Sports Dynamics of Carl Lowis through 100 m Race using Video Imagery

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Abstract

Dynamic tracking of moving object became possible by using video imagery. Especially in the field of sports dynamic analysis, video imagery gives useful information because of video camera takes 30 images per second. In this study, video images of world champion ship held in Tokyo, Japan in August, 1991 were analyzed from view of sports dynamics. Gold medalist Carl Lowis was selected for time-series digital photogrammetric analysis.

Keyword: Video imagery, Image Processing, Sports Dynamics

1. Introduction

Generally, video imagery provided by TV program includes many noises and there are no control points for orientation except a special case. Furthermore, it's must be considered that object and camera angle are always moving in the case of tracking of moving object.

Therefore, to utilize video imagery for dynamic tracking of moving object by the Digital Photogrammetry, there are two big subjects. One is an image processing and the other is a photogrammetric problem. On the other hand to analysis a dynamics of human movement, it's necessary to recognize a feature points of man such as knees, elbows, feet and etc. by an image processing technique.

The video images of World Champion Ship held in Tokyo 1991, have not any control point and these images were taken with a narrow angle lens. There are some orientation methods for CCD camera without control point[1)2)] or tracking system for moving object with CCD camera mounted on a motorized theodolite[3)], but in this study these method or system can't be utilized because of the video images was coped from TV. Orientation method for these images has to be developed.

This paper discusses about two complicated subjects through the video images of 100 m race of Carl Lowis and also shows the results of sports dynamics of Carl Lowis.

2. Image Processing

To analysis the dynamics of human movement by using video imagery, the first annoying subject is playback of clear imagery from noisy imagery. For example, Fig.2 shows an original imagery that Carl Lowis is running. Many white noise can be detected around him, these white noise gives big influence to the next feature extraction step. Next is recognition of feature points of man such as knees, elbows, etc. and automated positioning of the feature points.

Fig.1 shows image processing procedure by Personal Computer which used in this study.

