**A Proposal to Extend Concept Mapping to Concept Lattices for Representing Biology**

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***Abstract.*** Textbook biology knowledge is being represented as triples using concept maps. These triples can be extended to create concept lattices by representing objects and attributes in relation. By focusing on the nature of semantic relations, concept neighbourhood lattices can be generated for dependencies, associations. By representing the changes in the attributes of objects in time, concept lattices of dynamic propositions can be generated. As the knowledge base for the study is textbook biology, this research on using concept lattices in school, college biology education can be further developed with focusing on teaching learning, cognitive assessment.

***Keywords.*** Concept mapping, concept lattices, formal concept analysis, assessment, knowledge structure, biology

**Formal Concept Lattice for Knowledge Discovery**

Formal Concept Analysis (FCA) is a theory of data analysis which identifies conceptual structures among data sets. The FCA is considered as a method to structure, analyze and visualize data for its implications and dependencies. Knowledge Discovery (KD), is the nontrivial extraction of implicit, previously unknown, and potentially useful information from data. A *concept* is a unit of thought comprising of *extension* ie all *objects* and *intension* ie all *attributes* of the objects. The objects and attributes are related in hierarchical, subconcept-superconcept relations, the implication between attributes, and incidence relation of object having attributes. A group that combines the set of objects (G) with the attributes (M) in a relation (I) is called a formal context defined as a triple of (G, M, *I*) (Ganter & Wille, 1997). A formal context is generally represented as a binary incidence table in which the crosses represent the binary relation between the object set and the attribute set. Figure 1 shows a table of a formal context with a concept lattice indicating the relations of objects and their attributes.

| | female | juvenile | adult | male |
|---|---|---|---|---|
| girl | x | x | | |
| woman | x | | x | |
| boy | | x | | x |
| man | | | x | x |

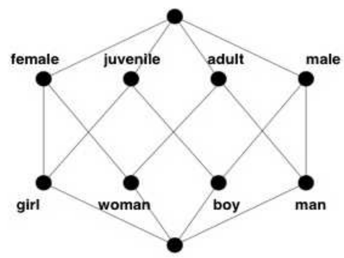


Figure 1: A illustration of formal context and concept lattice. (Source: Uta Priss, FCA Website, *http://www.upriss.org.uk/fca/fcaintro.html*)

**A proposal for Representing Textbook Biology Using FCA**

The texbook biology knowledge has been represented as simple propositions in the form of triples (Kharatmal & Nagarjuna, 2010). These triples have been extracted by and represented using the semantic relations referring the relations ontology, of the open biomedical domain (Smith, et al., 2005). Some of these relations belong to *part-whole, class-inclusion, spatial inclusion, function, attribution relations, cause-effect*, etc.

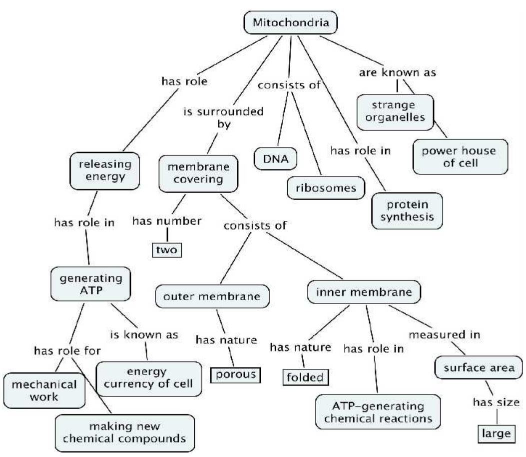


Figure 2: A Concept Map showing concepts connected with linking phrases (semantic relations).

**1. Creating Concept Lattices Based on Semantic Relations in Biology:** Textbook biology knowledge is mostly descriptive. Representing the same graphically would enhance its understanding at school, college levels. One of the ways is using concept maps – a two dimensional graphical representation using node-link-node form to create triples. Figure 2 shows a concept map showing concepts connected with semantic relations.

