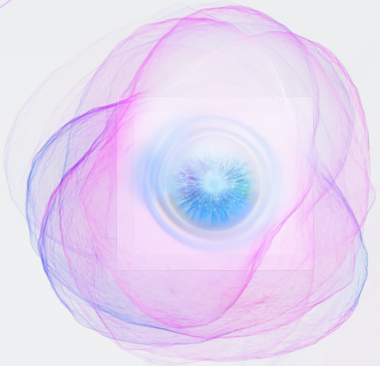

Emotion, Physiology, Motivated Action and Gesture/Expression for Humanoid Robots and Avatars

Mike Duncan & Ben Goertzel

Introduction

This document summarizes an approach to driving the emotional experience and expression of embodied agents controlled by OpenCog.

The two motivating examples here are:

- A humanoid robot with the ability to express emotion via its choice of animations, modulation of animations, and tone of voice; and to "experience" emotions via (in the OpenCog system controlling it) modulating its action selection and cognitive processes based on emotional factors.

- A humanoid avatar living in a 3D virtual world, such as Sophiaverse, with similar properties to the above robot.

The central idea presented here is to integrate the Component Process Model (CPM) with the Psi Model (the latter underlying OpenCog's OpenPsi framework for motivated action), two previously distinct models for describing and simulating human emotion. This integration leads to other useful things almost automatically, since close connections between CPM and facial expressions and other physiological parameters already exist and are documented.

The Component Process Model

We will not review the Psi model here as it has already been discussed and written about extensively in an OpenCog context (see e.g., Cai Zhenhua's paper from his PhD thesis). We will briefly review the CPM before getting started with our original suggestions.

The CPM has been selected for use here for several reasons, one of which is that it has already been explicitly connected with physiological parameters and facial expressions. Connecting CPM to Psi and unraveling the various details then gives us a holistic framework interrelating cognitive/perceptual control parameters (what Psi calls "modulators"), simulated-physiological parameters (e.g., heart rate), emotions (primary and secondary), animations and gestures and modulations of thereof, and evaluative processes assessing aspects of the system's state (what the CPM calls SECs, Stimulus Evaluation Checks).

For background on the CPM model of emotion and associated cognitive and biological dynamics, see the two papers:

- *The dynamic architecture of emotion: Evidence for the component process model, by Klaus R. Scherer* , http://www.affective-sciences.org/system/files/biblio/2009_Scherer_C&hE.pdf (see especially Table 1)

- *A systems approach to appraisal mechanisms in emotion, by David Sander*, Didier Grandjean, Klaus R. Scherer,* http://cms2.unige.ch/fapse/EmotionLab/pdf/SanderGrandjeanScherer_2005_neuralnetw.pdf (see especially Table 3)

See the Table below for a concrete flavor of the CPM:

Table 3
Predicted appraisal patterns for some major modal emotions

Criterion	ENJ/HAP	ELA/JOY	DISP/DISG	CON/SCO	SAD/DEJ	DESPAIR	ANX/WOR
Relevance							
Novelty							
Suddenness	Low	High/med	Open	Open	Low	High	Low
Familiarity	Open	Open	Low	Open	Low	Very low	Open
Predictability	Medium	Low	Low	Open	Open	Low	Open
Intrinsic pleasantness	High	Open	Very low	Open	Open	Open	Open
Goal/need relevance	Medium	High	Low	Low	High	High	Medium
Implication							
Cause: agent	Open	Open	Open	Other	Open	Oth/nat	Oth/nat
Cause: motive	Intent	Cha/int	Open	Intent	Cha/neg	Cha/neg	Open
Outcome probability	Very high	Very high	Very high	High	Very high	Very high	Medium
Discrepancy from expectation	Consonant	Open	Open	Open	Open	Dissonant	Open
Conduciveness	Conducive	Vcon	Open	Open	Obstruct	Obstruct	Obstruct
Urgency	Very low	Low	Medium	Low	Low	High	Medium
Coping potential							
Control	Open	Open	Open	High	Very low	Very low	Open
Power	Open	Open	Open	Low	Very low	Very low	Low
Adjustment	High	Medium	Open	High	Medium	Very low	Medium
Normative significance							
Internal standards	open	Open	Open	Very low	Open	Open	Open
External standards	Open	Open	Open	Very low	Open	Open	Open
Criterion	FEAR	IRR/COA	RAG/HOA	BOR/IND	SHAME	GUILT	PRIDE
Relevance							
Novelty							
Suddenness	High	Low	High	Very low	Low	Open	Open
Familiarity	Low	Open	Low	High	Open	Open	Open
Predictability	Low	Medium	Low	Very high	Open	Open	Open
Intrinsic pleasantness	Low	Open	Open	Open	Open	Open	Open
Implications							
Cause: agent	Oth/nat	Open	Other	Open	Self	Self	Self
Cause: motive	Open	Int/neg	Intent	Open	Int/neg	Intent	Intent
Outcome probability	High	Very high	Very high	Very high	Very high	Very high	Very high
Discrepancy from expectation	Dissonant	Open	Dissonant	Consonant	Open	Open	Open
Conduciveness	Obstruct	Obstruct	Obstruct	Open	Open	High	High
Urgency	Very high	Medium	High	Low	High	Medium	Low
Coping potential							
Control	Open	High	High	Medium	Open	Open	Open
Power	Very low	Medium	High	Medium	Open	Open	Open
Adjustment	Low	High	High	High	Medium	Medium	High
Normative significance							
Internal standards	Open	Open	Open	Open	Very low	Very low	Very high
External standards	Open	Low	Low	Open	Open	Very low	High

