Mapping emotion to color

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ABSTRACT

The sensitive artificial listener (SAL) project is interested in ways to elicit emotions from humans. This can be done in several ways; one of them is by presenting colors. The use of colors to stimulate a certain feeling, may it be calm, aggressive, energetic, happy etc. This paper tries to provide a method for generating colors to elicit a certain feelings based on an emotional state from the SAL agent. This is done by mapping the emotional state of the agent into a color. The emotional state is represented by two values Pleasure and Arousal these two form the two dimensional space in which the distinctive emotions can be placed. The emotional state of the agent is a point (coordinate) on the same 2d space, and by looking at the position of this point the current corresponding color can be calculated by interpolating between the emotions on the 2d space. The end use is to use colors elicit a certain feeling in the user, how the agent uses this to his advantage is up to the agent. Examples of use can be, the agents virtual body changes color (expressing his emotion), or the complete virtual world gets a change in color glow (a narrow emotional commitment), or a more physical example the lights in your house change colors (a broad emotional commitment).

Keywords

Emotion, color, emotional state.

1. INTRODUCTION

This research is part of the Sensitive Artificial Listener (SAL) project. The SAL project is aimed at eliciting emotions from the user. To do this we need to understand which emotions there are and how we have to present them to the user, in such a way that he/she is involved with them. The project is currently in its first stage and therefore it tries to be as basic as possible. Although SAL refers to one entity (one agent), the world that he inhabits is also occupied by several more agents, each with their own personality. The reason for the agents being there is for them to live in this world and for the user to have a certain goal to be done. This goal can only be achieved by using the agents. The communication between the user and the agents are based on actions and their emotional state. The agents can express their feelings/emotions through colors, behaviors and actions. Therefore it is important to know the meaning of a color in a certain situation. This paper tries to support the SAL project in finding an answer to a basic question 'What color does an emotion have'. This directly leads to a more technical question namely, how to perform the mapping of an emotional state into a color. The emotional state is presented by two values, one value for pleasure and a second value for arousal. These values are combined into a vector <pleasure, arousal> which can be plotted on a 2 dimensional field.

To realize this, a model is developed which takes as input an emotional state (in this case the vector) and gives a color as response. This way we can dynamically see which colors represent what emotions. The research in color-emotion is nothing new and follows a long path down in history back to Aristotle-Plato[9].

Colors are for many people an important source of information, they influence us, we make decisions based on what we see and how we interpret them. To achieve a simple yet good extendable model the main question is divided into the following sub questions.

1. First, what are the universal relationships between colors and emotion? The main problems one can see here are cultural difference, personal difference, society etc. but there are colors that share common meaning among a lot of people.
2. Second, The mapping of an emotion to a color.
3. Third and the last part, how can the model be adaptive to personal preferences. Therefore can include cultural differences and other factors.

At the beginning we want to know what emotions there are and foremost what are the basic emotions? The six basic emotions identified by Ekman and Friesen [14] and by looking at the way they are used by The Duy Bui [15] gave a way of thinking about the possibilities of how to create a model which supports several emotions. However this paper is about colors and emotions and not facial gestures and therefore it can keep its model focused at just one attribute. The main point for looking at what the basic emotions are, is to identify colors with emotions, because colors can have a positive but also negative effects and they can feel warm or cold.

2. METHOD OF RESEARCH

The first part of this paper is about the literature research. It discusses several color-emotion theories/models and compares them. Starting with color theory from Goethe, then the

extensive color-meaning list from Claudia Cortes, the experiment conducted by Naz Kaya, a commercial product called Color Wheel pro, a model by Shirley Willet and the work from Yan Xue who worked on the Philips ICat.

The second part is about the mapping of emotions to colors and the proof of concept. The mapping will first be explained by the use of the circumflex model of affect (Rusell 1980). Then a more formal description is given of how the mapping of emotions to colors will work, thus explaining the model.

The proof of concept is a program which makes use of the model and is able to show with the use of certain emotional state parameters a color and a simple facial gesture. The simple facial gesture is used as reference for the color.

3. LITERATURE RESEARCH

The literature research is based on certain domains, first a part from history with Goethe and his color theory, then a more global overview of color-meaning from Cluadia Cortes, followed by an user test conducted by Naz Kaya, the view of a Shirley Willett, a commercial product Color Wheel Pro mostly for designing websites, and at last a small implementation example from Yan Xue.

