Introducing Rigor in Concept Maps

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Abstract. Although concept maps have been found to be effective in science education research, these are critiqued for being informal due to informal usage of relation and attribute names thereby resulting in ambiguity. Refined concept mapping, a development over the regular concept mapping is an approach towards introducing rigor and parsimony in representing knowledge. The method proposed suggests to substitute the ambiguous relation names with well-defined relation names to concepts consistently while mapping a domain. We suggest the use of this method for introducing rigor in concept mapping and position it among the other models of knowledge representation in an inverse semantic spectrum.

Keywords: concept maps, conceptual structures, disambiguation, education, knowledge representation, rigor.

1 Introduction

Concept map, a two-dimensional representation of knowledge, is a simple graphical form of knowledge representation method comprising of nodes (concepts) and arcs (linking phrases). Although concept maps have shown to have significant impact in education[1], the knowledge representation community critiqued it for being informal [2,3]. In an analysis of four different types of knowledge representation models [2], concept maps, being one among them, are claimed to be informal. Although concept maps are easy to construct, the maps drawn by different persons of the same domain often do not match. This is due to the choice of different linking phrases, though the concept names chosen are often the same. While this may serve the purpose of eliciting the knowledge of the learner, often due to lack of discipline (rules) the propositions cannot express the intended meaning since the linking phrases are chosen from natural language. Examples given in section 2. This obviously prevents them from being fit for a formal representation [4], but also the free usage of linking phrases does not lead to rigor in representation of scientific knowledge [5]. We shall propose a simple methodology to refine concept mapping so as to make the representation more clear and rigorous. We suggest how this method can help students become rigorous by re-representing concept maps as refined concept maps. We also relate the program with existing attempts to represent knowledge for machines, and how it can play the role of a bridge method linking the informal models and formal models of conceptual structures.

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2 Refined Concept Maps—A Methodology for Introducing Rigor

Refined Concept Mapping (RCM) uses a finite set of well-defined relation names consistently to represent a body of knowledge. The Novakian or Traditional Concept Mapping (TCM) uses linking words such as—*is a, can be, have, may be*, etc. Since these linking words do not portray the exact meaning, we propose to replace them with semantically well-defined relation names such as—*part of, includes, surrounded by, located in, has function*, etc. Explicit use of conceptual relations (predicates) exemplified with constraints in conceptual graphs have also been one of the insights that we have drawn from for focusing on well-defined relation names in representing knowledge [6]. Since our domain is of biology, we draw from the Open Biological and Biomedical Ontologies (OBO) [7] foundry which is collaboratively developing and publishing well-defined relations—the OBO Relation Ontology (RO) [8]. For e.g. the OBO defines *part_of as: For continuants: C part_of C′ if and only if: given any c′ that instantiates C at a time t, there is some c such that c′ instantiates C′ at time t, and c part_of c′ at t.* Similarly, *located_in is defined as: C located_in C′ if and only if: given any c that instantiates C at a time t, there is some c′ such that: c′ instantiates C′ at time t and c located_in c′*. In OBO, the relation names are categorized as foundational, temporal, spatial and participation [9]. The relation names are chosen based on the classification scheme—inclusion (class, meronymy, (component-object, member-collection, portion-mass, stuff-object, phase-activity, place-area, feature-event), spatial), possession, attachment, attribution, antonym, synonym and case [10].

Now, we shall illustrate the methodology to transform informal (natural language) propositions into refined propositions by replacing merely the relation and attribute names with well-defined ones. This is how we propose rigor can be introduced. The following are the propositions from the traditional maps:

(1) [sharks]→(can be)→ [great white shark, tiger shark]
(2) [shark teeth]→(can be)→ [big, small]
(3) [nucleus] → (is a)→ [double layered membrane structure]
(4) [nucleus]→ (is one of the)→ [organelles in a cell]
(5) [nucleus]→(is present in)→ [each living cell]
(6) [nucleus] → (is small)→ [in animal cell]

The corresponding RCM propositions following the same order are:

(1′) [sharks] → (includes) →[great white shark, tiger shark]
(2′) It is possible that, [shark teeth]→ (has size)→ [big, small]
(3′) [nucleus] → (enveloped by)→ [double layered membrane structure]
(4′) [nucleus]→ (kind of)→ [organelles in a cell]
(5′) [nucleus]→(part of)→ [each living cell]
(6′) [nucleus]→ (part of)→ [animal cell]; [nucleus] →(has size)→[small]

We eliminated ambiguous relation name *can be* by resolving it into *includes* in (1′), *has size* in (2′), and appropriate possibility modality expressed by *can* *be* is inserted. In the propositions (3-6), one single relation name *is a* is being ambiguously used for four different meanings. This ambiguity is eliminated when substituted by appropriate relation names—*enveloped by, includes, part of, has size,* respectively shown in (3′-6′). The ambiguity of *is a* link is already being pointed by experts in the field of semantic network [11]. Unlike in TCM, in RCM we propose the possibility of inserting tags for modalities and quantifiers. Thus, along with rigor, the substitution also helped in enhancing expressivity.

We proposed this methodology for science education suggesting the transformation of conceptual structures of novices into experts and hypothesized that roots of rigorous representations lie in predicate terms [5,12,13]. The methodology adds weight to and is coherent with semantic holism [14], where the meaning of a node (term) arises by virtue of its position in the neighbourhood of the node, rather than from the node itself.

