Baseball Swing Pose Estimation Using OpenPose

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***Abstract*—This study explores usefulness of using the human pose estimation technique in sport. Since the expansion of deep learning techniques, human pose estimation became an important field of computer vision, it can be used in many applications like pose analysis, correction, training session, etc. The proposed method is used to estimate whether a baseball hitter performs a good swing. The hitter's limb coordinates are detected by the OpenPose model which is a real time multi-person detection system. The coordinates are used to calculate hip distance and limb angles, then the distance and angles are applied with our custom rules. The custom rules are made by researches and coaching experience in order to evaluate the swing of baseball hitter. Each rule is awarded differ points by its importance which we assumed. The goal of this study is using technology assistance in sport coaching scenario.**

Keywords—OpenPose, Swing, Pose Estimation

I. Introduction

Human pose estimation plays an important role in many fundamental researches. From the past to the present, most of studies analyze the body movement through visual data or data captured by sensor. With the computation, researchers could know things like how many degrees the subject's knees were or how much pressure the joints of subject were suffering. Then the studies could get some conclusions or suggestions to help people correcting or better knowing their bodies. At the beginning, the most of researchers utilized variable sensors to obtain the data of human body and then observe or compute with those data. However, those researches usually required expensive sensors to have precise data. Since the expansion of deep learning techniques, human pose estimation became an important field of computer vision, there is another option for researchers to obtain human body information. Finding human parts and detecting joints in the images or videos to let machine understanding human body, human pose estimation is able to apply in many applications such as pose analysis, correction, training session, etc.

Generally, human pose estimation approaches can be divided into two types, i.e. top-down and bottom-up. The top-down methods such as CPN [1] and HRNet [2] which firstly detect the human body and then solve the single person pose estimation problem. A two-step framework which used a human detector and then solved the pose estimation for each human. The running time of this approach tends to grow with the number of people in the image and make the real-time performance a challenge. On the other hands, the bottom-up approaches such as DeepCut [3] and OpenPose [4] which identified multi-person keypoints in the image directly and then utilized the associative algorithm to match the related human body and assigning parts to distinct individuals. The town-down approaches usually achieved higher accuracy than bottom-up ones, but lacked of real-time performance. On the contrary, bottom-up approaches have better real-time performance with a poorer accuracy.

In order to apply into baseball swing estimation scenario, this study chose one of the bottom-up approaches, i.e. OpenPose, for the real-time detection and estimation. The OpenPose model proposed by Carnegie Mellon University (CMU) have great real-time performance also certain degree of accuracy. Through multi-stage of its network architecture could quickly and accurately identify human parts from the image, also have better ability to deal with the occlusion and multi-person overlap problems.

The OpenPose proposed first real-time multi-person system to jointly detect human body and parts. It uses the first 10 layers of VGG-19 model to extract feature maps. The feature maps are processed with multiple stages convolutional neural network (CNN) to generate 2 branches. The prediction of branch 1 is the confidence map of each keypoint, and outputting a feature map for each keypoint. For example, there are J keypoints and then J feature maps would be generated. Branch 2 predicts a set of part affinity fields (PAF) newly defined by OpenPose. Each limb would be represented by a 2D vector. If there are C branches, C feature maps would be generated. This study utilized OpenPose for keypoint detection since OpenPose achieved a certain degree of accuracy and speed of human joints and limbs prediction in a multi-person and cluttered environment.

This study aimed to achieve two goals. First, this research attempted to develop a system which can quickly analyze how a swing was. Second, this study attempted to verify whether the proposed method with custom rules can distinct a good swing or a bad swing. This study arranged custom rules based on the previous researches and the coaching experience. The recorded videos were taken as input and the swings were evaluated with the custom rules. If the swing match the custom rules, the hitter will be rewarded some points. A score which consists of these points was used to measure the swing of hitter. In this work, there was a positive correlation between score and the hit distance measured in real world.

II. Method

A. Get the Keypoints of the Hitter

Baseball swing videos were used as input of OpenPose to obtain the keypoint information of the hitter. The body_25

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model from OpenPose could output 25 keypoint coordinates which across whole body, as shown in Fig. 1. The neck, left shoulder, right shoulder, left elbow, right elbow, right wrist, left wrist, right hip, left hip, left keen, right keen, left ankle and right ankle keypoints were used to further calculate angles and distances. In this study, custom rules (listed in Table I) were made by experience to analyze and evaluate the swing. The resolution of the network is 656 × 368 which was nearly same ratio with the input video, the setting achieved better speed and accuracy balance.

