Affective Computing of Constitutional States for Human Information Interaction

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Abstract. In this paper, a model for processing the affective properties of interaction between human and information is presented. During the interaction process between the human and the information system, various affects could be transferred from human to system and vice versa. Such transitions can be modeled by considering each affect as a combination of basic constitutional values over time. This model can facilitate bridging the gap of human and information during interaction.

1 Introduction

Human information interaction (HII) is an emerging area of study that investigates how people interact with information; its subfield human information behavior (HIB) is a flourishing, active discipline [4].

Affective Computing [13] is the study and development of systems and devices that can recognize, interpret, process, and simulate human affects. It is an interdisciplinary field spanning computer science, psychology, and cognitive science [18].

The aim of this paper is to bridge the gap between above two issues by incorporating HII and Affective Computing. Research on Artificial Intelligence propose that machine intelligence needs to include emotional intelligence and demonstrates results towards the goal: developing a machine's ability to recognize the human affective state given four physiological signals and compares multiple algorithms for feature-based recognition of emotional state from this data [12].

Cognitive scientists study intelligence and behavior, with a focus on how nervous systems represent, process, and transform information. Mental faculties of concern to cognitive scientists include language, perception, memory, attention, reasoning, and emotion; to understand these faculties, cognitive scientists borrow from fields such as linguistics, psychology, artificial intelligence, philosophy, neuroscience, and anthropology [15].

In order to process the affective properties of the interaction, an intelligent module is required to handle the internal states. That module should be in charge of affective state of the interaction. This phenomena is inspired from the affective advances in topics such as Human - Computer Interaction (HCI) and Human - Robot Interaction (HRI). The affective matters are dynamic during interaction and the system is highly situational. We employed an internal model of the Human - Information Interaction to generate an affective state and proposed a new mechanism for realistic and intelligent transitions in the model. Based on this model, certain behavior can be triggered when the system reaches a specific affective state.

Different methodologies have been used for dealing with the emotion and internal state. In earlier stages of research, fuzzy state machine based systems were introduced which was developed through a series of formative evaluation and design cycles [10]. State Machines [6] can be employed to produce basic moods. A multi-objective evolutionary generation process for artificial creature specific personalities (MOEGPP) [7] can be used where the dimension of the personality model is defined as that of optimization objectives. In that approach an artificial creature has its own genome in which each chromosome consists of many genes that contribute to defining its personality. In a different type of approach [5], the finger blood pulse fluctuations has been used for developing the online system to estimate a driver's internal state.

A large number of studies employed the Ortony, Clore, and Collins (OCC) model [11] as the fundamental model of emotion. For example, researchers have integrated that platform for modeling the emotions in embodied characters [2]. Another model [3] focuses on the role of emotion and expressive behavior in regulating social interaction between humans and expressive anthropomorphic robots, either in communicative or teaching scenarios. Cathexis [22] presents a distributed and computational model which offers an alternative approach to model the dynamic nature of different affective phenomena, such as emotions, moods and temperaments, and provides a flexible way of modeling their influence on the behavior of synthetic autonomous agents.

TAME is a framework for affective robotic behavior that deals with an exploratory experimental study to identify relevant affective phenomena to include in the framework in order to increase the ease and pleasantness of human-robot interactions. TAME stands for Traits, Attitudes, Moods and Emotions, the four components of the Personality and Affect module that is responsible for producing affective behavior [9, 1, 8].

The process of determining different states for the system can be referred to moods in a human being. From psychological point of view, a mood is a relatively lasting affective state. Moods differ from emotions in that they are less specific, often less intense, less likely to be triggered by a particular stimulus or event, however longer lasting. Moods generally have either a positive or negative valence. Unlike acute emotional feelings like fear and surprise, moods generally last for hours or days. Mood also differs from temperament or personality traits which are even more general and long lasting. However, personality traits (e.g. Optimism, Neuroticism) tend to predispose certain types of moods. Mood is an internal, subjective state, but it often can be inferred from posture and other behaviors [19].

