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Towards knowledge modeling and manipulation technologies: A survey

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ABSTRACT

A system which represents knowledge is normally referred to as a knowledge *based* system (KBS). This article focuses on surveying publications related to knowledge base modelling and manipulation technologies, between the years 2000–2015. A total of 185 articles excluding the subject descriptive articles which are mentioned in the introductory parts, were evaluated in this survey. The main aim of this study is to identify different knowledge base modelling and manipulation techniques based on 4 categories; 1) linguistic knowledge base; 2) expert knowledge base; 3) ontology and 4) cognitive knowledge base. This led to the proposition of 8 research questions, which focused on the different categories of knowledge base modelling technologies, their underlying theories, knowledge representation technique, knowledge acquisition technique, challenges, applications, development tools and development languages. A part of the findings from this survey is the high dependence of linguistic knowledge base, expert knowledge base and ontology on volatile expert knowledge. A promising technique for knowledge-based business management and other knowledge related applications is also discussed.

1. Introduction

This article surveys several journal articles, conference papers, serials and books on the implementation and challenges of various knowledge modelling and manipulation technologies. It classifies these technologies according to their development theories and structure, resulting to four categories; the linguistic knowledge bases (Baker, 2014; Fellbaum, 1998; Speer & Havasi, 2012), expert knowledge bases (Driankov, Hellendoorn, & Reinfrank, 2013; Kerr-Wilson & Pedrycz, 2016; Kung & Su, 2007), ontology (Khan, Ilyas, & Anwar, 2009; Fensel, 2004; Sánchez, 2010; Studer, Benjamins, & Fensel, 1998; Van Heijst, Schreiber, & Wielinga, 1997) and most recently the cognitive knowledge base (Wang, 2015b). Human knowledge is categorized at the levels of data, information, knowledge and intelligence. These categories are the fundamental cognitive objects in the human brain and cognitive systems (Wang, 2015c). The development of computers that display an intelligent behaviour has been the foundation of Artificial Intelligence (AI).

A system which represents knowledge is normally referred to as a knowledge *based* system (KBS). The most important component of any knowledge based system is the knowledge base. Based on the characteristics of knowledge, Dignum and vab de Riet (1991) defined a knowledge base as "*a set of statements that describe the knowledge about the truths of the actual world plus a set of constraints that describe statements that must be true in all possible worlds and statements that ought to be true in all possible worlds*" (pp. 4).

In the past, KBS development has been viewed as a transfer of human knowledge into the implemented knowledge base (Wielinga, Schreiber, & Breuker, 1992). This view was based on the theory that the required knowledge already exists and only needs to be collected and implemented. Usually, the required knowledge is acquired by interviewing an expert, and implemented in the form of production rules. However, this approach did not support a suitable representation of different knowledge types (Studer et al., 1998). The existence of different types of knowledge and the absence of satisfactory justifications of the rules makes the maintenance process difficult and time consuming. Thus, this approach was only feasible in the development of small scale prototypes, thereby ini-

