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Utilization of eye tracking technology to control lights at operating room

Asyraf Permana[1], Diah Rahayu Ningtias[2]

[1,2]Department of Electromedical Engineering, Sekolah Tinggi Ilmu Kesehatan Semarang, Indonesia

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ABSTRACT

The development of technology for control systems is increasing, especially to help people with disabilities and facilitate the performance of health workers. Where it is required to maintain the level of sterilization of equipment in hospitals. Eye tracking technology in the last few decades has developed very rapidly. This control system using eye tracking technology can be done with eye movements for those who experience mobility problems. This research aims to develop a light control system through eye activity using the Mediapipe framework from Google. In this study, 2 lamps (A and B) were used, each with a light intensity of 10W. In lamp A, the light intensity can be controlled by turning the light on or off using the blink of the right eye and the blink of the left eye, while lamp B can adjust the intensity of the light by opening both eyes (right and left). Research on a lighting control system using the eye tracking method with an image processing system has been successfully carried out. All data generated is based on activity, distance, eye position on the camera and differences in participant backgrounds.

Corresponding Author:

Diah Rahayu Ningtias
Department of Electromedical Engineering
Sekolah Tinggi Ilmu Kesehatan Semarang
Jalan Kolonel Warsito Sugiarto KM 2,5 Sadeng, Gunungpati, Semarang, Indonesia
Email: diahrahayuningtias@stikessemarang.ac.id
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1. INTRODUCTION (10 PT)

Development of eye movement recording technology and increasingly accurate eye detection methods, research in the field of eye tracking has begun to move into other scientific fields, such as medicine [1]. By knowing human eye movements, we can estimate whether a person suffers from abnormalities in the balance system or detect certain diseases. Eye tracking research to detect abnormalities in the human balance system is known as diagnostic eye tracking or medical eye tracking [2]. Recent studies of eye movements in reading and other information processing, such as music reading, typing, visual search. The main emphasis of this review is on reading as a specific example of cognitive processing. In previous research, to help the mobility of people with disabilities, a wheelchair was created that could be activated by the brain, speech control and eye control which included electrooculography technology [3]. Control systems using eye tracking technology have also spread to medical devices, for example to open or close operating room doors. In this study, eye tracking was used to control operating room lights, so that they could be turned on, off and their intensity adjusted just using eye movements.

Operating room lighting is one of the important things that can help the success of the operation. Good lighting settings can ensure the operating area is clearly visible, while also helping the medical team to work more efficiently. Eye tracking technology innovations can help doctors and medical teams during the operation process to turn on, turn off, or adjust the intensity level of lights in the room. The manual lighting control systems that are currently widely used can often disrupt work flow during operational procedures. By implementing an eye tracking system in the operating room light control, it is possible to detect eye movements to control the device hands-free so that it is more efficient. Eye tracking based control system can use Python. Python is the right choice for developing eye tracking-based applications because of its ability to integrate libraries such as OpenCV [4], which allows image processing and pattern recognition in real time. OpenCV is proven to be effective in tracking eye movements. Apart from that, other libraries in Python also make it easier to develop machine learning algorithms that can increase the accuracy of tracking systems.

Previous research shows that gesture tracking-based light control has been successfully implemented and proven by users. Therefore, this research provides software facilities that have a good accuracy with minimal problems and only uses desktop cameras to track participant movements. An operating room light control system based on gesture tracking using an RGB-D camera has been proven to be used effectively, with a tracking error rate that does not significantly affect smooth light control [5]. In addition, eye tracking-based control systems have also been tested in various other applications, such as human-computer interaction and surgical operations. Other research shows that eye movement-based control can be used effectively in computer interactions, allowing for more natural and efficient [6]. This system shows great potential in reducing manual intervention in operations.

