

A Crucial Investigation of Facial Skin Colour Research Trend and Direction

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Abstract

The research on facial animation is growing and became more sensible in terms of three dimensional data. The emergence of laser scans and advanced 3D tools imparted further towards the rapid development of complex facial model. This paper has given an overview on facial animation techniques such as blend shape interpolation, facial action coding system and parameterization. The major challenges, excitement, applications, recent progress and the future of various diversified facial animation methods are highlighted as well. The emotional theory, involving the cognition as one of the elements of emotion and emphasizing on somatic factors describing emotional expressions and its perception as the other elements are presented. The essential factors responsible for emotional colors manifestations to an individual are the key issues. The notable theories and models of Goethe, Claudia Cortes, Naz Kaya, Color Wheel Pro, Shirley Willet and Yau Xueon facial colors expressions are critically commented and a facile comparison is carried out. Furthermore, a detailed discussions on facial colors appearance are provided using image based skin color analysis and synthesis, reflectance based model, bidirectional texture function, physiology measurement based and emotional appearance models. The paper completed with the remarkable features official expression comprised of facial action coding system and MPEG-4 facial animation that enable considerable improvement on facial animation technology. Our in-depth appraisal on facial animation may contribute as taxonomy towards the development of human facial skin colors on 3D avatar including facial action coding system, emotion theory, color theory, animation via blending and image based color analysis useful for various applications.

Keywords: *Animation, Computer Graphics, Virtual Reality, Avatars, Hemoglobin and Melanin*

1. Introduction

Recent development in digital technology for stabilizing the high-speed processing of gigantic information is overwhelming. This enhanced the feasibility of long-distance communication such as conferencing and video telephony. A distinct element that facilitated the advanced communication competence of these systems is the presentation and estimation of emotions using the facial colors and expressions. Truly, emotion alters with the change of facial colors. These changes can be used for the fusion of the facial expressions to modify the basic emotions of visual anthrop-orphic agents. This may likely to

play a pivotal role in selecting the communication between computers and humans [1, 2]. The enhancement of the avatar's emotional expression by haptic sensation is reported [3]. Appearance of human facial colors is applied to influence the display of virtual facial image, emotional evaluation, individual identification and remote health care. This is regarded as one of the most peculiar manifestations among all human expressions[4]. Blushing is a common topic of psychological study and evidenced to be an important facial signal which serves vital functions in interpersonal communication [5]. Among psychologists, the explanations on human blushing still remain far from being understood. Most people consider blushing in public as an uncontrollable response and get embarrassment while they blush in public. Furthermore, blushing is a symptom that can make someone even worse suffering from social phobia [6, 7]. Meanwhile, pallor effects due to shock, fear or pain occur through temporary cerebral anemia and contractions of the treatment capillaries in the face due to an increase in cerebral blood flow. This action diminishes the blood flow in the face and forwards it to the brain for relief and recovery. Despite much research, the accurate measure of pallor is not found yet. Psychophysiological analysis of pallor is expected to provide known results because the red areas are more likely of pallor and their time pattern. Recently, a formal monitoring reveals that the pallor received far less attention in the psychophysiological analysis compared with redness. The vital component of the computer model for the identification of the main characters centered towards this phenomenon. In our opinion, for vascular emotions the skin color or tone determines their occurrence [8]. The previous studies focused mainly on the geometric features of these alterations. For instance, the facial surface animation including skin stretching and wrinkle structures are widely investigated. Changes in hemoglobin concentration can cause alterations in skin colors. It can also originate from the reaction of histamine or other skin conditions such as blushing and rashes. Specifically, blushing consists of a number of emotions such as joy, shame and arousal. Regardless of their ability to convey emotion, the dynamic changes that occur in skin pigmentation are mostly ignored in the existing skin appearance models [9-11]. Reasonable behavior and realistic appearance is essential for simulating communicative behavior.

2 . Facial Animation

Facial animation is attributed to be the most complex yet the most effective communication tool in the field of creative animation of virtual avatar or social agents [12]. Achieving high quality animation poses many challenges connected to the elements of the face including facial muscles, facial bones and synchronization of the lips in speech formation. Accurate and efficient identification of these elements require remarkable efforts and sufficient time for skilled animators. However, the knowledge of facial color animation is essential because facial expressions contain most of the information from which we recognize people's emotions and mental states. According to Thalmann [13], creation of believable facial animation is very significant because the human face is fundamental art object in understanding emotion. Hjortsjo (1969) developed the mimic language (ML) for facial expression and described the facial expression from the perspective of facial features, gestures and postures [14]. In ML, facial expressions are result from the combination of static structural and dynamic elements of the face such as the variation in form and appearance. The static aspects of the expressions are composed of the bone structure and soft tissues of the face. Conversely, the dynamic aspects of the facial expression originate from a mixture of soft facial features and changes in shape. In relation to this, Smith (2006) integrated the aspect of dynamic elements of the emotion state with individual's mental state [15]. Therefore, it is common to discuss different techniques introduced for facial animation.

2.1. Facial Animation Techniques

The classification of facial animation techniques into different categories is often tricky because no specific boundary between two methods do exist. However, recent techniques are adopted for the syntheses of several methods to achieve improved results. This is known to change and couple with its archaic informal name conventions [16]. Traditional facial animation methods comprise of blend or shape interpolations called morph target or moving vertices, which are curves or meshes of 3D face geometry. One disadvantage of these methods is that only one facial region is sampled at a particular time. Conversely, it is well known that facial regions are intimately correlated to each other. To achieve realistic effects, animators need to be very careful around the edges of different facial regions. Natural representation of the details and creases are extremely hard. Newer technologies are emerging to improve the results by providing better intuitive dimensions in creating facial animations [17-19]. Currently, several types of facial animation techniques are available including mixed and group based animation systems [20].

