

1. Preface

Knowledge Representation and Reasoning (KR) is a well-established and lively field of research. In KR a fundamental assumption is that an agent's knowledge is explicitly represented in a declarative form, suitable for processing by dedicated reasoning engines. This assumption, that much of what an agent deals with is knowledge-based, is common in many modern intelligent systems. Consequently, KR has contributed to the theory and practice of various areas in AI, including automated planning and natural language understanding, and to fields beyond AI, including databases, verification, software engineering, and robotics. In recent years, KR has contributed also to new and emerging fields, including the semantic web, computational biology, cyber security, and the development of software agents.

The KR conference series is the leading forum for timely in-depth presentation of progress in the theory and principles underlying the representation and computational management of knowledge and beliefs. Since 1989, it has been fostering not only communication and a cross-fertilization of ideas within the area but also collaboration across research boundaries. Its topics are diverse and cover a broad spectrum of research topics. To showcase the role of KR in key areas and in support of topic diversity, KR 2023 includes the following tracks and special sessions in addition to the main conference track:

- *Applications and Systems Track*: This track aims at providing researchers and industrial practitioners with a dedicated forum for presentation and discussion of new ideas, research experience and emerging results on topics related to applications of KR formalisms and automated reasoning systems. This track provides the opportunity for fostering meaningful connections between researchers from both practical and theoretical areas of AI and, at the same time, offers participants the possibility to learn about progress made on these topics, share their own views and elaborate about approaches that could lead to effective cross-fertilisation among research in challenging KR applications and new innovative systems for solving them.
- *Recent Published Research Track*: This track provides a forum to discuss important results related to KR that appeared recently in selective journals and conferences, but have not been previously presented at KR conferences.
- *Special Session on KR and Machine Learning*: This special session provides participants with the opportunity to make meaningful connections and develop a shared understanding of the challenges involved in developing innovative AI solutions that rely on a combination of insights and methods from ML and KR. This session has witnessed a growing interest over the past few years, partly due to increased activities in the field of explainable AI.
- *Special Session on KR, Robotics & Planning*: This special session provides participants with the opportunity to exchange about the synergistic interactions between KR and Robotics/Planning, and welcomes contributions that extend the state of the art at their intersections.

We received 339 submissions to the main technical program (including the Applications and Systems track, and the Special Sessions on KR & Machine Learning, and KR, Robotics & Planning), of which 80 (23.5%) were accepted (69 full papers and 11 short papers). In addition, we received 30 submissions to the Recently Published Research Track, of which 17 were accepted for presentation at the conference.

The following papers received the best paper awards of KR 2023:

- *Ray Reiter Best Paper Award*: “Streamlining Input/Output Logics with Sequent Calculi” by Agata Ciabattini and Dmitry Rozplokhas.
- *Marco Cadoli Best Student Paper Award*: “Knowledge Compilation and more with SharpSAT-TD” by Rafael Kiesel and Thomas Eiter.

The award winners were selected from nominations made by area chairs and PC members by this year’s award committee, consisting of Jim Delgrande, Jérôme Lang, and Mary-Anne Williams; we thank them all for contributing their time and expertise to this special task.

The program of KR 2023 included five invited talks by prominent researchers that focused on traditional KR fields, as well as established connections to applications and other research communities:

- Claudia d’Amato (University of Bari): *On the need of semantics when tackling Knowledge Graph completion under a Machine Learning perspective*
- Luc de Raedt (KU Leuven): *How to Make Logics Neurosymbolic*
- Michael Gelfond (Texas Tech University): *Knowledge Representation in the Languages of Logic Programs under Answer Set Semantics (“Great Moments in KR Talk”)*
- Torsten Schaub (University of Potsdam): *ASP in Industry, here and there*
- Rineke Verbrugge (University of Groningen): *Reasoning about reasoning about reasoning: from logic to the lab*

Continuing the good tradition of previous KR conferences, KR 2023 also hosted sessions that aimed at integrating young scientists into the KR family and connecting members of our research community in general:

- *Doctoral Consortium (DC)*: The Doctoral Consortium students delivered lightning talks during a session of the main conference where they could discuss their work with other conference participants.
- *Diversity & Inclusion (D&I)*: This year’s conference included a session devoted to fostering diversity and inclusion in our research community, as well as further D&I-related activities.

The tradition of *Test of Time* awards, initiated at KR 2020, is continued at KR 2023. The Test of Time award is for a paper published at least 15 years ago (counting from 2023) which has stood the test of time. This year the award goes to Judea Pearl and Thomas S. Verma for their KR 1991 paper “A Theory of Inferred Causation”.

For the second time, KR 2023 also awarded the *KR Early Career Award*. Researchers eligible for this award need to have completed their doctoral degree in 2021 or 2022. This year the award goes to Munyque Mittelmann for her work on strategic reasoning and its application to automated mechanism design.

