Emotions: a computational semiotics perspective

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Abstract

The discussion about the importance of emotions in the rational behavior of human being is not new. Neither is the discussion about emotions in artificial beings. The problem is that myth and misconceptions almost ever surround this discussion. It happens due to our difficulty to deal formally with the concepts of emotions. This paper uses the concepts of computational semiotics and others to give this discussion some theoretical background and possibly turn its implementation possible.

1. Introduction

Most of the misconceptions and myths that arise from the discussion of emotions in the AI context are due to our difficulty to model it. After all, what is an emotion? Is it a process? Is it an heuristic? Is it a goal? Moreover, what is the role of emotions? Why do we need emotions?

Recently many researchers have been studying those questions and, as we may expect, many different interpretations came up. This paper analyses the emotion in the context of computational semiotics and uses the interpretation given by Damasio [02] (one of the most commented in the recent literature). For a more complete review in computational semiotics, the reader might refer to [08] and [09].

2. What is an emotion?

A review of AI emotional models from 1960s to 1980s can be found at [12]. In this paper, Pfeifer shows how the AI and cybernetics approached emotions in many different ways into the AI and cybernetics. However, using his own words: " (...) this concerns in essence what one might call cognitive representations of emotions which can be used to represent knowledge about emotions, rather than emotion itself. (...) in a number of models only knowledge about emotions is represented; They don't include the "real" concept of emotion". Although there is a relatively long history for AI models of emotions, it is surprising how few approaches have been developed since so far. During 1990s, most of the development was based on the old ones. Basically soft computing approaches (e.g. fuzzy logic) were introduced to the 1980s models [13].

In 1994, Damasio published his famous book [02]: "Descartes' Error: Emotion, Reason and the Human Brain". His book is now considered a significant milestone in the research on human emotions. Damasio's book brings an important experimental perspective of the old ideas of William James [11] and Daniel Dennet [04] [03]. Damasio's work provides a biological framework to explain emotions not as a psychological state of the soul any more, but as a physical phenomena. Unfortunately, due to the complexity of the concepts involved, this point of view is not sufficient to guarantee an immediate feasible implementation, but on the other hand, it brings a number of new insights on how it can be implemented. [14] and [15] address one of them.

To understand Damasio's view of emotion, we first need to understand several other basic concepts: mind & body; imagetic thinking; somatic marker and intuition. Those concepts will not be fully detailed here. If the reader is interested in a complete description, he might want to refer to [02].

2.1 Mind & body

For Damasio, our mind is physically associated with our body through our brain. For him, the idea that the mind and the body can be dissociated and each one can be represented by a different state machine is wrong. He believes that it is not possible to consider each one as an independent entity without loss of information. Our body is not only a machine that holds an intelligent mind: our thinking is fully connected with our body, in other words, our mind is fully embodied into our body, not only held by it.

Note that it is completely different from the view in which the body acts only as a communication mean where electrical and chemical signs flow. The body state (and limitations) and the physical implementation of the mind have a definitive importance in the intelligent behavior because it influences not only in the "brain parameters" but also in the "brain algorithm." A computational model should consider this behavior.

2.2 Imagetic and distributed nature of thinking

Damasio, referring to Daniel Dennet's work, pointed out that the usual metaphor for our thinking is a movie where each frame has not only visual images but also images of the others 4 senses: olfaction, hearing, taste and touch. He shows that the big screen where this movie is projected does not physically exist into our brain. Instead of that, we process each kind of sense in physically different and distributed locations in our brain. The perception we have of the centralized nature of thinking is in fact an emergence phenomenon resulting from the time synchronization of all distributed processors. For Damasio, there are two basic kinds of mental image: *perceptual* and *dispositive*. A perceptual image is, in the biological level, a topographically organized neural activity into any sensorial cortex of the brain. A perceptual image might be generated by our sensors or by the other kind of image: the dispositive image. A dispositive image is what Damasio calls "dispositional representations." In this sense, dispositive image is a prototypical image that holds the rules to reconstruct perceptual images. The collection of all dispositive images constitutes our full repository of knowledge. A dispositive image, when properly excited (triggered), might produce (recall) perceptual images or excite another dispositive images. Damasio also names the perceptual image generated in the recalling process *recalled* image. Note that one dispositive image does not centralize the knowledge related to an object. Each dispositive image holds a different aspect of the same object and as we said before, when we think about this object, all images are triggered synchronously, creating the perception of a centralized unit that holds all related information about this object.