Concept lattices on lexical relations have been researched on the WordNet (Priss, 2010). Based on concept neighbourhoods, relatively smaller data can be extracted to create readable, non-overlapping lattices depicting the lexical relations. The study involved to create neighbourhood lattices based on synonym, antonym, hypernym, hyponym, meronym, etc. Influenced from this study, it is proposed that concept lattices of semantic relations can also be created. The dataset of textbook biology has been generated through concept maps and which has been represented as triples can be used for this purpose. It would be possible to generate concept lattices for each topic based on a particular kind of semantic relation such as *part-whole, class-inclusion, spatial inclusion, function, attribution, cause-effect,* etc. The concept lattices can bear advantage in grouping of concepts in a pattern of semantic relations. Figure 3 shows a preliminary concept lattice of an extracted data generated from concept maps (although this needs to be more refined). A sample of few concept lattices generated from textbook biology can be viewed from: http://gnowledge.org/~meena/concept-lattices/

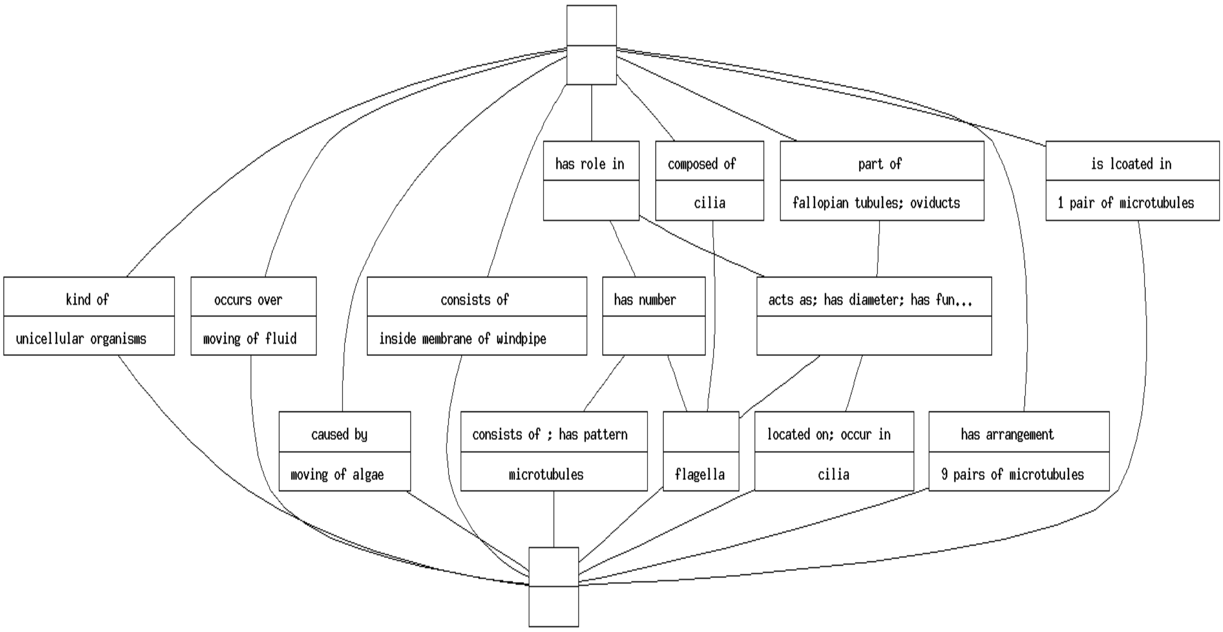


Figure 3: A preliminary concept lattice of textbook biology knowledge.

**2. Representing Processes Through Concept Lattices:** Within a specific relation for example, attribution relation, an object with its attributes can be created into a table of formal context, thereby generating a concept lattice. This would be a representation of objects in relations of their attributes in a given time. It would be further interesting to represent

