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Stefan Rank

Building a computational model of emotion based on parallel processes and resource management

• Freyung 6/6 • A-1010 Vienna • Austria •
• Phone: +43-1-5336112 •
• mailto:sec@ofai.at •
• http://www.ofai.at/ •

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Building a computational model of emotion based on parallel processes and resource management

Stefan Rank

Austrian Research Institute for Artificial Intelligence (OFAI)
Freyung 6/6, A-1010 Vienna, Austria
stefan.rank@ofai.at

Abstract. Dramatic story-worlds require software agents with emotional competences. I propose as building blocks for a computational model of emotion explicitly bounded resources and concurrently active processes acquiring and using the resources. A set of objectives for the implementation of such a model is presented based on limitations identified in earlier approaches towards the same goal. The proposed method for achieving these objectives involves incremental modelling of a growing collection of emotional episodes, with a clear delineation of technically necessary simplifications.

Key words: affective agent architectures, computational modelling, embodiment, design criteria

1 Introduction

Story-worlds are virtual worlds inhabited by synthetic characters that provide an environment in which users actively participate in the creation of a narrative. Several projects that include simulated worlds target the area of interactive narratives ranging from plot-driven to character-based approaches [13,15,5,12,11].

Character-based approaches require synthetic agents with autonomy and personality. Affective agent architectures [31,10] are used to construct these autonomous personality agents, and computational models of emotion are seen as a prerequisite for the required emotional and social competences.

For my work, I propose a computational model of emotion based on the management of parallel processes and the resources they access. Although the target domain is a virtual world, resources are intended for "physically" anchoring the agent in the world. The construction of an affective architecture then poses the question of what configurations of processes and resources are relevant for emotional phenomena prominent in stories (from social emotion episodes such as anger, shame, and gratitude to individual dispositions) and how are they coordinated.

The proposed approach is based on experience gained in creating synthetic actors [20,21]. The following section presents details on the limitations of earlier approaches and the objectives that result from addressing them. I propose to rethink the building blocks of affective agent architectures to provide for a reasonably complete and integrated agent architecture [30,3] while delineating shortcuts in modelling necessary for technical reasons or reasons rooted in the targeted scenario.

2 Objectives

In earlier work [20,21], I constructed agents to be used in story generation based on a BDI model by integrating an appraisal process and static reified emotion types as described in the OCC-model [17]. This approach can be successful for a given target scenario, i.e. if the details of the interaction between agents and their environment are suitably restricted. Compared to the richness of emotional life in humans, however, and also considering the possibilities of human-computer interaction in recent virtual worlds, several limitations became apparent.

– *Symbolic sensing and acting*: The simulation of sensing and acting in a virtual world by exchanging pre-structured symbolic information does not match the intricate relation between perception and appraisal in real life. The disambiguation, structuring, and valuation of information acquired in sensorimotor interaction is an integral part of appraisal.
– *Reified emotions*: The use of a small set of distinct emotion types as a mechanism rather than a means of analysis/reflection circumvents the need for a process-based implementation of finer granularity [19]. *But* emotions are events over time, vary over time, and include constituent processes at different time scales [7]. However, abandoning the use of reified emotions entails the issue of what alternative approach to adopt to define the specific emotional phenomena to be reproduced and evaluated. A possible solution may be to focus on the framing of independent appraisals as they occur inside the architecture or to defer to the recognition of expressive behaviour and coping behaviour (as in human-human interaction).
– *Rigid behaviour structures*: Classical BDI architectures use planners that are based on activity sequences of relatively coarse granularity. This often leads to easily recognisable repetitiveness. The proposal to use parallel processes that are by default independent is directly motivated by the need to overcome this limitation. Such a collection of processes however then needs flexible coordination mechanisms, regulatory components, and means to actively direct and focus attention (internally and externally). An agent that is situated in a world often exploits the structure of the world itself to limit the complexity of these coordination tasks. The embedding of the agent in its environment forms the agent's lifeworld [1].

These identified limitations led to adopting the following objectives and goals for the design of a revised agent architecture and matching target scenarios.

– *Sensing and acting over time*: In a virtual world, the designer can choose any mechanism for the implementation of sensorimotor interaction with the environment. To allow for the inherently temporal nature of emotional phenomena, a suitable mechanisms needs to be chosen. This is needed to introduce dynamicity that overcomes limitations rooted in the shortcuts often taken by symbolic approaches.

