Extracting Features of Human Knowledge Systems for Active Knowledge Management Systems

Yuan Miao , Robert Gay, Chee Kheong Siew, Zhi Qi Shen

ICIS/School of EEE, Nanyang Technological University, Singapore 639798

Abstract

It is highly desired for the research in artificial intelligence area to be able to manage knowledge as human beings do. One of the fantastic natures that human beings knowledge management systems have is being active. Human beings actively manage their knowledge, solve conflicts and make inference. It makes a major difference from artificial intelligent systems. This paper focuses on the discussion of the features of that human knowledge systems, which underlies the active nature. With the features extracted, further research can be done to construct a suitable infrastructure to facilitate these features to build a man-made active knowledge management system. This paper proposed 10 features that human beings follow to maintain their knowledge. We believe it will advance the evolution of active knowledge management systems by realizing these features with suitable knowledge representation/decision models and software agent technology.

Keywords:

Intelligence, Knowledge, Reasoning

1. Introduction

Using hybrid reasoning mechanism and being active are two important and related aspects of how human beings manage their knowledge.

It is well known that case-based reasoning and rule-based reasoning are two mechanisms human beings use[1-6]. It can be easily observed that the two mechanisms are often combined. Itzhak Gilboa and David Schmeidler [7] indicated that few real-life examples are able to be described only by CBDT (case-based decision theory) instead of EUT (expected utility theory), or vice versa. That is, human beings use hybrid inference and management systems to handle knowledge.

Some researchers have realized the point and proposed a number of hybrid systems [4-6]. The attempts of constructing hybrid systems that applied different methods are basically either proposing rule-based systems with support of case-based reasoning, or case-based reasoning with support of rule-based systems. Compared with man made knowledge management systems, human beings are more balanced and able to manage knowledge in a dynamic process. A human being's hybrid system starts from cases. The system is not good to memorize separate cases (as well as rules). It tends to find the relationship among the cases. Then cases are classified according to their difference. The classification makes it easier to know which case should be applied for a new query.

The common parts of cases are generalized as rules. It takes time for a rule to get stable. After that, rules have higher priority than cases to answer queries. After rules are stabilized, they are more reliable than cases. Though, if there is an exception, unless it can be well explained (such that a special reason caused the exception. The rule therefore needs not be revised.), the rule will be marked. Such marking will let the owner be more cautious when applying the rule later. It will also make the owner alert at information related, which he may use to solve the conflict.

Rules are subject to changes. When there are new cases or rules, related rules would be examined and revised accordingly. This process often calls up the related cases in memory to help solve conflicts and tidy up the knowledge base. This active nature makes the system dynamic and efficient. Human beings also exam the knowledge system even there is no conflicts. The examination tries to find more relationship and difference among rules and cases so that they can be applied more efficiently. The human beings knowledge management system is a hybrid dynamic system.

We use the term dynamic instead of incremental because "incremental" mainly refers to the ability of adding new rules/cases/pieces of knowledge. Human beings however, often revise their rules. Theoretically, deleting old rules (knowledge) and adding in new rules (knowledge) can have the same effect as revising. Though, the underlying mechanisms are very different.

This paper investigates the features of human beings dynamic hybrid knowledge management system. We believe it will advance the evolution of an active knowledge management system by realizing these features with suitable knowledge representation/decision models, and software agent technology.

2 Features of Human Knowledge Systems

The overall picture of human knowledge system described above is the first feature we would like to summary:

- **Feature 1. Human beings' inference systems are dynamic and hybrid**
- **Feature 2. Human beings want to know how and why, not only what**

A rule or a case normal tells "what" (the fact). For example:

It just rained = TRUE ⇒ Road is wet = TRUE (1)

Knowledge (1) tells a fact, which is the effect that rain can have. When the person holding knowledge (1) notices that the road is wet but there is no rain, he/she cannot explain the scenario. Based only on the knowledge of "what", there are a lot of limitations and easy-to-face conflicts. X. Z. Wang and D. S. Yeung [11] indicated that case-based reasoning faces problems that cannot be solved within the framework. Not knowing "how" and "why" contributes to the problems. When case-based reasoning is applied, the query case needs to be compared with the cases stored. Then the most similar case will be chosen and the corresponding action is adopted. As indicated by Wang, the situation that one stored case has similarity of (0.9,0.7,0.9,0.7) while another has (0.7,0.9,0.7,0.9), becomes a hard situation. One solution is to put up weights. Different features may have different weights. Then there will be an overall score [10]. This solution can help a bit. Though, chances are still high that two cases have the same overall score.

