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The Development of Human Motion Detection System

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Abstract. Motion capture systems have been widely used in field of sport science. However, such systems were very expensive and not affordable for common users. In this research, a video-based motion capture system was developed. With this system, three-dimensional human motion data was detected through commercial video cameras, simple calibrating process and markers. On the other hand, we used Vicon motion capture system to capture sport stretch to build a motion knowledge base. After analyzed these captured data, correct stretch motion patterns were built. A knowledge base was built after stretch motion patterns were analyzed. With this knowledge base and video-based motion capture system, users can do stretches at home, office and other environment. System will immediately give users proper instructions to prevent injuries. In the future, more exercise items and instruction will be added into this system so people can do exercise in safer way.

Keywords: pattern recognition, image calibration, motion tracking, automatic instruction

1. Introduction

Motion Capture System is widely-used equipment for collecting data in research of sport science and is employed in several domains: computer games, virtual reality, animation, etc. However, such systems need special training and techniques to operate. And collecting and process data were very time-consuming and cumbersome work. Although many commercial products had been available and more user-friendly products were available, the price was high and not affordable for normal people.

This paper proposed a prototype for motion capture and human motion instruction system. To develop such system, two major problems must be solved: 1) How to make human limbs recognizable for computer systems and 2) How to make computers recognize correct movement from series of movements. After both problems were solved, motion tracking system and analytical data were integrated into a prototype system. In this prototype system, each analytical data were stored in a knowledge base so that motion tracking system can compare captured track with knowledge base. This prototype won't give user any alarms until the system had detected different in movement pattern or posture. And there alarms were issued simultaneously while the user was executing the stretch exercises.

2. Related works

The training for sportsman and physical education were used to depend on coaches' and teachers' experience. The introduction of sport science promoted the training method into field of science. By analyzing data, coaches gave sportsman instructions in more precise ways. However in physical education, teachers have few devices to analyse student's performance. This became the barrier while teachers wanted

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to give further instruction to students. Teachers can provide better physical education lesson if they have some equipments to help their teaching activities [1].

2.1. Motion capture systems

Motion capture system, also known as "mocap system", is a device which can capture body movement. Such system can capture data for purpose of analyse or feedback in ways of real-time or off-line [2]. In general, there are three major models of motion capture: optical, electromagnetic and electromechanical [3].

Optical motion capture systems use high-speed cameras (two or more) to capture markers attached on human body. With proper calibration process, system can calculate position for each marker. Optical motion captures systems are very useful to capture fast motion data for analyzing. However, such system has drawback of high price (USD$ 100,000 to USD$250,000) and sensitive to environment. It also needs lot of data processing and post-production works. However, such system was one the most popular devices used in fields of sport science and animation movies.

Electromagnetic motion capture systems use transmitters (attached on subject) as markers. And the receivers immediately receive three dimensional motion data through the change of magnetic field. Such systems are easy to calibrate, useful in wide space and can instantly be seen on computer screen. The prices were lower (USD$5,000 to USD$150,000). However, electromagnetic motion capture system is sensitive to magnetic field (cell phone, power station, etc.). And it had limitation in frame rate. Electromagnetic motion capture systems were getting popular in field of animation movies and arts creation.

Electromechanical motion capture system uses mechanical devices to measure the rotation of human body limb. Such system can capture fast motion and can be presented synchronously. The price is lowest (USD$5,000 to USD$10,000). However, the mechanical device became burden and limitation to movement.

After comparing the advantages and drawbacks of these three models. We decided to use home video cameras to develop our motion capture system.

2.2. The application of motion capture system in physical education

The development of motor skills comes from two important elements: cognition and coordination. In a discussion of motor learning [4], three phases of motor skills acquisition were distinguished, from beginner to master level, which were called the cognitive phase, associative phase and autonomous phase. To obtain motor skill need observation, imitation and practices. Learners need continuous trial and correction to perfect movements [5]. Using motion capture system, we can analyse badminton [6], Golf Swing [7], Over-arm Throwing [8] and etc. Furthermore, motion capture systems can be used in analyzing delicate Chinese martial arts [9]. In addition to motion analysis, the captured data can also applied to create multimedia learning materials for Chinese Martial arts[10, 11], basketball [12], gymnastics [13, 14], and stretching [11, 15], etc. In multimedia learning, three views of messages needed to be delivered to learners: delivery of media, presentation modes and sensory modality [16]. In the past researches, researchers putted their focus on developing learning content and presentation platform. However, few researches focused on kinaesthetic feedbacks to learners.

