CLASSIFICATION TECHNIQUE FOR HUMAN EMOTION IN VIRTUAL REALITY USING GAME-BASED BRAIN COMPUTER INTERFACE

FARIS AMIN MUFLIH ABUHASHISH

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To my lovely beloved sweet wife and wonderful kids

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ABSTRACT

The substantial amount of reviews in the realms of computer graphics and the multimedia as well as emotion synchronizing and controlling techniques of 3-Dimension (3D) have thrown the 3D Virtual Human (VH) model in Virtual Reality (VR) into the spotlight. It only requires a small number of 3D VH model systems to manage emotions through sophisticated procedures that include human brain activity together with 3D emotion expression feedback. However, this circumstance leads to a deficiency in emotion interpretation. Emotion interpretation is crucial for the categorization of human sentiments so that they can be coordinated and plotted with a 3D VH model to generate the interaction outcome via emotional walking expression and reveal complete emotion interaction feedback in VR. This study recommends a hybrid emotion classification technique which attains the immersion of emotion interaction with a 3D VH model. This technique involves three steps. Firstly, the criterion of the obstacle that requires a solution is identified. The second step involves emotional feature extraction through a reformulated method, and categorization with a hybrid method and plotting with a defined formula. The third step entails the assimilation and execution of all the features of the recommended technique and mapping the classified emotions. This includes the implementation of a synthesis of emotional walking alongside emotion integration, brain activity and the 3D VH model. Ultimately, the recommended model is analysed and substantiated through actual emotion effects on the 3D VH model with emotional walking style in a VR circumstance. The classified accuracy percent is 88.7% that is achieved by the proposed technique. Outcomes from the tests established that the enhancement of immersion of emotional expression through this procedure is achievable through the utilization of game-based Brain Computer Interface (BCI) in the VR domain. The employment of this technique considerably elevates the realism and immersion of other applications such as robotics regarding emotion.

ABSTRAK

Sejumlah besar tinjauan dalam alam grafik komputer dan multimedia serta pelarasan emosi dan teknik pengawalan 3-Dimensi (3D) telah meletakkan model Maya (VH) 3D dalam Realiti Maya (VR) ke dalam sorotan. Ia hanya memerlukan sejumlah kecil sistem model 3D VH bagi mengurus emosi melalui prosedur yang canggih termasuk aktiviti otak manusia berserta dengan maklumbalas ekspresi emosi 3D. Namun bagitu, keadaan ini membawa kepada kekurangan dalam tafsiran emosi. Tafsiran emosi penting untuk pengkategorian sentimen manusia agar ianya boleh diselaraskan dan diplotkan dengan model 3D VH bagi menjana hasil interaksi melalui ekspresi berjalan secara emosi dan mendedahkan maklumbalas interaksi emosi lengkap dalam VR. Kajian ini mencadangkan satu teknik pengkelasan emosi hibrid yang mencapai kemasukan interaksi emosi dengan model 3D VH. Teknik ini merangkumi tiga langkah. Pertama, kriteria halangan yang memerlukan penyelesaian dikenal pasti. Langkah kedua melibatkan pengekstrakan ciri emosi melalui kaedah yang dirumus semula, dan pengkategorian dengan kaedah hibrid dan pemplotan dengan formula yang ditetapkan. Langkah ketiga melibatkan asimilasi dan pelaksanaan semua ciri daripada teknik yang disarankan dan pemetaan emosi-emosi yang dikelaskan. Ini termasuk pelaksanaan sintesis berjalan secara beremosi bersama integrasi emosi, aktiviti otak dan model 3D VH. Akhirnya, model yang dicadangkan dianalisa dan dibuktikan melalui kesan emosi sebenar ke atas model 3D VH dengan gaya emosi berjalan dalam keadaan VR. Peratus ketepatan yang dikelaskan ialah 88.7% yang dicapai dengan kaedah dicadangkan. Keputusan ujian menunjukkan bahawa peningkatan gabungan ekspresi emosi melalui prosedur ini boleh diperolehi menerusi penggunaan permainan berasaskan Antaramuka Komputer Otak (BCI) dalam domain VR. Penggunaan teknik ini begitu berjaya meningkatkan realisme dan gabungan aplikasi-aplikasi lain seperti robotik berkaitan emosi.

