Knowledge Representation and Reasoning: What's Hot

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Knowledge representation and reasoning (KR) stems from a deep tradition in logic. In particular, it aims at building systems that know about their world and are able to act in an informed way in it, as humans do. A crucial part of these systems is that knowledge is represented symbolically, and that reasoning procedures are able to extract consequences of such knowledge as new symbolic representations. Such an ability is used to deliberate, in an informed fashion, about the course of actions to take.

This very idea is radically new in human history (Levesque 2014). It comes about after a long gestation, stemming from Aristotle, who developed the initial notion of logic though unrelated to the notion of computation; continued by Leibniz, who brought forward a notion of "thinking as computation," though not yet symbolic; and later by Frege, who developed the notion of symbolic logic, though unrelated to computation; and finally by the breakthrough in human thinking of the early part of last century with Church, Godel, and Turing, who set the bases for symbolic logic bound together with computation and ultimately for Computer Science, though even they did not think about logic as a way of representing knowledge.

It was McCarthy (McCarthy 1959) who first had the very radical idea of building intelligent systems by focusing not on programming or on the details of the system architecture, but on the knowledge necessary to behave in an intelligent way. If a system were able to represent what it needed to know and draw conclusions from it in an automatic way, it would be able to deduce for itself how to behave intelligently.

Knowledge representation and reasoning is a well-established field of AI deriving directly from McCarthy's idea. Research in KR is currently present in the major AI generalist conferences like the International Joint Conference on Artificial Intelligence (IJCAI), the AAAI Conference on Artificial Intelligence (AAAI), and European Conference on Artificial Intelligence (ECAI).

The series of International Conferences on Principles of Knowledge Representation and Reasoning (KR) is one of the most scientifically respected conferences in AI. The KR conference series is a leading forum for timely in-depth presentation of progress in the theory and principles underlying the representation and computational management of knowledge. The first KR conference was held 25 years ago in 1989. The last KR edition KR 2014 was the 14th and was held 25th year of the first KR conference. Since the first KR conference there has been significant progress in KR and now we have many well developed KR formalisms with supporting theories, building-block results, reasoning systems, and applications. There are many books that present these developments. We have reached a stage where various disciplines in AI and Computer Science are now using KR. Among them is the use of KR in agents, semantic web applications, video understanding, natural language understanding, and many others.

The 2014 edition of KR was very special as it was held as part of the Vienna Summer of Logic, the largest scientific event in the history of logic. The Vienna Summer of Logic (VSL, www.vsl2014.at) consisted of 12 large conferences and 82 workshops.

The papers presented at KR 2014 can be broadly divided into the following areas: Description Logics, Reasoning about Actions and Processes; Belief Revision and Nonmonotonicity; General Knowledge Representation and Reasoning; Planning, Strategies, and Diagnosis; Answer Set Programming and Logic Programming; Argumentation; Automated Reasoning and Computation; Causality; and Rationality and Uncertainty. In addition application oriented papers where presented as Reports from the Field. Prior to the KR 2014 conference, in early 2013 the National Science Foundation of the USA sponsored and co-organized an workshop[1] titled "Research Challenges and Opportunities in KR" where international researchers in KR discussed various aspects of KR as a field. It was a consensus that KR had matured with a solid body of work, was being used in many applications and there was a big interest in enhancing its use. With that in mind the KR 2014 conference program had several invited talks and tutorials on emerging application areas as well as on traditional KR topics. This list of talks are good pointers to what is hot in KR. They were in the topics of: (a) role of KR in video understanding (Cohn. 2014); (b) role of KR in natural language understanding (NLU), and various available knowledge bases that can be and are being used in developing NLU systems (Ovchinnikova 2014);

[1] http://krnsfworkshop.cs.illinois.edu/

(c) research in dynamic systems and multi-agent systems (Baader 2014; Lomuscio 2014; Moss 2014) (d) connection between Databases, Ontologies and KR (Gottlob 2014; Rosati 2014) and (e) Situation Calculus (McIlraith 2014). Below we briefly elaborate on some of these and other hot areas in current KR research.

