Human Contour Extraction for Automatic Outdoor Golf-Swing Diagnosis

Tomonori MOCHIZUKI*, Masahiko UEDA†, Yoshiaki SHIRAI*, Nobutaka SHIMADA*
*Ritsumeikan Univ., Shiga, Japan
†SRI R&D Ltd., Kobe, Japan

***Abstract*— We propose a method to extract human contours for an automatic diagnosis system of an outdoor golf-swing. One of the most difficult problem is that background is not stable. We determine the criterion based on the color difference between the golfer and the background and the edge intensity. We deform bezier curves so that the criterion is maximized. We show that this is effective for extracting human contours which are necessary for the diagnosis of an outdoor golf-swing.**

I. Introduction

People hope a system which can diagnose their golf-swing easily in a short time with low price. An automatic golf-swing diagnosis system is developed for indoor use[1]. This system diagnose the user's golf-swing by extracting image features which is necessary for diagnosing swing and analyze them based on original golf instructor's knowledge. Many users hope this system to be able to diagnose their golf-swing in the open air, but it is difficult to improve its image processing algorithm so that it can be operated in the open air because illumination condition is not stable and therefore we can not extract correct human contour shapes by simple background subtraction. In this paper we propose a method to extract human contour which is necessary for outdoor diagnosis and show its effectivity.

II. System Specification

Fig.1 shows a configuration of this system.

Users are captured their swing from front side and lateral side. Number of frames per second is 60 for capturing fast swing. Two lights illuminate from the direction of two cameras. Users wear a jacket with colored marks and attach 3 color marks on their golf clubs to ease measuring their postures.

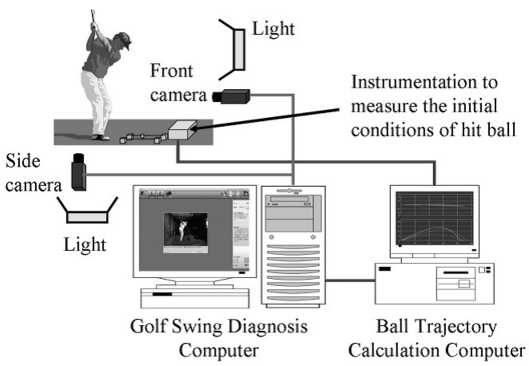

Fig. 1. System Component

In both sides, 150 images before golf-club strikes a ball and 30 images after that are used for diagnosis. The moment of strike is captured by a purpose-built measuring device. All images are used for measuring the trajectory of golf-club. 12 images are automatically selected as "check images" based on angles of golf-club and users' arm by image processing. Check-images are used for measuring users' postures.

The system extracts users' spine angles, knee positions, arm angles and so on from check-images. Finally the system diagnoses their swings from these features based on the original golf instructor's knowledge and output results and practical methods.

III. Issues of Image Processing in the Open Air

We can extract correct human silhouette shapes in doors by simple background subtraction, but it is hard to extract them in the open air because of unstable illumination condition which is triggered by change of weather.

Fig.2 shows a example which failed to extract human silhouette shape by background subtraction. This failure is caused by change of weather conditions. In this case, sunshine changes drastically in a short time while capturing swing images and therefore the brightness of grasses on background changes grossly.

If we cannot extract correct human silhouette shapes, we cannot extract correct human contours definitely. To extract features described at the end of Sec.II, it is necessary to extract correct human contours. So we need a method to extract correct human contours which are not affected by unstable illumination condition.

Fig. 2. an example of silhouette extraction failure (background image, swing image, silhouette image)

IV. Proposed Method for Contour Extraction

A. Methodology Overview

First, target images that we should extract human contours are 3 check-images captured from lateral side which are named “address image”, “top image” and “impact image”. “Address” is a state that the user takes a posture to ready to shot. “Top” is a state that the user takes a backswing. “Impact” is a state that the user strikes a ball. It is especially important to extract contours from these 3 images for diagnosis. We do not need to extract whole human contour, so we extract only contours shown in Table I. Fig.3 shows these 3 images and bold lines in Fig.3 should be extracted from these images.