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LIST OF ABBREVIATIONS

VE	-	Virtual Environment
VH	-	Virtual Human
VR	-	Virtual Reality
VRG	-	Virtual Reality Game
HFD	-	Highuchi Fractal Dimension
EEG	-	Electroencephalogram
3D	-	3-Dimension
BCI	-	Brain Computer Interface
HCI	-	Human Computer Interaction

LIST OF SYMBOLS

var(X)	-	Variance
std(X)	-	Standard Deviation
$\rho X,Y$	-	Correlation
Mo	-	Mode

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Many studies focused on 3D virtual human animation as one of the computer graphics fields. These studies cover a wide range of topics which include computer games, cartoons, computer simulation and motion picture special effects. According to Zhuang *et al.* (2008), investigators in this sphere are prone to slotting computer animation practices into the same category as computer graphics.

Free from the shackles of conventional methods, computer graphics developed briskly and innovatively in the animation domain and subsequently extended its influence to other areas of research. Many investigations in the past have delved into visualization and animation in a virtual situation (Rauterberg *et al.,* 2006; Basori *et al.,* 20011a). Several of these investigations focused on ways to facilitate interaction amongst 3D virtual humans via remote computers to realize human computer relations (Abásolo, 2007; Adamo-Villani, 2007; Greitzer, 2007; Marks *et al.,* 2007).

Over the last ten years, the emphasis of investigations in the field of computer graphics and the multimedia has swung towards virtual reality. These investigations focused on emotion interaction Rauterberg *et al.* (2006) and delved into the psychological aspects of multimedia relations between virtual reality and the real world for the generation of an interface and a medium that can pave the way towards good interaction. The depiction of a human being as a virtual human in a virtual circumstance is regarded as an interface that can formulate an amicable association between humans and computers (Wang *et al.*, 2005).

Currently, the methods employed for the management of 3D virtual human animation are inadequate and wanting in realism (Basori *et al.*, 2011a). Although an array of accepted mechanisms have been harnessed as 3D virtual human controllers, they fall short in the area of human interaction. These mechanisms include the joystick, game pad, mouse and keyboard. The controls for the present day gaming generation are dependent on sensors that include Kinect, XBOX, Gestures and Wii. Currently, the flexible management of interactive applications related to 3D virtual human animation is severely restricted (Oshita, 2011). The game player finds himself/herself restrained by the negligible degree of freedom on offer. The current control mechanisms available do not allow for the free movement of 3D virtual humans to be in tandem with the emotions of a player. At the very least, these mechanisms ought to permit the performance of a series of feats in accordance with the distinctive approach of a gamer (Oshita, 2011).

Emotion-based 3D virtual human animation is held in high esteem for its potential in the realm of animation Magnenat-Thalmann *et al.* (2006); Takamura *et al.* (2006) and Bailenson *et al.* (2007) as there is presently a dearth of interaction between gamers and games with regard to emotions (Oshita, 2011; Tanaka *et al.*, 2012). In response to this situation, Basori *et al.* (2011a) forwarded an innovative structure for emotional interaction in virtual reality by generating facial expressions founded on facial muscles, acoustics and haptics. Unfortunately, this approach still fell short in terms of immersive emotion interaction and consequently, the element of realism. Liu and Sourina (2013), however, confined their investigations on facial expression to brain activity. Taking off from the efforts of Basori, (2013) and Sourina (2013), they endeavoured to achieve complete feedback interaction regarding emotion with the emphasis on brain activity.

Utilizing a mind controller mechanism, the immersion emotional interaction is conducted solely through brain activity emotion. The feedback takes into account the full body gait of the 3D virtual human as well as the natural interaction in terms of emotion which will enhance the realism of a 3D virtual human in the virtual reality sphere. Subsequently, the interaction between gamers and games will take on a more realistic feel due to the enhanced human-like conduct of the animated 3D virtual human.

For the purpose of attaining immersive emotion, an emotion facet extraction is calculated based on the recommended reconstructed arithmetical element. This process is conducted based on actual human emotions drawn from the game player. Real human emotion is identified through the elicitation and analysis of brain signals. Then, Higuchi Fractal Dimension (HFD) is employed for an illustration on basic emotion data. And lastly, the Mode Statistical Feature is applied on the concluding outcome of the HFD as a recommended feature extraction procedure in order to calculate the emotion within the predetermined emotion interval.

The execution of a hybrid classification procedure with the Pearson correlation coefficient on the outcome of the feature extraction is suggested as an alternative procedure. The generation of emotions was achieved through an inclusive classified value of emotions in relation to their intervals. This hybrid procedure comprises self-assessment, the emotion dimension model and variance of brain hemisphere activity. The purpose of self-assessment is to establish the emotion of the subject that corresponds to the emotion model (arousal and valence) according to the International Affective Picture System (IAPS) and the International Affective Digitized Sounds (IADS). As for the emotion dimension model, each emotion is assigned into multidimensional, emotion valence or emotion arousal scales. These scales denote positive and negative emotions in relation to calmness and excitement and the emotions are categorized according to their scale. Variance of brain hemisphere activity is defined as the computation of the variation between the activities of the two hemispheres to establish the one with a superior level of activity. Subsequent to emotion mapping with a comprehensible and precise emotion, the mapping equation is utilized to match the emotion with the game player and the 3D virtual human model.

