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If you have an apple and I have an apple and we exchange these apples then you and I will still each have one apple. But if you have an idea and I have an idea and we exchange these ideas, then each of us will have two ideas.

George Bernard Shaw

5.1 Preamble

We have established KM as a strategic tool for providing competitive advantage to the organizations [Bansal, 2010]. Effective KM ensures knowledge assets to remain within the organization by identification, capturing, coding and facilitating sharing.

It is really a challenge to the knowledge manager to identify, capture, combine and codify the scattered organizational knowledge. At the various level of hierarchical structure in the organization, different types of knowledge exist. Also, at the functional level, the specialized knowledge is required in addition to basic domain knowledge. So KM initiatives must focus on identifying the knowledge assets in hierarchy and functional divisions of the organization. Efforts have been made in the previous chapters for developing frameworks for capturing and coding knowledge assets by using knowledge maps.

Concept mapping provides a framework for externalization of knowledge in a visual form that can easily be examined and shared [Canas, 1999]. Concept Mapping has been used as technique to codify knowledge for the development of expert systems and for knowledge preservation at NASA [Canas, 1999]. Concept Maps are considered as static knowledge capturing tool [Safayeni, 2005].

In software engineering, analysts use various tools like UML, DFD, ERD, Data Dictionary, Decision Trees and Tables etc. for gathering requirement of the client. Decision Trees are composed of nodes representing the end state and links representing the decision [Bai, 2003]. Decision Trees enable visual representation of complex decisions [Bai, 2003]. Use of DFD and Structured Chart as a knowledge map, have been shown in the previous chapter.
Capturing of domain knowledge of dynamic nature is more challengeable as compared to static knowledge [Harrison, 2007] [Harrison, 2009]. Hybrid Concept Maps like Cyclic Maps can be one of the solutions for capturing dynamic domain knowledge [Safayeni, 2005]. In this chapter, we have identified decision trees for representing dynamic domain knowledge. We have devised a hybrid framework for KM by combining decision trees with Concept Maps. Hybrid Concept Map has capability to represent concepts along with decision making knowledge structure.

With analysis of knowledge assets available in the organizations, this chapter provides a hybrid framework for capturing the dynamic domain knowledge that may reside at any knowledge layer.

Also, we show the layered arrangement of knowledge maps in a typical organization. This framework shows that Context Diagrams can be used for capturing system knowledge and can be used at upper layer; however, Concept Maps representing concepts and ideas shall be at lower layer.

### 5.2 Concept Maps

Concept Maps are one of the knowledge representing and organizing tools to help in understanding a concept, or domain knowledge. Hierarchical in nature, Concept Maps provide a schematic summary of a specific idea [Espinosa, 2007]. Concept Maps are the powerful tool in personalizing the learning process, sharing and managing knowledge [Espinosa, 2007]. Concept Maps makes tacit knowledge of an organization explicit, by visual means [Espinosa, 2007]. The biggest advantage of visualization technique is to give clear and easy to understand expression to domain knowledge. Also Concept Maps represent the levels of knowledge structure [Zhang, 2008].

Most of the time, experts do not know what they know and face difficulty in articulating the concept. Experts gain knowledge over the period of time by applying information into action, thinking and observation [Novak, 2006a]. Though it has been practice to capture expert knowledge with the help of interviews, reports and case studies, but Concept Maps based on
epistemological ideas are proved much better tools for capturing concept. Concept Maps have also been useful identifying knowledge gap apart from capturing expert knowledge [Novak, 2006a].

Concepts Maps are developed on Ausubel’s three ideas on cognitive development [Novak, 2006b]. First, as per Ausubel’s Assimilation Theory, development of new ideas and concepts take place on the basis of previously understood concepts and beliefs [Novak, 2006b]. Second, the concepts are having hierarchical structure, with more general ideas are at higher level and specific ideas are at sublevel [Novak, 2006b]. The third is meaningful learning helping in showing explicit relationship within the concepts and ideas.

Concept Maps are very simple and useful to way to show the concepts. Concept Maps show the concept (general one at higher level and more specific at sub level of this) with the help of a labeled box [Novak, 2006b]. The boxes are connected with lines having linking words, which show the meaningful relationships between the two concepts [Novak, 2006b]. Usually, Concepts are labeled with a noun and linking words are labeled with verbs [Canas, 2005]. This arrangement shows flow of information in hierarchical manner. So, Concept Maps are two-dimensional graphical tool that enables anybody to express their knowledge in a form that is easily understood by others [Canas, 2005]. A use of Concept Map with an example has been presented in Chapter 3.