The purpose of this study is to assist the performance of surgeons when performing surgery and requiring the lights in the operating room to be turned off, because doctors want to utilize direct lighting from the medical equipment being used. With that, doctors can be flexible in controlling the operating environment and maintaining the level of sterility in patients. Eye tracking software can be placed next to the doctor's operating table so that doctors can freely reach the software. In the future, the contribution of the development of the eye tracking method will not only be to control something but can also be used to diagnose a health problem non-invasive.

2. METHOD

Eye tracking is the development of eye movement recording technology using the eye detection method. Research in the field of eye tracking has begun to penetrate other scientific fields, such as the medical and automotive fields. By knowing the position and movement of the human eye, we can control something based on the movement of the eye [7]. Examples of the use of eye tracking in the medical field include open or closed operating room doors, controlling operating room lights, and open or closed trash bins in hospitals [8]. One of the studies related to the eye tracking system is operating an electric wheelchair, where the user's eye movements are transferred to the layer using an eye tracking system with optics. However, the results of the study produced a wheelchair that was difficult to control by the eyes [9].

A. Definition of Eye Tracking

With the development of eye tracking technology, we will develop this technology to control operating room lights which are equipped with 2 modes, namely turning on and off, and regulating the intensity of the lights. The first step we need to take is to identify the desired eye movement.

In general, it can be identified by 3 methods. The first is the Scleral Search Coil (SSC) method. This method uses contact lenses and uses an electromagnetic frame to determine the direction of eye movement. This method can provide very accurate measurement graphs, but is tiring for the user and requires expert when installing medical devices [10]. the second is using electro oculography (EOG), this method uses an electrode sensor that is attached around the eyeball, then the electrode will produce a potential difference between the other electrodes [11]. Third, by infrared technique or video oculography (VOG), this method uses image processing, namely measuring the position of the eyeball with infrared light and a camera that is sensitive to the reflection of infrared light [12]. Based on these three methods, we chose to take measurements using image processing using a laptop camera. This is because by doing so we will get measurement results from raw data which will later be processed into the program system.

B. Scheme of Eye tracking

In order for the eye tracking method to control an item to work, participant are needed so that the dtection of eye movements is carried out successfully. In Figure 1 above there are several points regarding the performance scheme for eye tracking. The eye tracking system will detect the user's eye movements using a camera or certain sensors, the system will monitor the user's head movements [14]. For example, swipe left, right, or up and down movements. There are two main areas investigated in the field of computer-based eye tracking, the first is eye location detection and eye gaze direction estimation. The direction of eye gaze can be estimated and then used directly in the software and tracked through the video frame. Data from eye tracking and head movements that have been obtained by the camera will be processed in the system program. The information obtained by the system will be used to control assistive devices such as wheelchairs, communication devices, and light controls.

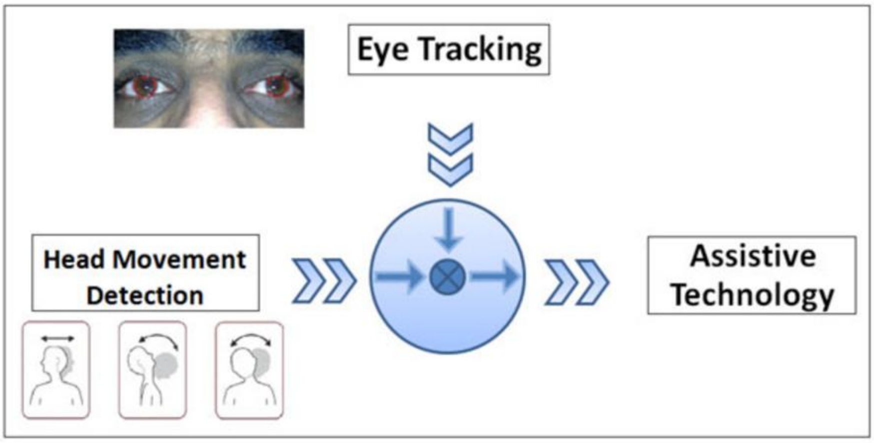

Figure 1. Scheme of eye tracking [13]