The last but one step involves the crafting of the 3D virtual human model to allow for the mapped emotion to attain the complete body walking style feedback in relation to emotion which is influenced by brain activity. Accordingly, immersive emotional interaction is also realized. The straightforward kinematics procedure is utilized for generating the 3D virtual human model and to maintain the inherent robust traits of the investigational model with regard to emotion.

The ensuing integration process moves on to fashion a walking style that is swayed by the real time emotion of a player. The real human emotion which is concurrently altered subsequent to coordination of the 3D virtual human model is then incorporated. In order to establish the emotion of the player and to coordinate this emotion with the 3D virtual human model in real time, the EPOC Emotive mind controller was employed. The EPOC Emotive mind controller has the capacity to interpret the brain activity signals ascertaining the player's emotion type.

This study made some progress in efforts to enhance the procedures related to the extraction of emotional features as well as the categorization and mapping of emotions. This paved the way for the incorporation of the player's emotion with the 3D virtual human model to realize immersion interaction between player and game through the utilization of a brain computer interface (BCI). Thus, other than enhancing the immersion of emotional expression, the realism of emotional interaction in a virtual reality circumstance is also elevated (see Figure 1.1).

1.2 Problem Background

The development of 3D virtual human animation leaves much room for improvement. This is particularly so in the areas of interaction and immersion (Basori, 2013; Oshita *et al.,* 2012). A substantial number of 3D virtual human animation investigators have conducted studies with the intention of enhancing their expertise in this domain and contribute towards its development especially in the context of realism. The overriding objective of researchers in this field is the elevation of immersion and interactivity between gamers/users and 3D virtual human animation in relation to behaviour based on the emotions of gamers/users (Bogdanovych, 2007; Yahaya, 2007; Hutchison, 2007).

A substantial number of procedures have been recommended for the inclusion of emotions in 3D virtual human animation (Bailenson *et al.,* 2007; Oshita, 2011; Oshita *et al.*, 2012). Acosta (2011) opines that in all likelihood, the fundamental elements that heighten the level of realism in 3D virtual human animation are walking real, feeling real, acting real, gaze moving real and talking real. In that sense, the artificial world or the 'like-real world' ought to be made up of an intricate fusion of animation and visualization (for instance user interface, navigation and convoluted model). The notion of 'walking real' denotes the simulation of the walking movements of a typical human being by a 3D virtual human. While the 'feeling real' notion relates to the virtual surroundings, the 'acting real' notion is in reference to the human-like behaviour of 3D virtual humans.

In an innovative endeavour, Traum (2008); Liu *et al.* (2011); Sourina *et al.* (2012); Basori (2013); Liu and Sourina (2013) attempted the portrayal of emotions by a 3D virtual human through the utilization of sound effects, facial expressions and the sense of feel. Zagalo *et al.* (2008) crafted and generated a 3D virtual human which had the capability of displaying specific emotions based on feel while sustaining the environmental alteration (saturation and brightness). Traum (2008) endeavoured to raise the human-like conduct of 3D virtual humans by enhancing their readiness to realize an elevated interactive communication avenue.

Rauterberg *et al.* (2006); Zagalo *et al.* (2008); Traum (2008) made an attempt to blend social parts, feelings and emotions to manage the navigation procedure of 3D virtual humans and generate an emotional circumstance for interaction. Human emotions entail the anticipation of better gains in the area of human-like simulation advances (Miranda, 2001). Researchers Hutchison (2007); Nunes *et al.* (2008) and Oshita *et al.* (2012) stated that the need to place more emphasis on technical issues such as sound manipulation, locomotion of the 3D virtual human, cursor navigation and the likelihood of scrutinizing the features through gamers or users need more focus and improvements. Improvements in these areas will enable users to not only feel, but also visualize the digital effects all through the period of the game (Nunes *et al.,* 2008; Basori 2013). Nunes *et al.* (2008) are of the opinion that passiveness and activeness are other facets that require more investigations.

