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Prototype Program Hand Gesture Recognize Using the Convex Hull Method and Convexity Defect on Android

Muhammad Adi Khairul Anshary[1], Eka Wahyu Hidayat[2], Tiara Amalia[3]
[123]Informatics Department, Siliwangi University Tasikmalaya, Indonesia

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ABSTRACT

One of the research topics of Human-Computer Interaction is the development of input devices and how users interact with computers. So far, the application of hand gestures is more often applied to desktop computers. Meanwhile, current technological developments have given rise to various forms of computers, one of which is a computer in the form of a smartphone whose users are increasing every year. Therefore, hand gestures need to be applied to smartphones to facilitate interaction between the user and the device. This study implements hand gestures on smartphones using the Android operating system. The algorithm used is convex hull and convexity defect for recognition of the network on the hand which is used as system input. Meanwhile, to ensure this technology runs well, testing was carried out with 3 scenarios involving variable lighting, background color, and indoor or outdoor conditions. The results of this study indicate that Hand gesture recognition using convex hull and convexity defect algorithms has been successfully implemented on smartphones with the Android operating system. Indoor or outdoor testing environment greatly affects the accuracy of hand gesture recognition. For outdoor use, a green background color with a light intensity of 1725 lux produces 76.7% accuracy, while for indoors, a red background color with a light intensity of 300 lux provides the greatest accuracy of 83.3%.

Corresponding Author:

Muhammad Adi Khairul Anshary,
Informatics,
Siliwangi University,
Jl. Siliwangi No.24, Kahuripan, Kec. Tawang, Tasikmalaya, West Java 46115, Indonesia
Email: adikhairul@unsil.ac.id

1. INTRODUCTION

Research on Human-Computer Interaction has influenced technological developments that can make work easier. One of the problems associated with Human-Computer Interaction is the development of input devices and the way users interact with computers. Input devices commonly used in computers today are keyboards, mice, joysticks, webcams and remote controls with wired or Bluetooth media for wireless. Meanwhile, the way users interact to communicate with computers is by direct contact with input devices in the form of touch or press.

Utilizing computer vision technology allows humans to interact with computers directly and naturally. One of the computer vision technologies is hand gesture which has advantages in its use because it is relatively easy for users to understand and is interactive. Gesture is a form of non-verbal communication with bodily actions that communicate certain messages, as a substitute for speech. Of the several advantages of hand gestures, there have been many studies regarding their use as a complement or substitute for conventional input devices[1]

However, so far, the application of hand gesture technology is more widely applied to desktop computer devices. As illustrated by several studies that have been done before, including research that applies hand gestures to operate television [2] and musical creation [3]. Another study discusses the application of hand gestures to identify finger gesture recognition [4] [5][6], this study focuses on the use of finger gestures read by a webcam on a desktop computer to replace the use of the mouse in operating computer. Another research use a webcam to recognize visual motion [7] The application of hand gestures in addition to computers is also carried out for navigation controllers on drones[8]. Hand gesture recognition is also implemented to translate Indonesian [9], Hindi [10] and American sign language [11] [12].

Meanwhile, current technological developments have led to various forms of computers, one of which is a computer in the form of a smartphone. Smartphone users continue to increase from year to year. In its use, smartphones require the development of the type of interaction between the user and the smartphone. Of the many studies related to human and computer interactions, especially hand gestures, as reviewed in the paper[13], the application of hand gestures on smart phone devices is still relatively small. Therefore, hand gesture technology needs to be applied in smartphones to facilitate interaction between the user and the device. In its application, it is necessary to pay attention to important things including the use of hand gesture algorithms, input devices available on smartphones and environmental variables that affect the performance of the application.

The hand gesture recognition system can be divided into two stages, which are the hand gesture acquisition phase and the recognition phase. The acquisition phase is getting the hand gesture of the patterns performed by the system user. For hand recognition, the dynamic stages comprise hand detection, hand segmentation, and hand tracking[6]. The process of hand tracking can be divided into two types, namely in a two-dimensional plane or in a three-dimensional plane. At this stage of the introduction of the identification process is carried out or the process of grouping(clustering)to interpret the hand gesture obtained from the acquisition stage.

The algorithm that commonly used in hand gesture recognition research is the convex hull algorithm. As in research the convex hull method has a convex polygon, a polygon that does not have a concave section. Research on hand gestures mostly implemented on a desktop where tracking is done using a webcam, therefore this research will be developed a lab-scale program in the form of a prototype hand gesture recognition on an android.

