World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:7, No:2, 2013

Capture and Feedback in Flying Disc Throw with use of Kinect

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***Abstract*—**This paper proposes a three-dimensional motion capture and feedback system of flying disc throwing action learners with use of Kinect device. Rather than conventional 3-D motion capture system, Kinect has advantages of cost merit, easy system development and operation. A novice learner of flying disc is trained to keep arm movement in steady height, to twist the waist, and to stretch the elbow according to the waist angle. The proposing system captures learners' body movement, checks their skeleton positions in pre-motion / motion / post-motion in several ways, and displays feedback messages to refine their actions.

***Keywords*—**Flying disc, throwing movement, Kinect, capture, feedback

I. Introduction

IN the field of sports science research, kinematic analysis of human body became popular in the last decade. Barris [1] surveyed vision-based motion analysis researches for sports. Moeslund [2] surveyed vision-based human motion capture / analysis systems. Miles [3] surveyed applications of Virtual Reality environments for ball sports. There are wide varieties of equipments adopted in these researches: GPS sensor, acceleration sensor, muscle sensor, HMD (Head Mound Display) etc. Among them, the major equipment is so called "motion capture systems" that measure many points of human body in three-dimensional space. Also the systems archive 3-D information along timeline. However, the major motion capture systems are extremely expensive, costing several hundred thousand dollars. Additionally, they require dedicated rooms, multiple cameras, special lighting capacity and dedicated "tracking suits" that specify a tracking point of human body. Furthermore, myriad steps are necessary to set up and data acquisition including the activity called "calibration", which adjusts the 3-D points of marking sensors on the tracking suit. As a result, this kind of analysis is infrequently performed outside of specialized research or specific studies of top athletes.

In contrast, Kinect device released by Microsoft Corporation in 2010 offers a simple and inexpensive way to perform 3-D analysis of a human body movement. First, the device itself costs only U.S.$110, which is far cheaper than conventional motion capture systems. Second, Kinect is capable of capturing data easily. It does not need any tracking suits nor complex set-up and operation procedure for data acquisition. Third, Microsoft has publicly released a software development kit (SDK) that includes the necessary library for data acquisition using Kinect. Application system developers are able to write customized Windows applications with use of this library in the C# or C++ languages.

The proposed research in this paper has 3 major points below:

(1) Utilizes Kinect
(2) Captures 3-D motion and give feedback to sports learners
(3) Target motion: flying disc throw

There are many preceding researches to analyze human body motion with use of motion capture systems including Kinect. Also, there are some researches to give automatic feedback messages to learners to refine their motion. The authors arranged these researches as shown in Table in order to survey categories (1) and (2).

Papers at upper left side in Table I utilize commercial or original 3D motion capture systems to analyze 3-D motion. Bideau [4] utilized Vicon 370 system to analyze relationship of movement between throwers and a goalkeeper of handball. Brodie [5] synthesized a body model of a ski racer from GPS information and video motion graphics. Corazza [6] synthesized a body model with use of 8 motion cameras and replays it in a virtual environment. Hachimura [7] developed a dance training support system with use of magnetic sensor system Fastrak and HMD.

TABLE I
ARRANGEMENT OF PRECEDING RESEARCHES

	Analysis	Feedback
Commercial/ Original 3D Motion Capture System	Bideau [4] Brodie [5] Corazza [6] Hachimura [7]	Ishii [8] Kwon [9] Soga [10]
Microsoft Kinect	Fujimoto [11] Hsu [12] Kato [13] Marquardt [14] Mitchell [15] Ogawa [16]	Chye [17]

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At upper right side, there are researches to give feedback messages to learners, based on 3-D captured data. Ishii [8] utilized a motion capture system IGS-190 for baseball batting movement. It also provided a comparing function between “goal motion” and learner’s one. Based on the comparison, the system showed messages to refine learner’s motion. Kwon [9] developed an original motion capture system for Taekwondo training. It also displayed a visual feedback to adjust one’s movement. Soga [10] proposed a training support system for rhythmic gymnastics. It adopted an optical motion capture system, compared the captured data and ideal motion data, and displayed feedback messages in the screen.

At lower left side in Table I, there are researches to analyze human motion with use of Kinect. Fujimoto [11] developed a dance training support system. It showed learner’s image and instructor’s ideal motion image in overlaying manner. Hsu [12] discussed many possibilities of Kinect utilization in various sports learning activities. Kato [13] developed a system to compare a professional player and a novice learner of soccer. Marquardt [14] diagnosed a pose of ballet dancer with use of Kinect. It is called “Super Mirror”, because common ballet studios use a mirror to check and adjust one’s pose. Mitchell [15] developed a Kinect based system to diagnose hand movement for playground game. Ogawa [16] developed a distance learning system. An instructor and a learner share a common virtual space, and compare their body motions.

