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Low Cost System for Face Mask Detection Based Haar Cascade Classifier Method

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ABSTRACT

In December 2019, there was a pandemic caused by a new type of coronavirus, namely SARS-CoV-2 (Severe Acute Respiratory Syndrome Corona Virus 2) spread almost throughout the world. The World Health Organization (WHO) named it COVID-19 (Coronavirus Disease). To minimize the spread of the COVID-19, the Indonesian government announced a policy for the social distancing of 1-2 meters and wearing a medical mask. In this study, a mask detection system was built using the Haar Cascade Classifier method by detecting the facial areas such as the nose and lips. The study aims to distinguish between using masks and on the contrary. It is expected that the mask detection system can be implemented to provide direct warnings to people who do not wear masks in public areas. The results using the Haar Cascade Classifier method show that the system designed is able to detect faces, noses, and lips at a light intensity of 80-140 lux. The face is detected at a distance of 30-120cm, while the nose is at a distance of 30-60cm, while the lips are at a distance of 30-70cm. The system designed can perform the detection process at a speed of 5 fps. The overall test results obtained a success rate of 88,89%.

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1. INTRODUCTION

At the end of 2019, a respiratory disease has been found. The first case of this disease occurred in December in the city of Wuhan, Hubei Province, China. In the following month, thousands of people had been infected by the virus. It spread to other provinces in China such as Zhejiang, Guangdong, Henan, Hunan, Beijing, and Shanghai [1]. On February 11 in 2020, World Health Organization (WHO) had named the virus, namely COVID-19 (Coronavirus Disease) which is a new type of coronavirus (SARS-CoV-2) [2]. The result of the retrospective investigation stated that the first case was related to the traditional market in the city of Wuhan [3].

WHO reported that COVID-19 can be transmitted by infected people through droplets expelled by the nose and mouth [4]. The virus will spread when the infected person coughs, sneezes, and even talks. The virus can also stick to any object and will be transferred to the hand when someone touches the object. The transmission rate of COVID-19 may increase due to social interaction in the crowd and touching objects in the public. The virus infection caused fever, shortness of breath, sore throat, cough, running nose, and even death [5].

Generally, small particles which a dimension of 60 to 100 m will be transmitted and then fall to the ground at 6 feet from the source. In rare cases, coughing and sneezing cause particles larger than 100 m to be transmitted up to 12 feet. However, the average transmission of the particle occurred between 4.5 to 6 feet from the source [6]. Many countries applied social distancing with different rules, the rule for the social distancing of 6.5 feet is applied in Indonesia, the rule for the social distancing of 5 feet is applied in Australia, the rule for the social distancing of 3 feet is applied in France and Denmark. The percentage risk of spreading COVID-19 through the air at a distance of 1 meter is 13%. At a distance of more than 1 meter, the risk is reduced to 3% [6].

To avoid the transmission of COVID-19, it is important to maintain a distance of 1 to 2 meters when conducting social interactions and also to wear a face mask. Based on the results of the study, the use of face masks is very important to prevent the transmission of COVID-19 [7–9]. The use of face masks could reduce the spread of small droplets expelled from the mouth and nose when coughing or sneezing. The decline in the growth rate of positive cases of COVID-19 after the implementation of the rules for the use of face masks and social distancing has occurred in the United States. The growth rate fell to 1.1% and the percentage of decrease is increased to 2% [6].

Research on face mask detectors has been carried out by M. Lambacing and Ferdiansyah [10]. In this study, a face mask was detected using Convolutional Neural Network (CNN) method by giving notifications via Telegram. The result produced a system that can detect the face mask using the CNN method. However, it did not mention the effect of light intensity and the distance of the detection process. The method used in this study also has a high computational level, so it cannot be used as a real-time detector in a low-cost system. In research conducted by [11], a Convolutional Neural Network-based object detection algorithm using MobileNet-V2 architecture was planted on Raspberry Pi 3 for the face mask detection process with 98% accuracy. It had a higher accuracy than the system of this research. However, the processing speed of the system is 0.33 fps due to the computational level of MobileNet-V2 being too heavy for Raspberry Pi 3. Therefore, it cannot be used as a real-time system. In research conducted by [12] and [13] provided the face mask detection system using a Convolutional Neural Network-based object detector algorithm with a processing speed of about 20 fps. However, the algorithm was planted on NVIDIA Jetson Nano and NVIDIA Jetson TX2 which have a much higher price than Raspberry Pi 3. Therefore, they cannot be called low-cost systems. To make it easy to implement using light computation, we choose the Haar Cascade Classifier method to detect the use of face masks. We experimented on the effect of light intensity and detection range of the system that has been built.