C. Eye Tracking Concept in Automatic Light

The eye tracking method requires a camera and monitor to detect the participant's eye movements to control something. That's why In Figure 2, the concept of applying automatic lights using eye tracking, the eye tracking system uses eye activity to control the lights, such as turning the lights on, turning them off, and adjusting the intensity of the light in the lights. The system is divided into 3, namely, the Desktop utilizes the opensource software Visual Studio Code which functions to create a system for processing data (imaging processing) from eye movements captured by the desktop camera, then the participant's eyes become the main input which will be monitored and processed by the system, lights as an output that is controlled by the eye after going through processing in the system that has been created.

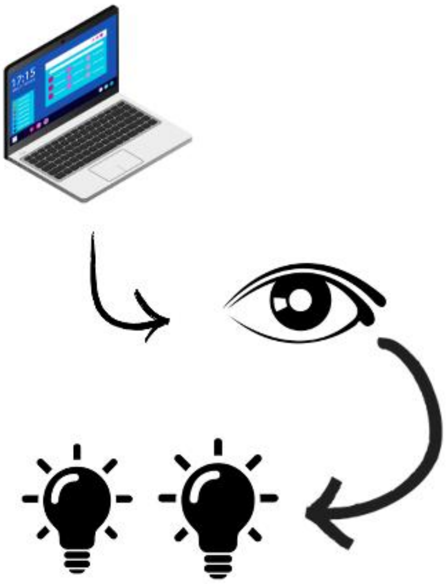

Figure 2. Concept of automatic light with eye tracking

Flowchart is an explanation of the flow when the tool is used The research flowchart can be seen at the Figure 3, which is the utilization of eye tracking to control the lights in the operating room using the python programming language which is started with the identification of landmark of the participants consisting of eyes, lips, and ears. Followed by identifying eye points which will later be processed by data whether the eys are open or closed,

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followed by the selection of mode 1 functions to turn on and off the light, while mode 2 functions to regulate the intensity of the light of the lamp.

