Development of Motion Analysis System using Acceleration Sensors for Tennis and its Evaluations

Takaya Maeda, Kenichirou Fuji, Hiroki Tamura, and Koichi Tanno

Dept. of Electrical & Electronic Engineering, University of Miyazaki, 1-1 Gakuen-kibanadai-nishi, Miyazaki-city, Miyazaki, 889-2192, Japan
(Tel : 81-985-58-7409; Fax : 81-985-58-7409)
(Email address: htamura@cc.miyazaki-u.ac.jp)

Abstract: The term biological motion is often used by researchers studying the patterns of movement generated by living forms and sport forms. We study the pattern recognition system of sport motion using the biological motion data. Biological motion data are acquired using 3D motion capture system. However, 3D motion capture system is too expensive. In this paper, the biological motion capture system was built using acceleration sensors. Our proposed system has the technique of Gaussian fitting and regression analysis. We tested our proposed system in the pattern recognition of the outdoor tennis and its evaluations.

Keywords: Motion Analysis System, Acceleration Sensors, Biological motion data, Gaussian fitting

1. Introduction

The motion capture system is one of the techniques to retrieve the action of the human body and the animal in the three-dimensional space in a computer as digital data. We wear a marker and a sensor on parts becoming the imperative construct of the movement such as the head or a hand foot joint and record those movements in the space. However, many cases were impossible to measure the outdoor sport. These systems were used a certain indoor. In addition, there are problems that the price of machine parts is expensive [1].

Therefore, in this paper, we built the motion capture system which used an acceleration sensor. The proposal system needs little load of the wearing, but it can acquire data fast outdoors. Because we can acquire many data by using this system, it is easy to build a database of outdoor sport. Therefore, in this paper, we build the database of the sports that individual difference is big and perform the operating analysis of data. We targeted the tennis. In this paper, we acquire the database of experienced persons and inexperienced persons form of tennis swing using the proposal system. And, we examine the point of difference of experienced person and inexperienced person for the form of tennis swing. We analyzed the data and performed the computer experiment that estimated of the tennis career. This paper used the technique of Gaussian fitting and multi regression analysis. From these experiments, we tried that find out a common knack from an experienced person.

2. Feature Extraction from Biological Motion

2.1 Procedure to obtain biological motion data

To obtain the biological motion data of subjects, we put 12 acceleration sensors (WAA-006: ATR-promotions Co.,Ltd) onto the subject's wrist / elbow / shoulder / waist / knee / ankle of both the left and the right side [2]. However, we analyzed three places of data of the wrist / elbow / shoulder of the dominant arm. These accelerations information are important place in the tennis form and the much clear than other datas changes in acceleration information. A motion sensing system is acceleration and a sampling frequency of the system is 237.5Hz. We show the photograph of Figure 1 when the player worn the acceleration sensors. The subjects are eleven male university students. The tennis experienced are five people, and the tennis inexperienced person are five people. These experimental conditions are similar to paper [3].

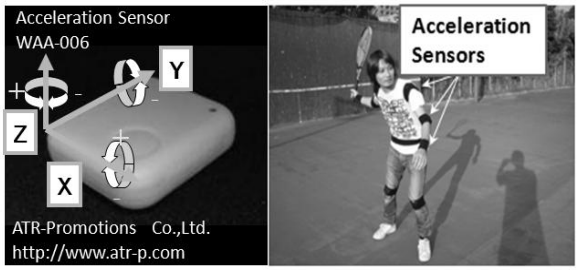

Figure 1.An acceleration sensor and the state that player wore the acceleration sensors.

2.2 The proposal analysis system.

In this subsection, we propose a feature extraction method for the estimates of the tennis career from the acceleration data. The proposed method is summarized in Figure 2.

As a first step, the player wears the acceleration sensor and play tennis to acquire acceleration data (X-axis, Y-axis, Z-axis). Next, one swing from acceleration data of the tennis swing were pulled out.