The procedure of this method is following.

1) We extract points on actual human contour which can be extracted by relatively easy way.
2) We make bezier curves which connect these points.
3) We transform these curves based on shape characteristics of each body site.
4) We deform curves with an optimization method so that the criterion we determine is maximized.

Details of these processes are described in following sections.

B. Extraction of Points on Actual Contours

We extract points on actual human contours by using color detection, edge detection and other methods. These points are used as end points of each bezier curves. We enumerate curves which is used for extraction of contours described in previous section and which points are used as end points of each curves below. We do not describe how to extract each points here because it occupies too much space.

- spine curves on address images and impact images
  - a point of back of the user’s neck
  - a point of back of the belt on the jacket
- curves of the back of right reg on address images and top images
  - a point of back of the belt on the jacket
  - a point of the user’s heel
- curves of the front of right reg on address images and impact images
- curves of the front of left reg on top images
  - a point of front of the belt on the jacket
  - an intersection point of right(left) leg and the mat under the user’s foot

TABLE I

CONTOURS SHOULD BE EXTRACTED FROM EACH IMAGES

state	contours should be extracted
address	spine, front of right leg, back of right leg
top	front of left leg, back of right leg
impact	spine, front of right leg

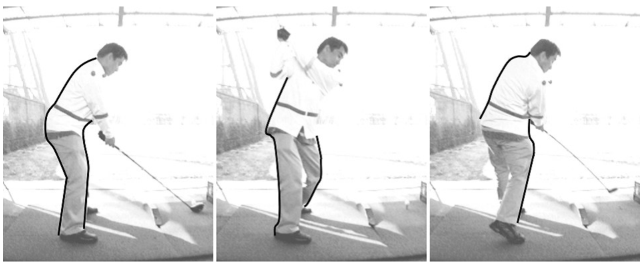

Fig. 3. lines to be extracted from address, top and impact images

Fig. 4. an example of feature points extraction from an address image

Fig.4 shows a result of points extraction from an address image. Left side of Fig.4 shows points on upper body. Right side of Fig.4 shows points on lower body. In this example, we extract extra points (front of neck and right toe) but they are not used in our method.

C. Initialization of Curve Shapes

We make bezier curves which connect points described in previous section and deform these curves so that their shape approach actual contour shape. We need to let each curves approximate actual contours before the optimization because of the characteristics of optimization method we use.

Initialization methods are different from each curves.

The spine curve on address image and impact image is initialized by moving all of its control points for vertical direction of the line which connects its end points and finding a positions of control points which the criterion described in sec.IV-E is maximized. Fig.5 shows an example of a spine curve’s initialization on an impact image. Left side of Fig.5 shows control points of curves and its direction of movement. Right side of Fig.5 shows an initialized curve.

Curves for legs are initialized based on knowledge of legs postures. For example, most of users bend their legs slightly when they take address posture. So we deform curves for legs according to such knowledge and positions of their end points on an address image.

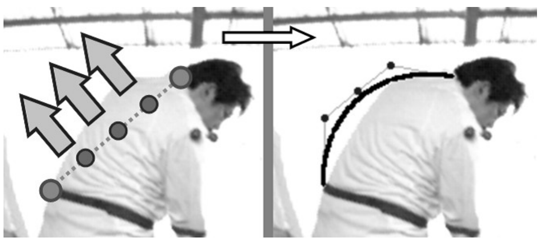

Fig. 5. an example of a spine curve’s initialization on an impact image

D. Curve Deformation with Optimization Method

The shape of a bezier curve is determined by positions of its control points. So we can express a curve's shape as a vector $\mathbf{x} = \{x_1\, y_1\, x_2\, y_2\, \cdots\, x_{n+1}\, y_{n+1}\}$ where the degree of the curve is n and positions of its control points are $(x_1, y_1), (x_2, y_2), \cdots, (x_{n+1}, y_{n+1})$.