We present the constitutional state model in the three dimensional space considering available models of emotion and then propose a new systematic method to demonstrate the alteration in affective states of the information system.

2 Modeling the Constitutional State

Energy and tension are believed as two principle parameters for representing the mood of a human being in psychological studies [14, 20, 21]. We have considered these two dimensions as Activation (Act) and Motivation (Mot) axes in the 2D Constitutional state plane [17].

Arousal, Valence and Stance [A,V,S] are considered as three main dimensions for emotional mapping to generate the 3D model [3]. We also model emotions in 3D space but beside Activation and Motivation, which is acceptable by most of researchers, we keep the third dimension for representing sub-states by considering the intensity of constitutional state [16].

Fundamental constitutional states can be considered as fragments which are presented by an area in above coordinate system. It should be noticed that these areas might have overlaps and could not be separated as pure/independent states. Each of the fundamental affective state fragments can be segmented into more detailed affects.

Mentioned constitutional state areas can be modeled by bean-shaped curves of genus zero with a single singularity with an ordinary triple point at the origin to illustrate their coverage in the affective coordinate system:

$$(x^2 + y^2)^2 = x^3 + y^3 + a(x^2 + x - y) \tag{1}$$

which gives the crooked egg curve when coefficient a is zero, and the bean curve when a is one.

State areas can be modeled by transecting the origin for plotting the above closed curve as $X_i = x_i - x_{Act_i}$, $Y_i = y_i - y_{Act_i}$ in the Activation-Motivation plane. So any affective states can be identified according to its transferred origin as Equation 2.

$$O_s = \begin{bmatrix} X_i = x_i - x_{act_i} \\ Y_i = y_i - y_{mot_i} \\ Z_{i,j} = z_{Sub_{i,j}} \end{bmatrix} \tag{2}$$

where i represents state and j shows the sub-state. By having the position of the origins, Equations 1 and 2 could be utilized in order to specify affective state areas. In this way constitutional state of the system can be presented in 3D emotional space.

3 Constitutional State Transition Based on Perception

During interaction between human and information different affects could be transferred from human to system. Such transitions can be modeled by considering each affect as a combination of basic affective values over time. Furthermore, the system itself is in one of the internal states at any given time. The affective state of the system at any time depends on its initial state plus the interaction result caused by the interaction input and that result should be affected by the extra parameters which push the resulted state towards a certain point in the affective space. To link interaction and constitutional state in the system, the transition in the affective constitutional state space has formulated as the following:

$$\boldsymbol{S}_{t_{Act,Mot,Sub}} = \boldsymbol{S}_{t-h} + \eta \boldsymbol{\Phi} + \beta \Gamma \boldsymbol{\Delta} \tag{3}$$

where $\boldsymbol{S}_t$ is the affective state of the system in the affective space at time t and $\boldsymbol{S}_{t-h}$ is affective state in time $t-h$, where h is the processing time gap because of the discrete system model;
$\boldsymbol{\Phi}$ is the vector field over the states which converges to a certain point in the affective state coordinate system. The convergence field varies by time in a similar manner as its changes in the human being, at least based on daily needs. Obviously a similar inducement can cause different reactions from the human in different times. This field also helps the affective state vector that doesn't move far away from the affective states' impact region. Vector $\boldsymbol{\Phi}$ can be considered as the gravitational field of a point mass c, located at point$P_0 \epsilon \Re^3$ having position $r_0 \epsilon \Re^3$ as:

$$\boldsymbol{\Phi} = \frac{-kc}{|\boldsymbol{r} - \boldsymbol{r}_0|}(\boldsymbol{r} - \boldsymbol{r}_0) \tag{4}$$