2.1.1. Shape Interpolation or Blend Shape

Blend shape which is also considered as shape interpolation animation has become the most used animation method and is commonly used in commercial animation software packages. Packages such as MAYA and 3D Studio max are embedded in blend shape. Blend shape is achieved by shaping distortion while fading it into another through marking corresponding points and vectors on the “before” and “after” shapes which are used in the morph. The major concept of these animators is to create several key poses of a subject to automatically interpolate the frames in-between via animation. Technically, blend shape animation is a point set interpolation where a linear function specifies smooth motion between two sets of key points. Generally, it is from models of the same topology. This type of animation process includes modeling of polygonal meshes of a human face to approximate expressions. Besides, it also takes account of visemes for synchronizing the position of lips with its speed [21] and then continues with the automatic blending of different sub meshes called morphs targets or blend shapes. Since the blend shape method generally uses a linear algorithm of topology of the face meshes, animators can control the weights applied on the vertices of polygonal models. Thus, the degree of blending is accurately controllable [22]. Almost all of the automatically generated frames in this method are resulted from the simple transformation of scale, movement, or rotation of rigid objects. Examples of rigid objects or parts in human body are arms and legs. However, no specific rigid parts of the human face are known. Accordingly, this poses a difficulty for shaping interpolation in facial animation due to intricate construction and curves of the face. Indeed, matching of each face model by adjusting the settings is very expensive. Overall, it is harder to work with a real human facial model than a fantasy 3D facial character. Arbitrarily exaggerated expressions can be created on avatar’s faces which may appear believable to people. For instance, the character Gollum in the movie “The Lord of the Rings” is an exaggerated expression. The rigid interpolations generated by the blend shape approach often impede the true nature of the animation in achieving realistic human facial emotional expressions. Several shape interpolation based methods are developed to get a smooth animation of the human face. One widely-used basic approach is the creation of a model face in the rest position. Then, using 3D modeling techniques, the points of a copy of that face are edited to make other faces. Typically, with the same topology the rested face is copied into different phoneme and expression states [23]. A typical facial animation using linear interpolation method is shown in Figure 1 (A)-(C).

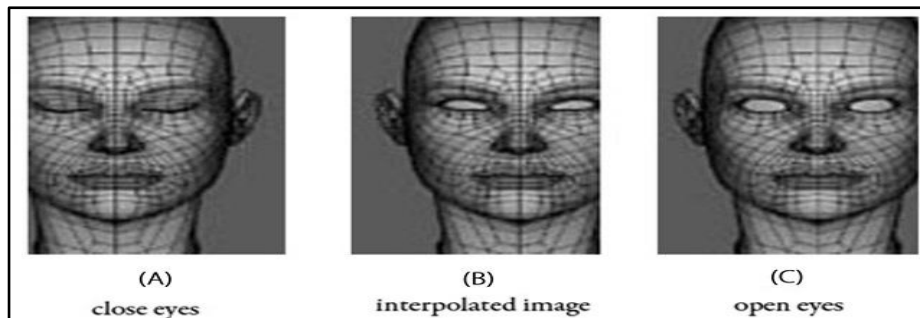


Figure 1. Linear Interpolation on Eyes from Close to Open with Interpolated
 $_eyes(t) = (1-t) * closed_eyes + t * open_eyes$, where t is between 0 and 1[22]

2.1.2. Parameterization

The limitations and restrictions associated with simple interpolations can be overcome by parameterization because animators use parameter values to control expressions. The first facial animation system was designed by Fred Parke's from University of Utah and the NY Institute of Technology [24]. He used a control parameterized method where the animation turned into a process of specifying and controlling set of values of the parameter as a function of time. By a combination of independent parameter values, ideal parameterizations can identify any potential face and expression. The main limitation with shape interpolation method is that the interpolation process of the animation cannot be controlled by animators because the computer automatically manipulates it. Even though the computer calculates and provides a suitable interpolation, the animators' manual adjustments become limited. Through parameterization, animators can have more freedom and specific facial configurations control. By combining the parameters together, a wide range of facial expressions with quite low computational costs can be achieved. Yet, parameterization has one big restriction which limits its uses. Conflicts may occur because it usually works on small facial regions. For instance, there are obvious motion boundaries between the facial regions as the parameters can only affect certain areas. As a result, during parameter configurations, animators may not get enough freedom. Facelift program for "The Sims" uses a version of production system with hierarchical parameterization and genetic programming to improve the past procedures [25].

2.1.3. Performance-driven Techniques

Performance-driven approaches for human motion production in computer animation industry are subjective [26, 27]. Obviously, the biggest challenges in computer graphics of facial animation are related to the dynamic properties of face which are too many and the associated delicate emotions that cannot be performed by moving slide bars or dragging control points [28]. However, the best technique for the creation of facial animation has to emerge with the face itself meaning the capturing of movements directly from real faces and transferring the information digitally. This was first invented by Lance Williams using few markers on the face, a video camera to scan the face and track the markers [29]. Performance-based animation uses interactive input devices such as data gloves, instrumented body suits and laser or video-based motion tracking systems [24]. The system possesses a video camera that captures points on the performer's face which moves with the head. The camera receives the position of markers or dots drawn on the face and simultaneously tracks the movements of real performers in three-dimensional models. Presently, all tracking devices for face are based on optical or video technologies. System such as Vicon tracks above 100 markers with more precise and realistic facial animations. Although the capture process is unstable, it is consistent and accurately tracks the neces-

sary processes. One achieves precise features of points and edges on the face by maintaining a great animation quality. The processed data from the camera can be used to create facial animation straight up or to infer AUs (Action Units) of the FACS technique. Performance-driven technologies are mainly classified in three categories including optical flow tracking, motion capture with or without markers and motion capture with key frame animation. The main challenges of these techniques are concerned with their data accuracies where the data from the systems need to be filtered before proceeding for animation. In this way animators can use the data-driven animations by setting errors. Motion capture is a very promising technique used for both commercial and academic purposes. Some of the most powerful facial animation techniques are Face Robot, Motion Builder, Crazy Talk, Zign Track, Facefx and Image Metrics. They own some striking features such as ease to handle, less time consuming and produce quite superior quality facial animations. The Motion capture techniques are in existence for the past few decades. For instance, the movie “The Polar Express” in 2004 implemented marker-less motion capture techniques to track the facial movements of all characters as illustrated in Figure 2 (A,B) Hundreds of motion points were captured for restructuring the realism [30-34].

