A Cognitive Model of Social Relations for Artificial Companions

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Abstract. Artificial companions are made to establish and maintain long-term relationships with users. In order to model the companion's social relations and to capture its dynamics, we propose a neural network model based on a formal representation of social relations. Based on psychological theories, we characterize social relations over two dimensions, namely liking and dominance. These two dimensions are formally described as a combination of beliefs and goals of the agent's mental state. Such a model allows us to automatically compute the social relation of a virtual agent towards its interlocutor depending on its beliefs and goals.

Keywords: Virtual agents, artificial companions, social relations, social dynamics.

1 Introduction

According to [1], a companion can be defined as *"a robot or a virtual conversational agent that possesses a certain level of intelligence and autonomy as well as social skills that allow it to establish and maintain long-term relationships with users"*. Our research work aims at developing virtual companions endowed with a cognitive model of social relations that allows them to (1) compute their social relations towards the user, (2) determine how this social relation evolves depending on the interaction and (3) influence their decision making. Indeed, a companion playing the role of a teacher should have a different behaviour than another one embodied as a play friend. In this paper, as a first step, we focus on the first problematic, that is how to compute the social relation of a virtual companion towards the user given the context of the interaction. More precisely, we propose a cognitive model in which the social relation of the companion is represented and initialized based on its goals and beliefs. The cognitive model is coupled with a neural network to represent the dynamics of the relation. From this model combining a formal representation and a neural network representation, several strategies emerge that enables a companion to determine how to modify its own relation towards the user.

2 Related Work

In the domain of virtual agents, social relations are often represented by a dimensional representation. Among these agents, some try to model the social

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relations and more precisely their dynamics during interactions. *Laura* [2], for example, encourages users to exercise on a daily basis. Laura's behaviour evolves over everyday interactions, through pre-scripted dialogues. The relationship is based on a stage model, which could be related to the dimension of intimacy.

One approach to model the dynamics of social relations is based on logical concepts. In [3], the authors try to team up humans with a group of synthetic characters, using a formal representation of liking and dominance. The evolution of these two dimensions rely on the content of the interactions between the agents. Finally, in [4], the author formalizes the five bases of power described by Raven [5] with four different categories. The author also models the agent's decisions, knowing the power relations in which it is involved.

Although most of the models above focused on the dynamics of social relations, few of them initialize these relations in a formal way. Indeed, the initial values of the social relations are generally fixed intuitively depending on the context of the interaction. In this paper, we propose a model to formally compute the social relation of a virtual agent considering the two dimensions of dominance and liking.

3 A Cognitive Model of Social Relations

In our research, we consider cognitive agents with an explicit representation of beliefs and goals that allow them to reason about their environments. As in [6], our cognitive agents have beliefs about the other agents, constituting a theory of mind (ToM). Therefore, the relation between an agent A and an agent B will change whenever A updates its beliefs about B. To capture the dynamics of the relation, the cognitive model is combined with a neural network representation. Each goal and belief of the agent is represented by a neuron. The importance accorded to these beliefs and goals by the agent is represented by the weights of the links of the neural network: the more important they are for the agent, the higher the influence on dominance and liking will be.

3.1 Liking

In our work, the formal representation of the liking dimension is based on Heider's Balance Theory [7]. This theory can be represented as a triangular schema between an agent A as the focus of the analysis, another agent B and an impersonal entity C, which could be a physical object, an idea or an event. Since the Balance Theory assumes that people tend to seek balanced states, two scenarios can be defined: (1) if A believes that both A and B share the same appreciation about a concept C, then A's liking towards B will increase. (2) On the other hand, if A believes that A and B have contradictory appreciations about the same concept C, then A's liking towards B will decrease.

To model the liking between an agent A and an agent B, we first need to represent each concept of agent A's world and its appreciation degree towards these concepts. In our model, each concept is represented by a neuron. The activation of this neuron represents the degree of appreciation of the concept. Then,

considering a theory of mind, we introduce A's beliefs about B's appreciations concerning these concepts, and we compute the values of agreement or disagreement. These values will eventually influence the final liking value, depending on the importance accorded by A to each concept. The more important A considers a concept, the more agreeing or disagreeing with B will influence its liking.

Since A's liking value towards B is based on beliefs and a theory of mind of the agent B, the agent A might like B, but B might dislike A. This is consistent with the work presented in [3] claiming that liking is not necessary mutual.

3.2 Dominance

The theoretical background for our formal model of dominance is based on the work of Emerson [8], and more particularly on his definition of dependence. For Emerson, the dependence of an agent A upon another agent B is "(1) directly proportional to A's motivational investment in goals mediated by B and (2) inversely proportional to the availability of those goals to A outside of the A-B relation". The motivational investment corresponds to the importance accorded by an agent A to a goal G for which another agent B has an influence (positive or negative). The availability of the goal, in the definition of Emerson, corresponds to the number of agents D different from B that also have a positive influence on the same goal G.

Our work differs from Castelfranchi's dependence theory [9] in the sense that our dependence is subjective: if the agent A does not believe that B can influence one of its goal, it will not be dependent. Another difference with this theory is that the agent B can, not only be helpful, but also threatening to one of A's goals. An agent B is said helpful if it can do an action that helps A to achieve its goal. On the contrary, an agent B is said threatening if it can do an action that prevents A to achieve its goal.

To model the dominance of an agent A towards an agent B, we first need to represent *A's dependence upon B*. For each goal of the agent A, we define two cases, represented by two neurons: B can be helpful or threatening. Then, considering a theory of mind, we represent A's beliefs about B's actions and their influence (which could be positive or negative) on A's goals. The more A considers its goals as important, the more A will be dependent upon B. We also introduce the number of potential helpers, inhibiting the dependence value. The second step is to model A's belief about B dependence. This can be done by modelling A's belief about B's goals and A's actions.

In his work, Emerson [8] defines the power of an agent A over an agent B as a potential influence depending on A's dependence upon B and B's dependence upon A. In our model, an agent A is dominant towards an agent B if A believes that B is more dependent towards A than A is towards B. Thus, the value of dominance is set as the difference between A's dependence towards B and A's belief about B dependence.

4 Conclusion

In this work, we introduced a cognitive model for artificial companions. The social relation between two agents is represented by two different dimensions: dominance and liking. Dominance can be defined by the degree of influence on the intentions of the agent's interlocutor. It also depends on the degree of dependence upon this same agent. The value of liking indicates the degree of like-mindedness between the two agents; an agent will like another agent if it believes that they share the same feelings (positive or negative) about particular concepts. We also introduced a neural network to model the dynamics of these dimensions. Agents may use different strategies to change their own mental state or try to influence other agent's relations.

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