

# Signed Formulae as a New Update Process

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## INTRODUCTION

The **agent** paradigm has recently increased its influence in the research and development of computational logic-based systems. A clear and correct specification is made through Logic Programming (LP) and **Non-monotonic Reasoning** that have been brought (back) to the spotlight. Also, the recent significant improvements in the efficiency of **LP** implementations for Non-monotonic Reasoning (De Schreye, Hermenegildo & Pereira, 1999) have helped to this resurgence. However, the agents need update constantly their knowledge base and, particularly the intentional base (rules) such that our agent has the ability to reacting to changes in dynamic environments is of crucial importance within the context of software agents. Such feature should correspond to a deliberative rational behavior wanted for our agents.

The quality of the service that an agent offers is based on the form in which an agent combines rationality and reactivity. A reactive agent can offer well evaluated recommendations but, this response is based on outdated information, while a rational behavior may generate recommendations based on the most recently acquired information. So, we are interested in developing environment-aware agents. For this reason, is very important to have an update process for agents, i.e., that it allows us to design agents with its rational component.

Over recent years, several semantics for logic program **updates** have been proposed (Brewka, Dix, & Knonolige 1997) (De Schreye, Hermenegildo, & Pereira, 1999) (Katsumo & Mendelzon, 1991). All

these semantic ones coincide in considering the AGM proposal as the standard model in the update theory, for their wealth in **properties**. The AGM approach, introduced in (Alchourron, Gardenfors & Makinson, 1985) is the dominating paradigm in the area, but in the context of monotonic logic. All these proposals analyze and reinterpret the AGM postulates under the **Answer Set Programming** (ASP) such as (Eiter, Fink, Sabattini & Thompits, 2000). However, the majority of the adapted AGM and update postulates are violated by update programs, as shown in (De Schreye, Hermenegildo, & Pereira, 1999). For this reason, we have been working in finding properties that our update operator satisfies (Osorio & Zacarías, 2003) (Zacarías & Osorio, 2005) (Arrazola & Zacarias, 2005). Our purpose is to build a semantics based on structural properties. This is our main objective in the **update** theory. In (De Schreye, Hermenegildo, & Pereira, 1999) (Osorio & Zacarias, 2003) (Zacarías, Osorio & Arrazola, 2005) (Zacarias, 2005) the authors present a set of properties that the update operator satisfies. In this paper we continue with this same research line presenting a novel proposal with the aim to enrich the **update theory** that we have begun in (Osorio & Zacarias, 2003) (Zacarías, Osorio & Arrazola, 2005) (Zacarias, 2005). This novel proposal contributes with two benefits. First, we conserve many of the properties presented in previous works (Osorio & Zacarias, 2003) (Zacarías, Osorio & Arrazola, 2005) (Zacarias, 2005), such as: Weak Irrelevance of Syntax (WIS). This property is similar to one postulate proposed by AGM, but in this case for **nonmonotonic logic** and under **Answer Set Programming** (ASP) introduced and defined by (Gelfond & Lifschitz, 1988).

## BACKGROUND

In this section, we present advances in the updates context. Also, we give some general definitions for our theory. We define our theory about logic programs.

### Advances on Updates

We consider the task of updating logic programs under **non-monotonic reasoning** and a purely logical view. Since an intelligent agent is situated in an environment which is subject to change, it is required the agent to be adapted over time. For agents utilizing logic programming techniques for representing their knowledge, it is required the agent to be capable of updating logic programs accordingly, in order to ensure adaptability. We chose one of the approaches; viz. update answer set semantics (Zacarias, 2005) (Osorio & Zacarias, 2003) (Eiter, Fink, Sabattini & Thompits, 2000) (Banti, Alferes & Brogi, 2003). Besides, an underlying update semantics, which specifies how new, possibly inconsistent information, have to be incorporated into the knowledge base, an agent needs to have a certain **update** policy, i.e., a specification of how to react upon the arrival of an update. The issue of how to specify change requests for knowledge bases has received growing attention more recently and suitable specification languages for **non-monotonic logic** programs have been developed (Leite, 2001) (Leite, 2002).

In (Zacarias, 2005) we have introduced a new proposal towards the enrichment of the update operator “ $\oplus$ ”. There, we have presented a refinement of the **stable model** semantics for the update operator. Also, we presented a new property that allows us to face updates where new information contains rules that define a conservative extension. So, we gave an extension of our properties proven in (Osorio & Zacarias, 2003), under N logic. This approach is based on the work made by Eiter et al. (Eiter, Fink, Sabattini & Thompits, 2000), and inspired in a recent approach presented by Alferes et al. (Banti, Alferes & Brogi, 2003). With this work, we improve and enrich the update operator proposed by Eiter et al. (Eiter, Fink, Sabattini & Thompits, 2000), giving as result a new update operator.

## UPDATES FOR REAL TIME APPLICATIONS

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In this section we present a novel mechanism that allows updating a knowledge base in a quick and easy way. Furthermore, this proposal satisfies similar structural properties to those that we have presented in previous works. So, we give the basic concepts for our theory and we present our main contribution based on **signed formulae** (Ariely, Denecker, Nuffelen & Bruynooghe, 2004).

### Preliminary

*Rules* are built from propositional atoms and the 0-place connectives  $\top$  and  $\perp$  using negation as failure ( $\neg$ ) and conjunction ( $\wedge$ ). A *rule* is an expression of the form:

$$\text{Head} \leftarrow \text{Body} \quad (1)$$

If Body is  $\top$  then we identify rule (1) with rule Head. If a Head is  $\perp$  then we identify rule (1) with a restriction. A *program* is a set of rules. A logic program  $P$  is a (possibly infinite) set of rules. For a program  $P$ ,  $I$  is a model of  $P$ , denoted  $I \models P$ , if  $I \models L$  for all  $L \in P$ . As it is shown in (Brewka, Dix, & Knollige, 1997), the Gelfond-Lifschitz transformation for a program  $P$  and a model  $N \subseteq B_P$  ( $B_P$  denotes a set of atoms that appear in  $P$ ) is defined by

$$P^N = \{rule^N : rule \in P\}$$

where  $(A \leftarrow B_1, \dots, B_m, \neg C_1, \dots, \neg C_n)^N$  is either:

- a.  $A \leftarrow B_1, \dots, B_m$ , if  $\forall j \leq n: C_j \notin N$ ;
- b.  $\top$ ,

otherwise

Note that  $P^N$  is always a definite program. We can therefore compute its least Herbrand model (denoted as  $M_{P^N}$ ) and check whether it coincides with the model  $N$  which we started with:

**Definition 1.** (Gelfond & Lifschitz, 1988)  $N$  is a **stable model** of  $P$  iff  $N$  is the minimal model of  $P^N$

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