Abbreviations. ENJ/HAP, enjoyment/happiness; ELA/JOY, elation/joy; DISP/DISG, displeasure/disgust; CON/SCO, contempt/scorn; SAD/DEJ, sadness/dejection; IRR/COA, irritation/cold anger; RAGE/HOA, rage/hot anger; BOR/IND, boredom/indifference.

The first column includes SECs. The table cells indicate the degree to which each of these SECs leads to the expression (or in some cases inhibition) of a certain emotion.

See also the spreadsheet **"SEC to Expression Table"** which contains (as well as some other stuff) an editable version of Table 1 from the first CPM paper referenced above. This table maps SEC values into physiological expressions, e.g. "novelty" corresponds to possibilities like "brows and lids up, frown, jaw drop, gaze directed."

What we can get from the CPM in a practical robot emotion control context, it seems, is two things:

- Direct mapping from SEC evaluations to physical expressions
- Mapping from SEC evaluations to emotions

Note here that

- Physical expressions emanating from multiple sources can be enacted concurrently or simultaneously and then blended together.
- The level to which a certain emotion is active may be the combination of multiple factors, e.g. the contributions of the many concurrent SEC factors may add up.

The Psi modulators play a different role than the CPM SECs. Specifically, the Psi modulators are parameters intended to modulate the behavior of e.g. action selection or motivated inference. The values of the modulators may then be modulated themselves by the SEC values.

Psi contains a theory of emotion, via which the nature of the emotions experienced by a cognitive system corresponds to the vector of modulator values. (So the modulators are considered as dimensions of an n-dimensional space, and commonplace emotions are mapped into regions in this space.) If we connect CPM and Psi and let the implementations of these models in OpenCog act in the most obvious ways, we then have a situation where

CPM SEC values drive emotion directly, and also drive Psi modulators
Psi modulators drive emotion directly as well

One could view this as redundant, and view the relation between Psi modulators and emotion as implicit and descriptive rather than as something that should directly drive modification of emotion-representing Atoms in OpenCog. So long as the emotions determined by SEC values are consistent with the modulator values determined by these SEC values, according to Psi theory, this would be no problem. On the other hand, all these mappings are sufficiently imprecise that it seems unproblematic and perhaps better to allow Psi modulators and CPM SECs to both guide the truth values of emotion-representing Atoms directly, and have their contributions combined via the revision rule.

Types of Variables/Entities Involved

Based on the integration of the CPM and Psi, what is proposed here is to formulate a set of hand-coded rules (ImplicationLinks) embodying relationships between the following types of entities.

1. SECs: Stimulus Evaluation Checks. Examples would be "Novelty" or "Urgency" or "Degree of control (over the situation)" or "intrinsic pleasure." In OpenCog each of these would be a GroundedPredicateNode which, when evaluated, would tell you the degree to which the given SEC holds at the current moment.

2. Modulators. These are parameters that guide the behavior of cognition and perception, e.g. "arousal", "securing threshold", "selection threshold", "resolution level." In Zhenhua's old OpenPsi implementation, these were updated ongoingly by modulator-update functions.

3. Emotions. While emotions are complex and multidimensional and there is no way to make a comprehensive list of all emotions that a complex cognitive system will experience, still for the immediate term it is useful to create Atoms in OpenCog corresponding to a list of basic emotions (the ones in Table 3 of the second CPM paper mentioned above may be a good start).

4. Physiological variables. These are simulations of physiological variables that vary in human beings in ways associated with emotions. An example is HeartRate. A subtler example is ergotrophic/tropotrophic balance (very roughly, the internal body balance between energetically doing new stuff, and focusing on rest and body maintenance)

5. Facial expression animations & gestures. At the moment these come from a fixed list of animations, though some animations have parameters associated with them.

One source of emotional facial expressions is this paper, which claims that human facial expression recognition boils down to expression of 22 elementary and composite emotions: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3992629/figure/fig01/

6. Animation and gesture modulations. An example would be "start this animation or gesture extra-fast."

7. Voice modulations and emotions. Vocal expression can be made to express basic emotions like happiness, sadness and surprise. Different types of voice modulation can also be done, e.g. wide, narrow, relaxed, tense, lazy, thin, full voice (each of these has different frequency characteristics).
Actually, nothing new needs to be done here, except to create new animations for the remainder of the emotions required (as already suggested above).