In such a case, human beings can distinguish it from trying to know why. Following are some classic questions from kids. A boy once asked his father why he (the son) is asked to call a friend of his father as uncle, but the friend of his father won't call him (the son) uncle. His father told him, "We call you Dear." Then he asked, "Can I call you Dear?" His father said, "Ok, Dear." And he got the puzzle: "Can I call him dear instead of Uncle?" As well: who actually is the "Dear"? The children consider all this type of questions while they grow up. They have to find explanations.

Now let us look at the knowledge (1) again. Human beings not only maintain the knowledge of the rain and wet road mentioned above, but also maintain the related *why* and *how*:

Road is wet = TRUE $\overset{because}{\Longrightarrow}$ there is water (2)
Rain introduces water: Rain ⇒ there is water (3)

Rained = TRUE ⇒ rain is comparatively even ⇒ not only the road is wet, but also trees, buildings (4)

Splash tank work = TRUE ⇒ normally the water cannot reach the roof of buildings ⇒ roof of buildings are dry (5)

He/she will also observe how different source of water can make the road wet. Then he/she will gain the following knowledge:

Rain makes the road wet gradually (6)
If it is a light rain (shower), there is less water (7)
Less water can dry up faster, especially when it is windy (8)

These knowledge can help him to explain later, if there was a light rain shower in the morning and he finds no wet roads on the way back home in the afternoon. A man-made intelligent system often fails to do so. Hence, without facilitating the how-and-why-mechanism of features, which affects the action, case-based reasoning cannot handle the similarity puzzles properly. This leads to the feature 3.

- **Feature 3. Based on the knowledge of *<u>how and why</u>* the causes contributing to the action, human beings can combine cases efficiently instead of choosing one of them**

Suppose there is a hot-tempered father who is a photographer. Once, his son is curious and took out some films to check up. This led to a bad experience: his father scolded him. Another case is that the boy found the paper of his father's work colorful. He then picked up a few pieces and played around, which led to another similar result: being scolded. Since the father does not explain to the boy that taking out the film will cause all the work to be destroyed; picking out some of pages will distort the order which takes him a long time to sort, the boy generalize a wrong rule based on the two cases: father's belongings cannot be touched. Without knowing the reason why the causes contribute to the action, cases cannot be combined properly. Isolated cases are not very useful and the knowledge system is not efficient.

Human beings note down what causes lead to the corresponding actions (cases), find out how/hwy the causes trigger the actions and sort out the knowledge base accordingly. Therefore, human beings often have handy rules/cases support their decision-making. There can be vase number of cases. Though, the number of axioms is very limited. The more detailed the rule/knowledge can be broken down, the closer they are to the axioms, and the easier they are organized, the easier contradiction can be solved. An active knowledge management system should try the best to break down the rules/knowledge, sometime with the help of human experts.

- **Feature 4. Human beings maintain rules in different levels**

Human beings maintain rules in different levels, according to how close the rules are to the cases. Duplication/short cuts are allowed for rules/cases/queries with frequent usage. It is similar to the cache technology. For example, if there are a lot of cases to be based upon in deciding whether to go out or not, and whether it is raining or not, a person maintains

If it is raining ⇒ Do not go out (9)

together with

If it is raining ⇒ May get wet ⇒ Not good to health ⇒ Do not go out (10)

Unless there is a conflict to be solved, he/she uses (9) instead of doing the inference of (10) every time. Though, (9) is a rule of higher level than (10). Whenever there is a conflict to be solved, he/she will go to lower level rules or even the cases. By doing so, he/she can check whether there is a way to go out in the rain without getting wet, if he/she really has to go out (exception or contradiction).

