Intelligent Virtual Agents in Collaborative Scenarios

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Abstract. Today, many interactive games and virtual communities engage several users and intelligent virtual agents (IVAs) all interacting in the same virtual environment, which additionally, may present collaborative tasks to the participants. The success of the interactions relies on the ability of the agents to meet the user's expectations, thus, showing a coherent and believable set of behaviours. For this reason, in scenarios where users and IVAs interact as a group, it is very important that the interactions follow a believable group dynamics. Focusing on this problem, we have developed a model that supports the dynamics of a group of IVAs, inspired by theories of group dynamics developed in human social psychological sciences. The dynamics is driven by a characterization of the different types of interactions that may occur in the group. The model was implemented in a computer game that engage the user with a group of four IVAs in the resolution of collaborative tasks. This game was used in an evaluation experiment which showed that the model had a positive effect on the users' social engagement in the group, namely on their trust and identification with the group.

1 Introduction

Intelligent Virtual Agents (IVAs) are commonly used in interactive games and virtual communities as a way to enhance the interaction experience of users. However, this positive effect will only be achieved if the agents are able to show coherent and believable behaviours.

Furthermore, some of these interactive systems present tasks to the participants that must be solved, collaboratively, in group. For example, in computer role-playing games several players form groups of adventures that undertake the challenges and quests of the game's world. However, in such collaborative scenarios the role of the IVAs is usually very restricted as they do not take an active part on the group. If they do participate in the group users frequently have strong control over the them, which, consequently, reduces their autonomy. For example, in the "Star Wars: Knights of the Old Republic"[6], the user starts the adventure with one character, but as the game evolves other characters join the player's quest and s/he will end up controlling simultaneously

an entire party of several characters. This fact decreases the players' perception of the synthetic members as individuals and increases the distance between the player and her/his character, which makes the users' interaction experience in the group less interesting.

We believe that the main reason because the IVAs do not successfully participate in the group with users is due to their lack of social skills to engage in the group social interactions. Research on IVAs has not been particularly focusing on this problem. It is usually centered on the interactions between a single user and a single character [5] [13] or on the interactions of the IVASs among themselves [17] [15] without considering the user within the group and without a common collaborative task.

In addition, we argue that it is not enough to endow the agents with social skills that allow them to behave in a coherent manner from an individual perspective, but it is also necessary that the agents are able to use their social skills to engage in a believable group dynamics. Thus, their behaviours should be coherent with the group composition, context and structure. In multi-agent systems (a related field of IVAs) we can find some work related to the simulation of group dynamics[14], however, it is usually centered on the issues of the efficiency of the group rather than the socio-emotional dimension of the group and the believability of the group interactions in relation to the user.

The goal of the work present here, is to enhance the role of IVAs in collaborative scenarios making them part of the group. To do that we have developed a model for the dynamics of the group, inspired in theories developed in human social psychological sciences. The model defines the knowledge that each individual agent should build about the others and the group and how this knowledge drives their interactions in the group.

The model was implemented in the behaviour of IVAs that collaborate with the user in the resolution of tasks within a collaborative game. The game was used in an experiment conducted to assess the influence of the model on the users interaction experience, which showed that the model had a positive effect on the users' social engagement with the group, namely their trust and identification with the group.

This paper describes the model for the synthetic group dynamics and the game and study developed to evaluate its effects on user's interaction with a group of IVAs.

2 The Test Case: *Perfect Circle*

Perfect Circle[1] is a game that engages the user in a collaborative task with a group of four autonomous synthetic characters. It takes the user into a fantasy world where certain gemstones contain the essence and power of the gods. In this world, certain men, the Alchemists, dedicate their lives to the study of the gemstones' powers and are looking for a special one that merges the power of all

[1] This game can be downloaded from *http://web.tagus.ist.utl.pt/ rui.prada/perfect-circle/.*

the seven essences (ruby, topaz, citrine, emerald, sapphire, amethyst and iolite), known as the Rainbow Pearl.

The user plays the role of one Alchemist that has joined a group of other four Alchemists to undertake the quest for the rainbow pearl, which they believe to be hidden in one of the elemental planes. These planes are reached through magic portals that can be activated by the powers of a given combination of gems. The goal of the group is to progressively gather the necessary gems needed to open one portal in order to proceed to the next one (see figure 1).

Fig. 1. The group of Alchemists is trying to activate one of the portals to move further in the planes.