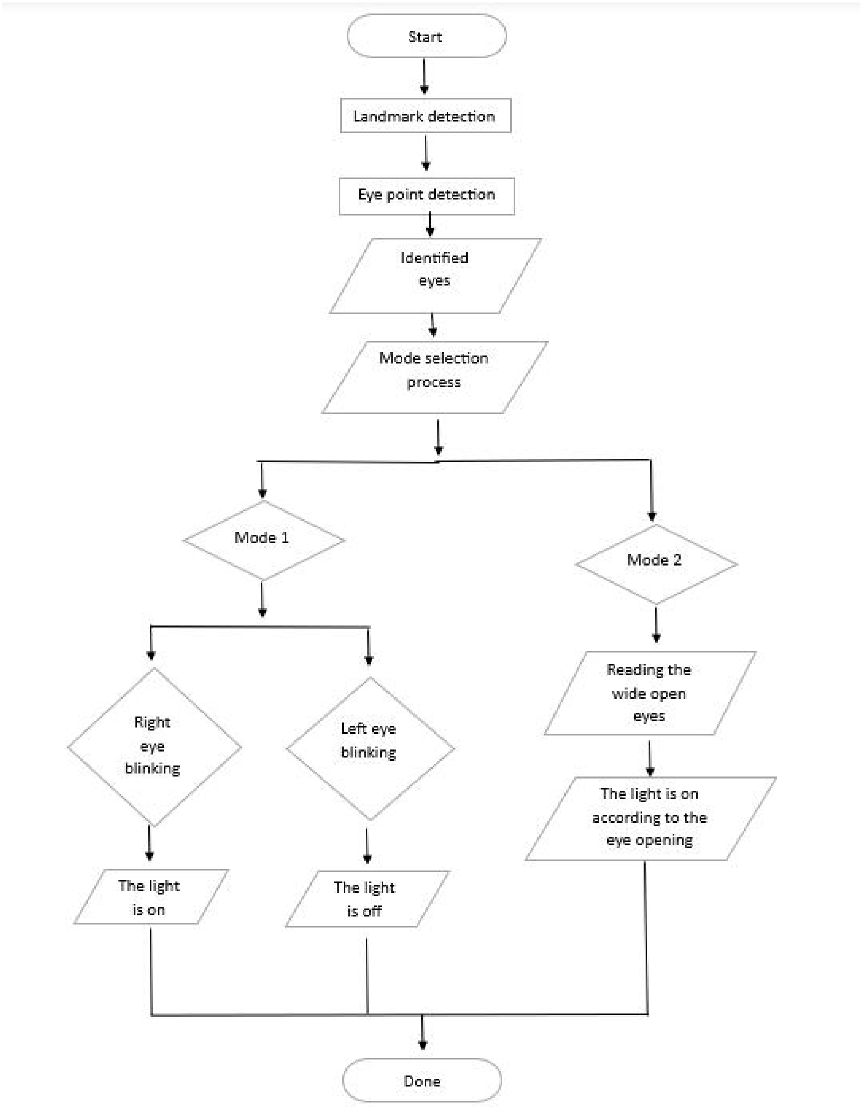

Figure 3. Research flowchart

D. Algorithm

The system process in detecting eye activity to control the light can be seen in figure 3, here is the explanation of each process design:

1. **Start**: Program start.
2. **Facial Landmark**: The program detects faces and landmarks (points on the face) using the camera, using functions
   "*if results.multi_face_landmarks*"
3. **Eye Blink Detection**: The program processes data from facial landmarks to detect whether the eyes are open or closed.
4. **Mode selection process:**
   A. If **mode 1** is selected:
   - **Check the blink of the right eye**:
     In the right eye blinks, the light is on. By using the function
     "*if right eye closed and not light_state*"
   - **Check the blink of the left eye**:
     In the left eye blinks, the light is off. By using the function
     "*elif left eye closed and light_state*"

   The program continues to run to monitor eye activity:

B. If **mode 2** is selected:

- **Read wide open eyes:**
  The program reads the width of the eyes to determine how much the eyes are open.by calculating the average EAR of both eyes, using the function
  "*defadjust light_intensity (left_ear, right_ear)*"
- **Set the light intensity**:
  Based on the width of the open eye, the intensity of the lamp is adjusted. The larger the open eye, the higher the intensity of the light produced by the lamp, by using function
  "*intensity = int(max(0, min(255, (average_ear - 0.2) / (0.3 - 0.2) * 255)))*"

5. End: The program ends.

E. Specifications of the Component Used

This research uses adapted tools and materials, including those in Table 1. Arduino Uno is a microcontroller based on the ATmega328P microchip microcontroller [15]. This board is equipped with a set of digital and analog input and output (I/O) pins that can be connected to various other circuits. This Arduino has an operating voltage of 5 Volts, with an input voltage of 7-20 volts, has 14 Digital I/O pins, 6 PWM pins (3,5,6,9,10, and 11), DC current per I/pin O: 20mA, DC current for 3.3v pin 50 mA, has 32 KB flash memory, SRAM; 2KB, EEPROM: 1 KB, Length 68.6mm, width 53.4mm, and weight 25 grams [16]. With these specifications, Arduino Uno can be used to create prototypes of electronic devices quickly and easily. The desktop used here is a Lenovo IdeaPad Slim 3 (14", Gen 8) which has specifications; Intel Core i5-12450H Processor with Integrategd Intel UHD graphics, and has an FHD 1080p camera with Privacy Shutter. As an output for eye movements, a 10W light is selected. which has 900 lumens, 12v output voltage with white light.

Table 1. Tools and Materials

Component	Amount
1. Arduino uno	1
2. Mobile device	1
3. Lamp 10W	2
4. Cables	4

D. Design of Hardware

In order for the hardware to look neat and aesthetic, a cover made of acrylic is made that can hold 1 arduino and 2 lamps. This cover is designed using sketchup software, the result of the design can bee seen in figure 4.

