A High-speed Estimation Method using the Shape Change Feature with a High-speed Camera

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Abstract

If there is quick motion, it is difficult to observe a change with an ordinary-speed camera. On the other hand, to capture the quick motion, a high-speed camera is often used. Capturing and processing in real time is difficult, because the amount of the data is very large. We propose a high-speed estimation method which uses ordinary and the feature of a quick change. This feature is generated from sequential images taken by a high-speed camera beforehand, and it becomes possible to estimate in high-speed with the ordinary camera. We propose an application to high-speed estimation of a shape of JANKEN (the finger-flashing game of paper-scissors-stone) in this paper. The change of the shape of JANKEN happens quickly, and estimation from the state after the hand flashing violates the rules of the game. Therefore, the estimation during shape changing is required.

In the first step, JANKEN is taken by a high-speed camera in front of a simple background. Then, a shape change feature is made from the sequential image of the changing process of the hand, and this is used for the feature dictionary for estimation. Next, a shape feature is made with an image taken by the ordinary camera, which is same as the feature of the high-speed camera. This feature is matched with the shape change feature generated by the high-speed camera. We estimate the shape of the hand which has small error as the hand of JANKEN.

Even when an ordinary camera is used, using this method, the momentary shape of a hand can be estimated before hand flashing is finished.

1 Introduction

An ordinary camera can only capture 30 frames per second. In the case of real time estimation of a shape, if change of the motion changes faster than 30 fps, it is difficult to observe a quick change with an ordinary camera. To capture a quick motion, a high-speed camera is often used, but capturing and processing with high-speed camera in real time is difficult, because the amount of data is very large. So we propose a high-speed estimation method with the ordinary camera using the shape change feature made by using the high-speed camera.

In this paper, we applicate this method to JANKEN-game. JANKEN is the finger-flashing game of paper-scissors-stone in Japanese. There are three kinds of hand shapes, "stone", "scissors" and "paper", and the stone wins the scissors, the scissors wins the paper, and the paper wins the stone. For the computer to win over the human every time, it needs to estimate the shape before the hand flashing is finished. However, it is difficult to acquire the change feature of the shape of the hand, because this change is very quickly represented a few frames by using ordinary camera. At present, a JANKEN estimation method that uses the image processing has been proposed[1]. It estimates the shape of the hand after flashing. On the other hand, our method can estimate the shape during flashing, and the estimation method with only the high-speed camera is proposed[2]. This method uses markers, and devices are very expensive.

The high-speed camera used this research can capture 240 frames per second. The shape change feature that generated by the high-speed camera prepares beforehand. The shape feature that is generated by the ordinary camera is matched with the shape change feature. We propose the method to estimate the shape of the JANKEN at high speed using The ordinary camera. We don't use special markers.

2 Generation of the shape change feature with a high-speed camera

2.1 The high-speed camera

InstaSlow model IS-244 made by SciMedia Ltd. is used[3]. This camera's frame rate is 240 frames per seconds, and the recording time is 4.27 seconds. An example of the process of change captured by this camera is shown in figure 1. In the game, we always start the stone, and the hand is changed to the stone, the scissors or the paper. These several processes are captured by the high-speed camera. Three features as the stone to the stone, the stone to the scissor and the stone to the paper are generated.

We use the angle distribution of hand outline, the distribution of distance between the hand outline and the center of gravity, and the roundness as features.

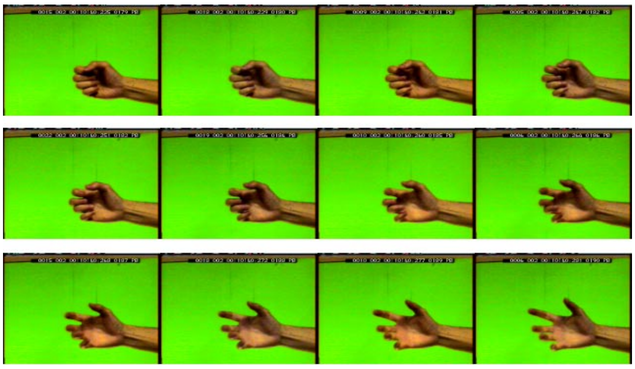

Fig. 1 Change of the shape of the hand captured by the high-speed camera

2.2 Detection of a hand region

The hand is captured by the high-speed camera and a region of the hand is detected. The noise is deleted by the erosion operation. The largest region is selected as the hand region by the labelling operation.

