Development of the Virtual Taekwondo Training Environment Prototype for Self-Directed Taekwondo Training

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Abstract—**Taekwondo is a martial art that has been practised by over 50 million people all over the world, and this number is increasing which makes Taekwondo more popular. Normally, Taekwondo training is conducted in a hall or large open spaces in the presence of a trainer. However, this approach has some limitations in supporting self-directed training. Even though there are several supplementary materials for Taekwondo training, they have many limitations. This paper introduces Virtual Reality and Motion Capture technologies as an alternative to the existing Taekwondo training approaches. The main advantage of these technologies for self-directed training is that they are able to imitate the trainer's movement and provide three-dimensional displays of body movements which can be viewed from any angles. This enables the trainees to understand and follow the movements without assistance from the real trainer. This paper presents the design and development of the Virtual Taekwondo Training prototype as supplementary material for self-directed Taekwondo training based on Virtual Reality and Motion Capture technologies. This prototype aims to provide a new approach to supplementary material that can provide trainees' satisfaction while doing self-directed Taekwondo training.**

Index Terms—**Motion Capture; Virtual Reality; Self-Directed Training; Taekwondo Training.**

I. INTRODUCTION

Taekwondo is one of the traditional martial art which is systematic and scientific, originated from Korea and now has become a modern international sport [1]. Taekwondo is different from other martial arts from the physical aspects since it is very dynamic with active movements involving physical training. It is also a martial art that focuses more on learning technique using hands, fists, elbows, knees, feet or any parts of the body. Usually, taekwondo training involves the trainees to learn from their trainer in a classroom or training club whereby the trainer will explain and demonstrate the Taekwondo movements, and then the trainees will follow the trainer. The trainer is essential in Taekwondo training since he/she is responsible for guiding and training the trainees on how to perform each of the movement correctly in order to improve and achieve successful performance [2],[3]. According to [2], training will be difficult when it involves large groups. Since Taekwondo training involves typically a large group of trainees, not all trainees are able to visually follow the demonstration by the trainer since they are standing far away or they might be blocked by other trainees [4]. Besides that,

the problem faced by the trainees is lack of time to attend the training classes, and sometimes the trainers are not available [5].

Thus, whenever the trainees wanted to practice to improve the Taekwondo movements, they will conduct self-directed training. It is a form of training without guidance from the trainer which allows the trainees to conduct their training anytime and anywhere. Frequently, self-directed training is conducted through the use of existing supplementary training materials such as DVD/CD (video), YouTube (online video sites), websites and books. However, the existing supplementary materials have various limitations [5]. The use of video as a medium of training is limited [6]. A significant problem in the used of videos is the lack of the third dimension and feedback [5], [7]. Even though the videos can be rewind, fast forward or backwards or pause, they cannot fully portray the body movements entirely [8]. While the use of books is not sufficient because the books lack interactive elements and the information is static which makes it challenging to follow regarding movements [9].

Therefore, there is a need to address the limitations of the existing Taekwondo supplementary training materials to improve the self-directed training quality and performance of the trainees. Thus, this paper introduces the Virtual Taekwondo Training Environment (VT^2E) prototype, a Taekwondo supplementary training material which is based on Virtual Reality (VR) and Motion Capture (MoCap) technologies. A VT^2E prototype has been designed and developed for this purpose, and the development flowchart is shown in Figure 1. The following section briefly discusses previous works related to the application of VR.

