Using Social Institutions to Guide Virtual Agent Behaviour

JeeHang Lee, Tingting Li, Marina De Vos, and Julian Padget
Department of Computer Science, University of Bath
Bath, BA2 7AY, United Kingdom
{j.lee, t.li, m.d.vos, j.a.padget}@bath.ac.uk

Abstract. One requirement by which virtual environments (VEs) are judged, is the believability of the virtual agents (VAs). One aspect of believability, is that agent responses to situations should not create cognitive dissonance and thereby distract the observer. One approach to this problem is the use of institutional models, in conjunction with classical AI techniques, to achieve the appropriate recognition of complex situations and provide guidance on the subsequent choice of action(s). We present a distributed approach in which externally governed norm-aware agents are used to control the performance of the VE characters, creating the capacity to improve both the effectiveness of the decision-making and the believability of the characters. We aim to show that the combination of an institution providing social reasoning and BDI agents providing individual reasoning, establishes a framework for enhancing believability by the interplay between: (i) the institution and IVAs in VEs, and (ii) norms maintained by the institution and the mental states of IVAs. From an engineering point of view, the framework provides a separation of concerns because the BDI agent is augmented with the capacity to process social obligations, while the specification and verification of social structure resides in the (possibly several) institutional models. We illustrate our approach with two scenarios: one on queuing and another on inter-personal distance theory.

Keywords: Intelligent Virtual Agents, institutions, BDI Agent, IVA architecture

1 Introduction

Virtual environments (VEs) have seen significant developments in recent years, moving from virtual worlds designed for specific purposes, such as on-line games, to more general-purpose environments not for entertainment but for serious games, resulting in changes in form, scope and purpose [28]. With these changes in application domain has come a demand for more realistic behaviour in the context of more sophisticated and dynamic VEs.

It has rapidly become unrealistic to put all the capability for an appropriate response into the intelligent virtual agent (IVA) itself. One approach to this problem is the use of institutional models, in which behaviour is refactored into two parts, one that resides in a special kind of environment in the form of rules and the other, in the agent, taking the form of an accepted AI solution – in the case presented here, the BDI architecture –
capable of interfacing to those rules and using them as necessary. Institutional models – also called normative frameworks – are seen as an effective way to capture the salient elements of human social structures [6] and can equally be applied in (participatory) VEs to provide IVAs with adequate knowledge of human social mores, or indeed the rules of whichever context in which we wish them to be able to behave properly.

The broader objective, for which this paper aims to lay the foundations, is to provide a way to engineer better situational awareness for IVAs without making the agents themselves significantly more complicated. Hence, it is the institutional models that act as the repositories of situation-specific behaviour. Previous work [3], amongst others, has chosen to interpret the institutionally-specified behaviour as an absolute directive, in effect rendering the agents automatons rather than autonomous, which perpetuates the rigidity of the behavioural response. This approach is typically referred to as regimentation. We believe that the IVAs should choose whether or not to take norm-compliant actions, according to information received from the relevant governing institution(s).

Not only does this preserve the principle of autonomy, more importantly, it results in decision-making and consequently action-taking that can take account of the fusion of institutional knowledge – which is general with respect to a kind of situation, but specialized to some degree by the history of the actions of participants and the roles they are playing – and individual knowledge – which is specific to the beliefs and goals of each actor. This approach is typically referred to as regulation.

With these aims in mind, the paper describes a flexible, distributed architecture for the establishment of a connection between IVAs and a regulatory institutional model. We illustrate its effects through two example scenarios, one a model of queuing and the other a model of Inter-Personal Distance (IPD) theory, by demonstrating how some simple norms may be used to govern IVA behaviour. Firstly, we introduce the distributed agent framework that supports the institutional model and governs IVAs situated in VEs, followed by an examination of how this combination has the potential to bring about improvements in the believability of virtual characters, specifically in terms of believable behaviours by the interplay between: (i) the institution and IVAs in VEs, and (ii) the norms maintained by the institution and the mental states of IVAs. We realize these components using the Jason [9] implementation of the BDI architecture and the InstAL institutional model [15], for reasons we explain in following sections.