Next, the wrist region is deleted. We use the palm region to detect the wrist, because the position of a palm isn't influenced by hand shapes of JANKEN. Calculation the maximum inscribed circle of a hand for stabilized palm detection is better, but fast processing is needed to estimate in real time. So, each pixel of hand region is scanned by narrowing a circle size gradually, and palm region is narrowed down fast. The palm region is detected by scanning each pixel by narrowing circle gradually as shown in figure 2. The radius of the circle is changed to 20 pixels from 33 pixels by basing on the hand size. Here, the palm region is calculated using fixed values. So, if the hand size in the image is big, the distance between the edge of the palm region and wrist position is long. If the hand size in the image is small, the distance between the edge of the palm region and wrist position is short. So, the corner position of the palm region as the wrist position is slid to the wrist side using fixed value. The wrist region is deleted. By doing so, this method can detect a hand region as shown in figure 3, and this method doesn't depend on the hand size.

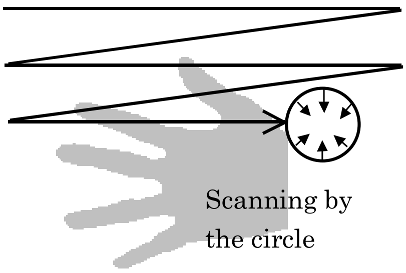

Fig. 2 detection of the palm region

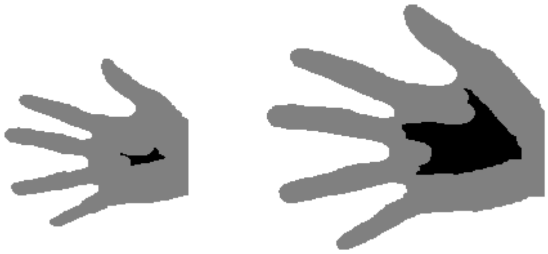

Fig. 3 The hand region (gray) without the wrist region using the palm region (black)

2.3 Calculation of the angle of the outline

The region size is calculated from the hand region. The outline is extracted from the edge of the hand region. The length of the outline is calculated to scan through it, and a list of the coordinates of the points on the outline is generated. Let the region S be a hand region and L be the length of outline for the roundness, R is calculated by eq.(1). Moreover, a list of the degree of the angle is calculated by line segments a, b, and c which is connected three points as shown in figure 4 by eq. (2). The outline of the hand is scanned, and the angle distribution of the hand outline is calculated.

$$R = \frac{4\pi S}{L^2} \quad (1)$$

$$\theta = \cos^{-1}\left(\frac{b^2 + c^2 - a^2}{2bc}\right) \quad (2)$$

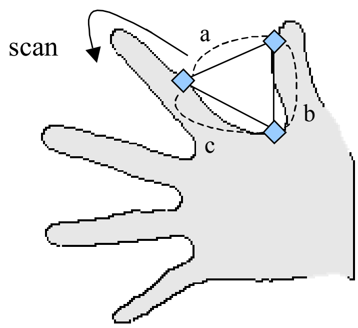

Fig. 4 Calculation of an angle distribution of a hand outline

When the length of line segments b and c are calculated by the ratio of the length of the hand outline, the length of outline is changed by each shape of the stone, the scissors and the paper. Moreover, the angle of the stone is needed to calculate with a rough angle, because if the interval of this line segment is short, an angle will appear in the contour of the hand, even if the finger is bent. So, the roundness is used to normalize the length of line segments b and c. The roundness of the stone is always large, and the roundness of the scissors and the paper are small. So the outline length is multiplied by the roundness such as eq.(3). The angle is normalized by *m*, for adjusting an angle will be stable during change process. In this paper, the value of *m* was used as m=5 experimentally decided.

$$b = R \times L / m \quad (3)$$

Table 1 The average of the length of *b* and *c*

	Outline length	Roundness	Length of *b*,*c*
Stone	316	0.707	36
Scissors	547	0.283	27
Paper	979	0.152	27

If the estimated hand is the state of the scissors or the state of the paper, the angle of fingers is needed to calculate using short distance. On the other hand, if the estimated hand is the state of the stone, the angle of fingers is needed to calculate using long distance. Our method can dichotomize those states of the JANKEN hand as shown in table 1. Calculated angle of each states is shown in figure 5, 6 and 7. In those figures, the smaller value of the outline distribution position is the thumb side, and the larger value of the outline distribution position is the pinkie.