Concept Maps are context dependent. Hence, for the same concept, concept maps may vary depending on the context [Canas, 2005]. Effectiveness of Concept Maps can be measured by level of expression about expert’s knowledge [Canas, 2005].

Concept Maps have found wide acceptability in science education and research by helping students, teachers and researchers in understanding and sharing the concepts and ideas [Iuli, 2004].

In a very interesting study, Canas [Canas, 2005] compared information and knowledge visualization. Also, this study shows that from Artificial
Intelligence perspective of knowledge representation methodologies do not emphasize on knowledge visualization techniques. Apart from research and teaching concepts, visualization techniques have got usefulness in business communities [Canas, 2005].

Business organizations like Banking and Insurance, which are highly knowledge intensive, must be provided with broad spectrum of knowledge base, and Concept Maps can be the best tool for this purpose [Fourie, 2004].

In the context of Banking and Insurance Companies, investment strategies, portfolio management and customer relations are important knowledge structures that an expert normally possesses [Fourie, 2004]. It is worth mentioning that these knowledge structures are majorly outcome of vast experience along with some basic fundamentals and concepts from books, literature and magazines [Fourie, 2004]. Hence, Concept Maps can be used for capturing knowledge from expert and shared with less experienced professionals for detecting area of improvement [Fourie, 2004]. Also, Concept Maps are suitable for both an organization and an individual for KM. It is noteworthy that an environment for knowledge creation and sharing always plays an important role irrespective of tool, technology and approach [Fourie, 2004].

Concept Maps have been useful in [Iuli, 2004]:

- Summarizing tacit knowledge of an individual- By drawing concept map of what a person know about a concept/ domain.
- Identifying and removing anomalies from the concepts- Comparing the concept map with the that of an expert and by applying facts.
- Identifying knowledge and understanding gap- By identifying limitations to draw concept map.
- Designing syllabus and instruction manuals- More useful as compared to text based description.
• Assessment tool for learning and understanding- May be used as an assessment class room teaching, training programs and workshops.
• Effective tool for sharing ideas and generating consensus about the concept and idea among groups.
• Effective tool for new knowledge creation and understanding the process about how new knowledge can be constructed.
• Tool for knowledge gathering and modeling.

To summarize about Concept Maps, we can conclude [Canas, 2005]:

• Concept Maps are two dimensional, hierarchical graphical tools. Hierarchical structure indicates flow of information. Concepts Maps can be drawn with any simple graphic software.
• More general concepts are presented at the top and more specific concepts at the bottom. Concept Maps may or may not be concept specific. While describing a concept, it can be taken to any direction depending on the context.
• Concepts are connected with links labeled with the relationships between the concepts in a domain. Lines representing links does not contain arrowhead, which other similar type of maps used.
• Concept Maps have a context. For two different contexts but for the same concept, concept maps may differ.

5.2.1 Issues with Concept Maps

Some times, it is difficult to apply any tool just similar as it is described in its literature. Real field application may vary from its theoretical application. On the basis of real problems, we have suggested the use of DFD and Structure Chart as process knowledge maps, though these tools have been developed for SSAD. Though we have not modified or changed the original structure of these tools.

An investigation on capabilities and limitations of Concept Maps [Derbentseva, 2004] shows possible variations on Concept Maps. Also, a
comparison has been made by Mauri Ahlberg [Ahlberg, 2004], which indicates variations done by various authors on Concept Maps to be useful in specific context.

Using arrowheads, more meaningful & long verbal expressions, connecting pictures, videos & sounds and order of reading from bottom to top, are some variations suggested by various researchers, which are originally not the part of Concept Maps [Ahlberg, 2004].

Safayeni, Derbentseva, and Canas [Safayeni, 2005] suggested modification in Concept Maps with incorporating cyclic structure to represent relationships between concepts and dynamic system thinking. There is no strong agreement among the researchers on the structure of Concept Map [Safayeni, 2005].

Relationship between the concepts may have two variance—Static and Dynamic [Safayeni, 2005]. Static relationship between concepts shows meaning, categorization, belongingness, composition like [Safayeni, 2005]:

- Invoice is a Business Document- Invoice is one the documents which are used in Business domain. So Invoice is in the category of Business Documents. Two concepts Invoice and Business Document are in static relationship. Some more examples are Car is a type of vehicle; Saving account is a type of bank account etc.
- Sunlight produces Vitamin D- This statement shows relationship between two distinct concepts i.e. Sunlight and Vitamin D in a particular context.
- Thermostat has Sensor- This shows the composition of a Thermostat.