Each of the members of the group have different skills, which allows them to gather gemstones from the ground and manipulate them in order to change their shape, size and essence.

Furthermore, every member in the group is engaged in the same goal, thus trying to solve the same task. However, there are many ways to reach a solution, and if each of the characters follows its own, the group may never solve the task. Thus, characters have to coordinate their actions in order to follow a similar strategy in the search for the correct stones to activate the portal.

For this reason, every action that is performed in the group concerning the resolution of the task is discussed by the group beforehand. The discussion protocol has three different steps:

1. First, one character declares that s/he wants to take a certain action (e.g. *"I think that it will be best if I merge these two sapphires"*).
2. The other characters respond to the proposal by agreeing or disagreeing with it.

3. Then, based on the opinions expressed by the group, the character decides to proceed with the execution of the action or to withdraw the proposal.

The group interactions are not restricted to the execution of the task. Each member can, at any time, engage in social-emotional interactions by encouraging or discouraging the other members of the group. Note that the user can perform, through her/his character, exactly the same type of actions in the group that the autonomous members do.

3 A Model for the Group Dynamics

In order to enhance the user's interaction experience in collaborative scenarios, such as the game described in the previous section, we have developed a model to support the dynamics of groups of IVAs, the SGD Model. The model was inspired on several theories of group dynamics developed in human social psychological sciences [7], [4] and [12] and is based in the principle that each IVA must be aware of the group and its members and should be able to build a proper social model of the group and guide its behaviour in the group with it. The model is characterized at four different levels: (1) **the individual level** that defines the individual characteristics of each group member; (2) **the group level** that defines the group and its underlying structure; (3) **the interactions level** that defines the different classes of interactions and their dynamics; and (4) **the context level** that defines the environment and the nature of the tasks that the group should perform.

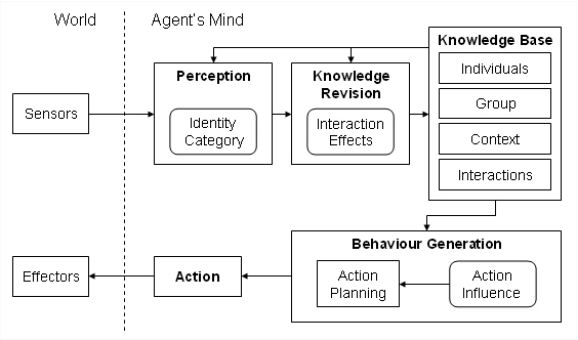

Fig. 2. The SGD Model in the agents' mind.

These four levels describe on one hand the knowledge that the agents should build and on the other the dynamics of their behaviour. This dynamics relies on the agents' perception of the group state, the group interactions and their capability to classify these interactions into one of the classes defined in the model

(interactions level). For example, agents must be able to recognize if the actions of the other members facilitate or not the resolution of the group tasks. Thus, the dynamics of the model is achieved through these three different processes (see figure 2):

1. **Classification of the Interactions:** First, the agent classifies the actions in the group into categories of interaction with specific semantics. For example, in this process the agent interprets if certain actions are helpful for the group of not. This process uses the information on the four levels of the agent's knowledge, specially on the interaction level, that defines the possible categories of interaction, and in the context level that defines how should the actions of the group be interpreted.
2. **Propagation of the Interaction Effects:** Then, based on the identified category, the interactions produce some changes on the knowledge, in particular on the individual and group level. For example, the interaction may change the social relations established between the members that it engages.
3. **Influence of the Agent's Actions:** Finally, the agent's perception of the group and its members influences the actions that it performs in the group. For example, if the agent is not motivated it will not try to solve the group's tasks.

3.1 The Individual Level

In the individual level each agent is modelled as a unique entity, having a name that identifies it in the group, a set of abilities that define the actions that it can perform in the environment which are related to the task (e.g. change the shape of one gem) and a personality. The personality is defined using two of the dimensions proposed in the Five Factor Model [11]: *Extraversion* that is related to the dominant initiative of the agent and, thus, will influence the agent's frequency of interaction; and *Agreeableness* that is related to the socio-emotional orientation of the agent so it defines the type of socio-emotional interactions that the agent will favour (e.g. more agreeable members will encourage the others more often).