3.1 Johann Wolfgang von Goethe

In his work "Color Theory" (Zur Farbenlehre 1808-1810) [8], there are several interesting parts he wrote about the meaning of color especially in part six "Sinnlich-sittliche Wirkung der Farbe".

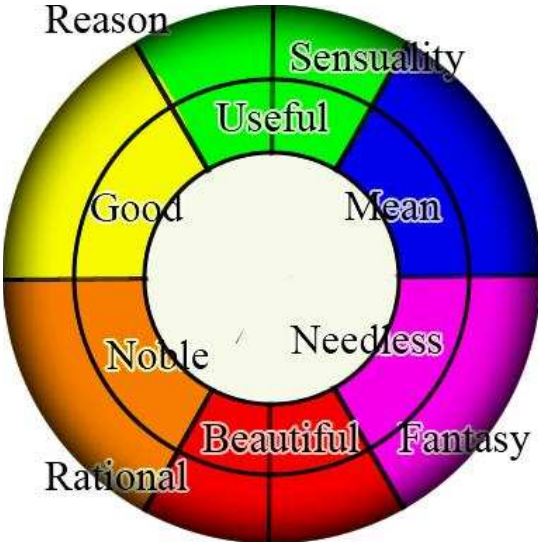

Figure 1. Goethe ColorCircle

He categorizes colors into a plus part and minus part. The plus part or positive part are the colors yellow, red-yellow (orange) and yellow-red (vermeil) these colors stand for arousing, lively and ambitious (regsam, lebhaft, strebend).The negative consist the colors blue, blue-red and red-blue, these colors stand for restless, yielding and yearning (unruhigen, weichen und sehnenden Empfindung). Table 1 shows a summary of color-meanings from Goethe. The exact interpretation for each color is however difficult, for he likes to describes the colors with examples instead of direct corresponding words, and it can therefore slightly differ from other views. Even more disturbing is his part about the color red, it seems as if it is only about purple (paragraphs 792-799).

Table 1. J.W. von Goethe color summary.

Color	Positive trait	Negative trait	Emotion
yellow	purity pleasant	unpleasant (green, "unreinen")	joy
yellow-red	energetic,	irritating	powerfull
red-yellow	energetic, warmth, passive		happiness
blue	comfort	void cold	sadness
red-blue	active	restless	discomfort
blue-red	more active	more restless	same as red-blue, but more negative
red	seriousness, dignity, grace/charm		faith
green	calm, neutral		calm

Combinations of colors are also discussed in his work (for example he states that yellow favors red-blue) however this research is only concerned about one valued color as output for an emotional state. It would be however an interesting question to produce these combinations to gain the right effect in a certain situation. The right effect would be the expected emotional feeling elicited by given colors.

3.2 Claudia Cortes

Research performed by Claudia Cortes delivers an extensive list of attributes of positive and negative traits [1]. It goes further then only summing some emotions for the specific color, but also what is commonly associated with the color. This however makes it difficult to abstract the different colors into their most intense emotional meaning. Still it has greatly influenced the chosen emotion meanings and location onto the special grid (which is the main part of the model)

A summary of the traits presented on her page is shown in table 2. Not all traits are shown; only those who overlap with used other sources, for a complete list visit.

Table 2. Claudia Cortes color extraction.

Color	Positive trait	Negative trait	Emotion
Red	active, emotional	offensive, embarrassed	anger, love
Orange	ambition	tiring	joy, determination
Yellow	lively, energetic	cautious	fear, Happiness/joy
Green	calm, neutral	greedy, sick	faith, greed
Blue	faithful, traditional	depressed	confident, sadness
Purple	leadership, passive	arrogant, sorrow	introspective, melancholic

This only lists a very small part from her site, and it contains only the information that is used in the proof of concept. On her page there is also information about symbolism, but that is out of the scope in this research.

3.3 Naz Kaya

The research done by Naz Kaya [12] shows how difficult it is to state things about colors and the way we interpret them. The results for the test were presented in frequency table. The emotion - color combination with the highest overall score from the test was taken into table 3.

Table 3. Naz Kaya color summary.

Color with Munsell notation	Emotion
Red (5R 5/14)	anger, loved
Yellow (7.5Y 9/10)	happy
Green (2.5G 5/10)	comfortable, hopeful, peaceful
Blue (10B 6/10)	calm
Purple (5P 5/10)	tired
Yellow-Red (5YR 7/12)	energetic, excited, no-emotion
Green-Yellow (2.5GY 8/10)	disgust, annoyed

Table 3. Naz Kaya color summary.

