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Analysis and Feedback of Baseball Pitching Form with use of Kinect

Yasuhisa TAMURA [a*], Taro MARUYAMA [a] & Takeshi SHIMA [b]
[a] *Department of Information and Communication Sciences, Sophia University, Japan*
[b] *Department of Health and Physical Education, Sophia University, Japan*
*ytamura@sophia.ac.jp

Abstract: This paper introduces an automatic analysis and feedback system for amateur baseball pitching learners with use of Microsoft Kinect. Compared with conventional 3-D motion capture systems, Kinect has advantages of reasonable cost and easiness of application system development for physical exercises. The authors developed a similar system for flying disc throw, which is disclosed in Tamura, Yamaoka et al. (2013) and Tamura, Uehara et al. (2013). In this paper a target motion is moved to baseball pitching, so focused body parts and judgment criteria were changed, although utilizing the same Kinect platform. The proposing system acquires postures and motions of amateur baseball pitchers, and judges them in 2 criteria: (1) maximum angle of elbow, and (2) hand twist, which were decided by a training expert. It also displays feedback messages to improve their motions. As a result, novice testees of the target group showed significant improvement of their pitching motions.

Keywords: Baseball, pitching movement, Kinect, analysis, feedback

1. Introduction

In a field of sports science research, motion analysis of human body has become popular in the last decade. Barris and Button (2008) surveyed vision-based motion analysis researches for sports. Moeslund et al. (2006) surveyed vision-based human motion capture / analysis systems. Miles et al. (2012) surveyed applications of Virtual Reality environments for ball sports. There are wide variety of equipments adopted in these researches: GPS sensor, acceleration sensor, muscle sensor, HMD (Head Mound Display) etc. Among them, the major equipments are so called "motion capture systems", that measure many points of human body in three-dimensional space in real time manner. However, the major commercial motion capture systems are extremely expensive, costing several hundreds of thousand dollars. Additionally, they require a dedicated equipped room, multiple cameras, special lighting facility and dedicated "tracking suits" to specify a tracking points of human body. Furthermore, myriad steps are necessary to set up and acquire data 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 other than specialized researches or specific studies of limited top athletes.

Among them, Microsoft Corporation released a device called Kinect in 2010. It provides 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, complex set-up, and troublesome operation procedure for data acquisition. Third, Microsoft has publicly released a software development kit (SDK) that includes necessary software libraries 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: baseball pitching

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 1 in general.

Table 1: Preceding Researches

	Analysis	Feedback
Commercial/ Original 3D Motion CaptureSystem	Bideau et al. (2004) Brodie et al. (2008) Corazza et al. (2006) Hachimura et al. (2004)	Ishii et al. (2011) Kwon and Gross (2005) Soga and Myojin (2008)
Microsoft Kinect	Fujimoto et al. (2012) Hsu (2011) Kato et al. (2012) Marquardt et al. (2012) Mitchell and Clarke (2011) Ogawa and Kambayashi (2012)	Chye and Nakajima (2012)

Papers at upper left side in Table 1 utilize commercial or original 3D motion capture systems to analyze 3-D motion. Bideau et al. (2004) utilized Vicon 370 system to analyze relationship of movement between throwers and a goalkeeper of handball. Brodie et al. (2008) synthesized a body model of a ski racer from GPS information and video motion graphics. Corazza et al. (2006) synthesized a body model with use of 8 motion cameras and replays it in a virtual environment. Hachimura et al. (2004) developed a dance training support system with use of magnetic sensor system Fastrak and HMD.

