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COLLABORATIVE HUMAN-LIKE MULTI AGENT SYSTEMS: AN OVERVIEW

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ABSTRACT

Currently affective intelligent systems have been researched for various purposes such as development of human-like societies, team training environments with simulated teammates and believable virtual environments. However, the affective multi-agent systems could be used in different, more advanced scenarios such as simulating emotionally intelligent community. For this reason advanced interaction mechanisms and affective agent architectures are needed. The paper reviews current state of the art in affective multi-agent systems by focusing on two issues: architecture for agents implemented in multi-agent system and interaction mechanisms among affective intelligent units.

KEYWORDS

Affective multi-agent systems, affective computing, collaboration, emotion modeling, emotional intelligence

1. INTRODUCTION

The research on human-like reasoning and behavior mechanisms has been a trend in artificial intelligence for several years. There are various purposes for which affects are used: simulating human-like behavior (Dey and Roberts, 2007), affective computing for better performance (Kazemifard, 2012), believable and emphatic human-computer interface (Guinn, 2014).

The current problem is that there are tasks, for example, on the Internet or other complex systems that are boring or time-consuming however require accuracy from the user. One possible solution for this problem is to develop an approach enabling users to delegate their tasks to agents. However, the way a particular person performs task differs from other people not only in terms of execution quality but also in terms of viewpoint and personal attitudes. For that reason it should be possible to add different personalities to particular agents. Moreover, by communicating with similar agents, higher efficiency of performing tasks could be achieved.

To implement agents with personality, social affective agents can be used. As a result the question arises on how to organize communication of affective agents in emotionally intelligent manner. Emotional intelligence is ability to recognize others' emotions, be aware of one's emotions and to be able to cope with them as well as to be able to employ these emotions for better results (Goleman, 1995). To achieve society of emotionally intelligent agents, affective multi-agent systems must be used and extended with well-defined interactions among agents.

As stated by Wooldrige (2009), there are two key problems to solve in multi-agent system development. The first problem is architecture of agents that are part of a multi-agent system. The second one is interaction among intelligent units. In case of emotionally intelligent society none of these questions is trivial as agents should not only implement emotions in the reasoning mechanism but also consider other members' feelings for better understanding of their peers and more effective communications.

The purpose of the paper is to analyze existing approaches and define gaps in current affective multi-agent system state of the art. To enable development of emotionally intelligent multi-agent systems, they should be viewed from the perspective of individual intelligent agents, as well as from the perspective of interactions among such agents.

The paper is organized as follows. Existing affective agent architectures and deployed emotional computing models are described in the second section. The collaboration mechanisms among these units are reviewed in the third section. The last section provides conclusions and future work.

2. AFFECTIVE AGENT ARCHITECTURES

Currently there are many emotion computation models (ECM) for various domains and purposes. These models differ in terms of psychological theories used (Marsella et al., 2014) and are integrated in various architectures. The existing ECMs and affective agent architectures from point of view of reasoning and output are directed towards two main goals: believable human-computer interaction (e.g. (Sun et al., 2013) which focus on developing emotional virtual tutor) and development of human-like reasoning for various purposes (e.g. Emile (Gratch, 2000) – affective architecture which helps analyzing how stress and emotions impact reasoning) (Marsella, 2014).

There are models that implement single-agent system whose further implementation in multi-agent systems is not discussed. One of such examples is FLAME model (El-Nasr et.al., 1998), which applies fuzzy rules to emotion calculation for affective reasoning. As the paper is focused on building affective multi-agent systems, it will analyze affective models that are either used for multi-agent systems implementation or at least with a discussed potential of doing so.

Before starting to describe various ECMs there should be paid some attention to the most common psychological models used in ECMs. In (Marsella, 2014) the underlying emotional theories in artificial intelligence are divided into several groups. The most used theories are appraisal theories and dimensional theories. The first kind of theories views emotions as appraisal of the current state and internal or external conditions of the agent versus desired state. The appraisal theory suggests that all emotions have triggers. Dimension theories, on the other hand, argue that decisions are made based on so-called core affect which is a stable, innate state that is only influenced by emotions.

