Chapter 5
Trends and Outlook

In the past, the field of knowledge representation already exceeded the academic and research spheres and emerged in practical use as well. Moreover, it also extended beyond the field of its origin, i.e. artificial intelligence, into other fields of computer science. One of the important factors that stimulated the thriving of ontologies in particular was World Wide Web, especially its recent evolution, the so-called Semantic Web. The idea of Semantic Web is consistent with some of the basic goals of knowledge representation. The vision of Semantic Web is to enable semantic interoperability and machine interpretability of data sets from various sources and to provide the mechanisms that enable such data to be used to support the user in an automated and intelligent way.

On the other hand, Semantic Web gives the impression of a deviation from the typical methods of knowledge representation, as it is characterized by a much larger number of data or knowledge sets and agents involved in the processes. In addition to its comprehensiveness, Semantic Web is also characterized by its openness, as it is, in contrast to traditional knowledge representation systems that are mostly available only in a closed laboratory environments, available to virtually everybody. The comprehensiveness and openness of Semantic Web also open several issues in the field of knowledge representation that will have to be addressed in the future and amplify the significance of attending to existing issues. As the majority of trends and challenges in the field of knowledge representation are connected with Semantic Web, the present chapter focuses on this area.

The comprehensiveness of World Wide Web and consequently the available knowledge respectively facilitate the problem of ontology learning. Traditional knowledge acquisition with a limited number of highly qualified experts is extremely time-consuming, which is why recently semi-automatic knowledge acquisition emerged based on the content of voluntary collaborative web projects. In this respect, the most useful type of data appears to be the semi-structured data available, for example, in online encyclopedias, such as Wikipedia (Nastase and Strube 2008), or the content recorded in a structured form that is computer-intelligible (Uchida et al. 1999; Jakus et al. 2012). Completely automated knowledge acquisition from a large number of unstructured documents with the

G. Jakus et al., *Concepts, Ontologies, and Knowledge Representation*,
SpringerBriefs in Computer Science, DOI: 10.1007/978-1-4614-7822-5_5,

aid of natural language understanding techniques is, in most cases, not usable in practice, as the results often prove to be unacceptable as regards the quality of the conceptual structures formed in the process. In order to establish a completely automated knowledge acquisition in the future, advances must be made both in the fields of natural language understanding and techniques of machine learning (Antoniou and van Harmelen 2004; Davies et al. 2006).

The next generation of semantic applications will thus be characterized by the acquisition of knowledge from several sources instead of acquiring it from merely one source covering all the needs of target applications. Similar trends can also be expected in the use of knowledge available in existing ontologies. As it is not likely for a single ontology to satisfy all the needs of a certain application, the trends nowadays move towards ontology integration (also known as ontology alignment, matching or mapping). Integrating ontologies is one of the most complex and at the same time most important issues related to the practical implementation of Semantic Web. Consequently, the trend of integrating ontologies has lately gained substantial attention also in the research spheres and has actually become one of the most active fields of research (see for example (Shvaiko and Euzenat 2008)). Although the results are very encouraging, so far integrated ontologies cannot be used in practice in most cases (Antoniou and van Harmelen 2004; Cimiano et al. 2006). Among several challenges connected with the representation of knowledge acquired from several distributed sources, we would like to point out the following issues as stated in (van Harmelen 2002; Antoniou and van Harmelen 2004; Davies et al. 2006; Schubert 2006):

- Due to the integration of knowledge from different sources, one of the challenges is ensuring a homogenous conceptualization of domains, as the contents of individual ontologies are very diverse and their vocabularies inhomogeneous, not to mention the differences in the quality of the presented knowledge.
- A substantial part of the Web is changing faster than traditional knowledge representation techniques can withstand. Problems can occur already when addressing the individual representations, as the missing links between data can cause a shortfall in the distributed knowledge base.
- In traditional knowledge representation, the statements recorded in the knowledge base are almost always considered correct. When a knowledge base is formed from several distributed parts with different administration, questions regarding trust, reputation, integrity and origin must be addressed.
- An important challenge is also the ontology evolution, i.e. the updating of ontologies due to the changes in the domain conceptualization. As certain ontologies are bound to evolve, most ontologies on a global scale will be mutually inconsistent. This is the exact reason why a very clear analysis of the relationships between the individual ontologies in networks and the determination of a formal model of network ontologies are required. The latter must support the evolution of network ontologies and must, in the case of any changes in one of the ontologies, ensure at least a partial consistency.