A lot of research in the field of facial recognition has been done [14]. One of the methods used in facial recognition systems is Haar Cascade Classifier as the face detector [15–18]. Besides being used as a face detector, this method could be used to detect other objects. This method has a low computational level, so it could be run as a real-time detector in a low-cost system. Research on the detection of face parts has been done by Vikram K. and S. Padmavathi [19]. They used the Haar Cascade Classifier method to detect eyes, nose, and lips.

During the COVID-19 pandemic, many public places have implemented a manual checking system for the use of face masks. The novelty of this research is the manual checking system has many weaknesses such as requiring a worker to be on standby to monitor visitors and allowing human errors to occur. To resolve the problem, a smart device that can detect the use of face masks is needed. As a consideration, the device must be cheap to be easy to market. In this research, an algorithm was designed to detect the use of face masks based on face, nose, and lips. The algorithm could be embedded into a low-cost system. The structure of the writing of this paper is as follows: in the second subsection of this paper on research methodology. in the third sub-section discusses the results and discussion. in the last sub-section discusses the conclusions and suggestions from the studies carried out.

2. RESEARCH METHOD

2.1. Face Mask Detection System

The overall system design can be seen in Figure 1. The hardware used as the brain of the system is a single-board computer called Raspberry Pi 3 model B+. The computer is in charge of processing digital images. To get the input data in the form of digital images, a camera with a capture resolution of 5 megapixels is used. The digital image captured by the camera will be processed by a computer to detect faces. If the face has been detected, then the next process is to detect two parts of the face, namely the nose and lips. If one or both parts of the face are detected, the system will detect that the target is not wearing a mask. And if the two parts of the face are not detected, then the system will detect that the target is wearing a mask. The programming algorithm used in this research is a Haar-like feature-based object detection system. The results of the detection process will be displayed by the system using the display screen. The software designed in this study was built using the Python programming language.

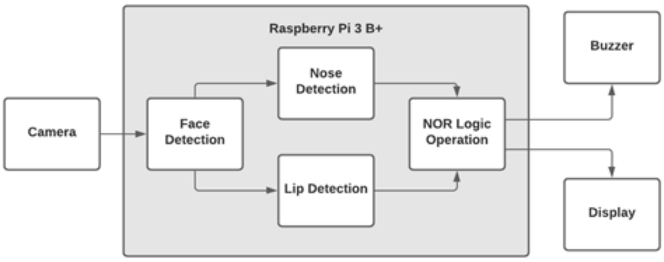

Figure 1. Block diagram of the system

2.2. Hardware Design

Dealing with the spread of the COVID-19 virus, technology that implements artificial intelligence is needed to assist government programs in suppressing the spread of COVID-19. The technology that is built is expected to be easy to implement, have a direct impact on the community and have a low cost. The design of a mask detection system at a relatively low cost uses hardware such as a 5-megapixel camera, Raspberry Pi 3 model B+, and a monitor screen used by admins to monitor users who do not comply with the rules for using masks in public places. The hardware design block diagram can be shown in Figure 2.

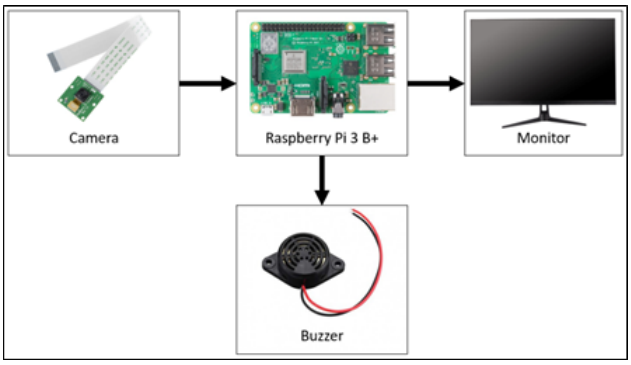

Figure 2. Hardware design

The camera shown in Figure 2 has the following specifications, the camera has an integrated 5647 OmniVision image sensor, the camera module produces 5-megapixel images and produces video with 1080p HD resolution at 30fps. The interface used on the camera is a 15 pin camera serial interface [20]. The Raspberry Pi 3 Model B+ is a mini-computer produced by Raspberry Pi Foundation. The specifications of the Raspberry Pi 3 Model B+ are that it has a Broadcom BCM2837B0 processor, Cortex-A53 (ARMv8) 64-bit SoC with 1.4GHz RAM. Memory 1GB LPDDR2 SDRAM [21].

