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8-Straight Line Directions Recognition Algorithm for Hand Gestures Using Coordinate Information

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좌표 정보를 이용한 손동작 직선 8 방향 인식 알고리즘

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Abstract In this paper, we proposed the straight line determination method and the algorithm for 8 directions determination of straight line using the coordinate information and the property of trigonometric function. We conduct an experiment that is 8 hand gestures are carried out 100 times each, a total of 800 times. And the accuracy for the 8 derection determination algorithm is showed the diagonal direction to the left upper side shows the highest accuracy as 92%, and the direction to the left side, the diagonal direction to the right upper side and the diagonal direction to the right bottom side show the lowest accuracy as 82%.
This method with coordinate information through image processing than the existing recognizer and the recognition through learning process is possible using a hand gesture recognition gesture.

Key Words : hand gesture recognition, hand tracking, HCI, image processing, pattern recognition

요 약 본 논문에서는 직선을 판별하는 판별방법과 또한 직선으로 판정되는 경우 직선의 8가지 방향에 대한 판정을 위하여 좌표정보와 삼각함수 성질을 이용하여 직선 8반향 알고리즘을 제안하였다.
본 실험은 각 동작 별로 100회씩 총 800회를 실험 하였으며, 본 논문에서 제안한 알고리즘을 통한 정확도는 왼쪽 위로의 대각선 방향이 92%로 가장 높았으며 왼쪽 방향, 오른쪽 위로의 대각선 방향과 오른쪽 아래로의 대각선 방향이 모두 82%로 가장 낮은 인식률을 나타내었다.
이 방법은 기존 방법과는 다르게 학습과정 없이 이미지 처리를 통해 얻은 좌표 정보만으로 손 제스처 인식이 가능하다는 것을 보여준다.

주제어 : 손 동작 인식, 손 추적, HCI, 이미지 처리, 패턴인식

1. INTRODUCTION

Many technologies are being researched which enable Human-Computer Interaction(HCI) in more convenient way amid rapid advancement of computer capabilities. Recently, the input modalities have

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expanded to include the touch, voice, gesture, etc., although the mouse(developed in 1960s) and keyboard which appeared later were used widely to give command to the computers thus far. In addition, various researches have been conducted on many different forms of user interface(UI) for the natural Human-Computer Interaction(HCI). Particularly, the motion recognition technology has been incorporated into the games such as the Natal of Microsoft, and the services which use the smart home environment or IPTV, as well as the games, are creating an increasing proportion of new value, and resultantly, researches have been conducted vigorously on the gesture recognition technology that enable more positive interaction with human, not the existing remote controllers.[1,2] Thus, there has been an increasing desire for Human-Computer Interaction(HCI), and in particular, the experiential interface, such as touch screen, haptic UI, etc., has drawn a growing interest, rather than the existing interface such as keyboard, mouse, joystick, etc.[3] Beside, the researches have been carried out vigorously in the field of gesture recognition which uses the advanced computer hardware and various sensors that have been developed to satisfy the desire of users for Human-Computer Interaction(HCI)[4].

2. RELATED WORKS

In the relevant studies regarding the recognition of gestures, the method of analyzing and recognizing the directional structure of hand gestures, dividing it by 45° using the movement direction vector of two points in two frames and classifying 4 directions for the gesture including left, right, up and down directions is suggested in [5]. In [6], the moving trajectory of all gestures is normalized to have 8-directionality by applying the syntactic recognition method. The normalization process finds the angle of movement vector in the hand region formed between 2 sequential frames using the trigonometric function. The method of normalizing in the closest among 8 directions from the obtained angle is studied. In [7], accumulated distance value of hand movements, accumulated angle value in the moving distance and the angle of gesture starting point and end point are obtained and feature points are calculated using the status diagram, and then these points are entered to the Support Vector Machine (SVM) to recognize gestures in 8 directions, left turn and right turn gestures. In [8], parameter is detected using the central coordinates from the image input through the kinect sensor and 6 types of gestures including left, right, up, down, left turn and right turn were recognized using HMM (Hidden markov model) from the obtained parameter. In [9], 8 types of gesture with both hands were recognized using the standards of vector quantization and similarity.