Color with Munsell notation	Emotion
Blue-Green (5BG 7/8)	annoyed, confused, sick
Purple-Blue (7.5PB 5/12)	calm, powerful
Red-Purple (10RP 4/12)	loved, no/emotion
White (n/9)	empty/void, innocent, lonely, peaceful
Gray (n/5)	bored, confused, depressed, sad
Black (n/1)	depressed, fearful, powerful

It must be noted that some frequencies for a given emotion-color combination came very close together; they are therefore both added into the table.

The table header mentions the Munsell color system or better said the Munsell color tree [4][6], this is an industrial standard and it describes colors in a 3 dimensional way <hue, chrome, value>, as shown in figure 2, and is probably the most used color system. A well know product based on this system is Color Wheel Pro.

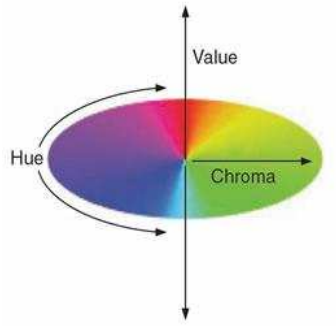

Figure 2. The Munsell color space.[7]

The Munsell Color system is based on the Newton color circle [5][9], but handling every aspect of color systems is a bit out of the scope.

3.4 Color Wheel Pro

The commercial program Color Wheel Pro [3] also gives certain definitions of what colors are to us. Based on the color-theory they provide a professional way of mixing colors.

Taken from their web-page the following table 4 is produced, summing the meaning of colors.

Table 4. Color Wheel Pro color summary.

Color	Positive trait	Negative trait	Emotion
Red	passion	offensive, courage	emotionally, intense, aggressive/anger
Orange	wisdom, desire	domination, distrust	joy, happiness
Yellow	freshness	sickness, jealousy	joy, happiness
Green	good health, growth	disorder, sickness, envy	greed
Blue	understanding	depression	trust
Purple	nostalgic, romantic	frustration	sadness
White	purity, safety	(not given)	(not given)
Black	elegance	death	power

Note on the summary, this is a short list, there are some traits that overlap each other and some that are even arguable about their exact meaning (if its more context depended). Looking at the given meaning of a color a suitable word was chosen that corresponds it the most.

3.5 Shirley Willett

A table of colors with their properties defined by Shirley Willett [2], the model presented is used as a guideline for the basic emotions with their colors. The model that she presents, figure 3, has many overlaps with the data found from Claudia Cortes work with the only difference it reduces the list to the basics.

Figure 3. Shirley Willett, Color codification of emotions.

The outside circle contains the positive traits, the second circle presents the six emotions, the inner circle are the negative traits, and the inner spot is depression which she has chosen as being the mixture of all negative traits. To keep it consistent, the information is also shown in table 5.

Table 5. Shirley Willett color table summary.

Color	Positive trait	Negative trait	Emotion
Red	enthusiasm	rage	anger
Orange	pride	disgrace	shame
Yellow	awareness	panic	fear
Green	satisfaction	hoarding	greed
Blue	clarity	racing	confusion
Purple	leadership	impotence	power

3.6 Yan Xue

In his master thesis on the Philips ICat he spends a few words on the use of color support. The ICat has the possibility to use certain colors (blue, red, green), these colors are elicited by color LEDs placed in the ears and the feet.

Although he doesn't say much about these colors, he makes primarily use of the so called warm/cold colors and made a

model upon these colors. The model is based on Russels circumflex model and is shown in figure 4

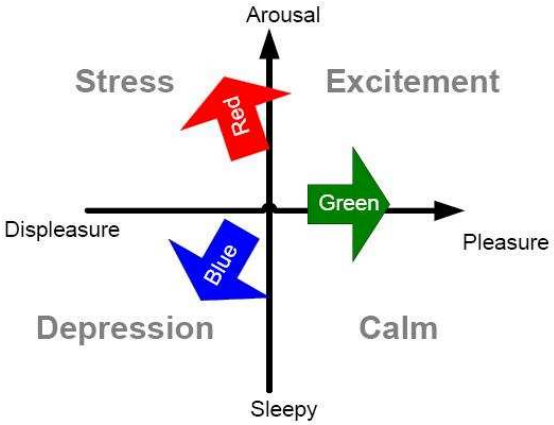

Figure 4. Yan Xue color distribution.