2.3. Software Design

Haar algorithm is a method that uses statistical in face detection. The method uses sample haar-like features [18]. The haar-like feature is one of the algorithms in image processing that is generally used for face recognition by learning to recognize parts of the face such as eyes, nose, and lips [19]. This method was first introduced by Viola and John in 2001 [22] [23] by creating an algorithm that is used to detect objects quickly based on the value of the feature not based on the pixel value of the entire image. Haar feature classification is the most important part of the face detection process. There are two types of images that are needed in the image data training process, namely positive images and negative images. A positive image contains an image of a face and a negative image contains an object other than the face or other than the object to be recognized [24]. The positive image that has been obtained will be selected based on the haar wavelet feature. The haar feature is to classify positive images into squares with light and dark areas as shown in Figure 3. The result of each feature is to divide the dark areas into bright areas as shown in equation 1.

$$P(x) = \frac{\text{Sum of dark areas}}{\text{Sum of bright areas}} \tag{1}$$

Figure 3. Haar-like features

The input of the system is a digital image which is frame by frame from a video stream taken by the camera. The image has an RGB (Red Green Blue) color space so it needs to be converted to a grayscale image for the haar-like feature extraction process. From the grayscale image, the face detection process is carried out based on the haar-like feature. If no face is detected, the system will return to take the next frame as input. And if a face is detected, the next process is cropping the image so that it produces a smaller image with only facial components. From the cropped image, the process of detecting two facial features is carried out, namely the nose and lips. If one or both of these features are detected, the system will detect that the target is not wearing a mask. On the other hand, if these two features are not detected, the system will detect that the target is wearing a mask. The design of the algorithm to detect the use of masks using the haar Like feature method can be shown in Figure 4.

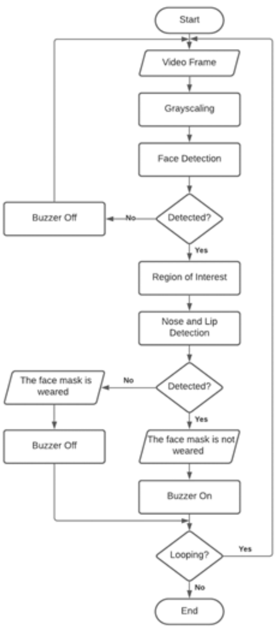

Figure 4. Flowchart of the system

3. RESULT AND ANALYSIS

3.1. Face Mask Detector Tools

After designing the hardware and software, the results of the design are implemented into a mask detector tool. The mask detector system tool consists of several components, namely Camera, Raspberry Pi-3, Buzzer, and Monitor. The results of a series of mask detector system tools can be shown in Figure 5.

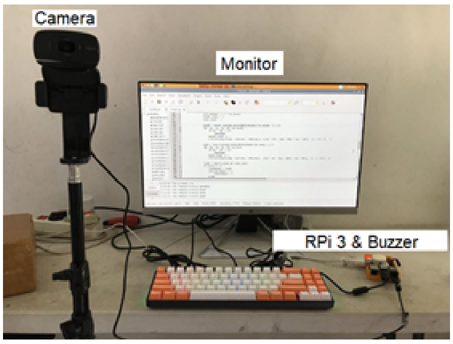

Figure 5. Face mask detector hardware

3.2. Distance Measurement of Face, Nose and Lip Detection

This test was conducted to determine the optimal distance from the system to detect the face, nose, and lips. The testing process is carried out by placing the face in front of the camera with a distance of 30cm to 120cm and a light intensity of 80 lux. The results of the detection distance and lip test are attached in Table 1.

Table 1. Distance measurement results

No	Distance (cm)	Face Detection	Nose Detection	Lip Detection
1	30	Detected	Detected	Detected
2	40	Detected	Detected	Detected
3	50	Detected	Detected	Detected
4	60	Detected	Detected	Detected
5	70	Detected	Not Detected	Detected
6	80	Detected	Not Detected	Not Detected
7	90	Detected	Not Detected	Not Detected
8	100	Detected	Not Detected	Not Detected
9	110	Detected	Not Detected	Not Detected
10	120	Detected	Not Detected	Not Detected

Based on the test results, the system can perform the face detection process at a distance of 30cm to 120cm. For the nose detection process, the system can do it at a distance of 30cm to 60cm. Meanwhile, at a distance of 70cm to 120cm, the system cannot perform the nose detection process. For the lip detection process, the system can do it at a distance of 30cm to 70cm. While at a distance of 80cm to 120 cm, the system cannot perform the lip detection process. The optimal distance to perform the face, nose, and lip detection process is no more than 50cm. The process of face, nose, and lip detection can be seen in Figure 6.

