REAL-TIME RENDERING OF FACIAL SKIN COLOURS TO ENHANCE REALISM OF VIRTUAL HUMAN

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This dissertation is dedicated to my family especially my father Prof. Dr. Hazim Ameen Alkawaz, my mother and my best friend Miss Lijah binti Rosdi for their endless support and encouragement.

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ABSTRACT

The research on facial animation has grown very fast and become more realistic in term of 3D facial data since the laser scan and advance 3D tools can support for creating complex facial model. However, that approaches still lacking in term of facial expression based on emotional condition. Facial skin colour is one parameter that gives an effect to increase the realism of facial expression, since it's closely related to the emotion which is happens inside the human. This research provides a new technique for facial animation to change the colour of facial skin for the avatar based on linear interpolation by referring to the previous works which are (Jung *et al.*, 2009; Kyu-Ho and Tae-Yong, 2008; Nijdam, 2006), also describes facial animation and the emotion that is related to the facial skin changes like blushing, anger or even sadness. The result of colour generation is comparable to the real human expression; furthermore it's also able to enhance the appearance of facial expression of the virtual human.

ABSTRAK

Penyelidikan mengenai animasi wajah telah berkembang pesat dan menjadi lebih realistik dari segi data 3D wajah sejak imbasan laser dan kemajuan alat 3D boleh menyokong untuk mewujudkan model muka yang rumit. Walau bagaimanapun, masih kurang pendekatan dari segi ekspresi wajah berdasarkan keadaan emosi. Warna kulit muka adalah salah satu ukuran yang memberi kesan untuk meningkatkan kesahihan ekspresi muka, kerana ia berkait rapat dengan emosi yang berlaku di dalam manusia. Kajian ini menyediakan teknik baru animasi wajah untuk menukar warna kulit wajah avatar berdasarkan perantara selaras dengan merujuk kepada kajian-kajian sebelumnya iaitu (Jung et al, 2009; Kyu-Ho dan Tae-Yong, 2008; Nijdam , 2006), juga menerangkan animasi wajah dan emosi yang berkaitan dengan perubahan kulit wajah seperti malu, marah atau sedih. Hasil dari penciptaan warna adalah setanding dengan reaksi manusia sebenar, tambahan pula ia juga dapat meningkatkan penampilan ekspresi wajah manusia maya.

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FACS	Facial Action Coding System
AUs	Action Units
MPEG4	Moving Picture Experts Group
FDPs	Facial Definition Parameters
HCI	Human–Computer Interaction

CHAPTER 1

INTRODUCTION

1.1 Introduction

Facial Animation is the main element that is used to express emotion and personality of human. Computer facial animation has many applications in different aspects, e.g. realistic virtual humans with various facial expressions have been used in the industry of entertainment and edutainment. In communication applications, it can improve the interaction between users and machines by using interactive talking faces and it also can attract users by providing a friendly interface. Fred Park in 1974 was the first person, who concerned about facial animation. Park is also the first person, who used the power of 3D computer graphics in a way that it delivers the highest level of control that drives the change of face appearance. This is unique because at that time for non-verbal communication and facial expression, the applications were mainly produced by computer generated actors, as well as from rich research instruments.

As the online game manufacturing is rapidly developed, it requires users to improve, enhance a greater quality of the graphics and to achieve a significant feat in artificial intelligence. These elements lead the gaming industry to be full with priceless artificial intelligence and graphics like real photos. Initially, the games were consisted of a few numbers of polygons in characters and were supported by a few active computers in that regard.

1.2 Problem Background

The recent development in digital technology has resulted into stabilization in high-speed processing of great quantities of information. Therefore, applications, which are used for long-distance communication such as conferencing and video telephone, are being constantly developed. Distinct elements that show the advanced communication technology of these systems is the presentation and estimation of emotions using the colour of the face as well as the expression. To be precise, if the colour of the face changes, emotional changes that are related can be used for the fusion of the facial expression to change the basic emotions of visual anthrop orphic agents; this may likely play a key role vetting communication between computers and humans (Yamada and Watanabe, 2004).