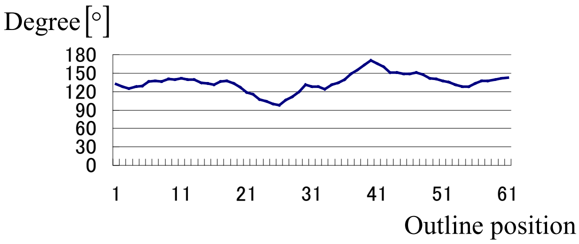

Fig. 5 The angle distribution of the shape of a hand (Stone)

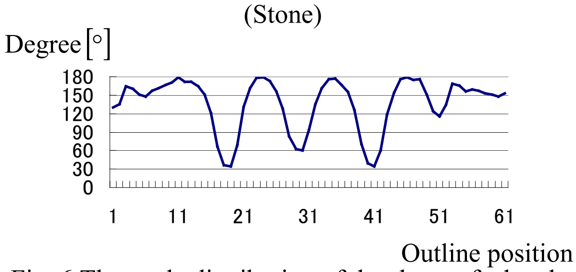

Fig. 6 The angle distribution of the shape of a hand (Scissors)

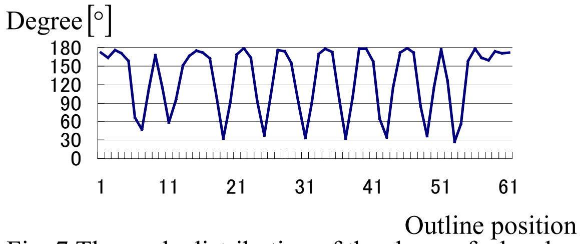

Fig. 7 The angle distribution of the shape of a hand (Paper)

2.4 Calculation of the distance from each point on the hand outline to the center of gravity

We use the distance from each point on the hand outline to the center of gravity with the angle distribution. The distribution of the distance of each point of the hand outline from the center of gravity is calculated by scanning entire points of the hand outline.

If that distance distribution is normalized by the distance of each outline point from the center of gravity and the outline length of the hand region, each states of JANKEN hand don't have the same variation scale. We need to consider using as well as the angle distribution.

So we use eq.(4) to normalize that distance distribution. Let the distance from each point of the hand outline to the center of gravity be *d*, the outline region of the hand region be *L*, and the area size of the hand region be *S*.

$$d' = \frac{dL}{4S} \quad (4)$$

The calculated distance distribution of each JANKEN hand from each point of the hand outline to the center of gravity is shown in figure 9, 10 and 11. In those figures, the smaller value of the outline distribution position is the thumb side and the larger value of the outline distribution position is the pinkie.

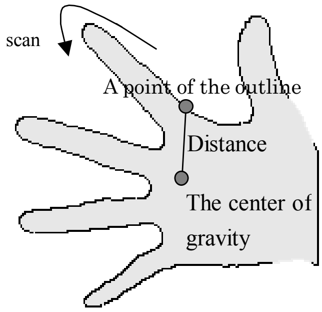

Fig. 8 Calculation of a distance between the hand outline and the center of gravity

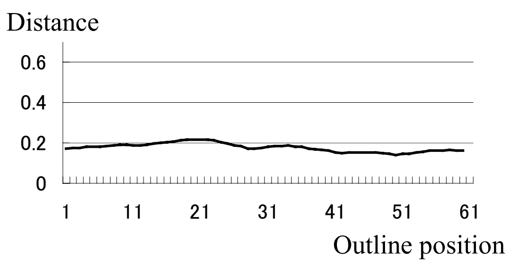

Fig. 9 The distribution of the distance between the hand outline and the center of gravity (Stone)

