Norms Evaluation through Reputation Mechanisms for BDI Agents

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Abstract. Open multiagent systems are systems populated with autonomous agents whose intentions are unknown. Due to this uncertainty, reputation mechanisms arise as a key technology when designing such systems. These mechanisms endow agents with the capability to reason about the behaviour of their potential partners regarding certain criteria, for instance, a particular norm. Although normative systems have been deeply studied, few attention has been paid on how agents use the norms to reason about the behaviour of their partners. In this paper, we face this problem by extending a BDI architecture that incorporates a reputation model (BDI+Repage) with a normative layer. Using the reputation mechanism together with this normative layer allow the agents to evaluate the behaviour of their partners according to both organisational and individual norms and use such information to reason about their future interactions.

Keywords. Cognitive Models, Reputation, Norms, Multicontext Systems, BDI

1. Introduction

In multiagent societies populated by real autonomous entities, i.e., entities that are free to behave differently as what it is expected/desired, it is almost mandatory to have behavioural control mechanisms. These mechanisms have to guarantee that the norms of the environment are observed and that, if they are violated, some kind of punishment will be applied. Regarding this, most of the efforts have been focused on the design of organisations [6,12], how agents internalise the norms [14] and how agents perform practical reasoning to act accordingly to the established norms [5,8,7]. Curiously, little attention has been paid on how agents evaluate the behaviour of their partners accordingly to the norms and how such evaluations are used in the reasoning process. This is the focus of the paper.

Although organisations may establish the norms that agents should accomplish, due to their autonomy it is not possible to guarantee that agents will follow them, even when they receive punishments. This puts honest agents in a poor and vulnerable situation, specially when the norms indicate how agents should act in the interactions. Thus, individual agents need mechanisms to evaluate potential partners accordingly to the norms. The organisational model presented in [2] is aware of such necessity, and includes, besides a governance mechanisms, a reputation mechanism to allow the agents evaluate partners not only accordingly to organisational norms, but also personal norms (usually more restrictive than organisational norms).

However this approach provides an organisation-oriented point of view, and does not tackle the individual level: how actually agents generate evaluations and how agents use them to reason. Hence, we need an agent architecture flexible enough to (1) include and express personal and organisational norms, (2) capable to generate evaluations and (3) use such evaluations in the normal reasoning process of the agent. For this enterprise, we extend the BDI+Repage model [10] defining in this paper the BDI+Repage+Norm model. The BDI+Repage model is a generic BDI agent architecture designed for social agents that includes the reputation system Repage [11], whose specifications coincide with the reputation mechanism described in the organisational model mentioned above [2]. The work presented in this paper concentrates on how the notions of *organisational* and *personal* norms can be fully integrated into the BDI+Repage model. Concretely, the aims of the paper are:

- *to demonstrate how agents evaluate the behaviour of their partners according to the organisational and personal norms*. We include a normative layer in the BDI+Repage model to express the norms. We provide mechanisms for capturing whether a given interaction has accomplished the defined norms and for informing the Repage model about this, which computes the evaluations. Furthermore, our model permits to express different levels of norm accomplishment.
- *to show how agents reason using the evaluations*. In the original BDI+Repage model, the evaluations that Repage generates are moved into the belief base of the agent and interact with the desires and intentions to finally produce the best *reasonable* action. The new BDI+Repage+Norm uses the description of the norms to move the evaluations from Repage into the belief base of the agent. In this way, the agent is aware of how its potential partners may act according to its norms (personal and organisational norms).

The remainder of the paper is structured as follows. In Section 2, we introduce the organisation+reputation model and also the BDI+Repage model, the basis for this work. Section 3 details the BDI+Repage+Norm agent architecture with a running example. Section 4, we present an overview of some related work. Finally, Section 5 concludes and describes the future work.

2. Preliminaries

2.1. Organisation and Reputation Models

The organisation model presented in [2] formalises a particular type of organised multiagent system - from now on *organisation* - following the framework proposed in [1] that provides a minimum set of mechanisms to regulate agents' interactions: $\mathcal{R}^{om}$ and

$\mathcal{ON}^{om}$. A $\mathcal{R}^{om}$ is an organisational mechanism based on roles that defines the positions agents may enact in the organisation (see [2] for more details).

