Development of Virtual Agents with a Theory of Emotion Regulation*

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1 Introduction

Over the past years, there has been an increasing interest in the application of *intelligent virtual agents* in various domains. In order to endow such virtual agents with more realistic affective behavior, it is important to provide them not only the capability to generate and regulate emotions, but also the ability to reason about the emotion regulation processes of other agents. To this end, the full version of this paper introduces a computational model for a *Theory of Emotion Regulation* (ToER). The model integrates three main components, namely a BDI-model for rational reasoning, a model for emotion regulation that was inspired by Gross's psychological theory [3], and a model for *Theory of Mind* (or ToM, see, e.g., [1]). The combination of these components enables an agent to reason about the emotional states of other agents, adapt beliefs about these states, and influence them if desired.

2 Conceptual Model

The foundation of the presented model for ToER is a standard BDI-model, which describes how an agent determines actions to be performed on the basis of beliefs, desires, and intentions. Next, this model is extended by introducing a component for emotions, thereby creating a so-called EBDI-model. Within this component, the *emotional response level* (ERL) that an agent experiences for a particular emotion is modeled by a real number in the interval [0, 2]. This ERL may be influenced by the observation of certain *events* in the environment (i.e., emotion elicitation). Each event has a number of attributes (represented by a number between 0 and 1) that determine to what extent they influence a certain emotion. In addition, for each agent a *baseline ERL* is assumed. This is a specific ERL that an agent (either consciously or unconsciously) tries to achieve, for a certain emotion. This process of striving to achieve a certain emotion (i.e., emotion regulation) is modeled by introducing a parameter β for *regulation speed*.

An overview of the complete EBDI-model is shown in Figure 1, where circles denote state properties and arrows denote dynamic relationships between them. The idea is that this model integrates the emotional component with the rational (BDI) component as follows. An agent usually reasons rationally, according to the BDI-model (lower part). Meanwhile, at any time point, it has a certain ERL, which is influenced by observations of events, and by its own emotion regulation processes, based on its baseline ERL (upper part). As long as the ERL stays within certain boundaries min and max, it only has a marginal impact on the agent's actions. It does influence its reasoning process (by influencing the desires the agent has, see the downward arrow), but the agent keeps on reasoning rationally. However, whenever the ERL becomes lower than min or higher than max, the reasoning process is bypassed, and the agent acts emotionally.

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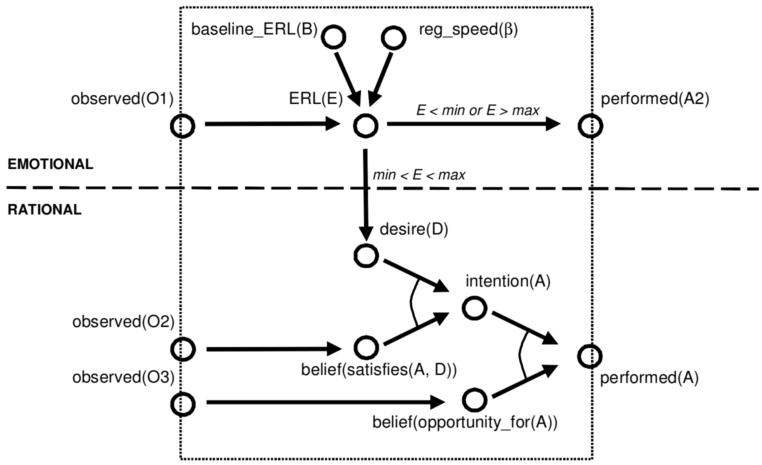

Figure 1. Generic structure of the EBDI-model

To make this EBDI-model the subject of another agent's theory of mind (thereby creating the complete ToER-model), the idea of *recursive modeling* is used. This means that the beliefs that agents have about each other are represented in a nested manner. For example, belief(agentA, ERL(agentB, 0.5)) states that agent A believes that agent B has an ERL of 0.5. By also allowing agents to have beliefs about dynamic relationships, they become able to reason about the dynamics of each other's emotional states. For example, if A believes that B has a medium emotional state, and A observes that B experiences a very emotional event, then A will believe that B's emotional state will increase. In addition, the agents also have the ability to update their ToER based on new observations, thereby learning aspects of each other's personality.

3 Validation and Conclusion

The presented model has been implemented and tested using the modeling language LEADSTO [2]. A number of simulations under various parameter settings have been performed on the basis of this model, which pointed out that it produced the expected behavior. Next, a virtual environment application has been developed in which several virtual agents with the model for ToER were incorporated. A test scenario has been set up in which 2 agents were involved: a *traveler* that has to travel through an imaginary world inhabited by dangerous creates towards a safe destination, and a *guide* that helps the traveler to navigate through the world by showing him the way. To evaluate the experience that the application produces in human users, 20 participants were asked to judge the behavior of the IVAs, by answering questions like "do you feel attached to the guide?" and "do you think the capability to estimate emotions makes the guide more realistic?". The initial results of this evaluation were very promising: the participants confirmed that the guide's capability to estimate and manipulate the affective behavior of the traveler was very believable, and indicated that it enhanced the perception of human-likeness.

References

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[3] Gross, J.J. (1998). The Emerging Field of Emotion Regulation: An Integrative Review. *Review of General Psychology 2*, no. 3, pp. 271-299.