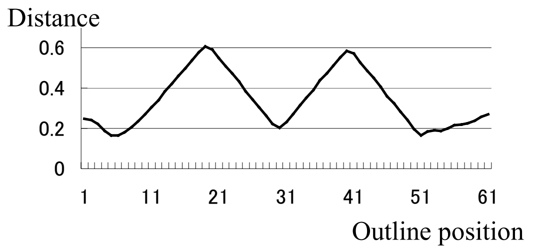

Fig. 10 The distribution of the distance between the hand outline and the center of gravity (Scissors)

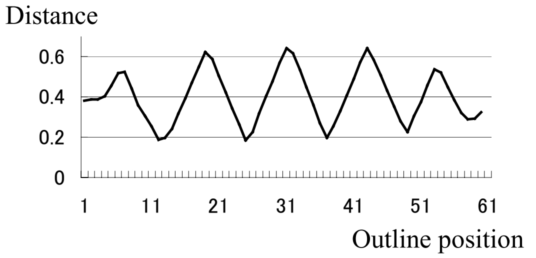

Fig. 11 The distribution of the distance between the hand outline and the center of gravity (Paper)

2.5 Generation of the shape change feature

If the angle distribution of a hand is simply used for the estimation, it is influenced by the interval of the fingers and rotation of the hand. That goes for the distance distribution from each point of the hand outline to the center of gravity. So the histogram of each distribution is used, and that histogram is normalized by the length of the outline. Those histograms of each state of JANKEN hand are shown in figure 12 and 13. We define the stone as the hand starting the JANKEN game. The process of the stone to the scissors, the paper and the stone to the stone are extracted from the shape change feature several times. Three feature dictionaries are made to integrate each roundness of the three hand shapes. The roundness value where change finished of the hand of the stone, the scissors and the paper are approximately 0.7, 0.28 and 0.15. Each roundness is normalized by the 4th power of a number approximation, because three roundness of each status is not stable to estimate. Let roundness be R, the normalized roundness be R', and it becomes equality by normalization as eq. (5).

$$R' = 2 \times (1 - R)^4 \qquad (5)$$

The change process of the hand's shape is extracted 32 frames (corresponding to 4 frames using an ordinary camera), because the hand flashing is taken during approximately 32 frames by the high-speed camera. The change of the angle distribution histogram of the process of the stone to the paper is shown in figure 14. The change of the distance distribution histogram of the process of the stone to the scissors is shown in figure 15. The normalized roundness is shown in figure 16.