Presently, the characters in the game appear to be more natural, but there are still challenges in expressing the emotions of characters in a detailed way. However, several colour model studies were only capable of proposing the facial colour model (Buddharaju *et al.*, 2005; Kalra and Magnenat-Thalmann, 1994; Yamada and Watanabe, 2004) that are based on pulse, skin temperature and real human blood flow. These mentioned techniques end up conveying the colour of the face with an increasing redness (Kyu-Ho and Tae-Yong, 2008).

Facial colours of humans are channeled to display the virtual effect, emotional estimate, facial image, remote health care and individual identification. In which, it can be regarded as one of the “the most peculiar and the most human of all expressions”(Darwin, 1872) . Blushing is a common topic of psychological study and it has been proven to be an important facial cue, which serves vital functions in an interpersonal communication (Ekman and W., 1974). The explanations of why people blush is still an issue among psychologists. Most people consider blushing in public as an uncontrollable response and most people feel embarrassed when they blush in front of others. Furthermore, blushing is a symptom that made it even worse for people who suffer from social phobia (Pan *et al.*, 2008).

On the other hand, pallor effects occur through temporary cerebral anemia and contractions of the treatment capillaries in the face due to the rising of cerebral blood flow. Pallor perhaps happens because of fear, pain or shock. This action decreases the blood flow in the face and forwards it to the brain for relief and recovery. In the literature that was done, the measurement for pallor was not found. Psychophysiological analysis for pallor is likely to provide known results because the red areas are more likely to show pallor and the time pattern of pallor. However, we have a formal monitoring that shows that the pallor has gained far less attention in the psychophysiological analysis as compared to redness. The central component of the computer model that is of interest is the identification of the main characters that reflect this phenomenon. We consider the emotions of the blood vessels and skin colour, as well as the accent sets occur (Kalra and Magnenat-Thalmann, 1994).

Former studies focus mainly on the geometric features of these alterations, for instance, the facial surface animation (e.g. skin stretching, wrinkle structures). Similarly, changes in hemoglobin concentration cause changes in skin colour. It may also because of the reaction of histamine or other skin conditions for example blushing and rashes. Blushing, specifically, consists of a number of emotions such as joy, shame and arousal. Regardless of its ability to convey emotion, the dynamic changes that occur in skin pigmentation are mostly ignored by present skin appearance models (Ersotelos and Dong, 2008; Jimenez *et al.*, 2010).

The creation of dynamic skin shading in film and game workflows depends mostly on artists, who carefully create all necessary skin textures. In the context of dynamic shading, an appearance rig is a structure that defines the details of the skin textures of 3D facial models. As models become more and more complex, it becomes increasingly difficult to define a consistent appearance rig that works well for many different characters; textures for each character must be created individually by hand, a slow and costly process that requires experienced digital artists. Alternative facial animation techniques circumvent this difficulty by relying on performance capture to simultaneously obtain dynamic geometry and appearance, but they are not designed to derive a generic, transferable model (Bradley *et al.*, 2010; Sagar, 2006).

Reasonable behavior and realistic appearance is essential for simulating communicative behavior. Postures and simulation also reflect the emotional behavior. Several models of emotions that are exist are such as the psycho-evolutionary theory, which was developed by Plutchik (Plutchik and Kellerman, 1980) and the FACS, which was brought up by Ekman. However, most of these models are appropriate merely for muscular expressions. In graphics too, the change in face colour is a less control field. Other physiological features such crying are also not considered. Blushing effects as shown by Kalra and Magnenat-Thalmann (1994) can occur when there is a very intense sensation (Jung *et al.*, 2009).

The most frequently affected parts are the cheeks; there is a relationship between temperature increase and blushing (Jung, *et al.*, 2009; Shearn *et al.*, 1990) . The usual blushing starts at 35s with the highest intensity after 15s. The face and ear blush likewise. Blood flow reduction causes pallor (Kalra and Magnenat-Thalmann, 1994)e.g. it is caused by fear. Parts that blush may also become pale. Sweat and weeping (sometimes accompanied by blushing) can be considered as vegetative functions that are controlled by the autonomic nervous system (ANS) (Jung, *et al.*, 2009).

