An Adaptive User-Interface Based on User's Emotion

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***Abstract*—In this paper, we introduce AUBUE - Adaptive User-Interface Based on User's Emotion in which a user's emotions are detected according to interactions of the user with keyboard; then user interface's color is adopted regarding to users' emotion. AUBUE includes four elements: keyboard interpretation, event interpretation, mood update, and color selection. In the keyboard interpretation element, interactions of a user with keyboard are analyzed with respect to some predefined parameters. In the event interpretation element, keyboard interactions are interpreted as active emotions of the user. Mood update element is responsible for mapping active emotions to a mood and updating current mood. Finally, the color selection element selects appropriate colors to cope with current mood. We have implemented AUBUE in a shape guess game.**

Keywords-Human Computer Interaction; Affective Computing; Adaptive Interface; Emotion; Mood; Color selection

I. Introduction

Nowadays, researchers are trying to create intelligent applications and they have realized the importance of emotions in attention, planning, learning, memory, and decision-making. This leads to efforts for creating emotionally intelligent interactive systems, which can detects human emotions, express emotions, and act properly considering human's emotions [1].

Emotional intelligence systems can be used in many ways, such as designing intelligence robots [2], household appliances [3], and user-interfaces [4]. In this paper, we focus on building emotionally intelligent user-interfaces software.

User interfaces are a critical part of software, since user interacts with software through them. Although there are too many rules and principles to design user-interface software, but interactive applications still have remarkable usability problems. A reason for these problems is that applications do not perceive or adapt to users' emotional state and users see the same user interface in different emotional states. In other words, user interfaces cannot understand users. As a result, users see an inappropriate feedback, and this may increase his/her frustration. Increasing user's frustration can decrease users' performance and concentration. Consequently, probability of making mistakes by users would increase [5].

To resolve these problems, we suggested an intelligent interface adopting its colors based on emotional states of users. The solution is intersection of human computer interaction (HCI) and affective computing. Human computer interaction involves the study, planning, and design of the interaction between people (users) and computers [6]. Affective computing is the study and development of systems and devices that can recognize, interpret, process, and simulate human affects [7].

Researchers identified four major methods of user emotion recognition: "(1) voice (prosody); (2) observable behavior, i.e. user's actions in the system interface (for example, chosen options and typing speed); (3) facial expressions; and (4) physiological signs (blood volume pulse, electromyogram – muscle tension, skin conductivity, breathing)" [8].

We utilize observable behavior method in this study because of simplicity (compared to other) and availability.

II. Background

A. *OCC emotion model*

In this research, Ortony, Clore, and Collins has been utilized (OCC) [9]. This model denotes twenty two different types of emotions. In this model depending on person's concern about events, actions, and objects, different emotions are elicited. In this research, only three OCC emotions are considered: joy, distress and angry.

B. *Mood*

The difference between emotion and mood is that mood is a longer lasting affective state. Mehrabian describes mood with the three traits pleasure (P), arousal (A), and dominance (D) [10]. "This model defines mood as an average of a person's emotional states across a representative variety of life situations. The three traits are nearly independent, and form a three dimensional mood space" [11]. In this space, each dimension takes values between -1.0 to 1.0. Table 1 describes the classification of moods according to position of their traits in the PAD mood space [11].

TABLE I. MOOD OCTANT OF THE PAD SPACE

+P+A+D = Exuberant	-P-A-D = Bored
+P+A-D = Dependent	-P-A+D = Disdainful
+P-A+D = Relaxed	-P+A-D = Anxious

+P-A-D = Docile	-P+A+D = Hostile

C. Fuzzy Systems

"Fuzzy systems are knowledge-based or rule-based systems. The heart of a fuzzy system is a knowledge base consisting of the so-called fuzzy IF-THEN rules. A fuzzy IF-THEN rule is an IF-THEN statement in which some words are characterized by continuous membership functions. For example, the following is a fuzzy IF-THEN rule: IF the speed of car is high, THEN apply less force to the accelerator, where the words "high" and "less" are characterized by the membership functions. A fuzzy system is constructed from a collection of fuzzy IF-THEN rules" [12].

