A MICROCONTROLLER-DRIVEN ENTRANCE GATE TO COMBAT RESPIRATORY VIRUS SPREAD

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Abstract*—Respiratory illnesses, including COVID-19, continue to be a significant public health concern worldwide. In this regard, public health organizations provide preventative measures, such as wearing masks, and practicing good hand hygiene, to help control the spread of respiratory illnesses. However, existing preventive measures may not be fully effective in ensuring compliance, especially in dispersed economic conditions, leading to continued risks of respiratory virus spread in public spaces. To address this challenge, this study proposes a microcontroller-driven system designed to monitor and regulate entry into public spaces, aiming to reduce the transmission of respiratory illnesses. The system employs a camera, a temperature sensor and an ultrasonic sensor to detect face mask usage, measure body temperature, and track the distance of hands from the sensor for automatic handwashing. Using deep learning method to measure accuracy rates of 0.90, 0.89, 0.89, and 0.89 for detecting face masks, precision, recall, and F1 score, respectively, and an accuracy of 99.18% in measuring body temperature. The system has the potential to enhance public safety significantly. The automatic door opening feature, triggered only when a person is wearing a mask, has an average body temperature, and has washed their hands automatically, adds to the system's efficacy. The system's ability to detect and respond to non-compliance with safety measures can help promote adherence to public health guidelines and reduce the risk of infection. This study's findings demonstrate the developed system's high potential to contribute to public safety in the era of respiratory viruses.*

Keywords*: safety measures, automatic detection, arduino mega, microcontroller-driven entrance gate*

Intisari— *Penyakit-penyakit yang terkait dengan pernapasan, termasuk COVID-19, masih menjadi perhatian utama kesehatan masyarakat di seluruh dunia. Terkait hal ini, organisasi kesehatan masyarakat telah menyediakan langkah-langkah pencegahan, seperti menggunakan masker dan menjaga kebersihan tangan untuk membantu mengendalikan penyebaran penyakit tersebut Namun, langkah-langkah pencegahan yang ada belum sepenuhnya efektif dalam memastikan kepatuhan yang mengarah pada risiko penyebaran virus pernapasan yang terus berlanjut di ruang publik. Untuk mengatasi tantangan ini, penelitian ini mengusulkan sistem berbasis mikrokontroler yang dirancang untuk memantau dan mengatur akses masuk ke ruang publik, yang bertujuan untuk mengurangi penularan penyakit pernapasan. Sistem menggunakan kamera, sensor suhu dan sensor ultrasonic untuk mendeteksi penggunaan masker wajah, mengukur suhu tubuh, dan melacak jarak tangan dari sensor untuk pencucian tangan otomatis. Dengan metode deep learning untuk mengukur akurasi deteksi masker wajah presisi, recall, dan F1 score masing-masing sebesar 0,90, 0,89, 0,89, dan 0,89, serta akurasi pengukuran suhu tubuh sebesar 99,18%. Sistem ini berpotensi untuk meningkatkan keamanan dari penularan penyakit pernafasan. Efektifitas sistem ini didukung oleh adanya fitur pembuka pintu otomatis yang hanya akan aktif ketika seseorang mengenakan masker wajah, memiliki suhu tubuh rata-rata dan telah mencuci tangan secara otomatis. Kemampuan sistem untuk mendeteksi dan merespons ketidakpatuhan terhadap langkah-langkah pencegahan, dapat membantu meningkatkan kepatuhan terhadap protokol kesehatan dan mengurangi risiko infeksi. Temuan dari penelitian ini menunjukkan potensi yang sangat tinggi dari sistem yang dikembangkan untuk berkontribusi pada keamanan masyarakat di saat maraknya virus pernapasan.*

Kata Kunci*: langkah pencegahan, deteksi otomatis, Arduino mega*

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INTRODUCTION

The COVID-19 pandemic has brought respiratory viruses to the forefront of public health concerns worldwide. Since its emergence in late 2019, the virus has spread rapidly across the globe, causing widespread illness, hospitalizations, and deaths. While COVID-19 has received the most attention recently, it is not the only respiratory virus [1] threatening public health. Influenza, for example, has been responsible for numerous pandemics throughout history [2] and continues to circulate yearly. Other viruses, such as respiratory syncytial virus (RSV) [3] and rhinovirus [4], are common causes of respiratory illness.