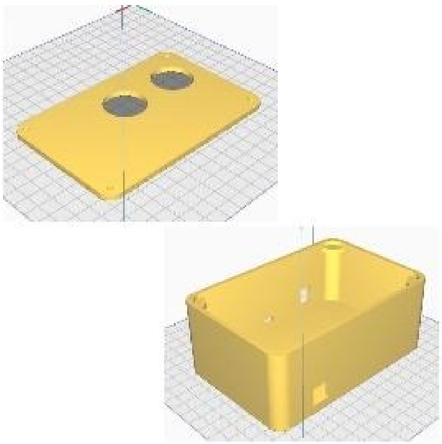

Figure 4. Design

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The result has a top part that is used to place 2 lights and a bottom part that is used to house the microcontroller. In this research, Arduino Uno is used as a microcontroller which will later be connected to a device or PC as a medium for creating software. Eye movements obtained from the PC camera are processed into the program system that has been created. There are 2 lights as indicators, the first light gets an output of 1/0 (on or off), while the second light gets an output PWM value of 0-255. The more we open our eyes, the brighter the light will be. On the other hand, if we close our eyes slowly then the lights will dim slowly. This is because the intensity of the light decreases.

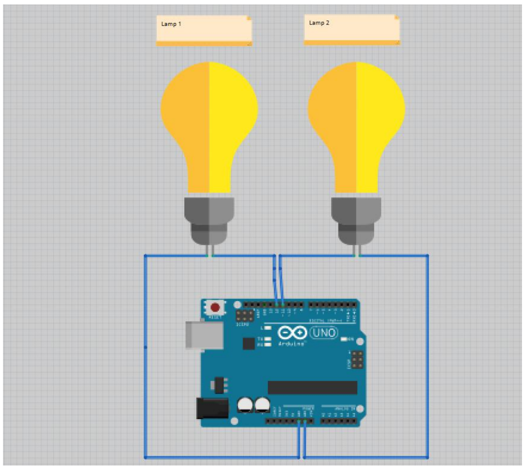

Figure 5. Wiring diagram hardware

Needed to design hardware so that we can know if 2 lights can be integrated with arduino. Therefore, he hardware design is made using fritzing software which can be seen in figure 5. There is a wiring diagram for automatic lighting control hardware which consists of several components, namely, Arduino Uno is a microcontroller based on the Atmega 328P microchip which is equipped with a set of input or output (I/O) pins which are connected to the desktop with an input voltage of 8.4V, This Arduino has an operating voltage of 5V with an input voltage of 7-20 volts, therefore the 1OW DC lamp was chosen which has 900 lumens with white light which can be activated with a voltage. 5 volts. Where the 1st light is connected to pin 12 on the Arduino and ground on the Aeduino, while the second light is connected to pin 11 on the Arduino and ground on the Arduino. How it works, when the laptop is activated and connected to a microcontroller, the microcontroller will automatically distribute power to the two lights. The lights will turn on, off, bright or dark, which will be adjusted by the participant's eye activity which will then be processed in the system first.

E. Scheme of Software

Figure 6 is a scheme for controlling operating room lights using eye tracking. Where the system for processing eye movements was created using Visual Studio Code, Open CV, and Python based on Mediapipe [17]. The use of this devices involves several libraries to calculate frequencies in real time, especially in creating landmarks on organs on the face such as the eyes, mouth, nose and ears. Then the program will trace these landmarks so that it can read whatever organs are being read. Visual Studio Code is open source software that has been developed by Microsoft [18]. Visual Studio is often used by programmers to carry out data processing. The programming language that is often used is Python, Python is a programming language that is often used to process images using libraries such as Open CV [19]. Open CV is a python library on windows, android, macOS that provides computer engineering implementations. Open CV is a platform that is popular with Computer Vision developers [20]. Python is a programming language that is easy to learn and can be executed line by line without needing to be compiled. Python can be run on various Windows, macOS, Linux systems without many changes and has an extensive library and supports third party libraries which makes it suitable for developing artificial intelligence [21]. In this research, the program that was created using Open CV in Python language was then connected to the Arduino Uno as hardware control. Then it is integrated into a webcam camera which functions to read the user's eye movements. Programmed eye movements can control the light on and also control the intensity of the light.

