knowledge, it would bring the greater economy benefit.

Knowledge selection agent: In the view of knowledge management, people can only assimilate limited knowledge. It is a very important issue to decide what knowledge to be assimilated and how to get high efficiency to get most perfect result. So we advise a brand new idea that is "knowledge competition". There is no doubt that, knowledge doesn't have discrimination of good or bad. But the same knowledge has different value in different era. Take Taiwan for example, in farming society, the skill of planting cane and banana has very high value. In industry society, the skill of oil and chemical has high value. The information society, information and communication lead the trend. Due to the changing of the society, everyone or every enterprise should have the vision of knowledge competition. In the other words, when people are choosing new knowledge, they have to consider the knowledge of competition first, because there are too many possible choices. Think about

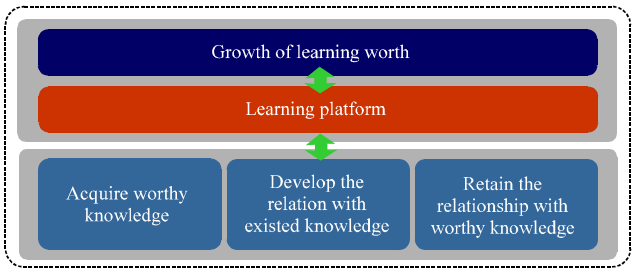

Fig. 10: Growth of learning worth model

it, it takes the same time to learn, person A whose competition of new knowledge of learning can create productivity of one hundred thousand dollars, person B only creates productivity of ten thousand. Person A would be transcended than B on competition advantage of economy.

LEARNING PROFITABILITY (LP)

The profitability of personal learning on the continuously time, deduct from the cost of acquisition, evolution and retention, it would be called the Learning Profitability. People can accord to follow formula to represent the learning profitability when they learn everything.

LP = (Learning Quantity×Beneficial Result of per-unit)-(Evolution Cost of Learning+Retention Cost of Learning)-(Acquisition Cost of first time Learning).

Affected learning factors:

- LQ: GLearning Quantity while one period (for example, read some books or words)
- BR: GBeneficial Result after learning per unit
- A: GAcquisition Cost of learning
- E: GEvolution Cost of learning
- R: GRetention Cost of learning
- D(t): GDecay-Rate function of learning, where T is persistent time of learning

We have two types need to be discriminative, continued learning type and non-continued learning. Because different types would be affected the learning evaluation result, they must be discriminated two kinds of type as following to discuss.

Continued learning type:

$$LP=\frac{LQ\times BR}{D(t)}-\frac{(E+R)}{D(t)}-A$$

Non-continued learning type:

$$LP=P\frac{LQ\times BR}{D}-\frac{(E+R)}{D}-A$$

where, P is a probability when learner would like to learn something.

Based on above definition, this article proposes the Growth of Learning Worth Model (LWG Model) in Fig. 10 and descript as following LWG is related information with learning growth. LWG is represented as Learning Worth Growth, it means as following:

- LWG : (acquire worthy knowledge) + (develop the relationship of past knowledge) - (cost of knowledge loss)

and the formula as following:

$$LWG = A(K_n)+D(K_e)-(1-r)\times R(K_e)$$

Where the factors is as following:

- K_n = Gpotential knowledge quantity
- K_e = Ginitial development stage, existed knowledge quantity
- $A(K_n)$ = Gcost function of acquired knowledge
- $D(K_e)$ = Gcost function of developed knowledge
- $R(K_e)$ = Gcost function of retentive knowledge
- r = Gexisting knowledge retention rate
- (1-r) = Gknowledge loss rate

Owing to learners have much choice when they want to learn new knowledge, learners must think about the knowledge competitiveness of learning. It took the same hours, the competitiveness of learning new knowledge of person A can have rather output value of one hundred thousand dollars. And person B has ten thousand dollars, so on the competition superiority of economy, A is greater than B. Therefore, effective knowledge selection is important for us.

CONCLUSION

Only efficiently utilizing knowledge will people call it knowledge management. In the knowledge society, the primary economic productivity is from the development and usage of knowledge. Moreover, the efficiency of managing knowledge affects much on the economic competitiveness and productivity. Knowledge state transition proposed in this dissertation includes six components: "Selection", "Acquisition", "Storage", "Manipulation and Sharing", "Extraction and Construction" and "Maintenance". It is to establish an integrity aspect and methodology of knowledge management, with procedural methods to enhance the efficiency and productivity of managing knowledge. It is also a methodology refers to the concept of software engineering and software life cycle. The better approach for the software crisis is to combine comprehensive methods for all phases in software development. Similarly, if knowledge management is not carefully and effectively carried out, the potential crisis will be the same as software crisis. Knowledge representation is now an important topic in research of knowledge management and business application. This article proposes a suitable model for managing and presenting knowledge by using computer aspect and show the important of learning mechanism. And it also constructs the knowledge map architecture; it mainly includes four parts - knowledge navigation, knowledge search, learning guiding and knowledge map management. As to the learning evaluation parts, this article will focus on three major topics: learning model, learning method evaluation and knowledge selection. In learning model, it is constructed by information technology, it not only could quantify these extract data and infer some formulas. This article also proposed the evaluation mechanism of learning method, included learning evaluation mechanism and knowledge selection, they can help us to use the right method to learning and choose the useful knowledge to management. It will focus on that, major is that let learner achieve auxiliary effect during learning process by information technology and can quantify and modularize, not infer automatically. When people want to hyperlink with external documents, it might have resource contended situation.

Furthermore, the users can employ the retrieval strength function to review whether there are sufficient and excellent knowledge channels in their memory to enhance the total retrieval strength. And then, they turn into searching for other suitable memorizing and learning methods to supply new knowledge channels for retrieving knowledge. The mechanism of knowledge memory cycle can be used to verify that the methods of learning and memorization are effective or not.

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