In tropical countries like Indonesia, factors such as high humidity, crowded living conditions, and poor sanitation can contribute to the spread of respiratory viruses. These factors can also exacerbate the severity of respiratory illnesses, as individuals with pre-existing health conditions may be more vulnerable to complications from viral infections [5]. For example, dengue fever, a mosquito-borne viral illness commonly found in tropical countries, can weaken the immune system and make individuals more susceptible to respiratory viruses [6]. In addition, chronic lung diseases, such as asthma and chronic obstructive pulmonary disease (COPD), are prevalent in tropical regions and can increase the risk of severe illness from respiratory viruses [7].

In the face of these ongoing threats, it is essential to implement measures to prevent the transmission of respiratory viruses. Safety measures [8], such as wearing face masks practicing good hand hygiene, and maintaining physical distancing, have been recommended by public health experts to help prevent the spread of respiratory viruses. However, enforcing safety measures to ensure adherence to safety protocols can be challenging, especially in public spaces where individuals may be less likely to comply with recommended measures.

Fortunately, there are several ways to promote compliance with safety measures and enforce adherence to safety protocols. One approach is to leverage technology, such as mobile apps or wearable devices [9]. For example, some organizations have implemented contact tracing apps to help track potential exposures to respiratory viruses. Wearable devices, such as smartwatches or fitness trackers, can also provide reminders to wear masks or maintain physical distancing. Enforcing safety measures using mobile apps or wearable devices may not be effective in societies with disparsed economic conditions. One logical reason is that access to technology may be limited, especially for individuals who cannot afford smartphones or wearable devices. Additionally, data privacy [10] and surveillance concerns may deter some individuals from using technology-based solutions to enforce safety measures.

Previous research has investigated various technologies to mitigate the spread of respiratory viruses such as Covid-19. One study focused on a mask detection and attendance tool using the YOLO method at an automatic office door based on a Single Board Computer [11]. However, the study had limited diversity in the face and mask datasets, which could affect detection results. Another study implemented human body temperature measurements using an LM35 temperature sensor [12]. The sensor, however, requires direct physical contact with the subject, which may not be suitable for respiratory viruses that are highly communicable. Apart from that, the sensor can accurately measure body temperature only when placed on the forehead or underarm of the human body. In the third study, the researchers designed an automatic body temperature measurement and hand sanitizer tool based on the Internet of Things (IoT) using an Infrared sensor [13]. However, the Infrared sensor's accuracy in detecting hand distance was limited due to sunlight exposure, mainly when used outdoors. Finally, a study implemented an automatic door barrier based on body temperature and an automatic hand sanitizer dispenser [14] While the study involved three stages in detecting visitors entering, measuring body temperature, dispensing hand sanitizer, and opening the door barrier based on standard body temperature readings, it had limitations in not detecting mask usage and still using a buzzer for notification, which could be disruptive for some individuals.

This research proposes an alternative solution to tackle economic disparities among individuals by implementing an automated system. The system is designed to conduct face mask compliance checks, mandate hand sanitizing, and perform temperature checks before granting entry to a building or room. By implementing such a system, accessibility and affordability can be improved for individuals of diverse economic backgrounds. This solution not only enhances public health and safety but also addresses the issue of economic disparities, making it a promising avenue for creating more equitable communities.

MATERIALS AND METHODS

In an effort to prevent the spread of the virus, many public spaces have implemented new measures, such as mandatory mask-wearing and hand sanitizing. One such measure is installing a gate system, such as the entrance of a public area. In this study, we used an Arduino board with various sensors to collect images, temperature, and distance of hand position to trigger the system to act as it intended. In addition, we also utilize Raspberry Pi to provide the computing capacity required for image detection and classification using deep learning method.

The equipment and materials used in this study included an Arduino Mega2560 board [15], an MLX90614 temperature sensor, a DS18B20 temperature sensor, a webcam, a DC pump, an HC-SR04 Ultrasonic sensor, servo motor, an MP3 Mini DFplayer module, an LCD, and a breadboard. We used the Arduino Integrated Development Environment (IDE) to program the board and collect sensor data. Besides we also use MobileNetV2 and OpenCV. Specification of the Arduino Mega2560 and MLX90614 is shown in Table 1 and Table 2, accordingly.