- *Embodiment for virtual worlds*: More generally the simulation of the virtual world needs to take issues of embodied grounding into account [6,2]. Direct consequences are the consideration of boundedness and tractability of the agent architecture. The (bodily) resources available to an agent are necessarily bounded. This includes the processing capacity leading to the necessity of tractable mechanisms. Further, the agent is "physically" located in a world and thus needs to obey the laws of this world. It can also exploit the structure this embedding provides in the form of its lifeworld.
- *Multimodality*: To ensure a virtual counterpart to sensing and acting that at least approaches the breadth of human activity, I target a scenario that involves four different modalities: seeing, hearing, smelling, and basic forms of physical movement and manipulation. The complexity of these modalities (and other objectives such as real-time interaction) limits the extent to which they can be simulated. Therefore it is necessary to simplify the mechanisms using for example false-colour rendering or simple spheres of influence to model vision and hearing respectively. The consideration of multiple independent modalities shall ensure a suitable balance between detail of simulation and broad coverage of agent-environment interaction.
- *Human-computer interaction*: Synthetic characters are intended for interaction with humans in real-time. Targeting interaction with humans from the start constrains the allowed pace of the model: timely interaction is neither too slow nor too fast.
- *Social setting*: A social setting, interaction between two (or more) agents and a human user, is fundamental in order not to lose core aspects of emotion from sight [18]. Many emotional phenomena can only occur in social settings.
- *Status of situational meaning structures*: 'Situational meaning structures' [7] (or appraisal frames) are hypothetical constructs that aggregate information of individual appraisal checks (or 'stimulus evaluation checks' [26]). When process-based models of emotion are implemented, a decision needs to be made on how, when, and whether to aggregate individual implemented appraisal checks into such a larger structure [24]. Pre-existing and static appraisal frames (such as reified emotion types) result in simple linear dynamics. To overcome this limitation, coordination mechanisms are needed, but it is an open research question whether the effects of independent appraisal checks are by themselves sufficient. The observed behaviour that is usually explained by situational meaning structures should be an emergent effect of such coordination (and any other) mechanisms.
- *Parsimonity*: From the perspective of designing an emotionally competent agent, it is preferable to employ a parsimonious model that is readily understandable. However, this desire might contradict the objective of grasping the complexity of emotional phenomena.

On a more general level, this research approaches the question of when emotional mechanisms are warranted in artificial agents. For which constellations of environment and agents are mechanisms modelled after human emotion useful or necessary? What emotions can even occur in the limited virtual environments that synthetic characters inhabit?

3 Method

I propose resources and concurrent processes as building blocks for the implementation of a revised model of emotional phenomena.

A *process* models one concurrent strand of activity in the agent. It can be active, i.e. allocated a "processing time" resource, or dormant. A change to the dormant state is triggered by waiting: for a specific resource; for communication from another process; or for the notification of a change in an observed process. A process can request control of resources. A process can start or stop another process, and transfer its processing time and other resources to it. Similarly, a (meta-level) process can act as a scheduler for other processes. Processes can observe and inspect the status of other processes, their communication patterns, their resource use, and request to be notified of changes in the preceding.

A *resource* is an abstraction for the limited control an agent has over the part of the world that constitutes it. Processing time is an abstract resource that limits the number and the speed of concurrently running processes. In the context of a simulation on a serial computer, this translates to how frequently and then for how long a process is allowed to run. Communication channels are a specific form of resource that allow direct communication between processes. Further, communication can be used as a means for synchronisation to model interdependencies between processes. Resources at the boundary to the agent's environment group sensors and actuators, reflecting the fact that the agent is always interacting with the environment rather than only receiving or sending [4].

Explicit time management needs to be introduced to ensure that interaction between subsystems (virtual environment and agent models) is scheduled in a fair and predictable fashion.

This methodology poses a significant challenge: a sufficiently complete and valid infrastructure is needed in which elements relevant for emotion are present and functional. Rather than creating one general model, I aim to incrementally model a growing collection of specific emotional phenomena. This approach allows to reduce the effort involved in creating such an infrastructure by allowing shortcuts to be introduced. One reason for the selection of the objectives introduced above is that these shortcuts, and the shortcuts that any implementation of a virtual world needs to take compared to real-world interaction, will be made explicit. Focusing on one specific phenomenon at a time also helps to avoid introducing unwarranted postulates needed in models claiming generality: e.g., a set of a priori personality parameters and very general competences such as a global planning process. See [22] for a first attempt at modelling an episode of disgust.