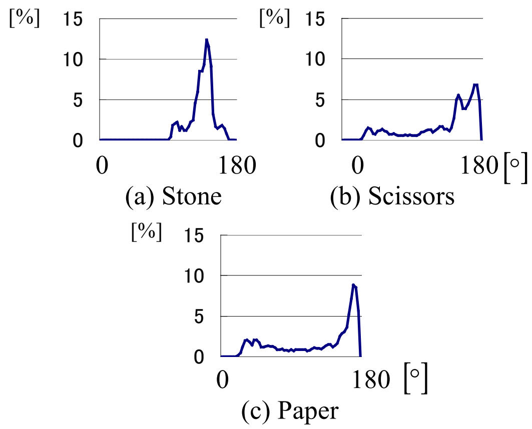

Fig. 12 The angle distribution histogram of each state of JANKEN

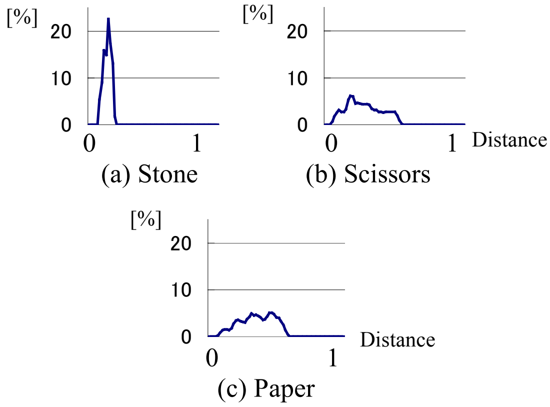

Fig. 13 The angle distribution histogram of each state of JANKEN

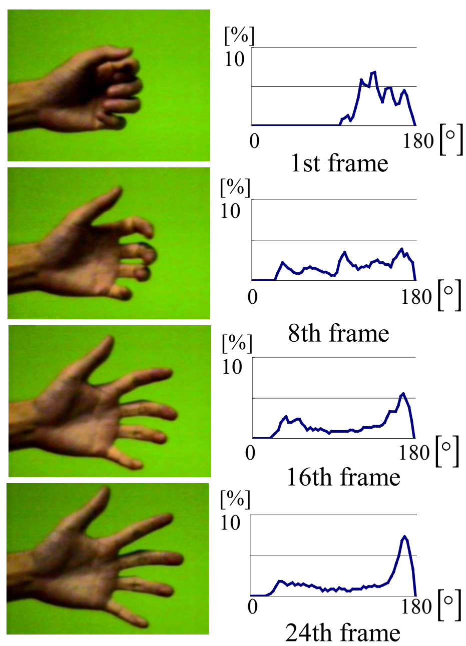

Fig. 14 The change of the angle distribution histogram of the process of the stone to the paper

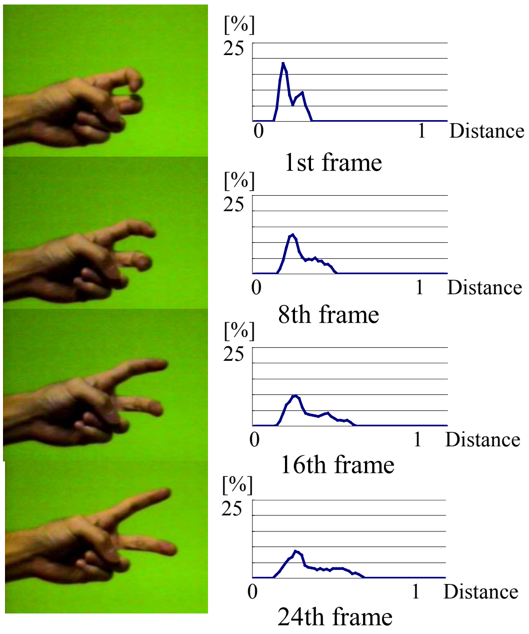

Fig. 15 The change of the distance distribution histogram of the process of the stone to the scissors

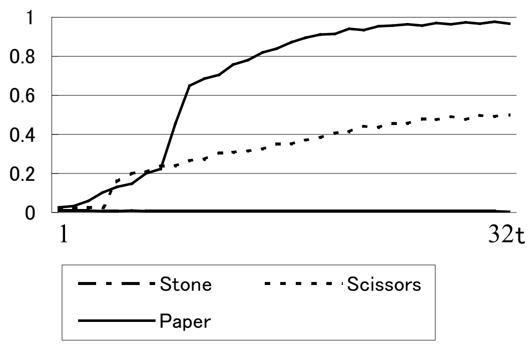

Fig. 16 The normalized roundness

3. Estimation of JANKEN by the ordinary camera

The shape change feature generated from the image sequence taken by the high-speed camera are used, and they estimate the hand's shape by only one frame taken by the ordinary camera. The shape feature is generated by same way as the high-speed camera. The hand's shape is estimated to compare the shape feature by the ordinary camera with the shape change features by the high-speed camera.

3.1 Generation of the shape feature

The generation of the shape feature with the ordinary camera is same procedure as the case of the high-speed camera. The binary image is made from an input image. The maximum region is chosen after the erosion operation and the labelling operation. A wrist position is detected by the method of section 2.2, and the region corresponding to the wrist is removed. The outline of the hand region is detected from the binary image. The roundness and each distribution are calculated by the outline scanning. The shape feature is generated same as the case of high-speed camera by each distribution histogram.

3.2 Matching with the feature dictionary

The feature dictionary with the high-speed camera is compared with the shape feature, and the shape of the present hand is determined by eq.(6).

$$e = \sum_{i=0}^{L} \left\{ \left(Da_i - a_i\right)^2 + \left(Dd_i - d_i\right)^2 \right\} + \left(Rd - R\right)^2 \tag{6}$$

Da : the dictionary of the angle distribution by high-speed camera
a : the angle distribution by ordinary camera
Dd : the dictionary of the distance distribution between the hand outline and the center of gravity by high-speed camera
d : the distance distribution between the hand outline and the center of gravity by ordinary camera
Rd : roundness by high-speed camera
R : roundness by ordinary camera
i : position of the distribution

When L has a small value, the dispersion of an angle distribution is changing as shown in figure 17. So L is decided as 60 which is smaller value and the value which the dispersion is not changing.

