Realistic Facial Animation Review: Based on Facial Action Coding System

Rahma M. Tolba, Taha Al-Arif, El-Sayed M. El Horbaty
Computer Science Department, Faculty of Computer and Information Sciences, Ain Shams University, Cairo, Egypt.
E-mail: rahma.tolba@cis.asu.edu.eg, taha_elarif@cis.asu.edu.eg, shorbaty@cis.asu.edu.eg

Abstract

Making realistic facial animation is one of the most challenging research topics in facial animation field because producing realistic photo and sentimental virtual characters require a combination of face modeling, animating, and rendering. Techniques that commonly used for facial animation are in need of naturalism. The most popular expression coding systems are FACS (Facial Action Coding System) and MPEG-4 (Moving Pictures Experts Group-4) Facial animation models. FACS is a landmark technique that enables remarkable improvements in making realistic facial animations. Where MPEG-4 Facial Animation provides a standard way of encoding facial actions by defining various parameters for a talking face. In this paper, we made a review on how to achieve realistic facial animation, focusing on the applications and limitations of the FACS comparing to MPEG-4 facial animation. The review inferred that FACS helps animators to represent and build realistic facial expressions by configuring all possible facial animation units of the human face.

Keywords: *Facial Animation, FACS, MPEG-4*.

1. Introduction

Computer facial animation is mainly an area of computer graphics that covers the techniques of making and animating a character face. The increasing appearance of virtual characters in media and applications, along with the availability of low-priced powerful desktops, has driven the recent interest in facial animation. There are a lot of published facial animation researches that are not known to general graphics community. Therefore, few number of authors made a review of facial animation topic, such as [1], [2], [3], [4] and [5].

It is important that animators and researchers in the field of Facial Animation to have a common language for encoding and expressing facial motion. Several parameterizations have been established as accepted standards in an attempt to taxonomies facial communications. Two of them have become pervasive in Facial Animation field, FACS and MPEG-4.

FACS was proposed by Ekman and Friesen in 1978 [6] and has been updated in 2002 [7]. It describes all the movements that can be observed in the face based on face anatomy. FACS was not originally designed to make facial animations. It was intended only as a way to score or describe facial movements. But due to its wide range along with defining facial actions, it has been used extensively in facial animation during the past few decades. FACS has become a standard in understanding facial behavior, not only in behavioral science research like psychophysiology [16], [17], [18], but also in fields like movies [8], video games [9], facial expression recognition, detection, generation and mapping [10], [11], [12], [13], and robots [14], [15]. By describing all possible movements performed by the human face, FACS helped animators to create realistic facial expressions, even for the positions of head and eyes.

MPEG-4 is an object-based multimedia compression standard that allows encoding independently different scene's audiovisual objects (AVO). It has Facial Definition Parameter set (FDP) and the Facial Animation Parameter set (FAP) which were designed to define the facial shape and texture, as well as reproducing the animation of faces such as expressions, emotions and speech pronunciation.

Computer Facial Animation has grown into a wide and extended field, that's why this review does not cover every part of the virtual character face, like eye animation [19], lips synchronization [19], skin modeling [20], tears simulation [21], wrinkles modeling, etc.

The rest of this paper is organized as follows: Section 2, briefly covers the related work in achieving realistic facial animation. Section 3, illustrated FACS recent applications and limitations. MPEG-4 facial animation has been discussed in Section 4. Section 5 compares between FACS and MPEG-4. Finally, conclusion and future work in Section 6.

2. Related Work

Facial animation has been the interest in computer graphics and animation communities [1], [22]. Great attempts have been made to generate the facial animation. Since the performance-driven animation method [23], also known as expression mapping, was introduced by Williams [24], it has been widely investigated [25], [26], [27], [28], [29], especially with the development of advances in 3D scanning and motion capture technologies [25]. Significant research efforts have been attempted to generate realistic facial animation since Parke groundbreaking work in 1972 [30]. We can achieve realistic facial animation through geometric deformations and image manipulations. Geometric deformations usually account for the shape and deformations unique to the physiology and expressions of a person. Image manipulations model the reflectance properties of the facial skin and hair to achieve small-scale detail that is difficult to model by geometric manipulation alone.