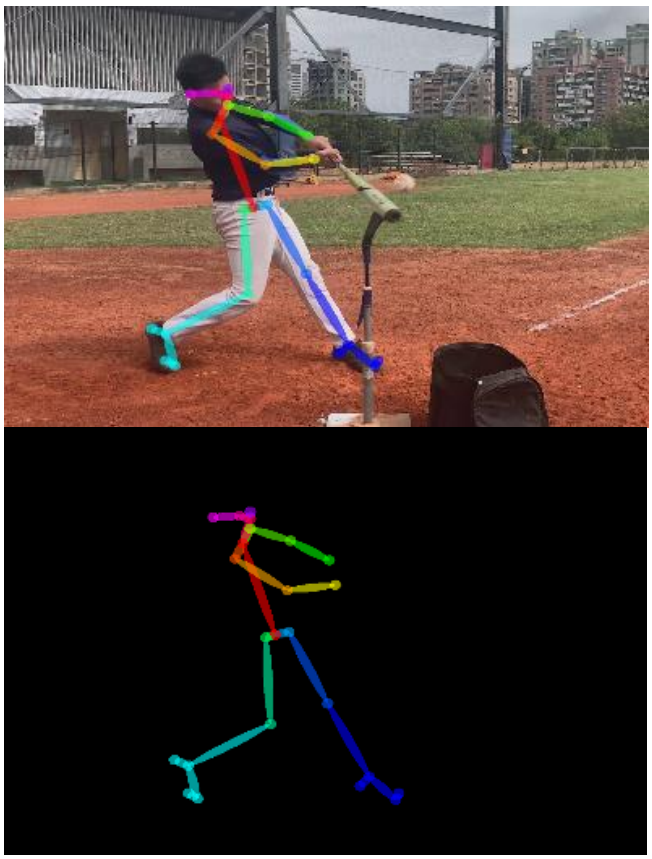

Fig. 1. The keypoints and skeleton of the hitter detected by OpenPose

B. *Limited the Amount of Detection*

Even though OpenPose is a multi-person detection system, only the detection of the hitter is needed for measuring in the baseball swing scenario. Thus this study limited the maximum number of detected people down to one, avoiding getting the extra human body keypoint which was not needed. The system only rendered the people who has the highest score in the scene, so it could remove some false positives of the detections. The score is based in person area over the image, body part score and joint score. To further reduce false positive showed in the video, the proposed system set the threshold higher than preset value at 0.4. If the threshold is higher than 0.5, it will only render very clear body parts. The proposed system might lose some keypoint and part detections during the swing. On the other hand, if the threshold was set lower than preset value, it might get more wrong guessed and occluded keypoints.

C. *Estimate the Swing Pose*

Batting, a fundamental element in Baseball, it is also the key to winning or losing a game. If there is no player with good batting technique to support the team, it is quite difficult to win a game. However, it is also a technique which is difficult to master. Hitter have to react quickly and accurately judge the ball pitched by the pitcher, then swing the ball at the appropriate timing, direction and strength. There are some basic rules for hitter to follow in order to have a good swing. The center of weight should move backwards instead of forwards. This is the first action that should be paid attention to when the hitter steps into the batter's box. Otherwise, the hitter will not be able to fully release the power at the moment of hitting the ball. Before hitting the ball, when the hitter's front leg steps forward slightly, the upper body should move backwards in the opposite direction. When the front foot is on the ground, the toes should be opened at an angle of about 45 degrees, and the bottom of the bat should face the catcher. Meanwhile, the knees, hip, shoulders should be evenly distributed on both sides of the home base, so that the hitter will have a good and stable hitting posture. The central axis refers to the head as the center point and maintained between the legs, as shown in Fig. 2. A good hitter must know how to learn and control the center of weight and center axis. When the central axis of the body is more vertical, the speed of the hip rotation will be faster, and the speed of the bat will be faster while swinging. In order to get a faster swing speed, the muscles and power of the lower body should be used to drive the bat, the starting sequence of the swing to get the most powerful force should be the sole of the foot, Knee, Hip, Hand. Since some of rules are difficult to be taught and master, the proposed method focused on hitter's body angles, which we believe is an effective way to improve hitter's batting ability.

