Cathexis: A Computational Model of Emotions

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Abstract

A computational model of emotions is presented, which addresses a number of issues and limitations of models proposed to date including the need for time-dependent models of basic as well as compound and mixed emotions, the need to consider both cognitive and noncognitive elicitors of emotion, the need for differentiating emotions from other affective phenomena such as moods, and most important, the need for a flexible way of modeling the influence and effects of emotions on the motivations and behavior of the agents. The computational model is described, and its current implementation in an architecture to develop emotional synthetic agents is briefly discussed.

1. Introduction

Emotions are a fundamental part of our lives, they influence the way we behave, and how we communicate with others, yet when we look at current research in Artificial Intelligence we see that not too much work is being done on emotions.

Recent developments in the area of synthetic agents, such as (Maes 1995; Blumberg 1994; Bates 1994; Elliot 1992), have promoted the study of emotions and their influences in behavior. Nevertheless, up to date, relatively few computational models of emotion have been proposed. For a comprehensive review of some of these models see (Pfeifer 1988).

This paper describes a computational model of emotions which addresses a number of issues and limitations of models proposed to date including the need for time-dependent models of the so-called basic emotions, the need for models of compound, mixed emotions and moods, the need to consider different systems for emotion activation, and the need for a flexible way of modeling the influences of emotion on the motivations and behavior of agents.

2. Overview of the Model

We have developed a distributed model for the generation of emotions and their influence in the behavior of autonomous agents. The model is called Cathexis and has been inspired by work in different fields including among others, Psychology, Ethology and Neurobiology. Figure 2-1 provides a high level view of the model's architecture. The following sections describe this architecture with some detail.

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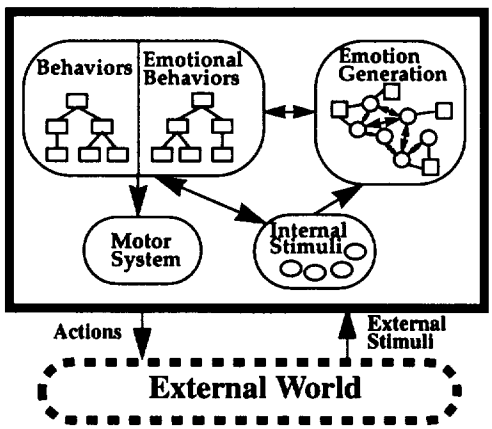

Figure 2-1 The Cathexis Architecture.

2.1 Modeling Affect in Cathexis: The Emotion Generation System

Emotions, moods, and temperaments are modeled in Cathexis as a network composed of special emotional systems comparable to Minsky's "proto-specialist" agents (Minsky 1986). Each of these proto-specialists represents a specific emotion family corresponding to one of the following *basic* or *primary* emotions: *Anger*, *Fear*, *Distress/Sadness*, *Enjoyment/Happiness*, *Disgust*, and *Surprise* (Ekman 1992; Plutchik 1994).

Within each proto-specialist, different sensors are monitoring both external (e.g. events in the environment) and internal sensory stimuli (e.g. drive levels, feedback from sensorimotor processes) for the existence of the appropriate conditions that would elicit the emotion represented by that particular proto-specialist. These sensors are arranged into different groups (cognitive and noncognitive) that correspond to the four different kinds of emotion activation systems suggested by Izard: *Neural*, *Sensorimotor*, *Motivational*, and *Cognitive* (Izard 1993). Input from these different sensors either increases or decreases the intensity of the emotion proto-specialist to which they belong.

Associated with each proto-specialist are two threshold values. The first threshold, α, controls the activation of the emotion. That is, once the intensity goes above this threshold, the emotion proto-specialist becomes "active" and releases its output signal to other emotion proto-specialists (either inhibiting or exciting them), and to the Emotional Behavior system which selects an appropriate behavior according to the state of these emotional systems. The second threshold, ω, specifies the level of saturation (i.e. maximum intensity) for an emotion proto-specialist. Another important element associated with an emotion proto-specialist is a decay function, $\Psi()$, which controls the duration of the emotion once it has become active. This function makes sure that unless there is some excitatory input for the emotion, its intensity is lowered and after a few cycles, once its intensity goes below the specified threshold, it becomes inactive.

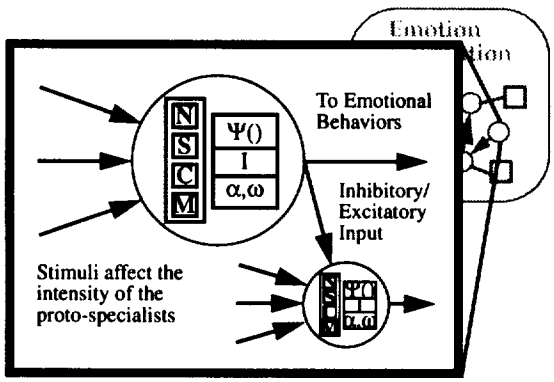

Figure 2-2 Each basic emotion is modeled by one emotion proto-specialist.

All of these emotion proto-specialists run in parallel and are constantly updating their intensities. No particular proto-specialist is in control of the system. In fact, in order to model emotion *blends* and *mixed* emotions, Cathexis allows for the co-occurrence (co-activation) of two or more basic emotions at the same time.