During efforts to enhance the human-like behaviour of 3D virtual humans, researchers have recommended a range of techniques to include emotion in the equation. Oshita and Ishikawa (2012) conducted an investigation on interface of action selection in the computer graphics and multimedia realm. With the emphasis on usability and precision, they conducted a comparison study on the mechanisms employed as an interface for interaction among players/users and the 3D virtual human model in a virtual situation. They settled on an interactive medium for interaction with VR which came with a degree of freedom and proved to be accurate.

In many interactivity models such as dancing motion, fight games, 3D virtual human walking and real-time interactivity, the utilization of 3D virtual human animation remains, for the most part, restricted (Oshita, 2011; Tanakaet *et al.,* 2012). The exclusion of real emotions hampers the ability of the gamer to direct the 3D virtual human to execute human-like walking, interactive dance animation and fighting moves (Oshita, 2011; Tanakaet *et al.,* 2012).

García Rojas *et al.* (2006) and Feng A. (2012) are of the opinion that the available 3D virtual human models are in need of more enhancement in terms of realism and interaction procedures owing to their deficiency credibility. García Rojas *et al.* (2006) recommended providing the 3D virtual human with a sexual category and emotional feelings. In order for the interaction and movements of the 3D virtual human to be more realistic, they have to stem from an actual human situation (Lamare, 2005; Oshita and Masaoka, 2011; Oshita and Ishikawa, 2012; Oshita *et al.,* 2012).

Oshita (2011) recommends a multi-touch motion interactivity process for the 3D virtual human model. He offers a direct touch interface whereby the player uses his fingers for interaction with the 3D virtual human model. While this recommended interface is unorthodox and innovative, it fails to accurately mirror the actual sentiments of a player when compared to the Brain Computer Interface (BCI) (Basori *et al.,* 2011a). As the player directs the movements of the 3D virtual human with his fingers, the interaction method is wholly reliant on his/her fingers. The focus of the majority of investigators is on managing the behaviour of 3D virtual human movements in relation to sentiments (Oshita *et al.,* 2012). The mechanisms employed for the management of 3D virtual human emotions are the joystick, control gloves, camera tracker, keyboard, mouse or brain-computer interface (BCI) (Basori 2013; Jatupaiboon *et al.,* 2013; Sourina *et al.,* 2012).

Investigations on the BCI have been gaining momentum over the last several years (Liu *et al.,* 2011; Sourina *et al.,* 2012). It is sought after for a variety of real time applications that include virtual medical schemes and video games (Liu *et al.,* 2011; Basori *et al.,* 2011a Sourina *et al.,* 2012). The adaption of the BCI throws up the opportunity to exploit new technology for the transference of the user emotional status into 3D virtual human movements. The BCI has the capacity to access brain activities and impart relevant information on the emotional status of the user (Sourina *et al.,* 2012; Jatupaiboon *et al.,* 2013). Currently, the available procedures are dependent on pre-developed datasets procured from the motion capture data or key farming methods to establish the sentiment of a virtual human (Sourina *et al.,* 2012; Jatupaiboon *et al.,* 2013).

Brain controllers are equipped with a substantial number of sensors that are affixed to the gamer's head. These sensors have the capacity to retrieve the brain activity data of gamers during the period of interactivity (Liu *et al.,* 2011; Sourina *et al.,* 2012; Jatupaiboon *et al.,* 2013; Basori, 2013). The mind controller examines and discerns brain activity prior to yielding data signals denoting the inner human emotion in preparation for a pre-process. Subsequently, it categorizes the emotion according to the supposition of the emotional model (Russel, 1980; Basori, 2013; Sourina *et al.,* 2012; Jatupaiboon *et al.,* 2013).

The Brain Computer Interface (BCI) technology makes available an unimpeded linkage between the brain and computer without the need for any muscular activity (Aloise *et al.,* 2010). As such, this technology allows for the accommodation of both fit and disabled individuals in the VR game domain (BEE *et al.*, 2009; Velasco-Álvarez and Ron-Angevin, 2010; Sourina *et al.*, 2012; Basori, 2013). The BCI has also made its presence felt in the medical sphere for prosthesis management and as biofeedback therapy for treating neurological ailments (Nijholt and Tan, 2007). In the video game domain, the BCI does away with conventional controllers such as the keyboard, mouse and joystick, and utilizes brain signals instead. Currently, total body interaction with 3D virtual human utilizing full immersion toward BCI is developing into the latest fad (Lotte, 2011).

Relevant information gathered from previous investigations Basori (2013); Faris *et al.* (2012); Jatupaiboon *et al.* (2013) and Sourina *et al.* (2012) point to the fact that the BCI has the potential to be an appropriate interfacing implement in a VR situation for the management of 3D virtual human walking motion in relation to emotion.