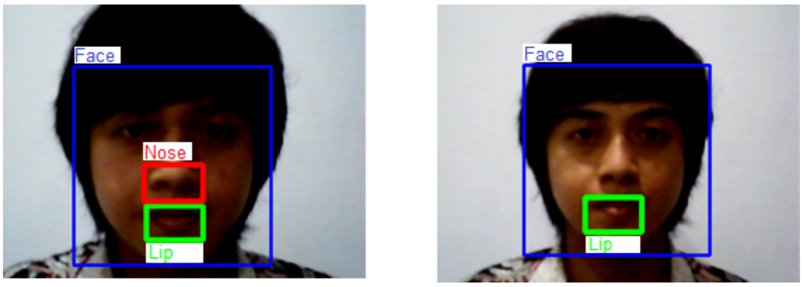

Figure 6. Face, Nose, and Lip detection: 1) At 50cm., 2) At 70cm

3.3. Experiment of Light Intensity Effect

The intensity of light in an image is very influential in the image processing process. If the image has a low light intensity, it can cause parts of the image to be detected to be blurred. This test was conducted to determine the effect of light intensity on the face, nose, and lips detection process. The instrument for measuring the intensity of light uses a lux meter. The testing process is carried out by placing the face in front of the camera with a distance of 50cm and a light intensity of 20 lux to 140 lux. The process of detecting the face, nose, and lips with a light intensity of 140 lux can be seen in Figure 7. The results of the detection distance and lip testing are attached in Table 2.

Table 2. Light Intensity Effect Experiment Results

No	Light Intensity (lux)	Face Detection	Nose Detection	Lip Detection
1	20	Detected	Not Detected	Not Detected
2	40	Detected	Not Detected	Not Detected
3	60	Detected	Not Detected	Detected
4	80	Detected	Detected	Detected
5	100	Detected	Detected	Detected
6	120	Detected	Detected	Detected
7	140	Detected	Detected	Detected

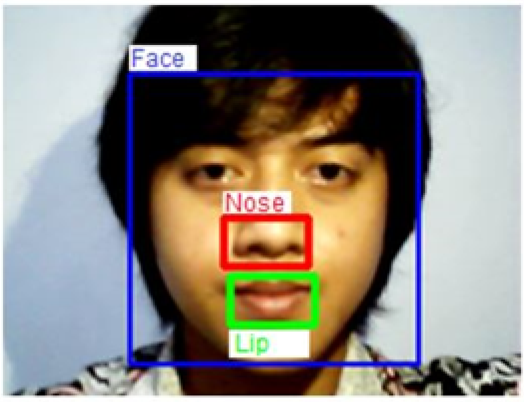

Figure 7. Face, nose, and lip detection at 140 lux

Based on the test results, the system can perform the face detection process at a light intensity of 20 lux to 140 lux. For the nose detection process, the system can do it at a light intensity of 80 lux to 140 lux. Meanwhile, at a light intensity of 60 lux and below, the system cannot perform the nose detection process. For the lip detection process, the system can do it at a light intensity of 60 lux to 140 lux. Meanwhile, at a light intensity of 40 lux or below, the system cannot perform the lip detection process. From these results, it is known that the intensity of light can affect the detection process.

3.4. Face Mask Detection Experiment

This test is carried out to determine the effectiveness of the detection process for the use of masks by the system that has been designed. The testing process is carried out by placing the face using a mask and without using a mask in front of the camera. The testing process can be shown in Figure 8.

Figure 8. Face mask detection experiment results

In the tests that have been carried out, the nose and lip detection process is needed as a reference that the target is wearing a mask or not. The image resolution processed in each experiment was 480 360 pixels using a Raspberry Pi 3 Model B+ as an image processor and capable of processing at an average speed of 5 fps. Whereas in previous studies it only reached 0.33 fps. There are studies with a process speed of 20 fps but these studies are not suitable for low cost systems because the manufacturing costs are quite expensive. There are 9 test results data. from the test results, there is 1 test result that is incorrectly detected of the face mask so that the test results obtained a success rate of 88.89%.

4. CONCLUSION

Based on the results of the research that has been carried out, it can be concluded that the system that has been designed is capable of detecting the face, nose, and lips at a light intensity of 80 lux to 140 lux with a detection distance of 30cm to 120cm for the face detection process, 30cm to 60cm for the face detection process. nose, and 30cm to 70cm for lip detection. The nose and lip detection process is needed as a reference that the target is wearing a mask or not. If the nose and lips are not detected on the face, then the target is classified as wearing a mask. If one of the nose or lips is detected or both are detected on the face, then the target is classified as not wearing a mask. The system that has been designed can perform the detection process at a speed of 5 fps. The overall test results obtained a success rate of 88.89%. For comparison, there is research that provided an accuracy of 98% but cannot be used as a real-time system because it had a processing speed of 0.33 fps. There are also researches that provided high accuracy with a processing speed of around 20 fps but use hardware at a very expensive price so it cannot be said to be a low-cost system. Therefore, this research provides an algorithm that is suitable to be implemented as a low-cost real-time system.

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