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Human Body Motion Similarity Analysis Using Markerless Motion Capture System

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Abstract: The similarity analysis system of the human body motion is needed at modern sport (e.g., martial art, aerobic) or dancing school. It can be uses as evaluation tools for instructor to measure a similarity the student movement with the reference movements that are taught by the instructor. In many computer vision research, this system work with multiple camera and need a lot of series sensor attached in human body. This motion capture system requires a careful and precision of camera calibration, also, make the actors uncomfortable with many sensors mounted on the whole body. For that reason, in this study, we used a technology that be able to support the evaluation process of human's movement without any sensor attached in human body (markerless). One of the available technology is the Microsoft Kinect camera. It has a markerless motion capture technology which can record the human's movement without any wearable sensors or equipment during the motions, so, the model can move conveniently. The evaluation of the similarity motion was done by calculating the joint angle and angular velocity of the motions which is showed from the graphics of every joint with cosine similarity methods by calculating the cosinus angle from two compared variables. Result of motion angle's measurement in aerobic, the average similarity value reached 81.12% and velocity measurement value reached 86.19%.

Key words: Human body motion capture, Microsoft Kinect, similarity analysis system, cosine similarity, velocity, measurement

INTRODUCTION

Motion capture is the recording process of motion from object or people. Capturing the motion will generate animation motion similar as actor or object motion. Currently, motion capture has become the most effective techniques for making animation in order to simplify and accelerate the process of making 3D animation object that has a shape like human. Motion capture can be applied to various aspect such as military, entertainment, sport, medical applications and for validation in computer vision and robotics field.

Markerless motion capture system has long been inve stigated in the field of computer vision with most studies focusing on using multiple cameras to capture user motions or appearances. Lately, microsoft has released a product Kinect inexpensive real time capture systems have drawn attention.

Kinect sensor is a technology created by microsoft that can detect human gestures for various purposes, such as a controller using body motion, education, games and also rehabilitation. The sensor is able to detect human motion based skeleton tracking and detecting the shape of the human body using depth sensor and camera RGB (Red Green Blue). By utilizing capabilities this sensor, we can build a system in which the actors can rate motion and position by comparing with role model data that already saved. This will increase the equivalence position performed by the actors.

Our research conducted by making a motion capture system that is implemented to analyze human body motion through comparison with a reference motion. Motion performed from the actor was captured with a motion capture system for analysis rhythm of motion that includes angle, velocity and acceleration of the motion then evaluated similarity with cosine similarity method. The result of the similarity can be analyzed whether the actor motion in accordance or not with the reference motion (Li *et al*., 2007).

The scope of this research is to get the BVH (Bio Vision Hirarchy) data (Meredith and Maddock, 2001) in real time motion using Kinect SDK 1.8. Motion data obtained from Kinect with 2 m distance between the actor and the camera. The obtained data processed in system then transformed becoming stickman motion model using OpenGL. The motion similarity assessment of the position and rotation skeleton between the reference and the actor is the final result.

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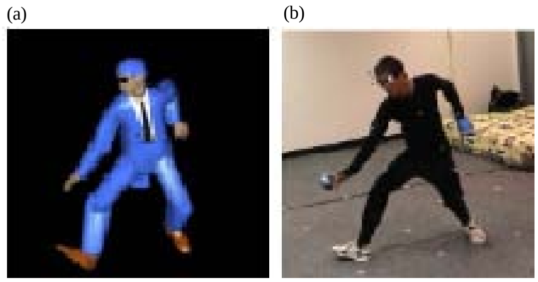

Fig. 1: Dance training: a) Layout from 3D viewer and b) Actual movement from dancer (Chan *et al*., 2011)

Motion capture system: Most of research utilizing motion capture technology is focused on the purpose of the motion analysis. One of the study about human body motion analysis is used to dance training research (Chan *et al*., 2011). Dancers can practice using visualization of the movement who was captured by optical motion capture system using these system. Layout of the 3D viewer and the actual movement of the dancers can be seen on Fig. 1.