where $c, k \in \Re$ are constant numbers, $r, r_0 \in \Re^3$, $\boldsymbol{\Phi}$ points toward the point r_0 and has magnitude $|\boldsymbol{\Phi}| = \frac{kc}{|\boldsymbol{r}-\boldsymbol{r}_0|^2}$; η is the adjusting parameter (which can be a number) for convergence vector field to emulate same functionality as desires for the human being; β is the affective state coefficient which represents the personality of the system that controls the rate of change in the mood. Larger β means that the state would change faster which makes the system more dynamic; Γ is the learning rate. The change in state is different when system has more interactions and this parameter helps to have more realistic changes in the affective state; $\boldsymbol{\Delta} = \boldsymbol{\Delta}_{Act,Mot,Sub}$ is the 3D normal vector to transfer the state over time in the affective state space based on the emotional input according to the system interactions. First two components are in the Activation - Motivation plane which are driven from emotional input:

$$\boldsymbol{\Delta}_{Act,Mot} = \sum_{m=1}^{6} e_{Mot_m} \boldsymbol{Mot} + \sum_{m=1}^{6} e_{Act_m} \boldsymbol{Act} \tag{5}$$

where $\boldsymbol{Mot}$ and $\boldsymbol{Act}$ are representations of Motivation and Activation axes in x and y directions in the Cartesian coordinate system and vectors e are corresponding value for basic emotions in Activation and Motivation directions. The third component of Δ represents the movement in sub-state direction which obtained from the rate of the first two components:

$$\boldsymbol{\Delta}_{Sub} = |\frac{d}{dt} \boldsymbol{\Delta}_{Act,Mot}| \boldsymbol{Sub} \tag{6}$$

where $\boldsymbol{Sub}$ is representation of sub-states axes in z direction in the Cartesian coordinate system. In this way the vector $\beta\Gamma\boldsymbol{\Delta}$ finds its direction to reach the next affective state. By considering sub-state as the third axis of the affective state coordinate system, the overall affective state formula considering the interaction and transition methodology can be presented as:

$$\begin{aligned}\boldsymbol{S}_{t_{Tot}} &= \boldsymbol{S}_{t-h}\\ &+ \eta\frac{kc}{|\boldsymbol{r}-\boldsymbol{r}_0|^2}\\ &+ \beta\Gamma(\sum_{m=1}^{6} e_{mot_m}\boldsymbol{Mot} + \sum_{m=1}^{6} e_{act_m}\boldsymbol{Act} + |\frac{d}{dt}\Delta_{Act,Mot}|\boldsymbol{Sub})\end{aligned} \tag{7}$$

The state point can be a part of the affective state subspace when point s is inside the volume v which is any of the affective sub-states.
In order to handle constitutional states of the system, we focus on affective properties of the system and introduced a systematic method to generate such affections. A certain behavior can be activated when the system is in specific constitutional states. This approach could then be used to support research where the affective computing of the constitutional state is integrated into explanations. For a set of responses and decisions made by the system the mapping of the affect modeled by the quartic equation is used as additional information to clarify why the responses and decisions were made. For example, if the decision is considered risky the representation of the emotional reaction can be transmitted. Then the system would provide an explanation to alleviate the humans concern. Additionally this affective computation can be used diagnostically providing explanation when the human finds errors in the system output. These explanations can augmented the communication using the computational model of the humans state and vice versa enhancing humans and information interaction.

4 Conclusion

We have presented a model of affective state-space for engaging interactive parameters between information system and users. During interaction various affects could be transferred between human and system. Such transitions was modeled by considering each affect as a combination of basic affective values over time. The system itself is in one of the internal states at any given time. The affective state of the system at any time depends on its initial state in addition to the interaction result by the interaction input and that result should be affected by the extra parameters which push the resulted state towards a certain point in the state-space. To link interaction and constitutional state in the system, the transition in the affective constitutional state space has been formulated. The model can be used in fine tuning explanations and strengthening the communication of information between the human and the information system. Such model can be employed in Human Information Interaction application.

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