Table 1. Arduino Mega2560 Specification

Num.	Element	Specification
1	Microcontroller	ATMega 2560
2	Operating voltage	5V
3	Input voltage (recom.)	7 – 12V
4	Imput voltage(limit)	6 – 20V
5	Digital I/O Pins	54 (15 PWM output)
6	Analog input pins	16
7	DC current for I/O pin	40 mA
8	DC current for 3.3V pin	50 mA
9	Flash memory	256 KB
10	SRAM	8 KB
11	EEPROM	4 KB
12	Clock Speed	16 MHz

Table 2. MLX90614 Datasheet

Num	Element	Specification
1	Operating temperature range	-40^{0}C – 125^{0}C
2	Object temperature range	-70^{0}C – 380^{0}C
3	Accuracy	+/-0.5^{0}C at room temperature +/0.1^{0}C for medical version
4	Resolution	10 bit PWM for 0.01^{0}C LSB internal
5	Operating voltage	3 - 5V

The gate system is similar to a typical parking lot gate, with a crossing bar that blocks the entrance to the area. However, this system is equipped with sensors that detect whether the person attempting to enter meets specific requirements, such as wearing a face mask, washing their hands, and having an average body temperature. If all requirements are met, the bar will lift automatically, allowing the person to enter. This gate system provides an added layer of protection for individuals visiting public spaces, ensuring that only those who meet the required safety protocols are permitted to enter. The general design of the system is shown in Figure 1.

We used an Arduino Mega board with 54 digital input/output pins, serving as our system's central control unit. The board was programmed using the Arduino Integrated Development Environment (IDE) and connected to a personal computer for programming and data transfer. We used a 5V power supply to power the board and connected it to the computer's USB port for programming. In addition to the Arduino board, we used a Raspberry Pi to process real-time face and mask detection captured by a webcam. The webcam captured images of a person's face and mask, while the Raspberry Pi processed the images using the OpenCV library and MobileNetV2 in Python.

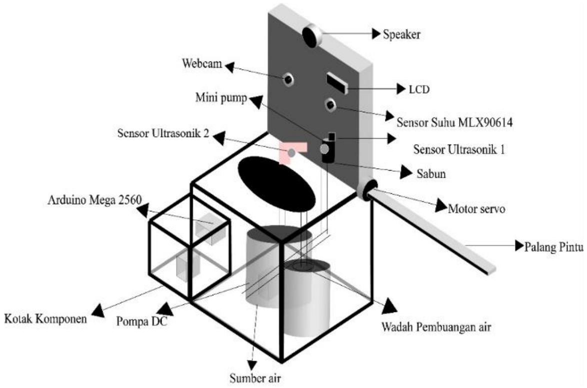

Figure 1. General System Design

First, for temperature sensing, we used an MLX90614 digital temperature sensor with a 1-Wire interface connected to the digital pin 2 of the Arduino board. We used a voltage divider circuit with a 10k ohm resistor to measure the temperature in Celsius non-invasively. Second, we used a USB camera with a 5-megapixel resolution for image capture, which was connected to the computer's USB port. We used the OpenCV library in Python to capture images from the camera and process them for object detection. We also used an ultrasonic sensor to detect a person's hand movement. The sensor was connected to the Arduino board and detected when a person's hand was near the system. To pump water out of the system, we used a DC pump. The pump was connected to the Arduino board and used to pump water out of the system when necessary. A servo motor was used to open and close the gate. The motor was connected to the Arduino board and used to open the gate when a person with a mask and average body temperature was detected. An LCD was used to display the body temperature measurement results. The display was connected to the Arduino board and showed the temperature reading of the person. In addition to

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these components, we also used a breadboard to connect the components and several jumper wires to create the necessary connections. The relations among the component mentioned above are shown in Figure 2.

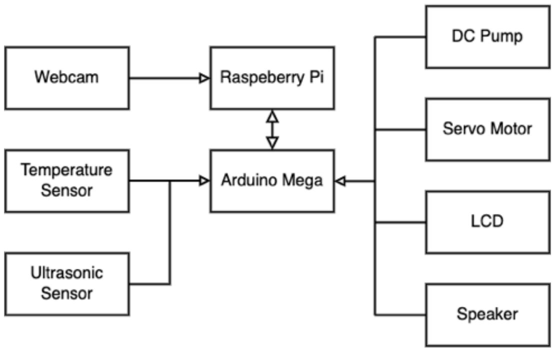

Figure 2. System Block Diagram

RESULTS AND DISCUSSION

In this section, we present our study's results involving Arduino, camera, temperature sensor, and ultrasonic sensor in conjunction with deep learning techniques for face detection and clasification. We will discuss the implications of these findings and their potential applications to promote compliance in safety measures. Additionally, we will highlight the limitations of our study and suggest areas for future research.