3.2 The Group Level

The group level contains knowledge related to the group's composition (e.g. set of members), identity and structure. The identity defines a way to distinguish the group in the environment (e.g. a unique name), thus allowing its members to recognize and refer to it. The group structure emerges from the social relations established between the members and can be defined in two different dimensions:

1. **Structure of power:** that emerges from the members' social influence relations. These relations define relations of power, they quantify the capacity of one agent to influence the behaviour of another. The influence is defined as the difference of power that one individual can exert on another and the power that the other is able to mobilize to resist [9].

2. **Sociometric structure:** that emerges from the members' social attraction relations. These relations are related to like (positive attraction) and dislike (negative attraction) attitudes. They are unidirectional and not necessarily reciprocal, thus, if one agent A has a positive attraction for agent B this does not necessarily mean that agent B has a positive attraction for agent A.

The social relations are directed from one agent, the *source*, to another, the *target*, and are assessed by a *value* which can be positive, zero or negative.

In addition to the relations that agents build with each other, agents also build a relation with every group that they belong to. This relation captures the member's attitude towards the group and supports the notion of membership. It categorizes the member in the group in two different levels:

1. **Motivation in the Group:** defines the level of engagement of the agent in the group's interactions and tasks.
2. **Position in the Group:** reflects the agent's relative significance in the group that defines how important are its contributions and how well are they accepted by the group. For example, actions performed by agents that have more social influence on the group members have stronger effects on the group process. The position of an agent in the group depends on the overall social influence that the agent may exert on the others, on the attraction that the others have for the agent and on the agent's relative expertise in the group.

3.3 The Context Level

The context level defines the knowledge that the agent builds concerning the environment where it performs and the nature of the group's tasks. One of these definitions is the task model, that allows the agent to interpret the group interactions in terms of their effects on the the task and, therefore, allows the agent to classify them in the instrumental categories. For example, if the group needs a squared ruby to open one portal, then any action that generates a squared ruby will be interpreted as a positive move for the group.

Additionally, the context may define some social norms that will guide the agent in the interpretation of the social-emotional interactions. These social norms define the acceptable behaviours and the misconducted interactions. For example, if one agent reiterates the importance of merging two sapphires right after the failure to perform such merge attempted by another member, this may be considered not polite and, thus, be interpreted as a negative socio-emotional interaction.

3.4 The Interactions Level

The interaction level describes the knowledge that the agent builds concerning the group interactions: their classification and dynamics. The dynamics reflects,

on one hand, the changes that the group interactions induce on the agent's perception on the group (*interaction effects*) and, therefore, on the knowledge the it builds about the group, and on the other hand, the rules that drive the behaviour of the agent (*action influence*).

The central notion is the concept of interaction with the group, which is related to the agents' execution of actions. An interaction is characterized by: (1) the set of *performers* that are responsible for the occurrence of the interaction; (2) the set of *supporters* that agree with the interaction and support it, but are not directly involved in its execution; (3) a set of *targets* that are affected by the interaction; and (4) the interaction's *strength* in the group, which determines its relative importance in the group and, therefore, determines the strength of the effects of the interaction in the group. This *strength* depends on the position in the group of the members that are responsible for its execution or have supported it. For example, if one member has a low position in the group and performs well one of the actions that are relevant for the group then it will gain a small amount of influence. However, if one influent member has agreed with the action, thus, supporting it, the amount of influence gained will be higher.

The Classification of the Interactions In order to model the dynamics of the group process we have classified the several possible group interactions into different categories. This categorization is then embedded in the knowledge that the agent has a priori and will support the agent's process of perception and identification of the interactions.

This classification is more than just the classification of the actions themselves. It depends on the actions' results, on the context of the execution, and also on the agents' perception of the group. Thus, for example, the same action can be perceived as a positive interaction to the group by one agent but negative in the view of another.

The classification, was based on the categories that Bales proposed on his IPA system [4]. Bales argued that members in a group are simultaneously handling two different kind of problems: those related with the group task and those related to the socio-emotional relations of its members. Based on this, in the model, the members interactions are divided into two major categories: the *instrumental interactions* that are related to the group task and the *socio-emotional interactions* that are related to the group social relations. In addition, the interactions can be classified as positive, if they convey positive reactions on the others, or negative, if they convey negative reactions.

The *socio-emotional* interactions fall into four categories:

1. **Agree [positive]:** this class of interactions show the support and agreement of one agent towards one of the interactions of another agent consequently raising the importance of that interaction in the group.
2. **Encourage [positive]:** this class of interactions represent one agent's efforts to encourage another agent and facilitate its social condition.