At upper right side, there are researches to give feedback messages to learners, based on 3-D captured data. Ishii et al. (2011) 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 and Gross (2005) developed an original motion capture system for Taekwondo training. It also displayed a visual feedback to adjust one’s movement. Soga and Myojin (2008) 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 1, there are researches to analyze human motion with use of Kinect. Fujimoto et al. (2012) developed a dance training support system. It showed learner’s image and instructor’s ideal motion image in overlaying manner. Hsu (2011) discussed many possibilities of Kinect utilization in various sports learning activities. Kato et al. (2012) developed a system to compare a professional player and a novice learner of soccer. Marquardt et al. (2012) 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 and Clarke (2011) developed a Kinect based system to diagnose hand movement for playground game. Ogawa and Kambayashi (2012) 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 and Nakajima (2012) 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 above, this research focuses on the motion of baseball pitching. According to this topic, there are some related researches. Lin et al. (2003) used Qualisys motion analysis system by Qualisys AB. The goal is to analyze the movement and velocity of “center of mass” in the pitching cycle. They found different moving speeds in different pitching phases (lowest position and late cocking). Theobalt et al. (2004) used a proprietary, multiple video camera-based motion capturing system. Aguinaldo et al. (2007) used Real-Time Motion Capture System by Motion Analysis Corp (120 fps). They set 18 marker points for upper body, in order to analyze peak shoulder internal rotation torque. 38 pitchers are categorized into 4 groups (Pro, College, High School, Youth). The

Professional group showed a significant result of rotation timing. Lapinski et al. (2009) developed a proprietary wearable sensing device with use of Analog Devices iMEMS ADSXR300 and ADXL210E, that also provide a wireless communication function. For reference, they utilized a motion analysis system from XOS Technologies with 10 motion analysis cameras. They analyzed acceleration and G-Force of pitchers' body points (hand, waist, forearm, chest and waist) and compared the results between their original system and optical motion analysis system. Ukita et al. (2014) developed a Kinect-based automatic rehabilitation system, and applied its motion as a baseball pitching in left tow and right hand velocity.

In above papers, most of them are utilizing commercial or dedicated motion capture systems. Only Ukita et al. (2014) utilized Kinect, but its focus is rehabilitation. In this sense, there is no preceding research to focus on baseball pitching training with use of Kinect device.

2. Proposed System

This paper proposes a system that will process data in three steps:
(a) acquisition of 2-D video images and 3-D position data for body points with use of Kinect,
(b) assessment of whether the baseball pitching movement is adequate or not, based on the position data acquired in (a), and
(c) display of feedback messages with 2-D motion image from (a) based on the results of the assessment in (b).

Details of these processes are given below.

2.1 Kinect and its Data Acquisition

Kinect is a device with a function to analyze the motion of human subjects in real time and 3-D manners. It was initially developed as a peripheral device to be connected to Microsoft's Xbox gaming system. Kinect includes a CMOS camera, infrared projector, image depth sensor, microphone, and one USB port for connection to a Windows PC. Kinect projects patterned infrared rays that are analyzed by CMOS camera to recognize the distance between the target player and the device. Also, with use of a machine learning function called "human pose estimation" developed by Microsoft Research Cambridge, Kinect is able to recognize 20 positions of target human joints and body parts with reasonable accuracy. 3-D coordinates of these positions are transferred to a connected Windows PC in 30 fps (frames per second) through the libraries included in the device's SDK.

2.2 Judgment of Pitching Form

This paper focuses on the assessment of baseball pitching movement. However, target skill levels of learners are totally diverse in beginner and professional learners. This study focused on absolute beginners and made assessments by comparing whether their pitching motions match a basic and standard one. The authors set two hypothetical criteria of the pitching motion: (a) maximum angle of elbow, and (b) hand twist. One of the authors (Shima) analyzed these aspects and tendencies during his coaching in college classes. They are shown in Figure 1.

The aspect (a) judges whether the right elbow (for a right-hand pitcher) is raised in enough height of not. An amateur pitcher tends not to raise his right elbow enough. In order to judge this point, the authors calculated the angle of hip center (#0) – shoulder center (#2) – right elbow (position #9) as θ_1. These numbers of 0, 2 and 9 are specified in Kinect SDK to identify 20 human joints and body parts. Kinect is able to measure the absolute height of elbow position, but stature varies on individual. Then in this paper, this angle of $\theta_1$was decided as a criterion. This θ_1 is judged as below. Points shown in parenthesis are used to evaluate performance at the time of experiment shown in Chapter 3.