Noiumkar and Tirakoat (2013) conducted the research of optical motion capture in sports science to analyze the movement in golf sport. The research describes the techniques of swinging golf club. However, in this research there was no analysis of the angle and velocity. Other research is done by Aji (2014) who conducted the research of markerless motion capture using Kinect Xbox 360. This study succeeded in capture skeleton position and calculate the angle difference between actor and reference from karate models. In this research, the application can capture the angle or position of the bones as much as one and could not capture the motion.

The applied system: The process of evaluating the motion in sport, dancing, martial arts activities, etc. has been conducted by the instructor in direct way. It means the instructor examine and evaluate every motion which has been done by the students at the same time they see each other. It is done regularly everytime the students have a practice together. The motion evaluation can be done in an easier way by utilizing the motion capture technology where the students not to perform any motion in front of the instructor but in front of the certain camera. The system which will be created can be seen in Fig. 2.

In Fig. 2, we can see the stage in this research. The similarity analysis system production is done by develop a computer application, so, the actor's movement and the reference's motion can be visually displayed on the screen. The evaluation of the motion is done by

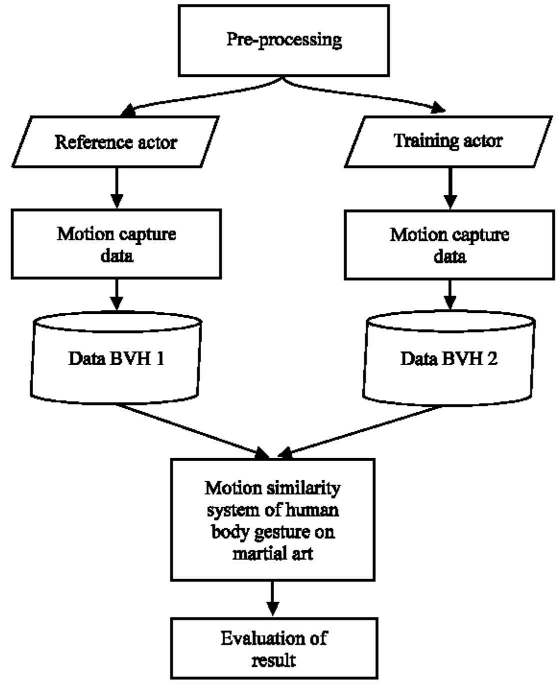

Fig. 2: Applied system

quantitatively calculating the value from the angle and the velocity, also from the angle's acceleration to obtain the similarity levels of the examined motions.

Systematical requirement analysis: In the motion's evaluation process, the instructor distributes his knowledges and experiences during his teaching of any particular motions to their students by giving advices.

The simple shows of the evaluation process is the instructor ask directly to their students to make a certain motion. If the motion is thought to be incorrect then he will show the right motion as correction.

This process can be accelerated by adding the one or more teachers or instructors therefore the required time in correcting the students wrong motion can be shorter. By additional helps the practice will be more efficient. However, not all institutions are able to add more instructors to support the teaching activity. In order to solve that problem we can use motion similarity application which can be independently conducted by the students without any helps from the instructor, however, it isn't meant to replace the instructor positions as the main educational source.

The Kinect camera sensor can read the human's motion by detecting any visible joints as shown in Fig. 3 (13) main joints in human's body will be used as comparison data including wrists, elbows, shoulders, hips, knees, ankles left and right and neck. For three other

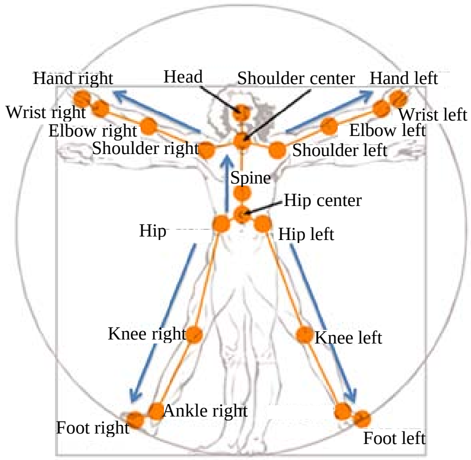

Fig. 3: The skeleton tracking on human's anatomy (Kinect, 2015)

spots or points rather than those joints such as shoulder center point, spine point and hip center point although they're readable by the Kinect sensor, they are not used in the evaluation process.