Since the year 2000, facial animation has been extensively developed on many levels. An example of a milestone in the use of computer facial animation was in the film trilogy, "The Lord of the Rings". In these movies, new hybrid techniques like FACS from psychological research mixed with motion capture and keyframe animation helped bring facial animation to a new realistic and expressive leverage point. This hybrid technique was also applied in movies like "King Kong", "Monster House", "Avatar" and other films [5]. It presented the Visual Effects (VFX) to the world [52].

Meanwhile, facial animation was also used in the game industry and played an important role in computer games such as "The Sims" which used Artificial Intelligence techniques when generating families of corresponding related face models [31]. The gaming industry also utilizes the FACS system to produce facial expressions for their characters like in "Half Life 2", the first-person shooter video game, which was released in November 2004, by Valve Corporation [54].

Facial animation techniques can be covered from two aspects: facial modeling techniques and animation data acquirement techniques. Facial modeling techniques include shape interpolations, parameterizations, muscle-based modeling and pseudo-muscle based models. Animation data acquirement techniques include speech-driven techniques, image-based techniques and data-capture techniques [2], [3]. FACS' simplicity overcomes interpolation limitation and makes FACS utilized widely with muscle or simulated muscle based approaches [36]. FACS' Action Units (AUs) or MPEG-4 Facial Animation Parameters (FAPs) are established to parametrically represent the facial animations in order to smooth the parameterization process.

Recent techniques are adopted for the composition of several methods to achieve improved results [20]. Ma et al. [32] improved parameterized face model of candied based on MPEG-4 and FACS. Others include mixed and group-based animation systems [33], [20]. Yu et al. [23] presented a realistic facial animation generation method based on facial expression mapping through recording AUs according to FACS from real humans and mapping to different face models. Luo et al. [34] proposed a real-time video-driven facial animation method to realistically animate a 3D virtual face. They also addressed in [35] the issue of synthesizing real-time expressive facial animation from videos by describing a real-time video-driven facial animation system.

3. Facial Action Coding System

Facial Action Coding System (FACS) is an anatomically based system for describing all observable facial movements. Each observable component of a facial movement is called an Action Unit or AU. Each AU corresponds to an individual face muscle (e.g., the Buccinator muscle underlies AU14: Dimpler) or muscle group (e.g., the Frontalis and Pars Medialis muscles underlie AU1: Inner Brow Raiser). Each AU is identified by a number (AU1, AU4, AU27, …etc.). FACS breaks down the human face into 46 basic action units, samples of these action units are presented in Table 1.

Table 1. Action Units Samples

AU	FACS Name
1	Inner Brow Raiser
14	Dimpler
5	Upper Lid Raiser
17	Chin Raiser

Facial expressions are generated by combining the action units. For example, combining AU6 (Cheeks raiser), AU12 (Lip Corner Puller), and AU25 (Lips Part) generates 'Happiness' expression as shown in Figure 1 (a). Another example, 'Surprise' expression, is shown in Figure 1 (b). Recently, FACS has been successfully adapted for several species rather than humans, such as chimpanzees [44], macaques [45], gibbons [46], dogs [47], Cats [48], and horses [49].