We are very grateful to our award committee—Meghyn Bienvenu, Jim Delgrande, and Tommie Meyer—for contributing their time, expertise, and effort in selecting the winners.

As in recent years, KR 2023 solicited workshop and tutorial proposals via an open call. The following workshops and tutorials with a variety of interesting and timely topics are offered to KR 2023 attendants:

Workshops

- 4th Workshop on Explainable Logic-Based Knowledge Representation (XLoKR 2023)
Franz Baader, Bart Bogaerts, Gerhard Brewka, Joerg Hoffmann, Thomas Lukasiewicz, Nico Potyka, Francesca Toni
- First International Workshop on Argumentation and Applications (Arg&App 2023)
Oana Cocarascu, Sylvie Doutre, Jean-Guy Mailly, Antonio Rago
- The Second Workshop on Knowledge Diversity (KoDis)
Lucía Gómez Alvarez, Rafael Peñaloza, Srdjan Vesic
- CME: the 2nd International Workshop on Computational Machine Ethics
Maurice Pagnucco, Yang Song, Louise Dennis
- Graphical Reasoning with Imperfect Data (GRID)
Sihem Belabbes, Juergen Landes
- The Seventh Image Schema Day (ISD7)
Maria M. Hedblom, Oliver Kutz
- AI-driven Heterogeneous Data Management: Completing, Merging, Handling Inconsistencies and Query-answering (ENIGMA-2023)
Salem Benferhat, Giovanni Casini, Andrea Tettamanzi, Thomas Meyer
- Cognitive Aspects of Knowledge Representation (CAKR)
Jesse Heyninck, Thomas Meyer

Tutorials

- Towards Causal Foundations of Safe AI
Francis Rhys Ward, Tom Everitt
- Concept Learning in Description Logics
Maurice Funk, Jean Christoph Jung, Axel-Cyrille Ngonga Ngomo, Frank Wolter
- Strategic Reasoning in Automated Mechanism Design
Munyque Mittelman, Aniello Murano
- Termination Analysis of Rule-based Ontological Reasoning
Marco Calautti, Andreas Pieris
- Statistical Relational AI – Exploiting Symmetries

Tanya Braun, Marcel Gehrke, Marco Wilhelm

- How KR Benefits from Formal Concept Analysis
Francesco Kriegel, Barış Sertkaya

We wish to thank everyone who contributed to making KR 2023 a success. We start with our Special Sessions and Track Chairs who significantly supported us in ensuring diversity of topics and establishing connections to other communities: Matti Järvisalo and Francesco Ricca (Applications & Systems Track), Tias Guns and Luciano Serafini (Special Session on KR & Machine Learning), Esra Erdem and Shiqi Zhang (Special Session on KR, Robotics & Planning), and Leila Amgoud and Martin Gebser (Recently Published Research Track).

We also thank this year's Area Chairs for the crucial role they played in the review and selection process, as well as our Program Committee members and additional reviewers for their thorough and timely reviews of the submissions.

Next, let us acknowledge the important activities that enriched the technical program of KR 2023. We are grateful to Nicolas Schwind and Serena Villata for selecting and coordinating the Workshop and Tutorial program, to Tanya Braun and Nico Potyka for organizing this year's Doctoral Consortium, and to Meghyn Bienvenu and Stefan Schlobach for organizing the Diversity & Inclusion session and activities. A big thank you goes to our local chair Pavlos Peppas for his fantastic job in providing a beautiful environment to the conference. We also thank Marcello Balduccini and Pedro Cabalar who so successfully recruited funding and sponsors, to our Publicity Chairs, Theofanis (Fanis) Aravanis and Guillermo Simari, for spreading information on the conference via mailing lists and on social platforms, and to Ioannis (Yannis) Konstantoulas for taking care of the KR 2023 website.

Finally, we would like to thank all of our colleagues who contributed to the continued success of the KR conference series through their active participation in KR 2023.

Pierre Marquis and Tran Cao Son, Program Chairs

Gabriele Kern-Isberner, General Chair

2. Invited Talks

On the need of semantics when tackling Knowledge Graph completion under a Machine Learning perspective

Claudia d'Amato

University of Bari

<http://www.di.uniba.it/~cdamato/>

Knowledge Graphs (KGs) are receiving increasing attention both from academia and industry, as they represent a source of structured knowledge of unprecedented dimension to be exploited in a multitude of application domains as well as research fields. Nevertheless, despite their large usage, it is well known that KGs suffer from incompleteness and noise since

they often come as a result of a complex building process. As such non-negligible research efforts are currently devoted to improve the coverage and quality of existing KGs. Particularly, for the purpose numeric based Machine Learning (ML) solutions are generally adopted, given their proved ability to scale on very large KGs. Numeric-based approaches mostly focus on the graph structure and they generally consist of series of numbers without any obvious human interpretation, thus possibly affecting the interpretability, the explainability and sometimes the trustworthiness of the results. Nevertheless, KGs may also rely on expressive representation languages, e.g. RDFS and OWL, that are also endowed with deductive reasoning capabilities. However, both expressiveness and reasoning are most of the time disregarded by the majority of the numeric methods that have been developed, thus somehow losing knowledge that is already available. In this talk, the role and the value added that the semantics may have for ML solutions will be argued and research directions on empowering ML solution by injecting background knowledge will be presented jointly with an analysis of the most urgent issues that need to be solved.