III. AUBUE: ADAPTIVE USER-INTERFACE BASED ON USER'S EMOTION

The overall architecture of AUBUE is illustrated in Fig. 1. AUBUE consists of four elements: keyboard interpreter, event interpreter, mood update and color selector. Each element will be discussed in the future sections.

A. Keyboard interpreter

This element detects pressed keys on the keyboard and calculates keyboard parameters. Keyboard parameters include: type speed (words per minute), number of backspaces, number of unrelated keys, and does the user use the keyboard or not. These parameters are sent to the event interpreter element.

B. Event interpreter

This element of AUBUE, converts the keyboard parameters of the keyboard interpreter to keyboard events and then convert keyboard events to the OCC emotions. Stathopoulou and et al. [13] specified some keyboard events. Their work has been extended here in two ways: using fuzzy sets instead of boolean values for each event and adding two new events: user uses the backspace rarely, user hits unrelated keys rarely.

Therefore, we have the following of keyboard events:

- user types slowly (k1)
- user types normally (k2)
- user types quickly (k3)
- user uses the backspace rarely (k4)
- user uses the backspace often (k5)
- user hits unrelated keys rarely(k6)
- user hits unrelated keys often (k7)
- user doesn't use the keyboard (k8)

These keyboard parameters are converted to a vector of keyboard events (k1, k2, k3, k4, k5, k6, k7, k8) in which k1 to k7 takes a value between 0 and 1 and k8 takes a boolean value. The fuzzy sets for these events are shown in Fig. 2, Fig. 3, and Fig. 4. Membership function uses to set fuzzy values for values of k1 to k7. For example, membership function of typing speed, receives the typing speed (word per minute) as an input parameter, and returns a value between 0 and 1 for each typing speed event (k1, k2, k3).

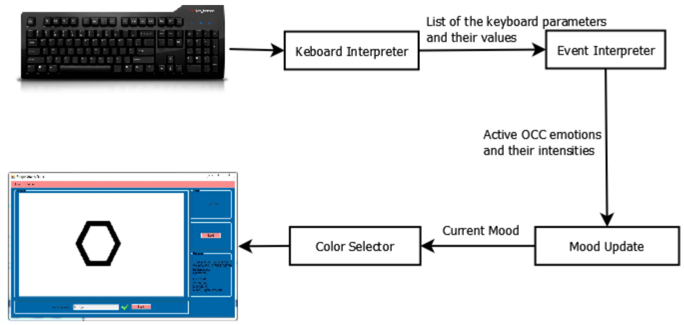

Figure 1. The architecture of AUBUE

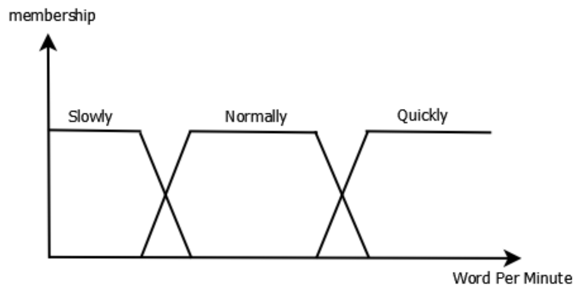

Figure 2. Fuzzy set of type speed

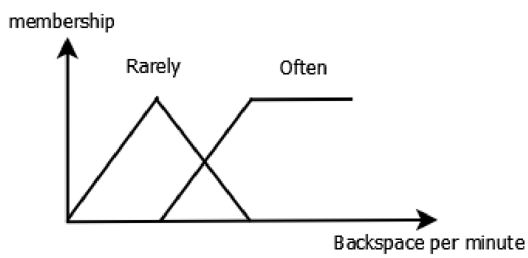

Figure 3. Fuzzy set of using backspace

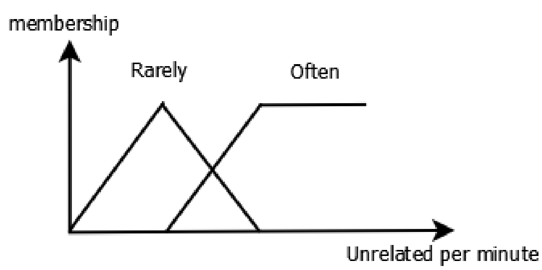

Figure 4. Fuzzy set of hitting unrelated keys

After acquiring keyboard events, it's time to use these keyboard events for specifying active emotions and their intensities. For this purpose, the method of SAW [14] is used. On the basis of this method intensity of an emotion is calculated by following formula (1).