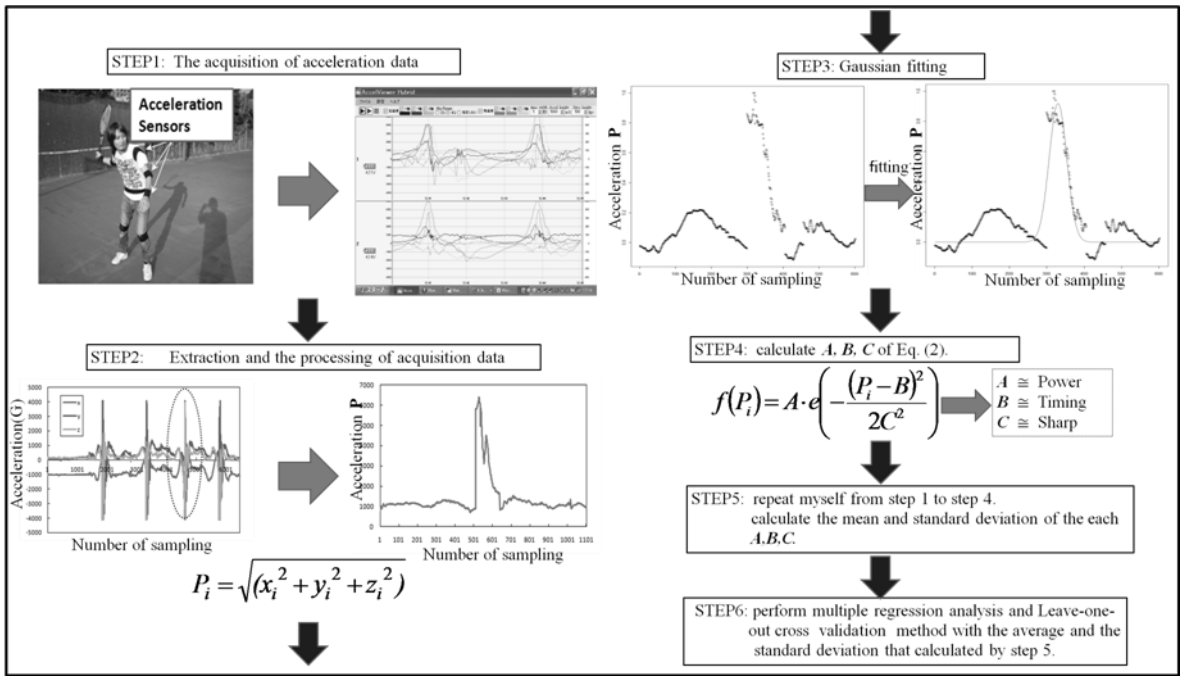

Figure 2. The summary of the proposal analysis system.

The STEP 2, *Pi* are computed by Eq.(1) [4]. *Pi* means the amount of the change of the acceleration of three axes. Next STEP3 and 4, we perform a Gaussian fitting with Eq.(2), and calculate ***A***, ***B***, ***C*** of Eq.(2). ***A*** means power, ***B*** is timing, and ***C*** is sharp of tennis form. The timing of ***B*** are calculated based on the shoulder. We repeat ourselves from STEP1 to STEP4. And we calculate the average and the standard deviation of the each ***A***, ***B***, ***C***. Finally STEP 6, we perform multiple regression analysis and Leave-one-out cross validation method with the average and the standard deviation from computed by this analysis system.

$$P_i = \sqrt{\left(x_i^2 + y_i^2 + z_i^2\right)} \quad (1)$$

$$f\left(P_i\right) = A \cdot e\left(-\frac{\left(P_i - B\right)^2}{2C^2}\right) \quad (2)$$

2.3 The interlocking movement characteristics of the dominant arm

We guessed that the interlocking movement of the wrist / elbow / shoulder of the dominant arm might be related to the person who experienced tennis. And, we presumed the career of tennis that uses only the interlocking movement by the previous research [3]. We show the graph of the wrist / elbow / shoulder in Figure 3 to express the interlocking movement characteristics of the dominant arm. As for the data, it normalized so that the maximum value becomes 1.0 and the average value becomes 0.0. We focus attention on the interlocking movement characteristics of the wrist / elbow / shoulder and calculate the degree of similarity ***E*** between two joints using Eq. (3). *N* in Eq.(3) is the number of the samplings, P_i^k is one of the data of the wrist / elbow / shoulder. P_i^l is a non- P_i^k information. We calculate the average and the standard deviation of Eq.(3). In this paper, we added the data of the degree of similarity ***E*** to the STEP6.