The remainder of this paper is organised as follows: related work and problems are discussed in Section 2. An outline of the formal and computational aspects of the institutional model is provided in Section 3. In Section 4, the overall agent deliberation framework and its mental model are described. This is followed by a discussion of the connection between the institutional model, norms and the mental state of agents. In Section 5 we demonstrate our approach in the context of two example scenarios. Finally, conclusions and future work are discussed in Section 6.

2 Background

In this section, we examine some of the related work in this area. We discuss how norms may be brought into the agent decision-making process in a MAS and consider the issue of (software) integration between institutions and VEs.
2.1 Related Work

Traditionally, AI researchers have paid much attention to agent behaviour in response to sensing the environment in which it is situated. Cognitive architectures [22, 20, 12–14, 11, 30, 26] analyse this information, make decisions, and do planning for the next behaviour to be carried out. All of these approaches effectively take the position that the entirety of the perceivable knowledge, possibly even its (partial) history and the whole of the decision-making process are internal to the agent, in order to make the system self-contained and perhaps also better to reflect the notion of an independent intelligent entity. Awareness of norms can be added to any agent architecture, although it is an open issue whether norms should be an external source of knowledge that delivers obligations (also called norms in some literature) to agents [1, 27], or be internalized in some way and then whether they are absorbed into the agent reasoning process [2] or kept separate so they can be ‘switched off’ when no longer applicable [17]. These issues aside, it is clear that the addition, somehow, of normative reasoning to intelligent agents is viewed as one way in which to enhance agent reasoning and response capabilities and in particular to enhance response in social settings. As Yee et al. [36] observe, almost all social behaviours occurring in virtual worlds by human users are governed by the same social norms as those in the real human society. This implies that if we wish the behaviour of IVAs to resemble that of humans more closely, then it is desirable somehow to convey those real world human social norms to the agents.

The implementation of institutions has broadly taken one of two approaches: regimentation or regulation, where the first requires total compliance of the agent with the norms – so they are no longer autonomous and violation is not possible – and the second provides compliance information to the agent, but the decision whether to comply or not remains with the agent – autonomy is retained, but violation is possible.

The regimentation approach is developed in [8, 35, 3, 7]. Electronic Institution (EI) is a representative example of an institution based upon regimentation, in which heterogeneous agents including humans and software entities can participate by playing different roles and can interact via speech acts [3]. The EI defines a set of constraints, such as what participants are permitted or forbidden to do. Each role identifies activities that agents should do in the current scene. Bogdanovych et al. [7] extend this approach to 3D EIs, called Virtual Institutions (VI), which are virtual worlds with normative control participants actions. They divide the 3D virtual world into a set of physical places, each of which is regarded as an ‘EI’, such as objects, rooms and buildings. Inside an EI, agents can take roles and carry out activities allowed by the EI. They also propose the use of VI as environments for imitative learning, which provides an apparatus for agents to learn behaviours from humans or other software agents.

The regulation (or governance) approach is explored in [18, 5, 24, 19, 10, 15]. This allows agents to have autonomy with respect to norms. In other words, norms can be both accepted and violated by agents depending on their situation. The goal generative approach [18, 19, 10] is a good example. In this approach, norms defined explicitly are coped with as one of the influential elements in the reasoning process of cognitive agents. Norms are not hard-wired into agents but can be acquired by agents through interactions with other agents which have different norms [32]. These norms are likely to be used in the process of decision making, either for the plan selection by preference
ordering of norms [18, 19], or for the goal generation with belief, intention, obligation
and desire [10]. This is very important aspect for norm-aware intelligent agents, because
not only can agents choose the fact whether norms might be violated or not, but also
norms might not always be necessary for agent decision making. This means norms
can be either totally neglected, partly considered or fully affective for the final decision,
depending on the situational information of the agent.

A different approach to the use of norms is proposed in Thespian by Si et al. [34].
This uses Partially Observable Markov Decision Processes (POMDP), as an alternative
to the explicit representation of norms, which provides social norms for the purpose of
improving agent social behaviours in a conversational context. The norms are entered
into the mental state of virtual agents as goals that the agent must, rather than ones it
may choose or not to achieve, making it akin to regimentation.