When $v(\mathbf{x})$ is an estimated value of contour $\mathbf{x}$ that can be calculated based on criterion described in sec.IV-E, we can say that $\mathbf{x}$ which gives maximum $v(\mathbf{x})$ is the best contour. So we search such a contour shape by moving each control points except end points, but it requires high calculation cost for exhaustive search because the number of degrees of freedom is $2(n-1)$ when the degree of the curve is n.

To reduce the calculation cost, we search the best contour shape by BFGS quasi-newton method. We can find the answer in a short enough time for practical use. Fig.6 and Fig.7 show an example of a transformation of a spine curve and a transition of its estimated value $v(\mathbf{x})$. We can say that the spine curve is transformed into the actual spine contour shape with a small number of calculation.

E. Criterion for Curve Deformation

We calculate the estimated value of each curves with edge intensity on curves and color difference value in anteroposterior areas of curves. Fig.8 shows anteroposterior areas of a curve, A_{in} and A_{out}. A_{in} is an area which is surrounded by the curve and the parallel curve which exists on the side of the user's body. A_{out} is an opposite area of A_{in}. The distance between the curve and each parallel curves is determined beforehand by the approximate width of a human body in captured image.

When we define v_{in} as the average value of color difference values in A_{in}, v_{out} as the average value of color difference values in A_{out} and v_{edge} as the average value of edge intensity on the curve, we can calculate the estimated value V with formula (1). w_{in} and w_{out} are weighting factors.

$$V = w_{in}v_{in} - w_{out}v_{out} + v_{edge} \qquad (1)$$

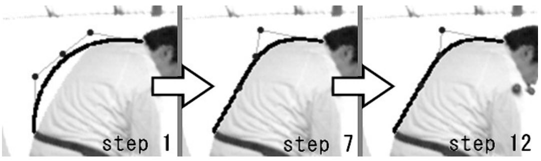

Fig. 6. an example of a transformation of a spine curve

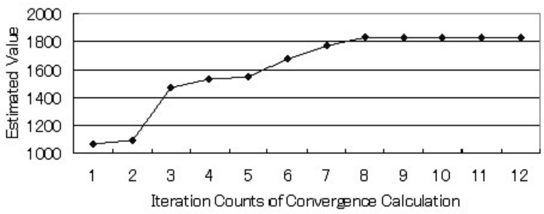

Fig. 7. a transition of estimated value

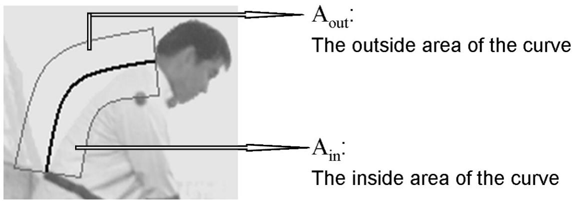

Fig. 8. anteroposterior areas of a curve

V. Results

Fig.9, Fig.10 and Fig.11 show examples of contours extraction from address images, top images and impact images. We confirmed that we can get contours which is necessary for diagnosis accurately enough at 12 weather patterns.

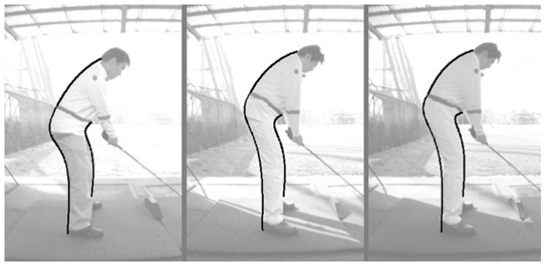

Fig. 9. extracted contours on address images

Fig. 10. extracted contours on top images

Fig. 11. extracted contours on impact images

References

[1] M.Ueda, M.Oonuki, Y.Shirai and N.Shimada, "Automatic Diagnosis System of Golf Swing", Proc. of The Impact of Technology on Sport 2, pp.271–276, 2007