Fig. 2. The central axis of the hitter

In Table I, if the hitter meets the rules which were set by experience and some swing mechanism researches [5-7], the hitter might perform a good batting result. Hay [8] suggested that when the hitter's front arm is straight or almost straight is the best time to swing. However, experimental results from Chuang [9] showed that the front arm angle of the hitter is around 125 to 130 degrees while hitting the ball. We believe if the hitter keeps front arm straight can bring more power to the ball at the moment of hitting, but previous experiments showed lower result. Thus, the proposed system set the rule of 145 to 180 degrees for the front arm angle. Cao [10] examined the average back arm angle of hitter is around 100 to 130 degrees for Taiwanese professional, collegiate and high school player.

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When hitter's back arm angle is 100 to 110 degrees, the bat would obtain the highest speed. Lin [11] pointed out the average keen angle of the leading foot is around 159.1 degrees. Therefore, this study set 150 to 170 degrees for the front leg angle.

TABLE I. CUSTOM ROLES MADE BY RESEARCHES AND EXPERIENCE

Rule	Condition
Hip Distance	< 76.8 pixels
Front Arm Angle	>145°, <180°
Back Arm Angle	>100°, <130°
Front Leg Angle	>150°, <170°
Back Leg Angle	>115°, <135°
Shoulder Angle	>170°, <190°

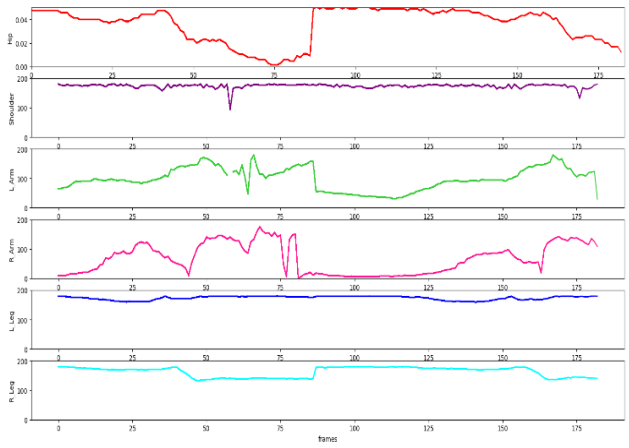

Fig. 3. Hip distance and angles of front arm, back arm, left leg, right leg, shoulder during a swing

D. Calculate the Body Parts Angle

After we obtained the keyopoint coordinates, the proposed system calculated the front arm, back arm, front leg, back leg angles by

$$cos\theta = (U \cdot V) / |U||V|, \quad (1)$$

U denotes a vector of the limb from one end to midpoint, V denotes a vector of the limb from another end to midpoint, for example: left shoulder to left elbow, left wrist to left elbow. θ denote the angle between two ends of the limb. Figure 3 shows an example of the calculation.

E. Evaluate the Pose by Score

If the hitter who match our custom rules during the swing will be rewarded some points, each rule rewarded differ points considering its importance (see Table II). Figure 4 shows the evaluation screen of the proposed system. Then the total of the rewarded points was mapped to 0-100.

TABLE II. POINTS REWARDED BY RULES

Rule	Reward Points
Hip Distance	30 points
Front Arm Angle	30 points
Back Arm Angle	20 points
Front Leg Angle	20 points
Back Leg Angle	15 points
Shoulder Angle	15 points

III. EXPERIMENT

In this study, a fixed ball stand is used. Its height was set to match the waist of each hitter. The hitter's lead foot was aligned with the ball stand and the back foot was not constrained. There was no restriction of the batting stance. There are ten baseball players from the baseball team of the Tunghai University selected as subject, which body information in average were 170.4±7.6 cm in height, 72.3±14.3 kg in weight. Each person swung for five times and the locations of their landing balls were recorded and observed whether their batting results match with the evaluations made by proposed method. This study was located in the Tunghai University baseball field. The swings were taken by a mobile phone at 1920 × 1080 resolution and 60 frames per second.