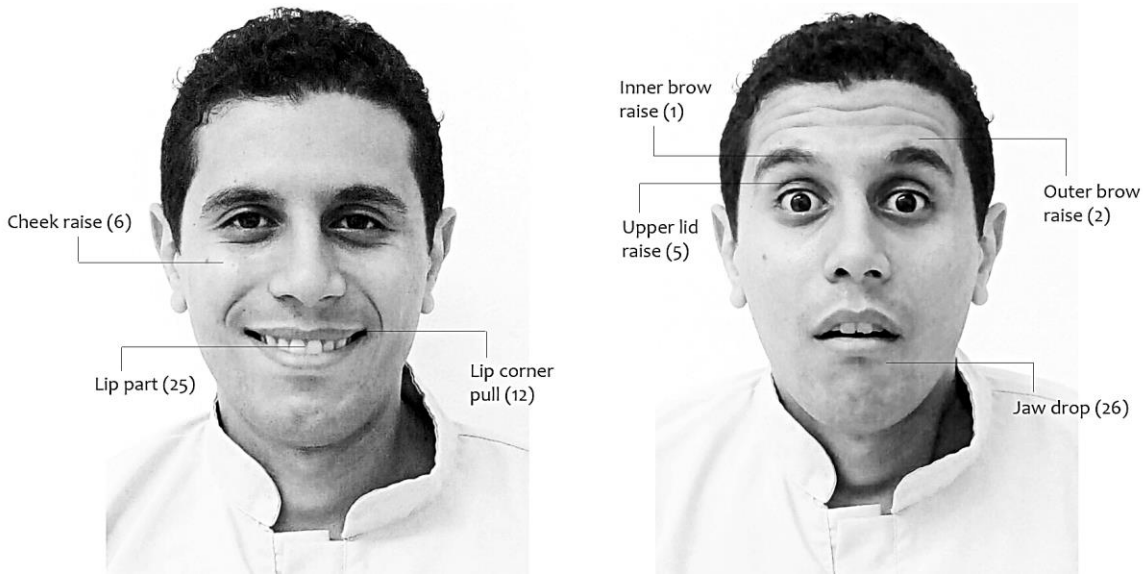

Figure 1. (a) Happiness (b) Surprise

3.1. FACS Appliccations:

There are two primary applications of FACS in the Facial Animation Field. First, in muscle based animation, FACS may be used as a guide to drive the required muscle activations to create a particular expression. Second, where a particular muscle model is not employed, FACS AUs are often used as a reference for creating key target shapes which will be blended together to animate the complete expressions [55].

FACS was applied to the Facial Expression Solver (a real-time system that captures the performance of the actor in the tracking workstation) in the production of "King Kong" movie in 2008. The system determines which Action Units in FACS are being activated to create the captured facial expression and automatically map the FACS poses onto a puppet's face. Utilizing the standardized 'language' of the FACS poses allows the system to drive a rig that can make thousands of different facial expressions. The authors introduce that this system is for realistic facial animation, and can deconstruct the facial motion capture data into semantically meaningful motion channels based on FACS which achieves a result with a high level of realism [54].

Unlike self-report measurements and physiological methods, FACS analysis of facial expressions supports a natural and intuitive interaction in psychophysiology [16], [17], [18]. Khorrami et al. [40] have shown how deep neural networks learn Facial Action Units when doing expression recognition. Amini et al. [12] presented HapFACS 3.0, a new free API and software for generating FACS-based facial expressions on 3D virtual characters that have lip-synchronized speech abilities. Alkawaz et al. [41] integrated blend shape interpolation (BSI) with FACS to create a realistic and expressive computer facial animation design. Roesch et al. [57] presented

FACSGen: a tool that provides researchers with total control over facial action units and allows the creation of realistic synthetic 3D facial stimuli, both static and dynamic, based on FACS.

3.2. FACS Limitations:

Despite FACS popularity, there are some drawbacks of using it …

1) FACS deals with what is clearly visible on the face and ignore the invisible changes which would be important to fully understand the psychology of a facial behavior [56].
2) FACS unable to encode various amplifications of an expression, as well as temporal patterns, due to its binary specification of muscle activation that limits muscles to either fully contracted or relaxed. This would be a problem when there is a need to represent smooth and continuous facial motion [56].
3) FACS unable to recognize the requirements for lip-synchronization because it does not cover all of the visible, distinguishable and reliable actions of the muscle controls in the lower parts of the face [20].
4) High-quality video equipment is required to code FACS.
5) FACS scoring relies on the estimation of trained experts and it is arduous and expensive to render the coding. Therefor Rothkrantz et al. [37] found new ways to code facial expressions semi-automatically using the FACS system.
6) FACS training itself requires about 3 months to study the FACS manual, and about 12 hours to take the FACS certification. [38]
7) Experimental results on a user-generated dataset in [39] showed that FACS does not provide any information about the degree of muscle activation.