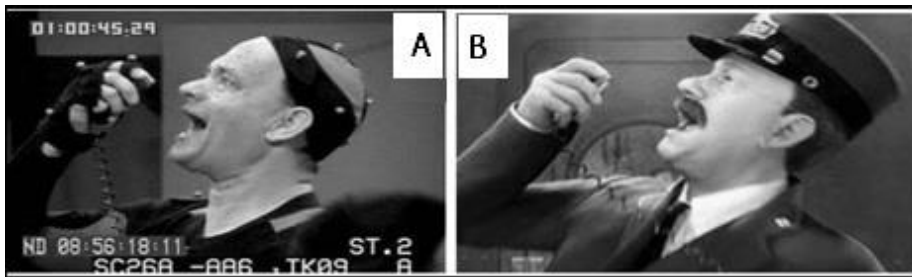


Figure 2. The Actor Tom Hanks (A) is Playing the Role of Conductor in the Film The Polar Express. (B) The Avatar is Driven by the Performance of the Actor[22]

2.1.4. Transferring Existing Animations to Different Models

The transfer of existing facial animations from a source model to a new target is the main concern. Different approaches are developed on model (cloning) due to tedious and time-consuming nature of the animation process. The easy replication of animations created by any tools or methods to new models allows animators to freely select from a large, great quality, facial and motions database animations. The animations can be reused and composed to new models even when there are differences. There is a tuning step for the new model after every transferred is made on a model specific animation which saves enormous labor costs. Performance-driven and data-driven animation can theoretically be regarded as specific ways of transferring. For this case the source used is the 2-D video footage. Furthermore, 2-D videos, existing 3-D animated face meshes and 3-D captured facial motion data can all be considered as the source even if the initial target is a 3-D face model [35]. Noh and Neumann in 2001 proposed an expression on cloning technique to create facial animations[36]. In their method, the transfer of existing facial animations to a new model is performed using the motion vectors of the vertex from the source model. This approach constructs a map from each vertex motion vector to a target model vertex even though the model contains different mesh geometry and vertex configuration. The mapping idea relies on the radial basis functions. Currently, many approaches are developed to construct the connections between the source and the target model for facile utilization of expression on cloning [37]. Pyun introduced a blend-shaped model containing 20 feature points and an algorithm to determine the displacement vector for the blending and tuning processes [38]. This model automatically extracts the feature points from the source for blending the facial expressions to the target model. However, proper blend-

shape approaches require performing the action. They are not applicable on a pre-designed blend-shape model because of the deficiencies of right configuration and setting.

2.1.5. Eye Emotion Synthesis

Facial animation must not only concern with the muscles of the face but must care the eyes which are crucial and subtle. Eye emotion is the powerful sign of the mental state and information manifestation of humans. People during talking sometime stare into each other eyes to sense the response in term of emotions, interest, information and attentiveness. Eyes being the “windows to the soul” gaze strong and delicate signals and make them significant for animation [39, 40]. However, the creation of truthful talking animators is exceedingly complex. Audiences do not pay much attention to the lip synchronization once there is eyes communication. Truly, the entire animation and game industry is obsessed with the lip synchronization rather than eye motion. In animated character the eye animation is either non-existent or precisely ill-timed. The main reason for the lacking of eye animation may be attributed to the large eye movement. Eye gaze that arise partly due to the eyelid motions and the deformations do not reveal any deterministic correlation. Consequently, the direct motion capture data is unable to produce convincing and useful eye animation, instead fabricate the slight flicks inside the eyes. Methods with motion capture must be developed for achievable tracking of pupil and iris movement. Besides, the key frame for eye animation is too expensive. The captured data cannot directly be used prior to the key frame movements due to technical hurdle and performance related issues [41].

2.1.6. Head Motion Synthesis

Naturally, head motions play a vital role in making attractive interactions in human-computer interface. Facial gestures possess significant and distinctive non-verbal information in human communication. For example, a basic nodding and rotation action of a 2-D smiley face is often used to represent right or wrong in an online question game. This is easily understood by the user without any change on the smiley face. Therefore, head should serve as a model for producing realistic facial animations besides the lips, eyes and muscles for effectively mimicking facial behavior. Head movement is straight forward either nodding or rotating. The entire facial expression is taken into account by animators for creating head movements. Researchers developing such techniques must be aware of the existence of perfect correlation between head movement and the facial expression, and the usefulness of head movement to the audience in grasping the avatars mental state. However, a facial gesture is primarily attributed to face muscles movements, eye animation and long head movements. The combination of other factors in creating head motions is also considered [89]. Busso asserted that the head motion patterns (in movement activation range and velocity) with the neutral speech are significantly different from that with emotional speech. The presented HMM (Head Motion Synthesis) framework provided the best description of the dynamics of head motions and generated natural head motions directly from acoustic prosodic features. Figure 3 displays the overview of HMM-based head motion synthesis framework [42]. A mechanism for controlling head movement of photo realistic lifelike agents is developed by Hiroshi. The agents can exist in various modes such as idling, listening, speaking and singing [43]. The situation imitates the manner in which the head motion of a person reveals the agents virtual personalities. Graf analyzed quantitative head and facial movement accompanied by speech to demonstrate the relation to the text’s prosodic structure [44]. The head movements are found vary depending on various verbal conditions. It is claimed that head movements strongly depend on different pitch accents and spoken text. Deng proposed a data-driven audio based head motion synthesis method to capture a real human face speaking. Various audio features were extracted and further analyzed using K-Nearest Neighbor (KNN) algorithm to syn-

thesize the head motions using audio input data [45]. Next, we continue the discussion on the theory and colors of emotions.