However, for the development of a process-based model some structuring principles are helpful. Based on earlier work [23], I use an initial typology of processes (e.g., activities, behaviours, tasks, regulation processes, and action tendencies) and based on the component process model of emotion [26], I assume five principal domains of resources corresponding to the five organismic subsystems involved in emotion.

3.1 Related work

The APOC framework [27] is intended to provide a universal formalism for (primarily robotic) agent architectures, based on building blocks called components that are connected by communication links. In [29], Sloman argues again that what is generally called emotion needs to be defined more rigorously in terms of architectural components and offers his own H-CogAff architecture. Another high-level architectural account of the human mind very similar to H-CogAff has been proposed by Minsky [16]. EM-ONE [28] is an implementation by Push Singh based on Minsky's theory that focuses on common-sense thinking in a physical scenario with two agents. EMA [9] is a computational model of appraisal based on the Soar architecture that implements checks posited by appraisal theories based on a symbolic representation of the agent's interpretation of its relationship to the environment. In [14], the authors apply the model to a relatively fast-paced emotional episode (captured on video) to model the dynamics of the situation.

3.2 Evaluation

The evaluation of the proposed agent architecture poses a significant challenge. The underlying motivation for implementing this system is the creation of synthetic characters to be used in effective human-computer interaction. The design of the architecture relies on and uses psychological theories of emotion. Its implementation is a research endeavour in computer science.

Three different (though related) disciplines suggest three different evaluation criteria: usability in the case of HCI, a test framework modelled after controlled laboratory experiments for psychology, and tests of feasibility and performance for computer science. In the scope of this work, relatively simple performance measures defined on a specific target phenomenon seem to be the most suitable evaluation criterion. An example could be a higher level description of a possible interaction sequence that can be matched against the trace of actual runs of the system. This can be used to test that intended phenomena do emerge for specific starting conditions and user interactions.

4 Conclusion and Future Work

I have presented an incremental approach to modelling emotional episodes based on concurrent processes. The concept of a resource is used to explicitly model boundedness. These building blocks are motivated by the needs of modelling a physical system, by the characterisation of emotion by psychological theories, and by practical implementation concerns.

To limit the scope of the proposed work, I exclude considerations of the ontogenetic development of such an architecture and the correspondence with current knowledge about brain anatomy [8]. Another candidate aspect for future work is extending the coverage of "higher level" capabilities such as complex memory formation, planning, and deliberation.

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References

1. Agre P., Horswill I.: Lifeworld Analysis. Journal of Artificial Intelligence Research 6(1):111-145, 1997.
2. Anderson M.L.: Embodied Cognition: A Field Guide. Artificial Intelligence 149(1):91-130, 2003.
3. Barsalou L.W., Breazeal C., Smith L.B.: Cognition as coordinated non-cognition. *Cognitive Processing* 8(2):79-91, 2007.
4. Bickhard M.H.: *Motivation and Emotion: An Interactive Process Model.* Department of Philosophy, Lehigh University, Bethlehem PA USA, 1999. `http://www.lehigh.edu/~mhb0/motemotion.html` [2007-04-19]
5. Cavazza M., Charles F., Mead S.J.: Character-based interactive storytelling. *IEEE Intelligent Systems* 17(4):17–24, 2002.
6. Chrisley R., Ziemke T.: Embodiment. In Nadel L. (ed.): *Encyclopedia of Cognitive Science*, Nature Publishing Group/Macmillan, London, pp.1102-1108, 2003.
7. Frijda N.H.: *The Laws of Emotion.* Lawrence Erlbaum Associates, Mahwah NJ USA/London UK EU, 2007.
8. Granger R.: Engines of the Brain: The Computational Instruction Set of Human Cognition. In Cassimatis N., Müller E., Winston P. (eds.): *Achieving Human-Level Intelligence through Integrated Systems and Research, AI Magazine*, pp.15-32, 2006.
9. Gratch J., Marsella S.: A Domain-independent Framework for Modeling Emotion. *Cognitive Systems Research* 5(4):269-306, 2004.