The most popular model from the group of appraisal theories is OCC model, introduced by Orthony, Clore and Collins (Orthony et al., 1988). OCC model groups emotions into three categories: the emotions elicited by objects; the emotions elicited by events and emotions, elicited by other agents. The popularity of the model is explainable with the relatively simple formalization and linkage to the traditional BDI architecture.

One of the most popular models of dimension theory is the PAD model (Mehrabian and Russel, 1974) that describes affect as a point between three values: pleasure, arousal, dominance. Finally, the dimension theories also contain personality models, such as widely used BigFive, also known as OCEAN. It describes five dimensions of personality: openness, conscientiousness, extraversion, agreeableness, and neuroticism (Digman, 1990).

Several ECMs use either one of these models, or their modifications, i.e., the architecture proposed by Korecko et al. (2014) uses OCCr model, which is hierarchical, formalized OCC model. However, majority of models use combination of these theories. For example, ALMA, multi-layered framework for enhancing virtual characters with emotional ability, maps and uses all three of abovementioned models in its multiple layers (Gebhard, 2005). ALMA has three layers which all reflect various levels of affect: emotion layer, mood layer and personality layer. Emotions are considered as short term affects which are directed towards some event, action or agent. Mood lasts longer than emotions and influences decisions and behavior. Personality layer does not change over time and describes basic mental characteristics of an agent. Emotion layer uses EmotionEngine which in turn uses combination of OCC model and BigFive model. The latter allows implementing personality layer. The EmotionEngine also includes modeling decay and intensity of emotions (Gebhard, 2003). The EmotionEngine is then enhanced with PAD model which is used as a tool for mood modeling (Gebhard, 2005). Although the framework itself is created to make agents more believable to user, ALMA has been connected with multi-agent systems development platform APL2 (Floor, 2012). Similarly, the PECS model at the beginning was created as a single-agent solution (Urban, 2001) but in (Schmidt, 2002) its inclusion in multi-agent systems was discussed. PECS is domain independent reference model for connecting four human behaviour drivers, namely physical conditions, emotional state, cognitive capabilities and social status (Urban, 2001). PECS agent has been implemented as a single agent “Adam”. PECS model is based on the definition of emotional intelligence. Emotional intelligence is ability to assess, understand, identify and manage emotions (Goleman, 1995). The components of PECS are created based on this definition.

The three level architecture is also a layered architecture used for agent-based simulation. It consists of reactive, routine and reflective level (Kazemifard, 2012). Firstly, the underlying ECM was GeMA – a generic model for computing emotions (Kazemifard, 2010), however to individualise agents and create variable society, in (Tavakoli, 2014) the personality, based on BigFive model, was added. The architecture was implemented in predator-prey environment.

The architecture in (Korecko et al., 2014) maps BDI concepts onto concepts of OCCr emotion model. The emotion itself is calculated on the basis of eliciting conditions and basic information obtained from OCCr model, and intensity of emotion. The decay of emotions is also taken into consideration. (Korecko and Herich, 2013). Similar architecture is O3A (Alfonso, 2015) which also exploits BDI architecture. In the (Daviet et al., 2005) authors create EFT model, based on emotion, feeling and temperament – levels which correspond to those of ALMA and three level architecture of Kazemifard. The model also employs OCC model and is implemented in BDI architecture.

In (Nedelec, 2005) the emotions are modelled in Fuzzy Cognitive Maps (FCM), again using OCC as a psychological model. By combining FCM and OCC, Fuzzy Emotion Maps are created which are used to model and implement virtual characters' emotions.

As can be seen from this overview, many models are quite detailed; most of them include more than one affect. Some models contain components which could be used for deeper understanding and more complex modeling of emotions, i.e., social component in PECS. For some models there is a possibility to add more rules or internal states, for example, in the form of Fuzzy Emotional Maps. The next chapter views how social interaction among affective agents is implemented.