Lots of people have the experience that if the "rule" is clearly explained to the kid, it is easier and more efficiently to be watched. This feature suggests that artificial knowledge management systems should also maintain knowledge in a hierarchic structure. As it is widely accepted that artificial intelligent system should be designed for particular domains, it is a reasonable deduction that a number of cases/rules are more frequently referred. A knowledge/rule/case cache should be arranged and fallback mechanism should be designed when contradictions occur.

- **Feature 5. Human beings are *active to tidy up* knowledge base**

As mentioned, human beings are curious. They are active in tidying up the knowledge base. Human beings tend to find the similarity and difference between rules and cases so that it will be efficient when they are called later. So far, no expert system is "curious". Normally, an expert system only solves the problem when it arrives. After that, it does nothing. While human beings ask more, which allow them have better management on the knowledge rules. Let us use the example of the rain and wet road again. It is a big improvement if a system can do what we have done above: two main rules with 5 supplementary rules for the relationship between "rain" and "wet road" (Rule (1)-(8)). However human beings do more. They will ask: how can I differentiate them? Once that the wet road is observed, a conclusion can be drawn that it may have been caused by the rain, may have been by the splash tank work, may have been by the flood or may have been by the broken pipe. A person would find that the rules are not easy to be used. He/she then tries to gain more information/knowledge related to the group of rules (cluster), out of his/her curiosity, to differentiate them.

(Pipe broken = TRUE) ∨ (Flood = TRUE) ⇒ (Trees are wet = FALSE) (11)

(Splash tank work = TRUE) ⇒ (Trees are wet = TRUE) ∧ (Houses are wet = FALSE) (12)

(Flood = TRUE) ⇒ (News report of the flood = TRUE) (13)

(Frequent rain in the last few days = FALSE) ⇒ (Flood = FALSE) (14)

(Temperature is under zero = FALSE) ⇒ (Possible Snow = FALSE) (15)

(Snow = TRUE) ⇒ (Snow on leaves) (16)

These knowledge are supplementary of the previous knowledge, which can help him/her determine the reason of the wet road fast and accurately.

Aside from observation, human beings also set up experiments to find out rules, which help them judge and manage the knowledge base well. The tidying up not only maintains the consistency of the knowledge base, but also tells how to use them. If you have only one rule, you will apply it when there is a query. (If it turns out to be a wrong decision, the knowledge will be adjusted, which is a feed back mechanism. We will discuss feedback later.) While if there are a lot of rules related, he/she needs to know in what circumstance, a rule can be applied. Therefore, he/she needs to find out the difference between the rules. In this way, human beings build up efficient knowledge base with huge volume of rules. Normally, the rules are very specific so that it is fast and accurate to be applied.

Maintaining similarity and difference of cases/rules is an important approach for a knowledge management system to sort out and classify the rules/cases. If necessary, supplementary rules should be accommodated to indicate how to use the similarity and the difference.

- **Feature 6. Human beings use fuzzy concepts**

Most of concepts that human beings use are fuzzy concepts. For an instance,

Tom is tall ⇒ let him sit behind (17)

There are no explicit definitions for "tall" and "behind". This feature is widely accepted and a lot of publications focus on how to apply fuzzy concepts to the conventional case-based/rule-based reasoning [17].

- **Feature 7. Human beings emphasize difference; zoom in and out to find the difference**

As mentioned, human beings like to compare things and memorize the difference, which help them manage the knowledge efficiently. As well, human beings often use fuzzy concepts. The combination of the two features result in a very powerful feature human beings knowledge system have: being able to zoom. For example, to sail in a straight line, the sailor needs to force to the right when the wind comes from the right, force to the left when the wind comes from the left. This rule can be represented by binary concepts When the rule is not enough to describe how to counter the wind, a more explicit description should be used: When there is strong wind from the right/left, force to the right/left firmly; When there is mild wind from the right, force to the right gently. The wind and the force are now described more explicitly to meet the need. Fuzzification is one of the foundations for the zooming.