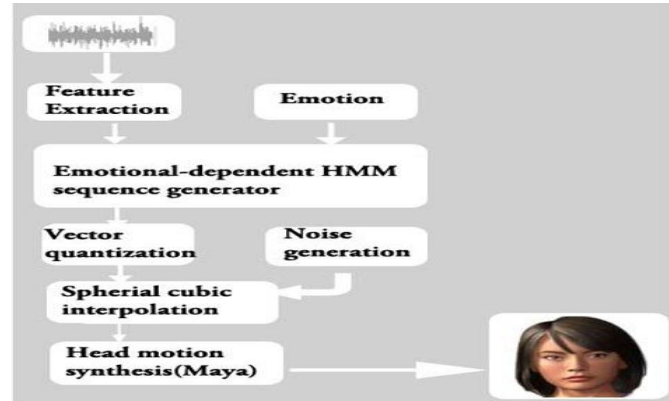


Figure 3. Schematic Diagram for HMM-based Head Motion Synthesis [42]

3 .Emotion Theory

Despite outstanding research the relationships on the constituent of emotion and associated representation remain debatable. Kleinginna *et al.*, [46] had compiled the definitions of emotions into more than 90 descriptions. Emotions are also described as the conditions of feelings [47, 48]. A condition of feelings that may have positive or negative affective valence is described as automatic arousal [49]. Varieties of the definitions of emotion by Frijda[50]result an unclear score for terms such as “emotion”, “feeling”, “mood” and “attitude”. Regardless of all these definitions the relationship between emotion and emotional stimuli remain ill-defined. Lopatovska and Arapakis [50] acknowledged that there are two categories of emotion theories. The first one involves cognition as an element that is necessary for emotion which can explain the expression of emotional events [51, 52]. This theory believes that cognitive activities may occur consciously or unconsciously, intentionally or unintentionally and in physical or intellectual aspect. Folkman *et al.*, referred the activity as cognitive appraisal [53]. Besides, the activity is also linked to the assessment while encountering the surroundings and is important for individual’s health. Lazarus mentioned that cognitive evaluation is important in the process of studying the meanings of stimuli and one can handle it. Meanwhile, Plutchik [54]introduced a new concept by combining emotion and animals’ instincts. Ekman [55] endorsed this view and added that emotions transforms as time passes and this is caused by adoption values. He mentioned that the basic role of emotion is to mobilize organisms to quickly respond to those events which are identical to the past one [56]. In the theory of information studies both notions are used either directly or indirectly. Based on the somatic emotional theory, some studies are aimed to identify the participants’ feelings on the assessment component from the emotional reaction [57-59].

4 .Emotion Color

Emotions are complex states of mind. They include physiological correlation, cognitive factors and social roles [60]. Emotions function provides an individual with energy in order to react to a behavior. Different types of emotions exist and the basic one cannot be breakdown. Basic emotions which are regarded as universal can occur even though there are different personal experiences and cultural variations. They can be identified solely through facial expression. The six types of basic emotions are happiness, surprise, disgust, anger, sadness and fear. Even though facial expressions are unintentionally expressed but can be controlled through practice [61]. Micheal [62] stated that the facial expressions

reflect social signal and manifest one's emotional states. Emotional states are manifested through facial expression and are commonly accompanied with color changes. These changes in color occur either with increasing or decreasing blood flow result rosiness or pallor. Colors play pivotal role for providing the viewer the information about the nature of objects. Any changes that occur to the objects are recorded by the observer. If the changes pertain to facial color then it must be linked to emotion. The correlation between emotion and color to human biology is verified. Parts of the colors can be redness (rosiness) or whiteness (pallor). There are varieties of colors to express emotion [61].

5. Theory of Emotion Colors

This section includes the history and color theory from Goethe, descriptions of color meanings as suggested by Claudia Cortes and Naz Kaya. In addition, the opinions from Wheel pro and Shirley Willett regarding emotion colors in designing websites are provided al. A process example from Yan Xue is underscored.

5.1. Color Theory of Johann Wolfgang von Goethe

“Color Theory”, a highly celebrated work by Johann Wolfgang von Goethe (2005) exhibited many remarkable points related to color meanings, especially in the “Sinnlich-sittliche Wirkung der Farbe”[63]. He defined colors as minus/negative part and plus/positive part, where the plus part such as yellow, red-yellow (orange) and yellow-red (vermeil)are related to arousal, lively and ambitious. Conversely, the minus colors represented by blue, blue-red and red-blue signify restless, yielding and yearning. Table 1 illustrates the significance of the colors according to Goethe.

Table 1. Color Summary of Johann Wolfgang Von Goethe

Emotion	Negative trait	Positive trait	Color
Calm		Neutral and Calm	Green
Red blue	More restless	More active	Blue-red
Faith		Charm seriousness,	Red
Joy	Reined, Green and Unpleasant	Purity and Pleasant	Yellow
Powerful	Irritating	Energetic	Yellow-red

5.2. Color Model of Claudia Cortes

Claudia Cortes established the characteristics of positive and negative colors attributes by summing up their associations with particular and described the relations of the colors. Even though it was difficult to extract colors meanings but an influence on the emotion implications and their grid locations are provided, which constituted the main elements of the model. The summary of those colors traits are listed in Table 2, where the overlap of traits is shown[63].