2.3 Emotions

According to Damasio's work, an emotion is a dispositive image that affects the body internal state. Note that emotion is not the perception of the body internal state or its change. This perception is the *feeling* not the emotion itself. Many authors consider feelings and emotions as synonyms. Here, they are different but correlated concepts.

There are two basic categories of emotions: primary and secondary. Primary emotions are innate and are often related to self-preserving and reproduction. Their triggering occur in an unconsciousness level when perceptive images excite them, causing a reaction that affects the body state.

Secondary emotions are similar to primary ones. Both of them affect the body state when excited. The difference between them is the fact that they are not innate. Additionally, secondary emotions may work both on consciousness and unconsciousness level. According to Damasio, it happens because they evolved from the primary emotions and use their mechanisms. This conscious part of secondary emotions occurs when they are triggered by some stimulus generated by a rational and conscious thinking.

So, the emotion is able to change the body internal state and consequently affects how the brain process others mental images. This interaction happens in two different ways: *changing the performance of the cognitive mechanism*; and *attributing an intuition (used in the mental processing) to another mental images through a mechanism called the somatic marker.*

2.4 Somatic marker and intuition

The essence of intuition is what Damasio calls somatic mark. The somatic mark is a value of desirability (apraisive knowledge from a computational semiotics point of view) that is attributed to any mental image. This value of desirability comes from the present state or predicted future states of the body and is attributed to an image by a mechanism called somatic marker. The somatic marker continuously analyses the body state using a body model and images with predicted future states of the body. The result of this analysis is used to make relations between mental images and the desirability of the body state. The concept of desirability is related to some basic instincts responsible to maintain the integrity of the individual and the preservation of the species.

2.5 Instincts x reason

The instincts, in the sense of reactive response, might be seen as dispositive images that generate behavior. Normally instincts are characteristics of the species and are related to auto-preservation. The reasoning might be considered as an instinctive process. For Damasio, the reasoning process in intelligent beings uses the intuition, and consequently the emotion mechanism, to drastically decrease the search space of solutions for complex problems. Without emotions, an analysis of a simple task would be impossible due to the number of alternatives to be analyzed. Damasio observed this fact in his patients.

3. The composite knowledge

Before discussing the computational semiotics view of emotions, it is necessary to introduce a new concept.

Peirce's semiotics introduced a signical taxonomy, where different kinds of signs (e.g. rhemes, dicents, arguments, icons, indexes, symbols, qualisigns, sinsigns, legisigns) addressing different characteristics of its structure and signic function were proposed. From Peirce's taxonomy, Gudwin [08] derived one taxonomy of types of knowledge, where each type of knowledge addresses a different way on a phenomenon from the world can be modeled. This taxonomy is the key in this computational semiotics view of emotions. Due to space limitations, it will not be reviewed all concepts of this taxonomy and an interested reader might want to refer to [09] [06].

The taxonomy of types of knowledge deals mainly with elementary knowledge types and atomic entities called knowledge units. To understand mental images and consequently emotions, we need to work with a more complex knowledge structure called composite knowledge.

Composite knowledge is a set of knowledge units (that can be classified into the elementary taxonomy) that holds an important property: the meaning of the set is different of the sum of meaning of each part. A composite knowledge unit may be classified into the same knowledge taxonomy of elementary units. In this case, its classification is based on the semantics of the hole set of knowledge (different from the sum of the semantics of each of its part).

4. Computational semiotics view of emotions

Based on the idea introduced in the last section, we may say that a mental image (either perceptual or dispositive) is a composite knowledge unit, and everything done in computational semiotics for elementary knowledge units, holds for it.