A $\mathcal{ON}^{om}$ is an organisational mechanism that regulates participants' behaviour by using norms, and it is the part of the organisational mechanism that is relevant in this paper. An organisational norm is defined as a tuple $\langle deon, Sit, Org\rangle$, where $deon$ is a deontic concept in the set {PROHIBITION, OBLIGATION, PERMISSION} representing the different constraining possibilities over the situation Sit (where an agent is playing a role and executing an action) within the organisation Org. Organisational norms are based on the following principles: *i)* are defined by the organisation, *ii)* are known by all participants in the organisation, i.e. they are publicly provided by the organisation and *iii)* have to be monitored and sanctioned by a third party entity (an authority) not involved in the situation.

Agents in an organisation are supposed to have their own preferences and goals. In [2] the concept of *personal norm* is proposed to represent agent's preferences over different situations in which other agents may be involved. Thus, a personal norm models how an agent wants the others to behave when interacting with it. A personal norm is defined as a tuple $\langle \mathcal{A}g, deon, Sit\rangle$, where $\mathcal{A}g$ is the owner of the norm, $deon$ is a deontic concept in the set {PROHIBITION, OBLIGATION, PERMISSION} representing the preferences of agent $\mathcal{A}g$ over the situation Sit. Personal norms are based on the following principles: *i)* are defined by only one agent, w.r.t. its preferences; and *ii)* are monitored and sanctioned by the owner of the norm.

Reputation mechanisms are well-known techniques to keep agents from unexpected behaviour (i.e. norm violations) since they provide agents with relevant information about the trustworthiness of others. The reputation model proposed in [2] establishes that the behaviour of an agent is evaluated taking into accounting a given *situation*, and the *organisational and personal norms* that regulate such situation.

2.2. The BDI+Repage Architecture

The BDI+Repage model presented in [10] describes a BDI agent architecture that incorporates the reputation model Repage [11] as a fundamental part of the reasoning process. In general, BDI models offer formalisations of cognitive reasoning in terms of the interaction among three main attitudes: *Beliefs*, *Desires* and *Intentions*. The peculiarity of the BDI+Repage architecture is that reputation information is explicitly calculated through the Repage model and introduced as beliefs. In this way, reputation information participates in the normal reasoning process of the agent, interacting with desires and intentions to finally decide an action to perform.

Repage [11] is a computational system based on the cognitive theory of reputation developed by Conte and Paolucci [3]. The system computes social evaluations: they indicate how good or bad a given target agent results to be in a given role. A social evaluation incorporates three main elements: a target agent, a role and a value that quantifies the evaluation.

In Repage, values are represented as probability distributions over a sorted set of labels $\{w_1, \ldots, w_n\}$. In the original version of Repage, they were exactly five linguistic labels: *Very Bad, Bad, Neutral, Good, Very Good*, however it can be generalised. The *meaning* of each label as well as their number is contextualised by the role the agent is playing. To compute social evaluations, Repage uses *third-party communicated social* *evaluations* sent by other agents, and the *outcomes* of direct interactions. Also, Repage distinguishes between two types of social evaluations: image and reputation. Image refers to an evaluation that is believed by the agent, while reputation to an evaluation that is known to circulate in the society.

For instance, we could have an agent i whose image about agent j as a *seller* is $[0.5, 0.3, 0.2, 0, 0]$ ($img_i(j, seller, [0.5, 0.3, 0.2, 0, 0])$). This implies that i *believes* that with a probability of 0.5 agent j acts *Very Bad* as *seller*, that with a probability of 0.3 j acts *Bad* and so on. Following the example, the meaning of the label *Bad* could indicate that the quality of the product obtained is between 20 and 40, the label *Very Bad* between 20 and 0, etc. The same agent i could hold a reputation also about j. For instance, $rep_i(j, seller, [0, 0, 0, 0.3, 0.7])$. In this case, the semantics of the evaluation is the same, but instead of i believing it, i acknowledges that other members of the society *say* it. Thus, agents can believe that an agent a is pretty good, and acknowledge at the same time that a's reputation is very bad. This difference is taken into account when both social evaluations are introduced as beliefs. Concretely, reputation predicates are introduced as beliefs of the form $B_i(S(\cdot))$ while images are introduced as simple beliefs $B_i(\cdot)$ (see section 3).

