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ScienceDirect
Knowledge-Based Systems 21 (2008) 52–61
Knowledge-Based SYSTEMS
www.elsevier.com/locate/knosys

Self-associated concept mapping for representation, elicitation and inference of knowledge

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Received 18 March 2006; received in revised form 1 November 2006; accepted 16 November 2006
Available online 11 December 2006

Abstract

Concept maps have been widely put to educational uses. They possess a number of appealing features which make them a promising tool for teaching, learning, evaluation, and curriculum planning. This paper presents self-associated concept mapping (SACM) which extends the use of concept mapping by proposing the idea of self-construction and automatic problem solving to traditional concept maps. The SACM can be automatically constructed and dynamic updated. A Constrained Fuzzy Spreading Activation (CFSA) model is proposed to SACM for supporting rapid and automatic decisions. With the successful development of the SACM, the capability of Knowledge-based systems (KBS) can be enhanced. The concept and operational feasibility of the SACM is realized through a case study in a consultancy business. The theoretical results are found to agree well with the experimental results.

Keywords: Knowledge representation; Self-associated concept maps; Concept mapping; Knowledge management; Knowledge-based systems

1. Introduction

Cognitive psychology stated that people do not learn by memorizing, instead, they learn by summarizing, relating, and organizing concepts into their cognitive structures [1]. New knowledge is assimilated into their cognitive structures through construction and not merely acquired [30]. Based on this learning theory, a method known as concept maps was developed. Concept maps are widely used as a means of visualizing one's inner cognitive structures. Concept maps require users to identify, graphically display, and link key concepts by organizing and analyzing information. They make the structure of knowledge visually explicit and conceptually coherent. There are numerous applications for concept maps including communication [25,34,40], teaching [2,12,22,31], assessing users understanding [6,37,38], curriculum design [7,28], planning [11,36], etc. Numerous of tools and commercial software have been developed including construction tools of concept maps in different education and business settings [9,14,16,17,20,21,27,39], tools for handheld devices supporting mobile learning [3], tools for navigation and discovery concept map in a repository [26] and so on. Moreover, several researchers have developed different methodologies to extend the usage of concept map [5,6,17,18,24].

In the past, concept maps are manually constructed by the users and the usages of concept maps are focused on educational purpose. Although a number of concept mapping tools are available, the construction and interpretation of concept maps are still heavily relied on human being. Traditional maps are static after the development process, which require human interventions for any later changes of the maps. The construction of the maps is difficult, time consuming and expensive. Moreover, the interpretation of concept maps rely on human who is not suitable tool for computational inference.

On contrary to the current trend of the development of concept maps, this paper attempts to give the idea of

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doi:10.1016/j.knosys.2006.11.015

concept maps with self-construction ability and automatic problem-solving ability. The extended concept map is called Self-Associated Concept Map (SACM). SACMs can be automatically constructed and dynamically updated from a knowledge repository with structural historical records. A Constrained Fuzzy Spreading Activation (CFSA) model is incorporated in the SACM which enables the decision supporting function for providing rapid and automatic decisions. With SACM, the capability of Knowledge-based systems (KBS) can be enhanced and extended. The paper starts by reviewing the related work and then describes the proposed SACM. The capability of the SACM is realized by a case study in a consultancy business. The results indicate that the proposed idea of SACM is well suited for KBS with real-world data.

2. A comparison between Traditional Concept Mapping and Self-Associated Concept Mapping

2.1. Traditional concept maps

Concept map has its root from its relationship to memory and learning theory. Semantic memory theory believes that knowledge is stored in a network format where concepts are connected to each other [8]. The more tightly interconnected the knowledge representation, the more likely it is that a person will recall information at the appropriate time. As a result, a network representation can be used to show the integration of different concepts. The theory has resulted in different terms being used to describe concept maps including semantic networks [13,15] and knowledge maps [19].

In 1984, Novak proposed concept map to represent knowledge [29–31]. It is an instructional method that integrates new information into an old knowledge structure. It promotes conceptual understanding by displaying meaningful patterns of ideas. Knowledge is graphically displayed as a network of nodes and links. A concept map consists of sets of propositions. Each proposition is made up of a pair of nodes and a link connecting them. The labeling of nodes contains the concepts. The labeling of the links provides information about the nature of the relationships. Cross-links sometimes appear to show the connections between and among concepts, create an interdisciplinary space for inquiry and learning, or provide examples for clarifying the meaning of a given concept. Concept maps are varying on the basis of an individual area of interest and style. Fig. 1 shows an example of concept map. There are propositions in the concept map: (Concept Map consists of Concepts), (Concept Map consists of Relations), (Concepts denoted by Nodes), (Relations denoted by Links).

Several research studies have developed different methodologies to extend the usage of concept map. Lin et al. [24] introduce a concept map focusing on the propositions with weights, which is named “weighted concept map”. Chen et al. [5] proposed an extended concept maps called attributed concept maps (ACM). ACM associates its

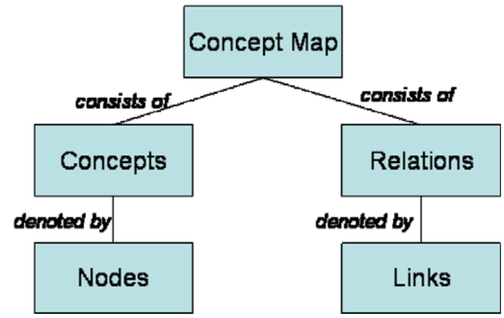

Fig. 1. An example of concept map.

concept nodes and relation links with attribute values which indicate the relative significance of concepts and relationships in knowledge representation. A Two-Phase Concept Map Construction (TP-CMC) algorithm is proposed by Sue et al. [35] to automatically construct a concept map of a course by historical testing records. They apply Fuzzy Set Theory to transform the numeric testing records of learners into symbolic, apply Education Theory to further refine it, and apply Data Mining approach to find its grade fuzzy association rules. Then, they use multiple rule types to further analyze the mined rules and a heuristic algorithm is proposed to automatically construct the concept map according to the results of the analysis.

Recently, more and more researches are applying concept maps on knowledge management. Concept mapping is provided as a knowledge management tool so that concepts can be captured, queried, and perhaps most importantly connections discovered and reasoned about [14]. Current research work is focusing on the construction of theoretical frameworks and design of human–machine interfaces (e.g. [19,26]). They provide tools for creating custom templates, publishing the maps as web pages, associating documents and URLs with concepts and some query and search capabilities. However, this is insufficient for performing such knowledge management activities since most of the work is still relied on human being. It seeks for a tool with the ability to automatically discover implicit connections, generate new maps, maintain evolution of maps, reasoning, and inferencing.

In order to support the automatic inference of concept map, spreading activation (SA) is adopted. Similar to concept maps, the SA model also has its roots from its relationship with human memory [33]. It has often been associated with semantic networks. During spreading, the activation input of a node in the network is calculated based on the following equation:

$$I_j = \sum_i O_i w_{ij} \qquad (1)$$

where I_j is the total input of node j, O_i is the output of node i connected to node j, and w_{ij} is a weight associated to the link connecting node i to node j.

After the input value of a node has been computed, the activation level of the node is determined by a function of the input: