Research on recognition of movement using an optical motion capture system

Shun Shiotani*, Satoru Kizawa, Masaki Tamura, and Ayuko Saito

Department of Mechanical Science and Engineering, School of Advanced Engineering, Kogakuin University, Tokyo, Japan
E-mail: s518028@ns.kogakuin.ac.jp

Abstract
The batter's motion during batting was measured using an optical 3D motion capture system. As a result, coordination of these specific body parts may be used as a criterion when a person recognizes the movement of swinging a bat.

We recognize human movements by detecting the human body parts motions. Recognition is the identification of something as having been previously seen, heard or known. Even in the case of a rigid link model, where joints are connected by straight lines, a person can recognize its movements by detecting the links motions. Even when the marker trajectories obtained from an optical motion capture are seen, a person can detect the changes in the marker positions and identifies them as having been previously seen, heard, or known. Therefore, a person seems to be able to recognize the characteristics of human movements by detecting the point cloud motion.

In this study, we attempted to extract the features of marker trajectories during hitting a baseball obtained from an optical motion capture system. During a baseball game, a batter faces a pitcher. A batter recognizes the motion of the pitcher and anticipates the pitch. A pitcher also recognizes the batter's motion and decides how to pitch. It is useful to develop effective coaching techniques by clarifying how and when a pitcher and a batter recognize each other's motion.

The batter's motion during batting was measured using an optical 3D motion capture system. We focused on the trajectories of reflective markers attached to the batter and obtained the characteristics of the marker trajectories. The singular value decomposition was applied to the marker coordinates to verify the coordination between marker motions [1][2]. This study could be useful for clarifying the cognitive structure of human vision.

The experiment was conducted at Kogakuin University, Hachioji campus. A healthy male participated in the experiment. Study approval was obtained from the Research Ethics Board, Kogakuin University. The participant gave his written informed consent to participate after understanding the purpose and requirements of the study. Kinematic date were collected using an optical motion capture (MAC3D; Motion Analysis). The sampling frequencies of the optical motion capture was 100 Hz. The positions of reflective markers for the motion capture system were determined by reference to the Helen Hayes Marker set (Fig.1). The reference coordinate system in the laboratory and the standing positions of a batter is shown in Fig. 2. The batter was instructed to swing a bat 5 seconds after the start of measurement. The purpose of this study is to analyze the motion when swinging a bat. In order to eliminate complicated movements that are likely to show individual differences, the batter was instructed to swing a bat without changing the standing position.

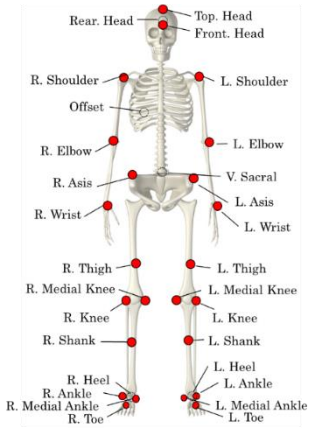

Fig.1 Helen Hayes marker set.

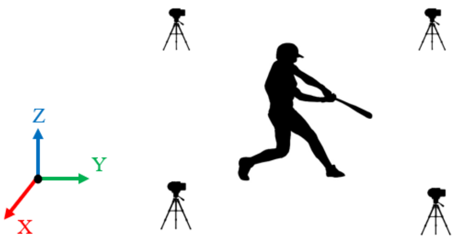

Fig.2 Reference coordinates and batter's position.

During the experiment, the batter swung a bat in the positive direction of the Y-axis. In order to detect the characteristics of the batter's motion when viewed from the pitcher, we focused on the reflection marker coordinates on the X-Z plane in Fig. 2. Figure 3 shows the results of the reflection marker trajectories on the X-Z plane. The horizontal axis is the X-coordinate and the vertical axis is the Z-coordinate. The result indicates that the batter's motion is clearly left-right asymmetrical. The result also indicates that both the left and right wrists rotate on the X-Z plane when

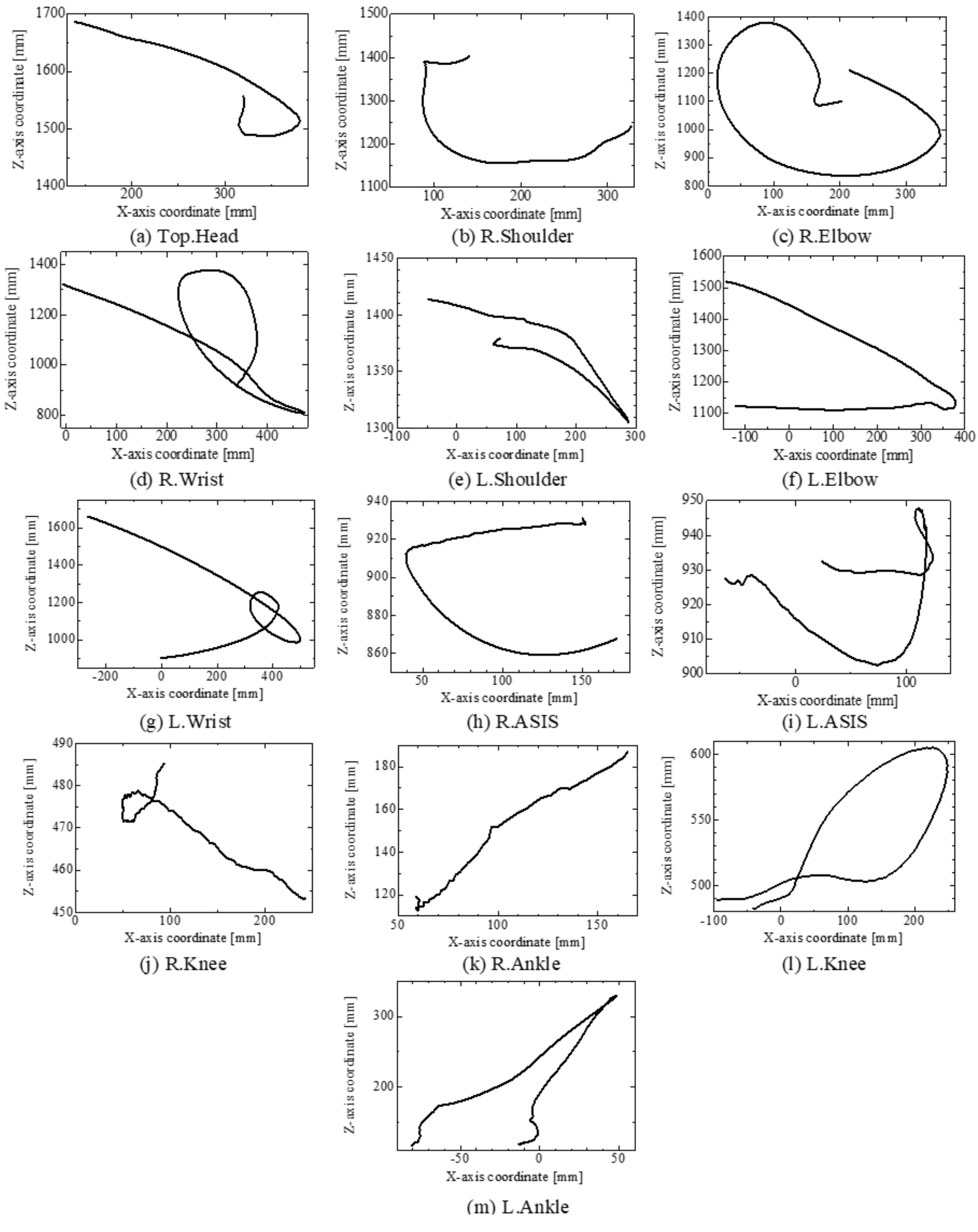

Fig.3 Marker trajectories in X-Z plane during batting obtained from the 3D motion analysis system.

swinging a bat. Therefore, we determined that the left and right wrists' movements had similar trajectories.

The coordination between the marker coordinates of a person swinging a bat was examined by applying singular value decomposition.

The marker coordinates were converted into dimensionless quantities of -1 to 1 as follows:

$$X(t) = \frac{2(X_{raw} - X_{min})}{X_{max} - X_{min}} - 1 \qquad (1)$$

where $X(t)$ represents the normalized X-coordinates; $X_{raw}(t)$ represents the X-coordinates obtained from an optical 3D motion capture system; X_{max}, and X_{min} respectively represent the X-coordinates for each body part. The normalized Z-coordinates were calculated in the same way.

The observation matrix consists of dimensionless quantities of the normalized X- and Z-coordinates. The observation matrix $R(X,Z,t)$ is composed as follows:

$$R(X,Z,t) = \begin{pmatrix} X_{TH}(t_1) & Z_{TH}(t_1) & X_{LS}(t_1) & Z_{LS}(t_1) & X_{LE}(t_1) & Z_{LE}(t_1) & X_{LW}(t_1) & Z_{LW}(t_1) & \cdots & X_{RW}(t_1) & X_{LAS}(t_1) & Z_{LAS}(t_1) & X_{RAS}(t_1) & Z_{RAS}(t_1) & X_{LK}(t_1) & Z_{LK}(t_1) & X_{LA}(t_1) & Z_{LA}(t_1) & \cdots & X_{RA}(t_1) & Z_{RA}(t_1) \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \cdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \cdots & \vdots & \vdots \\ X_{TH}(t_m) & Z_{TH}(t_m) & X_{LS}(t_m) & Z_{LS}(t_m) & X_{LE}(t_m) & Z_{LE}(t_m) & X_{LW}(t_m) & Z_{LW}(t_m) & & X_{RW}(t_m) & X_{LAS}(t_m) & Z_{LAS}(t_m) & X_{RAS}(t_m) & Z_{RAS}(t_m) & X_{LK}(t_m) & Z_{LK}(t_m) & X_{LA}(t_m) & Z_{LA}(t_m) & & X_{RA}(t_m) & Z_{RA}(t_m) \end{pmatrix} \quad (2)$$

Here, $X_{TH}(t)$ and $Z_{TH}(t)$ are the X- and Z-coordinates of the Top.Head marker, $X_{LS}(t)$, $Z_{LS}(t)$ are the X- and Z-coordinates of the L.Shoulder marker, $X_{LE}(t)$, $Z_{LE}(t)$ are the X- and Z-coordinates of the L.Elbow marker, $X_{LW}(t)$, $Z_{LW}(t)$ are the X- and Z-coordinates of the L.Wrist marker, $X_{RS}(t)$, $Z_{RS}(t)$ are the X- and Z-coordinates of the R.Shoulder marker, $X_{RE}(t)$, $Z_{RE}(t)$ are the X- and Z-coordinates of the R.Elbow marker, $X_{RW}(t)$, $Z_{RW}(t)$ are the X- and Z-coordinates of the R.Wrist marker, $X_{LAS}(t)$, $Z_{LAS}(t)$ are the X- and Z-coordinates of the L.ASIS marker, $X_{RAS}(t)$, $Z_{RAS}(t)$ are the X- and Z-coordinates of the R.ASIS marker, $X_{LK}(t)$, $Z_{LK}(t)$ are the X- and Z-coordinates of the L.Knee marker, $X_{LA}(t)$, $Z_{LA}(t)$ are the X- and Z-coordinates of the L.Ankle marker, $X_{RK}(t)$, $Z_{RK}(t)$ are the X- and Z-coordinates of the R.Knee marker, $X_{RA}(t)$, $Z_{RA}(t)$ are the X- and Z-coordinates of the R.Ankle marker.

The observation matrix [Eq. (2)] is decomposed into the basis vectors as

$$R(X,Z,t) = \sum_{j=1}^{n} \lambda_j V_j(t) Z_j^{T}(X,Z) \quad (3)$$
$$(j = 1, \ldots, n, \; n = 26),$$

where λ_j is a singular value. The motion modes are defined in descending order of λ_j.

The contribution ratio β_j of the singular value in the j-th motion mode is

$$\beta_j = \frac{\lambda_j}{\sum_{j=1}^{n} \lambda_j^{2}} \quad (j = 1, \ldots, n, \; n = 26) \quad (4)$$

where j is the number of columns in the observation matrix.

Fig. 4. First mode result.

Fig. 5. Second mode result.

The results of singular value decomposition of the marker locus of the body part are shown in Fig. 4 and Fig. 5. The movements of specific joints (right shoulder, left elbow, left wrist, left pelvis, right knee, and right ankle) were generated in the first mode shown in Fig.4. The movements of specific joints (head, left shoulder, right hip, left knee, and left ankle) were generated in the second mode shown in Fig.5. Coordination of these specific body parts may be used as a criterion when a person recognizes the movement of swinging a bat.

References:

[1] Funato, T., Aoi, S. and Tsuchiya, K., Quantitative evaluation of the intersegmental coordination during human locomotion, Journal of the Robotics Society of Japan, Vol. 28, No. 8 (2010), pp. 996-1003 (in Japanese).

[2] Hayashi, Y., Tsujiuchi, N. and Matsuda, Y., Quantitative evaluation concerning principal gait locomotion pattern of a trans-femoral amputee with a prosthetic limb based on the intersegmental coordination, Transactions of the JSME (in Japanese), Vol. 81, No. 825 (2015a), DOI : 10.1299/transjsme.15-00020.