Motion capture system had been one of the most popular devices to detect and track human's movements. In the past, the captured data had been done on finding human's movement features in sport. The process of analysis can observe movement quality [17]. Integrating these features and multimedia learning materials can give learners immediate feedbacks while they are doing their exercises.

3. Method

The first thing to build a system to detect human spacial movements need to make computer system able to catch the object three-dimensional coordinations and to track the motions. To make these tracks meaningful for computer system, it need to give some feature patterns for some motions so that these track can fit the motion patterns. At last, these two parts must be integrated so learners can gain proper feedback.

3.1. Three dimensional reconstruction and motion tracking

Suppose there is a person with markers attached on his/her joints. Relative to this person, there were

some (more then two) cameras around this person. To detect these markers captured on single camera, we applied Houth Transform to detect markers filmed on single frame of one camera [18] and then label each marker. After labelling, the corresponding points in different cameras' view can be identified. Using Epipolar Geometry, three-dimensional coordinates of every point will be calculated and labelled.

After labeling three dimensional points, we use nearest-neighbor algorithms to find the relation between two frames so the track for each point can be calculated after calibration. Then we can have each joint's track in space(See Fig.1).

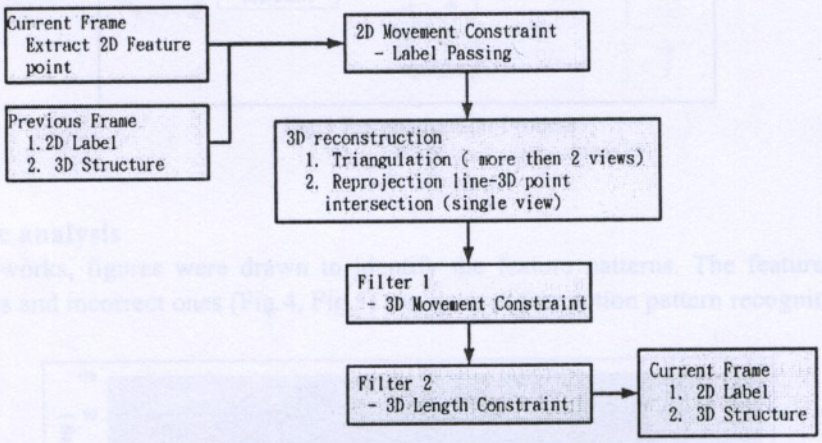

Fig.1 Three dimension reconstruction and tracking

3.2. Kinematic analysis

To obtain proper motion features, we use Vicon 624 system to capture 50 sets of different stretch exercises each set contained 2 correct movements and 3 incorrect movements for analyzing. The correct movements were following the guideline described in the book "Sports Stretch" [19]. Each set was calculated with kinematic parameters (position, angle, velocity and angular velocity). After calculation, analytical graphs for different body limbs and joints were plotted to identify the difference between correct movements and incorrect movements. Any differences shown on these graphs will be recorded as the bases to pattern recognition.

4. Result

The result of study had three major parts: Motion tracking system, kinematic analysis and prototyping system. Described as following.

4.1. Motion tracking system

According to the previously analysis, system were designed to capture subject's motions from four different angles (four cameras). System architectureis shown as following(Fig.2).