The application requirements which are needed to be prepared such as hardwares for output, data processing and human's detector position sensor. Hardware for output application can be using monitor or projector and for the data processing we need a computer which will transform the data to be the information needed and the last thing is the Kinect sensor to capture the human's position and transform it to be a digital data.

This application will create information in form of a punctual motion value and the evaluating value. These values are obtained by averaging the balance of every joint's angles. The recording process is begun when the teacher is ready to perform certain motion in front of Kinect sensor. Afterwards, the students take turn to do the desired motion. The data will be saved automatically in the computer and then the system will be able to do the motion similarity evaluation process by taking the saved data. From now on the students will be called as Actor and the instructor as reference and on the other hand the user is one who operates the application. As described before, it can be concluded that the application system which will be built has some required specifications such as:

- The application should be integrated with the Kinect sensor and should be able to read the records of Kinect sensor
- The application should be able to compare the records between the reference model and the actor model
- The application should be able to perform the information to the user

MATERIALS AND METHODS

Similarity analysis method: The motions may vary based on the requirement where motions of every body parts produce different angles. Due to this reason, the parameter used in this research is limitation at the angle from body parts, angle's velocity and the angle's acceleration.

The parameter of motion angle: The angle which is used is the one between skeleton and other skeleton beforehand. The measurement of motion angle is used by measuring the relative angle which is by measuring two closely placed skeletons. The illustration of measured relative joint's angle (such as on elbow, thigh and knee joints) can be seen in Fig. 4a.

The obtained data from BVH (Li *et al*., 2007) is only in form of initial distance and rotation of each skeleton, so calculation to determine the location of every joints is needed, based on the rotation in each axis. The angle from the motion can be presented in 3D coordinate. The rotation matrix is using the right-hand system. The positive angle is on same direction as finger's fold way when the right hand is directed to positive coordinate. The rotation angles by rotate axis, x-zaxis are symbolized continuously by ω, φ and κ. Figure 4b shows the coordinates used to calculate angles. The rotation process follows below sequences:

- Rotation towards axis-X (ω)
- Rotation towards axis-Y (φ)
- Rotation towards axis-Z (κ)

After conducting the skeleton's rotation based on each axises, then, we will obtain the coordinate of every joints. To calculate the angle between two skeletons requires three points of joints which is located on both skeletons.

Locate the position in the coordinate axis: The coordinate position of skeletons is needed to calculate the angles formed by the two skeletons. There is no skeleton's coordinate in the BVH file, however, the existing data expressed as the skeleton's hierarchy. The offset of each skeletons based on hierarchy, amount of frames and the channel contains the skeleton's rotation data towards x, y and z axises. Method to locate the position in the coordinate axis is can be seen by Guerra (2005).

The obtained position of skeleton in coordinate will be used for angle's calculation. To calculate the angle among the skeletons needs the the coordinates of the joints, the parent's joints and the child's joints is by using cos θ. Algorithm in obtaining the angle can be described by Guerra (2005).

The parameter of motion velocity: After calculating the angle, then we need to calculate the angle velocity. It is defined as the angle's change per time unit and as vector unit which is also the rotation velocity of an object. The vector direction of perpendicular angle towards rotation field in direction is determined by right hand rule. If ω is angle velocity and θ is angle then, the angle velocity is:

$$\omega = \frac{d\theta}{dt}$$

Where:
dθ = Angle change
dt = Time change

The parameter of motion acceleration: Angle's acceleration is defined as change rate of an angle's velocity. It indicates how fast an angle's velocity changes per a time unit. If α is angle's acceleration and ω is angle's velocity, then angle's acceleration is:

$$d\omega$$

Motion similarity calculation: The motion similarity calculation used is cosine similarity (Nogueira, 2011). It is used to see the relationship between two curves or graphs. Each curve will be divided into some parts based on x axis and each part will be vector. The obtained vectors will be compared with the other vectors whose same x coordinate. To calculate the value of cose for each vector pairs using:

$$\cos\theta = \frac{\overrightarrow{AB}.\overrightarrow{BC}}{\|AB\|.\|BC\|}$$

Then calculating the average of cosine similarity. The result will produce value between -1 until 1. If it's 1 then both vectors are same or going in same way. It will be 0 if both vectors form the 90° angle and will be -1 if both vectors are in contrast way.

