Research theme for a PhD project

INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES CENTRE VAL DE LOIRE

Probabilistic Epistemic Logics

Project Description. Existing probabilistic epistemic logics are based on precise probabilities [1,2], this means that they allows us to formalize statements such as "Bob knows that he has probability $\frac{1}{6}$ to get the number 2 by throwing the dice". However there is no probabilistic epistemic logics allowing us to formalize the following statement "Bob knows that candidate A has between 45% and 55% of chances to win the election, but he does not know the exact chances candidate A has to win the election". To formalize that type of situations, one needs to use imprecise probabilities instead of exact probabilities. Solving this problem is a key step to be able to formalize many real life situations ; indeed in life we mostly have statistical knowledge that gives us interval of probabilities and not a specific value.

This project aims at creating a family of probabilistic epistemic logics that provides a mathematical base to study knowledge and reasoning based on imprecise probabilities. To do so, we propose to develop step by step an epistemic logic based on imprecise probabilities: (a) to define imprecise probabilities on boolean algebras (these are used to interpret classical propositional logic), (b) to define probabilities on boolean algebras with operators (these are used to interpret epistemic logics), (c) to define dynamic epistemic logic (that is built using boolean algebras with operators) with imprecise probabilities.

Since the end goal of the project is to provide a usable tool to formalize complex real life problems such as for instance privacy protocols in social networks and knowledge representation for AI, we will also aim at (1) developing the relational semantics of these logics and (2) studying the proof theory and the complexity of the proof search for these logics [3].
(1) In the paragraph above we explain how we will develop the algebraic semantics[1] of epistemic logics with imprecise probabilities. Based on that result we will be able to develop the relational semantics[2] of these logics. That step is important because for many applications, it is more intuitive to reason on the relational structures than on the algebras.
(2) Since the ultimate goal is to design logics that provide an adequate tool to formalize and study real life problems, it is important to understand how to prove that a set of models satisfies some properties (e.g. "If a cellphone application follows the privacy policy A, then the data collected about a user does not allow to estimate the city the user lives in with probability greater than 0.1.") and the complexity of that computation.

References

1) Achimescu, Baltag, and Sack. The Probabilistic Logic of Communication and Change. JLC, 2016.
2) Conradie, Frittella, Palmigiano, Tzimoulis: Probabilistic Epistemic Updates on Algebras. LORI 2015: 64-76
3) S. Frittella, G. Greco, A. Kurz, A. Palmigiano, V. Sikimic. A multi-type display calculus for dynamic epistemic logic. Special issue on Substructural logic and information dynamics, Volume 26 (6): 1961-2015 (2016).

[1]We talk about algebraic semantics because we interpret the formulas on algebras: boolean algebras and boolean algebras with operators.
[2]We talk about relational semantics because we interpret formulas on a structure defined with a set and relation on that set. Depending on the point of view these structures can be called frames, graphs, automata or even co-algebras.

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Dr. Sabine Frittella, associate professor at INSA Centre Val de Loire, is an expert in epistemic logics and their applications. She is studying mathematical logic (algebraic semantics and relational semantics of modal logics), proof theory, formalizing problems in privacy, marketing, social sciences with logic and developing new logics when needed. She has on going collaborations with many logicians around the world: Dr. Alessandra Palmigiano (TU Delft, the Netherlands) and Dr. Giuseppe Greco (Utrecht University, the Netherlands), Pr. Alexander Kurz (University of Leicester, the United Kingdom), Dr. Willem Conradie (University of The Witwatersrand, South Africa) and Pr. Minghui Ma (Sun Yat-Sen University, China).