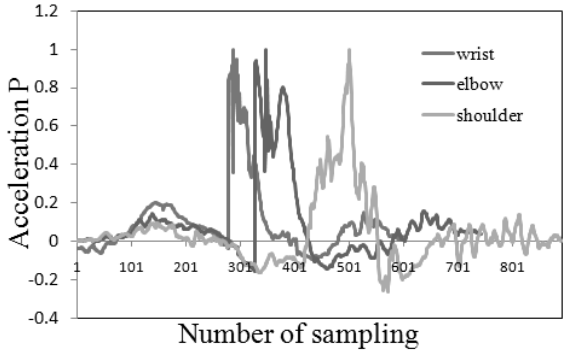

Figure 3. The interlocking movement characteristics of the dominant hand

$$E(\text{degree of similarity}) = \sqrt{\frac{1}{N}\left|\sum_i^N \left(P_i^k \times P_i^l\right)\right|} \quad (3)$$

3. Experiment Results

In order to test the effectiveness of proposal analysis system, we compared its performance with only used ***A***,

B, ***C*** and only used the degree of similarity ***E.*** In this paper, we perform multiple regression analysis and evaluate using Leave-one-out cross validation method.

3.1 The results of multiple regression analysis

We show the result of the multiple regression analysis how we used only the degree of similarity ***E*** in Figure 4. From t value and the P value of the analysis result, we understood that wrist / elbow (average) of Eq.(3) and wrist / shoulder (standard deviation) of Eq.(3) were meaning for tennis career. We assume these two elements ***E***'. Next, we show the multiple regression analysis how we used the ***A*** (Power), ***B*** (Timing), ***C*** (Sharp) of Eq.(2) in Figure 5. The simulation of Figure 5 was used 8 elements. 8 elements are the average value. Finally, we show the multiple regression analysis how we used ***E'*** and the ***A*** (Power), ***B*** (Timing), ***C*** (Sharp) of Eq.(2) in Figure 6. The simulation of Figure 6 was used 9 elements. A value of R^2 (a coefficient of correlation) got results more than 0.8 from Figure 4 and Figure 5 and Figure 6. In three graphs, when a predicted value by the multiple regression analysis assumes the smallest person boundary value among the person who experienced tennis, we can pull the boundary line of an experienced person and the inexperienced person. But only one person did wrong identification among inexperienced people in Figure4. A graph of Figure 6 was the best in these computer simulation results. Therefore, we selected the results of Figure 6, and to analyze it in detail in the next subsection.

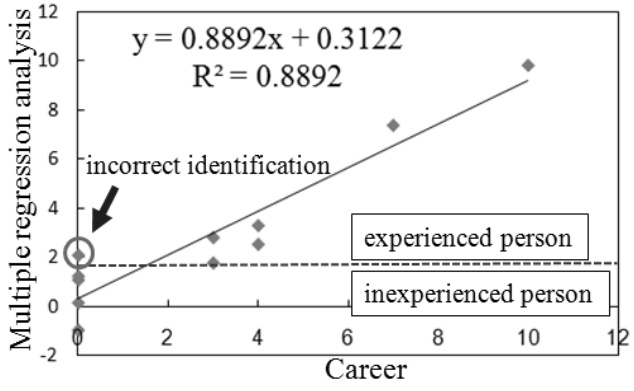

Figure 4. The result of the multiple regression analysis using the degree of similarity ***E***.

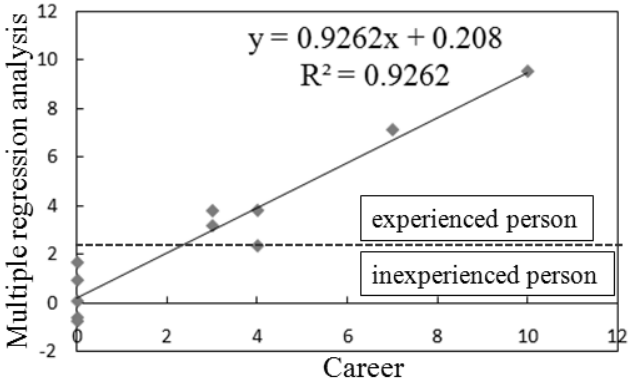

Figure 5. The result of the multiple regression analysis using the ***A*** (Power), ***B*** (Timing), ***C*** (Sharp).

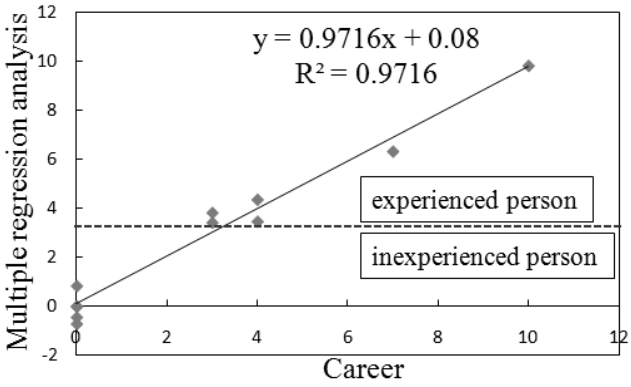

Figure 6. The result of the multiple regression analysis using the degree of similarity ***E***' and the ***A*** (Power), ***B*** (Timing), ***C*** (Sharp).

