Designing a 3D Painting Gallery based on Facial Expression

Saeedeh Bayatpour and Carman Neustaedter
School of Interactive Arts and Technology, Simon Fraser University
250 – 13450 102nd Avenue
Surrey, BC, Canada, V3T 0A3
[sbayatpo, carman_neustaedter]@sfu.ca

ABSTRACT

This work presents a virtual painting gallery that gives the user the ability to move around the paintings with three goals: navigating by facial expression, giving user valuable feedbacks about his/her facial expression and investigating the effective of emotional content of paintings on users. The designed system can be used to assess emotional state of the user through facial expression using a computer vision system. The data is used for navigation in a virtual environment. In this virtual painting gallery, paintings are classified in two categories (happy and sad) based on their emotional content.
To evaluate the system, I conducted a pilot study. The results of interview with a few participants in the pilot test show that user can easily control the navigation in the virtual gallery and getting appropriate feedbacks. On the other hand, visiting images with happy or sad contents cannot strongly affect user's emotional state.

The paper's accompanying video is here:
https://www.youtube.com/watch?v=NyW2XXKxT3I&feature=youtu.be

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Facial Expression, Emotion, computer vision system, 3D painting gallery

INTRODUCTION

Emotion is one of the most important concepts in psychology, human computer interaction and many other areas. Facial expressions are one of the most important ways of conveying emotion, and are controlled by facial muscles and skin movements [13]. Hess et al. [10] investigated facial reactions to the emotional facial expressions of people as either affective or cognitive. Erickson and Schulkin [11] described the relationship between perception and presentation of facial expressions as cognitive processes. Facial expression can be analyzed through image processing techniques or facial electromyography [13].

In game design and virtual environments, facial expression can indicate the emotional response of the user to different features of a game and the environment and thus is used to provide feedback for developers to improve their future designs [14-18]. The purpose of this work is to use such feedback loop in real-time for controlling the virtual environment system. The environment used in this work is a painting gallery. The visitors are eager and interested to watch as many paintings as they want. Navigation through a virtual gallery is usually done with computer mouse or keyboard arrow keys. However, we believe integrating facial expression with the system for navigation in a virtual gallery is an innovative approach that provides more engagement and interaction of the user with the system. In the case of virtual painting gallery using facial expression for navigation in a specific direction can be used to give the user feedback about his/her facial expression based on the visited kinds of paintings (happy or sad). The system can also encourage user for changing the facial expression with full control in the direction that he wants. For example, if the user realizes that he is mostly looking at sad paintings, it means that he has a sad facial expression. Therefore, the visitor may decide to change his facial expression to happiness that leads to looking at some paintings with happy style. This system can be placed in home or work environment for entertainment and also to give the user feedback about his/her facial expression.

Indeed we have three goals with designing such a system: 1- Using facial expression for navigation through the virtual environment 2- Using the system for getting feedback about user's facial expression 3- Investigating how effective are the paintings to change visitor's emotional state based on the emotional content of the paintings.

One of the most important aspects of virtual environments is navigation. Usually, designers use keyboards, arrow keys, pad tracks and mouse for navigations. We believe facial expression can be a new way for navigation in a virtual environment. Using facial expression in addition to

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traditional kinds of navigation opens up new ways of interaction with a system. In the current work, visitors actively control navigation in the virtual environment through their facial expressions. Such system can be helpful for people with disabilities who cannot easily use input devices such as keyboards or mouse.

Regarding our second goal, the facial expression is an important factor to convey emotional state of people to others. Therefore, we believe we can get and analyze the facial expression data through this system and give user the corresponding valuable feedback based on the response of the system to user's facial expression. In other words, an important part of the interaction between user (visitor) and the system (virtual painting gallery) is associated with the facial expression of the visitors and the feedback that user receives from the system. The response of the system to specific facial expression is leading the visitor toward happy or sad painting with the corresponding emotional content. The system informs user that the visited paintings were happy or sad ones.

The third goal of the system is relevant to the nature of the visual art pieces in the painting gallery. It is clear that the paintings convey some emotions directly and indirectly to the users. I have selected two series of paintings with happy and sad emotional content. I tried to provide a connection between the direction of movement and the related facial expressions. For this purpose I put images with corresponding emotional content in the direction that is matched with the user's facial expression. For example, if the user shows happiness and it makes him to move in right direction in the virtual gallery, he is able to visit paintings that are classified as having happy emotional content and vise versa. The system is designed in a way that if the user decides to change his current emotional state based on the received feedback from the system, the emotional content of the paintings can help him. For example, if the user finds out through the system's feedback that his current facial expression is more toward sadness, he can consciously change his facial expression to happy face and watch some paintings with happy emotional content. If the paintings that are used are strong enough to convey their corresponding emotional content to the user the system can achieve this goal. This approach is usually used by art therapist to change a patient's mood by asking them to watch some art pieces with a desired emotional content.