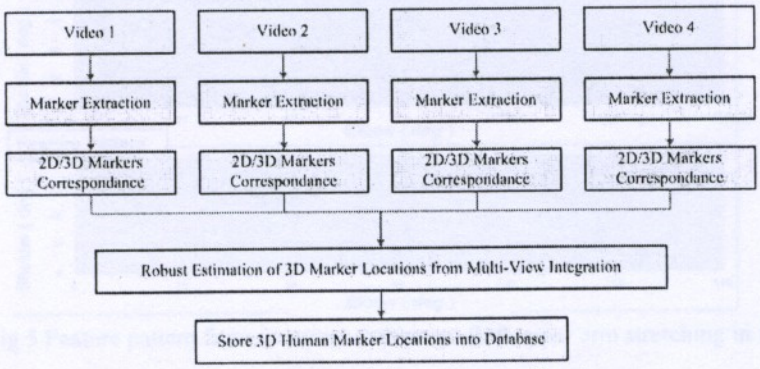

Fig.2 Motion tracking system architecture

From the analysis, feature pattern between correct and incorrect movement can be distinguished. And such differences can be used for pattern recognition. The motion tracking system can use this pattern to differentiate correct movement from incorrect ones.

4.3. Prototyping system

After motion capture algorithm and kinematic analysis works were finished. Human motion detection system was developed (Fig.5, Fig.6).

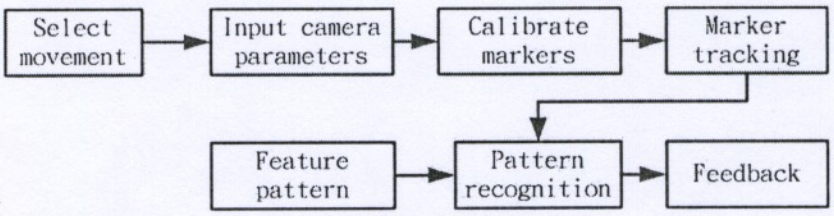

Fig.5 Tracking Process

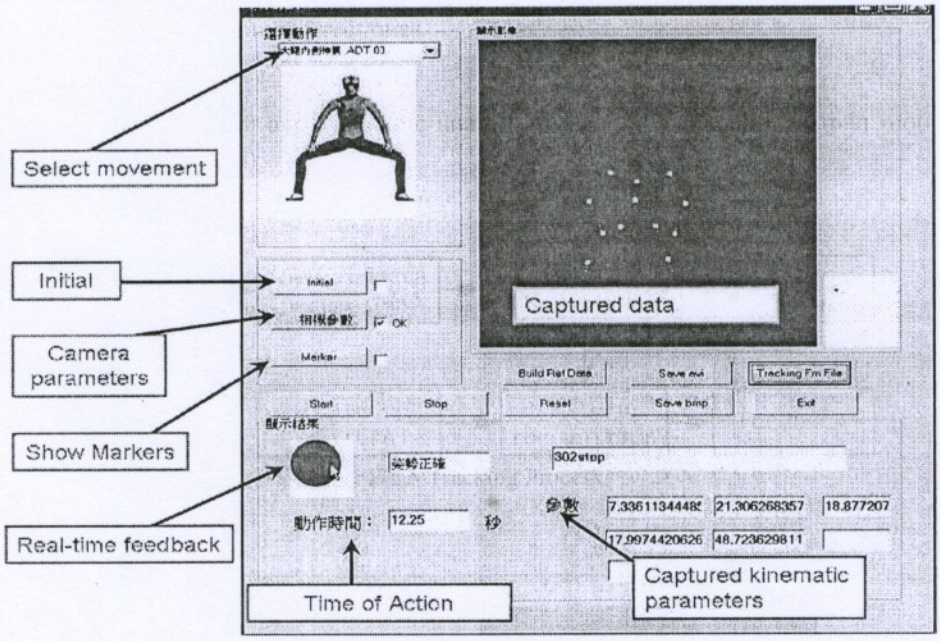

Fig.6 Human Motion Detection System

.This system can automatically calibrate cameras, capture and label markers and track user's movements. System will immediately give user real-time feedback (green for correct and red for incorrect) when he or she is executing selected stretch exercise.

5. Conclusion and discussion

Although this system had developed, there are some improvements need to be done:

- Due to limitation of camera frame rate, which means system can process at most 30fps to provide real-time feedback. However, our algorithm was not fast enough process all frames from video cameras.
- The instruction part of software can only point out the differences between subject and feature patterns. However, this feedback was numerical. The numerical feedback need to associate with more specific instructions.