4. MPEG-4 Facial Animation

Facial animation was adopted into the MPEG-4 standard due to its increased applications. MPEG-4 Facial Animation outlines many parameters of a talking face in a standardized technique. It successfully describes the Face Definition and Animation Parameters for facial action encoding. MPEG-4 specifies and animates 3D face models by defining Face Definition Parameters (FDP) and Facial Animation Parameters (FAP). FDPs enclose information for constructing specific 3D face geometry, and FAPs encode motion parameters of key feature points on the face over time. Face Animation Parameter Units (FAPU) that scale FAPs for fitting any face model, are defined as the fractions of key facial features, such as the distance between the two eyes [5].

In MPEG-4, the head is grouped into 84 feature points (FPs) in which every such point describes the shape of an area. Figure 2 approximately illustrates part of the MPEG-4 feature points in a front face. After excluding the feature points that are not affected by FAPs, 68 FAPs are categorized into groups. Examples of these groups are shown in Table 2.

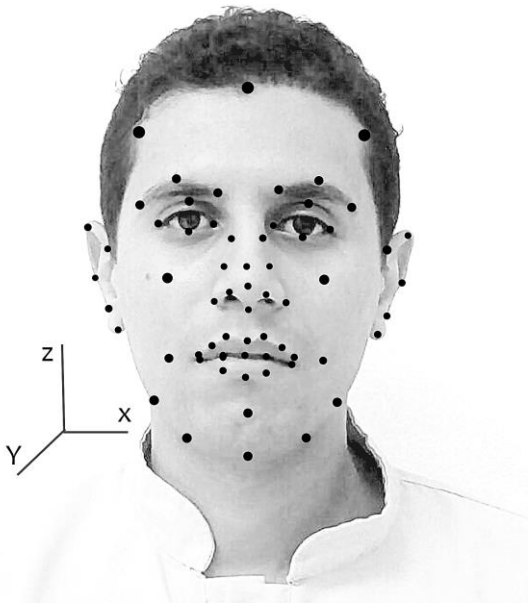

Figure 2. Part of the MPEG-4 feature points in a front face [42].

Table 2. Examples Of FAPs Groups In MPEG-4 [42].

Group	Number of FAPs
Viseme and expressions	2
Lip, Chin and Jaw	26
Eyebrow	8
Tongue	5
Cheeks	4

The FAPs are two categories, one represents the facial expressions which includes six basic emotions such as anger, sadness, surprise, joy, fear, and disgust. The other one focuses on certain facial areas like the left corner of the mouth, the bottom of the chin and the right eyebrow. It is important to mention that FAPs do not require any geometric models or synthetic face to be used. They simply sketch the desired movements and are independent of the animation methods [20]. For more details about MPEG-4 facial animation standard, please refer to the MPEG-4 facial animation book [42].

As we see in modern animation systems, MPEG-4 standards define a 3D facial and body model animations (FAPS / BAPS respectively) technique. El Rhalibi et al. [43] introduced a framework based on 3D Homura that integrate MPEG-4 standards to highly realistic animation streams known as Charisma, which can be applied for animation systems used with modern games and virtual characters in the web. Furthermore, MPEG-4 delivers a scripting language capable of producing parameters [20].

5. FACS VS MPEG-4

MPEG-4 is sometimes seen just as a formalization of FACS, but what makes it fundamentally different approach is that, unlike FACS, it lacks the direct correspondence between animation parameters and facial muscles. FACS provides a very reliable description for the face upper parts but it does not for the lower parts of the face. That limits FACS from being the dominant technique in the Facial Animation field.