Table 2. Color Extraction by Claudia Cortes

Emotion	Negative trait	Positive trait	Color
Melancholic, introspec-	Sorrow, arrogant	Passive, leadership	Purple
Greed, faith	Sick, greedy	Neutral, calm	Green
Sadness, confident	Depressed	Traditional, faithful	Blue
Anger, love	Embarrassed, offen-	Emotional, active	Red
Happiness/joy, fear	Cautious	Energetic, lively	Yellow

5.3. Color Model of Naz Kaya

The difficulty in defining colors meanings and their interpretation can be found in the work of Naz Kayas [64]. The emotion and color combination with the peak of overall score from frequency test are summarized in Table 3 [65].

Table 3. Color Summary by Naz Kaya

Emotion	Color with Munsell notation
Annoyed, disgust	Green-yellow (2.5gy 8/10)
Tired	Purple (5p 5/10)
No emotion, excited, energetic	Yellow-red (5yr 7/12)
Loved, anger	Red (5r 5/14)
Peaceful, hopeful, comfortable	Green (2.5g 5/10)

5.4. Colors from Wheel Pro

The commercial program Color Wheel Pro that has contributed to the definitions of colors meanings and associated traits is furnished in Table 4 [65]. In fact, there are overlapping traits commonly depending on their context and their exact meanings are dubious. The most appropriate words based on the meanings of the colors are tabulated.

Table 4. Definitions and Attributes from Color Wheel Pro

Emotion	Negative trait	Positive trait	Color
Power	Death	Elegance	Black
Sadness	Frustration	Romantic, nostalgic	Purple
(Not given)	Power	Safety, purity	White
Aggressive	Courage	Passion	Red
Joy, happiness	Distrust, domination	Desire, wisdom	Orange

5.5. Model of Shirley Willett

Table 5 represents the colors and their characteristics from the perspective of Shirley Willett. The colors and their properties act as the standard for the relationship between basic emotions and colors. [64].

Table 5. Colors and the Associated Traits by Shirley Willett

Emotion	Negative trait	Positive trait	Color
Greed	Hoarding	Satisfaction	Green
Confusion	Racing	Clarity	Blue
Anger	Rage	Enthusiasm	Red
Fear	Panic	Awareness	Yellow
Shame	Disgrace	Pride	Orange

5.6. Theory of Yan Xue

Yan Xue had developed a model based on the colors and used Russell circumflex model as a basis as depicted in Figure 4[65]. He demonstrated the utility of color support in

his work on Philips ICat. The ICat used blue, red and green to produce LED colors for placing them in feet and ears.

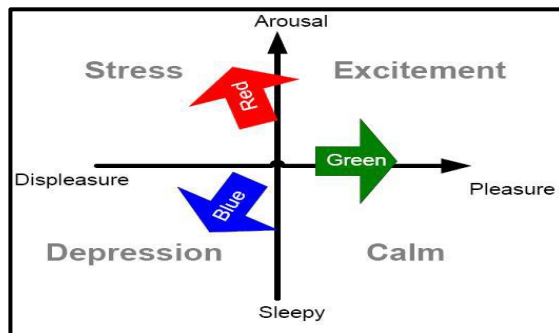


Figure 4. The Color Distribution used by Yan Xue[65]

5.7. Comparison of Different Emotion Colors Models

This section compares the merits and demerits of different emotion color models in detail discussion. The interpretation of Naz Kaya has tremendously contributed in delivering the colors meanings and their implications. The model of Claudia Cortes supports these interpretations for the basic colors. The complexity of Goethe's theory makes it difficult for implementation because the truthfulness of the information is tough to verify. Nevertheless, the model of Shirley Willet is highly useful in providing meanings of emotion colors. Finally, Yan Xue model renders a simplistic interpretation of three basic colors RGB. Interestingly, the basic emotion "surprise" does not have any color. The following discussion will be synthesis, analyses and appearance of facial colors.

6. Facial Color Appearance

Facial color appearance models became remarkably popular in sports and film industry. Facial appearance (expression) changes regularly during speeches, exercising and emotional moments. Reproduction of facial expression in real time is quite challenging because people are not only conscious but very sensitive to the look of their skin. Most facial color appearance models of skin possess two layered translucent structure and relates the expression to the distribution of melanin and hemoglobin in the blood which is well confirmed [66-68].

6.1. Image Based on Skin Color Analysis and Synthesis

Capturing the skin image for reproducing the colors depends on analysis and synthesis. This provides highly realistic representations for human faces because effects such as self-shadowing, inter-reflections and subsurface scattering are implicitly captured. Pighin et al. reproduced faces using view-dependent texture mapping [69] under static illumination conditions. Recent efforts on facial imaging allowed variations in lighting for static faces [70, 71], expressions[72] and real-time performances[73]. Debevec *et al.*, introduced relightable 3-D face models by mapping image-based reflectance characteristics onto 3-D scanned geometry [71]. The use of color space analysis is implemented to separate the image data into specular and diffuse components to extrapolate into new view. While their method looks into the aggregate behavior of subsurface scattering, specific diffusion parameters are not inbuilt. Therefore, this model is incapable of producing correct subsurface scattering effects neither for close up light sources nor for high-frequency spatially varying illumination. Borshukov and Lewis achieved subsurface scattering by combining an analytic surface BRDF (Bidirectional Reflectance Distribution Function) with an image-space approximation and created great real face models for the movie industry. Sand-

er *et al.*, developed a variant of this method for real-time face rendering on modern graphics hardware. Tsumura *et al.*, illustrated a single skin image of hemoglobin extraction and melanin pigmentations shown in Figure 5 (A-C).