Zooming in and out helps human beings maintain a sufficient and efficient knowledge system. When there is a need, human beings will adjust the fuzzification factor and make more explicit description. Artificial intelligent systems normally do not have the ability to adjust the concepts of the rules when the rules seem not able to make the proper judgment. To build an efficient artificial knowledge management system, zooming function is necessary.

- **Feature 8. Human beings ponder over their knowledge (Feedback)**

Human beings always ponder over their knowledge. Otherwise, they will be regarded as stubborn. Cases are stored first. When there are enough cases, generalization will be made and rules will be obtained. Rules are more stable and reliable than cases. However, when exceptions occur, people become very cautious to apply the rules. Zooming in is also applied to observe until the reason of the exceptions is found. Then either the rules are adjusted or supplementary rules are put up for the exceptions. Knowledge base revision normally discards old rules and forms new rules. Human beings instead, revise rules and put up "notes" or supplementary rules for existing rules. They only discard a rule when it is totally wrong, such like the rule discussed in Feature 2: "father's belongings cannot be touched".

Rules of human beings are maintained in different levels. Such as "no speed can be faster than light speed" is quite a fundamental rule; Rule (9) is a much less fundamental one. The sources of the rules are also stored with the rules. They will be referred when contradiction occurs. Normally, after rules are formed, the underlying cases are not used. After certain period, some of the cases may be even forgotten. For example, if the doctor wants to check whether a patient's food is healthy or not, what is the possible reason of his uneasy, most probably, he cannot remember what he had for dinner each day the previous week. What he can tell is that basically the ingredients are lots of sweets, meant and a little vegetable. Artificial knowledge management systems are capable to memorize more cases than human beings do. Though, having an efficient feedback mechanism to maintain the rules and cases is still important.

- **Feature 9. Linguistic concepts have implications**

D. Dvir and et. al [16] proposed a type of feature with text value, as an example, a city name. The valid value is simply "*Vancouver*" or "*New York*" or others as the name of the city.

However, a text value has either no use in a reasoning process, or has a lot of implications. A city with a name of "*New York*" means

- it is in US;
- it is at the east coast of US;
- it has a large population;
- it is a financial center;
- and so on.

Therefore, "*New York*" implies all the background knowledge related to it. Those knowledge that is related to the current reasoning problem will be considered. Human beings use a lot of linguistic concepts and most of them have implications in reasoning.

In an artificial knowledge management system, it is not easy to build up all these background knowledge. A solution is to explicitly put up all the implied factors that contribute to the inference/action.

- **Feature 10. Human beings remember patterns**

Most of the reasoning systems do not allow circles. Circles can cause a lot of problem in logic. However, feedback is a very common phenomenon. Instead of regarding it as a circle, human beings memorize the pattern. With the help of some formal tools (mathematics and other theories), human beings are able to get a description of the pattern of the feedback system. For example, the description can be: the system will be directly stabilized after a small disturbance; or it will experience a few rounds of regulations and then reach the equilibrium; or it will finally be trapped in a limit circle. After that, the pattern is the element he/she carries on with his/her reasoning.

Figure 1 shows the mechanism to use pattern to address circles:

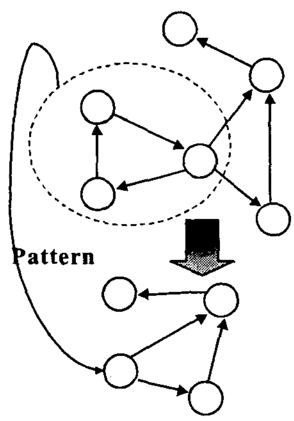

Figure 1. Use Pattern to represent circles

In an active knowledge management system, similar mechanism can be used to avoid circles, or an inference mechanism that supports circles is needed. Anyway, it is highly recommended that feedback be facilitated in the framework as it is very important and widely exists in real systems.

3. Facilitating Human Being Features in Active Knowledge Management Systems

Based on the above features extracting from human knowledge management system, we are working on a framework for active knowledge management system to facilitate all the features. It is an agent based hybrid system.