- $125 <= \theta_1$: too much (35 points)
- $115 <= \theta_1 < 125$: a little much (40 points)
- $105 <= \theta_1 < 115$: good (50 points)
- $90 <= \theta_1 < 105$: a little few (40 points)

- $\theta_1 < 90$: too few (10 points)

The aspect (b) is twist of the right hand (for a right-hand pitcher). In order to throw a fast ball, right elbow should go forward rather than his body. In other words, his elbow should be twisted, not be strait. In order to measure it, the authors focus on the angle of pitching target – right elbow (#9) – right hand (#10) as θ_2. In this paper, this angle of θ_2 is judged as;

- $110 <= \theta_2$: good (50 points)
- $100 <= \theta_2 < 110$: moderate (40 points)
- $\theta_2 < 100$: not enough (30 points)

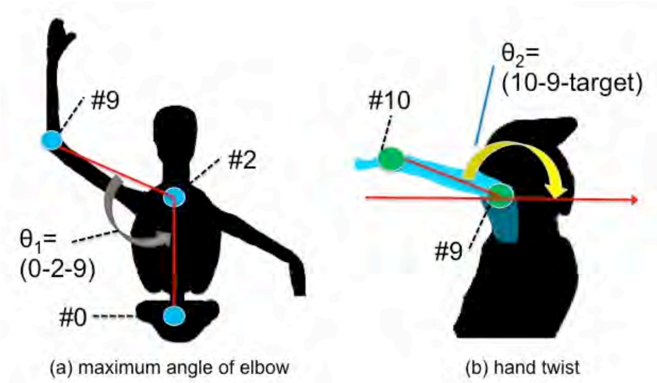

Figure 1. Judgment of Pitching Form

In the previous studies (Tamura, Yamaoka et al. (2013) and Tamura, Uehara et al. (2013)), the target motion was flying disc throw. In this case, the main focus was height of right hand (#10). If this height changes widely, he is difficult to throw the disc to the intended target. However, in the baseball pitching, the main issues are the maximum angle of elbow and hand twist, as shown in Figure 1. This difference can be implemented after the judgment criteria is identified and quantified, but the criteria itself should be determined in discussion with a professional sports trainer.

As introduced in Chapter 1, there are some preceding researches to analyze baseball pitching forms. These researches focus on mainly speed, torque, acceleration and G-force of body points. However, they have little insights why and how the speed etc. come from. In other words, They do not show a "good" pitching form. In this paper, the authors set a hypothesis of a "good" form, and show judgment criteria as stated above.

2.3 Visual Feedback

In order to provide visual feedback to pitching learners, the authors also developed a visual feedback interface. It contains a real time 2-D video of pitching action and both quantitative numbers and qualitative feedback sentences of form judgment result described in section 2.2. Figure 2 shows a snapshot of the developed visual feedback interface. The proposing system is reset when a target person raises his left hand and then starts the analysis.

3. Experiment

In order to verify the effectiveness of the proposing system described above, the authors performed an experiment. The authors collected 40 testees in Sophia University. Some of them belong to athletic clubs in the college, but none of them have been trained as a baseball pitcher.

First, as a pre-test, all of the 40 testees were examined the precision of pitching forms 5 times. After that, the testees were divided into two groups of a target group (TG) of 20 and a control group (CG) of 20, whereas pitching performances of the two groups are to be statistically non significant. Next, as a test, the TG members were given feedback in 15 times of pitching movements with use of the proposing system. On the other hand, the CG members had no feedback from the proposing system in same 15 times of pitching. Last, as a post test, all members including TG and CG were assessed their pitching forms with use of the proposing system, without any feedback.