Algorithms used for the gesture recognition include Neural Networks and HMM (Hidden Markov Models). Neural Networks can recognize poses and gestures and obtain a high accuracy by enough learning but network learning takes a long time and a good result cannot be guaranteed in comparison to the time required. HMM (Hidden Markov Models) provides a good solution for the hand gesture and pose recognition but a good result cannot be guaranteed in comparison to the time required just as Neural Networks and it is difficult to understand the actions inside of HMM unlike the multi-level Neural Networks [10]. And also, the recognition method with angular chain code is frequently suggested among the gesture recognition methods and the recognition method of 8 directions. This method provides simple and easy recognition but only the starting point and the end point are used so that it has some disadvantages that it cannot recognize a changing value and it is sensitive to noise in the boundary value[11,12].

This study is intended to present the coordinate information-based linear & directional recognition algorithm which involves the recognition of skin color based on the data fed from the camera alone without using special equipment and subsequent extraction of hand central point through the color space transformation(conversion) and binarization and the input of hand's various movements depending on the change in the position of the central point.

3. HAND GESTURE RECOGNITION ALGORITHM USING COORDINATE INFORMATION

The algorithm proposed in this study is the linear 8 directional hand motion recognition method using the difference in the 'distance between the starting point and the ending point' and the 'distance between the starting point and middle point' of coordinates based on the coordinate information of the input data.

First, the hand central point is extracted. The process of extraction is as follows:

The color space of the image input is converted into the YCbCr color space and the hand region is extracted and binary-coded is that $B(x,y)=1$, $\mathrm{if}\,[C_r(x,y)\in[133,173]]\cap[C_b(x,y)\in[177,127]]$ and otherwise $B(x,y)=0$ [13].

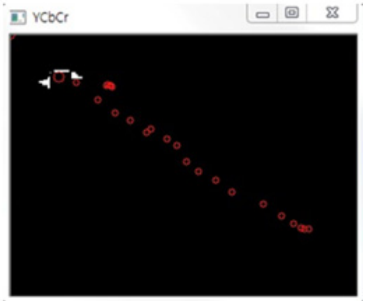
To improve the reliability of the extracted area, the morphology calculation is conducted[14]. The algorithm suggested in this paper uses the coordinate information, so it finds the central point in the hand region extracted for recognizing the hand gesture and recognizes the gesture with the central point (1)

$$C(x,y)=\frac{\sum_{i=0}^{N}P_i(x,y)}{N} \tag{1}$$

Where, $C(x,y)$ is the central point on the extracted region, $P_i(x,y)$ is the pixel coordinate of the extracted region, and N is the number of total pixels in the extracted region.

After the central point of the hand is extracted, the coordinates that connect the central point of the hand are traced to recognize the gesture. [Fig. 1] shows the screen where the gesture is entered, and [Fig. 2] is the plot of traced coordinates.

[Fig. 1] Gesture Input Screen



[Fig. 2] Straight Line Tracking

In order to improve the accuracy in the hand movement recognition, the coordinates including the maximum and minimum information from the x_i values for all i are eliminated in consideration of the environment noises from the coordinates (x_i,y_i) entered based on the path of coordinates that trace the central point of the hand, and similarly, the coordinates that have the maximum and minimum values for y_i are removed. Generally, a total of 4 coordinates from the entered coordinate data can be eliminated in such case.

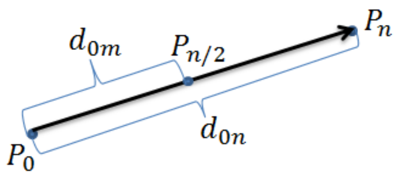
Also used here is the difference in the "distance d_{0n}" which is the amount of space between the starting

$P_0(X_0, Y_0)$ and the ending point $P_n(X_n, Y_n)$ of the input coordinates and the "distance d_{0m}" between the starting point and the middle point in order to determine whether the path of the coordinates that tracked the hand motion is linear.

Here, d_{0n} means the distance on the general Euclid plane.