So, even though there are no explicit models to represent emotion *blends* (e.g. *Grief*), they exist as part of the interaction between two or more active basic emotions. The intensity level and the influences (both expressive and experiential) of each of the active emotions, give emergence to these secondary emotions.

Following a psychobiological perspective, Cathexis differentiates between moods and emotions in terms of levels of arousal: Emotions may consist of high arousal of specific proto-specialists. These proto-specialists, however, may also be activated at low levels by a variety of internal stimuli, as well as relatively weak perceptual inputs. Thus, moods may be explained as low tonic levels of arousal within emotional systems, while emotions would be explained as high levels of arousal in these same systems. So, while high arousal of emotion proto-specialists will tend to inhibit other proto-specialists, mild arousal may very well allow several systems to be concurrently active, leading to the chance of an enormous display of mood states (some of which could be described with common labels, such as *cheerful*, *irritable*, *melancholic*, *anxious*, and so on) compared to the limited number of basic emotional states.

Finally, temperaments are simply modeled through the different values the activation threshold α can have for the different proto-specialists. Thus, an individual who has propensities to be in *fearful* moods might have a lower threshold for the emotion of *fear* in comparison to other individuals who do not.

2.2 Emotional Behavior System

The Emotional Behavior System decides what behavior is appropriate for the agent to display given its motivational state (i.e. the state of the agent's drive and emotional systems) at a given time.

The Emotional Behavior system is a distributed system composed of a network of behaviors, such as "engage in fight", "avoid anger", or "smile". Each of these behaviors competes for the control of the agent. The decision of what behavior is active at some time is based on the value of each behavior. This value is recalculated every cycle and depends on several factors, called the *releasers* for that behavior, which may include motivations (emotions, moods, drives and pain), as well as a variety of external stimuli.

Each Emotional Behavior contains two major components:

- *Expressive Component*: which contemplates the different aspects of the expression of emotions such as prototypical facial expressions, body posture, vocal expressions, and so on.
- *Experiential Component*: which represents the emotion experience as a manifestation of action readiness, influences in the agent's motivations, and perceptual biases, among others.

3. Implementation and Results

Cathexis has been implemented in its totality as part of an object-oriented framework that allows agent developers to create emotional agents. This framework has been implemented in C++ and another implementation in Java is under way.

The framework has been used to build an environment in which the user interacts with "Simón", a synthetic agent representing a young child. The main goal of creating Simón was not to create an emotional, believable agent, but rather to build an environment that would serve the purpose of a test-bed in which we could experiment and test the internals of the Cathexis model.

Interactions and experiments with Simón have shown that Cathexis allows us to model different kinds of emotional phenomena and gives us enough flexibility to design different affective styles for an agent.

4. Conclusions

We have presented Cathexis, a distributed model for the generation of emotions and their influence in the behavior of autonomous agents. By drawing on ideas from several different fields, Cathexis offers an alternative approach to model different types of emotions, such as basic emotions, emotion blends, and mixed emotions. The model considers the dynamic nature of emotions, and, in contrast to other models proposed to date, it considers both cognitive and noncognitive elicitors of emotions, and it differentiates emotions from other affective phenomena, such as moods. Finally, it provides a flexible way of modeling the influence of emotion on the behavior of the agent, which takes into account aspects of both the Expressive and Experiential components of emotion.

The complete Cathexis model is described with greater detail in (Velásquez, J. 1996).

References

Bates, J. 1994. The Role of Emotion in Believable Agents. *Communications of the ACM* 37(7): 122-125..

Blumberg, B. 1994. Action-Selection in Hamsterdam: Lessons from Ethology. *Third International Conference on the Simulation of Adaptive Behavior*, 108-117. MIT Press.

Ekman, P. 1992. An Argument for Basic Emotions. In: Stein, N. L., and Oatley, K. eds. *Basic Emotions*, 169-200. Hove, UK: Lawrence Erlbaum.

Elliot, C.D. 1992. The Affective Reasoner: A Process Model of Emotions in a Multi-Agent System. Ph.D. Thesis, Institute for the Learning Sciences, Northwestern University.

Izard, C.1993. Four Systems for Emotion Activation: Cognitive and Noncognitive Processes. *Psychological Review* 100(1)68-90.

Maes, P., et al. 1995. The ALIVE System: Full-body Interaction with Autonomous Agents. In: *Computer Animation '95 Conference*. Geneva, Switzerland.

Minsky. M. 1986. *The Society of Mind*. New York: Simon & Schuster.

Pfeifer, R. 1988. Artificial Intelligence Models of Emotion. In: Hamilton, V., Bower, G., and Frijda, N. eds. *Cognitive Perspectives on Emotion and Motivation*, 287-320. Netherlands: Kluwer.

Plutchik, R. 1994. *The Psychology and Biology of Emotion*. New York: HarperCollins.

Velásquez, J. 1996. Cathexis: A Computational Model for the Generation of Emotions and their Influence in the Behavior of Autonomous Agents. S.M. Thesis. Dept. EECS, Massachusetts Institute of Technology.