Finally, at the lower right side, there is one preceding research similar to the proposing method. Chye [17] utilized Kinect to diagnose Karate pose. He compared 4 joint points of an instructor and a learner, calculates their Euclid distances, and gives feedback messages to the learner.

As mentioned in the third point written above, this research focuses on the motion of flying disc throw. The authors have previously published research on the movement itself [18] [19] [20] [21] [22]. Also the authors applied these results to actual physical education tasks through the development of multimedia teaching materials [23] [24]. Beyond them, Sasakawa [25] analyzed the throwing motion, while Koyanagi [26] formularized the characteristics of the applicable movement with use of a disc with an inertial sensor. Murayama [27] conducted research on guidance using an instantaneous feedback system, while Takeuchi [28] conducted analysis with use of a motion capture system.

This paper proposes a real time, 3-D motion capture and feedback system using Kinect, which targets novice learners to throw a flying disc. The system allows the learners to observe their own movements through video playback in real time. Also it diagnoses their joint movement and gives feedback messages automatically on their throwing form. Practiced use of the proposed system will give learners a visceral grasp of the correct throwing form, which will in turn lead to improved accuracy of throwing performance. In addition, if employed as part of physical education instruction, it is expected that the system will aid instructors in providing individualized critique to learners and will contribute to the efficiency of the instructional environment.

II. Features of Kinect

Kinect is a device that is able to analyze the motion of human subjects in three dimensions. Initially developed as a peripheral apparatus to be connected to Microsoft’s Xbox gaming system, Kinect includes a CMOS camera, infrared projector, image depth sensor, microphone, and a USB port for connection to a Windows PC. Kinect projects patterned infrared rays that are analyzed by its CMOS camera to recognize the distance between the player and the device. Also, through the machine learning function called “human pose estimation” developed by Microsoft Research Cambridge, Kinect is able to recognize the positions of subjects’ joints with reasonable accuracy. Fig. 1 shows 20 recognizable points by Kinect (Microsoft calls them “skeleton positions”).

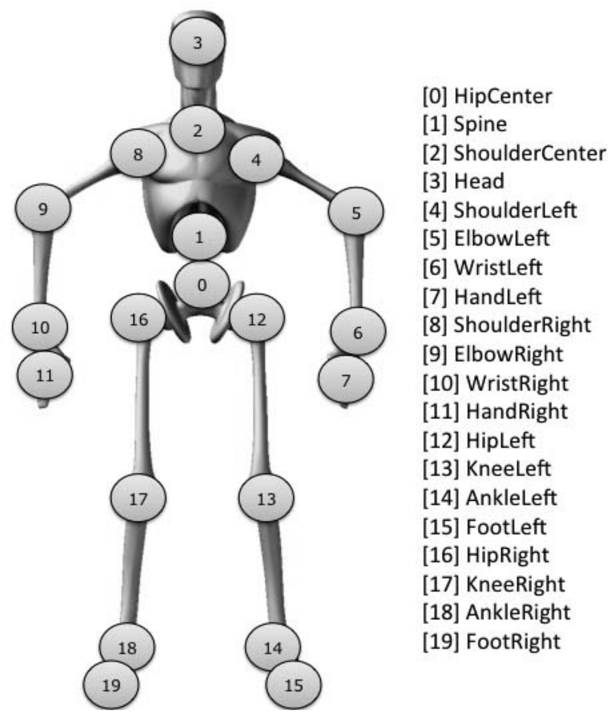

Fig. 1 Joints recognizable with Kinect

The coordinates of each point detected by Kinect can be read into a Windows PC using the library included in the device’s SDK. There are two types of coordinates.

(1) Point: coordinates of the joints on a two-dimensional video image acquired by the camera. They are displayed as 2-D (x,y) coordinates. Image resolution and frame rate options are as follows.

- 640 x 480 x 15 frame
- 640 x 480 x 30 frame
- 1280 x 960 x 12 frame

(2) Position: 3-D coordinates (x,y,z) of the points in a virtual 3-D space.

III. Features of the Proposed System

This paper proposes a system that will process data in three steps: (a) acquisition of 2-D video images and Position data for each point; (b) assessment of whether the flying disc throwing movement is correct or incorrect based on the Position data acquired for each point; and (c) display of feedback messages with 2-D motion images from (a) based on the results of the assessment in (b). Details of each process step are given below.

A. Acquisition of Kinect Data

The SkeletonStream properties in the Kinect library must be enabled in order to acquire Kinect data. Similarly, the coordinate data for each point must be extracted from the data embedded in the Kinect.JointType category structure, which is also available in the library. Point coordinate data values can be used to assess motion in real time.