The Damasio's claims that the body can not be dissociated from the mind (the key for his view of emotions), does not have any direct match to any concept of Peirce's semiotics. Worst than that, Umberto Eco [05] says that semioticists should not consider the physical restrictions of the interpreter. At first, one may think that there is a conflict between Damasio and Umberto Eco's ideas. Our claim is that this conflict does not exist at all. In the semiotics context the interpreter body might be seen just as a global state that have a direct influence into all semiosis processes that take place into the interpreter's mind. In this perspective, an interpretant with an emotional content affects this global state. In human beings, this global state is related to the interpreter's body but it might be different in other contexts like in artificially generated semiosis.

5. A path to implementation: somatic agent

In the AI domain we are interested to synthesize intelligent behavior in digital machines. This goal equivalent, in the computational semiotics domain, is the synthesis of the semiosis process. As we said before, the introduction of the emotions in the sense given by Damasio allows an implementation of emotion-based semiosis. To implement such system we developed an architecture called somatic agent. The somatic agent is an architecture based on the idea of blackboard [01] and implements many of Damasio's concepts: imagetic thinking; emotions; somatic marker and intuition based reasoning.

The somatic agent architecture consists in 6 independent and unsynchronized modules that communicate each other through a blackboard-like work memory. All 6 modules communicate using the same data structures: mental images. The implementation of mental image is based on the idea that it is a composite knowledge. The 6 modules are: sensing; actuator; body modeler; somatic marker; rational processor and finally the dispositive memory.

5.1 Mental image

As we said before, the mental image is the elementar data unit used in the system. All modules communicate one to each other using mental images. The mental image implementation follows the idea that it is a composite knowledge. In this way, it is possible to create a hierarchical structure that holds all possible mental images and allows a blackboard-like implementation aimed by this system. There is no directional communication flows in this system. All messages are posted in the working memory and all modules may access it.

The hierarchical structure for mental images derives from the knowledge taxonomy proposed by Gudwin [08][09] and from the objected oriented theory. From Damasio's work, there are two basic types of mental images: perceptive and dispositive (see section 2.2). The working memory holds any kind of perceptive images while dispositive images are supported by the dispositive memory (section 5.2.4).

Dispositive images will be discussed in section 5.2.4. Perceptive images are *rhematic specific* composite knowledge units [08][09] and are classified according the structure depicted in Figure 1 (using the UML notation [10]):

A perceptive image holds the following attributes and associations: Type; desirability; time stamp; mean life; "created_by" and "created_from" pointers; consequence pointer; data. These attributes and associations are depicted in Figure 2. The dispositive image will be discussed further.

The attribute "type" specifies the type of the image. It might be redundant in the implementation if the language being used allows reflexive operations (like Java does). In this case, the type of the knowledge is directed determined by the image subclass and no indicator in necessary. The attribute "desirability" will be addressed in section 5.2.3. The attribute "timeStamp" shows the time when the image was created and the "meanLife" term specifies how long it will last. Following the Damasio's ideas, a mental image lasts for a finite time. How long this time is depends on how frequently it is used.