II. RELATED WORK

VR has been known since the 1980s, and it can be interpreted as a computer-simulated environment where users can interact, navigate and view in real time [10]. VR is a human-computer interface that allows users to explore, manipulate, real-time visualisation and interaction then become immersed in a computer-generated simulation environment [11]. The use of VR technology offers unique experiences to the users which include representative, detailed, and realistic view of the environment. Users can also interact with the VR system in unlimited time and place for
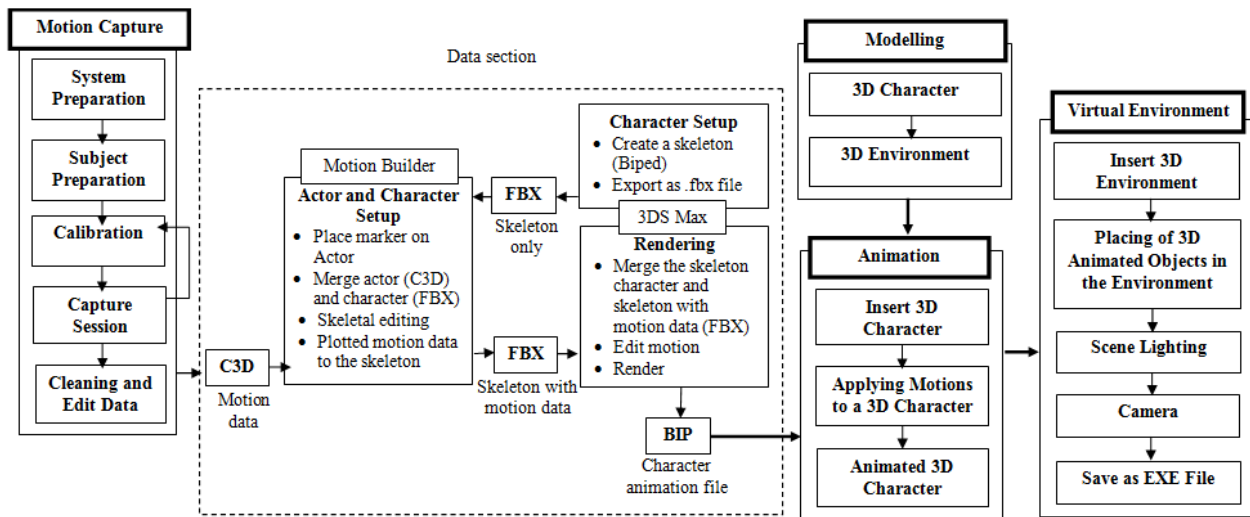
Figure 1: A flowchart for developing the VT^{2}E prototype

self-training [12]. VR is widely used in computer-based training [13], [14] including the study of human motion [15]. Recent advances in VR has been implemented and applied in dance and martial arts [16], [5], [17], sports [18], [19] and rehabilitation training [20], [21], [22].

A VR training system developed by [5] proposed a dance training system that tracks full body based on MoCap and VR. The system uses the MoCap suit technology that allows users to follow the movement of the virtual teacher to improve their performance. This system also provides immediate feedback to users to correct the mistake and improve their performance. The results of this study have shown that the system can make the learning process more fun and motivate the users to learn.

[23] developed a system for edutainment of Thai martial arts and self-defence based on MoCap technique. The results show that the edutainment can generate interest to students in Thai culture and the right techniques can be obtained. [4] proposed a martial art training system by using MoCap. This system can provide three benefits which include; the users can use the system at any time when they feel free, this system provides immediate feedback that can help trainees in training and the real trainer also get the benefit. [24] proposed a VR motion training system that tracks full body for practising Chinese martial art Tai Chi to improve the training performance. This system is the first system that uses wireless full-body Virtual Environment (VE). The following section elaborates on the design and development of the VT^{2}E prototype.

III. DESIGN AND DEVELOPMENT OF VT^{2}E PROTOTYPE

In order to overcome the limitations of the existing supplementary Taekwondo training materials, the VT^{2}E prototype has been proposed as a new approach to supplementary material for self-directed Taekwondo training. The design and development of the VT^{2}E prototype consist of four phases namely; MoCap, modelling, animation and Virtual Environment (VE). Brief descriptions of the four phases are presented in Table 1.

Table 1
Phase Description

Phase	Description
MoCap	The process of recording the movements of the real Taekwondo trainer to provide the reliable motion data
Modelling	The process of creating the 3D Taekwondo character and environment
Animation	The process of giving the illusion of motion for the Taekwondo character together with the MoCap data.
VE	The process of creating the realistic environment of the VT^{2}E prototype for the interaction between the trainees and the environment

The design and development of the VT^{2}E prototype phases are explained as follows.

A. MoCap

MoCap technique has been widely used in various fields of applications. MoCap is a technology that can store data and track the full body movement [25]. The primary purpose of the MoCap technology is to create varieties of applications as it can capture the human movement [26]. In developing the VT^{2}E prototype, the Qualisys MoCap system was used to capture the 3D motion of Taekwondo movements. The system utilised five high-speed Oqus cameras, a set of passive markers, Qualisys Track Manager (QTM) for the tracking software and other integration peripheral hardware. The MoCap phase was divided into five sub-phases namely; system preparation, subject preparation, calibration, capture session and cleaning and editing data. The sub-phases of the MoCap are discussed as follows.