(a) Front View (b) Side View

Figure 3. The implemented system

The implementation of this system is shown in Figure 3. The system operation is supposed to start by the detection of masks using a webcam. If a person is detected not wearing a mask, a notification is played through the speaker, prompting them to wear one. After the person has put on their mask, the system checks their body temperature using an MLX90614 temperature sensor. If the person's body temperature is above 37.5°C, the speaker will play another notification. Following the temperature check, the person's hands are washed by placing them near an ultrasonic sensor that triggers a DC pump to push water out. Once all the health protocols have been followed, the servo motor is activated to lift the bar. Thus, the crossing bar will not be lifted if health protocols are not completed.

In order to ensure that the designed system operate as intended, as set of tests were conducted. The first test aimed to evaluate the accuracy of the MLX90614 temperature sensor by calibrating it using a digital thermometer. The sensor was calibrated within the 2-5 cm range to obtain more accurate readings. The calibration process involved calculating the average sensor value closest to the normal temperature, which was found to be 32.60°C before calibration.

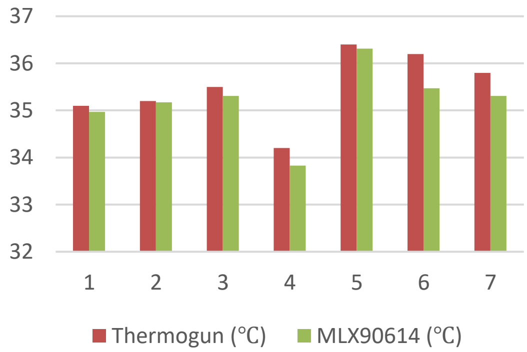

Figure 4. The temperature measurement comparison

Based on the test results, shown in Fig. 4, it can be concluded that the MLX90614 sensor's readings were comparable to those obtained using a Thermogun, with an average difference of 0.29 and an average sensor accuracy of 99.18%. However, environmental factors could affect body temperature and alter the quality comparison results, as the temperature tolerance ranges from 0.5-1.5°C.

Testing was also conducted to ensure that the ultrasonic sensor capable of sensing the existence of hand before activating washing hand facility. The testing aims to discover how long the distance of hand can be detected by the sensor. The result can be seen in Figure 5. Based on the Figure, it can be concluded that the comparison results from the ultrasonic sensors are not significantly different from measurements using manual measuring tools such as rulers or meters, with an average percentage error of 0.76%. However, it is essential to note that these results may be affected by environmental conditions and the quality of the equipment used. Therefore, further testing may be required to ensure accuracy and reliability. Additionally, exploring the potential advantages and limitations of using ultrasonic sensors over

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traditional measuring tools in different contexts and applications may be beneficial.

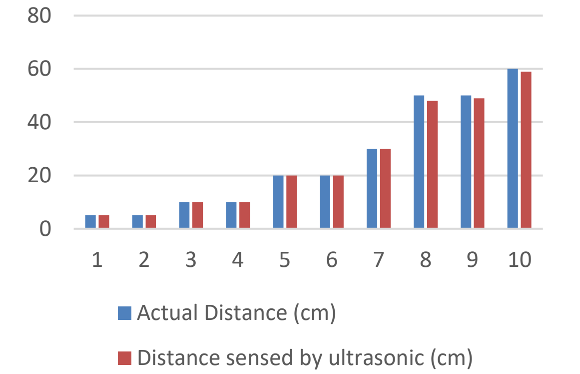


Figure 5. The ultrasonic capability of sensing distance of the hand

To provide a capability of detecting and classifying image, we use MobileNetV2 and train a model over Face Mask Dataset from Kaggle.com consisting of 7553 face images grouped into two classes; 3725 images with masks and 3828 images without masks. In addition to that, we also used five self-captured images with masks and 20 images without a mask. As shown Figure 6, the training and validation accuracy of the dataset exhibit promising results at Epoch two and reach stability by Epoch 5. Similarly, training and validation loss decrease at epoch two and stabilize by epoch 5. After training the dataset with an 80/20 split for training and testing, respectively, the model was evaluated using a classification report to obtain the evaluation results. In particular, the accuracy, precision, recall and F1-score is > 0.90.