- Such system can only detect the gesture of human movement. As to sports stretch, it is difficult to detect the muscle stretching. More bio-feedback devices (EMG, ECG, etc.) need to be integrated to detect real physical condition.
- In the future, we wish to use fewer and cheaper video capture devices to improve this system. And more sports activities can be analyzed to generate their feature pattern to verify the feasibility of this system.

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7. References

[1] M.-K. Lo, "The Application of Movement Analysis Model Towards Teaching of Physical Education", *Journal of Physical Education and Sports*, vol. 12, pp. 175-188, 2001.

[2] D. J. Sturman, *A Brief History of Motion Capture for Computer Character Animation*, 2007.

[3] C.-T. Yang, *The Development of an Optical Webcam Motion Analysis System - For 2D Gait Analysis*, National College of Physical Education and Sports, Taoyuan, Taiwan, 2004.

[4] P. M. Fitts, *Perceptual-motor skill learning. In A. W. Melton (Ed.), Categories of Human Learning,*, Academic Press, New York, 1964.

[5] W. C. Chen, "The Application of Multimedia in Physical Education", *National Sports Quarterly*, vol. 23, pp. 102-109, 1994.

[6] J.-B. Shieh, *The qualitative analysis of badminton forehand overhead clear*, National College of Physical Education and Sports, Taoyuan, Taiwan, 2003.

[7] C.-Y. Yang, *A Comparison Between Elite Collegiate Men and Female Golfers in Wrist Isokinetic Strength and Kinematics during Downswing*, National College of Physical Education and Sports, Taoyuan, Taiwan, 2003.

[8] Y.-C. Liu, *The Effect of Different Weight on Throwing Pattern and Muscular Activation of Over-arm Throwing*, National College of Physical Education and Sports, Taoyuan, Taiwan, 2004.

[9] W.-P. Fu, *The Kinetic Chain Analysis of Opening Palm in Cheng Style Gao Branch of Ba Gua Zhang*, National College of Physical Education and Sports, Taoyuan, Taiwan, 2005.

[10] F.-C. Chu, *The Study of a Web-Based Computer-Assisted 3D/VR Learning Material – for the Chinese Martial Art of Zhong Yi Quan*, National College of Physical Education and Sports, Taoyuan, Taiwan, 2001.

[11] C.-Y. Shiu, *The Developing of a Web Based 3D/VR Stretching Learning System for the Office Worker*, National College of Physical Education and Sports, Taoyuan, Taiwan, 2003.

[12] Y.-K. LEE, *On-Line Physical Education Assisted Learning System—A Case Study on Basketball Instruction at the Elementary School*, National College of Physical Education and Sports, Taoyuan, Taiwan, 2003.

[13] C.-R. Chen, *The Development of a Web-Based 3D/VR Movement Learning System for Children*, National College of Physical Education and Sports, Taoyuan, Taiwan, 2003.

[14] T.-C. Lin, *The Development of a Situated and 3D/VR Floor Exercise E-Learning System for Primary School Students*, National College of Physical Education and Sports, Taoyuan, Taiwan, 2005.

[15] W.-C. Hsu, *The Development of a Web Based 3D/VR Tai Chi Chuan Learning System —the Forty-two Movements Style*, National College of Physical Education and Sports, Taoyuan, Taiwan, 2004.

[16] R. E. Mayer, *Multimedia Learning*, Cambridge University Press, New York, USA, 2002.

[17] Y.-T. Huang, *A quantitative study of Time, Space, and Weight Elements in Laban Movement Analysis: Using Action Drives as a tool*, National College of Physical Education and Sports, Taoyuan, Taiwan, 2006.

[18] R. O. Duta and P. E. Hart, "Use of the Hough Transformation to detect line and curves in pictures", *Com. ACM*, vol. 15, pp. 11-15, 1972.

[19] M. J. Alter., *Sport Stretch*, Human Kinetics, Champaign, IL, 1998.