$$\text{Emotion}[i] = W_{i,k1}k1 + W_{i,k2}k2 + W_{i,k3}k3 + W_{i,k4}k4 + W_{i,k5}k5 + W_{i,k6}k6 + W_{i,k7}k7 + W_{i,k8}k8 \qquad (1)$$

Where Emotion [i] is the intensity of i-*th* emotion and it is between 0 and 1. Also, k1 to k8 refers to the value of eight keyboard events. Another parameter is W which is the weight of an event. This means that how much an emotion is influenced by a keyboard event. For example, $w_{1,k2}$ present the influence of k2 on joy.

Weights are extracted according to an empirical study [15]. Concerning keyboard events, this study has the following results:

- A user types normally: neutral 55 %, happiness 25 %, other 20 %
- A user types quickly: neutral 35 %, happiness 43 %, other 22 %
- A user types slowly: neutral 20 %, sadness 38 %, anger 27 %, other 15 %
- A user uses the backspace key often: sadness 30 %, anger 60 %, other 10 %
- A user hits unrelated keys on the keyboard: sadness 25 %, anger 40 %, other 35 %
- A user does not use the keyboard: sadness 32 %, anger 27 %, other 41 %

For weight of k4 and k6, not mentioned in above list, one half of the weight of k5 and k7 is used respectively. As a result, the equation of each emotion is written as (2), (3) and (4):

$$Happiness = (0.25 * K[2]) + (0.43 * K[3]) \quad (2)$$

$$Sadness = (0.38 * K[1]) + (0.15 * K[4]) + (0.3 * K[5]) + (0.125 * K[6]) + (0.25 * K[7]) + (0.32 * K[8]) \quad (3)$$

$$Anger = (0.27 * K[1]) + (0.3 * K[4]) + (0.6 * K[5]) + (0.2 * K[6]) + (0.4 * K[7]) + (0.27 * K[8]) \quad (4)$$

Therefore, the event interpreter returns vector with 3 elements which each element of this vector presents intensity of an emotion.

C. *Mood Update*

The overall task of this element is mapping the active emotions generated by event interpreter into the PAD mood space, and updating the current mood. For mapping the OCC emotions into the PAD mood space a mapping table is used [11, 16]. This mapping table contains 16 OCC emotions and their corresponding point in the PAD space. Table 2 presents the mapping table between OCC emotion and PAD space.

When active emotions have been mapped into the PAD space, emotion center is calculated by getting average of all mapped emotions. Then, current mood is updated using the pull and the push functions. The pull function is active when the current mood position is between the PAD space's zero point and the emotion center. In the pull function, current mood is attracted towards the emotion center. The push function is called when the current mood is either after or at the emotion center. In the push function, the current mood is

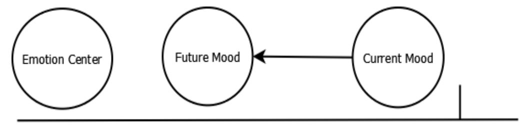

Figure 5. Pull function

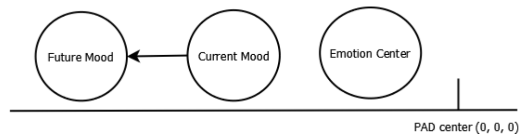

Figure 6. Push function

pushed away from the emotion center [11]. Pull and push functions are illustrated in Fig. 5 and Fig. 6.

The output vector of the event interpreter is represented as E_a, current mood of user as M_{Cur}, and average of mapped emotions (emotion center) as E_c.