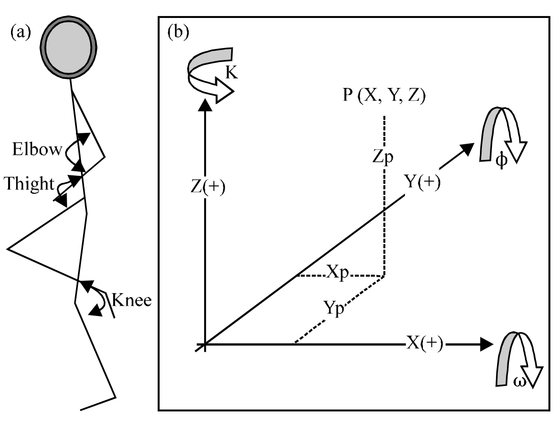

Fig. 4: a) The measurement of relative joint's angle and b) 3D coordinate

RESULTS AND DISCUSSION

The motion capturing is conducted to get the BVH file which will be compared similarity (Catuhe, 2012). First, the reference model stands in the T-pose before starting any motion as shown in Fig. 5a. Motions to be performed in this research is a basic aerobic. The movement is marching (or walking in place), bicep curl (a bending movement on elbow joint and straighten) and the lunges (pushing foot motion alternately left and right as the body direction), the screenshot can be seen on Fig. 5. The motion is begun when the user gives instruction or the model can see it himself the system readiness to record.

The skeleton on Fig. 5 shows that the motion capturing from the reference model is appropriate with the stickman position which had been recorded on BVH file.

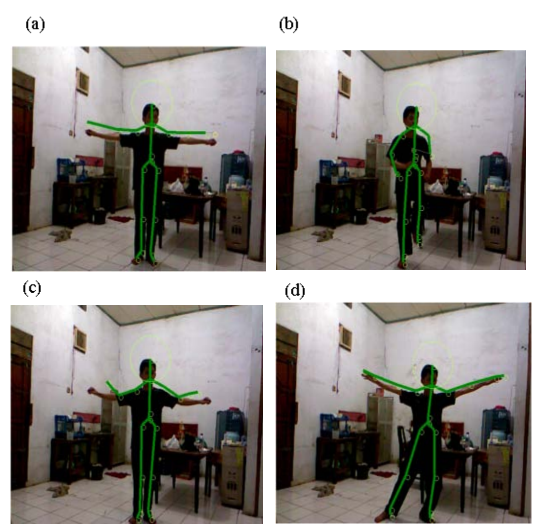

Fig. 5: a) Reference movement for T-pose; b) Marching; c) Bicep curl and d) Lunges