The BDI+Repage model [10], shown in Figure 2 [1], is specified as a multicontext system, which provides a framework to allow several distinct theoretical components to be specified with the mechanisms that link them together by a set of bridge rules (see Figure 1). Each context can be seen as a logic and a set of formulas written in that logic. Bridge rules are the mechanisms used to infer information from one context to another. Each bridge rule has a set of antecedents (preconditions) and a consequent (postcondition). The consequent is a formula that becomes true in the target context when the antecedents hold in their respective contexts.

The BDI+Repage model incorporates one context for each attitude (Belief, Desire and Intention), one for the Repage model, and two functional contexts (Communication (CC) and Planner (PC)). The **Belief context**(BC) includes the believed knowledge of the agent. The deductive system in this context is a probabilistic dynamic belief logic in which formulas like $(B_i[\alpha]\varphi, p)$ indicate that agent i believes that after the execution of action α, the probability that formula φ holds is p. The **Desire context**(DC) is defined as a logic of preferences based on Lukasiewicz logic. Theories in this logic determine the desires of the agent and have the form $(D_i^+\varphi, d)$ and $(D_i^-\varphi, d)$ ($d \in [0, 1] \cap \mathbb{Q}$) meaning that agent i will have a level of satisfaction (in the former) or disgust (in the latter) d, if φ holds. Finally, the **Intention Context**(IC) holds formulas like $(I_i\varphi, d)$, where $d \in [0, 1] \cap \mathbb{Q}$. Intentions determine the trade-off between positive and negative countereffects of trying to achieve φ. The semantics of intentions indicate that the higher the grade is, the better the trade-off is for the agent.

Desires lead the reasoning process, and the interactions among attitudes is done though the activation of the bridge rules. Bridge rule 1 applies when a general positive desire, for instance $(D_i^+\varphi, 0.5)$, finds a way to be fulfilled through the performance of an action with certain probability, for instance, $(B_i([\alpha]\varphi), 0.3)$. Then, a more *concrete* desire that incorporates what has to be done to fulfil the desire is generated, in this case, if g function is defined as the product: $(D_i^+[\alpha]\varphi, 0.15)$. 0.15 is obtained multiplying the strength of the desire with the probability coming from the beliefs. Intuitively, this

[1]The original BDI+Repage model is composed by those elements in the figure depicted using continuous lines.

1:
$$\frac{DC : (D_i^{+}\varphi, d_\varphi) \quad BC : (B_i([\alpha]\varphi), p_\varphi)}{DC : (D_i^{+}[\alpha]\varphi, g(d_\varphi, p_\varphi))}$$

2:
$$\frac{DC : (D_i^{-}\varphi, d_\varphi) \quad BC : (B([\alpha]\varphi), p_\varphi)}{DC : (D_i^{-}[\alpha]\varphi, g(d_\varphi, p_\varphi))}$$

3:
$$\frac{\begin{array}{c} DC : (D_i^{+}[\alpha]\varphi, \delta) \\ DC : (D_i^{-}[\alpha]\psi_1, \delta_{\psi_1}) \\ \cdots \\ DC : (D_i^{-}[\alpha]\psi_n, \delta_{\psi_n}) \\ PC : act(\alpha, P), PC : P \end{array}}{IC : (I_i[\alpha]\varphi, f(\delta, \sum_{k=1}^{n} \delta_{\psi_k}))}$$