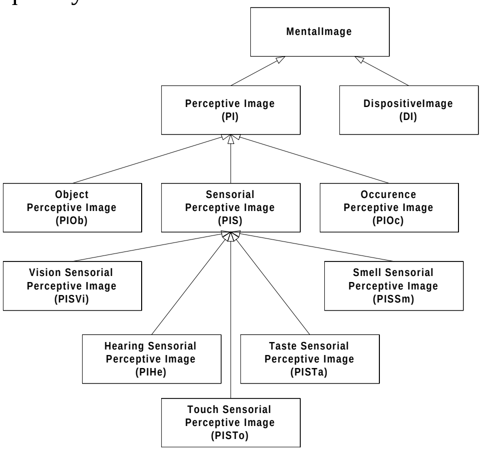

Figure 1 - Class structure for perceptive images

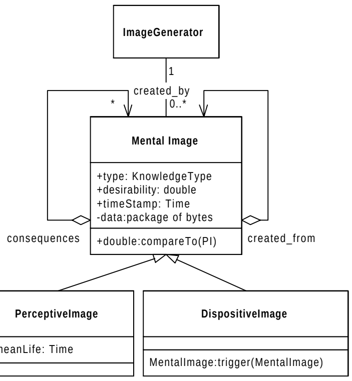

Figure 2 - Details of mental image class

The association "created_by" allows an image to designate its own creator. An image creator is an object from the "ImageGenerator" class that will be detailed ahead. The association "created_from" indicates which images were used in the image creation process. The association "consequences" does the inverse mapping: It shows which other images were created based on this image.

The attribute data contains the information that the image holds. This data has a different meaning in each different image subclass. In a visual perceptive image (PISVi) this data usually represents an image. In a hearing perceptive image (PIHe) it is usually a sampled sound. For more details about all possible meanings of those images, see the taxonomy of knowledge in [08], [09] or [06].

All images might be compared on to each other through the perceptive image method "compareTo" (see Figure 2). This method returns a value into the [0..1] interval where 0 means no similarity (total difference) and 1 mean equality. This method is very important for the somatic marker and the rational processor modules.

5.2 Image generators (and consumers)

As we said in the beginning of section 5, six independent and asynchronous modules connected to a work memory compose the somatic agent. Those modules are objects from classes derived of a generic class called "ImageGenerator". An "ImageGenerator" object is an entity able to read/post images from/to the working memory. It usually creates an image based on external world (sensors) or based on another images placed into the working memory.

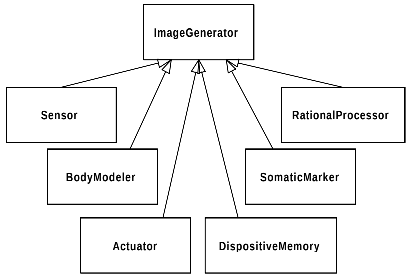

Figure 3 - ImageGenerator classes

The section that follows will detail each image generator subclasses.

5.2.1 Sensor

The sensor module creates perceptive sensorial images based on sensorial data obtained in the external world and posts them into the working memory. It may also read perceptive sensorial images, concatenate and create another sensorial image with higher level sensorial data. Sensors are responsible not only for external world monitoring, they also monitor the system body, posting mental images related to any sensible body state change, in the working memory.

5.2.2 Body modeler

As we will see in the next section, the somatic marker mechanism uses a body model to process mental images. This body model is a perceptive image that holds a *rhematic object specific* knowledge [09][07]. The body modeler module read sensorial images in the working memory, processes it, and actualizes the body model image.

5.2.3 Somatic Marker

The somatic marker is a mechanism responsible to calculate a degree of desirability to every mental image in the system (see section 2.4). This mechanism does not operate at conscious level in the sense that the rational processor of the somatic agent does not have any control over it and it has access to any mental image produced in the system.

This desirability value will be used by the rational processor as some kind of intuition about an image and is calculated using innate rules or by image similarity. Most of this work is possible due to the mental image method “compareTo” and the association “created_from”. Additional work is necessary to find similar images into the set of mental images contained by working memory. This work is easily done in massively parallel structures like our brain but very expensive in digital computers. It happens because it is necessary to compare all images between themselves (complexity $O(n^2)$). Due to this fact the somatic marker does not perform all analysis, selecting randomly the images to be analyzed.

The desirability value should not be confounded with emotions. It is only a judge value given to an image based on the somatic state and innate knowledge.

5.2.4 Dispositive Memory

The dispositive memory is a module that holds a collection of dispositive images. Those images are triggered (section 2.2) by perceptive images in the working memory or as result of others dispositive image triggering.

Dispositive images are similar to perceptive images. The difference is that it holds generic knowledge instead of a specific one. This is shown in Table 1, where: R means Rhematic; D means Dicent; Ic means iconic; Ob means object; Sp means specific; G means generic; Sy means symbolic; In means indexical; Se means sensorial; Oc means occurrence. For example, {RIcSeSp} means a Rhematic Iconic Sensorial Specific knowledge.