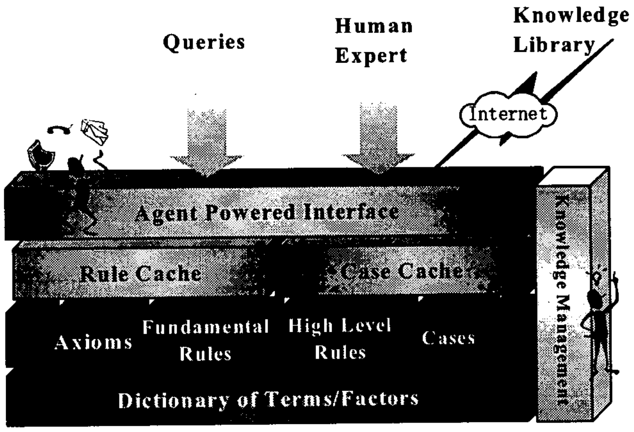

Figure 2 Framework of the active knowledge system

From the described features, we know that an active knowledge management system should be able to infer over fuzzy concepts, be able to zoom in and out, be active, be able to describe how features contribute to the decision (action), be able to describe circle (feedback, pattern) and be able to interface with explicit systems. Obviously, a modeling theory that can describe the knowledge is needed. During our research, we found that FCM/DCN (Fuzzy Cognitive Map/Dynamic Causal Network) [12, 13] is a possible modeling tool to support agent based active knowledge management systems. FCM/DCN basically is a rule-based system. However, it has good potential to host the case-based systems, which makes it one of our choices to facilitate all the features we proposed.

An FCM is usually represented by a digraph, in which vertexes represent concepts and arcs between the vertexes indicate causal relationships between the concepts. Therefore, every arc represents a rule. Figure 3 shows a simple example of an FCM for modeling the relationship among afforesting, logging, profit making and the environment.

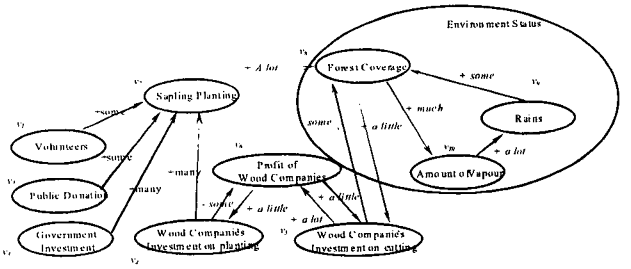

Figure 3. Fuzzy Cognitive Map of afforesting and environment

An FCM digraph can be represented by its adjacency matrix. As shown in Figure 3, suppose the adjacency matrix[1] is W^T,

$$W = \begin{bmatrix} \cdots & \cdots & \cdots \\ \cdots & w_{ij} & \cdots \\ \cdots & \cdots & \cdots \end{bmatrix} =$$

$$\begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & +\textit{a little} & 0 & +\textit{a little} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & +\textit{a little} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -\textit{some} & +\textit{a lot} & 0 & 0 & 0 & 0 & 0 \\
+\textit{some} & +\textit{some} & +\textit{many} & +\textit{many} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & -\textit{some} & 0 & +\textit{a lot} & 0 & +\textit{some} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & +\textit{a lot} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & +\textit{much} & 0 & 0
\end{bmatrix}$$

The scenario illustrated in Figure 3 is that: the effort of volunteers' work, public donation and government investment will result in more sapling planting, which contributes to the improvement of the environment; this will increase the forest coverage resulting in good ecological cycle; on the other hand, too much logging by timber companies will damage the ecosystem.

The vertexes (the concepts) take binary values 1 or 0 as their states. For instance, the state of v_1, x_1, equals to 1 or 0 indicates whether there are volunteers or not. Arcs between vertexes represent the causal relationships between the concepts. They are represented by linguistic terms, such as *"a little"*, *"very little"*, *"much"*, *"very much"*, etc.. The linguistic terms can be fuzzified in the interval [0,1].

Given the causal relationships represented in the FCM, the inference can be carried out in the decision making process. In an FCM, the state of a vertex/concept is determined by its causal inputs. For instance, as shown in Figure 3, given woodcutting and sapling planting rates, v_8 can infer whether the forest coverage will increase or decrease. This mechanism is represented by the vertex functions [12].