Therefore, this study will implement hand gesture technology on smartphones that use Android as the operating system. The algorithm used is the convex hull and convexity defect algorithm for recognition of the network on the hand that is used as system input. Meanwhile, to ensure that this technology runs well, tests were carried out with 3 scenarios involving variable lighting, background color, and indoor or outdoor conditions. With this test, it is hoped that data will be obtained regarding the best conditions for the implementation of hand gestures on an Android smartphone.

2. METHOD

The research about hand gesture recognition using the convex hull and convexity defect methods on android through several processes described in the following flowchart.

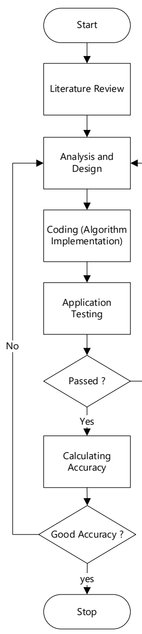

Figure 1. Flowchart of Research

2.1. System Requirement Analysis

At this stage, analyzing system requirements such as functional requirements and non-functional requirements (hardware and software requirements) can help identify and test all needs and obstacles that occur for proposed improvements.

2.2. System Design

Design of the prototype program hand gesture recognition is illustrated using the following flowchart diagram:

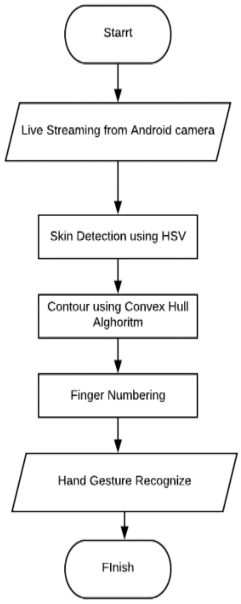

Figure 2. Flowchart Prototype Program Hand Gesture Recognize

1. Data Retrieval Live-Streaming

Data input is a live picture of one hand with an open position to the front and back of the hand with the RGB color space from smartphone camera.

2. HSV Skin Detection

The Data with RGB color space is converted to HSV color space to get the range of minimum and maximum values for each component of Hue, Saturation, and Value. The range of values got is then processed through the threshold process so that the difference between the hand and the background is known.

3. Contour Process Using Convex Hull Algorithm

Using a convex hull in the contour process on the area of hand as an object is a step that must be passed before entering the convexity defect process. The convex hull at a set of points Q (CH (Q)) can be found by determining the smallest convex set containing all points at Q. In an n dimension (CH (Q) is the entire slice of all convex sets containing Q. So for N dot {p1, p2, ..., pN} ϵ P.

$$CH(Q) = \left\{ \sum_{j=i}^{N} \lambda_j P_j \; ; \; \lambda_j \geq 0; \; \sum_{j=i}^{N} \lambda_j = 1 \right\} \quad (1)$$

In image 3 where there is a collection of points called hull points forming a convex set and the six outer points connected to form polygons are convex hull, in these two dimensions also known as convex polygons.

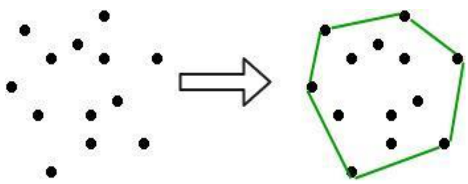

Figure 3. Polygon Shape of Convex Hull

After the formation of a convex polygon is continued by looking for important values that can be obtained through convexity defects. Convexity defect is a feature available in OpenCV that functions to find defects between convex hull formed with contours of polygons. The defect is useful for finding features in a polygon, so it can detect human fingers.

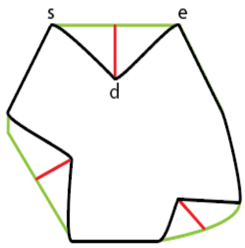

Figure 4. Illustration of Convex Hull and Convex Defect

Image 4 above, looks convex hull depicted with a green line that encloses the polygon with a black contour line. The "s" and "e" symbols show the "starting point" and "end point" of the convexity defect. While the symbol "d" symbolizes the "depth point" between the contour and the hull convex line or can be called the "se" line. The red line that is "depth" or the depth of the defect is the distance from "d" to the line "se". Features can be found by utilizing the starting point, end point, depth point, and depth of the polygon. Depth can be searched by calculating the starting point (S), end point (E), and depth point (D) represented as points S (x1, y1), E (x2, y2), D (x0, y0) in the following formula:

$$d = \frac{|(x_2-x_1)(y_2-y_1)-(x_1-x_0)(y_2-y_1)|}{\sqrt{(x_2-x_1)^2-(y_2-y_1)^2}} \quad (2)$$

4. Finger numbering

Finger numbering is determined by the amount of depth got from the process convexity defect. The amount of depth that is known affects the result of recognizable hand gestures.