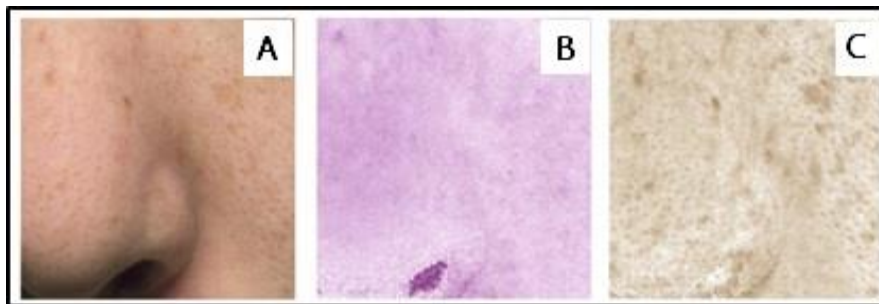


Figure 5. Melanin and Hemoglobin Maps Extracted from a Single Image using Independent Component Analysis(A): Original Image, (B): Melanin and(C): Hemoglobin)[74]

An image-based model requires huge data storage systems, hard to edit and the dimensions are not highly physical in terms of light-skin interaction. Simulation of local light sources and reproduction of spatially-varying illumination remain a difficult task[75] especially when the shadows from distant sources do not agree with the shadows from local one. For instance, when a light source close to the nose is illuminated then an image-based method would foresee zero reflection as the light from distant source is blocked by the nose. The introduction of reflectance based models provides further thrust towards the development of skin colors appearances.

6.2. Reflectance Based Model

The skin color appearance is known to differ depending on the lighting, viewing conditions and the direction of reflection on the skin. Varieties of skin reflection models from simple BRDF approximations to the light scattering [76, 77] and methods that simulate small-scale anatomy and physiology details [78] exist. The former one is based on the approximation of 1-D light transport which does not capture the characteristic subsurface scattering of the translucent materials. Models relying on an accurate volumetric light transport simulation are naturally too complex and very slow for real-life graphics applications. Furthermore, models based on the diffusion approximation offer a compromise between accuracy and complexity. Donner, et al. introduced a simple approach using the diffusion dipole approximation to evaluate optical parameters of materials including two samples of the skin [79]. This method is limited to homogeneous and semi-infinite slabs with regular scattering and absorption properties. Despite the limitation of the dipole model in approximating the appearance of heterogeneous materials it still remain active. Jensen and Buhler used the translucent model and varied other parameters to match a given albedo texture [80]. Later on, the method is also adopted by Hery [81]. Several workers successfully exploited the dipole model with fully spatially varying parameters [82]. However, the use of a model in the presence of heterogeneity is not properly defined particularly when large variations in parameters occur within small area. Most of the models considered the transportation of light between two points on the material because it depends only on a single set of homogeneous parameters. Weyrich *et al.*, analyzed the variations in the reflectance of facial skin under 149 topics subjected to various external conditions. The parameters of skin reflectance are calculated by spatially varying subsurface scattering, texture and specular reflection [83]. Donner and Jensen introduced the diffusion multi-pole approximation to interpret thin slabs and multi-layered translucent materials [66]. Their model was able to capture the accurate reflectance of translucent layered

materials but could not obtain optical parameters for precise materials. Subsequently, the multi-pole approximation was purposely employed in the creation of spectral shading model for the skin where a minor set of chromophore parameters were used to regulate the overall skin appearance. D'Eon *et al.*, (2007) employed the multipole model to run contemporary graphics hardware [84]. Spatial variations on the surface are again approximated with an albedo modulated texture to interpret interactive layered translucent materials. General heterogeneous bidirectional surface scattering reflectance distribution function (BSSRDF) models are developed with the precise target of obtaining parameters from measurements [85-87]. These models identified the relationship between incident and extant light but left out the physical key and physiological structure of the material. For the skin, it is important to understand the relationship between the structure, pigmentation and reflectance to derive the physical models for forecasting the appearance of arbitrary skin samples. Wang *et al.*, demonstrated a volumetric representation on heterogeneously scattered materials via a mathematical method [88]. The heterogeneous diffusion on the GPU is considered even though it was difficult to discretize the geometry to coupled poly-grid. Donner *et al.*, simulated the skin reflectance by considering the light inter-scattering between skin layers[67]. The applied method called chromophore spectra derived the spatial chromophore distributions from multi-spectral photographs of skin. Ghosh *et al.*, [89] considered both structured light and polarization to obtain the skin layer properties using a multi-layered scattering model.

6.3. Bidirectional Texture Function

Determining the skin appearance at finer scale is often complicated as it contains several color variations from pores, wrinkles, spots and freckles. A comprehensive model of skin appearance must therefore consider all the skin textures. The bidirectional texture function (BTF) introduced by Cula *et al.*, [90] is a very useful concept for modeling the appearance of texture. The considered the variations in the appearance are related to the changes in lighting and viewing direction as shown in Figure 6. Cula *et al.*, applied captured images of the skin while varying the viewing and lighting locations. The images obtained from different body regions differ because the skin texture varies according to body region, age and gender. A distinctive Skin Texture Database (STD) with high resolution images of several skin types is established [91].