The natural interaction management of 3D virtual human motion is generated by the game system through inner human emotions by the utilization of a mind controller. Among the most economical game-based mind controllers available is the emotive mind controller (Liu *et al.*, 2011; Sourina *et al.*, 2012; Basori, 2013). According to previous studies, the mind controller, otherwise known as the brain-computer interface, controls nearly all the emotions that are founded on applications (Liu *et al.*, 2011; Sourina *et al.*, 2012; Basori, 2013). This study opted for the BCI as it has the capacity to interpret the brain activity that corresponds to the emotions of the user (Basori, 2013; Jatupaiboon *et al.*, 2013). The game-based BCI mechanism interprets and identifies the bandwidth of signals related to human emotions that require further classification (Sourina *et al.*, 2012; Basori, 2013; Jatupaiboon *et al.*, 2013).

Koelstra *et al.* (2012); Sourina *et al.* (2012); Basori (2013) and Jatupaiboon *et al.* (2013) utilized the BCI to acquire signals denoting human emotions and achieved classification for between four to eight emotions. They disclosed that the fundamental predicament that comes with the utilization of emotion classification is that the number of emotions it can classify is limited and no benchmark related to these emotions.

Nevertheless, Liu *et al.* (2011); Sourina *et al.* (2012) and Basori (2013) utilized the emotions acquired for facial expressions as a feedback. The researchers stated that the existing emotion feedback lack of realism in two portions; first is the feedback technique and the second is the classification methods that are being used. Few researchers succeeded in establishing and modelling the acquired inner human emotions onto the facial features (but not on the moving body) of the 3D virtual human model to generate emotional interaction, but still lack of realism (Basori, 2013). As for future efforts, Basori (2013) proposed the coordination of human emotion with the 3D virtual human motion to portray the interaction feedback through the 3D virtual human model walking style in relation to human emotion. Although a substantial number of methods have been proposed for emotion classification utilizing EEG signals, their performance in this area still inefficient classification result with previous methods so still lack of realism (Koelstra *et al.*, 2012; Sourina *et al.*, 2012; Basori, 2013; Jatupaiboon *et al.*, 2013).

Horlings *et al.* (2008); Koelstra *et al.* (2012); Basori 2013 and Liu and Sourina (2013) recommended and utilized three varying emotion classification methods: the emotional dimension model, emotional self-assessment as well as brain activity with hemisphere variance. The results from these investigations revealed that these methods are reliant on a single factor (single class) for emotion classification that makes it poor. Furthermore, Chanel G. (2009); Mauss *et al.* (2009); Koelstra *et al.* (2012) and Liu and Sourina (2013) observed that the outcomes attained through these methods were imperfect and that a limited classification reference label denoting a particular sentiment was non-existent. As such, they are of the opinion that more studies are needed to boost the performance of these methods.

In conclusion, the potential for enhancing the interface managing 3D virtual human motion in the context of emotion in the VR gaming circumstance appears promising. The objective here is to attain the highest level of interactivity achievable. The route to this objective comes in the form of 3D virtual human motion enhancement in the context of emotional feedback. The 3D virtual human motion feedback in the VR domain needs to be improved as it is presently lack of realism (Basori, 2013).

The recognition of emotion utilizing EEG signals together with an emotional dimensional model was achieved by (Liu and Pan, 2005; Lichtenstein *et al.,* 2008; Cabredo *et al.,* 2012). They realized the classification of the emotions happy, fear, sad, frustration, excitement. However, in spite of their achievement, they opined that classification through these methods is still limited, no benchmark and there was still much room for improvement.

The highest classification rate attained by the emotion self-assessment classifier was 97.4% (Bos, 2006). The investigator observed a high level of correlation between the self-assessment classifier and the EEG brain signal denoting real emotion. He disclosed that this outcome will encourage more in-depth studies on emotion classification procedures and pave the way for improvements.

As for the brain activity with hemisphere variance classifier, Shiffer *et al.* (2007); Horlings *et al.* (2008) and Kaffenberger *et al.* (2010) attained the classification of four emotions: happiness, sadness, fear and anger. They also confirmed that each induced emotion correlated with each brain hemisphere. They opined that this accomplishment will open the door for improvements to this classifier through further investigations.

The performance of currently available emotion classifiers leave much to be desired as they achieve classification through a single class method and a single parameter. Also, in terms of emotion interaction, there have not been any moves to investigate the management of 3D virtual human emotion with full body interaction based on human emotion (Oshita and Ishikawa, 2012; Oshita *et al.,* 2012; Tanaka *et al.,* 2012; Basori, 2013). For the most part, the focus of studies in this domain has been on the management of facial expressions, and this is not wholly dependent on emotional brain activity it uses other devices i.e. hand gestures or the sole utilization of BCI (Basori, 2013; Liu *et al.,* 2011).