2.2 Problems

The VI in [7], despite regimentation, is a positive demonstration of benefits of integrat-
ing institutions with VEs, showing how norms can affect participants’ behaviour. How-
ever, there are some drawbacks to their approach. The most significant, in our view, is
that agents do not have the possibility to reason about norm compliance: they are re-
quired to follow pre-defined behaviours without consideration of the current situation.
Furthermore, these behaviours are tied to specific roles, so that an agent must choose to
take on a role that was defined when the EI was specified. An agent can reason about
its situation, but actions are restricted to those defined as norm-compliant at the design-
time of the institution. Thus, the agents are subservient to the goals of the institutions
and should only choose to surrender their autonomy for the period of institutional inter-
action, if the outcome aligns with their own goals. Furthermore, there appears to be no
scope for adaptation to account for a changing environment.

The issues identified above provide much of the motivation to pursue the more flex-
ible approach of regulation. However, regulation, as a principle, is only part of the
picture, in that it addresses how norms are part of the agent sense-deliberate-act cycle.
Equally important, at least when aiming to build an operational system, is how that nor-
mative information is communicated to the agent, in what form, how it is incorporated
into the mental model and whence it comes. The last is where the institutional model
fits in. A further essential requirement, we believe, is the scope to adapt to a chang-
ing environment and to revise norms over time, rather than fixing them at the time the
institution is designed, hence allowing for norms to express new goals as the system
evolves. We are not concerned here with how that revision or evolution takes place, but
simply that the architecture should provide sufficient flexibility for it to be possible.

The distributed architecture sketched earlier, emphasises asynchronous execution
and messaging (in the form of publish/subscribe), which means that components deal
with inputs as they occur, in an event-oriented manner. From the regulatory institu-
tional approaches cited above, we choose to use that of Cliffe [15], because it describes
an event-oriented institutional model and because others have successfully connected
it with the Jason agent platform [4]. Furthermore, this approach would be amenable to
implementation of the norm-aware agent model put forward by Alechina et al. [1], in
which the environment (as it is called in that paper) delivers obligations to the agent.
This provides both a form for the communication of norms, in contrast to communicating and incorporating the rules themselves as other approaches to norm incorporation have suggested. Such an approach keeps the agent decoupled from the institution: there is no need to switch off or switch between sets of rules, because they reside in the institution. However, the agent can be governed by the institution through the communication of obligations, brought about by the actions of the agents that are monitored by the institution and, using the constitutive norms of the institution, turned into institutional actions, when recognized as such. Whether the agent observes the obligation or not is determined by its decision-making process, thus autonomy is retained. By using externally governed norm-aware agents to control the performance of the VE characters, the capacity is created to improve both the effectiveness of the decision-making and the believability of the characters.

3 The Institution

The actual modelling of the institutions is achieved by InstAL, an institutional action language proposed by Cliffe et al. [16]. Underpinning the action language is a formal mathematical model and an equivalent computational model implemented in Ans-Prolog. We briefly give overview of both models, adapted from the citations given, for the sake of making this paper self-contained.

3.1 Formal Model

InstAL’s underlying principle is the interpretation of exogenous events in the context of the institution, using [33]’s principle of conventional generation. The normative effects of these events are recorded in the institutional state.

Two types of events are defined in the model: (i) external events (Eextr) capture the events happening in the VE, and (ii) institutional events (Einst) are the interpretation of external events in the institutional context. Following the “count as” principle introduced in [33], external events can be interpreted into the corresponding institutional events. For example, an external event “say hello” occurring in VE, counts as an institutional event “request chatting”. Institutional events are divided into two groups: institutional actions (Eact), indicating changes in the institutional states, and violations (Eviol), generated by performing non-permitted actions or non-satisfied obligations.

The institutional state is represented by a set of facts, called fluents $\mathcal{F}$. At any given instant, their presence denotes the veracity of the fact and the absence otherwise. Therefore, a state formula is a combination of positive or negative fluents: $X = 2^{\mathcal{F} \cup \neg \mathcal{F}}$. Different aspects of the normative state are denoted by subsets of $\mathcal{F}$: (i) permission ($P$) denotes an event can occur without generating a violation, (ii) power ($W$) indicates some event is empowered and may so bring about institutional change, (iii) obligations ($O$) specify that an event must happen before the occurrence of some other event, or a violation is generated, and (iv) domain fluents ($D$) describe domain-specific properties.