2.3. Testing

Program testing planning is carried out using the black-box method for testing by running the application directly so it can be known if there are errors in the lab scale program. The introduction of hand gesture recognition based on Android, besides the calculation of the accuracy of the recognition of the number of fingers is done.

2.4. Analysis the Result

The results of a prototype lab-scale program hand gesture recognition using the algorithm convex hull and convexity defects android-based that have been obtained, then the level of accuracy is analyzed.

3. RESULTS AND DISCUSSION

3.1. System Testing (Black-box)

System testing aims to improve the interface and buttons running under the application design.

Table 1. Testing Black-box

No	Scenario of	Expectation	Response	Conclusion
1	Exit Application	Will end and exit the program	Exit	Accepted
2	Change camera	Will replace the camera used to be a front camera (secondary cam)	Camera change	Accepted
3	Display video streaming from camera	Will display video streaming from the front camera or the main camera handphone	Video appears	Accepted
4	Set the area thresholding	Will change the density of the area thresholding	Images thresholding changed	Accepted
5	displays the status of the device (width, height)	Will display the status fps, width, height	Status appear	Accepted
6	Display numbers after doing touch on hand area A	number of digits from the identified finger will be	Displayed number	Accepted

3.2. Analysis and Results of Hand Gesture Recognition

Tests are carried out with the following scenarios:

1. Streaming Data is performed with six kind of hand gestures.

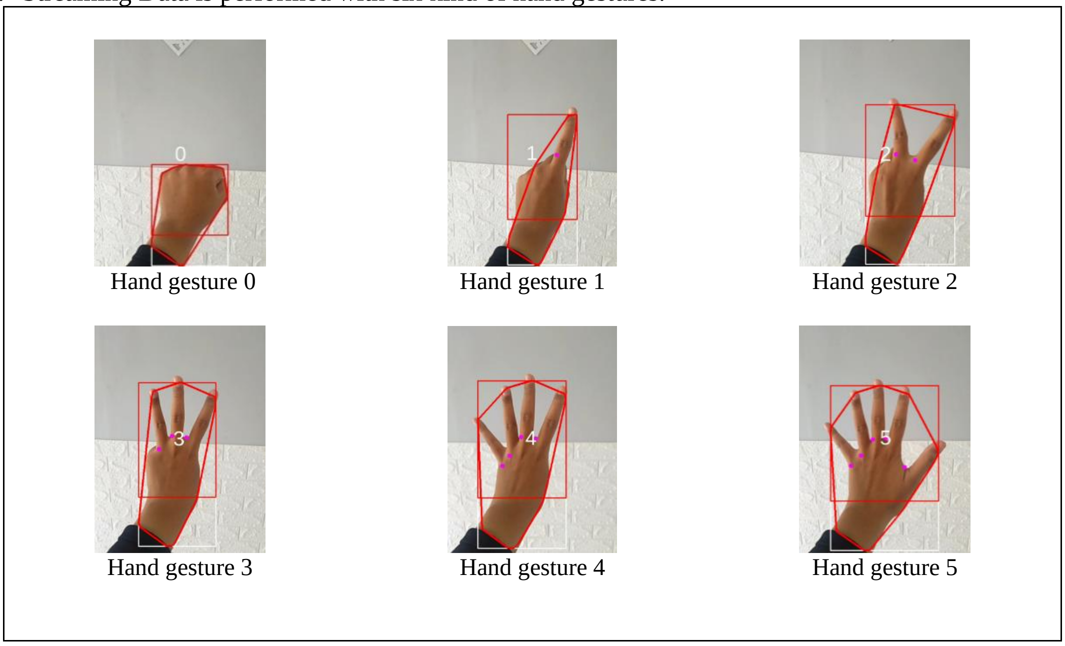

Figure 5. six kind of hand gestures

2. The detection of hand gestures starts after the action is performed touch on the hand area.
3. Detection results that meet the requirements will display a number in accordance with the provisions of the program.
4. The test was carried out on several conditions of light intensity, background color (red, green, blue), and indoor or outdoor conditions.
5. The experiments were done for each gesture five times.