1) System Preparation

Before capturing the real movement of the subject, the first thing is to ensure that the system has been correctly setup. That includes hardware requirements and installation, plugin and software installation. Figure 2 shows the system preparation in the MoCap phase. In this phase, five Oqus cameras were used to capture the actual motion of the subject. The Oqus camera has the advantage in capturing every movement, and it is designed to capture the MoCap data with high accuracy. The cameras have been arranged around the subject to ensure that all the cameras were able to capture the subject's movements from any angle by detecting the markers that have been placed on the subject's bodysuit. The combination of all the cameras enables fast and accurate data

to be produced. The hardware for this system mainly comprised of computers with Windows 7 (64-bit and 32-bit) and XP Professional (32-bit). The QTM was used to capture and collect any data through the MoCap system, and it can generate data in the form of 2D, 3D and 6 Degree of freedom (DOF) in real time with minimal latency.

Figure 2. System preparation

2) Subject Preparation

In the subject preparation, it is vital to ensure that the subject has worn the proper MoCap suit. This is to ensure that the markers can be placed on the MoCap suit. The subject is recommended to wear a tight suit instead of a loose suit. The placement of the markers are essential in capturing the movement, and they are required to be attached correctly to the bodysuit relative to the bones of the subject in order to capture a much better motion data. For the VT^{2}E prototype, 20mm and 25mm diameter markers were used for capturing a full body human movement. According to [27], while capturing the motion data, it is important for each marker to be captured by at least three cameras simultaneously to ensure that the object to be produced in the form of a 3D representation. In the VT^{2}E prototype, altogether 43 markers were placed on the subject. Figure 3 shows the subject preparation process where the markers were attached to the MoCap suit.

Figure 3. Subject preparation

3) Calibration

The calibration of the MoCap system involves a system and subject calibrations. System calibration is about the types of calibration devices, while the subject calibration is about the subject to be captured. In order to get a cleaner data, the calibration must be conducted properly.

When the markers have already been attached to the subject's body, the role of the cameras is to detect the markers. All the cameras have to be properly set up to ensure that all the markers on the subject's body could be detected and the MoCap software could see the markers in all the cameras. The camera position could not be changed once it has been set up. This is because it would interfere with the data unless the MoCap process is stopped and the MoCap system is recalibrated.

In ensuring that the subject's movements were to be captured entirely, another calibration process is required. The subject is required to do the "T" position, scaling position, and range of motion. Figure 4 shows the calibration process for the "T" position of the subject. In this case, the subject has to do a simple movement like walking to ensure the MoCap system could track the markers on the subject. If there were some missing and uncompleted data, the MoCap process must restart with the capturing of the "T" position, scaling position, and range of motion again. In this stage, all the markers were identified and labelled.

Figure 4. Calibration process

4) Capture Session

The capture session started with the World Taekwondo Federation (WTF) Taekwondo form 1 (Taegeuk II Jang). Taegeuk II Jang is the most basic form of Taekwondo movement. The movements of Taegeuk II Jang consist of walking stance, front stance, front kick, low block, high block, inside the block, and middle punch. The time taken to carry out the capture session was approximately thirty minutes for the Taekwondo form 1 movement. Figure 5 shows the subject performing the Taekwondo form 1 movement while the MoCap system is capturing the motion data.

Figure 5. Capture session

5) Cleaning and Edit Data

The MoCap data from the capture session needs to be cleaned and edited to produce useful motion data. In this case, the wrong data will be removed and replaced with better data [28]. Cleaning and editing of the data have to be done due to several factors which include; environment, subject's physical abilities and limitations of the hardware and software in the MoCap system [29]. This could cause the markers not to be seen (detected) by the cameras and produced gaps in the data. Sometimes, the overlaying of the marker's data occurs when one of the markers existed in two different parts at the same time and labelled with the same marker label. In this situation, the proper identification of markers is important in detecting the correct markers. Here, the missing markers of the subject were defined, and undefined markers were detected. Figure 6 shows two screenshots of cleaning and editing motion data.
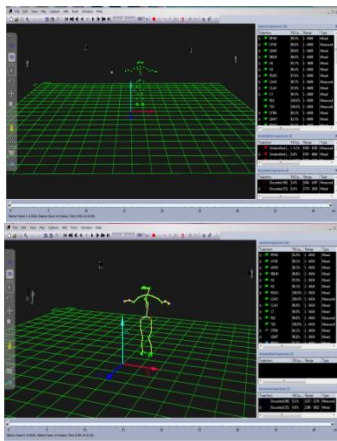

