Modeling Emotions in Multi-Agent Systems based on Petri-Net Modeling Technique

Julia Fix[1], Daniel Moldt[1], Christian von Scheve[2]

[1] University of Hamburg
Department for Informatics
[2] University of Hamburg
Department for Sociology

Abstract. Starting from the hypothesis that emotions can be an important factor in the design of (multi-)agent systems we follow two directions within our research: First we focus on theoretical foundations of emotional phenomena; second, we aim to build a conceptual framework for modeling emotion in context of multi-agent systems. In this paper we discuss the use of Petri net formalisms for representing different aspects of emotions in a multi-agent system. Futhermore we propose the adoption of the Socionics modeling approach, initially specified in [2003b], for modeling theories of emotion.

1 Introduction

The increasing interest to investigation of emotional phenomena in the classical emotion research domains like psychology, neurology and cognitive science leads to new insights regarding the influence of emotional mechanisms on individual behaviour, on the social interaction, on the development of normative structures in the society etc. These new ideas are being adopted, investigated and applied in classical computer science research fields, like Human-Computer Interaction (HCI), Artificial Intelligence (AI) and Distributed Artificial Intelligence (DAI).

Today the research field of Affective Science ([2003a]) is divided into numerous theories, concepts and models and it still lacks an integrated computational theory of emotion in view of their large-scale causes and effects, both for the individual agent and the multi-agent society. Yet the special needs of emotion implementation in a multi-agent system require an appropriate theoretical underpinning for either psychological aspects of emotion, e.g. for the representative model of emotion appraisal, or sociological aspects, e.g. social determinants of emotions and their implications for the social structure ([2005b], [2005a]).

For an appropriate modeling of emotion in distributed artificial systems we need an integrated theorie of emotion which combines psychological, sociological, neurological and cognitive approaches to emotion. In this matter, a special aim of our research is the development of an appropriate technique for modeling emotional concepts and theories. By means of this general technique we seek to facilitate the integration of different theoretical perspectives on emotion in a unique model, describing different aspects of emotional phenomena

and processes. Moreover, allowing representation of emotional theories with an original informatical modeling technique, we facilitate their integration into any computer applications and especially provide a possibility to combine different theoretical approaches and models of emotion in a single multi-agent system.

In this paper we propose the adoptation of the Socionics modeling approach to transform the theories of emotion into a formal informatical representations on the basis of reference nets modeling formalisms, which is an extension to a Petri-net modeling technique. The Socionics approach was initially specified and evaluated in [2003b] for sociological theories. The applied modeling formalisms suports direct integration of the resulting models into an executable multi-agent architecture MULAN, which is also implemented with reference nets, and thus enables simulation and evaluation of the modeled theories.

After short introduction to Petri nets/ reference nets modeling formalisms in the next section we discuss the use of application of Socionics modeling approach to model theories of emotion.

2 Modeling Emotional Agent Systems with Petri-nets

We seek to accomplish the integration of cognitive science and social science approaches to emotion using a general modeling technique that allows building a unique integrative model of emotion that (a) is usable in an MAS context and (b) provides general theoretical underpinnings for an implementation of emotion in (distributed) artificial systems. A practical evaluation of Petri net formalisms has revealed its important advantages for modeling different sociological theories ([2003b]). Basing upon these results, we propose application of Petri Net / Reference Net modelling technique for modeling emotion-based processes and concepts in multi-agent systems.

Unlike other automata formalisms Petri nets allow for direct modeling of concurrency (i.e. independent events and processes). High-level Petri nets permit the representation of recursive structures and emergent processes and are able to inherently express structural as well as process concepts at the same time. Due to its operational semantics and the broad range of available analytical methods, modeling with Petri nets allows an evaluation and formal checking of semantics of the models. Well established extensions of the basic formalism and sophisticated tool sets for most of these extensions exist. E.g., reference nets ([1998]) enable the execution of arbitrarily complex Java programmes through the use of synchronous channels ([1992]). Together with these extensions, Petri nets provide a powerful instrumentarium for modelling dynamic, hierarchical and recursive structures, as described by psychological, neurological and social theories of emotion. In addition, the formal representation of emotion models facilitates their integration into the computational domain. Further details on reference nets modeling are omitted here, but can be found in either [2003b] or [2004]). An efficient editing and simulating tool called RENEW (Reference Net Workshop, [2005c]) provides a powerful support for designing and evaluating of petri net / reference net models.