After each swing, the location of landing ball was recorded and measured by laser rangefinder. Laser rangefinder sent a pulse toward object and measured the time taken by the pulse, then it calculated the distance between laser rangefinder and object. The distance is measured from the home base.

The simulation results is showed in Figs. 5 and 6, the orange line denoted the score of each swing and the blue line denoted the hit distance of each swing. The experiment results showed that there was positive correlation between score and distance.

In most of case, the hitter who got higher score did swing farther. However, there is still problem remaining. If the hitter hit the top or bottom of the ball will significantly affect the hit distance. This might cause hit distance was not as far as expected while the hitter got higher score.

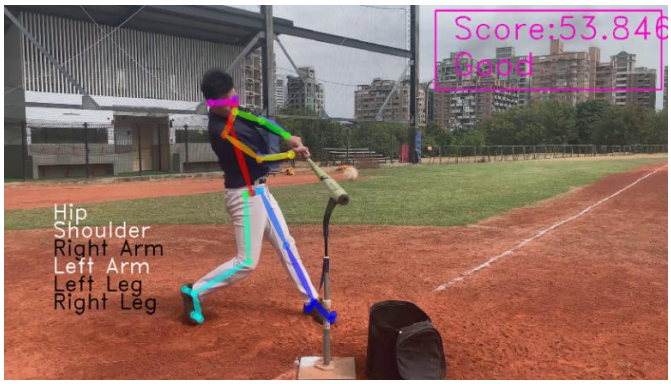

Fig. 4. Evaluation screen of the proposed system: the white texts are the satisfied custom rules

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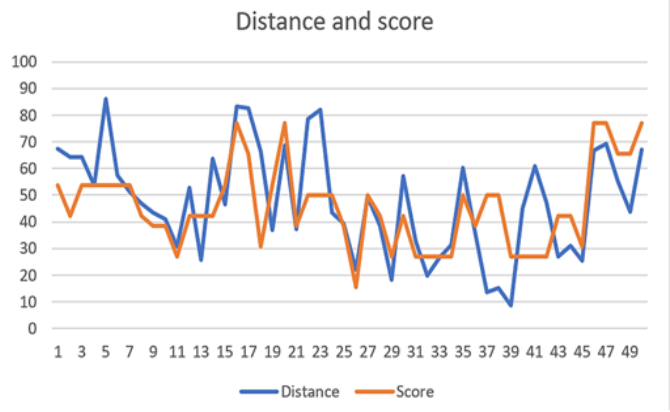

Fig. 5. The hit distance of each swing and the score judged by the proposed system

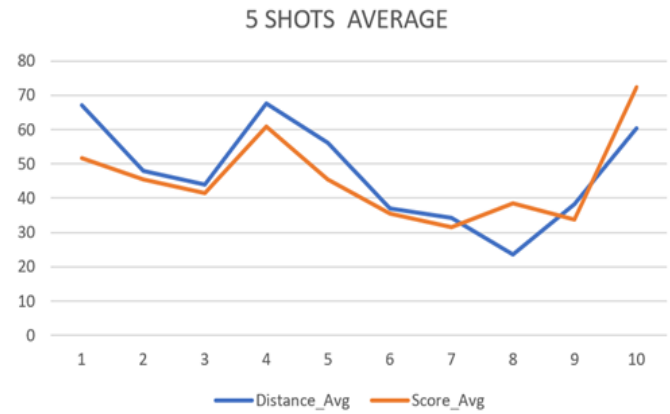

Fig. 6. The average hit distance of 5 shots made by same hitter and the average score of 5 shots judged by the proposed system

IV. Conclusion

This study attempted to build a system to evaluate baseball swings helping baseball players to correct their swinging poses. The proposed system revealed there is a positive correlation between a score created by system and the distance the player swung in real world. This correlation represents most of the players who matched custom rules set up in this work swung farther. The proposed method mainly helps baseball hitters to correct their body angles despite there are still other factors might affect the batting result significantly, e.g., timing, swing speed and batting stance. The batting angle also affect the swing result prediction. Nevertheless, most of factors mentioned above need plenty of time and experience to correct or improve. In the contrast, correcting pose is a quicker and effective way to make hitter have better performance. With this work, baseball players could review their swinging pose and correct their posture like increase or decrease the angle of certain body part. Either the information is able to perform as a reference to correct posture or be used in training sessions and games.

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