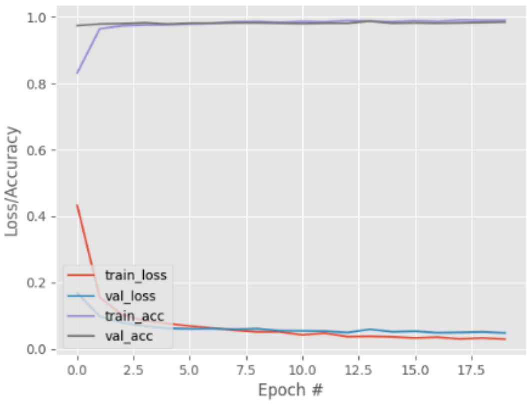


Figure 6. Training Loss and Accuracy

Several tests were conducted concerning detecting and classifying faces with or without masks. The first test determines the system's ability to detect faces from various angles, ranging from 0 to 180 degrees. Some of the test results can be seen in Table 3. It can be concluded that faces without masks can be detected at all tested angles. However, faces with masks at 0 degrees and 180 degrees angles cannot be seen.

Furthermore, the test was conducted to determine the extent to which the system can detect the facial object. The testing was conducted indoors with sufficient lighting, and the testing distance ranged from 50 cm to 3 meters. The experiment shows that the system can detect faces at distances ranging from 50 cm to 3 meters. However, at a distance of 3 meters when a person wears a mask, the system cannot detect the face due to the dataset collection process, where a distance makes facial features unclear, resulting in the face not being recognized and the mask not being detected.

Thirdly, the testing was conducted to evaluate the mask classification capability of the system. This test aimed to determine the system's accuracy in classifying faces with and without masks. The test was conducted 40 times under different conditions, such as facing right or left and covering the nose and mouth with other objects. The results of the face mask detection test were included in a confusion matrix in Table 4, which provides information on True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN) results. Based on the information above, calculations were performed to determine the accuracy, precision, recall or sensitivity, and F-1 Score, presented in the following confusion matrix table. From Table 4, it can be seen that the values for True Positive (TP) are 16, True Negative (TN) is 20, False Positive (FP) is 2, and False Negative (FN) is 2. These data were then used in mathematical calculations to obtain the accuracy, precision, recall, and F1-score values. The accuracy of the face detection with masks from 40 experiments was 0.9. The precision calculation, which measures the level of correct predictions, resulted in a value of 0.89 from 40 experiments. The recall or sensitivity calculation, which measures the proportion of true positive results compared to the actual positive labels, resulted in a value of 0.89 from 40 experiments. The F1 Score, the harmonic mean of precision and recall, also yielded a value of 0.89.

Table 3. Face or mask detection's angle testing

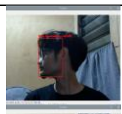
Trial Num.	Angle	State	Meaning
1	0^0		Face is detected
4	90^0		Face is detected
10	60^0		Face mask is detected

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Table 4. Confusion Matrix

N=40	Actual Positive(1)	Actual Negative(0)
Prediction Positive (1)	True Positive = 16	False Positive = 2
Prediction Negative (0)	True Negative = 20	False Negative = 2

Table 5 . Overall system testing

Trial Num.	Face mask used	Temp. (^{0}C)	DC Pump	Servo Status	Sequence of Speaker Output
1	Yes	35.67	Active	Opened	Correct
2	No	Inactive	Inactive	Closed	Correct
3	Yes	35.47	Active	Opened	Correct
4	Yes	36.21	Active	Opened	Correct
5	Yes	37.81	Inactive	Opened	Correct
6	No	Inactive	Inactive	Closed	Correct
7	Yes	38.21	Inactive	Opened	Correct
8	Yes	35.70	Active	Opened	Correct
9	Yes	34.97	Active	Opened	Correct
10	Yes	35.31	Active	Opened	Correct

Finally, the overall system testing and analysis are conducted to determine if the system can function adequately according to pre-determined functional and non-functional requirements. The results of the testing can be seen in Table 5. It shows that the system can detect whether someone is wearing a mask. If not, the system will notify the speaker to wear a mask, and the other components in the subsequent process, such as the MLX90614 temperature sensor, DC pump, and servo, will not be activated. Furthermore, if the system detects someone wearing a mask, the temperature sensor will be activated to catch the person's body temperature. If the person's body temperature is high, i.e., above 37.5 °C, the system will notify the speaker that the body temperature is high. Other system components, such as the DC pump and servo, will not be activated. However, if the person's body temperature is below 37.5 °C, other system components, such as the DC pump and servo, will be started. The table also indicates instances where the speaker occasionally does not provide notifications.