MPEG-4 defines 66 low-level FAPs and two high-level FAPs. The low-level FAPs are based on the study of minimal facial actions and are closely related to muscle actions. They represent a complete set of basic facial actions, and therefore allow the representation of most natural facial expressions. Meanwhile, FACS clearly define facial expressions by combining the actions unites that are based on the facial muscle.

MPEG-4 covers FACS limitation in Lip-Synchronization by using the existent number of FPs in the mouth region that create very granular and precise shapes in the lip region at all times [58] as shown in Figure 3.

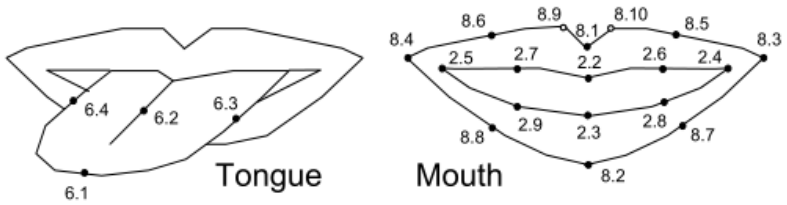

Figure 3. MPEG-4 FPs for the mouth and tongue [50].

Some movements, such as contraction of the orbicularis oculi muscle movements and wrinkling of the nose are absent from MPEG-4. FACS clearly defined the orbicularis oculi with AU6 and AU7, and AU9 for the nose wrinkling. FACS provides a more comprehensive parameterization of facial movement than the set of parameters presently included in MPEG-4. In addition, FACS can help with the problem of ground truth when assigning emotional or cognitive labels to a set of facial movements. For example, the MPEG-4 high-level emotion descriptor for joy is "the eyebrows are relaxed, the mouth is open, and the mouth corners are pulled back toward the ears". This description omits the contraction of the orbicularis oculi muscle. It also might confuse a fear mouth, which pulls the mouth corners towards the ears using the risorious muscle, with the smiling mouth, which pulls the mouth corners towards the temples using the zygomaticus major [53]. Where FACS clearly defined the risorius muscle and the zygomaticus major in AU20 and AU12, respectively. We summarized all the mentioned basic distinctions between FACS and MPEG-4 in Table 3.

Table 3. Basic distinctions between FACS and MPEG-4.

	FCAS	**MPEG-4**
Facial Features Classification:	Using 46 AUs based on underlying facial muscles	Using FAPs that describe the position of a certain part of a face.
Facial Expression:	Described by a combination of multiple AUs.	Expressed by FAPs through FDPs.
Corresponds between Animation Parameters and Facial Muscles:	Exist using AUs.	Lacks the direct correspondence.
Lip- Synchronization:	Unable to recognize the requirements for it [20].	Animates speech automatically and realistically [58].
Orbicularis Oculi muscle movements:	Are defined using AU6 and AU7 [6].	Some movements are absent [50].
Fear Mouth and Smiling Mouth:	Are clearly defined using AU20 and AU12. AU20: uses risorius muscle to pull the mouth corners in Fear. AU12: uses zygomaticus muscle in Smiling [6].	Are confused because high-level emotion descriptor omits the contraction of orbicularis oculi [51].

6. Conclusion and Future Work

The quest for developing realistic facial animation is ever-growing and to many aspects to be considered, like hair, skin, tongue, tears, etc., in order to achieve realistic facial animation. FACS has been used widely in facial animation field to assist animators to clarify and produce lifelike facial expressions. FACS' Action Units (AUs) or MPEG-4 Facial Animation Parameters (FAPs) are established to parametrically represent the facial animations in order to smooth the parameterization process and get realistic results.

In future work, we will overcome one of the FACS drawbacks by defining distinguishable and reliable actions to control some of the lower face muscles that will help to make the facial animation more realistic.