By observing a trace of exogenous events, the VE’s institutional states evolve accordingly. To this end, two transformer functions are provided: (i) the generation relation ($G$), generates institutional events from the occurrence of external/institutional events subject to conditions on the state, and (ii) the consequence relation ($C$), updates
\[ I = \langle E, F, G, \Delta \rangle, \] where

1. \( F = W \cup P \cup O \cup D \)
2. \( E = E_{ex} \cup E_{inst} \) with \( E_{inst} = E_{act} \cup E_{viol} \)
3. \( G : X \times E \rightarrow 2^{F_{inst}} \) where \( C(\phi, e) = (C^\downarrow(\phi, e), C^\uparrow(\phi, e)) \) where
   (i) \( C^\downarrow(\phi, e) \) initiates fluents
   (ii) \( C^\uparrow(\phi, e) \) terminates fluents
   (iii) with \( \phi \) a condition on the state \( \phi \subseteq F \) and \( e \in E \)
4. \( \Delta \subseteq F \)
5. State Formula: \( X = 2^{\mathcal{F}} \cup \neg \mathcal{F} \)

\[ \begin{align*}
   p \in F & \iff \text{influent}(p), & (1) \\
   e \in E & \iff \text{event}(e), & (2) \\
   e \in E_{ex} & \iff \text{evtype}(e, \text{obs}), & (3) \\
   e \in E_{act} & \iff \text{evtype}(e, \text{act}), & (4) \\
   e \in E_{viol} & \iff \text{evtype}(e, \text{viol}). & (5) \\
   C^\downarrow(\phi, e) = P \iff \forall p \in P \cdot \text{initiated}(p, T) \\
   & \iff \text{occurred}(e, T), EX(\phi, T). & (6) \\
   C^\uparrow(\phi, e) = P \iff \forall p \in P \cdot \text{terminated}(p, T) \\
   & \iff \text{occurred}(e, T), EX(\phi, T). & (7) \\
   G(\phi, e) = E \iff g \in E, \\
   & \text{occurred}(g, T) \iff \text{occurred}(e, T), \\
   & \text{holdsat}(\text{pow}(e), T), EX(\phi, T). & (8) \\
   p \in \Delta & \iff \text{holdsat}(p, 100). & (9)
\end{align*} \]

\begin{minipage}{0.4\textwidth}
\textbf{Fig. 1.} The institutional model (a) Formal specification of the institution and (b) translation of institutional rules into \textit{AnsProlog}
\end{minipage}

institutional states by adding or removing fluents, subject to the occurrence of some event and other conditions. Therefore, given an event trace and initial state \( \Delta \) of an institution, the corresponding institutional model, i.e., a sequences of corresponding states, can be generated. To summarize, an institution is a tuple \( I := \langle E, F, G, \Delta \rangle \) and the main features are defined in Figure 1(a).

### 3.2 Computational Model

The formal model of institutions described above can be translated to a corresponding computational model using answer set programming.

\textit{ASP} [21] is a declarative programming paradigm under the answer set semantics. Instead of designing solution to a problem, \textit{ASP} only requires the description and constraints to the solution, and then finds the solutions. The basic elements are atoms, that can be given a value, true or false. Atoms can also be negated by \textit{negation as failure}. The general form of an \textit{ASP} rule is syntactically like that of a Prolog term, comprising a head and a body, such that the truth of the former is implied by that of the constituents of the latter. Rules with no head express \textit{constraints}, indicating undesirable rules that solutions should not satisfy. Thus, an \textit{ASP} program is a conjunction of rules. Solutions are found by assigning values to atoms in order to satisfy all the rules stated in the program in a minimal and consistent fashion. Each such solution is an answer set.