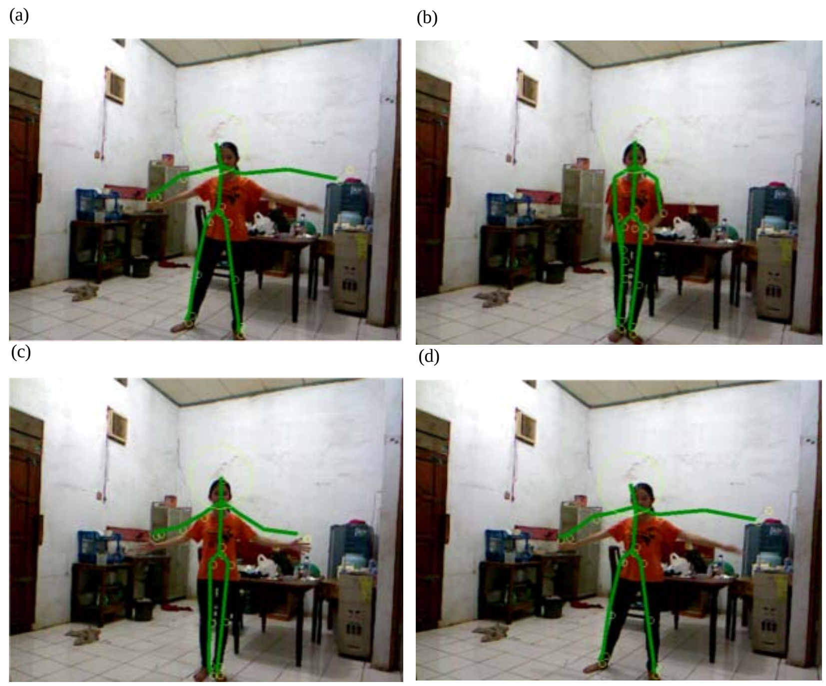

Fig. 6: a) Actor movement for T-pose; b) Marching; c) Bicep curl and d) Lunges

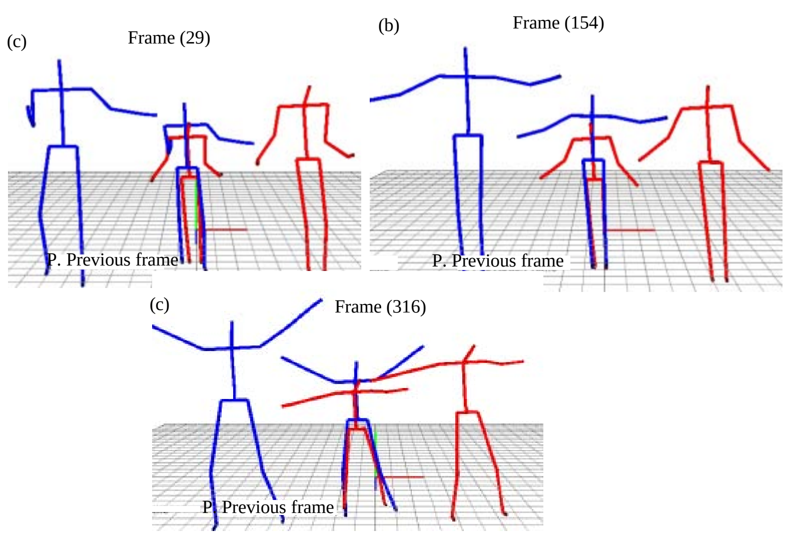

Fig. 7: a) Compare result BVH for marching; b) Bicep curl and c) Lunges

Next step is the recording motion of the actor model as shown in Fig. 6. The screenshots were taken on the same frame as on the reference model.

Similarity, analysis of the motion can be done by visually observing and obtaining the calculation result from the angle's average and from angle's velocity of each joints. Figure 7 shows the visualization example of motion on the system that had been made using the feature to display the data of motion angle on the left side.

The visualization model from the left side is the motion data from reference model and on the right side is the motion data from the actor model. Besides showing the movement in form of stickman and angle's calculation result of every joints, the end result of similarity also can be showing the angle's similarity and velocity from both models. Figure 8 shows the similarity display between both motions.