Table 2. Results of Testing program Hand Gesture Recognition

Hand gesture	Light (lux)	Testing					Accuracy
		1st	2nd	3rd	4th	5th	
0	13	v	v		v	v	80%
	45	v	v	v		v	80%
	300		v	v	v	v	80%
	1259	v	v	v	v	v	100%
1	13	v	v	v	v	v	100%
	45		v	v		v	60%
	300	v	v	v	v	v	100%
	1259	v	v		v	v	80%
2	13	v			v	v	60%
	45	v	v			v	60%
	300	v	v	v			60%
	1259	v	v	v	v	v	100%
3	13	v	v	v		v	80%
	45	v	v	v		v	80%
	300	v		v		v	60%
	1259	v	v	v	v	v	100%
4	13	v	v		v	v	80%
	45	v	v	v	v	v	100%
	300	v	v	v	v	v	100%
	1259	v	v	v	v	v	100%
5	13	v	v	v	v	v	100%
	45	v	v	v	v	v	100%
	300	v		v		v	60%
	1259	v	v	v	v	v	100%

Check mark on the table indicate that hand gesture can be recognize correctly. The number of hand gestures that can be correctly recognized is the average value calculated using the formula below:

$$\bar{x} = \frac{(x_1+x_2+\ldots+x_n)}{n} 100\% \qquad (3)$$

Then, the results are obtained as in Table 3.

Table 3 average accuracy

Light (lux)	Accuracy Level
13	83.3%
45	80.0%
300	76.7%
1259	96.7%

Table 3. is the average percentage of accuracy first testing scenario with light as a variable and carried out indoors, showing the highest accuracy value got in light intensity 1259 lux with a value of 96.7%, and the lowest accuracy value at light intensity of 300 lux, while at an intensity of 13 lux and 45 lux get an accuracy value 83.3% and 80%.

In the 2nd scenario, a hand gesture test is carried out to form the numbers 0 - 5 using a background of Red Green and Blue. The test was carried out outdoors with lighting 15 lux, 50 lux, 135 lux, 1725 lux. The test results after calculating the average can be seen in the following table

Table 4. Average accuracy for second scenario

Background color	Intensity light (lux)			
	15	50	300	1725
Red	33,3%	46,7%	56,7%	13,3%
Green	16,7%	36,7%	63,3%	76,7%
Blue	13,3%	73,3%	63,3%	33,3%

The results of the accuracy calculation in the table 4 show the highest and lowest values for each background color condition. The red background condition gets the highest accuracy value of 56.7% at the brightness level of 300 lux and the lowest accuracy of 13.3% at the brightness level of 1725 lux. The green background condition gets the highest accuracy value of 76.7% at the brightness level of 1725 lux and the lowest accuracy of 16.7% at 15 lux. Whereas on the blue background the highest accuracy is 73.3% at 50 lux light intensity and the lowest accuracy is 13.3% at 15 lux brightness level.

The 3rd scenario is a hand gesture test by making the numbers 0–5 and adding the background color Red Green Blue. This test is carried out indoor with lighting 15 lux, 50 lux, 300 lux, 1725 lux. The test results after calculating the average can be seen in the following table

Table 5. Average accuracy for thrid scenario

Background color	Intensity light (lux)			
	15	50	300	1725
Red	16,7%	46,7%	83,3%	23,3%
Green	0,0%	10,0%	53,3%	73,3%
Blue	0,0%	63,3%	76,7%	70,0%

Table 5 shows the accuracy of the application when used indoors with different background color conditions and light intensity. The red background condition got the highest accuracy value of 83.3% at a light intensity of 300 lux, while the lowest accuracy was 16.7% at a light intensity of 15 lux. The green background condition got the highest accuracy of 73.3% at 1725 lux light intensity, while at 15 lux light intensity, hand gesture was not detected at all. Whereas on the blue background the highest accuracy with a value of 76.7% at a light intensity of 300 lux and the same as on the green background, at a light intensity of 15 lux, the hand gesture was not detected at all.

4. CONCLUSION

Hand gesture recognition using convex hull and convexity defect algorithms, which have been implemented on many desktop computers, can also be implemented on smartphones with the Android operating system that utilize the built-in camera of the smartphone. The accuracy of hand gesture recognition is influenced by several variables. From all the test scenarios that have been carried out, it can be seen that the testing environment is indoors or outdoors greatly affects the accuracy of hand gesture recognition. Large light intensity is needed for indoor applications without a color background. As for the light intensity on a color background, not all light intensities are large, resulting in good accuracy. For outdoor use, a green background color with a light intensity of 1725 lux produces the greatest accuracy, namely 76.7%, while for indoors, a dark red color with a light intensity of 300 lux produces the greatest accuracy, namely 83.3%.

The suggestions that can be put forward to become improvements and considerations is in this research, hand pattern recognition is only initials from 0 to 5, for development the output of hand gesture can be developed into other signals not only numbers 0 to 5. Furthermore, it is still unstable, especially in the contouring process of the hand object area. To overcome this, you can try to add an incremental algorithm that can form a better 3D convex hull or use pixel segmentation with YCbCr color space before entering the convex hull process.

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