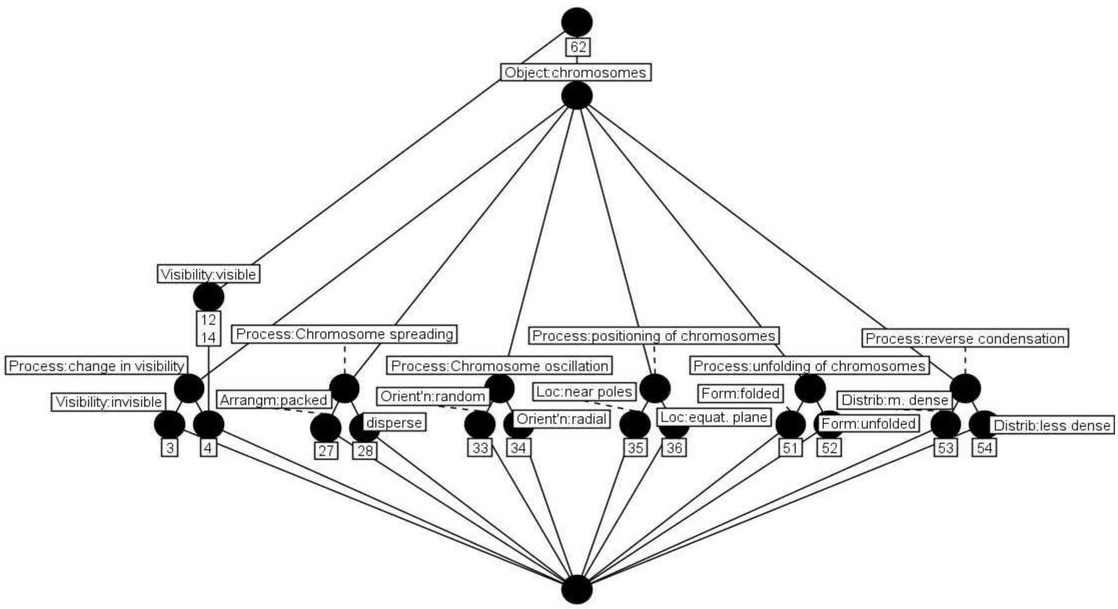


Figure 4: Concept lattice depicting the change in attributes of objects during process.

the changes in the attributes during an event or a process. The lattice thus generated would illustrate the changes in time as a result of a process as shown in Figure 4. Two processes showing changes in attributes with time is illustrated in Figure 5.

| Process | Time | Size | Appearance |
|---|---|---|---|
| Reduction of nucleoli | 1 | large | |
| | 2 | small | |
| Nucleoli Formation | 1 | | blurred |
| | 2 | | distinct |

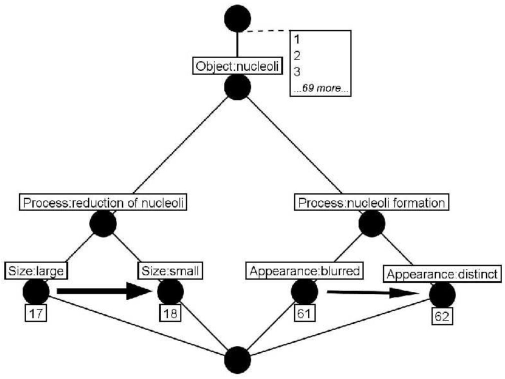


Figure 5: Two processes showing change in attributes at t.

**Summary**

One of the fundamental ideas in cognitive psychology is that learning takes place by the *assimilation* of new concepts and propositions into existing and prior concept and propositional frameworks held by the learners (Ausubel, 1978), also referred to as the individual's knowledge structure or *cognitive structure*. A very widely used tool in teaching learning has been concept maps – a two dimensional graphical representation in the form of *node (concepts)* and *links (linking phrases)* wherein concepts are linked to other concepts to form valid propositions as a triple: node-link-node. *Concept mapping* has been used in teaching learning to facilitate knowledge acquisition. There is a substantial body of research on using concept mapping for representing learner's knowledge structure, eliciting misconceptions, depicting conceptual change, in assessment, etc. (Mintzes, et al., 1997). An underlying assumption in learning is that understanding is conceived as a rich set of relations among concepts. Assessment using concept mapping probes inter-relations between concepts through making graphs, and making explicit the nature of links between concepts (Ruiz-Primo & Shavelson, 1996). Assessment using concept maps involves *a task, a response format, a scoring system*. Among these the methodology of task design, response formats, have been explored for different types such as – draw concept map, fill-in-the-nodes, fill-in-the-links, draw concept maps by chosing from the given linking words, etc. Psychometric properties of assessment such as reliability, validity have been analyzed with concept mapping. Following the theoretical framework, a suitable methodology of task design, response formats, a variety of exercices, empirical studies for qualitative or quantitative analysis for teaching learning can be created using concept lattices. The FCA method developed in 1980s has successfully been applied to many fields, such as medicine and psychology, musicology, linguistic databases, library and information science, ecology, and others. The most widely used application of FCA has been for KD in the domain of biology and medicine (Poelmans, 2010). The concept lattices bear advantages in extracting, visualising, determining groupings of patterns. Further, it would be required to develop its methodolgy of task, response format, scoring system for its use in teaching learning. So far there has been work on using FCA for research purposes, and it would be an additional advantage of *applying concept lattices in education.*

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