Surprise, fear and happiness are accompanied with very light colours. Sadness and disgust are usually linked with colours of medial lightness, and anger is mostly associated with dark. Colours associated with fear and sadness are actually desaturated (close to 0, 0), whereas surprise, happiness and anger are related extremely to chromatic colour (Pos and Green-Armytage, 2007).

The skin of the face is rich with vessels. A vast quantity of blood vessels and a high level of activity in the facial skin by the enzyme may reflect the high metabolic activity. There are many kinds of formal subsidiarity in the face. Kalra and Moretti (1994) conducted a study of vascular patterns in the skin in different areas of the face. The region based approach highlighted that areas like the nostril and forehead have bilateral divisions at sharply acute angles called "fronds" and areas such as cheeks and jaws from one side branching nearly at right angles is called "candlestick" (Kalra and Magnenat-Thalmann, 1994; Moretti *et al.*, 1959).

Some areas show in-between types of subsidiary between the "frond" and "candelabra". Numerous areas portrayed several forms in the capillary stream to the skin. There are many regional varieties and any one region varies greatly according to the individual, especially with the age component. These differentials may highlight why certain areas show more external activity than others. For example, the redness may be seen more on the cheeks, ears and forehead rather than the rest of the body (Kalra and Magnenat-Thalmann, 1994). Table 1.1 shows the variation of emotion on facial expression

Table 1.1 Emotion and facial expression (Jung, *et al.*, 2009)

EMOTION	FACIAL APPEARANCE VARIATION
Neutral	No changes, neutral face colour
Joy	Cheeks become rosy
Enthusiasm/ Ecstasy	Cheeks become rosy, tears of happiness
Surprise	Cheeks become rosy
Disgust	Cheeks become pale
Down	Low watery
Sadness	Cheeks become blushing, raised lacrimation
Grief	Cheeks become blushing, blotchy red and intensive lacrimation
Apprehension	Cheeks become pale
Fear	The whole face is pale
Panic	Face becomes pale, sweat on the forehead, low lacrimation
Annoyance	Cheeks become blushing
Anger	Cheeks become blushing, blotchy red in the face
Rage	Cheeks become blushing, blotchy red in the face, the face is red

Overview of visually distinguishable emotional states caused by vegetative functions, used for the parameterization of emotions that result in different facial complexions (Jung, *et al.*, 2009).

Figure 1.1 The first three images show anger, hence the cheeks are blushing and then red blotches appear. The fourth image shows the subject is weeping badly and similarly the cheeks are blushing. In the last three images, colours of the face have been changed, droplets appear and effects like perspiration or nose bleeding can also be simulated. (Jung, *et al.*, 2009).

The combination of facial expressions and emotional colours can be seen in Figure 1.1 .The corresponding emotion is easily perceivable and more plausible for strong emotions. The changes for skin can be categorized according to a parameterized emotional model. A group of test on possible skin changes from the physiological and psychological knowledge was carried out in order to explain the model. The combination of droplet flow and colour change can be used to provide a convincing real world emotion. (Jung, *et al.*, 2009).

The animated facial models are not just less expensive as compared to human performers but they are also more elastic, in which it offers customization in style and appearance. These advantages can provide users with alternatives to substitute computer-generated models with human actors. Several ways are used to achieve 3D or 2D models in animation. A software modeling tool can be used to manually

generate the animation, which is done by capturing it from a 3d clay model with a digitized pen that is attached to a mechanical arm, which will calculate the location of the tip of the pen. Besides, it can be taken from an actual human by cameras or other scanning technology. The obtained 3D data is further parameterized into a mathematical representation as in splines, implicit surfaces or polygonal models, and then it can be manipulated by using the computer (Cerekovic *et al.*, 2007; Cosi *et al.*, 2005). Review of previous works on facial animation are presented to give clear picture of existing research that has been done as shown in Table 1.2