The detail procedures of each step in Fig.1 are as follows,

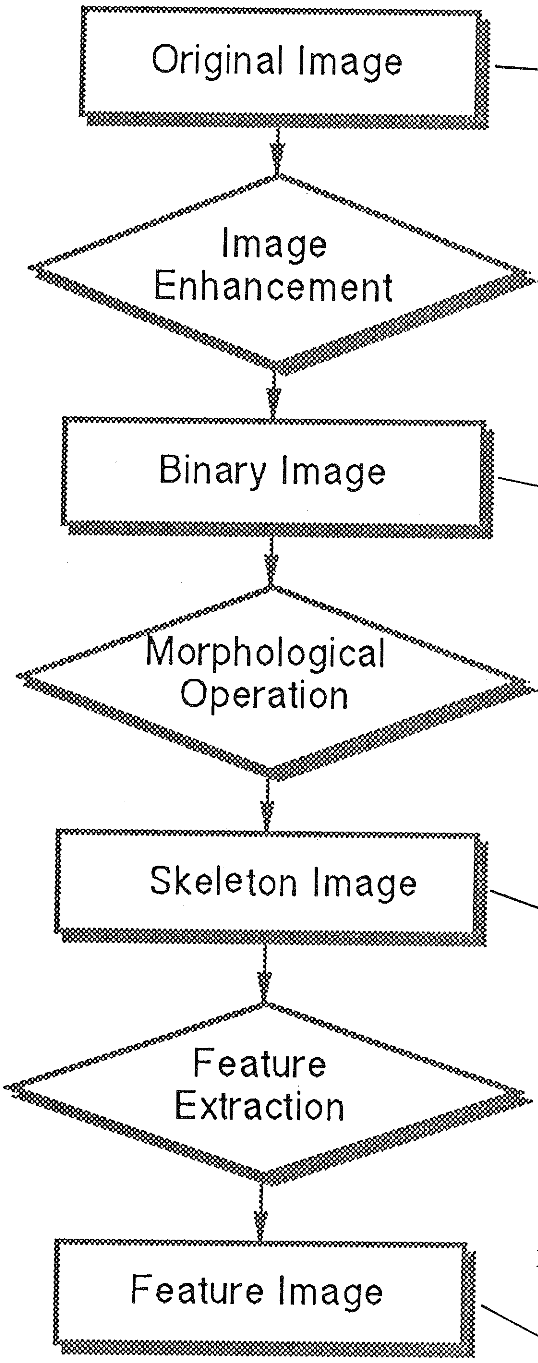


Fig.1 Image Processing Procedure

Fig.2 Original Image at 4.8 second

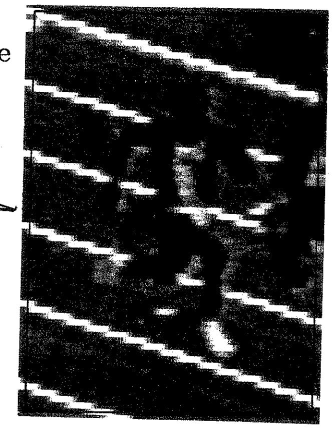


Fig.3 Binary Image

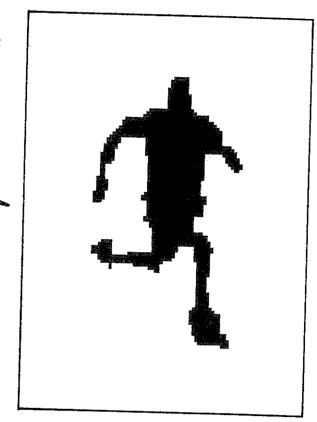


Fig.4 Skeleton Image

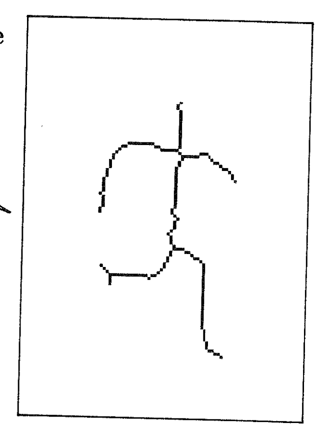
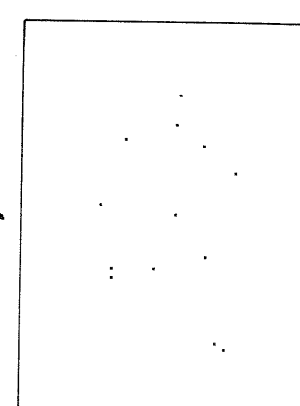


Fig.5 Feature Points Image



1. Image enhancement
1-1 Appointment of window
1-2 Smoothing with edge preserving
1-3 Operation between different images to erase white track lines
1-4 Sharpening by Laplacian
1-5 Binarization
1-6 Preparation of Histogram for X and Y directions to erase small region of noises
1-7 Region Segmentation
In this step, small region can be erased based on the histogram which were prepared in step1-6.
2. Morphological Operation
2-1 Expansion
2-2 Contraction
2-3 Thinning by Hilditch
3. Feature Extraction
3-1 Skeleton
3-2 Feature Points

Fig.2 shows an original 4.8 second image while Fig.3,4 and 5 show the results of each step image. Fig.6 shows overlapped image on the original image. Table 1 shows the results of pixel and line number for the feature points(Fig.7) of Carl Lowis at 4.8 seconds from the start.

Table 1 Pixel and Line of Feature point

No.	Pixel	Line
1	289	201
2	288	211
3	263	238
4	308	227
5	271	216
6	297	218
7	288	241
8	281	259
9	298	255
10	267	259
11	302	284
12	267	262
13	305	286

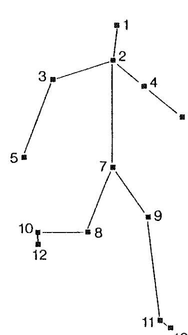


Fig.7 Feature Points

3. Sports dynamics of Carl Lowis

Recently sports dynamics analysis has received more attention. The basic physical elements of this analysis can be summarized as follows,

1.Mechanical energy=potential energy(mgh) + kinetic energy ($mv^2/2$)