We conducted a pilot study to find out how effective the system was for navigation through paintings based on facial expression, interacting with the user and giving valuable feedback about user's emotional state. Also, we were looking for the effect of paintings on viewer's emotions. We would like to know if the images have strong effects to modify the user's emotions. The results show that participants can effectively use their facial expression for navigation in the direction that they want. They also stated that the system feedback is relatively informative about their emotional states. However, no strong effect was found on the user's emotional state.

Overall, our prototype points to new approaches and challenges in designing a system in virtual environment that utilizes user's facial expression as an input for interaction with the system and giving feedback to the user about emotional states. The results of this study can be used for designing a better and more immersive system for interaction with the user with the purpose of giving feedback.

In this paper, first we outline the related work on this study. Second, there is a section about implementation of the prototype system followed by results and conclusion.

RELATED WORK

To give a firm theoretical and practical basis to this study, we outline the related literature on this interdisciplinary research that includes human emotions, the relation between visual art and emotions and virtual environments.

Theories of Emotions

Emotion is a broad concept in psychology and there are different ways of measuring, evaluating and studying it. El-Nasr et al. [1] provided an overview of different aspects of emotions and various approaches to measure it. They refer to emotional affordance that is highly related to the concept of emotions. Emotional affordance is defined as "… *a wide range of affective elements that could provide opportunities for emotional reaction*". El-Nasr et al. [1] showed how color, lighting, environment design and narrative affect the emotional response of viewers in a virtual 3D environment. El-Nasr et al. [1] also introduced four specific components of emotions: behavioral reactions, expressive reactions, physiological reactions, and subjective feelings. Emotional assessment can focus on one of these components or any combination of these components. They also showed that the process of assessing emotions can be conducted through various psycho-physiological approaches such as: fMRI, EEG and EMG or a qualitative approach. All the psycho-physiological methods are roughly costly; in addition to the needs of an accurate device, the data needs lots of post processing to remove noise and obtain useful information. El-Nasr et al [1] described that self-reporting is a common qualitative approach for assessing the emotional state of people that is conducted through surveys, interviews, and think-loud protocols. Also, observations and analysis of non-verbal behaviors is another qualitative approach.

Robinson [2] focused on the sources of emotion. She argued that "emotions are not cognitive judgments but involve possibly unconscious appraisals that are specifically focused on our current actions, action tendencies, or goals. This appraisal is accompanied by physiological changes (e.g. increased heart rate, sweating)". She believes a stimulus evokes the same kind of initial emotion in

different individuals; "their overall reactions may be entirely different because their cognitive monitoring is strongly individualized." This individuality is related to memory. This part of the memory is "a memory of physiological reaction patterns" such as fast heart rate, high blood pressure, and high temperature. Experience emotion is a part of emotional perception that is related to past emotional experiences.
These literatures are useful to more deeply understand the concept of human emotions. In this study, a component of emotion that is expressive reactions is used by assessing facial expression data.

Facial Expression
Facial expression is one way of expressing and conveying emotional state of individuals. Facial expression occurs because of movements of facial muscles and skin. Facial expression can happen both voluntarily or involuntarily [13]. In visual spaces such as game design and virtual environments, facial expression demonstrate the emotional response of the user to the content and its different features Therefore, it provides useful feedback for designers about designing the visual space [14-18]. Philipp et al. [23] used facial electromyography to indicate immersion in virtual environment. They also demonstrate the relationship between presence of virtual humans in the environment and the sociality effects of it on facial expressiveness.

Facial expression can be analyzed through image processing and computer vision techniques [12]. Also, facial electromyography (fEMG) is another common approach to detect and measure the facial muscle activities through the corrugator muscle that is associated with frowning, and the zygomaticus muscle, which is associated with smiling [13]. Facial expression is commonly used to characterize happiness and sadness emotions. For example, facial expression is used to test the audience responses to new products, computer games and immersion in virtual environments.

The Relationship between Visual Art and Emotions
Berlyne [3] discussed the relationship between visual art and emotions. He claimed that each stimulus has a series of factors that have a quality of arousal potential. These factors are called *collative variables* such as complexity, novelty, uncertainty and conflict. He conducted two experiments to assess the effect of complexity on interest and pleasure. The results of this study show that there is a non-linear relationship between emotions such as interest and novelty and the complexity of the art piece.