4:
$$\frac{IC : (I_i[\alpha]\varphi, \epsilon_{max})}{CC : does(\alpha)}$$

P, Q:
$$\frac{BC : B_i\varphi}{PC : \varphi}, \quad \frac{BC : B_i\varphi}{RC : \varphi}$$

B:
$$\frac{CC : rec_{ij}\varphi}{RC : comm_i(j, \varphi)}$$

Figure 1. The bridge rules found in the original BDI+Repage model. We also keep them the new model.

value represents an expected level of *satisfaction* if action α is performed. Rule 2 does the same for negative desires. In this case, the generated value represents an expected level of *disgust* if α is carried out. Rule 3 is in charge of generating intentions. Since a single action can achieve both positive and negative desires, rule 3 takes them into account by performing a trade-off between expected levels of satisfaction and expected levels of disgust if a given action is performed. Usually, f function is defined as the difference. Finally rule 4 chooses the intention with the highest trade-off and executes the corresponding action. In section **??** we illustrate such reasoning process in a study case. Rules P and Q introduce knowledge into the PC (planner) and Repage contexts, while rule B transforms a received information into a communication predicate that can be understood by Repage.

3. The BDI+Repage+Norm Architecture

In this section we show how the organisational mechanism $\mathcal{ON}^{om}$ described in section 2.1 is integrated in the BDI+Repage model described in section 2.2. We assume that agents are aware of the norms of the society, and due to that, are capable of evaluating other agents' behaviour according to them. Next subsection includes an informal description of the new model by means of an illustrative example. Following this, we provide the formal construct which extends the original BDI+Repage model to the new BDI+Repage+Norm model.

3.1. Norms and the BDI+Repage Model: An illustrative example

Let us consider a supply chain (SC) formed by beverage/food providers and pubs. Pubs contact the beverage and food providers with the aim of buying the goods that they later will sell to their customers. The following roles participate in such SC:

Providers	sell their goods to the *Pubs*.
Pubs	buy beverages and foods from *Providers* and sell them to *Customers*.
Customers	buy the beverages and foods sold by *Pubs*.

For our example we stress on the relationships between pubs and providers. Those relationships are regulated by some market rules, that all participants must fulfil. In the scenario we take the perspective of a BDI agent (from now on *our* agent, or agent i) that

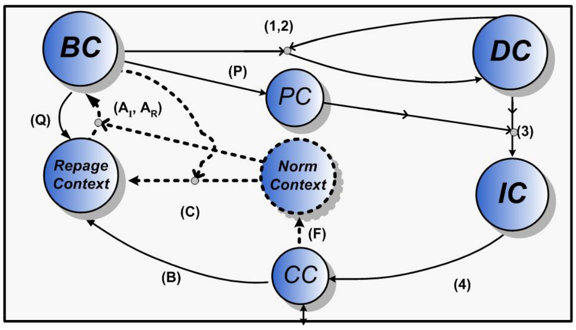

Figure 2. A graphical representation of the BDIRepage+Norm model. Elements with dot lines are the new elements introduced in this paper.

represents a pub owner. This agent needs very often to place orders to refill the stock. *Our* agent has a set of possible providers to choose from, and makes the selection following certain criteria (monetary cost, delivery time, quality of the product, etc.). One of these criteria is the observance of norms. For instance, one of the organisational norms that rules our scenario is:

- **ON** - *Orders must not be delivered later than 7 days after the date they were placed.*

1. Norm **ON** is evaluated after the action *placeOrder* is performed by an agent playing the role *pub*.
2. This evaluation can be done because after the action, a *fulfilment* indicates that the number of days for the delivery was exactly $dTime$.
3. If $dTime < 7$ the norm is fulfilled while if $dTime \geq 7$ the norm is violated. In both cases, this information is taken into account by the reputation model for future interactions.

Notice that it is not the same to deliver the product in 8 days than in 20. For this, we introduce the concept of *evaluative patterns* of a norm, which enriches the reasoning capabilities of the agent. Following the example, we consider four evaluative patterns for ON: $dTime < 7$, $7 \leq dTime < 9$, $9 \leq dTime < 15$, $15 \leq dTime$. After a transaction, the fulfilment of the norm regarding *dTime* is classified in one and only one of the previous evaluative patterns. This information is introduced into the Repage context. Then, as explained in section 2.2, Repage computes a probabilistic distribution (over the four possible patterns) that estimates the potential behaviour of the agent playing the role seller.