How to Make Logics Neurosymbolic

Luc de Raedt

KU Leuven

<https://wms.cs.kuleuven.be/people/lucderaedt/>

Neurosymbolic AI (NeSy) is regarded as the third wave in AI. It aims at combining knowledge representation and reasoning with neural networks. Numerous approaches to NeSy are being developed and there exists an 'alphabet-soup' of different systems, whose relationships are often unclear. I will discuss the state-of-the art in NeSy and argue that there are many similarities with statistical relational AI (StarAI).

Taking inspiring from StarAI, and exploiting these similarities, I will argue that Neurosymbolic AI = Logic + Probability + Neural Networks. I will also provide a recipe for developing NeSy approaches: start from a logic, add a probabilistic interpretation, and then turn neural networks into 'neural predicates'. Probability is interpreted broadly here, and is necessary to provide a quantitative and differentiable component to the logic. At the semantic and the computation level, one can then combine logical circuits (ako proof structures) labeled with probability, and neural networks in computation graphs.

I will illustrate the recipe with NeSy systems such as DeepProbLog, a deep probabilistic extension of Prolog, and DeepStochLog, a neural network extension of stochastic definite clause grammars (or stochastic logic programs).

Knowledge Representation in the Languages of Logic Programs under Answer Set Semantics ('Great Moments in KR' Talk)

Michael Gelfond

Texas Tech University

<http://redwood.cs.ttu.edu/~mgelfond/>

In this presentation I will talk about several classical problems of knowledge representation and their solutions given in the language of logic programs under the answer set semantics and its extensions. These will include formalization of defaults and their exceptions,

development of theories of action and change, solutions to planning and diagnostic problems, combining logical and probabilistic reasoning, etc. The list is far from complete — I will only talk about developments in which I had some degree of personal involvement. I also briefly describe the role of these ideas in industrial applications, and outline several important open problems.

ASP in Industry, here and there

Torsten Schaub

University of Potsdam

<https://www.cs.uni-potsdam.de/~torsten/>

Answer Set Programming (ASP) has become a popular paradigm for declarative problem solving and is about to find its way into industry. This is due to its expressive yet easy knowledge representation language powered by highly performant (Boolean) solving technology. As with many other such paradigms before, the transition from academia to industry calls for more versatility. Hence, many real-world applications are not tackled by pure ASP but rather hybrid ASP. The corresponding ASP systems are usually augmented by foreign language constructs from which additional inferences can be drawn. Examples include linear equations or temporal formulas. For the design of “sound” systems, however, it is indispensable to provide semantic underpinnings right from the start. To this end, we will discuss the vital role of ASP’s logical foundations, the logic of Here-and-There and its non-monotonic extension, Equilibrium Logic, in designing hybrid ASP systems and highlight some of the resulting industrial applications.

Reasoning about reasoning about reasoning: from logic to the lab

Rineke Verbrugge

University of Groningen

<https://rinekeverbrugge.nl/>

When engaging in social interaction, people rely on their ability to reason about other people’s mental states, including their goals, intentions, knowledge and beliefs. This theory of mind ability allows them to understand, predict, and even manipulate the behavior of others. People can also use their theory of mind recursively, which allows them to understand sentences like “Alice believes that Bob does not know that she wrote a novel under pseudonym”. In the current era of hybrid intelligence, teams may consist of humans, robots and software agents. For better coordination, it would be beneficial if the computational members of the team could recursively reason about the minds of their human colleagues. While the usefulness of higher orders of theory of mind is apparent in many social interactions, empirical evidence so far suggests that people usually do not use this recursive ability spontaneously, even when doing so would be highly beneficial. In this lecture, we discuss some of our computational modelling research and empirical experiments. How do children develop second-order theory of mind? Can we entice adults to engage in higher-order theory of mind reasoning by letting them play games against computational agents? What’s logic got to do with reasoning about reasoning about reasoning? Do corvids have any theory of mind? And how about ChatGPT?

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Special Session on KR & ML

- **Tias Guns**, KU Leuven, Belgium
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Special Session on KR, Robotics & Planning

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