Silvia [4] assessed appraisals theories. According to this theory, emotions can be differentiated based on different groups of evaluations. These groups of evaluations are appraisal structures, which are different for each emotion. For example, appraisal structure of anger and interest are different. In other words, appraisal theory emphasizes on subjective evaluations as much as collative variables in Berlyne's theory [3]. Silvia [4] states that appraisal theory leads to a wide range of emotions such as happiness, shame, guilt, disgust, contempt and embarrassment in comparison to Berlyne's theory that was limited to positive or rewarding responses.

Cupchik et al. [5] determined factors that involve in aesthetic perception of paintings along with the experience of emotion. They designed a study to find more about the factors that involve in aesthetic perception of paintings along with the experience of emotion. The study was based on statistically analyzing the obtained fMIR signal data in visual art. This study showed that orienting of attention and perceptual facilitation has a significant effect in aesthetic perception of an art piece. This study is one of the rare works in the literature that focused on painting styles and aesthetic perception of the viewer that can help with better understanding of these two factors.

Also, increasing technology in digitized images has entered in many areas including art. However, there are a few works in the literature that focused on analysis of painting features or analysis of digitized images based on emotional content. Ohmi and Awata [6] investigated the effect of color and luminance feature of paintings on emotional content.

Machajdik and Hanbury [7] have suggested a method to retrieve images based on emotional content. For this purpose, they used emotions classification to index the emotions that arise in the viewer of an image. The researchers tried to develop a method to extract emotional content of the images based on low-level features of image: color, texture, content and composition. They used wrapper-based algorithm, genetic search algorithm and principal component analysis that are computational algorithms to classify images based on emotional content.

Savazzi *et al*. [8] studied the response to paintings in adolescence. In this work the researchers focused on content of paintings. The authors claimed that "adolescents may experience conventional pictorial art in a peculiar way" because the physical and psychological changes in this age may influence the perception and evaluation of art. Results showed that images from nature are more beautiful and attractive than human images for adolescents. The results of eye-tracking data showed that the human body is more attracting than the face for adolescents. However, a similar study showed that adults' attention was first on the face and later on arms and legs [9].

These studies can help to find more information about the effect of visual arts such as paintings on human emotions. This information can support the third goal of our study that is investigating how effective the paintings are in changing the user's mood based on the emotional content of the

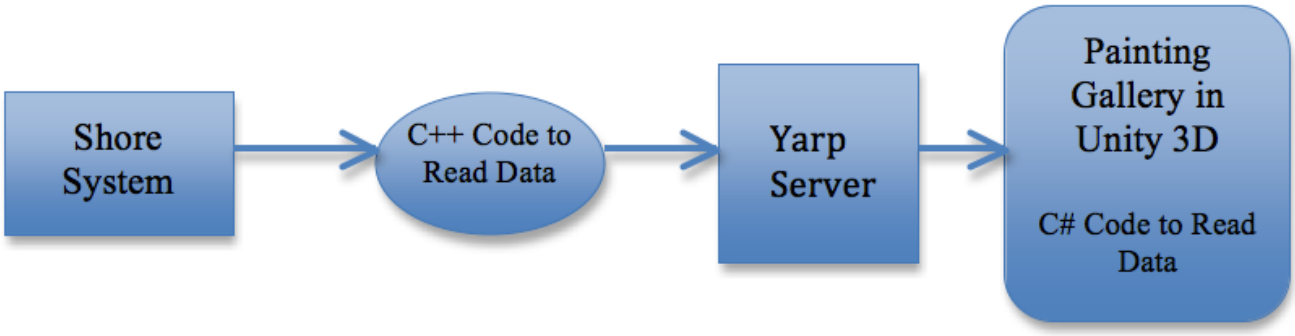

Figure 1. A schematic representation of the system.

paintings. Furthermore, in this work for the first time, we investigate the effect of paintings on people in a virtual painting gallery and through using facial expression.

Virtual Environments

Virtual realities or virtual environment is a computer simulation of a 3D environment that is used to create a simulation that responds and reacts to users in real–time. A suitable interaction between the technology and human sensorium can provide a sense of immersion and presence in virtual environments.

Schuemie et al. [19] investigated the effect of using virtual environment as a form of psychological therapy. In their research they concluded that because major gaps still exist in the knowledge related to presence, the measures that were used couldn't reliably determine the effectiveness of VR for psychological therapy. The authors recommend that researchers need to look beyond presence in virtual environments.