B. Assessment of Throwing Form

This paper is interested in the assessment of good or bad flying disc throws. However, the skill levels of learners are hugely diverse, with intermediate learners and above representing the most difficult subjects to biomechanically assess. Consequently, this research focused on absolute beginners and made assessments by comparing whether or not their throws matched a basic standard throwing motion.

In making the assessments, the throwing movement was divided into the three phases of (a) pre-motion (take back), (b) motion (swing), and (c) post-motion (release). Assuming a right-handed thrower, the phases were judged by the following parameters.

(a) $x11 < x2$
(b) $x2 <= x11 < x9$
(c) $x9 <= x11$

These numbers are the point numbers from Fig. 1. ‘x’ represents horizontal coordinates, with movement in the direction of the right hand receiving a positive value. In (a), the take back phase, the thrower’s right hand is left of the body’s center; in (b), the thrower’s right hand is between the body’s center and the elbow; and in (c), the finish, the thrower’s right hand is to the right of the right elbow. Fig. 2 shows a representation of these three phases.

Next, assessments were devised on five points: (1) the take back (before the throw), (2) the height of the right hand, (3) changes to the height of the right hand, (4) the angle of the right elbow, and (5) the twisting of the waist.

(1) was judged as to whether or not it conformed with the parameters for phase (a). Novices tend to have insufficient take back and have a throwing motion akin to a ring toss. In order to prevent this, it should be determined whether the thrower has a proper take back motion before the throw.

(2) is relevant to all phases of the throw: a, b, and c. It assesses whether the right hand is properly below the level of the shoulder but above the solar plexus and is expressed by this formula:

$y1 < y11 < y2$

Novices tend to allow their right hand to rise above their shoulder during phases (a) and (c). Hence this assessment is effective for spotting this error.

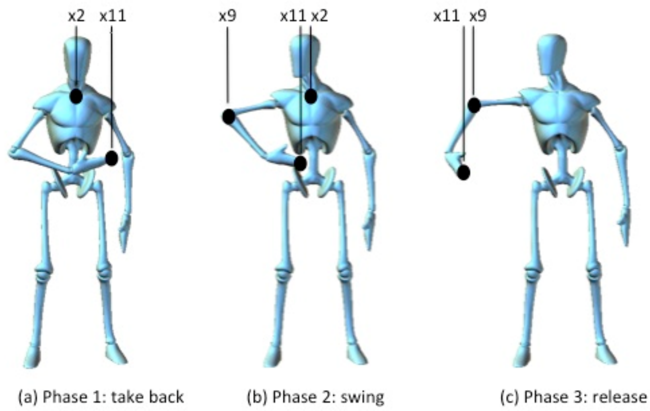

Fig. 2 Phases of the Throw

(3) is similar to (2) and assesses movement patterns that tend to prevent the disc from flying parallel to the ground, such as a throw that bows upward or downward, or a throw that swings upward. In concrete terms, if the position of the right hand is analyzed for each phase, the following judgments can be made:

- Bowing upward: (a) OK or Low & (b) High & (c) OK or Low
- Bowing downward: (a) OK or High & (b) Low & (c) OK or High
- Swinging: (a) Low & (c) High

Here a, b, and c represent the above mentioned phases and “Low” means $y11 < y1$, “OK” means $y1 <= y11 < y2$, and “High” means $y11 >= y2$.

(4) assesses whether the angle made by the right shoulder, right elbow, and right wrist is 120 degrees or greater during phase (b). Some novices tend to fully extend their arm when throwing the disc, causing them to lose the angle of the elbow that helps produce speed and spin.

(5) assesses whether there is sufficient twist in the waist during phase (a), the take back phase. In the x-z planes, tangents for the right and left foot vector (14, 18) and waist vector (12, 16) were calculated. Specifically, the following conditional expressions were used.

$m1=(z14-z18)/(x14-x18)$
$m2=(z12-z16)/(x12-x16)$
if $(m2-m1)/(1+m1+m2) >=0$ then OK

Under the current assessment approach, the conditions are set to require the above vectors to be parallel (that is, the above discriminant = 0).

C. Display of the Assessment Results

The system shows the assessment results noted in III B with acquired 2-D moving images noted in III A. Fig. 3 shows an example screenshot of the developed system.

IV. Discussion and Observations

The system proposed on this paper has moved beyond the first stages of development, and, as shown in Fig. 3, is currently undergoing field tests and modifications. The points listed below, starting with assessment of throwing form from Section III B, are currently being examined in the laboratory.