The computational model of an institution comprises: (i) base component, initiates/terminates fluents, generates violation events if necessary, (ii) time component, defines time predicates as observed event and forms time sequence, and (iii) institution-specific component. The mapping from formal model to \textit{AnsProlog} literals is given in Figure 1(b). When an event occurs at time \( T (\text{occurred}(e, T)) \), the corresponding institution event is generated \( (\text{occurred}(g, T)) \) subject to some conditions \( EX(\phi, T) \). When an institutional event occurs, some fluent might be initiated \( (\text{initiated}(p, T)) \) or terminated \( (\text{terminated}(p, T)) \) at the same time \( T \). The literal \((\text{not}) \text{holdsat}(f, T)\)
represents the fluent $f$ holding positive (negative) at time $T$. The initial states of institution at time $t_0$ is encoded as $\text{holdsat}(f, t_0)$.

4 Agent Deliberation with the Institution

The institutional model of the preceding section describes the essential mechanisms for the recognition of socially significant situations and provides guidance on the subsequent choice of actions.

In this section, we introduce the distributed agent framework which consists of an institution supporting social reasoning, and BDI agents supporting individual reasoning. To begin with, the architecture of this framework is presented from an engineering perspective, explaining in detail how the coupling is accomplished between the institutional model and the VE wherein the VAs (controlled by BDI agents) are situated. Subsequently, we discuss from the operational perspective how the mental model of the framework is implemented. To do so, we illustrate the internal mental state changes associated with how an institution and norms affect the individual reasoning process.

We describe the distributed agent framework with regards to the assumptions that agents: (i) recognise the existence of the institution, and (ii) are norm aware In this paper, we do not address the issue of norm recognition or norm deliberation.

4.1 Architecture

Existing examples of agent platforms working with VEs [3, 32, 7] have quite a high degree of integration, tight coupling, or bespoke software involved. Close integration is potentially beneficial for performance, but potentially problematic when one of the software components changes. Thus, we concluded that it was desirable to decouple agent platform and VE to minimise the impact of change in one on the other, but close enough to deliver acceptable performance and genuinely distributed execution. Furthermore, existing architectural approaches would only get harder to maintain if we sought to integrate a third component – the institution – into the system.

We use a lightweight distributed framework, originally conceived for distributed sensors, as a means to provide an appropriate level of communication and decoupling. It presents a simple and flexible programming environment, using publish and subscribe streams, supported by XMPP server technology, to connect multiple software components that can operate on one computer or over a local or a wide area network. We realize the system of [25] by setting up a Jason platform [9] for the BDI agents and the libOMV [29] interface to the Second Life server as clients to an XMPP server. Subsequently, we can incorporate the institution component by connecting it using the same pub/sub mechanism.

The software architecture of our agent framework is shown in Figure 2. The diagram is more general than the system we describe here, in that it refers to a connection manager (libOMV, in this case) and virtual and real environments (Second Life, in this case). Different VEs can be connected, as can device interfaces with the real world, such as Kinect, for gesture recognition, both of which have been done. Thus, it is possible to support all four combinations of human/IVA interaction within a VE.
The IVA has two components: (i) the virtual character, that resides in the VE and which is capable of sensing and acting in that environment, and (ii) the intelligent (BDI) agent, that resides on the agent platform, which senses outputs from the virtual character and generates actions that are inputs for the virtual character. The sensory data from the virtual character to the BDI agent may either be raw or processed in some way (see upper left part of Figure 3). Likewise, the actions sent from the intelligent agent to the virtual character may either be precise actions or high level commands to be broken down (see upper right part of Figure 3). Thus, decision making is carried out by the BDI agents and each BDI agent is directly mapped to a virtual character. The beliefs of the BDI agent are established by percepts received from the VA, along with norms (permissions, obligations, prohibitions), received from the institution(s). The role of the institution is in formulating and communicating normative position information corresponding to environmental events delivered by BDI agents. This information may then become a part of a belief set in the BDI agent and hence part of the agent’s decision-making process. The next section describes the interaction between the BDI agent and the institution in more detail.