As the emotion dimension classifier is founded on a single class and its classification of human emotion is also limited to one parameter, it is deemed a limited classifier. Its classification capacity is restricted and the classified emotions cannot be labelled (Liu *et al.,* 2011; Basori *et al.,* 2011). The emotional self-assessment classifier only achieved the classification of four emotions (Sourina *et al.,* 2012). Sourina *et al.* (2012) disclosed that the performance of the self-assessment classifier is restricted and that it could not generate a generalized outcome. As such, this classifier failed to attract the attention of other investigators in this sphere. The brain activity and hemisphere variance procedure fared poorly as it struggled to classify just six emotions (Shiffer *et al.,* 2007; Horlings *et al.,* 2008; Kaffenberger *et al.,* 2010).

The outcomes attained by the three methods were deemed acceptable although (a) the classification is limited to a single approach and (b) the methods failed to generalize the outcomes (c) couldn't provide a benchmark. Among others, the investigators achieved the classification of the fundamental emotions of happiness, sadness, fear and disgust. These emotions were utilized in VE with a degree of freedom. These studies reveal the potential for human emotion classification. There is still a long way to go and further in-depth investigation are in the offing for the enhancement of these methods in anticipation of more vibrant and wide-ranging outcomes (Basori *et al.,* 2011a; Koelstra *et al.,* 2012; Basori, 2013; Liu and Sourina, 2013).

According to relevant literature, the recognition of emotion is crucial to emotion establishment. A substantial number of investigators in this domain are focused on enhancing the performance of classification algorithms in the context of emotions. This investigation recommends a merging of three procedures for the enhancement of emotion classification. Called the hybrid emotion classification technique, it covers the second phase of the study framework and the second goal of this investigation.

This investigation emphasizes on the development of a new classification procedure with the objective of (a) increase number of extracting of emotion features (b) generating more vibrant and wide-ranging outcomes (c) increasing the number of classified emotions and (d) implementing these emotions on the whole body movement of a 3D virtual human while utilizing the brain computer interface (BCI) for emotion expression.

1.3 Problem Statement

Numerous techniques and devices have been forwarded for the utilizing EEG brain activity in virtual environment in term of emotion i.e. game-based brain computer interface (Basori, 2013). Furthermore, the analysing of EEG brain signals for the classification of emotions utilizing non-invasive techniques can prove to be demanding (Yuen *et al.,* 2013; Liu and Sourina, 2013; Basori, 2013). Thus, emotion classification and mapping methods need more enhancement (Chanel G., 2009; Mauss *et al.,* 2009; Liu and Sourina, 2013; Basori, 2013).

The three obstacles that should be solved in this thesis are as follows: (a) emotion feature extraction (b) emotion classification and mapping technique (b) emotion interaction and feedback technique by utilizing EEG brain activity using game-based brain computer interface, these techniques do not have the capacity to generate comprehensive and generalized results (Koelstra *et al.,* 2012; Basori 2013; Liu and Sourina, 2013; Oshita, 2013; Jatupaiboon *et al.,* 2013). An improved emotion classification, mapping methods in addition to utilizing EEG brain activity using game-based brain computer interface will lead to elevated realism in the VE (Basori, 2013; Liu and Sourina, 2013; Oshita, 2013). Figure 1.1 illustrates visualization research domain and shows the focus of research as well, the research focus is highlighted in bold fonts within the Figure 1.1.