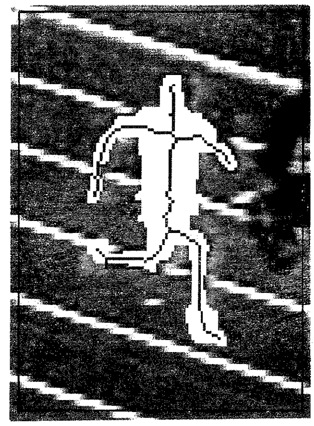


Fig.6 Compound Image

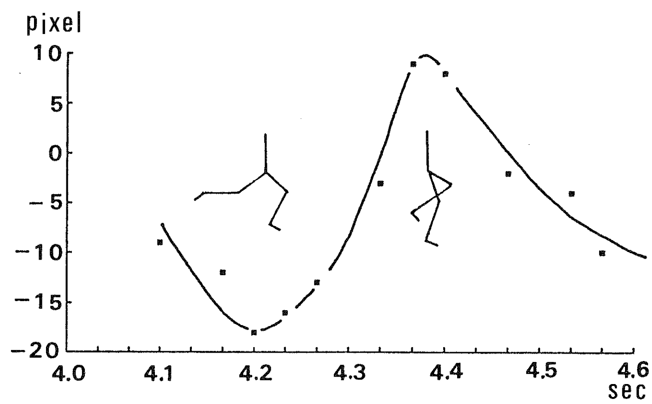


Fig.8 Horizontal Displacement of Right Knee

2.Impulsive force=Newton's 2nd Law of Motion(ma)

where m;mass weight(Carl louis 80kg), g;the acceleration of gravity, h;height, v;velocity, a;acceleration

Fig.8 shows the results of the horizontal displacement of Carl Lowis's right knee. This graph shows the motion from right-foot push off(4.1 sec.) to the next right foot push off(4.57 sec.). This cycle represents one stride of running.
The pixel(Vertical axis in Fig.8) represents the horizontal displacement from the pixel at the top of the head to that at the right knee. Values below zero thus mean that the right knee is located behind the top of the head, while values above zero mean that the right knee is ahead of the top of the head. At a pixel value of zero, the opposite leg is just crossing. The minimum pixel value at 4.2 sec. thus mean that the knee is farthest behind from the head (the knee is most

extended) and also the maximum pixel value at 4.37 sec. mean that the knee is farthest in front of the head (the knee is most retracted).

The pixel distance from its value at 4.33 seconds to that at 4.37 seconds is large. The large displacement of the right knee means that its velocity, kinetic energy and impulsive force are all large. Carl has large impulsive force for subsequent movement in running, so he has great thrust(ground reaction force).

It can also be said that the flexed leg links the moment of inertia to increase the angular velocity of the swinging thigh. Rapid leg retraction at the knee appears to control the thigh movement, which is based on feedback and feedforward. These results which are obtained in this study are useful not only sports dynamics but also for biomechanical analysis of human movement.

4. Orientation

Each image has not any control point except white straight line of the running course. Camera angle and focal length are always changing. To orient these images, it's necessary special idea.

White track lines are very noisy for the image enhancement. In the case of orientation, however, these white lines give useful information. For example, Fig.9 is an image at the goal. X and Y-coordinates can be estimated by crossing points of track line because of the width of each track line and each line section are given. Here, orientation becomes two-dimensional projective transformation as follows.

$$X=\frac{b_1x+b_2y+b_3}{b_7x+b_8y+1}$$

$$Y=\frac{b_4x+b_5y+b_6}{b_7x+b_8y+1} \qquad (1)$$

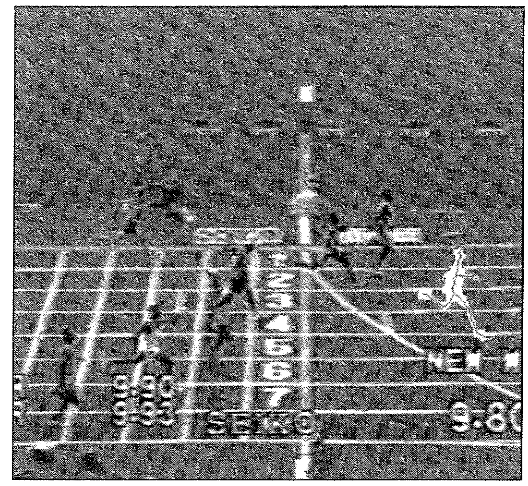


Fig.9 Image of Neighborhood Goal

Eight unknown parameters in Equ.(1) are estimated more than four control point by the least square solution. The collinearity equation can be rewritten as follows,

