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THE DEVELOPMENT OF A LOW COST MOTION ANALYSIS SYSTEM: CEKAK VISUAL 3D V1.0

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ABSTRACT: To date, there is lack of biomechanical characterisation on defensive technique (martial arts) due to the unavailability of appropriate motion tracking system that can be used to characterise the technique in quasi-training environment. Therefore, this paper presents the development of a novel low cost motion analysis system, Cekak Visual 3D v1.0 which is capable to track dual martial art practitioner's skeleton motion in a single frame view using integration of Matlab GUIs and Microsoft Kinect. The accuracy and precision of the coordinate data recorded by the system was tested to ensure the quality of the system. The systems perform the tracking motion with a single Kinect which is a combination of various sensors (RGB and depth sensor) thus makes it capable in providing three dimensional coordinate data. The analysis reveals that Visual Cekak 3D v1.0 resulted lower percentage error with high internal consistency (Cronbach Alpha, α = 0.904). The proposed marker-less system is capable to track and store dual skeleton data in a single session tracking. This capability makes the systems suitable in providing quasi-training and natural setting environment for any martial arts biomechanics investigation. Therefore, we believe that the system provide new concept development for basic research in martial arts biomechanics.

Keywords: Cekak Visual 3D, Low Cost, Martial Arts, Motion Analysis System, Seni Silat Cekak Malaysia

1. INTRODUCTION

Motion capture is a process where a movement can be recorded digitally and most commonly used in Martial Arts Biomechanics [1]–[3]. Analysis on trends of publications each year reveals that motion capture technology as a research tools is currently attracting more attention from the martial arts biomechanics community [4]. Shinagawa and Nakajima (1997) for instance, have used this method to analyse human stability by capturing body movement by using a few camera video [5]. The system is then used to analyse Shorinji Kempo, a technique in Chinese Martial Art in order to verify the three dimensional analysis system. The motion capture activities is also observed in Wong and Fok (2007) work on stance position effectiveness study in providing striking force in aspects of Tai Chi Chuan (side kick, roundhouse kick, rising kick, straight punch) with the aid of the smart motion capture system. Recently, Motion Capture (MoCap) Systems like the Vicon (U.K) and Eva Real Time (U.S.A) is available to serve the need in biomechanics study and was observed has been used to characterize pushing and kicking technique [6], [7]. The capability to rapidly track (multiple points) small and high speed movement in three dimensional space [8], [9] maybe the reason on why Motion Capture technology are more popular compared to others available research tools.

Despite its popularity, motion capture technique possesses several limitations. Existing motion capture system requires multiple expensive high performance cameras structured and calibrated within a controlled environment system (dedicated room, tracking suit and lighting capacity) [6], [9], [11], [12]. Due to that, this technology must undergo complicated set up for the advanced hardware that makes the process complex resulting difficulties for the system to be used in quasi-training environment such as sport field and training studio [13]. The cameras restrictions also create another drawback which is the markers placement. The marker attached will probably affect the subject's movement and its placement is time consuming [14].

Factors mentioned encourage the exploration towards low cost and portable solution [10], [15]. There are several potential devices that can replace the role of expensive high performances cameras such as web cam, depth cameras and RGB sensor [16]–[18]. Recently, the availability of Kinect™ sensor released by Microsoft Corporation in 2010 offers a great potential to be used as an alternative low-cost motion tracking tool. This cost effective, light and portable devices [14] is capable to substitute the role of digital high speed camera with the ability to provide an array of three dimensional coordinate data. Thus, this features contributed in a large number of applications such as 3D measurements, angle measurements, gait tracking, postural control observation, motion assessment, rehabilitations, ergonomics, coaching, metrological evaluation as well as the martial arts biomechanics

[19]–[22]. Virtual Sensei Lite is an example of Kinect application in martial arts biomechanics study. This system helps the karate practitioners in their training session to characterize their motion as well as to enhance their capacity [10], [21].

Martial art is an affiliation of systematic techniques designed to response towards an attack (defensive technique - evade, fend off, grab, block) and to incapacitate the attacker (offensive technique - kick, punch, strike, punch) [4]. The difficulty on preparing the quasi-fighting environment may contribute to the imbalance research patterns (offensive vs defensive) in martial arts biomechanics study [4]. A systematic defensive technique in Seni Silat Cekak (a traditional Malay Martial Style) for instance can be explored extensively. Doubts on defensive technique capability and effectiveness in deflecting the incoming force (attacking force) [23] may be answered scientifically. The feasibility of Virtual Sensei Lite to characterise offensive technique inspired the development of a system which is compatible to characterise the defensive technique and consider the quasi-training environment for more realistic data (tracking dual skeleton).