As we will see in section 3.4, two bridge rules introduce such evaluations as beliefs. One the one hand, Repage information provides for each agent evaluations according to the evaluative patters. On the other side, the desires of our agent determine a preference between each one of the situations. For instance, our agent i can have the following desire: $(D_i^+ dTime < 7, 1)$ indicating that i wants to achieve a $dTime$ lower than 7 days with a strength of 1. So, she wants the norm completely fulfilled. However, in another situation we could have: $(D_i^+ dTime < 7, 1), (D_i^+ 7 \leq dTime < 10, 0.7), (D_i^- 10 \leq dTime, 1)$. In this case, agent i wants with maximum strength a delivery time below 7 days, but also would consider a delivery time between 7 and 10 days, with less strength (0.7). What agent i rejects with maximum strength is a delivery time higher or equal than 10.

We argue that the separation between an objective evaluation and the desired behaviour is crucial for real autonomous entities. Then, an agent can change the desires but keeping and using the same evaluations.

3.2. The Norm Context (NC)

The new BDI+Repage+Norm multicontext model is represented with the tuple $Ag = \langle\{BC, DC, IC, PC, CC, RC, NC\}, \triangle_{br}\rangle$. These correspond to Belief, Desire, Intention, Planner, Communication and Repage contexts, respectively, plus a new NC (norm context). The set of bridge rules $\triangle_{br}$ incorporates the original rules $1, 2, 3, 4, P, Q$ and B, shown in Figure 1, plus the modified rules A_I and A_R (section 3.4), and rules F, R and C (section 3.3) that are new and related to the norm context. Figure 2 shows a graphical representation of this multicontext specification.

To specify NC we define the language L_{norm} as a first-order language with the special predicates $F(\cdot)$ and $N(\cdot)$ to model fulfilments and evaluative patterns respectively. We restrict the language to a conjunction of such predicates. It is important to remark that the language is used to describe how the norms are evaluated. Thus, there is no reference to the deontic notion of the norm, which are implicit in the description and in the desires of the agent.

3.2.1. The syntax of L_{norm}

The two special predicates in L_{norm} are identified by their sorts. The sorts that L_{norm} includes are a finite set of agent identifiers $\mathcal{A}$, a finite set of role identifiers $\mathcal{R}$, the finite set $\mathcal{I} \subset I\!N$ of indexes to identify each evaluative patter of a norm and a countable set of time instants $\mathcal{T}$ to represent the time that fulfilments are produced. To express the content of the normative patters and fulfilments we need an object language that *talks* about the domain and that must be the same used in the beliefs, desires and intentions. Such language is L_{basic}[2]. We introduce each φ belonging to the set of well-formed formula of L_{basic} ($wff(L_{basic})$) as the constant $\lceil\varphi\rceil$ for L_{norm}. This allows L_{basic} expressions to be nested in first-order L_{norm} predicates.

Let $\varphi, \phi \in wff(L_{basic})$, $j \in \mathcal{A}$, $r \in \mathcal{R}$, $n \in \mathcal{I}$ and $t \in \mathcal{T}$, the predicates of the language are:

- $N(n, r, \lceil\varphi\rceil)$: It describes an evaluative pattern for a given role. For instance, the norm ON has four evaluative patterns and can be represented as

$$\begin{array}{l} N(1, provider(ON), \lceil dTime < 7\rceil) \\ N(2, provider(ON), \lceil 7 \leq dTime < 9\rceil) \\ N(3, provider(ON), \lceil 9 \leq dTime < 15\rceil) \\ N(4, provider(ON), \lceil 15 \leq dTime\rceil) \end{array}$$