10. Gratch J., Marsella S.: The Architectural Role of Emotion in Cognitive Systems. In Gray W.D. (ed.): *Integrated Models of Cognitive Systems*, Oxford University Press, New York, pp.230-242, 2007.
11. Louchart S., Aylett R.: The Emergent Narrative theoretical investigation. In Proc. of the International Conference on Narrative and Interactive Learning Environments NILE04, Edinburgh UK EU, pp.25-33, 2004.
12. Loyall A.B., Reilly W.S.N., Bates J., Weyhrauch P.: System for Authoring Highly Interactive, Personality-Rich Interactive Characters. In Boulic R., Pai D.K. (eds.): Proc. of the 2004 ACM SIGGRAPH/Eurographics Symposium on Computer Animation, Grenoble France EU, ACM Press, New York NY USA, pp.59–68, 2004.
13. Magerko B., Laird J., Assanie M., Kerfoot A., Stokes D.: AI characters and directors for interactive computer games. In McGuinness D., Ferguson G. (eds.): *Proc. of the 19th National Conference on Artificial Intelligence*, July 25-29, 2004, San Jose CA USA, AAAI Press, Menlo Park CA, pp.877–883, 2004.
14. Marsella S., Gratch J.: EMA: A Computational Model of Appraisal Dynamics. In Gratch J., Marsella S., Petta P. (eds.): Agent Construction and Emotion: Modelling the Cognitive Antecedents and Consequences of Emotion. In Trappl R. (ed.): *Cybernetics and Systems 2006*, Austrian Society for Cybernetic Studies, Vienna Austria EU, pp.601-606, 2006.
15. Mateas M., Stern A.: Façade: Architecture and Authorial Idioms for Believable Agents in Interactive Drama. In Proc. of the 6th International Conference on Intelligent Virtual Agents (IVA'06), August 21-23, Marina del Rey CA USA, pp.446-448, 2006.
16. Minsky M.: *The Emotion Machine*: Commonsense Thinking, Artificial Intelligence, and the Future of the Human Mind. Simon & Schuster, New York, 2006.
17. Ortony A.: On Making Believable Emotional Agents Believable. In [31], pp.189-212, 2003.
18. Parkinson B.: Putting Appraisal in Context. In [25], pp.173-186, 2001.
19. Petta P.: The Role of Emotions in a Tractable Architecture for Situated Cognizers. In [31], pp.251-288, 2003.
20. Rank S.: *Affective Acting: An Appraisal-based Architecture for Agents as Actors*. Institute for Medical Cybernetics and Artificial Intelligence, Medical University Vienna, Master Thesis, 2004.
21. Rank S.: Toward Reusable Roleplayers Using an Appraisal-based Architecture. In Payr S. (ed.): *Educational Agents and (e-)Learning*, Applied Artificial Intelligence 19(3-4):313-340, 2005.
22. Rank S., Petta P.: Basing artificial emotion on process and resource management. In *Proc. of the second International Conference on Affective Computing and Intelligent Interaction* ACII2007, Lisbon Portugal EU, Sept. 12-14, 2007, to appear, 2007.
23. Rank S., Anjos P.L., Petta P., Aylett R.: What is In an Affective Architecture for Situated Agents? Cañamero L. (ed.): Humaine Deliverable D7a: WP7 Workshop Proceedings, King's College London UK EU, July 4-5, 2005.
24. Reisenzein R.: Appraisal processes conceptualized from a schema-theoretic perspective: Contributions to a process analysis of emotions. In [25], pp.187–201.
25. Scherer K.R., Schorr A., Johnstone T. (eds.): *Appraisal Processes in Emotion: Theory, Methods, Research.* Oxford University Press, Oxford/New York, 2001.
26. Scherer K.R.: What are emotions? And how can they be measured? *Social Science Information* 44(4):695-729, 2005.

27. Scheutz M., Andronache V.: The APOC Framework for the Comparison of Agent Architectures. In Jones R.M.(ed.): *Intelligent Agent Architectures: Combining the Strengths of Software Engineering and Cognitive Systems: Papers from the 2004 AAAI Workshop*, AAAI Press, Menlo Park CA USA, pp.66-73, 2004.
28. Singh P.: *EM-ONE: An Architecture for Reflective Commonsense Thinking*. Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, Cambridge MA USA, PhD Thesis, 2005.
29. Sloman A.: What Are Emotion Theories About? In Hudlicka E., Cañamero L. (eds.): *Architectures for Modeling Emotion: Cross-Disciplinary Foundations*, Papers from the 2004 AAAI Spring Symposium, March 22-24, 2004, AAAI Press, Menlo Park CA USA, Technical Report SS-04-02, pp.128-134, 2004.
30. Thorisson K.R.: Integrated A.I. systems. *Minds and Machines*, doi:10.1007/s11023-007-9055-5, Jan.16, 2007.
31. Trappl R., Petta P., Payr S. (eds.): *Emotions in Humans and Artifacts*. MIT Press, Cambridge MA USA/London UK EU, 2003.