- In practice, the term "ontology" stands for the conceptual structures of different semantic depths: from common hierarchies and taxonomies to structures with extensive semantic features. In order to be able to support the trend of more and more complex, personalized and intelligent applications, future trends shall require a change from using "surface" conceptual structures to the use of structures with a richer semantic content. The reason for this trend lies in the fact that only the latter can support the use of effective reasoning methods and will allow a more efficient use of web sources for the acquisition of new knowledge.

In general, most attention in the field of knowledge representation is given to the development of ontologies as the conceptualizations of the real world, while the development of the mechanisms of their use often lags behind. In the future, more attention will have to be given to the standardization and implementation of efficient mechanisms for the use of knowledge gathered in ontologies. The issues that have to be addressed according to (van Harmelen 2002; Antoniou and van Harmelen 2004; Brewster and O'Hara 2004; Schubert 2006), are the following:

- One of the very important challenges in the field of knowledge representation is the development of ontologies and the mechanisms of their use with the goal of changing the ontologies into a base for reasoning (and not only the data models or data structures shared among applications). One of the conditions required for this goal to actually be reached is the development of sound and complete reasoning engines. The complexity of the development of reasoning engines with the afore-mentioned features, however, mostly depends on the expressiveness of the language used to record ontologies.
- In the case of Semantic Web, the traditional ideal of sound and complete reasoning must be abandoned, as this is almost impossible due to the complexity of the Web and the diversity of the data sources. The actual level of soundness and completeness of reasoning will mostly depend on the availability of appropriate sources. In most cases, the conclusions will be merely approximations, whereby the reasoning engine shall, at best, also provide the evaluation of the quality of the approximation.
- Typically, a knowledge base is constructed with regards to the purpose of its use. As the purpose of the Semantic Web ontologies can often be unpredictable, more attention will need to be given to developing knowledge representations that will be more task-independent.
- An important challenge is also the development of query and reasoning mechanisms that could be used with a large number of distributed ontologies, in the case of potential inconsistencies between individual ontologies, with limited resources, such as memory, storage space and network latency, and that would be able to make sound compromises between the resource use and the quality of the results.
- As automatic reasoning can be based on knowledge from an unknown source, more attention will need to be given to the development of justification mechanisms and the verification of the conclusions acquired with this process.

- One of the future challenges is also the development of the methods of uncertain, statistic or speculative reasoning (e.g. analogical or abductive reasoning). Despite the fact that such reasoning does not necessarily ensure correct conclusions, it is much more similar to the way people think and solve problems.

To conclude, we would like to point out a very important research field, key to the development of artificial intelligence and information and communication technologies in the future. We refer to the development of autonomous systems that would be able to perform various complex tasks in dynamic environments and would also possess context awareness of their actions (Antoniou and van Harmelen 2004). The expression "context awareness" stems from the field of ubiquitous computing and describes the ability of detection and reaction to the changes in the immediate environment of a certain computer system.

Knowledge representation holds one of the key roles in the development of context awareness. The ontologies offer a viewpoint on a specific domain, with the former being the result of a consensus of a group of interested users put into a specific context. In the future, mechanisms need to be developed that will tailor ontologies to the needs of specific users in their actual context. The challenges in this field comprise of the formal presentation of the context, the determination of the formal relationships between different contexts of ontology use, the development of mechanisms for the selection of the appropriate context in a given situation and reasoning based on context (Davies et al. 2006). The development of reasoning based on context is especially important for user profiling, application personalization and mobility support. The examples of applications including the afore-mentioned areas are nowadays very popular social networks.

To summarize, the results achieved in the domain of knowledge representation so far seem tentative and incomplete. Much work remains to be done. It is expected that under the auspices of Semantic Web and other accompanying concepts and visions, such as intelligent and personalized content retrieval, cloud computing, ubiquitous computing and, last but not least, artificial intelligence, the development of the field will continue.

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