Adaptation and Decision-Making Driven by Emotional Memories

Luís Morgado[1,2] and Graça Gaspar[2]

[1] Instituto Superior de Engenharia de Lisboa,
Rua Conselheiro Emídio Navarro, 1949-014 Lisboa, Portugal
lm@isel.ipl.pt

[2] Faculdade de Ciências da Universidade de Lisboa,
Universidade de Lisboa, Campo Grande, 1749-016 Lisboa, Portugal
gg@di.fc.ul.pt

Abstract. The integration between emotion and cognition can provide an important support for adaptation and decision-making under resource-bounded conditions, typical of real-world domains. The ability to adjust cognitive activity and to take advantage of emotion-modulated memories are two main aspects resulting from that integration. In this paper we address those issues under the framework of the *agent flow model*, describing the formation of emotional memories and the regulation of their use through attention focusing. Experimental results from simulated rescue scenarios show how the proposed approach enables effective decision making and fast adaptation rates in completely unknown environments.

1 Introduction

Growing experimental evidence from neurosciences indicates that emotion plays a fundamental role in human reasoning and decision-making (e.g. [7, 11]). On the other hand, the importance of emotional phenomena in learning and adaptive behavior is also well documented (e.g. [17]). This evidence of an encompassing role of emotion in cognitive activity has stimulated the development of cognitive models that incorporate emotional modeling (e.g. [3, 13]). Even traditional decision research has begun to incorporate emotion in models, as is the case of *decision affect theory* [18], and of some authors that propose emotion as an integral part of bounded rationality (e.g. [12, 9]).

However, two main problems are recognized underlying this emotion-based approach: (i) the tightly intertwined relation between emotion and cognition, which is hardly compatible with patching emotional phenomena as an addition to the cognitive mechanisms of an agent [1]; (ii) the dynamic and continuous nature of emotional phenomena, which is highly constrained by the classical notion of a discrete emotional state and its assessment via verbal labels [24].

In our view, to address these issues we must go beyond the classical separation between emotion and cognition and recognize their symbiotic relation. That is, emotion is a result of cognitive activity and cognitive activity is modulated by emotion, in a dynamic process that unfolds through time according to agent-environment

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interaction. We concretized this view by developing an agent model where emotion and cognition are modeled as two integrated aspects of intelligent behavior. Two main aspects are involved in this relation between emotion and cognition: (i) the regulation of cognitive activity due to the present achievement conditions; and (ii) the modulation of the changes in the cognitive structure due to past experiences (i.e. the formation of emotional memories). In this paper we will focus on this second aspect, that is, how can emotional memories enhance the adaptation and decision-making under time-limited conditions.

The paper is organized as follows: in sections 2 and 3 we present an overview of the emotion and agent models that support the proposed approach; in section 4 we further detail the agent model regarding emotional memory formation and activation and its use in decision-making; in section 5 experimental results from a simulation of a rescue environment are presented; in section 6 we establish comparisons with related work and draw some conclusions and directions for future work.

2 The Flow Model of Emotion

In the proposed model we adopt a view where emotional phenomena result from the dynamics of cognitive activity. This view is in line with emotional models proposed by some authors (e.g. [6, 24]).

However, a distinctive aspect of the proposed model is the fact that those dynamics are rooted on the dynamics of energy exchange between the agent and the environment. This is possible due to conceiving an agent as an open system that maintains itself in a state far from equilibrium, yet keeping an internally stable overall structure. This kind of systems is known as dissipative structures [15]. Adopting this view, the agent-environment relation is determined by the relation between the agent's internal potential, its *achievement potential*, and the agent-environment coupling conductance, the *achievement conductance*. The achievement potential represents the potential of change that the agent is able to produce in the environment to achieve the intended state-of-affairs. The achievement conductance represents the degree of the environment's conduciveness or resistance to that change, which can also mean the degree of environment change that is conducive, or not, to the agent intended state-of-affairs. In a dissipative system the achievement potential can be viewed as a force (P) and the achievement conductance as a transport property (C). The behavioral dynamics of an agent can therefore be characterized as a relation corresponding to a flow, called *achievement flow* (F), which results from the application of potential P over a conductance C. These behavioral dynamics, expressed as energy flows, are considered the root of emotional phenomena, underlying and modulating cognitive activity. They are described as a vectorial function ED, called *emotional disposition*, defined as:

$$ED \equiv (\delta P, \delta F) \quad \text{where} \quad \delta P = \frac{dP}{dt} \quad \text{and} \quad \delta F = \frac{dF}{dt} \tag{1}$$

As can be seen in figure 1.a, at a given instant $t = \tau$ an emotional disposition vector has a quality, defined by its orientation (or argument) and an intensity defined by its module. Each quadrant of the two dimensional space $\delta P \times \delta F$ can be directly related to a specific kind of *emotional disposition quality* as indicated in figure 1.b, although