  Since each role can be evaluated in different norms, we consider evaluative patterns for each role $\times$ norm, as shown in the example ($provider(ON)$). We will write $N_i(n, r, \lceil\varphi\rceil)$ to indicate that agent $i \in \mathcal{A}$ is the holder of the predicate.
- $F(j, r, \lceil\phi\rceil, t)$: It indicates that after an interaction with agent j playing the role r at time t, ϕ holds. For instance, the formula

$$F(j, provider(ON), dTime = 6, 2)$$

[2]We assume that L_{basic} has associated a consequence relation $\vdash_{basic}$

indicates that the result of the interaction with agent j playing the role $provider$ at time 2 has been a delivery time of 6 days. Again, we write $F_i(j, r, \varphi, t)$ to indicate that agent i is the holder of the predicate.

For a consistent interpretation of the norm context, we require that L_{basic} predicates involved in evaluative patterns of the same role are pairwise disjoints. Formally, let us consider the set of evaluative patters over the role r: $N_i(1, r, \varphi_1), N_i(2, r, \varphi_2), \ldots, N_i(p, r, \varphi_p)$. Then, we must guarantee that for each m, n such that $m \neq n$ and $1 \leq m, n \leq p$, it happens that $\varphi_n \wedge \varphi_m \vdash_{basic} \perp$. This ensures that two or more evaluative patterns do not cover the same space.

Intuitively, the evaluative patterns classify the possible results that the agent wants to evaluate, providing semantics to the evaluation of norms. After each transaction, the fulfilment is captured by $F(\cdot)$ predicates in the NC-context. Through the appropriate bridge rules, the information is introduced into the Repage context as outcomes. This mechanism is explained in the next subsection.

3.3. Rules F and C

In the one hand, rule F is in charge of introducing fulfilments into the norm context, in the form of $F(\cdot)$ predicates . We assume that the communication context is able to capture the fulfilment of the transactions and generate such predicates (it is domain-dependent).

On eh other hand, Rule C is in charge of generating outcome predicates to feed the Repage model. It is defined as:

$$\textbf{C:} \quad \frac{\begin{array}{c} NC : N_i(d, r, \varphi) \\ NC : F_i(j, r, \phi, t) \\ BC : B_i(\phi \rightarrow \varphi) \end{array}}{RC : Outcome(j, r, d, t)}$$

Again, following the example, if agent i after interacting with j generates through rule F the predicate $F_i(j, seller, \lceil dTime = 8 \rceil, t)$, rule C would fire as

$$\textbf{C:} \quad \frac{\begin{array}{c} NC : N_i(2, provider(ON), \lceil 7 \leq dTime \leq 10 \rceil) \\ NC : F_i(j, provider(ON), \lceil dTime = 7 \rceil, t) \\ BC : B_i((dTime = 8) \rightarrow (7 \leq dTime \leq 10)) \end{array}}{RC : Outcome_i(j, provider(ON), 2, t)}$$

Under the assumption that the norm context is consistent as defined above, rule C is only fired one time for each fulfilment. With outcome predicates, Repage is able to calculate probability distribution for each agent and role over the defined evaluative patterns.

From outcomes and communications, Repage generates image and reputation predicates (see section 2.2), and through rules A_I and A_R the knowledge is introduced into the belief context.

3.4. Rules A_I and A_R

In the original BDI+Repage model these rules are in charge of updating the beliefs of the agent with the information coming from the reputation model. In the extended model we have modified the original rules to take into account the information contained in the norm context:

$$\frac{\begin{array}{c} RC: img_i(j,r,[V_1,V_2,\dots]) \\ NC: N_i(1,r,\varphi_1) \\ NC: N_i(2,r,\varphi_2) \\ \dots \end{array}}{\begin{array}{c} BC: (B_i([r_\alpha(j)]\varphi_1, V_1)) \\ BC: (B_i([r_\alpha(j)]\varphi_2, V_2)) \\ \dots \end{array}} \;\; \mathbf{A}_I\text{:} \qquad \frac{\begin{array}{c} RC: rep_i(j,r,[V_1,V_2,\dots]) \\ NC: N_i(1,r,\varphi_1) \\ NC: N_i(2,r,\varphi_2) \\ \dots \end{array}}{\begin{array}{c} BC: (B_i(S([r_\alpha(j)]\varphi_1, V_1))) \\ BC: (B_i(S([r_\alpha(j)]\varphi_2, V_2))) \\ \dots \end{array}} \;\; \mathbf{A}_R\text{:}$$