4.2 Mental model

The mental model of the distributed agent framework is shown in Figure 3. As might be expected, this is somewhat different from a conventional agent platform, because changes of mental state not only depend upon percepts from the VAs, but also on the normative information from the institution that are incorporated as percepts. In this section, we describe how this mental model implemented, combining the institution, norms and the BDI agents. To begin with, definitions and formalizations are provided for the key concepts and entities. With these in place, we discuss how the mental state changes through interplay both between the institution and IVAs, and between the normative percepts (received from the institution) and mental states of IVAs.
Given an established VE, a group of IVAs co-exist and thus share a common environment, meaning they can each observe the same environmental changes, and can interact with each other.

Within the virtual world, the actions of the VAs bring about observable changes in the environment, which are perceived by the VAs and presented to the BDI agents and the institution as events. Thus, the VA act as sensors and filters for both BDI agent and institution and in consequence the agent and the institution are both aware of the same events (see left hand side of Figure 3). We refer to these as external events because they occur external to the institution (see line 2 of Figure 1(a)).

We use the concept of event to refer to the symbolic representation of some captured data about the environments. The Recognising component in the VA is responsible for turning whatever is observable in the VE into this symbolic representation. We assume that the perception and recognition of all external events is carried out by VAs. Although all these events are delivered to the BDI agent, only some of them may be meaningful to the agent, and those that are not are ignored. The same applies to the institution: if there is no constitutive rule for an external event, then it is not of relevance for the institution. It should be noted that an event that is not meaningful in itself to the agent, but is to the institution, may consequently bring about an institutional change that is in turn relevant for the agent, because the event may cause the institutional recognition of a situation that affects the normative position of the agent: see the flow on the left hand side of Figure 3 from the institution to the agent. Thus, the institution consumes events from the VE and provides a social interpretation of them to the co-located IVAs, in terms of normative position information (permission, obligation), which is incorporated into the agent’s mental model, broadly in line with the ideas set out in [1], and subsequently may be taken into account by the agent’s decision-making process. In so doing, the agents may exhibit socially aware responses to situations, which may be perceived by humans as more believable.
Institutions and IVAs The instantiation of the institution is carried out by an external process called the Institution Manager, which provides the interface between the institution and the VA (event feed from VE) and the BDI agent. The institution provides two services for the BDI agent: (i) the interpreting of VE events and delivery of normative position updates, and (ii) a query mechanism, whereby the BDI agent can ask the institution for information about the normative position. The sequence of the runtime reasoning model are depicted in Figure 4, reflecting the description above:

1. The VA perceives information about the environment,
2. Percepts are delivered to the BDI agent which updates its beliefs,
3. Events are delivered to the Institution, which updates the normative state,
4. Queries are delivered to the Institution, which triggers a reasoning process (in ASP) and replies with information about the normative state, which which the agent updates its beliefs,
5. Normative information is delivered to each BDI Agent, which updates its beliefs.

Thus, the IVA is able to extend the information it has thanks to the social reasoning capability provided by the institution. The notation $\mathcal{N}(E_{\text{norm}})$ denotes the social normative information returned from the institution associated with the co-located IVAs. Once passed to the agent, the normative information can be incorporated in the belief base of the BDI agent.

Normative information and IVA Mental States Normative information is communicated from the institution to the BDI agent and typically becomes part of the belief base. In this mental model, normative information is complementary information for each agent rather than a separate part of the mental state. This normative information becomes a part of the belief base and perhaps a subgoal for the achievement of primary goal. If an institutionally generated obligation is adopted as a final goal, the agent would in effect be regimented, thus the model can fall back to fully regimented, if the agents have the appropriate behaviours. The actual form of the normative information is represented as: $\text{obl}(act)$ or $\text{perm}(act)$, which mean that an agent $X$ is obliged to perform action $act$, or an agent $X$ is permitted to perform action $act$, respectively. A BDI agent will then take action $act$, if it satisfies a belief or a subgoal of its main goal. If not, the obligation is ignored and a sanction may follow.
5 Illustrative Examples

We have set up two experimental scenarios in order to show how the system works. In the first we consider a queuing situation and in the second a situation concerning inter-personal distance.