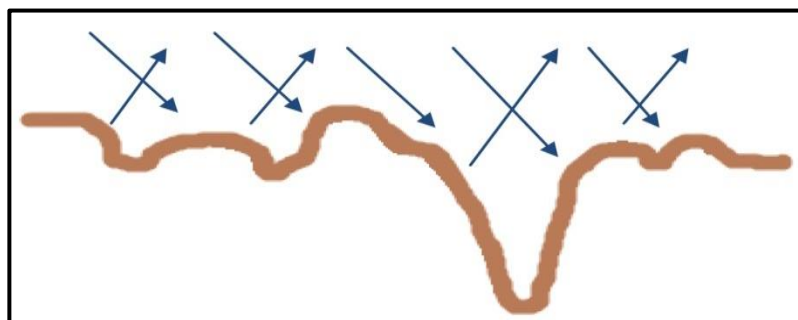


Figure 6. Illustration of Bidirectional Texture Function[91]

6.4. Physiology Measurement Based Models

In dermatology, physiological measurement methods are applied to blood hemoglobin samples for ex vivo histological examination or in vivo non-invasive point measures [92] as shown in Figure 7(A-C).

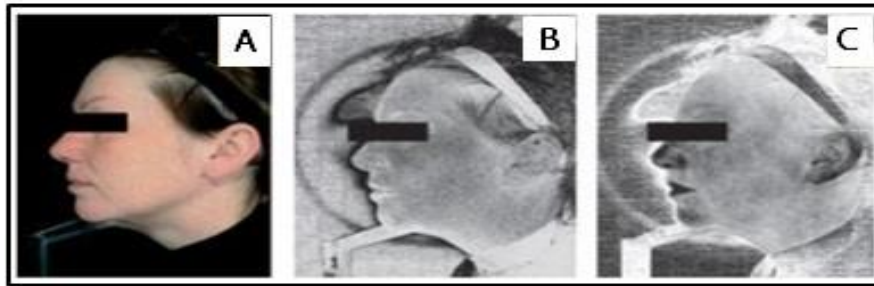


Figure 7. Example of Noncontact Point Measure Chromophore Map. (A): Original Digital Photo, (B): Melanin Concentration Map and (C): Hemoglobin Concentration Map [92]

Lately, Jimenez *et al.*, demonstrated similar non-invasive procedures for in-vivo mapping of hemoglobin concentration and distribution across wide areas of the skin. They relate the change of hemoglobin with dynamic facial expression [10].

6.5. Emotional Appearance Models

Presently, the simulation of emotional appearance of the skin for different facial expressions is routinely performed [93]. The simulation models are user friendly even though they do not correlate real to actual hemoglobin or melanin maps. Kalra and Thalmann simulated changes in the skin for redness and pallor[8]. Yamada and Watanabe examined blood flux based on anger and dislike[94]. They measured concurrent changes in facial skin temperature and color for these emotions and mapped them into an average image for facial color expressions. Jung et al. demonstrated the skin colors changes based on complex parameter sets using fourteen states of emotions[95]. Melo and Gratch simulated blushing directly on a user-defined color change to different areas of the face [96].

7. Facial Expressions

In Psychology, the in-depth analyses of facial expression generated renewed interests for decades. The attraction in this area is centered towards the understanding of human's information transmission and receives using their faces. It also intends to unfold the effects of mental and physical disabilities on facial movements. The expression on the faces of patients suffering from depression is often undergoes through a number of stages relating to their illness. It is hoped that breakthroughs in the treatment of patients may occur via facial monitoring of illnesses. Another area of interest to psychologists is the facial deception, which identifies whether a person is lying or not. When somebody is lying, it is easy to notice some conflict in the appearance on the face because there is more than one visible expression gets manifested on the face. Perception comes naturally and by studying the agreements and differences in movements with each other it is possible to interpret facial expressions [97-99].

7.1. Facial Action Coding System

Facial action coding system (FACS) is a scheme developed by Paul Ekman and Wallace Friesen that measures and describes the facial behaviors by understanding the texture, movement and anatomy of every facial muscle [12]. FACS is a known standard that demonstrates how each facial muscle is responsible for changing the facial appearance. It is derived from a facial anatomy analysis, which describes human face's muscles conduct including the movements of the tongue and jaw. Through exploring facial anatomy, one concludes that the changes in facial expressions are caused by facial actions. FACS starts working from facial actions to understand facial behaviors. Facial action units (AUs) are

made in accordance to these actions and every AU involves numerous facial muscles. When an expression is made, the involved muscles cannot be recognized easily. Conversely, each muscle is divided by two or more AUs to explain quite self-governing actions of various muscle parts. FACS divides the human face into 46 action units. Every unit embodies an individual muscle action or a group of muscles that characterize a single facial position. The principle is that every AU is the smallest unit which cannot be reduced into minor action units. Nevertheless, by accurately sorting out various AUs on the face, FACS is capable of mimicking all the facial muscle movements[100]. The creation of facial appearance is the combination of action units that produce altered facial expressions. For example, combination of AU4 (Brow Raiser), AU15 (Lip Corner Depressor), AU1 (Inner Brow Raiser) and AU23 (Lip Tightened) generates a sad expression. Originally, FACS was not introduced for generating facial animations but it was rather aimed in describing the score in facial movements. Recently, the widespread usage and overwhelming acknowledgement for facial actions enables its useful exploitation in facial animation. FACS assists animators to exemplify and build realistic facial expressions by configuring all possible facial animation units of human face with the descriptions of measuring the positions of head and eye [22]. Unlike other muscle-based techniques, FACS studies the actions that are caused by the muscles instead of investigating the muscle directly[101]. The facial expressions are complicated because no expression is made by only one muscle. In fact, a single muscle is responsible for the creation of various expressions. The overall configuration and mechanism is very complex. Moreover, study of each muscle individually to facilitate a clear comprehension in facial action and subsequent expressions would be extremely difficult. FACS is very effective in distinguishing the actions of upper facial parts, but not the entire face. Particularly, FACS does not count for all of the visible, distinguishable and reliable actions of the muscle controls in the lower facial parts which make it unable to recognize the lip-synchronization requirements. Generally, FACS describes most expressions and movements by facial action coding. It offers very dependable face codes on the upper areas of the face including foreheads, eyelids and eyebrows. Nonetheless, FACS overcomes the limitation of interpolation and is a landmark for facial animation methods. It is extensively used with muscle or simulated muscle-based approaches. The explanations for signal sampling AUs are furnished in Table 6 and Table 7 displays the generation of the basic expression based on facial action.

