Revisions of Orders in Dynamic Systems

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Current reasoning systems attempt to model an agent's knowledge and interaction with its environment in a symbolic manner. This environment, its *world* is generally dynamic and changing due to natural evolution or the actions of other agents that are a part of it. In consequence, an agent that is a part of a reasoning system must have the following components: a *knowledge base* where its knowledge of the world is stored, a *communication mechanism* with the environment and other agents in it, and a *means of modifying* its knowledge of the environment.

Knowledge may be represented by a logic language which is propositional, first order, modal or extentions of these. Each one of these alternatives has advantages as well as disadvantages. The higher the expressive power of a given language, the more computational problems there are regarding complexity and decidability.

Communication mechanisms can be varied, depending on the environment being modeled. They can be multimedia mechanisms such as microphones, speakers, video cameras, infrared sensors, motion detectors and even wired or wireless systems where information is transmitted without any kind of preprocessing. They are irrelevant, however, for the purpose of our research because we are focused in the development of the knowledge system.

Mechanisms for modifying knowledge may be modeled by what is known as Belief Change Theory. Belief Change Theory assumes that the underlying language is at least propositional. An agent's knowledge is represented as a set of sentences and new information as a single sentence. In turn, every change operator takes a set of sentences and a single sentence and produces a new set of sentences as a result.

The belief revision framework

Belief revision is the process by which an agent changes its set of beliefs, making a transition from one epistemic state to another. When such an agent learns new information it may realize that this information clashes with its old beliefs. In this case the agent has to revise its belief set and decide which of the old beliefs need to be eliminated in favor of the new information.

One of the most fundamental approaches to the formalization of the dynamics of beliefs is the AGM model [1], proposed by Carlos Alchourrón, Peter Gärdenfors and David Makinson. In the AGM approach the epistemic states are represented by belief sets, that is, sets of sentences closed under logical consequence.

Let $\mathbf{K} = Cn(\mathbf{K})$ be a belief set and α a sentence in a propositional language L. The three main types of changes are the following [6]:

- **Expansion**: A new sentence is added to an epistemic state regardless of the consequences of the so formed larger set. If "**+**" is an expansion operator, then $\mathbf{K}+\alpha$ denotes the belief set **K** expanded by α.
- **Contraction**: Some sentence in the epistemic state is retracted without adding any new belief. If "$\div$" is a contraction operator, then $\mathbf{K}\div\alpha$ denotes the belief set **K** contracted by α.
- **Revision**: A new sentence is consistently added to an epistemic state. In order to make this operation possible, some sentences may be retracted from the original epistemic state. If "*****" is a revision operator, then $\mathbf{K}*\alpha$ denotes the belief set **K** revised by α.

Expansions can be defined as the logical closure of **K** and α: $\mathbf{K}+\alpha = \mathbf{Cn}(\mathbf{K} \cup \{\alpha\})$. It is not possible to give a similarly explicit definition of contractions and revisions using logical and set-theoretical notions only. These operations can be defined using logical notions and some selection mechanism. Contractions and Revisions are interdefinable by the following identities:

- **Levi Identity**: $\mathbf{K*\alpha = (K\div\neg\alpha)+\alpha}$
- **Harper Identity**: $\mathbf{K\div\alpha = K \cap K*\neg\alpha}$

Thus, given a definition for one of these operators we can obtain the other by using the above identities. Each operator may be presented in two ways: by giving an explicit construction (algorithm) for the operator, or by giving a set of rationality postulates to be satisfied. Rationality postulates determine constraints that the operators should satisfy. They treat the operators as black boxes; after receiving certain inputs (of new information) we know what the response will be, but not the internal mechanisms used.

One of the most controversial postulates of revision operators in the AGM model is success. *Success* states that the new information is always accepted in the revised belief set. That property is the weak side of the AGM model. A wide treatment of revision operators in which that property does not hold can be found in [9].

We propose a model of plausibility in which, instead of assigning a degree of importance to each sentence, we assume that there is an informant which provides it. This is to say, each sentence in the knowledge base is provided by an informant.

Associated with each knowledge base K, there is an *informant set* I_K. For each informant set I_K there is a plausibility relation R_{I_K}. In order to simplify the notation we will eliminate the subindex K for the informant set and the subindex I_K for the plausibility relation (I and R respectively). When we must carry out a change operation in which belief elimination is necessary, we eliminate those beliefs provided by the less reliable informants. This translates to informants which are lesser under the plausibility relation R.

The role of this research

This research's central idea is not the definition of change operators based on plausibility. What we present are change operators that allow the modification of each informant's degree of credibility relative to the other informants in I. For example, if an informant provides information that proves to be wrong, the agent may decide to decrement its relative degree of credibility. If, on the other hand, an informant provides information that often turns out to be true its credibility should be raised. Some interesting related work can be found in [10,11].

An first approach to this research has been presented in [12]. We have a universal set of informants $\mathbf{I}$, and that, of these informants, some are to be considered more reliable than others. This is to say, in any case in which two distinct informants provide an agent with contradictory information the more trustworthy one is to be believed over the other. The agent must, therefore, have a mechanism by means of which the set $\mathbf{I}$ is ordered. To this end we present the following concept.

Definition: Given a set of informants $\mathbf{I}$ we will call any binary relation $\mathbf{G} \subseteq \mathbf{I}^2$ a generator set over $\mathbf{I}$. An informant i is less trustworthy than an informant j according to $\mathbf{G}$ if $(i,j) \in \mathbf{G}^*$.

$\mathbf{G}^*$ represents the reflexive transitive closure of $\mathbf{G}$. It is desirable for $\mathbf{G}^*$ to be a partial order over $\mathbf{I}$, although according to the preceding definition this is not always the case. We address this matter in the following definition.

Definition: A generator set $\mathbf{G} \subseteq \mathbf{I}^2$ is said to be sound if $\mathbf{G}^*$ is a partial order over $\mathbf{I}$.

Why is it desirable for a generator set to be sound? For a relation to be a partial order it must obey reflexivity, antisymmetry and transitivity. Given a generator set $\mathbf{G}$ it is obvious that its reflexive transitive closure, $\mathbf{G}^*$, will obey reflexivity and transitivity. However if antisymmetry is not respected

then there is at least one pair of distinct informants, i and j such that both $(i,j) \in$ **G*** and $(j,i) \in$ **G***. This would mean that both i is less trustworthy than j and that j is less trustworthy than i. Given that these beliefs are contradictory, believing them simultaneously would lead the believing agent to inconsistencies.
The main role of this research is to define change operators over partial orders. A first approach to that has been presented in [1], where expansion, contraction and revision operators are defined. Change operators can be defined in two ways: by giving constructions (algorithms) or by giving characteristic postulates. We want to define:

- **Nonprioritized revision operators**, *i.e.*, operators in which te new tuple (i,j) is not always accepted.
- **Consolidation operators**, *i.e.*, operators to restore soundness to the generator set.

In this way, we will present a complete set of changes to be applied to generator sets. If we view every belief in the epistemic state of an agent as provided by an informant belonging to a generator set, we can dynamically modify the order among beliefs throughout the agent's span of existence.

Clearly, what follows is to devise ways of handling the perception of changing plausibilities in real sources of information. Such is the case of weather forecasting systems, predictors of stock market behavior, etc. From these examples we will seek to understand the complexities of dynamic updating in decision making and advising systems.

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