The reason for taking notion of this concept is because apart from the other models/theories this concerns a physical object which is capable of interacting with its user [11].

3.7 Comparing the different models

The data gathered from this literature research is strongly filtered in such a way that it is usable in the proof of concept. The amount of color meanings is deep and wide which makes it hard to work with. The most valuable part is the research conducted by Naz Kaya, it provides a good view on what meaning colors can have. It is strongly supported by Claudia Cortes work for it inhibits almost all parts of the outcome into the basic colors. Goethe's work however is difficult to place, it has some certain degree of truth in it but it is not easy to confirm. Shirley Willets model however shows a compact model giving clear answers to what a color can be. And the last model by Yan Xue shows a very simple way of how to interpret the three basic colors RGB.

One thing is surprising, it doesn't have a color. Although the word "surprise" is a basic emotion (as Ekman says) it is not explicitly mentioned with a color.

4. MAPPING OF EMOTIONS TO COLORS

Here the mapping is described, by identifying the input, the procedure of mapping and gaining the desired output.

4.1 Input and output

Before an emotional state can be mapped into a color, it must be clear what defines an emotional state. Taken from the same idea as used by Cythia Breazeal [13] for defining the emotional expression in an sentence, the emotions can be placed in a multidimensional space which comes close to the same idea. This corresponds again with the idea of Russels circumflex model of affect [10].

In this case arousal and pleasure are used as axes, figure 5. This defines a 2D plane on which the certain emotions can be placed. The scale of the 2D plane and the exact placement of the emotions is not the prime concern of this research, and is an open issue.

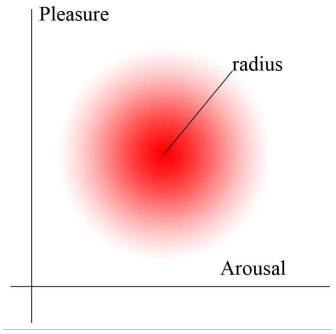

Figure 5. The main axes of the grid.

With this installment we can separate the different emotions from each other and give them their own attributes, which are in this case colors.

4.2 Information on the grid

As mentioned before the placement of emotions is not the vital point but it is necessary to place them logically. The placement and the spread of the emotion is a very delicate thing to do, and the placement will always be arguable for emotions, for they can be quite different from person to person. However the research conducted by Russel and Bullock [10], provides a good model, figure 6, to work with.

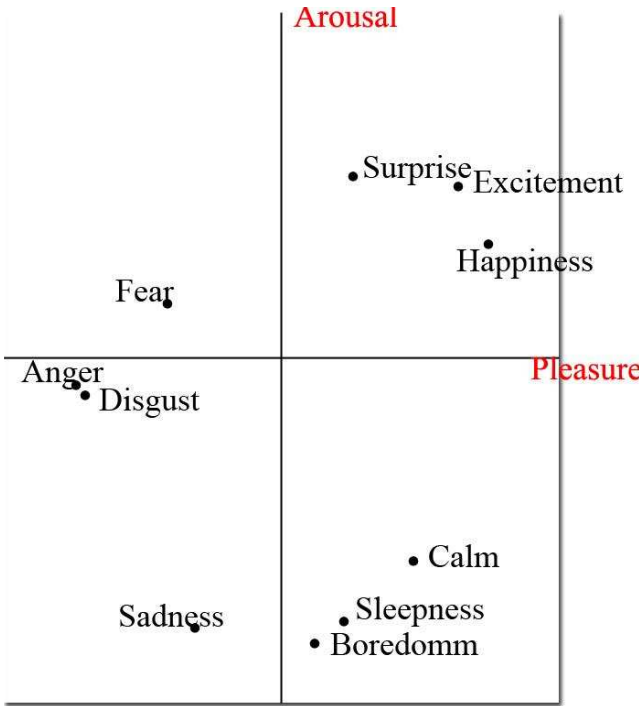

Figure 6. Two-dimensional scaling solutions of 10 facial expressions of emotion.[10]

The following definition applies:

There is a set of emotions
an emotion has a name, a color (RGB notation), a set of coordinates and a radius of affect.The use of multiple coordinates makes it possible to have a better control on the area an emotion occupies.

The radius has a fading effect, this ensures that emotions that overlap each other are interpolated correctly. The closer one is to the emotion the more the color will be present.