CONCLUSION

The system can detect face mask usage with accuracy, precision, recall, and F1 score of 0.90, 0.89, 0.89, dan 0.89, respectively. Additionally, the system can measure body temperature with an accuracy of 99.18% and the distance of hands from the sensor for automatic hand washing by an error rate of 0.76%. However, further research and validation under real-world conditions are needed to confirm its effectiveness in reducing the spread of respiratory illnesses and promoting compliance with public health guidelines. Overall, the developed system represents a promising solution to the challenges posed by respiratory viruses and has the potential to play a critical role in ensuring public safety in the future.

REFERENCE

[1] C. C. Wang *et al.*, “Airborne transmission of respiratory viruses,” *Science (1979)*, vol. 373, no. 6558, p. eabd9149, 2021.

[2] M. E. Nickol and J. Kindrachuk, “A year of terror and a century of reflection: perspectives on the great influenza pandemic of 1918–1919,” *BMC Infect Dis*, vol. 19, pp. 1–10, 2019.

[3] M. B. Battles and J. S. McLellan, “Respiratory syncytial virus entry and how to block it,” *Nat Rev Microbiol*, vol. 17, no. 4, pp. 233–245, 2019.

[4] H. Ortega, D. Nickle, and L. Carter, “Rhinovirus and asthma: Challenges and opportunities,” *Rev Med Virol*, vol. 31, no. 4, p. e2193, 2021.

[5] S. Caini *et al.*, “The epidemiology and severity of respiratory viral infections in a tropical country: Ecuador, 2009–2016,” *J Infect Public Health*, vol. 12, no. 3, pp. 357–363, 2019.

[6] O. L. Agudelo Rojas, M. E. Tello-Cajiao, and F. Rosso, “Challenges of dengue and coronavirus disease 2019 coinfection: two case reports,” *J Med Case Rep*, vol. 15, no. 1, pp. 1–6, 2021.

[7] M. Varmaghani, M. Dehghani, E. Heidari, F. Sharifi, S. S. Moghaddam, and F. Farzadfar, “Global prevalence of chronic obstructive pulmonary disease: systematic review and meta-analysis,” *East Mediterr Health J*, vol. 25, no. 1, pp. 47–57, 2019.

[8] L. Martinelli *et al.*, “Face masks during the COVID-19 pandemic: a simple protection tool with many meanings,” *Front Public Health*, vol. 8, p. 606635, 2021.

[9] A. Channa, N. Popescu, J. Skibinska, and R. Burget, “The rise of wearable devices during the COVID-19 pandemic: A systematic review,” *Sensors*, vol. 21, no. 17, p. 5787, 2021.

[10] H. Cho, D. Ippolito, and Y. W. Yu, “Contact tracing mobile apps for COVID-19: Privacy considerations and related trade-offs,” *arXiv preprint arXiv:2003.11511*, 2020.

[11] P. E. Masudia, M. Kusumawardhani, D. Marya, K. Varadiba, and M. E. Bagaskara, “Rancang bangun sistem deteksi suhu tubuh dan hand sanitizer nirsentuh pada

prototype pintu geser otomatis," *JURNAL ELTEK*, vol. 19, no. 2, pp. 17–24, 2021.

[12] U. Achlison, "Analisis Implementasi Pengukuran Suhu Tubuh Manusia dalam Pandemi Covid-19 di Indonesia," *Pixel: Jurnal Ilmiah Komputer Grafis*, vol. 13, no. 2, pp. 102–106, 2020.

[13] Y. Hendrian, "Perancangan Alat Ukur Suhu Tubuh dan Hand Sanitizer Otomatis Berbasis IOT," *Jurnal Infortech*, vol. 3, no. 1, pp. 33–39, 2021.

[14] Y. Adinata, K. Gunadi, and I. Sugiarto, "Aplikasi Deteksi Jumlah Orang pada Area Indoor Untuk Mendukung Pelaksanaan PPKM dengan Metode YOLO," *Jurnal Infra*, vol. 10, no. 1, pp. 135–141, 2022.

[15] R. Teja, "Arduino Mega Pinout| Arduino Mega 2560 Layout, Specifications," *Electronics Hub*, vol. 20, 2021.