In this paper, we proposed a novel low cost motion analysis system to address the problem of preparing the quasi-training environment to obtain the kinematics in the upper and lower extremities of Seni Silat Cekak practitioner during the defensive technique execution. The proposed system was compared with Virtual Sensei Lite system and the accuracy and consistency of the data acquired was observed.

2. SYSTEM DESCRIPTION

The schematic diagram (Fig.1) simplifies the principle of motion analysis system operation on how the system provides the kinematic of the motion with the help of inverse kinematic approach. In order to develop an alternative system, the proposed system must be able to provide the position data that were digitized at equal time increments throughout the movement sequence. The chosen device to substitute the role of high performance cameras for the proposed system is Microsoft Kinect Sensor.

2.1 Kinect Sensor

Microsoft released the Microsoft Kinect Sensor and refer it as a Natural User Interface Device [24]. This device core application is to control the Xbox console via gestures, movements and spoken commands [20]. As such the Kinect capable to drive software as well as manipulate and interact with virtual worlds through whole body movements [24].

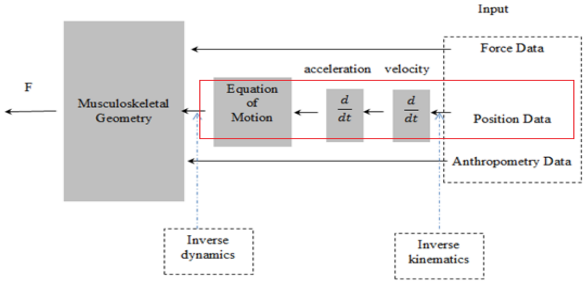

Fig. 1 Principles of Motion Analysis System Operation (Inverse Kinematic Approach)

Kinect sensor comprising of RGB camera, an infrared (IR) emitter and IR depth sensor [25] Those sensors make it capable to captures depth and color images at 30 frames per second to generate three dimensional (3D) points from an infrared pattern projected on the subject [8]. Researchers have discovered that the depth sensing technology of Kinect could be extended far beyond the gaming application as this technology offers much lower cost than traditional 3D cameras. Moreover, it is easy to operate and may offer a portable 3-D motion analysis system to overcome the limitation of the existing systems that require the laboratory experimental set up [25]. The Kinect sensor has found itself in the mainstream of development of a low cost alternative for measurement and motion of human kinematics analysis [10].

2.2 Graphical User Interface: Cekak Visual 3D

This system able to track and store dual skeleton data in a single session (Fig.2). Cekak Visual 3D will process data in three steps which is position data acquisition of each point, calculate the kinematic data and visualize the kinematic data for each skeletal point. The skeletal data captured, consisted of three dimensional coordinate data of 20 skeletal joints. The marker-less based system tracked the skeletal joints by software developed using Matlab.

The following flowchart (Fig.3) simplifies the steps on how the Graphical User Interface (GUI) of the system was used. It can be seen that the workflow process involved three main processes. The Kinect sensor tracks the movement and the GUI will view the dual skeleton joints in RGB image. (Fig.2). The coordinate data will be recorded and saved in excel file format. The position data recorded was then playback in order to trim the data for the best frame selection. This information was then will be imported to the tracking and analysis process which applies the numerical approach (central difference method) to compute the time derivation of displacement (velocity and acceleration) for the analysis and data visualization

$$v_i = \frac{s_{i+1} - s_{i-1}}{2(\Delta t)} \quad (1)$$

$$\boldsymbol{a_i} = \frac{v_{i+1} - v_{i-1}}{2(\Delta t)} = \frac{s_{i+2} - 2s_i + s_{i-2}}{4(\Delta t)^2} \quad (2)$$

Fig. 2 User interface of proposed system (Main & Sub Window)