3. **Disagree [negative]:** this class of interactions show disagreement of one agent towards one of the interactions of another agent, consequently decreasing the importance of that interaction in the group.
4. **Discourage [negative]:** this class of interactions represent one agent's hostility towards another agent and its efforts to discourage it.

In addition, we defined four categories of instrumental interactions, that are:

1. **Facilitate Problem [positive]:** this class of interactions represent the interactions made by one agent that solves one of the group problems or ease its resolution.
2. **Obstruct Problem [negative]:** this class of interactions represent the interactions made by one agent that complicates one of the group problems or render its resolution impossible.
3. **Gain Competence [positive]:** this class of interactions make one agent more capable of solving one problem. This includes, for example, the learning of new capabilities, or the acquisition of information and resources.
4. **Loose Competence [negative]:** this class of interactions make one agent less capable of solving one problem. For example, by forgetting information or loosing the control of resources.

The Dynamics of the Interactions The interactions constitute the mechanism that create the dynamics in the group. Such dynamics is supported by the classification presented on the previous section and is modelled through a set of rules that follow the ideas found in the social psychological theories of group dynamics. For example, we use ideas from the theory of social power by French and Raven [9] and Heider's balance theory [10].

These rules define, on one hand, how the agent's and the group's state influence its behaviour and the occurrence of each kind of interaction, and on the other, how the occurrence of each type of interaction influences the agent's and group's state.

First of all, the interactions of one member in the group depend on its individual characterization as well as her/his perception of the group state. Thus, the member will interact in a completely different way according to different group situations, such as for example, in groups with different elements or with different emergent structures. To model this we defined a set of rules that describe the conditions that are more favourable for the occurrence of each type of interaction:

1. In general the frequency of the interactions depends on the agent's *motivation*, *group position* and *personality* [16] [12] [1]. Thus, highly motivated agents engage in more interactions, as well as agents with a good group *position* or high *extraversion*. On the other hand, agents not motivated, with a low *position* in the group, or with low levels of *extraversion* will engage in few interactions or even not interact at all.

2. The agent's personality also defines some of the agent tendencies for the *social emotional interactions* [1]. Thus, agents with high levels of *agreeableness* will engage more frequently in positive *socio-emotional interactions* while agents with low *agreeableness* will favour the negative *socio-emotional interactions*. For example, if an agent fails to perform and important action in the group, it will probably be encouraged to try again and not to give up by the members that are very agreeable, while the disagreeable members will probably discourage her/him.
3. Furthermore, the agent's skills influence the occurrence of the *instrumental interactions*. Thus, more skillful agents will engage in more *instrumental interactions* than non skillful agents [12].
4. Moreover, agents with higher *position* in the group are usually the targets of more positive *socio-emotional interactions* while the agents with lower *position* are the targets of more *negative socio-emotional* interactions [12][2].
5. In addition, when one agent is considering to engage in a *socio-emotional interaction* its social relations with the target are very important. Members with higher *social influence* on the agent and/or members for which the agent has a positive *social attraction* will be more often targets of positive *socio-emotional interactions*, otherwise they will be more often targets of negative *socio-emotional interactions*. Thus, agents will encourage those they like or those that have high influence over them.

Furthermore, when agents get the perception of the execution of one interaction, they react to it according to the classification that they internally give to the interaction. These reactions are translated into changes on the perceived state of the group. These changes follow the set of rules described below:

1. The *positive instrumental interactions* will increase its performers *social influence* on the members of group, by means of expert and information power [9], as well as its own *motivation*. Which means that any member that demonstrates expertise, solves one of the group's problems or obtains resources that are useful to its resolution, will gain influence over the others. On the other hand members that obstruct the problem or loose competence, will loose influence on the group and become less motivated.
2. *Socio-emotional interactions* by their turn are associated with changes in the *social attraction* relations. One agent changes its attraction towards another agent positively if it is target of positive *socio-emotional interactions* by that agent and negatively otherwise. The encourage interaction has the additional effect to increase the target's *motivation* in the group.
3. Agents also react to *socio-emotional interactions* when they are not explicitly the targets of the interaction. Following Heider's balance theory [10], if one agent observes a positive *socio-emotional interaction* on an agent that it feels positively attracted to, then its attraction for the performer will increase. If the agent performed a negative *socio-emotional interaction* then the observer's attraction for the performer would decrease.

