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Rational Architecture = Architecture from a Recommender Perspective

Marc van Zee
University of Luxembourg

Abstract

An Enterprise Architecture (EA) provides a holistic view of an enterprise. In creating or changing an EA, multiple decisions have to be made, which are based on assumptions about the situation at hand. In this thesis, we develop a framework for reasoning about changing decisions and assumptions, based on logical theories of intentions. This framework serves as the underlying formalism for a recommender system for EA decision making.

1 Introduction

Modern day enterprises face many challenges, such as changes in the economic climate, mergers, acquisitions, business models, deregulation of international trade, etc. These changes are fueled even more by the advances of eCommerce, Networked Business, etc. [Tapscott, 1996]. For senior management of an enterprise it is important to steer/direct enterprise transformations. Enterprise architecture is considered to provide such a mechanism. It is usually defined as: “those properties of an enterprise that are necessary and sufficient to meet its essential requirements”.

In creating or changing an enterprise architecture, multiple decision have to be made. These decisions are to a large extent based on assumptions about the situation at hand (the environment, the strategic direction of the enterprise, goals of the stakeholders, etc.). In practice, organizations are confronted with frequent changes and challenges to these assumptions. The aim of this thesis is to develop a logical framework for EA decision making as a basis for a recommender system.

Since it is inherently difficult to plan architectural design, the planning theory used should be able to represent abstract and ambiguous plans, alternative and back-up plans, and mechanisms for the revision of plans. In particular, classical planning techniques are often not sufficient, and have therefore been extended with the theory of intentions.

Intention commitment and revision strategies originate from the philosophical theory of action, and were introduced in the mid eighties in planning theory to reason about plan revision [Cohen and Levesque, 1990], and over the past two decades the theory has been subsequently improved and simplified [Lorini and Herzig, 2008] and applied to, for example, agent based software engineering. It has been called the belief-desire-intention or BDI theory.

Our central research question is as follows:

> How can logical theories of intention from Knowledge Representation be extended with change over time and uncertainty, so they can serve as an underlying formalism for a Recommender System for high-level decision-making?

This break down into the following sub-questions:

1. We assume that it is important to reason about changing intentions in time in high-level decision making in enterprises. How can existing theories intentions be extended to support change in time in such decision making?
2. We assume that it is important to reason about (qualitative and quantitative) uncertainty in high-level decision making. How should the extended logical theory of question (1) be extended to support different types of uncertainty?
3. How to implement the resulting logical theory of question (2)? In other words, what is its computational complexity?

2 The Recommender Perspective

Shoham recently changed the focus on intentions from its historical philosophical perspective to a computer science database perspective of revising plans in the context of beliefs [Shoham, 2009]. We therefore use Shoham’s proposal of revising plans in the context of beliefs as the starting point for our methodology, and coin it the *recommender perspective*, where the beliefs represent the assumptions of the plans (see Figure 1).

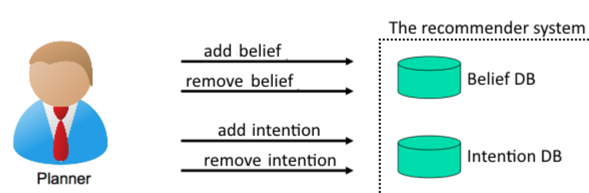

Figure 1: The Recommender Perspective

The recommender system consists of a belief-intention database, capturing specific interactions between beliefs and intentions. The database is used by a (human) planner that is engaged in some form of practical reasoning and stores its intentions and beliefs respectively in an intention database and a belief database. Besides the standard functionality of storage and retrieval, the belief and intention databases satisfy the following three consistency conditions: First, the belief database is internally consistent. Secondly, the intention database is internally consistent. Thirdly, the belief database and the intention database are mutually consistent.

2.1 The Logic

In a recent publication [van Zee *et al.*, 2015a], we develop a logic for the recommender system. Since we would like to be able to reason about *changing* beliefs and intentions, it is our aim to develop a logic about action and time, such that this logic can be used within a more general framework of belief revision. It is this constraint of using the logic within a belief revision setting that drives the design of the logic. Therefore, since belief revision is originally defined for propositional logic, it is our methodology to stay as close to propositional logic as possible. The logic we develop is called Parameterized-time Action Logic. The language of this logic contains formulas to reason about preconditions, postconditions, and the execution of actions. Atoms in the language are parameterized with the state at which they are true. The language of the logic is generated from the following BNF grammar:

$$\varphi ::= p_t \mid pre(a)_t \mid post(a)_t \mid do(a)_t \mid \Box_t\varphi \mid \varphi \wedge \varphi \mid \neg\varphi$$

The logic bears close similarity to a logic proposed by Icard *et al.* [Icard *et al.*, 2010]. However, we show in the same publication that there is no finitary sound and complete axiomatization for their syntax and semantics. We provide an axiomatization for our logic and prove that it is sound and strongly complete with respect to a tree semantics.

2.2 AGM Revision

In a paper published in these proceedings [van Zee *et al.*, 2015b], we provide AGM postulates for belief revision in the logic of the previous section. Moreover, we show that we can obtain the Katsuno-Mendelzon representation theorem [1991] by restricting the logic to formulas representing beliefs up to a certain time. Finally, we show that we can express the Darwiche-Pearl postulates [1997] for iterated revision in our logic, and we can obtain their representation theorem as well.

2.3 Coherence between Beliefs and Intentions

The previous two sections describe a logic for revision of the belief database. In a future paper, we extend this framework with intentions, which are formalized as pairs of the form (a,t), denoting that action a is intended at time t. We then formalize Shoham's *coherence conditions* between beliefs and intentions in our logic:

1. At most one action can be intended for any given
2. If you intend to take an action, you believe that its postconditions hold.
3. If you intend to take an action you cannot believe that its preconditions do not hold.

Based on these conditions, we study the revision of beliefs and intentions.

3 Future Work

Shoham emphasizes that his model has to be extended in a variety of ways, and for our application the extension with (both qualitative and quantitative) uncertainty is the next step. Following that, we study the computational complexity of the framework. In parallel, we explore whether the Enterprise Architecture community can benefit from our approach as well. We made a first attempt in a publication where we developed a naive first-order logic formalisation of an existing framework for decision capturing in Enterprise Architecture [van Zee *et al.*, 2014].

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