3.2 The result of Leave-one-out cross validation method

From many analysis results, we selected the three following elements using t value and P value.

- The timing ***B*** of elbow (standard deviation)
- The degree of similarity of wrist / elbow (average)
- The degree of similarity of wrist / shoulder (standard deviation)

We show the result of the multiple regression analysis how we used three elements mentioned above in Figure 7. From Figure 7, value of R^2 got results more than 0.8.

The result of the Leave-one-out cross validation method using three elements are shown in Figure 8. When a predicted value by the multiple regression analysis assumes the smallest person boundary value among a person who experienced tennis, we can pull the boundary line of an experienced person and the inexperienced person. As a result, only one person did wrong identification among inexperienced people.

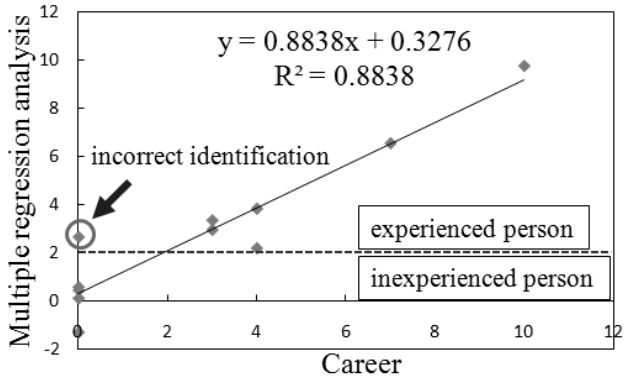

Figure 7. The result of multiple regression analysis.

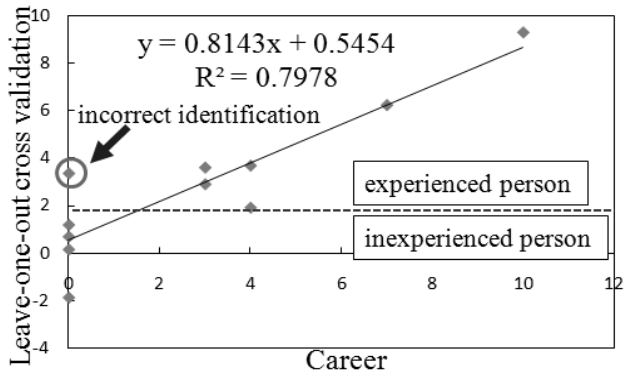

Figure 8. The result of Leave-one-out cross validation method.

4. Conclusion and Future Work

We aimed for examining the point of difference of experienced person and inexperienced person for the form of tennis swing. In this paper, we built the motion capture system which used an acceleration sensor. We acquire the database of experienced persons and inexperienced persons form of tennis swing using the proposal system. And we analyzed these data and performed the experiment that estimated of the tennis career. For sports, we were able to extract power and timing and sharpness and the interlocking movement characteristics of the joint from acceleration information. As a result, we could discriminate the inexperienced person from an experienced person from tennis swing with an acceleration sensor and was able to find out a thing such as a common knack from an experienced person. It is thought that three points of the following are common to an experienced person in conclusion.

1) The movement of the shoulder and the elbow is stable.

2) The interlocking movement characteristic of the elbow and the wrist is strong.

3) The interlocking movement characteristic of the wrist and the shoulder is stable.

In future work, we must increase the number of subjects. We think that it raises the reliability of this study.

References

[1] Hiroki Tamura, Daisuke Sasajima, Koichi Tanno, Takako Toyama (2008), "Human Motion Recognition System using Nintendo wii Remote Controller", in Japanese, Memoirs of the Faculty of Engineering, Miyazaki University, 37:PP141-146

[2] Hidenori Maruta, Masahiro Ishii (2007), "Feature extraction from Biological motion of human gait patterns for emotion discrimination", IAPR Conference on Machine Vision Application, 13-15, pp492-495

[3] Kenichirou Fuji, Takaya Maeda, Hiroki Tamura, Takako Toyama, Kouichi Tanno (2010), "Development of Motion Analysis System using Acceleration Sensors for Outdoor Sports and its Applications (in Japanese)", HINOKUNI information symposium

[4] Takaya Maeda, Hiroki Tamura, Takako Toyama, Kouichi Tanno, Masahiro Ishii (2009), "A study about the feelings estimate from ambulation movement (in Japanese)", Student Activity Committee, Kyusyu Section IEICE