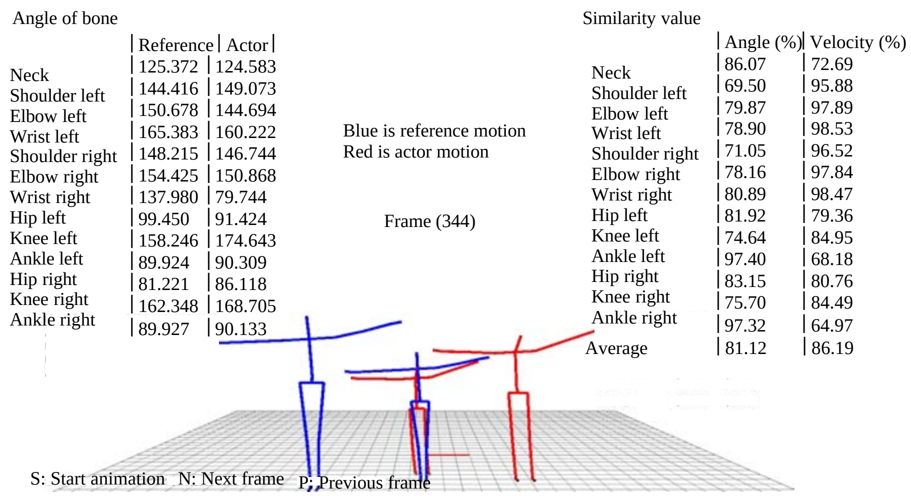

Fig. 8: Similarity result for bicep curl

CONCLUSION

The markerless motion capture system and similarity analysis of the human's body motion has been develop in this research as computer application. This application can be implemented to any fields in which needs the coaching persons to evaluate the students motion such as martial arts, aerobics and dancing. It doesn't mean to replace the intructor/coach position for evaluation task, but this application can be used to help reducing the work of a teacher with many students.

The aquired data is presented in BVH (BioVision Hierarchy) format. This BVH file is compared between the instructor's and student's files to obtain similarity. The similarity measured is the motion angles and velocity angles of each joints and its average. Evaluation result in this research using the cosine similarity method showed that the analyzed motions had high similarity level. The parameter of motion angle's measurement, the average similarity value reached 81.12% and for the parameter of velocity measurement, the average similarity value reached 86.19%.

The motion capture system in this research still has several flaws such as it can not record the high speed motions and it can not evaluate the crossed-positioned skeletons precisely.

SUGGESTIONS

The suggestion for the next development is using two or more calibrated Kinect sensors to create one joint point. So, the BVH position will be more accurate. In the other side for visualization of similarity analysis can be developed by 3D Model therefore the visualization will become clearer. This system is also can be implemented widely in other fields such as Intelligent Transportation System (ITS). Using depth information ability in kinect system, seemed to be a very promising novel approach in real-time application. For instance, in ITS field, Kinect sensor system can be uses as vehicle tracking, pedestarian detection, obstacle detection on the road, road event detection (congestion, accident) or as assistive driving tools such as driver distraction detection or navigation.

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REFERENCES

Aji, C., 2014. Design of application ratings position karate using kinect sensor technology. BA Thesis, University of Surabaya, Surabaya, Indonesia.

Catuhe, D., 2012. Programming with the Kinect for Windows Software Development Kit. Microsoft Press, Washington, USA., ISBN:9780735666818, Pages: 207.

Chan, J.C., H. Leung, J.K. Tang and T. Komura, 2011. A virtual reality dance training system using motion capture technology. IEEE. Trans. Learn. Technol., 4: 187-195.

Guerra, F.G., 2005. Optical motion capture: Theory and implementation. RITA., 12: 61-90.

Li, C., S.Q. Zheng and B. Prabhakaran, 2007. Segmentation and recognition of motion streams by similarity search. ACM. Trans. Multimedia Comput. Commun. Appl. TOMM, Vol. 3, 10.1145/1236471.1236475

Meredith, M. and S. Maddock, 2001. Motion capture file formats explained. MCS Thesis, University of Sheffield, Sheffield, England.

Nogueira, P., 2011. Motion capture fundamentals: A critical and comparative analysis on real-world applications. Masters Thesis, University of Porto, Porto, Portugal,https://paginas.fe. up.pt/~prodei/dsie12/papers/paper_7.pdf

Noiumkar, S. and S. Tirakoat, 2013. Use of optical motion capture in sports science: A case study of golf swing. Proceedings of the 2013 International Conference on Informatics and Creative Multimedia (ICICM), September 4-6, 2013, IEEE, Thailand, Asia, ISBN:978-1-4799-3702-8, pp: 310-313.