3. AFFECTIVE AGENT INTERACTION SOLUTIONS

There have been several implementations of affective multi-agent systems which from the point of view of interaction can be generally divided into two groups, namely multi-agent systems that allow passing emotions and multi-agent systems that enable agents to experience emotions towards messages however do not pass emotions themselves. For example, in PECS-based multi-agent systems, discussed in (Schmidt, 2002), to implement interactions among agents in agents' world model the connector element is used. However this element is specifiable by a user, i.e. there are no guidelines for implementation of any communication mechanisms. The agent model still contains social status component which stores attributes that display agent's sociality (e.g., social status, social needs, etc.) (Urban, 2001) which is promising from the perspective of creating emotionally intelligent interactions among agents. Similarly, in the work done by Tavakoli (2014), agents, depending on the personality, have social parameters which cause them to interact with other agents. In the simulations the upbringing effect of social interactions was undeniable. However, there are no details on protocols used for agent communication implying that standard communication mechanisms are used.

The latest work in affective MAS area is done by Korecko et al. (2014a). It implements emotional agents as non-playable characters in a virtual reality. The emotional agents in this case simulate potential victims in a building under fire. The purpose of the system is to educate and train students who might be involved in rescue. In (Korecko et al., 2014b) the emotional engine JBdiEmo is implemented. The engine is based on Jadex – agent-oriented reasoning software platform for BDI agents (Korecko et al., 2014b). The inter-agent messaging is used to model emotions that are experienced towards other agents. In this messaging system, the messages are sent when event that can trigger emotions occurs. However, the interactions are defined as simple rules and messages which contain specific attributes and names, and other agents perceive received emotions as true. Floor (2012) has developed ALMA mapping onto APL2. This implementation, same as O3A architecture (Alfonso, 2015), uses messages for emotion elicitation meaning that emotions are directed towards incoming messages. There are no emotions directed towards other agents (e.g., towards their behavior).

As human interactions differ, depending on mental state, there should be possibility to model wide variety of these interactions. This option is available in multi-agent system developed by (Nedelec, 2005). The mechanism for implementing such uncertainty is social interaction matrices which are created from static and dynamic affects of an agent. The agent can find out another agents mental state by exploring social interaction matrix. In (Daviet, 2005) the conceptual solution is offered - agent emotions are given via messages which receiving agent can interpret as either being good or bad.

In several models there has been discussed complex plan or decision making among affective agents, as well as emotion contagion in a group (Saunier and Jones, 2014). In this paper these approaches are not discussed as the goal is to consider social and emotional interaction among several agents for better understanding, not to model decision process of a crowd.

4. CONCLUSION

The paper overviews the existing affective agent architectures and interactions among such agents with the aim of defining gaps for development of emotionally intelligent multi-agent system. There are many advanced ECMs that are based on numerous psychological theories; there are many affective agent architectures that in turn are based on these ECMs and consider various affects, including mood, personality, emotions, etc. Some of personality models, for example, three level architecture of Kazemifard, are usable for intelligent units that represent users as they provide wide spectrum of possible variations.

However, to achieve better results and enable agents to form alliances that can be used for increasing efficiency, as well as to model competitive and social human-like agents, the detailed interaction mechanisms among emotional units are needed as the systems which contain specific social simulations can be better in simulation of human beings.

These mechanisms should enable two main options.

1. Communication of tacit, i.e., inexplicable emotions of an agent in order for other agents to see agent's personality without directly communicating. Although some of existing models, e.g., Korecko's et al. model, allows experiencing emotions towards actions of other agents, there are no models that allow experiencing emotions towards other agent's emotions.
2. Reasoning on other agents' emotions in order to elaborate on higher level. To implement various emotions of various complexities, there should be several levels of interaction meaning that direct interpretations should be separated from more advanced emotions. Direct interpretation of emotions has been implemented in various OCC-based models. The simplest example of such first-level interaction is seeing and evaluating agent's behavior, and deciding on what to feel towards the agent. However, human beings often understand that the behavior of another human being might not be enough to evaluate their performance. Such higher-level interactions (e.g., *I think that he/she feels*) lead to more complex behavior and emotional mechanisms.

Such high social understanding of agents might lead to personal, competitive agents who would be able to negotiate and understand each other in a better way. Currently there are no special mechanisms which would allow implementing complex and more importantly various emotion detection in a multi-agent system. Such mechanisms are needed to enable development of emotionally intelligent multi-agent system.

Future work in this area includes research on formalization methods that would allow to model and represent multiple levels of emotions in agent interactions as currently this field lacks of such interaction mechanisms. Also, the general multi-level architectures should be researched to conclude how and if multi-level interactions are implemented.

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