And also, the central coordinates from the n number of coordinates entered are expressed as $P_m = P(x_m, y_m)$. If the number of coordinates entered is an odd number, the $\frac{n+1}{2}$th coordinate is the central point, and the if the number of the coordinates entered is an even number, the $\frac{n}{2}+1$th coordinates is the central point. For example, if the number of coordinates entered is 9, the 5th coordinate is the central point, and if the number of coordinates entered is 10, the 6th coordinate is the central point.

In the case of linear open curve as shown in [Fig. 3], the distance d_{0n} between the starting point and the ending point is generally larger than the distance d_{0m} between the starting point and the middle point. In other words, $d_{0n} > d_{0m}$ constitutes.



[Fig. 3] Standard Line Gesture Image

This can be expressed as linear if $d_{0n} - d_{om} \geqq 0$ Using the difference between the distance d_{0n} between the starting point $P(X_0, Y_0)$ and the end point $P(X_n, Y_n)$ and the distance d_{0m} between the starting point and the midpoint from the data input, it is determined whether the path of coordinates which trace the hand is linear or not. At this time, the coordinates $P_i = P(X_i, Y_i)$ are based on the sequence of input time. In this paper, it is tended to suggest the algorithm which can determine the linearity according to the difference in the distance between coordinates and recognize the directionality of a straight line using the given coordinate information in case it is a straight line.

Considering that the coordinates for the center of hand moved are $P_i(X_i, Y_i)$, x_0 and y_0 which become the standard for recognizing the directionality of the linear hand gesture mean the initial values at $P_0 = P(X_0, Y_0)$, the coordinates entered first by the time sequence.

Assuming that $x_{\min}$ is the smallest value among the coordinates of the x input coordinate values and that the largest value is $x_{\max}$ it can be expressed using the formula (2) and (3).

$$x_{\min} = \wedge_{i=0}^{n} |x_i| \tag{2}$$

$$x_{\max} = \vee_{i=0}^{n} |x_i| \tag{3}$$

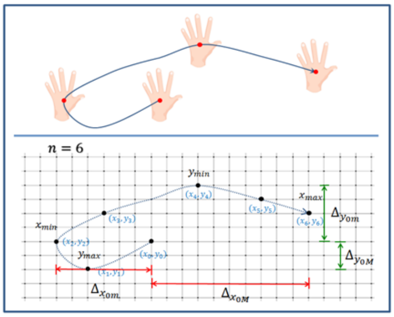
In the same way, the values for the y coordinates can be expressed similar to formular (2), (3) respectively.

Using the formula (2), the length for the variation on each x coordinate can be assumed as follows (4),(5): and y coordinate can be get similar to

$$\triangle x_{0m} = |x_0 - x_{\min}| \tag{4}$$

$$\triangle x_{0M} = |x_0 - x_{\max}| \tag{5}$$

Formula(4) means the smallest variation towards the x axis at the starting point of x coordinate, while formula(5) means the largest variation. In the same way, the maximum and minimum values of the variation for the y axis and each variation as shown in [Fig. 4]



[Fig. 4] middle point movement and variation

This paper presents the linear & directional hand motion recognition algorithm using the coordinate information as follows:

1st step: Enter the hand motion coordinate data, i.e., $P_0(x_0,y_0), P_1(x_1,y_1), \cdots, P_n(x_n,y_n)$.

2nd step: Determine the leftward and rightward direction based on the difference in the variation on axis. In other words, the linear hand motion is made leftward $\mathrm{if}(\triangle x_{0m} > \triangle x_{0M})$. The linear hand motion is made rightward $\mathrm{if}(\triangle x_{0m} < \triangle x_{0M})$. The linear hand motion is made vertically $\mathrm{if}(\triangle x_{0m} = \triangle x_{0M})$.

$$\begin{cases} L, & \mathrm{if}(\triangle x_{0m} - \triangle x_{0M} > 0) \\ R, & \mathrm{if}(\triangle x_{0m} - \triangle x_{0M} < 0) \\ U \text{or } D, & \mathrm{if}(\triangle x_{0m} - \triangle x_{0M} = 0) \end{cases} \quad (6)$$

3rd step: Determine the upward and downward direction based on the difference in the variation on axis. In other words, the linear hand motion is made upward $\mathrm{if}(\triangle y_{0m} \geq \triangle y_{0M})$. The linear hand motion is made downward $\mathrm{if}(\triangle y_{0m} < \triangle y_{0M})$.