1. $E_a = [e_1, e_2, e_3]; e_i \in [0, 1]$
2. $MappedEmotions[i] = [e_i * \alpha_{i1}, e_i * \alpha_{i2}, e_i * \alpha_{i3}]$
3. α_{ij} = OCC to PAD convert matrix (Table 2)
4. $E_c = [\frac{\sum_{i=1}^{3} MappedEmtions[i][1]}{3}, \frac{\sum_{i=1}^{3} MappedEmtions[i][2]}{3}, \frac{\sum_{i=1}^{3} MappedEmtions[i][3]}{3}]$

TABLE II. MAPPING FROM OCC TO PAD SPACE

Emotion	Pleasure	Arousal	Dominance	Mood type
Joy	0.40	0.20	0.10	+P+A+D Exuberant
Distress	-0.40	-0.20	-0.50	-P-A-D Bored
Anger	-0.51	0.59	0.25	-P+A+D Hostile

Now, for updating the current mood, the following equation is used:

$M_{cur}[i]$ = {

1. $M_{cur}[i] + E_c[i] * (1 - M_{cur}[i]) : M_{cur}[i] , E_c[i]>0$
2. $M_{cur}[i] + E_c[i] * (1 + M_{cur}[i]) : M_{cur}[i] , E_c[i]<0$
3. $(M_{cur}[i] + E_c[i]) / (1 - \min(M_{cur}[i] , E_c[i])) : (M_{cur}[i]>0 \text{ and } E_c[i] < 0) \text{ or } (M_{cur}[i]<0 \text{ and } E_c[i]>0)$

} (5)

In this equation, $M_{cur}[i]$ is the i-*th* dimension of M_{cur}. For example $M_{cur}[1]$ is the pleasure's value of M_{cur}.

Mood is a long lasting affective state and should not change rapidly. For example if a person is in a highly positive mood, a brief negative emotion cannot make this mood negative. Equation (5) prevents rapid changes in the current mood. Also, this equation causes either push or pulls events.

In order to assign a name to the current mood which indicates its intensity, distance from the current mood to the PAD space's zero point is measured. The maximum distance is $\sqrt{3}$=1.73, because the points in the PAD space take value between -1 and 1. This distance is divided into three parts and use Table 3 for assigning a name to the current mood. For instance, if current mood is exuberant and its position in the PAD space is (0.2, 0.4, 0.1) then current mood is slightly exuberant.

D. Color Selector

After specifying a current mood, it's time to select appropriate colors for the current mood. An appropriate color to cope with a mood, especially a negative one, is a color causing an opposite mood. For example, when a user is in bored mood (-P-A-D), we should select colors that cause excited mood (+P+A+D). For mapping PAD mood space to colors Table 4 is used [17].

In Table 4, colors are based on Hue and Tone system, and the RAL Design System is applied. In the RAL System Design, each color is distinguished by 3 parameters of lightness (L), chroma (C) and hue (h); (CIELAB LCh). This color system is in form of a sphere having three axes. The L axis represents lightness and is vertical. Lightness starts from 0 (absolute black) and continue to 100 (absolute white). The C axis represents chroma or saturation. Chroma ranges from 0 at the center of the circle (completely unsaturated) to 100 or more at the edge of the circle (very high Chroma). The h axis is known as hue and starts from 0 and continues to 360 (around the circle). Hue specifies type of color. For example, if hue is 30, it means that color is red. Fig. 7 shows the LCh color space [18].

The color parameters for the colors in Table 3 are represented in Table 5 and Table 6.

TABLE III. MOOD INTENSITY

Distance to PAD space's center	Intensity
0 ~ 0.57	slightly
0.58 ~ 1.15	moderate
1.16 ~ 1.73	fully