References:

[1] N. Ersotelos and F. Dong, "Building Highly Realistic Facial Animation: A Survey", The Visual Computer, vol. 24, Iss.1, pp.13-30, 2008.

[2] L. Li, Y. Liu and H. Zhang, "A Survey of Computer Facial Animation Techniques", International Conference on Computer Science and Electronics Engineering, 2012.

[3] H. Ping, L. Abdullah, P. Sulaiman, and A. Abdul Halin, "Computer Facial Animation: A Review", International Journal of Computer Theory and Engineering, Vol. 5, No. 4, 2013.

[4] G. Sandbach, S. Zafeiriou, M. Pantic and L. Yin, "Static and Dynamic 3D Facial Expression Recognition: A Comprehensive Survey", Image Vision Computing, Vol. 30, No. 10, pp. 683-697, 2012.

[5] Z. Deng and U. Neumann, "Data-Driven 3D Facial Animation", British Library, 2008.

[6] P. Ekman and W. Friesen, "Facial Action Coding System: A Technique for the Measurement of Facial Movement", Consulting Psychologists Press, Palo Alto, 1978.

[7] P. Ekman, W. Friesen, and J. Hager, "Facial Action Coding System", The Manual on CD ROM, A Human Face, Salt Lake City, 2002.

[8] B. Flueckiger, "Computer Generated Characters in Avatar and Benjamin Button", Translated from the German by Benjamin Letzler, 2011.

[9] Sujonoa and A. Gunawana, "Face Expression Detection on Kinect using Active Appearance Model and Fuzzy Logic", International Conference on Computer Science and Computational Intelligence (ICCSCI), pp. 268 – 274, 2015.

[10] A. Dapogny, K. Bailly and S. Dubuisson, "Confidence-Weighted Local Expression Predictions for Occlusion Handling in Expression Recognition and Action Unit Detection", Springer Science+Business Media, New York, 2017.

[11] P. Tripathi, K. Verma, L. Verma, and N. Parveen, "Facial Expression Recognition Using Data Mining Algorithm", Journal of Economics, Business and Management, Vol. 1, No. 4, November 2013.

[12] R. Amini, C. Lisetti, and G. Ruiz, "HapFACS 3.0: FACS-Based Facial Expression Generator for 3D Speaking Virtual Characters", IEEE Transactions On Affective Computing, vol. X, No. X, September 2014.

[13] C. Butler, L. Subramanian and S. Michalowicz, "Crowdsourced Facial Expression Mapping Using a 3D Avatar", In Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems, pp. 2798-2804, California, USA, May 2016.

[14] I. Menne and B. Lugrin, "In the Face of Emotion: A Behavioral Study on Emotions Towards a Robot Using the Facial Action Coding System", HRI '17 Companion, Vienna, Austria, March 2017.

[15] I. Menne, C. Schnellbacher, and F. Schwab, "Facing Emotional Reactions Towards a Robot – An Experimental Study Using FACS", Springer International Publishing, ICSR, pp. 372–381, 2016.

[16] S. Lwi, J. Casey, N. Nguyen, P. Whalen, D. Keltner, and R. Levenson, "Short Alleles, Bigger Smiles? The Effect of 5-HTTLPR on Positive Emotional Expressions", Conference Paper in Psychophysiology, September 2013.

[17] J. Miranda, T. Fernandes, A. Sousa and V. Orvalho, "Interactive Technology: Teaching People with Autism to Recognize Facial Emotions", In Autism Spectrum Disorders - From Genes to Environment book, September 2011.

[18] G. Bersani, F. Bersani and G. Valeriani, "Comparison of facial expression in patients with obsessive-compulsive disorder and schizophrenia using the Facial Action", Article in Neuropsychiatric Disease and Treatment Journal, December 2012.

[19] I. Ali, A. Basori and G. Sulong, "Emotional Facial Expressions, Eye Behaviors, Lips Synchronization: Current and Future Direction", Life Science Journal, 2014.