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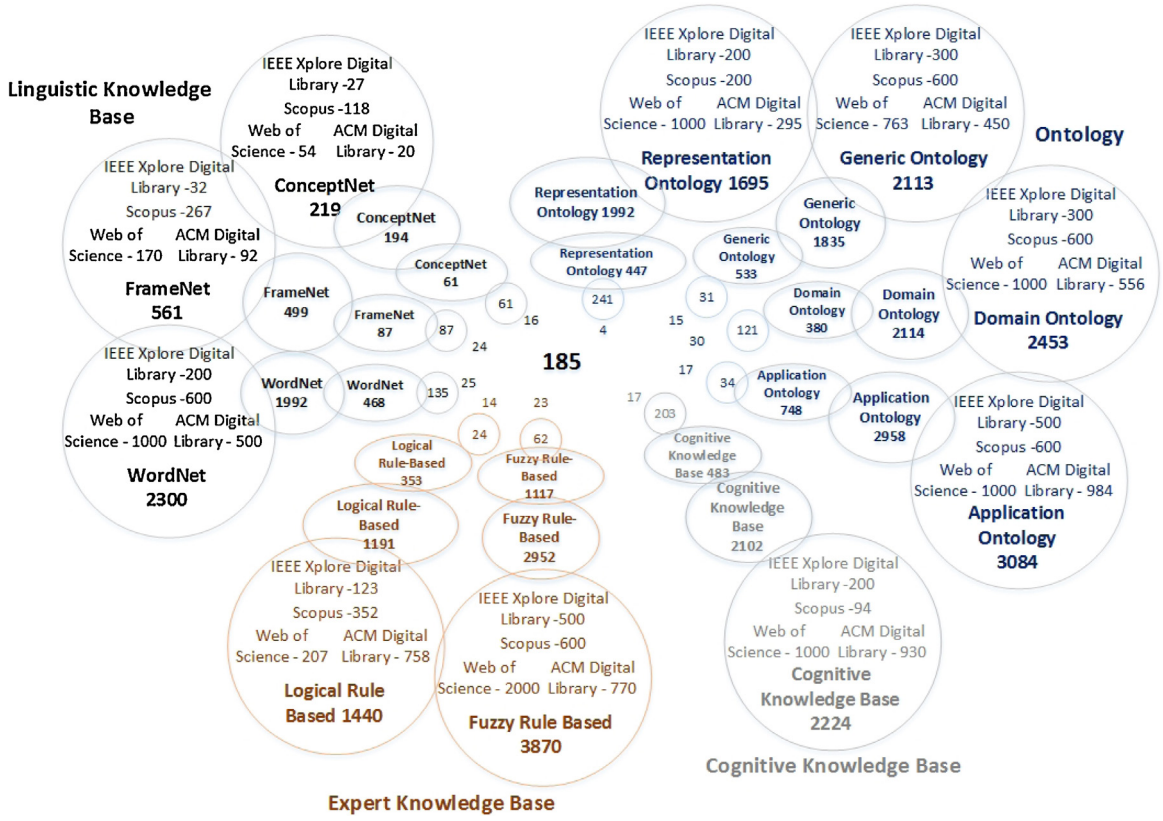

Fig. 1. Survey process.

tiating a paradigm shift from the transfer approach to the modelling approach (Ramirez & Valdes, 2012). The modelling approach is not intended on simulating the entire cognitive process of an expert, but to create a model which offer similar results in problem solving.

The main objective of this research is to survey existing knowledge base modelling and manipulation technologies, with the aim of identifying different knowledge representation, implementation and acquisition techniques. This survey could provide novice researchers with a tool to select appropriate knowledge representation and implementation techniques, while providing experts with a broader view to introduce novel techniques. Previous researchers have conducted surveys on knowledge based systems, for example, Liao (2003) did an analysis on knowledge management technologies and applications, Plant & Gamble, (2003) discussed the important research in knowledge-based system life cycles and development, while Sahin, Tolun, and Hassanpour (2012) reviewed the current approaches and applications of hybrid expert systems. Our current review follows similar methodologies as the previous researchers. However, we focus on a broader aspect of knowledge modelling and manipulation technologies. To the best of our knowledge, this is the first study which provides a broad view on the various categories of knowledge modelling and manipulation technologies, their implementation and challenges. We suggest 8 research questions as shown in Table 1. These questions are primarily centred around knowledge base modelling and implementations.

The structure of the article is as follows: First, the outline of the survey process is discussed in Section 2. In Section 3, we provide detail review of the knowledge base modelling and manipulation technologies. We give a detailed analysis of the results in Section 4. Section 5 discusses the need for knowledge based business management. The directions for the further is highlighted in Section 6 and the limitations of the survey in Section 7. Finally, we present our findings and conclusions in Section 8.

2. Survey process

The articles included in our survey were extracted from 4 main digital database of academic journal articles. These digital libraries include Scopus, Web of Science, IEEE Xplore and ACM. These libraries were selected based on their impact evaluation and wide coverage of peer-reviewed journals in multiple academic disciplines. The inclusion of relevant articles in this survey was decided in 5 steps as shown in Fig. 1, using EndNote Desktop application. First, the digital libraries were searched based on keywords corresponding to the categories of knowledge base modelling technologies and the articles were restricted to publication between the year 2000 and 2015. Then, duplicated articles were removed. Articles published in both journals and conference proceedings, with the same title published by same authors, in the same year are regarded as duplicates. In this situation the article published in journal is selected, neglecting the one published in conference proceeding. Thirdly, the full texts of the remaining articles were searched online. This resulted to a reduced number of articles as seen in the third oval shape in Fig. 1. The fourth step involved relevance sorting, which required searching the full text based on some combination of keywords relevant to each category. Lastly; the remaining articles were read to identify information related to the different categories: knowledge base representation; implementation; acquisition technique; application; implementation tools and limitations.

This process resulted to 185 articles, excluding the subject descriptive articles which are mentioned in the introductory parts. The analysed articles consisted of journal articles, conference proceedings, books and serials. They were examined based on