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Engineering Computational Emotion—A Reference Model for Emotion in Artificial Systems

Springer

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Under the consent of my beloved David who has loved me and has supported all my hours of study. And the consent of my parents, my sister and my family, that has given me all their love trying to understand me…
...let me to dedicate this work to my beloved grandparents and grandmothers, who might be taking care of me from the sky.
I miss you.
To: Amalia, Agustin, Nati and Eloy

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I hope to continue my research with them.

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Great thanks to all

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Abstract

Emotion is generally argued to be an influence on the behavior of life systems, largely concerning flexibility and adaptivity. The way in which life systems act in response to particular situations of the environment has revealed the decisive and crucial importance of this feature in the success of behaviors. And this becomes a source of inspiration for artificial systems design.

During the last decades, artificial systems have undergone such an evolution that each day more are integrated in our daily life. The subsequent effects are related to an increased demand of systems that ensure resilience, robustness, availability, security, or safety among others. These attributes raise fundamental challenges in control and complex systems design.

This thesis has been developed under the framework of the Autonomous System project, a.k.a the *ASys Project*. Short-term objectives of immediate application focus on the design of improved systems, seeking more intelligence in control strategies. Besides this, long-term objectives underlying *ASys Project* concentrate on high-order capabilities such as cognition, awareness, and autonomy.

This work is placed within the general fields of*enginery* and*emotion science* and provides a theoretical foundation for engineering and designing computational emotion for artificial systems. The starting research question that has grounded this thesis aims at addressing the problem of emotion-based autonomy. And how to feedback systems with valuable meaning conforms the general objective. Both the starting question and the general objective have underlaid the study of emotion, the influence on systems behavior, the key foundations that justify this feature in life systems, how emotion is integrated within the normal operation, and how this entire problem of emotion can be explained in artificial systems. By assuming essential differences concerning structure, purpose, and operation between life and artificial systems, the essential motivation has been the exploration of what emotion solves in nature to afterward analyze analogies for man-made systems.

The approach provides a reference model in which a collection of entities, relationships, models, functions, and informational artifacts are all interacting to provide the system with non-explicit knowledge under the form of emotion-like relevances. This solution aims to provide a reference model as a framework to design solutions for emotional operation, but related to the real needs of artificial systems.

The proposal consists of a multi-purpose architecture that implements two broad modules in order to attend: (a) the range of processes related to the environment affectation, and (b) the range or processes related to the emotion perception-like and the higher levels of reasoning. This has required an intense and critical analysis beyond the state of the art around the most relevant theories of emotion and technical systems, in order to obtain the required support for those foundations that sustain each model.

The problem has been interpreted and is described on the basis of *AGSys*, an agent assumed with the minimum rationality as to provide the capability to perform emotional assessment. *AGSys* is a conceptualization of a *model-based cognitive agent* that embodies an inner agent *ESys*, the responsibility for performing the emotional operation inside of *ASys*.

The solution consists of multiple computational modules working federated and aimed at conforming a mutual feedback loop between *AGSys* and *ESys*. Throughout this solution, the environment and the effects that might have an influence on the system are described as different problems. While *AGSys* operates as a common system within the external environment, *ESys* is designed to operate within an*inner environment* built on the basis of those relevances that might occur inside of *AGSys*. This allows for a high-quality separated reasoning concerning mission goals defined in *AGSys* and emotional goals defined in *ESys*. This way, a possible path for high-level reasoning under the influence of goals congruence is provided.

The high-level reasoning model uses knowledge about emotional goals stability, hence allowing for new directions in which mission goals might be assessed according to the situational state of this stability. This high-level reasoning is grounded by the work of *MEP*, a model of emotion perception that is conceived as an analogy of a well-known theory in emotion science. The work of this model is described under the operation of a recursive-like process denoted *R-Loop*, together with a system of emotional goals that are assumed to be individual agents. This way, *AGSys* integrates knowledge about the relation between a perceived object and the effect which this perception induces on the situational state of the emotional goals. This knowledge might afford a new system of information that might provide the sustainability for a high-level reasoning. The extent to which this reasoning might be approached is just delineated and assumed as future work.

This thesis has been studied from a wide variety of fields of knowledge. These knowledge categories can be classified into two main area groups: (a) the fields of psychology, cognitive science, neurology, and biological sciences in order to obtain understanding concerning the problem of the emotional phenomena, and (b) a large amount of computer science branches such as autonomic computing (AC), self-adaptive software, self-X systems, model-integrated computing (MIC), or the paradigm of Model Driven Engineering among others, in order to obtain knowledge about tools for designing each part of the solution.

The final approach has been mainly performed on the basis of the entire acquired knowledge and described within the fields of artificial intelligence, Model-Based Systems (MBS), and additional mathematical formalizations to provide punctual understanding in those cases that have required it. This approach describes a reference model to feedback systems with valuable meaning, allowing for reasoning with regard to (a) the relationship between the environment and the relevance of the effects on the system, and (b) dynamical evaluations concerning the inner situational state of the system as a result of those effects.