Figure 6. Screenshots of cleaning and editing motion data

B. Modelling

In the design and development of the VT^{2}E prototype, the modelling phase of the 3D character and the environment is the most fundamental process. All these tasks were developed using the Autodesk 3DS Max 2016. In this sub-phase, the 3D character of a female Taekwondo trainer has been developed. The 3D environment, such as the area of a Taekwondo hall, was developed for making the environment look realistic. The modelling phase was divided into two sub-phases; namely 3D character and 3D environment. The sub-phases of the Modeling are discussed as follows.

1) 3D Character

For the VT^{2}E prototype, a female human character was developed as shown in Figure 7. The character wears the V-neck uniform with a blue belt. The modelling of the character involves several phases; namely head, torso, leg, arm, hand and clothes modelling.

Figure 7. A female taekwondo characters

2) 3D Environment

In modelling the VT^{2}E prototype, it requires a suitable environment such as a room or hall. For the VT^{2}E prototype, a Taekwondo training environment has been designed.

C. Animation

The animation phase for the VT^{2}E prototype involved the use of the 3DS Max 2016 software. The female Taekwondo character animation performed the walking stance, punch, kick and block movements. The animation phase was divided into three sub-phases namely; insert the 3D character, applying motion to the 3D character and animating the 3D character. The sub-phases of the Animation are discussed as follows.

1) Insert the 3D Character

After creating the 3D environment that is the Taekwondo training environment, the next process was to insert the female 3D character into the environment.

2) Applying Motion to the 3D Character

Before applying the MoCap data to the 3D character, the character has to be rigged that is inserting the biped (skeleton) to the character and using the Physique modifier to attach the skin of the character to the biped. These will ensure that the character moves according to the biped. Once ready, the MoCap data in the form of a BIP file was applied to the 3D character.

3) Animating the 3D Character

After the MoCap data has been applied, the 3D character can move according to the motion data.

D. VE

For the VE phase, Quest3D version 4.2.2 software was used. Quest3D utilises connection of channels to generate interactions [30]. VE has the potential to provide animation effects in order to ensure realism and the loyalty levels can be enhanced [31]. The VE phase was further divided into five sub-phases namely; insert 3D Environment, placing of a 3D object in the environment, scene lighting, camera and save as an Exe file. The sub-phases of the VE are discussed as follows.

1) Insert 3D Environment

The first process in the VE is to insert the 3D environment. The 3D environment of the Taekwondo training environment makes the VT^{2}E prototype looks more realistic.

2) Placing of 3D Object in the Environment

Once the 3D environment is ready, the process is to place the 3D animated Taekwondo character into the environment.

3) Scene Lighting

The next process in the VE process is lighting. The lighting is one of the most critical aspects of VE because it can produce a more attractive environment and able to attract the users [32]. Thus, good lighting technique is vital in order to create the quality environment.

4) Camera

The camera setup is essential to ensure that the camera has been placed in the right position and angle. In the VT^{2}E prototype, the camera can be set up either as a first-person view or orbital view.

5) Save as an Exe File

The final phase was the output. The output must be produced and save as an executable file format for VE.

IV. CONCLUSION

Research in the utilisation of VR and MoCap technologies for the purpose of self-directed Taekwondo training is still scarce. As such, this paper has looked into the possibility of introducing a new approach to training through the use of the two technologies. VR has been recognised as a medium that is capable of providing the third dimension compared to other forms of supplementary training materials such as books, videos, texts and pictures. We have elaborated on the development of the VT^{2}E prototype which is targeted to the trainees who are interested in self-directed Taekwondo training. The VR and MoCap technologies that have been discussed in this paper can provide strength in guiding the trainees while doing the self-directed training to solve the limitations of the existing supplementary Taekwondo training materials. It is hopeful that this prototype can be a guide for self-directed Taekwondo training in enhancing the skills and performance and indirectly fulfil the trainees' satisfaction.

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