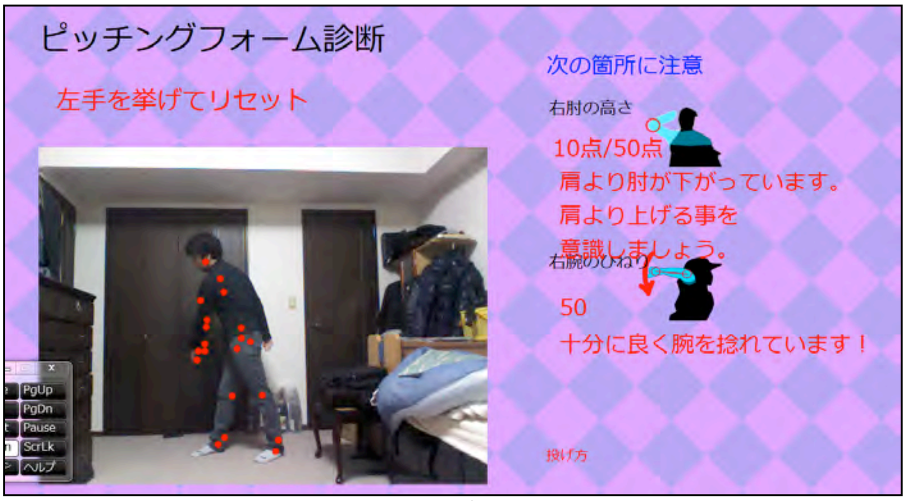

Figure 2. Screen Shot of the Proposing System

The authors compared the result of the post test, focusing on improvement of their performance. The result of t-test among all TG and CG testees, p value was p=0.227, which showed there was no significance between TG and CG in performance improvement. Then, in order to perform more detailed analysis, total testees were divided into six groups according to TG and CG, and also their performance groups; upper, intermediate, and lower. When TG and CG are compared in the same groups, p values were: Upper group: p=0.515, Intermediate group: p=0.706, and Lower group: p=0.061.

This result shows that the p value of lower groups shows a tendency of significance, while upper and intermediate groups are not significant totally. This phenomenon is similar to the experiment performed previously in Tamura, Yamaoka et al. (2013) and Tamura, Uehara et al. (2013).

4. Discussion & Conclusion

The result of experiment in Chapter 3 shows a tendency of significance only for relatively lower-graded learners. A possible reason of this point is that judgment points and their evaluations hypothesized in Section 2.2 fit exercises for novice learners of baseball pitching. In other words, there should be some other judgment points and evaluations for upper than intermediate learners. This point is thought as one of the future issues.

As a conclusion, this paper has presented a system with use of Kinect device for analysis of and feedback on the motion of baseball pitching. A result of experiment shows that this method is thought to be useful for relatively novice learners to improve their movement. Future research issues contain a work to refine the current system vis-à-vis the points noted in Chapter 3, and retry to validate the efficiency of the proposing system with improved methods and sequence.

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References

Aguinaldo, A. L., Buttermore, J. & Chambers, H. (2007). Effects of upper trunk rotation on shoulder joint torque among baseball pitchers of various levels, Journal of Applied Biomechanics, 23(1), 42.

Barris, S. & Button, C. (2008). A Review of Vision-based Motion Analysis in Sport, Sports Medicine, 38(12), 1025-1043.

Bideau, B., Multon, F., Kulpa, R., Fradet, L., Arnaldi, B. & Delamarche, P. (2004). Using virtual reality to analyze links between handball thrower kinematics and goalkeeper's reactions, Neuroscience Letters, 372(1-2), 119-122.

Brodie, M., Walmsley, A. & Page, W. (2008). Fusion motion capture: a prototype system using inertial measurement units and GPS for the biomechanical analysis of ski racing, Sports Technology, 1(1), 17-28.

Chye, C. & Nakajima, T. (2012). Game based approach to learn Martial Arts for Beginners, IEEE 18th International Conference on Embedded and Real-Time Computing Systems and Applications (RTCSA), 19-22.

Corazza, S., Muendermann, L., Chaudhari, A. M., Demattio, T., Cobelli, C. & Andriacchi, T. P. (2006). A Markerless Motion Capture System to Study Musculoskeletal Biomechanics: Visual Hull and Simulated Annealing Approach, Annals of Biomedical Engineering, 34(6), 1019-1029.