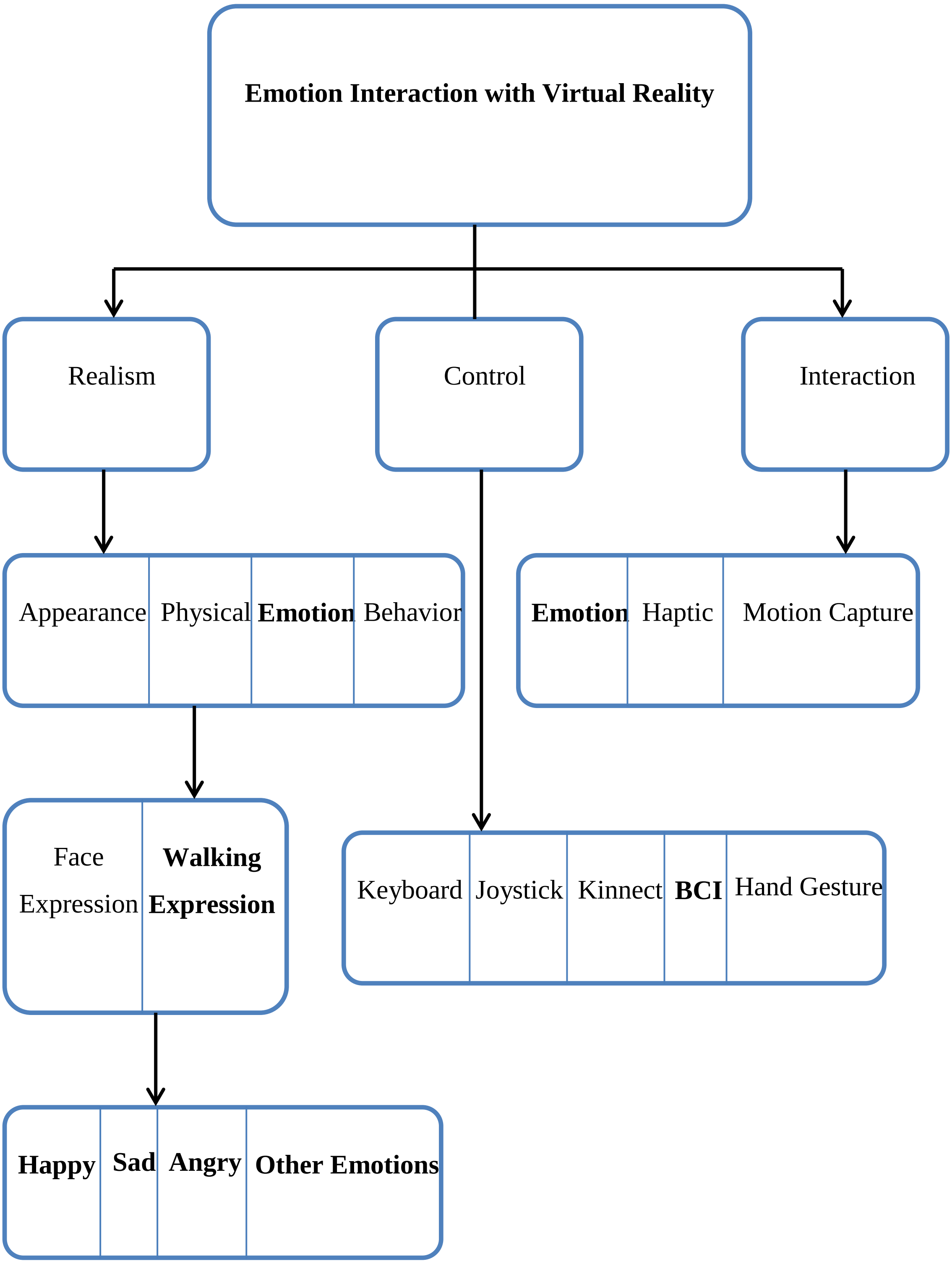

Figure 1.1 : Visualized Research Domain.

1.4 Research Aim

The aim of this study is to introduce a classification technique founded on real-life human emotions toward low cost and game-based BCI to attain realistic interaction between user and VE in term of emotion.

1.5 Research Objectives

The objectives of this research are as follows:

1. To redefine an innovative statistical method for the extraction of emotional features that denotes emotion data from EEG brain signals
2. To propose a hybrid emotion classification technique for the classification of human emotions
3. To map and coordinate human emotions with a designed 3D virtual human model for enhancing the interaction with the VR situation through the application of the recommended classification procedure
4. To evaluate the performance of the proposed technique toward enhancement the realism of VE

1.6 Research Scope

The 3D virtual human emotions mentioned in this investigation are in relation to the walking movements in the context of emotion. These movements are transformed in accordance with the user’s frame of mind (happy, sad, angry and disgusted) during the course of interaction. The emphasis, where the virtual human model is concerned, is solely on a walking style. The emotive mind controller mechanism is utilized as an external input to enable users to feel at ease while controlling the walking movements of the 3D virtual human model. The emotive controller is also used for simulating the walking style of the avatars.

Each game player will be provided with a user interface for the inclusion of realism in the context of emotions. The user interface controls and synchronizes the real life human emotions as well as the animated walking movements of the 3D virtual human. Happy and sad are the two fundamental emotions exploited by this study. Happiness portrays a positive emotional trait, while sadness portrays a negative emotional trait. Other emotions which include anger, fear and disgust are excluded from this investigation as well as from the model.

1.7 Research Significance

The mode statistical feature algorithm was the first contribution to this investigation. It was employed for the extraction of human emotional features and was applied on the EEG data that denote the emotion of players. This algorithm comes with the capacity to elevate the quality of the emotion derived from the player.