The key idea is that each linguistic label of the probability distribution provided by Repage and a role r refers to a unique evaluative pattern, i.e. a single predicate N. Also, since an agent j in a role r determines a concrete interaction model (that we reduce to a single action), the agent can infer the probability to achieve certain results after interacting with j in the role r.

To illustrate this, imagine that agent i has interacted with j as $provider$ several times, and that most of the times the delivery time was below 7 days ($dTime < 7$). Assuming the evaluative patterns for norm ON in the example of section 3.2.1, Repage may have generated the following image predicate $img_i(j, provider(ON), [0.8, 0.1, 0.1, 0])$. In this situation, rule A_I is fired instantiated as follows, assuming that $provider_\alpha(j)$ is the action $order(j)$

$$\mathbf{A}_I\text{:} \quad \frac{\begin{array}{c} RC: img_i(j, provider(ON), [.8, .1, .1, 0]) \\ NC: N_i(1, provider(ON), \lceil dTime < 7 \rceil) \\ NC: N_i(2, provider(ON), \lceil 7 \leq dTime < 9 \rceil) \\ NC: N_i(3, provider(ON), \lceil 9 \leq dTime < 15 \rceil) \\ NC: N_i(4, provider(ON), \lceil 15 \leq dTime \rceil) \end{array}}{\begin{array}{c} BC: (B_i([order(j)]dTime < 7, .8)) \\ BC: (B_i([order(j)]7 \leq dTime < 9, .1)) \\ BC: (B_i([order(j)]9 \leq dTime < 15, .1)) \\ BC: (B_i([order(j)]15 \leq p, 0)) \end{array}}$$

For instance, the formula $(B_i([order(j)]dTime < 7, .8))$ in the belief context indicates that agent i believes that after executing the action $order(j)$ she will obtain $dTime < 7$ (delivery time below 7 days) with a probability of 0.8. This information is used later in the BDI reasoning if the agent *desires* to interact with somebody in the role $provider$.

4. Related Work

Different definitions to norms and norms kinds have appeared in the literature. Some of them with similar definitions of organisational and personal norms [4,13,5]. We explain here though the ones that define agents architecture to deal with norms, and in special, those that also use a BDI architectures.

In [9] the authors extend the BDI language allowing it to modify plans at runtime in reaction to newly accepted norms. The approach proposed in NoA [8] takes a BDI architecture and changes the focus of agent behavior from achieving desires to fulfilling norms. In [5] the authors propose a modified BDI interpreter loop that takes norms and obligations into account in an agent's deliberation. The approach presented in [7] does also describe a multi-context BDI model by including commitments to the three contexts already defined by the architecture (belief, desire and intention).

The main different between such approaches and ours is that we focus on presenting how agents evaluate the behaviour of other agents according to the organisation/personal norms and use such evaluations to reason.

5. Conclusions and Future Work

From the idea that reputation values may fluctuate as a consequence of violation or fulfilment of norms in organisational environments, we have specified a reasoning model that allows the agent to integrate norms and reputations to its reasoning machine based on the BDI architecture. For that purpose we have used an already developed organisation+reputation theoretical model [2] and also a BDI model [10] that uses a reputation mechanism such as *Repage*.

As future work we plan to investigate on how the norms are adopted by the agent, i.e., how they are incorporated into the norm context. In this paper we assume that the norms are already inserted in the norm context and, thus, the adoption mechanism is not described. In addition, we will also investigate the relationship between norms and desires (specially focusing on personal norms).

We also intend to explore how the numeral BDI extensions mentioned in Section 4 can be incorporated to our approach. Finally, we plan to test our model simulating some different scenarios in a specific domain.

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