Initially the neutral emotional state has the same neutral color gray as from the Naz Kaya test (note that there are other options for a neutral color) which has Munsell color N/7.

To determine the color of a non-direct emotional state the following is defined.

E is finite set of emotional states
$E = \{e, e', \ldots\}$

e is an emotion defined $e = \langle coordinate, radius \rangle$

$coordinate = \langle x,y \rangle$ defines a position on the 2D plane

radius defines the area of effect using linear interpolation

Let p be the coordinate of which the color is to be determined.

R^e is the subset of R containing only those emotions that contain coordinate p in their radius of effect.

To check if p is within an emotional-state's *radius*
$difference = coordinate_e - coordinate_p$
$distance = \sqrt{(difference_x)^2 + (difference_y)^2}$

e will be added to the set R^e if $distance < radius_e$

Let

$color = \langle R,G,B \rangle$ be a color and *cfinal* the desired color.

Initially *color* will be equal to a default neutral color. Then for each emotion in R^e, the following steps are taken.

- The first step is to calculate the difference between the current color and the emotional color.

Let *cdif* be the color difference between the current color (*cfinal*) and the emotional color. The RGB values can differ in format, in OpenGL for example the values for RGB are float values between 0 and 1. However another format very known is an integer value range from 0 to 255. (24bit, usually plus blending makes 32bit)

Thus if an emotional color is $\langle 157, 255, 128 \rangle$ and the current color *cfinal* is $\langle 128, 128, 128 \rangle$ then *cdif* will be $\langle 157, 255, 128 \rangle - \langle 128, 128, 128 \rangle = \langle 29, 127, 0 \rangle$

- The second step is the intensity of the emotion color; this determines how much the color is changed into the emotional color.

intensity = 1 - *distance* / *radius*

distance is the distance between *p* and the current emotion (coordinate) and *radius* is the given radius from the current emotion.

- 3rd step. Finally update the color.

*cfinal(R) = cfinal(R) + difference(R)*intensity*
*cfinal(G) = cfinal(G) + difference(G)*intensity*
*cfinal(B) = cfinal(B) + difference(B)*intensity*

The overall function is then $f(x,y): p \rightarrow color$

5. PROOF OF CONCEPT

The program is written in Microsoft Visual C# 2.0 and makes use of OpenGL for its graphical output. The main reason for using OpenGL is because of the ability to easily extend the model to a 3D environment.

5.1 The plain grid

The grid in this case is kept 2 dimensional and uses the Arousal and Pleasure parameters as axes and has a fixed bounding area of -10 by 10. The real bounding area however is defined by the emotions with their coordinates, the fixed bounding here is only an implementation choice for drawing a nice grid. On the grid the emotions are placed by coordinates, the chosen emotions are emotions for which a distinctive label is known (Mixture between Naz Kaya and Russell).

5.2 The use of colors

Primarily the same colors are used as from the Naz Kaya research and used a small program called BabelColor to convert the Munsell color notation into RGB notation.

Emotions that overlap in radius are being interpolated, such that the color of each emotion is mixed into each other. The question that now arises is, are these mixed colors correct for the specific <Pleasure, Arousal> coordinate. The user test for this is yet to be done (and is not part of this paper).

5.3 The use of a face

During the making of the proof of concept, there was no reference with the color, therefore a simple facial gestures, based on Bezier Curves, was also implemented. It is not as advanced as the facial gestures as from The Duy Bui or from Breazeal but they are sufficient. They are easily to change, since the face consists of eight Bezier lines. Each line has a start point and end point and two control points to generate the curve. Each basic emotion has its own "face" and the faces are interpolated between overlapping emotions, just like the colors.

5.4 Onscreen

The user is able to move a cursor, figure 7, on the grid, figure 8, and when a mouse click occurs the current face will be updated with a new color and face gesture.