The second contribution to this study is the hybrid classification algorithm. It comprises three components: self-assessment, the emotion dimension model and brain activity variance. This algorithm executes the classification of the real human emotion to the two accentuated fundamental emotions of happiness and sadness. Subsequent to the classification of emotion, a contemporary numerical formula for the mapping of emotion was employed to map the classified emotions and the outcomes will be mapped to the emotions happy and sad. The accuracy and clarity in relation to the classification and mapping of emotion are ensured by the utilization of the classification and mapping algorithms.

The most significant contribution of this study is the development of an innovative hybrid classification process to be utilized for the interaction of emotion. Emotion interaction is by way of the fashioned 3D virtual human with an emotional walking style. The emotion of the player is revealed through the walking style of the 3D virtual human. Its walking style takes on a happy gait when the player is in a good frame of mind and a sad gait when the player is feeling down. The 3D virtual human was fashioned to facilitate the course of interaction. The emotion interaction portrayed by the walking style of the 3D virtual human was achieved through the employment of the BCI.

Our recommended procedure involves real life human emotions expressed through the walking motion of a 3D virtual human. This is significant for the enhancement of realism in reality games of the future. Additionally, this study performs stimulation utilizing aural-visual effects to reinforce the emotional features of the 3D virtual human and elevate the level of communication between user and model.

1.8 Thesis Organization

This doctoral thesis has been divided into seven chapters, as follows: Chapter 1 explains the introduction and thesis statement, Chapter 2 states the literature review, Chapter 3 describes methodology and research design, Chapter 4 describes a new method for feature extraction, emotion classifier and emotion mapping as well, Chapter 5 describes the 3D virtual human model regarding emotional walking synthesis, Chapter 6 describes that covers stimulation external and input recognition, testing and evaluation. Finally Chapter 7 concludes and expects for future studies. The content of the chapters are briefly illustrated as the followings:

Chapter 1 aims stating the of the thesis ` statement. It starts with the introduction and then problem background. Then it suggests the problem statement. The aims and objectives are then followed by the scope and limitation which are described clearly. The structure of thesis is outlined at the end of the chapter.

Chapter 2 aims at bringing up an in-depth literature review divided from previous studies. of all the three major areas; the use of brain computer interface device in the computer graphics and multimedia domain, human emotion theories and computer walking motion. Emphasis is laid on the various contributions and limitations of the proposed algorithms and techniques in all three relevant areas.

Chapter 3 is devoted to the description of the research design and methodology which is used to solve the problems outlined in chapter 1. This chapter also gives the flowing details of how the problem will be solved using certain procedures. Then testing and evaluating of the results are concluded.

Chapter 4 aims at dedicating a portray for a procedure on solving the first and second objectives of this thesis i.e. using a new statistical feature extraction that becomes the first contribution on the thesis. And for the second contribution, this chapter will discuss how to use a new hybrid method as emotion classifier with implementing a new statistical feature which will be used as an emotion classifier to be further used for mapping to 3D virtual human motion walking model based on emotional expression. Also this chapter will discuss deeply how to propose and produce a new equation for mapping process as a basis to convert emotion into a value usable for 3D virtual human model emotional walking expression. The result of this chapter will also become a key for synchronization with emotional walking expression model. In addition, chapter 4 also explains how to create particular emotional expressions. The chapter also contains evaluation process in order to test whether the proposed methods have produced the correct result or not.

Chapter 5 sheds the light on complying the third contribution as mentioned earlier to produce 3D virtual human emotion walking model. This chapter will discuss a lot on how to build a 3D virtual human model for emotional walking expression. The result from synthesis of emotional walking is integrated and synchronized through the EPOC Emotiv mind controller. A prototype of 3D virtual human model is created on this chapter to be further used to accommodate the signal from Emotiv mind controller. This signal will be stimulated by standard audio video systems to produce the emotion expression. This signal will be synchronized with the emotional walking style expression model in Chapter 6.

Chapter 6 is a detailed of evaluation phase which is conducted in this chapter is based on an empirical study and usability testing to users. The evaluation method is divided into two parts i.e. objective and subjective evaluation. The specific tasks of user that is used in benchmarking with similar system are described in detail in this Chapter.

Chapter 7 aims at concluding the thesis outputs and recommending for further future studies in the conducted research. This chapter is important to give a clear picture about the linkage between the thesis goals and the results that have been achieved and also the limitations that need to be carried out in the future. The future studies are presented as well to give an opportunity to other researchers in the future.

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