Dynamic relationship between the two concepts shows propagation of change in these concepts [Safayeni, 2005]. The dynamic relationship shows the effect of changes in the quantity, quality or state of one concept causes corresponding changes in the quantity, quality or state of another related concept [Safayeni, 2005]. With original Concept Maps, one could not show dynamic relationship specifically, however to make these maps more comprehensive and useful, cyclic concept maps can be used [Safayeni, 2005].
Dynamic relationship between the concepts can be seen, when the decision has to be taken for selecting from possible options. For the example, take two concepts *Income* and *Tax*, now how much tax is to be paid? This cannot be represented through Concept Map. It is obvious that range of *Income* and type of income decides the *Tax* (If *Income* is above the range, Then pay some % for as a *Tax*), but there is no provision for representing this knowledge in concept map.

We take another example, like *Boiler* and *Feed Pump*. Say, *Feed Pump* feeds *Water* to *Boiler*. Here are three concepts: *Water*, *Boiler* and *Feed Pump*. *Feed Pump* feeds *Water* to *Boiler*, when water level goes below to certain predefined level (If *Water* level is below to a value, Then feed water to *Boiler*). Now, concept map does not suggest any way, to show when to feed *Water* to the *Boiler*?

This type of situation arises in organizations, very often and hence for complete understanding of concepts, original concept maps put limitation.

We see this dynamic relationship between the concepts as *if-then* relationship, and this gives us a basis to suggest new hybrid concept map in combination with Decision Trees.

### 5.3 Decision Trees

Decision Trees are one of the software engineering tools, which are useful in capturing expert knowledge. An expert takes some decision in certain condition which can be represented with Decision Tree very easily. Decision Trees are useful in helping to choose between several possible actions [Bai, 2003]. Decision Trees are also used in Artificial Intelligence as knowledge representation and acquisition method [Bai, 2003]. The unique feature of Decision Trees is that they possess capability to learn automatically [Bai, 2003].

Decision Trees serve as a decision making tool, in which one can explore several available options and analyze possible outcome after choosing those
options. For example, Decision Trees are helpful in taking the decision for optimizing the resources, balancing the risks and calculating expected expenditure in the organizations [Webref, 2007].

Decision Tree is a diagram of decision (Fig. 5.1). This diagram is read from left to right, or top to bottom. The left most node, in a decision tree is called root node or decision node, which is represented as small square. Each line towards the right (branches), drawn from the root node, show possible solution i.e. set of available decision alternatives [Webref, 2007]. One and only one of these alternatives can be selected. Each line has label, which shows short description of the solution [Webref, 2007]. At the end of each line, there is a result for corresponding alternative.

If the result of that alternative is uncertain, then at the end of that line a small circle (chance node) is drawn and then all possible results are shown through the lines [Webref, 2007]. The probability of uncertainty is represented with the value at the chance node in parenthesis. If the result is another decision then again another square is drawn. The right end of each path through the tree is called an endpoint, and each endpoint represents the final outcome of following a path from the root node.

![Decision Tree Diagram]

**Fig.5.1: Schematic Arrangement of Decision Tree**
Use of Decision Trees in software engineering is very prominent while designing business domain. However, use as knowledge map is uncommon. Being a tool used in SSAD, Decision Trees are easy to be coded in any programming language, thus making system automated.

We found suitability of Decision Trees to codify domain knowledge in combination with Concept Maps. In next section of this chapter, we have shown this Hybrid Concept Map with an example.

5.4 Concept Map as Domain Knowledge Map

We have discussed and shown with the example, use of Context Diagram (Level 0 DFD) as system knowledge map. Concept Maps can be used for capturing domain knowledge. We have compared the Context Diagram with Concept Maps in view of knowledge maps. Context Diagram represents schematic arrangement of components/ departments/ sub-systems within the boundary of system for which knowledge map is being represented. Concept Maps do not show the schematic arrangements, but they show underlying principle and concept about the components/ departments/ sub-systems.

![Layered Arrangement of Knowledge Maps in an Organization](image)

**Fig.5.2: Layered Arrangement of Knowledge Maps in an Organization**
In an organization, we can see layers of knowledge maps (Fig.5.2), where Context Diagram on the upper layer shows schematic arrangement and Concept Maps are at lower layer shows the domain knowledge. Considering layered arrangement of knowledge maps in an organization, we have created Concept Map (Fig.5.3) for various concepts as in Context Diagram shown in Fig.4.2 in Chapter 4.