$$X= [\{a_{11}(Z-Z_0)+a_{13}X_0\}x+\{a_{21}(Z-Z_0)+a_{23}X_0\}y-\{a_{31}(Z-Z_0)+a_{33}X_0\}f] / (a_{13}x + a_{23}y -a_{33}f)$$

$$Y= [\{a_{12}(Z-Z_0)+a_{13}Y_0\}x+\{a_{22}(Z-Z_0)+a_{23}Y_0\}y-\{a_{32}(Z-Z_0)+a_{33}Y_0\}f] / (a_{13}x + a_{23}y -a_{33}f) \qquad (2)$$

In Equ.(2) a_{ij} are elements of rotation matrix of coefficients with omega-phi-kappa. X_0, Y_0, Z_0 are camera position and f is focal length. Focal length is needed to solve the Equ.(2) and approximate value of focal length is estimated by the relationship between the length of goal line on the image and actual length. Comparing the right-hand sides of Equ.(1) and Equ.(2), exterior orientation parameters are calculated by using b_1-b_8.

Considering that the video camera is fixed from start to end in spite of rotation angles always changing, camera position for all images can be determined from the above equation. Although there are four unknown parameters (omega phi kappa and focal length) for the each image. Focal length can be estimated by utilizing the width of track line. Except the goal and start images, it's impossible to estimate X-coordinate(along track). However, Y-coordinate(cross track) can be estimated from the width of track line.

Although initial kappa can be regarded as a line inclination angle, omega, phi and kappa can be calibrated from the second equation of Equ.(1) and (2).

Finally, exchanging Y and Z axis under the condition that Carl Lowis is running on the same parallel plane(2) perpendicular to the camera (Fig.10), feature points coordinates (X',Y') are calculated from Equ. (3).

$$X'=(Z'-Z_0')\frac{a_{11}x+a_{21}y-a_{31}f}{a_{13}x+a_{23}y-a_{33}f}+X_0'$$
$$Y'=(Z'-Z_0')\frac{a_{12}x+a_{22}y-a_{32}f}{a_{13}x+a_{23}y-a_{33}f}+Y_0' \qquad (3)$$

In Equ.(3), $(Z'-Z_0')$ is constant as a distance from the camera to the running track of Carl Lowis is constant.

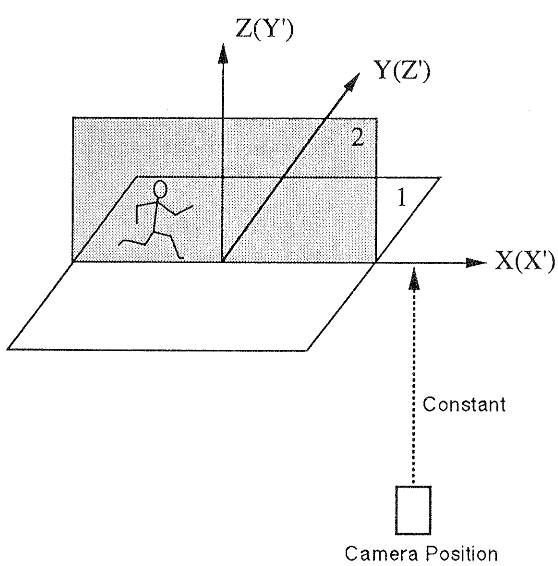


Fig.10 Geometric relationship between XYZ and X'Y'Z' planes

5. Conclusions

An image processing procedure for feature extraction of human body has been developed in this study. 13 feature points are automatically extracted by this procedure with 32 bit PC. Although binary image which is taken through the image enhancement process is an image like silhouette, it's impossible to extract all feature points automatically. However, dynamic analysis for some feature points for example knee can be performed by this procedure. The horizontal displacement of Carl Lowis's right knee was analyzed in this study. Orientation for each image should be performed by orientation method which is discussed in this paper.

Consequently, this method should be improved further. For example, on the way of image enhancement process, binary image for only white track line should be created. This image will give useful information for orientation such as a line inclination(kappa), width between the track lines and pixel-line coordinates for cross points with horizontal and vertical lines. These automated process should be developed for dynamic analyses with sequential multi-images of TV video camera.

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