Definition 1 ***vertex function***: A ***vertex function*** f_{T_i,v_i} is defined as:

$$x_i = f_{T_i,v_i}(\mu) = \begin{cases} 1 & \mu > T_i \\ 0 & \mu \le T_i \end{cases}, \quad \text{where } \mu,$$

$$\mu = \sum_j w_{ij} \cdot x_j \text{, is the total input of } v_i.$$

A vertex function aggregates the rules and gives an overall

[1] w_{ij} is the weight of a_{ji}, it represents the causal relationship from v_j to v_i. The adjacency matrix is $\{w(a_{ij})\}=\{w_{ji}\}=\{w_{ij}\}^T=W^T$.

score. The conventional vertex functions of FCMs are too simple and need to be expanded [14].

As mentioned, a FCM basically is a rule-based reasoning system, with arcs representing the rules. While if we regard a set of initial states and the corresponding outputs as cases, FCMs also have a good potential to be a case-based reasoning system. Such a system could possibly be able to represent cases and explain why different features contribute to the action.

In Figure 3, the environment can be regarded as a whole concept, or be broken down as *Rain*, *Amount of Vapor* and *Forest Coverage*. This shows that FCMs are able or have the potential to zoom, to represent feedback, to use pattern and so on. As well, the *shortcut*: better *Forest Coverage* →More *Rain* can be broken down to as: better *Forest Coverage*→ more *Vapor* →More *Rain*.

FCMs basically meet the needs of being able to infer over fuzzy concepts; being able to describe circle and being able to interface with explicit systems. Though, as shown, its capability is not enough. Miao and Liu [14] expand FCMs to DCNs. FCMs can facilitate fuzzy inference.

One may argue that most rule-based/case-based hybrid systems have such potential or somehow has the ability. Though, the ability is limited. Although, we can see a bit of the "why" mechanism in the existing hybrid systems, it is hard to find a system which represents the "how" mechanism. Miao and Liu [14,15] show that without the ability to describe how the effect takes place, a lot of contradictions could show up. For example, if one gets the money and decide to plant trees on the mountain, the saplings can be planted fast. But it takes years for the saplings to grow up and become trees. While if one wants to destroy the forest, in a couple of months, men can chop down all the trees. Without noting the difference, the aggregation (done by the vertex functions, in term of FCMs) of rules will easily lead to contradiction. This is also true for case-based reasoning.

Though, FCMs describe concepts with binary or triple concepts. This makes it difficult to facilitate fuzzy concepts and zoom in and out. DCNs expand concept state sets to fuzzy sets and real intervals, which are not only able to use fuzzy concepts, facilitate zooming in/out, but also able to communicate with explicit systems. The inference of DCNs is carried out by numerical calculation.

Most of the existing artificial intelligent systems do not have a mechanism to represent temporal concept and describe how the rules take effect, or how the features contribute to the action, which is different from what human beings do. DCNs not only take into account the temporal concept, but also introduce inner state into arcs (rules) that makes it able to describe the pattern and how the features result in the decisions (actions).

Basically, DCNs meet our requirement except being active. To make the system active, we need to further expand the DCNs by making use of software agent technology. Software agent technology is the first major technology that claims autonomy as one of its main features. Agents present a nature merge of object orientation and knowledge-based technology. Agents have the potential for simulating a lot of human being's knowledge management behavior. The DCNs can be used to represent the knowledge (rules and cases) of agents and enable the agent doing inference based on hybrid reasoning mechanisms. This enable the agent based active knowledge management system to perform the features extracting from human being knowledge management systems.

In the active knowledge management system, agents are used to tidy up the knowledge base. Agents try to find out the similarity and difference among rules and cases, connect to the Internet and then other knowledge libraries to get information/knowledge to manage or improve the rules/cases, send requests to human experts so that they can help to solve the contradictions or sort out the knowledge base.

4 Conclusion

This paper proposed 10 features that human beings follow to manage their knowledge systems. Some of them are not easy to be found in the existing man-made knowledge systems. By doing this, we hope to make a clear picture of how human beings' knowledge systems are. This set a foundation of designing agent based active knowledge management system that can facilitate all the features.

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