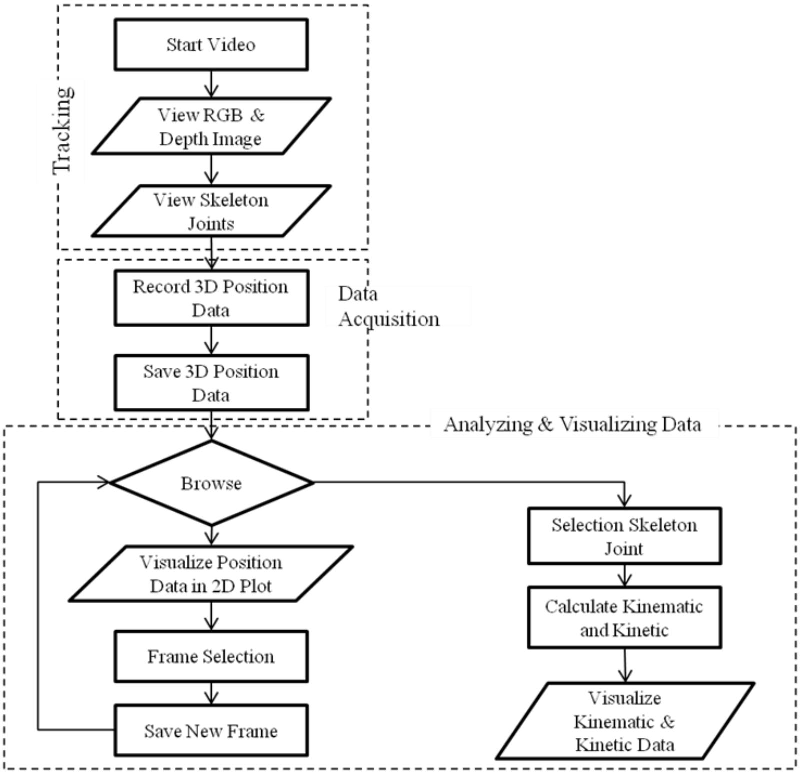

Fig. 3 Workflow of the Cekak Visual 3D v1.0

2. PRELIMINARY EVALUATION

In order to further the development of Cekak Visual 3D v1.0, an accuracy and consistency test were carried out. The accuracy of a measurement system rely on the degree of closeness of measurement to its true value while precision is the degree which repeated measurements shows the same results [20]. In order to observe accuracy, the differences between the data measured by Cekak Visual 3D and the actual values (manually measured by range finder) were calculated. Finally, the SD and Cronbach Alpha value measure the precision of the system.

3.1 Accuracy and Precision

Fig.4 shows the comparison of the accuracy and precision between Cekak Visual 3D and Virtual Sensei Lite based on percentage error, standard deviation and Cronbach Alpha's value. The data from each system were averaged in order to be compared with the manual measurement value. The graphs reveal that Cekak Visual 3D observed lower percentage error which is below 5% and consistent standard deviation, SD. The analysis reveals that Visual Cekak 3D resulted lower percentage error with high internal consistency (consistent Standard Deviation and Cronbach Alpha, α = 0.904).

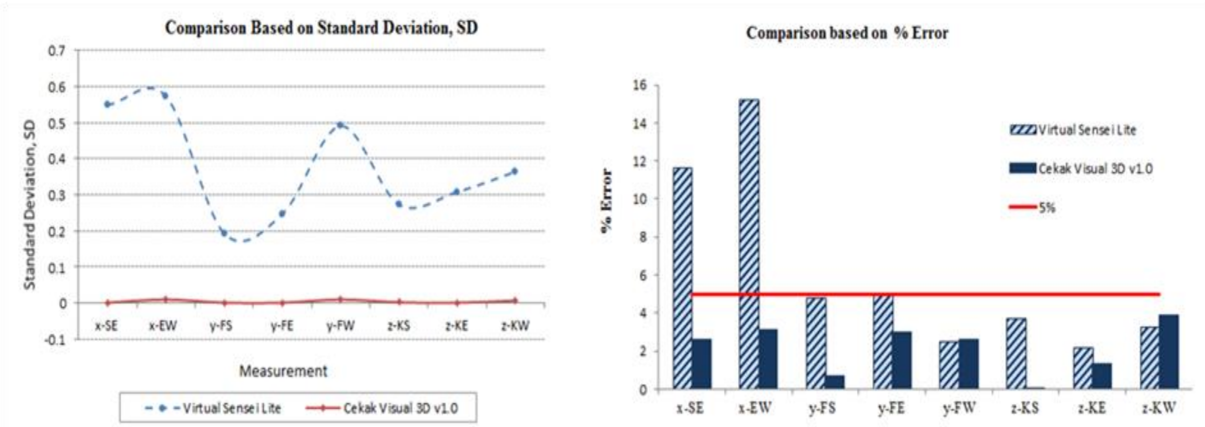

Fig. 4 Accuracy and consistency comparison

4.0 CONCLUSION

This paper has proposed a low cost motion analysis system for martial arts purposes. A preliminary evaluation on system capabilities was reported to observe the accuracy and precision of the substitute device proposed. Future research will work on refining the reliability test and enhancement of the system capability to determine the kinetics of martial arts motion.

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