[20] M. Alkawaz, D. Mohamad, A. Basori and F. Mohamed, "A Crucial Investigation of Facial Skin Colour Research Trend and Direction", International Journal of Multimedia and Ubiquitous Engineering, Vol. 10, pp. 295-316, No. 1, 2015.

[21] M. Rahim, A. Basori, S. Saadi, A. Rad and A. Rehman, "Emotional Facial Expression and Tears Simulation: An Analysis & Comparison of Current Approaches", 3D Research Center, Kwangwoon University and Springer-Verlag Berlin Heidelberg, 2015.

[22] Z. Deng And J. Y. Noh, "Computer Facial Animation: A Survey" , pp.1-28, Springer Press, Data-Driven 3d Facial Animation, 2007.

[23] H. Yu, O. Garrod, R. Jack and P. Schyns, "Realistic Facial Animation Generation Based on Facial Expression Mapping", 5th International Conference on Graphic and Image Processing, Vol. 9069, 2014.

[24] L. Williams, "Performance-Driven Facial Animation", In Siggraph '90, Acm Press, pp. 235–242, 1990.

[25] L. Zhang, N. Snavely, B. Curless and S. Seitz, " Spacetime Faces: High Resolution Capture For Modeling And Animation", ACM Transactions On Graphics 23, pp. 548-558, 2004.

[26] C. Curio, M. Breidt, M. Kleiner, Q. Vuong, M. Giess and H. Bulthoff, "Semantic 3D Motion Retargeting for Facial Animation", In Proceedings of the ACM APGV, pp. 59–64, 2007.

[27] J. Noh and U. Neumann, "Expression Cloning", In Proceeding of Siggraph, pp. 277–288, 2001.

[28] V. Blanz, C. Basso, T. Poggio and T. Vetter, "Reanimating Faces In Images And Video", In Proceeding of Eurographics, pp. 641–650, 2003.

[29] Q. Zhang, Z. Liu, B. Guo, D. Terzopoulos and H. Shum, "Geometry-Driven Photorealistic Facial Expression Synthesis", IEEE Transactions On Visualization And Computer Graphics, vol. 12, no. 1, pp. 48–60, 2006.

[30] F. Parke, "Computer Generated Animation of Faces", In Proceedings of the ACM annual conference – vol. 1, pp. 451-457, Boston, Massachusetts, USA, 1972.

[31] S. DiPaola, Investigating Face Space, In ACM SIGGRAPH 2002 Conference Abstracts and Applications, SIGGRAPH '02. ACM, pp. 207-207, New York, 2002.

[32] B. Ma, J. Yao, R. Yan and B. Zhang, "The Improvement of Parameterized Face Model of Candide Based on MPEG-4 and FACS", International Journal of Electrical Energy, Vol. 2, No. 2, June 2014.

[33] A. Basori and A. Qasim, "Extreme Expression of Sweating in 3D Virtual Human", Computers in Human Behavior, vol. 35, pp. 307-314, 2014.

[34] C. Luo and Z. Wang, "3D Virtual Facial Animation for General Users", Journal of Computer-Aided Design and Computer Graphics, Vol. 27, No.3, March 2015.

[35] C. Luo, C. Jiang, J. Yu and Z. Wang, "Expressive Facial Animation from Videos", Image Processing (ICIP), IEEE International Conference, 2014.

[36] C. Liu, "An Analysis of the Current and Future State of 3D Facial Animation Techniques and Systems", Master Thesis, Communication University of China, Canada, 2009.

[37] L. Rothkrantz, D. Datcu and P. Wiggers, "FACS-coding of Facial Expressions", In Proceedings of the International Conference on Computer Systems and Technologies and Workshop for PhD Students in Computing, Article No. 30, Bulgaria, June 2009.

[38] Pocket Guide, "Facial Expression Analysis", iMotions, 2016.