Table 1.2 Summarize of research on facial animation

Author	Title	Finding	Future Works
(Pan, *et al.*, 2008)	The Impact of Avatar Blushing on the Duration of Interaction between a Real and Virtual Person	The participants detected more blushing on the avatar's cheek rather than the whole-face	Increase resources into sufficient depiction of the whole face blushing
(Jung, *et al.*, 2009)	Real-Time Rendering of Skin Changes Caused by Emotions	The majority of models are merely appropriate for muscular expressions.	
(Yamada and Watanabe, 2004)	Effects of Facial Colour on Virtual Facial Image Synthesis for Dynamic Facial Colour and Expression under Laughing Emotion	Bi-synthesis analysis for dynamic facial colour and expression to illustrate the virtual facial images' smiling emotion	
(Melo and Paiva, 2007)	Expression of Emotions in Virtual Humans Using Lights, Shadows, Composition and Filters	The present work utilizes a model for the emotional expression in virtual humans using shadows, lights, filters and composition	With more exploration of lighting techniques, light expression could be improved
(Kyu-Ho and Tae-Yong, 2008)	Facial Colour Adaptive Technique based on the Theory of Emotion-Colour Association and Analysis of Animation	The FCAT development, which is considered with emotional reaction and facial colour rate by analyzing colour-emotion relationships.	Future research shall work on improving the FCAT in which a function is added that changes the facial colour regionally

1.3 Problem Statement

Based on the observation of issues and problem on facial animation as emotional expression of the avatar, we have found that the appearance of skin colour is an important issue that needs to be solved immediately. This is because the colour of skin on facial area is able to give additional value to facial expression of avatar during emotional situation. The main research question for this research is "*how to change the colour of facial skin according to the emotion condition of the avatar?*" These are some research questions that can be derived from main research question:

- Why the current facial expression of the avatar still need skin colour tuning?
- What is the parameter to adjust facial skin colours?
- How to render the skin changes of facial expression?
- How to define the colour properties?
- What are the requirements of a facial animation system?
- What kind of facial expressions are most shown in a conversation?

1.4 Research Aim

To create a technique to produce skin colours of avatar face based on emotion colour technique using linear interpolation.

1.5 Research Objective

This thesis has three main objectives that will be conducted during research study:

i. To study and investigate the effect of colour to emotional facial expression
ii. To produce a technique for facial animation to change facial skin colour based on emotion colour technique using linear interpolation
iii. To develop a prototype for the proposed method

1.6 Research scope

The scope of this research is defined as:

1. The emotion on this research covers the emotions that are related to the facial skin changes like blushing, anger or even sadness (The Microsoft Visual C# language used as a programming language, linear interpolation and Facial Action Coding System that algorithms used in this work).
2. Within the above mentioned scope, the work presented in this thesis covers the following areas:

    i. Four facial expression anger, happy, sadness and fear.
    ii. Expression synthesis
    iii. Emotion colour

1.7 Significance of Study

The research on facial animation has growth very fast and become more realistic in term of 3D facial data since the laser scan and advance 3D tools can support the creation of complex facial model. However, it is still lacking in term of facial expression based on emotion condition. Facial skin colour is one parameter that contributing to augmenting the realism of facial expression, because it is closely related to the emotions, which are happened inside the human, such as anger, sadness or even blushing.

1.8 Organization of this thesis

This research is organized into five chapters. Chapter one defines Facial Animation, explains the problem background, highlights the problem statement, sets up the objectives of this study, fixes the scope of the study and concludes by thesis organization. Whereas, chapter two contains the Facial Animation, Facial Animation Techniques , Shape Interpolation or Blend Shapes and Parameterization; also the emotion Theory and Emotion Colour. Moreover, chapter two explains some theory of colour, Facial Action Coding System and MPEG-4 Facial Animation. Followed by, chapter three, which illustrates the research methodology that can resolve the problems and achieve the objectives predetermined in chapter one. Furthermore, chapter four depicts and discusses the results of the proposed method as well as the comparisons that evaluate the proposed method against previous methods and closely related with the facial skin colour of real human. Finally, chapter five displays the summary, conclusions and the contributions for this work.

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