Slater et al. [20] investigated the role of *the body* in the real world and in the virtual world, along with the concept of proprioception as it is related to presence. Through their virtual environment, the participants use 'gestures' such as walking in place or climbing, to virtually walking through or climbing as ways to move through the virtual environments. The results show that there is high sense of presence with the virtual navigation.

Hoffman et al. [21] used functional MRI (fMRI) to study the illusion of presence between a low–tech virtual environment and a high–tech virtual environment. The result shows experiencing a strong illusion of presence in virtual environment despite all the available physical constraints.

Since the virtual environment in this study is a painting gallery, the above information about virtual environment can help for better designing the environment and provide the required factors for designing an immersive virtual environment. Also, the studies that include psycho-physiological or physiological measurement in virtual environment can help us in assessing facial expression while user is exploring in a virtual gallery.

DESIGN PRINCIPLE

As mentioned the proposed system has three main goals: navigation based on analysis of facial expression, getting feedback about facial expression and provide an opportunity to study the emotional effect of paintings on the visitors. Therefore, we tried to integrate all these goals in such a design. In the current work, the system has a simple design (it will be developed in the future works); it consists of a route with happy paintings on right side and sad paintings on left side. The user can move toward left and right side to visit paintings that are associated with his facial expression. The emotional content of visited paintings (happy or sad) gives user feedback in a simple label that visited paintings are more toward happiness or sadness. Consequently, the feedback about visited paintings is associated with the feedback about the visitor's facial expression for watching those paintings. Since paintings are classified based on their emotional content on two sides of the visitor's route, he can simply express his impression about the effect of happy or sad paintings on his emotional state.

In more details, the 3D painting gallery environment gives users the ability to move in a route to visit paintings that are associated to happiness or sadness. If user shows happiness, he can move to the right side and visit the painting with happy content and if the user shows sadness he moves to the left side to visit the painting that has sad contents. The user will move back to the center of the route responding to neutral states. The system gives the user real-time feedback on how many of the visited paintings are corresponding to happiness and how many are associated with sadness. This feedback is shown by two labels on the top left corner of the interface as shown in Figure 2.

User's happiness and sadness levels were extracted from a camera-based computer vision Fraunhofer Shore system [12]. Using Yarp server [22] as a middleware provides the ability to send real-time data from the Fraunhofer Shore system to the Unity project. A schematic representation of the system is shown in Figure 1.

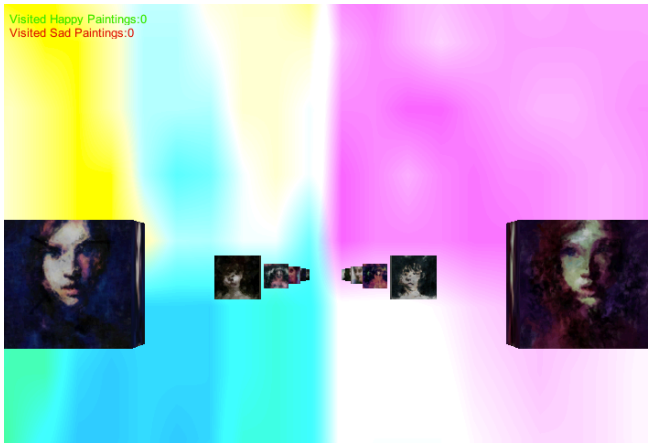

Figure 2. A representation of the virtual environment when user does not show happiness or sadness.

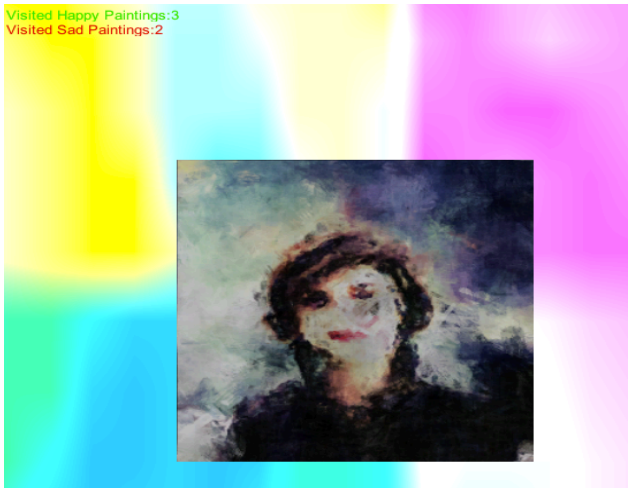

Figure 3. Watching a painting with a good resolution from a suitable angle of view needs the corresponding facial expressions (happy or sad).