TABLE IV. MAPPING PAD SPACE TO COLORS

P	A	D	Color
+	+	+	
+	+	-	
+	-	+	
+	-	-	
-	+	+	
-	+	-	Not specified
-	-	+	
-	-	-	

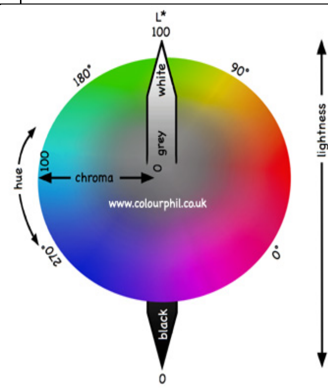

Figure 7. LCh color space

TABLE V. CHROMATIC COLORS USED IN MAPPING PAD SPACE TO COLORS

Hue	Dark	Deep	Vivid	Brilliant	Light
30 (red)	L: 30, C: 30	L: 30, C: 45	L: 40, C: 60	L: 50, C: 40	L: 70, C: 30
80 (yellow)	L: 60, C: 40	L: 60, C: 70	L: 80, C: 90	L: 80, C: 60	L: 80, C: 40
160 (green)	L: 30, C: 30	L: 40, C: 45	L: 50, C: 60	L: 40, C: 40	L: 70, C: 20
260 (blue)	L: 30, C: 20	L: 40, C: 30	L: 40, C: 45	L: 60, C: 35	L: 70, C: 25
320 (violet)	L: 20, C: 25	L: 30, C: 35	L: 40, C: 40	L: 50, C: 30	L: 70, C: 20

TABLE VI. ACHROMATIC COLORS USED IN MAPPING PAD SPACE TO COLORS

	Black	Dark	Medium	Light	White
Achromatic color stimuli	L:0, C:0	L: 30, C: 0	L: 50, C: 0	L: 70, C: 0	L:100, C:0
Warm grays hue (80)		L: 30, C: 10	L: 50, C: 10	L: 70, C: 10	
Cool grays hue (260)		L: 30, C: 10	L: 50, C: 10	L: 70, C: 10	

Now, suitable colors regarding the current mood could be chosen. These colors should be selected for the background and foreground of user-interface. It's important to select colors which their combination is suitable. Table 7 represents preferred foreground colors for important background colors [19].

TABLE VII. PREFERRED FOREGROUND/BACKGROUND COMBINATIONS

Background	Acceptable foregrounds
Black	Dark Cyan, Light Green, Dark Yellow, Light Cyan, Dark White, Light Magenta, Light Yellow, Light White
Blue	Dark Green, Light Green Dark Yellow, Light Cyan Dark White, Light Yellow Light White
Green	Black Light Yellow Dark Blue Light White
Cyan	Black Light Yellow Dark Blue Light White
Red	Light Green Light Cyan Light Yellow Light White
Magenta	Black Light Cyan Light Yellow Light White
Yellow	Black Dark Blue Dark Red
White	Black Dark Blue

IV. IMPLEMENTATION

AUBUE was implemented in the form of a shape guess game. In this game, shapes are shown one by one and user must type the name of each shape. When the user is typing the shape's name, the keyboard interpreter elicits keyboard parameters. For example, to elicit typing speed, a timer which starts when a shape showed and stop when the user typed correct or wrong answer is used.

As represented in Fig. 8, current mood of a user is detected as slightly anxious (-P+A-D), and both of background and foreground colors has been changed to appropriate colors to cope with this mood.

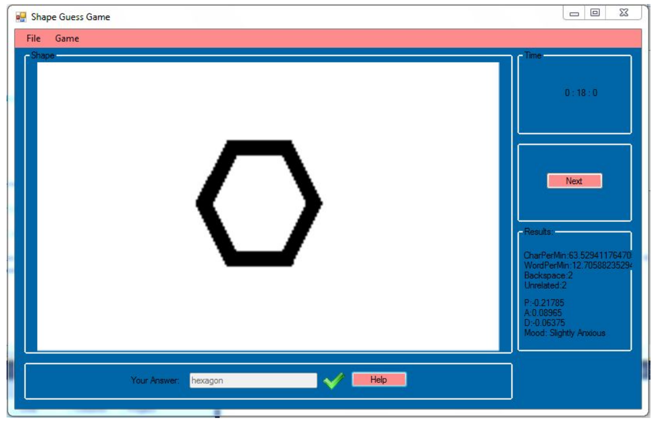

Figure 8. Implementation of AUBUE

V. CONCLUSION

In this paper, we introduced the AUBUE, architecture for intelligence user interfaces. In this architecture, colors of user interface change according to the emotional states and mood state of users. Emotional states of a user are specified according to his/her interactions with the keyboard. For modeling emotional state of the user, we used joy, distress, and angry in OCC emotion model. After detection of emotions and their intensities, the current mood of the user is updated, and finally appropriate colors for the user interface are selected regarding user's current mood.

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