Table 6. Representation for the Signal Sample Action Units

AU	FACS Name	AU	FACS Name	AU	FACS Name
6	Check Raiser	23	Lip Tightened	15	Lip Corner Depressor
1	Inner Brow Raiser	26	Jaw Drop	5	Upper Lid Raiser
17	Raiser Chin	20	Lip Stretcher	9	Nose Wrinkle
4	Brow Lower	14	Dimpled	16	Lower Lip Depressor
10	Upper Lip Raiser	2	Outer Brow Raiser	12	Lid Corner Puller

Table 7. Our Explanation for the Generation of the Basic Expression based on FACS

Expressions	Involved AUs
Anger	AU (26+4+17+10+9+20+2)
Fear	AU (2+4+5+26+15+20+1)
Happiness	AU (14+12+6+1)
Sad	AU (23+1+ 15+4)
Surprise	AU (1+2+5+15+16+20+26)

7.2. Moving Picture Experts Group

The moving picture experts group (MPEG-4) is an ISO standard for multimedia MPEG41997. Since its release in 1999, many researches are concentrated on this standard because it can be used in a wide range of video and audio recording as well as in 3D graphics. The MPEG-4 being the only reliable standard dealing with facial animation is used as a basis for the development of new methods. Several investigations in the area of facial animation are carried out to describe and represent precise facial actions with predefined groups of “codes”.

The FACS is perhaps the first prosperous effort in this regard even though not directly related to animation and graphics research. Lately, the MPEG-4 standard is focusing more on the integration and communication aspects of multimedia contents and is getting further attention in facial animation areas [102]. MPEG-4 Facial Animation (FA) outlines many parameters of a talking face in a standardized technique. It successfully describes the Face Definition and Animation Parameters for facial action encoding. In MPEG-4, the head is grouped into 84 feature points (FPs) in which every such point describes the shape of an area. They are used to outline the parameters of animation on the face to conform the standard when switching between other models. For the current standard, there are 68 universal Facial Animation Parameters (FAP). Every FAP corresponds to a FP and expresses the low level facial actions like jaw-down and more complex higher level actions such as smiling. The FAP being independent of model geometry requires systematic calibration before it is applied on different models. This is achieved by using FAP units (FAPU) which is defined as a distance between facial features and is not universal. It is exclusive to the 3D face model where ever applied. Therefore, when a standard FAP with corresponding FPs and FAPU are available the values can be adjusted and decided on a new model freely by exchanging information from the face models. They together permit a receiver system to produce a facial animation by using any graphics method based on low level commands in FAPs. The FAPs consist of two categories in which the first one represents the facial expressions by themselves with high level considerations. It includes six basic emotions such as anger, sadness, surprise, joy, fear and disgust. Two parameters are only allowed to be used by animators to create a relatively good animation by performing linear interpolation between each expression. The other parameters of facial animation focus on certain facial areas, for example, the left corner of mouth, bottom of the chin and the right eyebrow, to cite a few. This can encode a higher degree of facial actions with more sophistication. It is important to mention that FAPs do not require any geometric models and synthetic face to be used. They simply sketch the desired movements and are independent of methods of animation. They can be utilized in applying pre-learned image transformations on the basis of detecting locations of facial features to a real 2D picture. This in turn generates visual effects like facial expression, talking, or any further facial movements. Furthermore, MPEG-4 delivers a scripting language capable of producing parameters[103, 104].

8. Conclusion

We provide a detailed overview on facial animation techniques signifying theories and models for emotional expression and facial colors. The past development, present art of research in implementation and future prospects of facial skin colors on 3D avatar is underlined. Theory of emotion that includes emotion color as subtype with several models of emotional colors is emphasized. Manifestations of facial expressions are described using FACS and MPEG.

Several prominent facial animation techniques such as blend shape interpolation, parameterization, performance driven processes, transfer existing animations to different models, eye emotion synthesis and head motion synthesis with their overwhelming success and limitations are underscored. The urgent need of facial animation in the entertainment industry, telecommunication medicine and many others are stressed. It is recognized that the future advancements of facial animation would be mostly guided by computer graphic technologies. The new forms of motion capture techniques are developed as the dominant approaches for performing fast, flexible and realistic animations. The significance of colors in providing the information about the nature of objects, stimulation to the viewer to respond to a group of circumstances and their close relations to emotion are highlighted via the example of Felice Casson court proceedings. The color theory confirms the strong correlation between emotion and human biological responses. Varieties of colors exist to express emotion and a part is manifested as redness (blushing) or whiteness (pallor). Defining the precise correspondence rules between emotions and colors will remain a challenge. The current facial expression of virtual human is still lacking in terms of providing realistic appearance through their facial skin colors and texture changes. This will continue to encourage in performing better color classification to determine the facial skin colors changes of the avatar. The established methods are still limited in generating colors for synchronizing real skin color changes. Their RGB properties are still deficient on representing facial color changes since the skin colors are mostly affected by oxygenation and de-oxygenation of hemoglobin. The mechanism of oxygenation and de-oxygenation in determining the facial skin colors changes will remain future key issue. This exhaustive and informative review article is believed can serve as taxonomy for a better understanding the research advancements towards human facial skin colors on 3D avatar.

Acknowledgements

Authors are grateful to Universiti teknologi Malaysia, Research Management Centre (RMC) of UTM, Department of Informatics, Faculty of Information Technology, Institut Teknologi Sepuluh Nopember Surabaya, Indonesia.

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