Knowledge type	Mental Image	
	Perceptive	Dispositive
{RicSeSp}	X	
{RicSeG}		X
{RicOcSp}	X	
{RicOcG}		X
{RicObSp}	X	
{RicObG}		X
{Dsy}		X
{Dic}		X
Designative	X	
Apraisive	X	X
Prescritive		X

Table 1 - Mental images and knowledge taxonomy

Based on their contents we may say that there are two different types of dispositive images. They are emotional and ordinary dispositive images. The emotional dispositive image is so called because once trigged it will produce a prescritive knowledge that will change the internal state of the body. The ordinary image differs from the emotional because its triggering either do not affect the body internal state or it effects both the body state and the external world simultaneously.

The emotional dispositive image is what one may call emotions and the perceptive images that capture its effects in the body state are what one may call feelings.

5.2.5 Actuator

Actuator is the module responsible to capture mental images with prescritive content in the working memory and use them to act in the external world.

5.2.6 Rational processor

The rational processor is the module responsible to conscious behavior generation. Note that it is responsible to higher levels behavior. Most of lower level behaviors, like reactive ones, are responsibility of the dispositive memory module.

Generally speaking, the rational processor consumes images of the working memory, performs abduction, induction and deduction over them. This semiotic cycle produces new images that are posted in the working memory. Its implementation may be any kind of semiotic machines as production systems, neural networks, etc.

It is important to note that the implementation of the rational processor should consider the desirability value calculated by the somatic marker mechanism. The way that Damasio describes it usage suggests that it may be used in a branch-and-bound algorithm to reduce the search space in decision make tasks.

5.3 Putting all together

Once defined the roles played by each system module, they may be integrated using the either Object Network (ON) or Field Object Network (FON) framework [09][07]. Because an Object Network simulation tool is being developed by our research team (see Figure 4), we chose the ON to implement the system.

For more details about ON mathematical specification the reader may refer to [08][09].

The final architecture is depicted in Figure 5. In this model each module is mapped in an ON place, resulting in at least six parallels and asynchronous processes that may be implemented into a single computer or distributed over a network.

The final architecture, capture the emotion mechanism placed by Damasio. Now we are implementing a test application to ensure its availability, efficiency, and robustness.

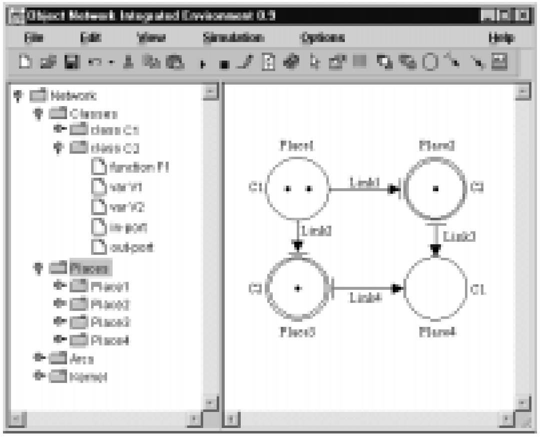

Figure 4 - Sample screenshot of the Object Network simulation tool

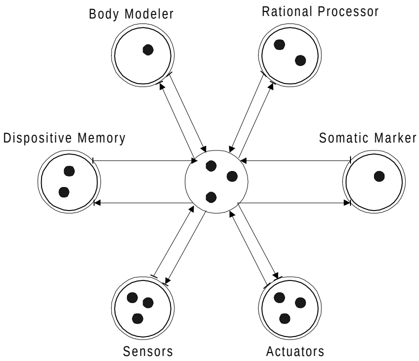

Figure 5 - ON system representation

6. Conclusions

The emotion must be seen not as a *heuristic* that leads to an optimal solution to any problem but as a *process*, that turns complex tasks possible. In this paper we show how the real concept of emotions can be captured and implemented. For that, we used some concepts of computational semiotics and Damasio's theory of emotions.

Currently we are working in an application example that will be a subject for future publications.

7. Acknowledgments

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