- Assessment of the "height of the right hand" has point #1 (the solar plexus) as its lower limit, but this parameter may be too restrict. Point #0 (waist level, in other words) may be a more appropriate lower limit.
- Further patterns are possible in regards to the formula used for assessment (3) and judgment of a throw as "bowing upward," etc. It is necessary to add additional throwing patterns, acceptable ones and clearly erroneous ones, as we gather measurements from further experiments.
- Assessments (4) and (5), judging the angle of the right elbow and the twist of the waist, respectively, are still at a trial stage. It is necessary to consider and debate their validity in light of actual throwing movements.
- Assessment (5), twisting of the waist, currently is calibrated for '0' waist twist even during the take back phase, which means that parallel waist and feet receive a positive assessment. Other options exist, though, such as a negative value indicating twisting of the waist.

These assessments are designed to determine what kind of feedback is effective for instructing rank beginners and novices limited specifically to throwing a flying disc. Below are points under consideration with regard to the functionality of the proposed system.

- Currently, the feedback given to the learner is text only. Adding audio and voice functionality will likely make the feedback more readily apparent to the learner.
- As mentioned in Section II, there are two types of coordinates that can be obtained with Kinect: Point and Position. Currently, however, only Position coordinates have been utilized, which, although sufficient for assessing throwing form, would benefit from the inclusion of Point information. This would allow for the display of specific tracks/trails indicating proper height, arm movement, etc. within the images shown in Fig. 3. This would likely improve the effect of the feedback.

V. Conclusion

This paper has presented a system using Kinect for analysis of and feedback on the motion of throwing a flying disc. Future research will work to refine the system vis-à-vis the points noted in Discussion and Observations (Section 4), test the system in providing feedback to actual learners, and verify the validity of the system.

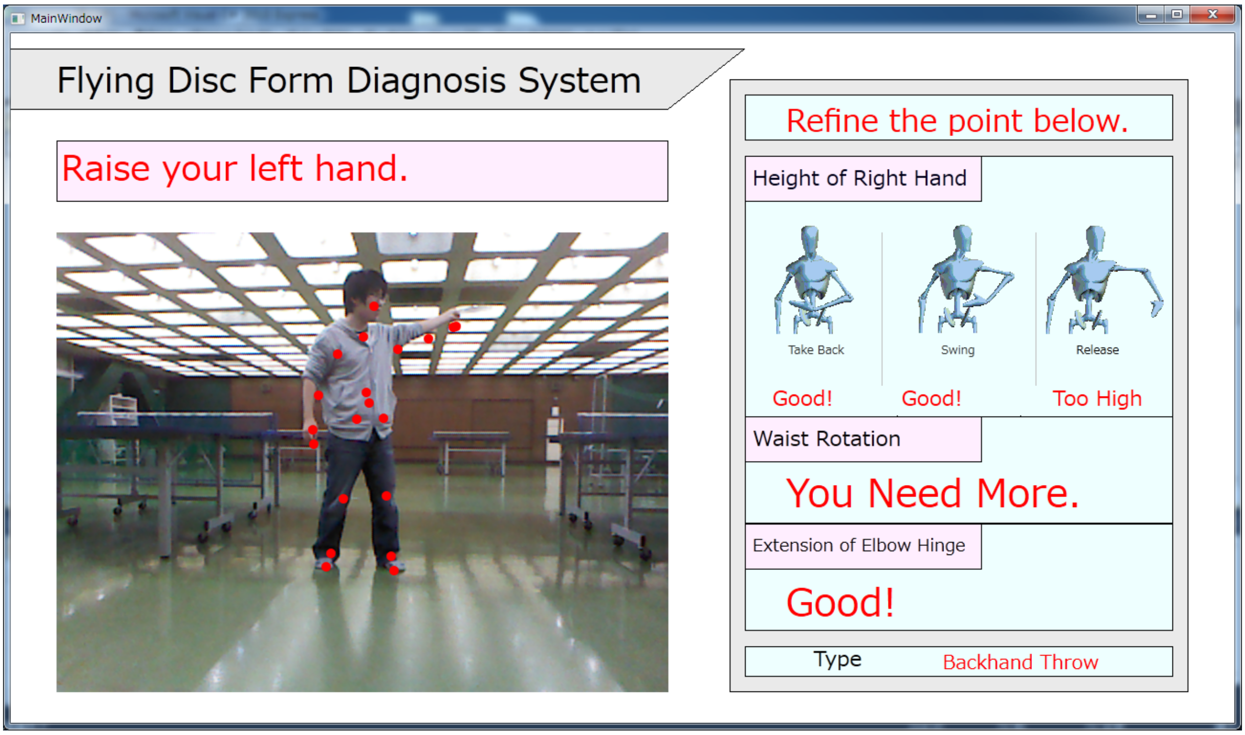

Fig. 3 Sample Screenshot

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