**Fig.5.3: Concept Map Corresponding to Context Diagram of a Department**
While discussing B-C Model of knowledge map development, we have shown a process- “Preparing the Panel of Practical Examiners”, and for which prepared matrix type process knowledge map. Same process has been represented in previous chapter, with the help of Structure Chart, which is much better and easy to understand process knowledge map. However, process knowledge maps work on execution level and do not reflect the understanding. Hence, process specific knowledge and domain specific knowledge can be mapped with Concept Maps, along with process knowledge maps. Considering the matrix type process knowledge map, here again (Fig.5.4):

<table>
<thead>
<tr>
<th>Component</th>
<th>Steps</th>
<th>User(s)</th>
<th>Input(s)</th>
<th>Output(s)</th>
<th>Step Specific Knowledge</th>
<th>Process Specific Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>List of subjects</td>
<td></td>
<td>Member of BOS / HOD</td>
<td>Scheme</td>
<td>List of subjects for which practical exam will be conducted</td>
<td>Current Scheme</td>
<td>Rules to form BOS. Who can be the member of board of studies? Role and responsibilities. Examination related ordinances and statues. How to change scheme? Latest decision by BOS like inclusion or deletion of</td>
</tr>
<tr>
<td>List of examiners</td>
<td></td>
<td>Member of BOS / HOD</td>
<td>List of subjects for which practical exam will be conducted, database of examiners</td>
<td>List of examiners who can be called for the examination</td>
<td>Rules</td>
<td></td>
</tr>
<tr>
<td>Allocate the examiners</td>
<td>HOD / Director</td>
<td>List of examiners who can be called for the examination</td>
<td>Proposed Panel for the examination</td>
<td>Format</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fig.5.4: Concept Map Linked with Process Knowledge Map**
5.4.1 Hybrid Concept Map

With showing concept of thermostat, Safayeni [Safayeni, 2005] suggested use of Cyclic Concept Map. We strongly feel that this makes concept more complicated and also limited its computational abilities. Apart from that quantitative values that are associated with relationship of two concepts having dynamic nature, can not be represented through Cyclic Concept Map. We suggest inclusion of Decision Tree in this situation, instead of Cyclic Concept Map.

Fig.5.5(a) shows a Concept Map used by Safayeni [Safayeni, 2005] for Thermostat and we have modified this Concept Map by including a Decision Tree, which makes it Hybrid Concept Map as shown in Fig.5.5(b).

![Concept Map for Thermostat](image)

Fig.5.5(a): Concept Map for Thermostat [Safayeni, 2005]
By including Decision Tree for the concept signal, we have tried to show effect of different values of signal. Changes in values of signal make changes in the state of Heat & AC. This could not be represented effectively with original Concept Map. Use of Decision Tree makes it clearer to understand. Also this gives decision-making capability to concept map, which otherwise needs a separate or additional, knowledge map.

![Fig.5.5(b): Hybrid Concept Map for Thermostat](image-url)
In next example, due to space constraint, we have shown partial process of marketing in a typical organization. Now, in every marketing department, officers make marketing tours to meet the existing and prospective customers. However, their tour expenses are limited and according to their position in the department. Accounts department, approves/ partially approves/ rejects these expenses based on the case may be. Figure 5.6(a), shows Concept Map for this, and then Fig.5.6(b) adds decision making capability to this map by concatenating Decision Map.

![Concept Map for Marketing Process (Partial)](image-url)

**Fig.5.6(a): Concept Map for Marketing Process (Partial)**
Fig. 5.6(b): Hybrid Concept Map for Marketing Process (Partial)
5.5 Summary

Organizational knowledge at various layers needs specific arrangement to capture & codify. In this chapter, we have devised and suggested use of Concept Map and Hybrid Concept Map for capturing domain and dynamic domain knowledge from system perspective. Earlier studies have shown the use of knowledge map mainly for codifying static knowledge.

Also, we have suggested layered framework for knowledge maps. Concept Maps, provides required domain knowledge, may or may not be made available at various level of organization. Access to Concept Maps may be provided on the basis of authorities and level of priority.

Dynamic domain knowledge, when two concepts are related in such a way that changes in one affects the other, need to capture & codify. Original Concept Map does not codify this knowledge that we have done through Decision Tree.

From the computational perspective also, Decision Tree are easy to convert into an automated system. Concept Maps can be developed through concept clustering algorithms [Hong-zhen, 2008] and hence can be fitted in our B-C Model [Bansal, 2007] of knowledge map development.

Contributions made are briefly put in here as:

- Concept Maps are very useful in representing organizational domain knowledge in addition to Context Diagram.
- A layered framework of knowledge maps shall be helpful in arranging various Context Diagram and related Concept Maps.
- Concept Maps shows limitation in codifying dynamic knowledge.
- Decision Tree based Concept Map (Hybrid Concept Map) gives a solution to codify dynamic knowledge.