We use Second Life as the VE in which all actions and interactions take place. IVAs are modelled by the combination of the openmetaverse library [29], for the virtual characters and BDI agents implemented in Jason [9]. Openmetaverse allows not only for the creation of VAs, but also the scripting of behaviours using combinations of various atomic actions. Jason provides a platform for the creation and programming of BDI agents using an extension of Agentspeak. The institution is specified using InstAL, the Institutional Action Language, which provides the social reasoning process.

5.1 Queuing

It is common in the society modelled in this scenario, that anyone who wishes to enter somewhere, or get on something is obliged to wait their turn in a queue. Of course, people who arrive later join the end of the queue. If someone arrives who is disabled or old, the social obligation is for those queuing to make a space for them at the front. Here, we model and demonstrate a such situation with two human users and three IVAs in a virtual world.

Initially, the VAs are dispersed, pursuing their own activities in the vicinity of the boat. As soon as the conductor (a human user) announces that boarding is starting, the VAs start to congregate at the gang plank and form a queue. When the disabled/old agent appears, it requests them to make space it. A sequence diagram for this scenario is provided in Figure 5.

In the normal course of events, IVAs take actions by individual reasoning, when beliefs are satisfied by its perceptions such as the case of $EVT<Go(Destination)>$. In the mean time, the delivery of percepts may cause
state update, or a query to the institution. Eventually however, the final decision on which action to take is accomplished through the combination of internal knowledge in BDI agents and normative information from the institution. Sometimes, such as in the case of \texttt{EVT<Detect(Disabled)>}, the outcome of social reasoning affects the agent behaviour directly. Nevertheless, it should be clear that plan selection is not purely determined by normative requirements, but depends on internal computation in Jason. Some frames extracted from the video are shown in Figure 6.

### 5.2 Inter-Personal Distance

Inter-Personal Distance (IPD), also known as proxemics, stands for the personal space between oneself and others [23]. We noted earlier, in Section 2.1, an interesting finding by Yee et al. that social interaction in VEs between avatars controlled by humans, appear to be subject to the same IPD social norms as in the real world. From this observational study, we may suggest that behaviours of VAs is likely to more believable if they are able to replicate human behaviours governing by social norms. Hence the motivation for the simulation of IPD in this second scenario.

To this end, we aim to show a simple IPD demonstration, in order to explore the effect of intimacy on IPD. The social norm in relation to intimacy and IPD is that: if people get too close to a person with whom they are not sufficiently intimate, then people typically either change their eye gaze or move to keep the proper level of IPD [31]. We simulate this with one human user and two IVAs.

The brief scenario for this example is that a human user meets two IVAs. One of the IVAs is friends with the human-controlled character, the other is not. Thus, when the human character greets them, the expected behaviour of the one known to the human is to react with greetings and maintain proximity. However, the other does not greet in return and also changes its eye gaze to maintain a proper level of IPD. Figure 7 shows a sequence diagram of the IVAs used in the example. Some frames extracted from the video are shown in Figure 8.

### 6 Conclusion and Future Work

In this paper, we aim to set out a framework for more believable IVAs, by providing better situational awareness while avoiding burdening the agents themselves with sub-
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This is achieved by a flexible, distributed communications middleware that enables the connection of VAs in a VE, BDI agents and a regulatory institutional model. We present two small demonstrations that serve to illustrate how the VA, controlled by the BDI agent behaviours, is influenced by social reasoning in the institution. However, a proper evaluation of the effectiveness of the approach requires careful and extensive planning, probably with assistance in experiment design from psychologists.

A potential benefit of the institutional approach is that the rules governing behaviour for a particular situation would be collected in one, or perhaps several closely related, institutions. This should help with authoring, validation, deployment and maintenance. For now, we do not consider the problems arising from institutional overlap – that is, when more than one institution recognises a situation – but note this an active research topic in the normative systems community and one that must be addressed and resolved in due course.

This presentation has only discussed institutions with fixed, predefined rules. For more realistic modelling, it would be desirable to allow rules to change over time and for new rules to be created and even whole new institutions. Both norm emergence, leading to the creation and incorporation of new rules and norm revision, would seem substantially more knowledge or more rules about every situation they might encounter.
to be essential features for the long-term utilisation of institutions in intelligent VEs and learning, in a variety of forms, will be investigated in future work.

References