Description Logics. Description logics have become one of the main sub area of KR. However, description logics are transforming deeply in these years. They are moving from a component of a more general reasoning system to the central representation tool for knowledge representation in data management settings. In particular the notion of ontology-based data management has emerged, with the idea of superimposing an ontology as a shared conceptual layer (expressed in suitable description logics) over a set of data sources forming a data layer, and using the ontology as a virtual schema for querying the data sources. The ontology and the data sources are connected through declarative mappings that provide the semantic relationship between the two layers. This new setting is shaping the current research on description logics, where notions such as light-weight description logics, data complexity, query answering, and query rewriting and processing, are becoming main-stream research subjects. Practical realizability of the proposed techniques is put forward and a rich set of tools have been developed. This is complemented with work in very different areas such as update, belief revision, forgetting, module extractions, and error pinpointing. Interestingly some of the research in this field as become quite sophisticated mathematically, leveraging on model theory in modal logic, connection with theory of databases, and connecting with deep questions in CSP such as nonuniform complexity.

Reasoning about Actions. Reasoning about actions is another traditional area of KR. One of the most long lasting line of research in this area is that on the Situation Calculus, first introduced by John McCarthy in 1963 as a way of logically specifying dynamical systems. Such work has culminated with the publication of Ray Reiter's seminal book (Reiter 2001). Since then researchers continue to extend the situation calculus, and use it to investigate and formalize a variety of phenomena related to reasoning about actions. Such a significant scientific deployment is providing crucial help in the specification and implementation of a diversity of automated reasoning endeavors including diagnosis, web services composition and customization, and non-classical automated planning. More traditional lines of research have recently been complemented by a shift of interest from reasoning about single actions to reasoning about processes and high-level programs. Generally speaking, the community is exhibiting an interest in program/process verification aspects and in forms of model checking. Recently, some interesting decidability results of verification of processes in situation calculus have been proven, which use techniques that integrate model checking and databases. Work on process analysis using reasoning about action techniques and frameworks have found applications in other research areas such as service composition and orchestration and business process analysis. Research in multi-agent systems have led to new results and dimensions, such as techniques for processes synthesis and planning based on strategy logics such as ATL, reasoning and verification with strategic knowledge, model checking of autonomous agents systems, and reasoning about and planning with knowledge and belief goals.

KR Formalisms and techniques. While good progress has been made in specific KR formalisms such as Answer Set Programming, Logics of Uncertainty and the earlier mentioned Description Logic, there is now emerging interest in combining the strengths of these individual formalisms so that one can use a single formalism to reason about ontologies, about uncertainty, about quantitative parameters, about defaults and about priorities.

Reasoning about causality and rationality continues to be a hot area. The techniques of argumentation continue to be improved and used in new ways and in new formalisms and belief revision and merging continues to play an important role in KR. For example, in multi-agent reasoning where one may need to reason about agents' beliefs and knowledge, belief revision is needed (instead of belief updates) to characterize effect of actions that change the belief of agents.

Emerging Applications. With the success of IBM's Watson and other developments there is now great interest in combining knowledge and reasoning with vision and natural language processing (NLP) to develop better scene understanding systems and natural language understanding systems, respectively. For example, the AAAI 2015 Spring symposia has two different symposiums on KR, one on Commonsense reasoning and another on integrating symbolic and neural approaches. A particular development that is driving broader interest in KR applications is the automatic extraction of knowledge from other data, such as text and images.

References

Baader, F. 2014. Ontology-based monitoring of dynamic systems. In *VSL/KR. Keynote*.

Cohn., A. 2014. Knowledge representation meets computer vision: from pixels to symbolic activity descriptions. In *KR. Invited Talk*.

Gottlob, G. 2014. Datalog+/- : Questions and answers. In *KR. Invited Talk*.

Levesque, H. 2014. On our best behavior. *Artificial Intelligence* 212:27–35.

Lomuscio, A. 2014. Verification of multi-agent systems against epistemic specifications. In *KR. Tutorial*.

McCarthy, J. 1959. Programs with common sense. In *Proceedings of the Teddington Conference on the Mechanization of Thought Processes*, 756–791.

McIlraith, S. 2014. Situation Calculus: The last 15 years. In *KR. Invited Talk*.

Moss, L. 2014. Dynamic epistemic logic and its interaction with knowledge representation. In *KR. Tutorial*.

Ovchinnikova, E. 2014. Natural language understanding with world knowledge and inference. In *KR. Tutorial*.

Reiter, R. 2001. *Knowledge in Action: Logical Foundations for Specifying and Implementing Dynamical Systems*. MIT Press.

Rosati, R. 2014. Query answering and rewriting in ontology-based data access. In *KR. Tutorial*.