[2] Note that an agent has an high group position if it has high influence over the others and/or if the others have an high social attraction for it.

The intensity of the interactions' effects described on the previous rules depends directly on the strength of the interaction in the group, which depends of the position in the group of its performers. For example, encourage interactions performed by members with a better position in the group will increment more the target's motivation.

4 Evaluation

We have conducted an experiment with the Perfect Circle game, in order to evaluate the effects of the SGD Model on users that interact with groups of synthetic characters. The experiment was conducted with 24 university students, 20 male and 4 female, using two main control conditions:

1. **Use of the SGD Model:** we built two different versions of the game: one where the characters followed the SGD Model and other where they did not. When the characters did not use the model they were not able to engage in socio-emotional interactions, except Agree and Disagree (without any socio-emotional connotation). In addition, their frequency of interaction was always constant and the decision to proceed with a proposed action was not weighted by the members' group position, it was a simply majority rule.
2. **The Group Initial Structure:** subjects can start the game in a group with non neutral initial social relations of attraction and influence, which means that the initial group can have different levels of cohesion. Such levels may be very high or very low. We have considered two different scenarios: one where the group has neutral social relations and another where the members of the group dislike each other, which, takes the group cohesion to very low levels. Note that this condition can only be applied when the game is run with the believable group dynamics component.

Following the work of Allen et al.[2] we have decided to measure the users' interaction experience by measuring the users' trust and identification with the group. Allen et al. have conducted an experiment to measure the satisfaction of the members of a group that performed their tasks through computer-mediated interactions. They argue that, since trust and identification have a strong relationship with group satisfaction [8] [3], using their measures is a good approach to assess the user's satisfaction in the group.

During the experiment we divided the subjects into three different groups with 8 elements each. Each group played the game with a different condition: (C1) the first group played the game without the SGD Model; (C2) the second played with the SGD Model and with the group at neutral cohesion levels; (C3) and the third played with the SGD Model but with the group at low levels of cohesion.

Subjects played the game for an hour and afterwards had half an hour to answer a questionnaire, similar to the one used by Allen et al.[2].

We have analyzed the questionnaire results using the Kruskal-Wallis non-parametric test which computed the mean-ranks shown in figure 3.

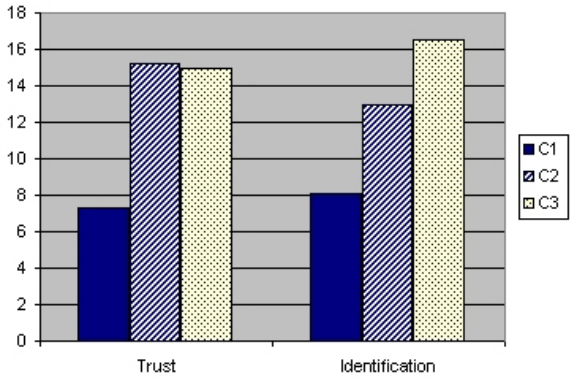

Fig. 3. Kruskal-Wallis test mean-ranks results. The Asymp. Significance for Trust was 0,039 and for Identification was 0,051.

The chart on figure 3 shows a comparison of the group trust and group identification measured on the three control conditions. As one can see, there is a clear difference on the levels of trust and identification observed on the subjects that played with the SGD Model and those who played without the SGD Model. Trust and identification were higher when the synthetic characters followed a believable group dynamics. There is also some difference between the identification of the subjects with the group on condition C2 and condition C3, which we believe is due to the fact that in the first case the group socio-emotional interactions were mostly positive, what may be less believable than a group where the socio-emotional interactions are both positive and negative, as the second case. However, we need further evaluation on this issue.

5 Conclusions

In this paper we argued that usually IVAs do not take an active role in collaborative scenarios with users because they do not have the desired social skills to engage in the group interactions.

Thus, to enhance the participation of the agents in the group, we have proposed a model that supports their group behaviour, which was inspired by theories of group dynamics developed in human social psychological sciences. This model defines the dynamics of the group based on a characterization of the different types of interactions that may occur in the group. This characterization addresses socio-emotional interactions as well as task related interactions.

The model was implemented in the behaviour of IVAs that collaborate with the user within the context of a computer game (*Perfect Circle*). This game was used in an evaluation experiment that showed that the model had a positive effect on the users' social engagement in the group, namely on their trust and identification with the group.

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