Towards a Unified View of Logic Programming and Non-Monotonic Reasoning

Antonio Brogi[1], Evelina Lamma[2], Paolo Mancarella[1], Paola Mello[2]

[1]Dipartimento di Informatica, Università di Pisa
Corso Italia 40, 56125 Pisa, Italy
Tel: +39 50 887252, Fax: +39 50 887226
brogi,paolo@di.unipi.it

[2]DEIS, Università di Bologna
Viale Risorgimento 2, 40136 Bologna, Italy
Tel: +39 51 6443033, Fax: +39 51 6443073
evelina,paola@deis33.cineca.it

1 Abstract

The area of Logic Programming (LP) and Non-Monotonic Reasoning (NMR) is undoubtely one of the hot research areas in Artificial Intelligence. The need for extending pure logic programming (Horn clauses) to deal with some form of non-monotonic reasoning was recognised since the early years of logic programming. Negation-as-failure was introduced to express negative information, and it has been recognised later as a suitable form of non-monotonic reasoning in LP. More recently, other extensions have been proposed to further enrich the expressive power of LP in order to make it a general formalism for knowledge representation. Among others, we mention *abductive* LP [7, 4, 10] and LP with *classical* (or better *explicit*) negation [9, 12].

The formalisation of these extensions have called for new semantics capable to capture their intended meaning and for new proof procedures in order to make these extensions practically useful. For instance, even for the case of negation-as-failure itself (better negation-by-default), a number of different semantics characterisations have been defined from different perspectives (e.g., [8, 15, 13]). Something similar is happening for other extensions such as abductive LP [7, 4] and LP with explicit negation [9, 13, 14]. For each extension, in spite of the huge number of proposals, there is no general agreement on what its semantics should be. Formal comparisons among different semantics are hard to be drawn, mainly because they are often based on different grounds. It should be mentioned, however, that some work has been done recently in this direction [1, 3, 14, 2].

The ongoing proliferation of alternative proposals may ultimately create a sort of "labyrinth of LP and NMR" with the potential risk of getting too far away from LP, and thus moving far from a LP-based knowledge representation formalism.

Another crucial issue is to understand the relations among different extensions. For instance, the relation between negation-by-default and abduction has been thoroughly studied starting from [7]. Dung's work on argumentation [6, 5] represents a remarkable attempt to provide a uniform view of extended LP which encompasses the various extensions proposed so far. The intuitive notions of arguments and attack between arguments may be adopted for both reconstructing a number of NMR formalisms and understanding different semantics of extended LP in a quite simple way.

The goal of this work is not to propose yet another semantics for extended LP. Instead, our aim is to provide a simple formulation of a LP-based framework where three main extensions of LP for NMR are treated uniformly, namely negation-by-default, explicit negation and abduction. Our framework can actually be viewed as an argumentation framework in the style of Dung [5], but based on the well-known notion of Herbrand model.

We focus on *abductive logic programs*, that is normal logic programs augmented with abduction and explicit negation. We view an abductive logic program as a positive program where both explicitly negated literals and negation-by-default literals are mapped into new positive atoms. The semantics of an abductive logic program (called *abductive semantics*) is then defined in terms of the Herbrand models of the positive program associated with it. Intuitively the idea is to restrict, in a step-wise fashion, the set of Herbrand models of the positive version of a program in order to identify the intended models of the original program. We show that our semantics captures in a uniform setting many existing semantics developed for both normal programs and logic programs with explicit negation.

Though a great deal of work has been done on semantics issues of extensions of LP towards NMR, relatively little effort has been expended on issues related to the computation and implementation of non-monotonic LP semantics.

Moreover, in this work, we present a query-based proof-procedure for abductive logic programs, which is a simple extension of that first presented in [7] and further developed in [4, 11]. The proof-procedure is shown to be sound and weakly complete with respect to the abductive semantics. As a by-product, we also prove a weakly completeness result for the proof procedure by Eshghi and Kowalski [7] with respect to the scenario semantics by Dung [4].

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