3 Discussion

Cognitive development studies, in the context of teaching-learning, compared the conceptual structures of novices and experts in terms of coherence, abstractness, parsimony, integration, explicitness etc. [15,16,17]. Following [16], we attempted to make the implicit meaning explicit by re-representing the relation names. Therefore, the suggested transformation method of RCM can be used in teaching-learning context. Although, the set of relation names in RCM are part of a natural language, the rigor is introduced by following well-defined terms consistently.

Knowledge Representation (KR) studies by both cognitive and computer scientists also suggest gradual transitions from less formal to more formal representations, implicit to explicit, more ambiguous to least ambiguous giving rise to an inverse spectrum as shown in Fig. 1 (partially adapted from [18]).

The current semantic web project is also making knowledge more and more explicit to enable partial interpretation by computers. Our suggested methodology of RCM may also contribute to meet the objective of semantic web by focusing on the predicate terms instead of object terms.

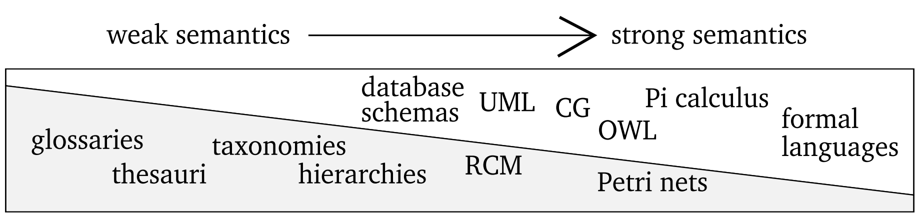

Fig. 1. Semantic spectrum presented indicating the inverse relation between ambiguity and rigor. The KR models on the left are more ambiguous and less rigorous whereas on the right are less ambiguous and more rigorous. The position, scale and the models presented are merely an indicative of the idea and not comprehensive.

References

1. Mintzes, J.J., Wandersee, J., Novak, J.D. (eds.): Teaching Science for Understanding– A Human Constructivist View. Academic Press, USA (1998)
2. Sowa, J.: Concept mapping. Talk Presented at the AERA Conference, San Francisco (2006), http://www.jfsowa.com/talks/cmapping.pdf
3. Kremer, R.: A Concept Mapping Tool to Handle Multiple Formalisms. In: Proceedings of AAAI Spring Symposium on Artificial Intelligence in Knowledge Management, pp. 86–93 (1997), http://www.aaai.org/Papers/Symposia/Spring/1997/SS-97-01/SS97-01-016.pdf
4. Canas, A.J., Carvalho, M.: Concept Maps and AI: An Unlikely Marriage? In: Proceedings of SBIE: Simposio Brasileiro de Informatica Educativa, Manaus, Brasil (2004)
5. Kharatmal, M., Nagarjuna, G.: A Proposal to Refine Concept Mapping for Effective Science Learning. In: Canas, A.J., Novak, J.D. (eds.) Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping, San Jose, Costa Rica (2006)
6. Sowa, J.: Conceptual Structures: Information Processing in Mind and Machine. Addison-Wesley Publishing Company, USA (1984)
7. The Open Biological and Biomedical Ontologies, http://www.obofoundry.org
8. The OBO Relation Ontology, http://www.obofoundry.org/ro/
9. Smith, B., Ceusters, W., Klagges, B., Kohler, J., Kumar, A., Lomax, J., Mungall, C., Neuhaus, F., Rector, A., Rosse, C.: Relations in Biomedical Ontologies. Genome Biology 6(5) (2005), http://genomebiology.com/2005/6/5/R46
10. Winston, M., Chaffin, R., Herrman, D.: A Taxonomy of Part-Whole Relations. Cognitive Science 11, 417–444 (1987)
11. Brachman, R.: What IS-A Is and Isn't: An Analysis of Taxonomic Links in Semantic Networks. IEEE Computer 16(10), 30–36 (1983)
12. Kharatmal, M., Nagarjuna, G.: Exploring Roots of Rigor: A Proposal of a Methodology for Analyzing the Conceptual Change from a Novice to an Expert. In: Canas, A.J., Reiska, P., Ahlberg, M., Novak, J.D. (eds.) Concept Mapping: Connecting Educators. Proceedings of the Third International Conference on Concept Mapping, Tallinn, Estonia & Helsinki, Finland (2008)
13. Kharatmal, M., Nagarjuna, G.: Refined Concept Maps for Science Education–A Feasibility Study. In: epiSTEME 3 Third International Conference on Review of Science, Technology and Mathematics Education, Mumbai, India (2009)
14. Quine, W.: From a Logical Point of View. In: Nine Logico-Philosophical Essays. Harvard University Press, USA (1953)
15. Brewer, W., Samarapungavan, A.: Children's Theories vs. Scientific Theories: Differences in Reasoning or Differences in Knowledge? In: Hoffman, Palermo (eds.) Cognition and the Symbolic Processes: Applied and Ecological Perspectives, pp. 209–232. Erlbaum, New Jersey (1991)
16. Karmiloff-Smith, A.: Beyond Modularity: A Developmental Perspective on Cognitive Science. MIT Press, USA (1995)
17. Nagarjuna, G.: Layers in the Fabric of Mind: A Critical Review of Cognitive Ontogeny. In: Ramadas, J., Chunawala, S. (eds.) Research Trends in Science, Technology and Mathematics Education. Homi Bhabha Centre for Science Education, Mumbai (2006)
18. McGuinness, D.: Ontologies Come of Age. In: Fensel, D., Hendler, J., Lieberman, J., Wahlster, W. (eds.) Spinning the Semantic Web: Bringing the World Wide Web to Its Full Potential. MIT Press, USA (2003)