3D Virtual Environment (Painting Gallery)

The system interface is a simple 3D painting gallery in Unity 3D environment. In this work, I designed a route through which visitors (represented by a moving camera in the Unity environment) can move with a constant speed. This route is on Z-axis. A series of paintings are located on both sides of the route. The left side consists of 6 paintings associated with sad emotional content and the 6 paintings on the right side are classified as happy images (these paintings are selected and tagged based on their emotional content from SFU ivislab in other studies). The user moves forward in the middle of the route when he is at neutral state (not happy or sad) as shown in Figure 2. However when he shows sadness he will move towards the left side and when he shows happiness he moves towards the right side to watch the corresponding paintings. In other worlds, users only have one degree of freedom (left or right) on X-axis to move based on facial expression. The user can pause motion using space key to watch a painting as much as he wants and use the space key again to continue moving.

Furthermore, the paintings are located in a way that the user at each position is able to watch either happy or sad painting. The user can look straight ahead in neutral state and watch both sides at an angle in small size with low resolution. However, for watching a painting with a good resolution from a suitable angle of view the user needs to show the corresponding facial expression (Figure 3).

Facial Expression Analysis

The Fraunhofer Shore system is based on a computer vision approach to analyze and characterize the facial expressions collected by a standard web camera. This system continuously returns values on a scale from 0-100 to represent the four emotional dimensions of happiness, sadness, surprise and angriness of the user as shown in Figure 4. In this work, we focused only on sadness and happiness values of the Shore system.

In order to transfer real-time data from the Shore system to the Unity project, we used Yarp server [22]. Yarp is a middleware layer that provides the ability of transferring real-time data and communication between different software systems.

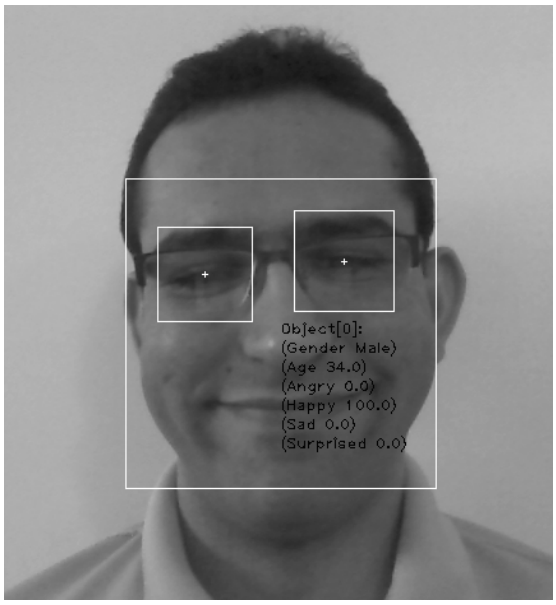

Figure 4. Using Shore system to analyze facial expressions.

SYSTEM EVALUATION

In order to evaluate the designed system, we conducted a pilot subjective experiment with 3 participants.

Experiment Design

First, the purpose of the experiment, the procedure, data confidentiality and risks were explained to the participants. Participants were asked to navigate through the system and pay attention to the system's feedback. Then, we conducted semi-structured interviews with each participant individually. Interviews were almost 5 minutes. In the interviews the researcher asked about participants initial feeling, how difficult was to navigate through the system with facial expression in the direction that they want, how was the effect of systems feedback on them? (Was it accurate and helpful?), could the system feedback encourage users to change their facial expression to move in another direction? And finally, how was the effect of paintings on their feelings?

All users agree that they can move easily through paintings with facial expression but all of them mentioned that the designers need to provide more smoothed navigation. So far, the movement and navigation has fluctuations. This is due to getting real time data from the Shore system. In future works this data needs to be smoothed. All the participants found feedbacks of the system interesting about the visited painting. In the current system the user get feedback about the content of visited paintings and based on that he will be informed about the facial expression that he had so far. One participant suggested that system could directly show the happiness or sadness level in real-time in addition to showing the number of happy or sad visited paintings. This is an interesting idea that will be implemented in the next version. Moreover, only one of the participants believe the paintings has a small effect on his emotional state, others think these paintings are not strong enough to be able to change visitors' emotional state.

RESULTS AND CONCLUSION

We designed a system for navigation in a 3D painting gallery through paintings with happy or sad content. The navigation is based on analysis of facial expression. This system provides a feedback to user about the visited sad or happy paintings and therefore about his emotional state while watching the paintings. These feedbacks can encourage users to change their emotional state to some extent by purposely changing their facial expressions. This system can be placed in a home or work environment to give users feedback about their facial expressions.

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