[39] Sujonoa and A. Gunawana, "Face Expression Detection on Kinect using Active Appearance Model and Fuzzy Logic", International Conference on Computer Science and Computational Intelligence (ICCSCI), pp. 268 – 274, 2015.

[40] P. Khorrami, T. Paine and T. Huang, "Do Deep Neural Networks Learn Facial Action Units When Doing Expression Recognition?", In Proceedings of the 2015 IEEE International Conference on Computer Vision Workshop (ICCVW), pp.19-27, version 3, March 2017.

[41] M. Alkawaz, D. Mohamad, A. Basori and T. Saba, "Blend Shape Interpolation and FACS for Realistic Avatar", 3D Research Center, Kwangwoon University and Springer-Verlag Berlin Heidelberg, 2015.

[42] I. Pandzic and R. Forchheimer, "MPEG-4 Facial Animation: The Standard, Implementation, And Applications", John Wiley & Sons, 2002.

[43] A. El Rhalibi, C. Carter, S. Cooper and M. Merabti, "Highly Realistic MPEG-4 Compliant Facial Animation with Charisma", In Proceedings of 20th International Computer Communications and Networks (ICCCN) Conference, USA, August 2011.

[44] L. Parr, B. Waller, S. Vick and K. Bard, "Classifying Chimpanzee Facial Expressions Using Muscle Action", Emotion TOC Journal, pp. 172–181, February 2007.

[45] L. Parr, B. Waller, A. Burrows, K. Gothard and S. Vick, "MaqFACS: A Muscle-Based Facial Movement Coding System for the Rhesus Macaque", Am J Phys Anthropol, pp. 625–630, December 2010.

[46] L. Scheider, B. Waller, L. Oña, A. Burrows and K. Liebal, "Social Use of Facial Expressions in Hylobatids", PLOS ONE, March 15, 2016.

[47] B. Waller, K. Peirce, C. Caeiro, L. Scheider, A. Burrows, S. McCune and J. Kaminski, "Paedomorphic Facial Expressions Give Dogs a Selective Advantage", PLOS ONE, Volume 8, December 2013.

[48] C. Caeiro, B. Waller, A. Burrows, www.catfacs.com, October 2017, Department of Psychology University of Portsmouth, UK.

[49] J. Wathan , A. Burrows, B. Waller and K. McComb, "EquiFACS: The Equine Facial Action Coding System", PLOS ONE, August 2015.

[50] Visage Technologies, "MPEG-4 Face and Body Animation (MPEG-4 FBA): An overview", pp. 30-36, Sweden, 2012.

[51] M. Bartlett, "Face Image Analysis by Unsupervised Learning", Springer Science & Business Media, pp. 69-78, 2012.

[52] I. Failes, "Masters of FX: Behind the Scenes with Geniuses of Visual and special Effects", CRC Press, February 2016.

[53] M. Bartlett, "Face Image Analysis by Unsupervised Learning", Kluwer Academic Publishers, 2001.

[54] B. Li, "Creating 3D Tutorial System for Facial Animation: Visualizing Facial Muscle System Based On Facial Action Coding System", Master thesis, Drexel University, Pennsylvania, June 2014.

[55] H. Bastani, "A Nonlinear Framework for Facial Animation", Master thesis, University of Toronto, 2008.

[56] T. Küderle, "MUSCLE-BASED FACIAL ANIMATION", Diploma Thesis, University Of Applied Science Wedel (FH), Germany, 2005.

[57] E. Roesch, L. Tamarit, L. Reveret, D. Grandjean, D. Sander, and K. Scherer, "FACSGen: A Tool to Synthesize Emotional Facial Expressions through Systematic Manipulation of Facial Action Units", Springer Science+Business Media, LLC 2010.

[58] R. Duarte, A. El Rhalibi and M. Merabti, "Coarticulation and speech synchronization in MPEG-4 based facial animation", Kybernetes, Vol. 43 Issue: 8, pp. 1165-1182, 2014.