Fujimoto, M., Terada.T. & Tsukamoto. M. (2012). A Dance Training System that Maps Self-Images onto an Instruction Video. ACHI 2012 (The Fifth International Conference on Advances in Computer-Human Interactions), IARIA, 309-314.

Hachimura, K., Kato, H. & Tamura, H (2004). A Prototype Dance Training Support System with Motion Capture and Mixed Reality Technologies, Proc. IEEE International Workshop on Robot and Human Interactive Communication, 20-22.

Hsu, H. J. (2011). The Potential of Kinect as Interactive Educational Technology, 2nd International Conference on Education and Management Technology, 13, 334–338.

Ishii, K., Soga, M. & Taki, H. (2011). Proposal and development of reversal motion skill leaning support environment, International Conference on Information Technology Based Higher Education and Training (ITHET), 1-6.

Kato, K., Namiki, Y., Thepvilojanapong, N., Tetsutani, N. & Ohta, Y. (2012). Exploring Analysis of Football Actions Cosidering Correlation of Joints in the Body, Ninth International Conference on Networked Sensing Systems (INSS), 11-14.

Kwon, D.Y. & Gross, M. (2005). Combining Body Sensors and Visual Sensors for Motion Training, ACM SIGCHI International Conference on Advances in computer entertainment technology, 94-101.

Lapinski, M., Berkson, E., Gill, T., Reinold, M. & Paradiso, J. A. (2009). A distributed wearable, wireless sensor system for evaluating professional baseball pitchers and batters, Proc. ISWC'09, 131-138.

Lin, H. T., Su, F. C., Nakamura, M. & Chao, E. Y. (2003). Complex chain of momentum transfer of body segments in the baseball pitching motion, Journal of the Chinese Institute of Engineers, 26(6), 861-868.

Marquardt, Z., Beira, J., Em, N., Paiva, I. & Kox, S. (2012). Super Mirror: a kinect interface for ballet dancers, Proc. 2012 ACM annual conference extended abstracts on Human Factors in Computing Systems Extended Abstracts (CHI EA '12), 1619-1624.

Miles, H.C., Pop, S. R., Watt, S. J., Lawrence, G. P. & John, N. W. (2012). A review of Virtual Environments for Training in Ball Sports, Computers & Graphics, 36, 714-726.

Mitchell, G. & Clarke, A. (2011). Capturing and Visualising Playground Games and Performance: A Wii and Kinect based Motion Capture System, Proc. Int'l Conf. Electronic Visualisation and the Arts (EVA'11), 218-225.

Moeslund, T.B., Hilton, A. & Krüger, V. (2006). A Survey of Advances in Vision-based Human Motion Capture and Analysis, Computer Vision and Image Understanding, 104, 90-126.

Ogawa, T. & Kambayashi, Y. (2012). Physical Instructional Support System Using Virtual Avatars. ACHI 2012, The Fifth International Conference on Advances in Computer-Human Interactions. IARIA, 262-265.

Soga, A. & Myojin, Y. (2008). Educational Applications for Learning Rhythmic Gymnastics Rules Using Motion Data, Journal of Media Information and Television Engineering, 62(2), 222-226. (in Japanese)

Tamura, Y., Yamaoka, K., Uehara, M. & Shima, T. (2013). Capture and Feedback in Flying Disc Throw with use of Kinect, Int'l Journal of Sports Medicine and Sports Sciences, 74, 313-317.

Tamura, Y., Uehara, M., Maruyama, T. & Shima, T. (2013). Feedback of Flying Disc Throw with Kinect: Improved Experiment, Proc. ICCE 2013, 196-201.

Theobalt, C., Albrecht, I., Haber, J., Magnor, M. & Seidel, H.P. (2004). Pitching a baseball: tracking high-speed motion with multi-exposure images, ACM Transactions on Graphics (TOG), 23(3), 540-547.

Ukita, N., Eimon, K. & Röcker, C. (2014). Mining Crucial Features for Automatic Rehabilitation Coaching Systems, Int'l Workshop on User-Centered Design of Pervasive Healthcare Applications.