Chapter 5

A Computational Basis for the Emotions

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ABSTRACT

In order to achieve ‘affective computing’ it is necessary to know what is being computed. That is, in order to compute with what would pass for human emotions, it is necessary to have a computational basis for the emotions themselves. What does it mean quantitatively if a human is sad or angry? How is this affective state computed in their brain? It is this question, on the very core of the computational nature of the human emotions, which is addressed in this chapter. A proposal will be made as to this computational basis based on the well established approach to emotions as arising from an appraisal of a given situation or event by a specific human being.

INTRODUCTION

Previous research in psychology and neuroscience has strived to reach the basis of the emotional process, but the resulting models and theories have often not been translated into a computational representation. In the literature, we can distinguish between those theories advocating a basic emotions approach, a dimensional approach and an appraisal based approach.

In the basic emotion theories (e.g. Plutchik (2001), Panksepp (1982)), it is assumed that different processes underlie a small set of basic emotions; more complex emotions would arise from subtle variations on these basic ones. If this were represented computationally, the dif-
ferent basic emotions could have differing and separate underlying computational systems. In this vein, a computational model of fear has been proposed by Armony et al. (1995), based around the amygdala as a central structure in fear production, assuming that fear is caused specifically by a (potential) threat and different structures would be responsible for producing other emotions. This model is based on fear conditioning research by LeDoux (1992), in which it was shown that the amygdala is particularly active in this process. Although this model reproduces experimental results in detail, such specific neural modules have never been located for other emotions. It has later been proposed that the amygdala functions as a relevance detector (Sander et al., 2003) – where stimuli evoking fear tend to be highly relevant.

Dimensional theories state that an emotion is defined by its location in a multidimensional space, where the number and character of the dimensions varies, but tends to include some variation on valence (positive – negative) and arousal (high – low). Computationally, this would translate to a separation between different modules for the different dimensions, rather than a separation between the different emotions, where the output would not consist of categorised emotions but rather of gradual changes in emotional feelings and behaviour. Although it seems that neural responses to valence and arousal can indeed be dissociated (Grimm et al. (2006), Anders et al. (2004)), results are not so clear cut that it is possible to point to delineated neural substrates. Nevertheless, psychological research using a statistical technique to identify the principal contributors to a particular phenomenon (Principal Components Analysis) has pointed to the existence of precisely four dimensions (Fontaine et al., 2007).

A combination of these two approaches can be found in the work of Russell and Fieldman-Barrett (1999), where core affect is proposed as a two dimensional, permanently present emotional state that does not need to be directed at any particular object or event, whereas prototypical emotional episodes are event-driven and form categories. No explicit computational account is given of this theory, but it suggests some sort of sum or multiplication of the outputs of the dimensional and basic emotion systems as described above.

A more causal analysis of the emergence of emotions, appraisal theory, states that emotions are a function of the individual’s interpretation of the situation in terms of (potential) harm or benefit to this individual. A recent, detailed account of appraisal theory is proposed in the Component Process Model (CPM) (Scherer (2001), Sander et al. (2005)), in which four different Stimulus Evaluation Checks (SEC) – each consisting of several more specific checks – produce different changes in the emotional state. In this account, the SEC’s (Relevance, Implication, Coping potential and Normative Significance) are sequential, and each SEC can produce output to various neural systems. As such, a corresponding computational model would contain four modules that are connected in sequence, which each receive input from and produce output to several other neural systems. In such a system, there would not be any one specific emotional output; rather, the emotion would be dispersed across a range of neural systems, most of which would not be specifically ‘emotional’ in nature.

Ortony et al. (1988) have presented a more inherently computational model of the appraisal process, in which emotions are considered to be valenced reactions to either consequences of events, actions of agents or aspects of objects, whereby different other factors such as desirability and agency further discriminate emotions within these categories. A computational structure is clear from the outline of the model in Figure 1. However, there is no connection to potential neural correlates in this model. It should be noted that there is an assumption in this approach that the emotional outputs are categorised, whereas in the CPM this is explicitly not the case.

Thus, quantitative analyses of the emotional process are still scarce, despite the fact that many
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