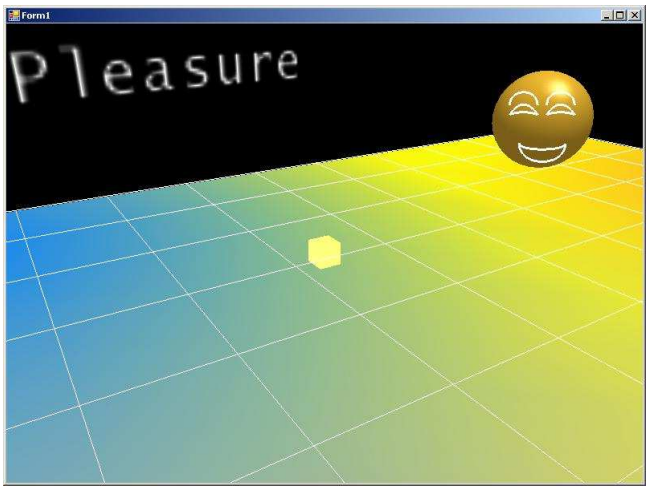

Figure 7. Close lookup on the cursor, the yellow cube

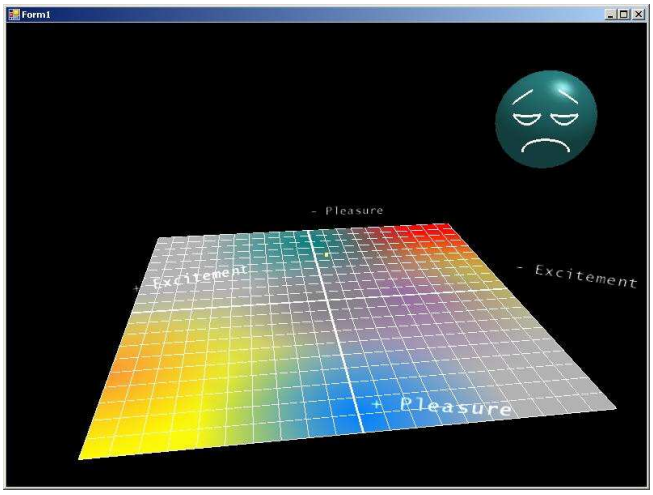

Figure 8. Overview of the grid

5.5 Extensibility and personal adoptions

With the 2D plane it is already difficult to identify where certain emotions are situated, however a 2D plane is in most cases not enough to define the more subtle emotions, therefore a third axis would be the best addition, any further and it would become too complex and disorderly. A 3 dimensional space would still be presentable on the screen. The meaning of the third axis could be “stance” or “experience”[13]. As in “how well is it experienced by the user”. To explain the axes one can say the following: is the current state arousing, does one have pleasure and how intense does one experience it.

A new problem comes to rise with certain spaces where there are no emotions defined, for example an high arousal state with adequate pleasure but absolutely no experience (a negative value), is that possible?

6. CONCLUSION

Coming back to the questions stated at the introduction.

1. What are the universal relationships between colors and emotion?
   This paper has shown a couple of model/theories about color-meaning they all have some overlap but they also show a great deal of vague interpretation. This is because the color is situation, history, personal dependent.

2. How is the mapping done?
   The mapping is done by looking at models that already exist for other attributes; by combining the color-meaning research and the facial expression research.
   The advantages of this method are that it follows ideas that have been researched thoroughly. It also is an easy compact way to gain a fast result to work with.
   The down side of this approach is however the use of a radius which is not known for the emotions, a better solution would be defining the relations of the emotions towards each other.

3. How can it be extended?
   The biggest advantage would be an 3rd axis. More extensibility is however further research.

From observations by using the program it proofs that the proof of concept program is an easy and maintainable way to do fast user testing. However it certainly give rise to certain questions. Although the model gives an easy way to test certain attributes on their truth. In this case user tests can be conducted by setup the emotions on the plane and let the user decide if they agree on what’s being presented to them. But there is a limitation in technical sense. For example when using the Munsell color system, there is no guarantee that it will show the exact color from the Munsell system since the color output is depending on the software (drivers, OpenGL) and the hardware (Graphics card, monitor) which differs from system to system.

7. FURTHER RESEARCH

The placement of the several emotions in an 3D space, this can provide a great advantage (this is yet to be proven) for more flexibility.

To gain an even more flexible adaptation and automatic adaptation of the emotions (moving or flexible emotions), instead of static adjustments, would be required. An idea is to use a neural network to adjust the preferences of color for a certain stimuli. This stimuli can be several things in such a way emotion color can change upon other influences, direct surrounding, in order not to get the wrong mixture of colors.

The use of a radius to determine the affect range of an emotion is not really a solution, it must use some other technique to interpolate between the several emotions. Thus the emotional transitions between the main emotion points without the use of a radius. This would alsovercome the issue of having places with no emotional influence, as stated in section 5.5.

Acknowledgement

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