3 Applying Socionics Modelling Approach for Modeling Theories of Emotion

To provide an appropriate theoretical underpinning for emotion modeling in (distributed) artificial systems, we aim at constructing a coherent conceptual framework for integrating psychological and social science perspectives on emotion. The formal model, on which the representation bases, is the recursive formalism of reference nets, as described in the previous subsection. With the help of this formalisms first of all a compact implementation of the multi-agent architecture MULAN is designed ([2004c]). Secondly it serves as a description language for the considered theories of emotion ([2003b]).

Proceeding in accordance with the general methodic and praxis of socionic modeling approach we aim to model psychological, sociological and neurological theories of emotion. Such modeling delivers an implementation of the central aspects of a theorie as a set of Petri nets, which can be integrated as a programming unit in an executable multi-agent system MULAN. Furthermore, this kind of modeling facilitates direct comparison of the theoretical statements, which take their origin in various theoretical approaches, through analysis of the corresponding Petri net models. A combination of several Petri net models delivers an integrated representation of certain aspects of emotionality, in which statements from different theories of emotion can be unified in a more general model.

In the first modeling step the textual representation of a theorie is translated into a set of net models, which specify the central elements of the theorie and their causal relationships. By means of detailed analysis of the resulting nets one would try to recognize the intrinsic model structure, which is constituted through the interaction of the model elements and which reflects the dynamics of their interaction.

The analysis of the Petri-net representations of processes and structures treated by a theorie of emotion often delivers (mutual) references or causalities between modeled elements, which cannot be directly derived from the original textual description. Thus we can obtain a more abstract representation of structural correlations (e.g. through falting the respective Petri net models) or can combine some seemingly discontiguous parts of the modeled theorie to a more general model (by means of combinig the corresponding nets). Besides these internal references within the scope of one theorie of emotion it is also possible to make up external references on some other theories of emotions, as the Petri net modeling facilitates the comparison of the fundamental intrinsic structures and processes specified in the theories and allows to identify structural analogies.

Since any informatical modeling technique demands precise specification of the modeled subject, it is easier to reveal the underspecified points or inconsistencies of a theoretical approach when converting it into a set of Petri net models. On the one hand these inconsistencies can be revealed by means of static analysis of model structures. On the other hand and particularly however it is done in the course of model simulation, which can even desclose some implicit propositions that were not expatiated in the original textual representation of the modeled theorie.

4 Discussion

In what follows, we will very briefly evaluate the modeling approach presented above and the perspectives it holds in view of modeling the functionality of natural emotional mechanisms in (multi-) agent systems. Nearly all computer science models of emotion share the fact that they are based either on psychological or on neurobiological theories of emotion, ignoring the fundamental social components of emotion and their significant influence of the social phenomena, which get especially relevant in distributed systems. However, a sociological consideration of emotions can open new and promising perspectives for computer science (cf. [2005a], [2005b]). In view of emotional agents being applied to distributed or multi-agent systems, we suppose that the foundational functional components of emotion in (artificial and/or hybrid) social aggregates have to be taken into account.Generally speaking, modeling the social functions of emotion is supposed to improve multi-agent systems, for example in view of alternative coordination solutions and robust structuration processes. However, strong evidence has yet to be presented that AI-models of emotion do indeed facilitate better solutions in this respect.

Using a reference net modeling technique we access the possibility to simultaneously represent interdisciplinary approaches and specifications of emotion within a hybrid reference-net based framework and to simulate the resulting Petri-net models. The openness and flexibility of this approach foster an analysis of different theories (of different disciplinary origin) and computational models of emotion using the same modeling technique within the proposed framework.

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