The present shape of the hand is estimated by the dictionary that has the minimum value e as the accumulation of the square error.

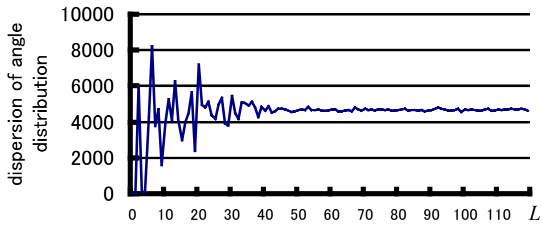

Fig.17 The angle distribution of the paper

4. Experiment

This system is required to execute with high-speed processing, because a hand flashing process is happened only as long as approximately four frames, in the ordinary camera. We are using a PC that has the Pentium 4,2.0GHz, it can execute with 30 frames per second in the case of the image resolution 320x240. We experimented for 5 subjects who tried 10 times each, and the success rate of estimation was 100%.

An estimation of success is checked by displaying the same hand as the shape of a user's hand. Figure 18 is an execution scene of this system that displayed the winning hand to the user. Before change of the hand finishes, the winning hand to the user is displayed.

When we estimate the hand flashing by this system actually, the first point of estimation success was examined. The first position of estimation success was at changing process of the shape of hand since hand flashing. The situations of the process of the stone to the scissors and the stone to the paper were captured at 240 frames per second by the high-speed camera. We estimated such as estimation by the ordinary camera using the image by high-speed camera. We checked visually one image captured with the high-speed camera in steps of one frame. The start and the finish position during sequence of flashing is determined.

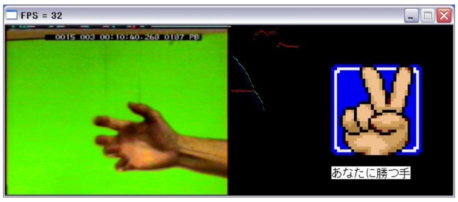

Fig. 18 Execution scene

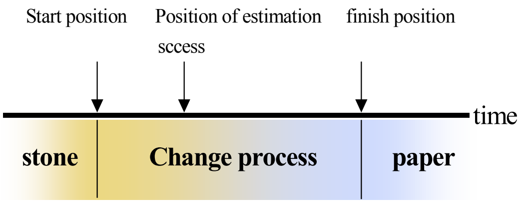

Fig. 19 The point of estimation success

As shown in figure 19, the point of estimation success investigates where estimation is successed after change of the shape of the hand started. We repeated this process of experiment 10 times, and the average was divided by frame rate. The value which was converted into time is shown in table 2. This system can estimate the hand after approximately three frames from start by the ordinary camera. Before change of the hand from the stone to the scissors or the paper, the hand flashing takes an average of 130.2 m sec (approximately four frames using an ordinary camera). On the other hand, by this method, after change of the hand starts, this system can estimate after an average of 29.6 m sec. That is, this system can estimate the three frames in four frames by the ordinary camera. In the process of changes to the paper from the stone, the shape of hand was mis-estimated as the scissors as long as 10.4m sec. When it converts into the frame rate of the ordinary camera, it is 1/2 or less frame that incorrect estimation appears, after change of a hand starts. Figure20 is the image of point of estimation since hand flashing.


Fig. 20 The estimated hand

Table 2 The estimated result in the change process of the hand

	Stone-> scissors	Stone-> paper
Cange process	130.0m sec	130.4m sec
Position of Estimation scess	28.8m sec	30.4m sec
Error	0m sec	10.4m sec
The number of estimatable frames	3.04	2.91

5. Conclusion

We used the high-speed camera, which can capture 240 frames per second, and the feature is made by change of the angle distribution of the outline of a hand and the roundness. The feature dictionary is made based on these features. We proposed a method that can estimate the shape of the hand at high speed, even when the ordinary camera of 30 frames per second is used. Moreover, when the roundness determines the shape of the hand that is simple, the difference does not appear as the process of the stone to the scissors and the process of the stone to the paper. The changing process of the hand was able to estimate correctly by this method.

Moreover, the example of application to JANKEN estimation by the feature of the high-speed camera was described. In the future, we are going to apply this approach to other estimation of shape.

References

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