This can be expressed in a formula as follows.

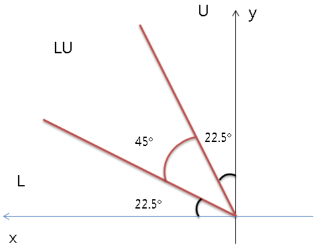
$$\begin{cases} U, \mathrm{if}(\triangle y_{0m} - \triangle y_{0M} \geq 0) \\ D, \mathrm{if}(\triangle y_{0m} - \triangle y_{0M} < 0) \end{cases} \quad (7)$$

4th step: After determining the left, right, up and down directions of the hand gesture using Formulas (6) and (7), the threshold value by the proportional formula of trigonometric function can be obtained from the following formula.

Determine the diagonal direction using the proportional expression of trigonometric function.

$$\frac{(\triangle x_{0m}, \triangle x_{0M}, \triangle y_{0m}, \triangle y_{0M})\sqrt{2-\sqrt{2}}}{\sqrt{2+\sqrt{2}}} \quad (8)$$

Here, the reason to use the threshold value drawn from the formula above is as follows. In [Fig. 5], the hand should be in the range between 0° and 22.5° in order to recognize the L direction, the hand should be in the range between 22.5° and 67.5° in order to recognize the LU direction, and the hand should be in the range between 67.5° and 90° in order to recognize the U direction.



[Fig. 5] L, LU and U recognition ranges in the LU direction

And, the following formula is the half-angle formula of trigonometric function.

In this formula, the ratio of hypotenuse, bottom side and height is $2 : \sqrt{2+\sqrt{2}} : \sqrt{2-\sqrt{2}}$. In other words, In order to be in the range of 22.5°, the ratio of bottom side and height is $\sqrt{2+\sqrt{2}} : \sqrt{2-\sqrt{2}}$. And also, in case of 67.5°, the ratio of bottom side and height is $\sqrt{2+\sqrt{2}} : \sqrt{2-\sqrt{2}}$.

Therefore, this can be applied to LU, as Formulas (9).

$$\begin{cases} L, & \mathrm{if}\left(\triangle x_{0m} > \dfrac{\triangle y_{0m}\sqrt{2-\sqrt{2}}}{\sqrt{2+\sqrt{2}}}\right) \\ LU, & \mathrm{if}\left(\triangle x_{0m} \le \dfrac{\triangle y_{0m}\sqrt{2-\sqrt{2}}}{\sqrt{2+\sqrt{2}}}\right. \\ & \quad AND \\ & \quad \left.\triangle y_{0m} \le \dfrac{\triangle x_{0m}\sqrt{2-\sqrt{2}}}{\sqrt{2+\sqrt{2}}}\right) \\ U, & \mathrm{if}\left(\triangle y_{0m} > \dfrac{\triangle x_{0m}\sqrt{2-\sqrt{2}}}{\sqrt{2+\sqrt{2}}}\right) \end{cases} \tag{9}$$

We can find LD, RU and RD Similar to formular (9)

4. EXPERIMENTAL RESULT

This paper is prepared using the OpenCV 2.2 library based on Microsoft Visual Studio 10.0 as shown in <Table 1>. And, the resolution of the camera used to receive the data input for the experiment is 320 x 240.

For examining the accuracy of gesture recognition suggested in this paper, the test contents are classified into two items, and the details of the test contents are as <Table 2>. The accuracy in the 8-direction recognition of standard straight line and the 8-direction recognition of modified straight line is measured

〈Table 1〉 experiment environment

Item	Contents
Tool	Microsoft Visial Studio 10.0
Library	OpenCV 2.2
camera resolution	320x240

〈Table 2〉 Test contents

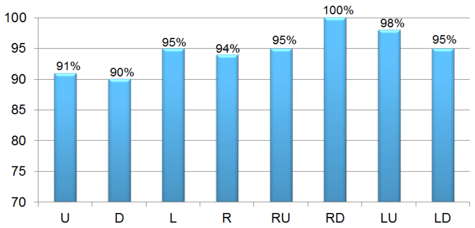
Defined hand gestures	Number of tests
8 directions of standard straight line	A total 800 times including 100 times for each direction
8 directions of modified straight line	A total 800 times including 100 times for each direction

The 8-direction test of standard straight line is carried out for two hand gestures including straight line hand gesture and curved hand gesture. A total of 800 times including 8 types of hand gesture in 8 directions of standard straight line for 100 times each are carried out to measure the accuracy.

