Course on Logic-based Merging

Ramón Pino Pérez

Spring, 2018

Contents

Two-sentence description of the course

In this course we will present the foundations of the belief merging operators: a model of fusion information based on logical representation of the information. We will give constructive methods for building operators aiming to merge pieces of information coming from several sources.

Two-paragraph description of the course

Belief merging aims at combining several pieces of information when there is no strict precedence between them. The agent faces several conflicting pieces of information coming from several sources of equal reliability and he has to build a coherent description of the world from them. The aim of this course is to give an account of the main tools developed in last years in the area of belief merging. We will focus on the case where the pieces of information have logical representations.

Rationality postulates, like in belief revision, have been proposed to characterize belief merging operators. These postulates are closely related to the revision ones. Nevertheless there is an important difference, namely the social aspect of merging: one needs some postulates to say how to solve the conflicts between the sources of information. So it is possible to distinguish different families of merging operators, depending on their behavior with respect to the sources, like a majority behavior for instance. An important aspect of this logical characterization is the possibility of stating representation theorems that provide a constructive way to define merging operators satisfying all the desired logical properties. We will develop these constructive methods.

Justification

Belief merging is an important issue of many AI fields. In particular, the problem of merging multiple sources of information is especially important in distributed databases, multi-agent systems, and in distributed information systems. Inconsistency problems can occur when one wants to combine several sources of information. Consider a set of belief bases coding the belief of several human experts. In order to build a general expert system it is reasonable to try to combine all these belief bases in a single belief base that expresses the belief of the expert group. This process allows to discover new pieces of belief distributed among the sources. For example if an expert knows that a is true and another knows that $a \rightarrow b$ holds, then the "synthesized" belief knows that b is true whereas none of the experts knows it. This was called *implicit belief* in [16]. However, to simply put these belief bases together is a wrong solution since there could certainly be contradictions between some experts. Thus, having techniques to perform this task in a coherent and predictive way is important in areas of AI concerning distributed information.

Detailed outline of the course

The course will be made in four sessions.

First session: the fundamentals

1. Introduction to problem of merging of information
2. A historical review of the logical approach to merging
3. Logical representation of the information fusion
4. Rationality Postulates
5. Representation Theorem

Second session: constructions

1. Distance based operators
2. Formula-based operators
3. DA^2 operators
4. Disjunctive operators
5. Conflict-based operators
6. Default-based operators

Third session: relations with other operators and complex representations

1. Merging operators and revision operators
2. Merging operators and confluence operators
3. Merging operators and update operators
4. Merging complex epistemic states

Fourth session: Merging operators and Social Choice Theory

1. Modular representations theorems
2. Merging operators and impossibility
3. Merging operators and strategy-proofness

Potential target, Prerequisite knowledge, Objectives

Potential target: Novices aiming to discover a new topic in AI. Expert non specialists aiming to become acquainted with logical approaches to merging information.

Prerequisite: A basic course in Mathematical Logic would be desirable.

Objectives:

1. To introduce novices to major topics of Artificial Intelligence.
2. To introduce expert non specialists to an AI subarea.
3. To motivate and explain a topic of emerging importance for AI.
4. To offer a survey of a mature area of AI research.
5. To provide instruction in a now established but specialized AI methodology.
6. To establish bridges between an AI area and Social Choice Theory.

Bibliography

[1] Konieczny, S. and R. Pino Pérez: 1998, 'On the logic of Merging'. In *Proceedings of the Sixth International Conference on Principles of Knowledge Representation And Reasoning, KR'98*. Trento, Italy. June 2-5, 1998, pp 488-498. Morgan-Kaufmann Publishers.

[2] Konieczny, S. and R. Pino Pérez: 2002a, 'Merging information under constraints: a logical framework'. *Journal of Logic and Computation* **12**(5), 773–808.

[3] Konieczny, S. and R. Pino Pérez: 2011, 'Logic Based Merging'. *Journal of Philosophical Logic*, 40: 239–270.

[4] Konieczny, S. and R. Pino Pérez: 1999, 'Merging with integrity constraints'. In *Proceedings of the Fifth European Conference on Symbolic and Quantitatives Approaches to Reasoning with Uncertainty, ECSQARU'99*, London, UK, July 1999, **Lecture Notes in Artificial Intelligence**, vol. 1638, pp 233–244, Springer, 1999.

[5] Konieczny, S. and R. Pino Pérez: 2002b, 'On the frontier between arbitration and majority'. In: *Eighth International Conference on Principles of Knowledge Representation and Reasoning (KR'02)*. pp. 109–118.

[6] Konieczny, S. and R. Pino Pérez: 2005, Propositional belief base merging or how to merge beliefs/goals coming from several sources and some links with social choice theory'. *European J. Oper. Res.* 160 (3) 785–802.

[7] Chacón, J.L. and R. Pino Pérez: 2006, 'Merging Operators: beyond the infinite case'. *Information Fusion*, 7 (1) 41–60.

[8] Konieczny, S. and R. Pino Pérez: 2008, 'Confluence operators'. In *Logics in Artificial Intelligence.* Steffen Hölldobler, Carsten Lutz, Heinrich Wansing , Eds. **Lecture Notes in Computer Science**. Vol. 5293. pp 272-284. Springer, 2008.

[9] Mata, A. and R. Pino Pérez. 'Logic-Based Fusion of Complex Epistemic States'. In *Symbolic and Quantitative Approaches to Reasoning with Uncertainty.* Weiru Liu, Ed. **Lecture Notes in Artificial Intelligence**. Vol. 6717. pp 398-409. Springer, 2011. ISSN 0302-9743

[10] Amílcar Mata Díaz and Ramón Pino Pérez. Impossibility in belief merging. *Artificial Intelligence*, 251:1 – 34, 2017.

[11] Chacón, J.L. and R. Pino Pérez: 2012a, 'Duality between merging operators and social contraction operators'. In *Logic for Programming, Artificial Intelligence, and Reasoning.* N. Bjørner and A. Voronkov, Eds. **Lecture Notes in Computer Science**. Vol. 7180, pp 183-196. Springer, 2012. ISBN 978-3-642-28716-9.

[12] Chacón, J.L. and R. Pino Pérez: 2012b, 'Exploring the rationality of some syntactic merging operators'. In *Advances in Artificial Intelligence, IBERAMIA 2012.* J. Pavón, N. D. Duque-Méndez, and R. Fuentes-Fernández, Eds. **Lecture Notes in Artificial Intelligence**. Vol. 7637, pp 21-30. Springer, 2012. ISBN 978-3-642-34653-8.

[13] Konieczny, S. and R. Pino Pérez: 2013, 'Confluence operators and their relationships with Revision, Update and Merging'. *Annals of Mathematics in Artificial Intelligence*, 69(1): 73–101.

[14] Pino Pérez, R. and C. Uzcátegui: 2010, *Dinámica del Conocimiento.* Ediciones IVIC, Caracas, 2010. ISBN 978-980-261-122-5.

[15] Pino Pérez, R.: 2013 *Matemáticas de las elecciones.* Ediciones IVIC, Caracas, 2013. ISBN 978-980-261-143-0.

[16] Halpern, J. and Y. Moses: 1992, 'A guide to completeness and complexity for modal logics of knowledge and belief'. *Artificial Intelligence* 54 (3), 319–379.