〈Table 3〉 8-direction recognition test result of standard straight line

	U	D	L	R	RU	RD	LU	LD
Recognition rate	91%	90%	95%	94%	95%	100%	98%	95%
Mis-recognition rate	9%	10%	2%	6%	5%	0%	2%	5%

According to <Table 3>, (RD) gesture to the right bottom side shows a satisfactory result as 100% but (D) gesture to the bottom side shows the recognition rate of 90% as the hand gesture test result in 8-directions of standard straight line. This shows that the moving speed or direction may vary depending on the user. The hand gesture recognition test result in 8 directions of standard straight line can be expressed on a drawing as [Fig. 8].



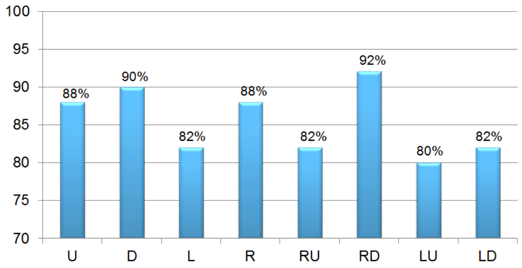
[Fig. 8] Hand gesture recognition rate in 8 directions of standard straight line

In general, when a person makes a linear hand gesture, he/she makes a modified hand gesture in 8 directions of standard straight line presented in 4.1 as well as in various forms. Therefore, 8 types of modified straight line are defined in this paper as shown in <Table 4> and the test is carried. In <Table 4>, the same determination with the test subject's intention to enter data is considered as the recognition rate.

<Table 4> Hand gesture recognition test result in 8 directions of modified straight line

Modified Straight Line			
Recognition rate	88%	90%	82%
Mis-recognition rate	12%	10%	18%
Modified Straight Line			
Recognition rate	88%	82%	92%
Mis-recognition rate	12%	18%	8%
Modified Straight Line			
Recognition rate	80%	82%	
Mis-recognition rate	20%	18%	

In this test, 8 hand gestures are carried out 100 times each, a total of 800 times, and for the accuracy through the algorithm suggested in this paper, the diagonal direction to the left upper side shows the highest accuracy as 92%, and the direction to the left side, the diagonal direction to the right upper side and the diagonal direction to the right bottom side show the lowest accuracy as 82%. The contents in <Table 4> can be expressed on a graph as [Fig. 9].



[Fig. 9] Hand gesture recognition rate in 8 direction of modified straight line

5. CONCLUSIONS

For the hand gesture recognition algorithm in this paper, the algorithm to recognize the 8-direction of straight line using the coordinate information is suggested to recognize the image coordinate data input from the camera without the use of a specific device.

Among the previous direction recognition methods, the method of using angular chain code has some disadvantages that it cannot recognize a changing value and it is sensitive to noise. In this paper, the linear and circular hand gesture recognition algorithm which can remove extreme points from coordinate input values as the method to minimize this noise to improve accuracy is suggested.

The algorithm presented in this paper distinguishes between a straight line and a curve using the difference between the distance between the starting point and the end point and the distance between the starting point and the midpoint from the input data coordinates.

And also, the algorithm for 8 directions of straight line using the coordinate information and the property of trigonometric function is suggested to determine 8 directions of straight line in case of a straight line.

It is expected that this hand gesture recognition algorithm will be developed into the base technology that enables human-computer interaction through various types of user interfaces for more natural interaction with the computer. The human-computer interaction methods include the method of using voice, body or hand gestures and human face. The gesture-based user interface has many advantages in the aspect that it can enable the interaction in intuitive and various forms. Therefore, more services that use the smart home environment or IPTV create new values so that the studies on the gesture recognition technology which enables the active human-computer interaction, not the previous remote control, are expected to be carried out actively.

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