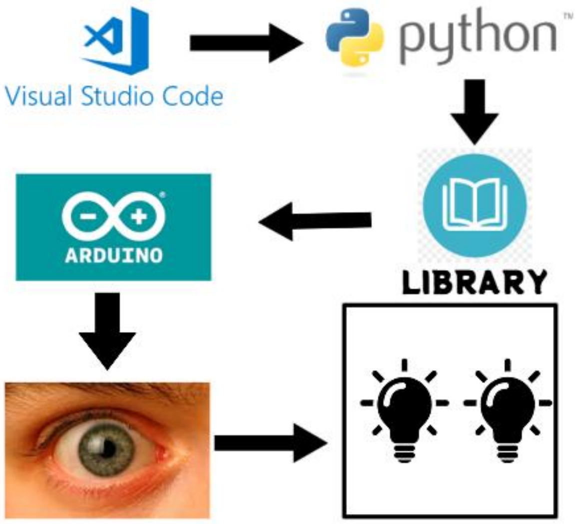

Figure 6. Scheme of research

```python
import cv2
import mediapipe as mp
import module
import serial  # Untuk komunikasi serial dengan Arduino
import time

print("Program started")

mp_drawing = mp.solutions.drawing_utils
mp_drawing_styles = mp.solutions.drawing_styles
mp_face_mesh = mp.solutions.face_mesh
```

Figure 7. Library Python

In Figure 7 is a Python program library displayed in VS code with serial communication to interact with the Arduino Uno microcontroller. "CV2" is a library for processing video captured by a desktop camera to detect faces and eyes, "mediapipe as mp" is a machine learning library for detecting organs on the face such as eyes and ears, "serial" is a library for serial communication between Python and Arduino to send command data to control two lights. “mp.solutions.drawing_utils” functions to draw a facial mesh captured by the camera frame, “mp.solutions.drawing_styles” functions to draw facial features with a predetermined appearance, “mp.solutions.face_mesh” functions to trace facial meshes from 468 points on the face that are used to detect detailed features on the face such as eyes, nose, mouth.

```python
def toggle_light(left_eye_closed, right_eye_closed):
    global light_state
    if right_eye_closed and not light_state:
        # Jika mata kanan tertutup dan lampu mati, nyalakan lampu
        light_state = True
        print("Lampu dinyalakan")
        arduino.write('ON\n'.encode())  # Kirim perintah "ON" ke Arduino
    elif left_eye_closed and light_state:
        # Jika mata kiri tertutup dan lampu menyala, matikan lampu
        light_state = False
        print("Lampu dimatikan")
        arduino.write('OFF\n'.encode())  # Kirim perintah "OFF" ke Arduino
```

Figure 8. On off lamp coding

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In Figure 8, there is a coding that functions to determine whether the participant's eyes are open or closed, because each indicator for the right and left eyes is different. The right eye turns on the light and the left eye turns off the light by blinking. Therefore, there is a program function definition which consists of "def toggle_light(left_eye_closed, right_eye_closed):" functions to control the status of the light going off or on based on the condition of which eye is blinking, whether the left eye is blinking or the right eye is blinking, "global light_state" functions to save light output (on or off), "if right_eye_closed and not light_state" functions to give a command if the right eye is blinking then the light is on and sends the ON command to the Arduino via serial using the function "arduino.write('ON\n'.encode())", while the function "elif left_eye_closed and light_state:" gives a command if the left eye flashes, the light will go out by sending a command to the arduino serially with the function "arduino.write('OFF\n'.encode())".

```
def adjust_light_intensity(left_ear, right_ear):
    # Hitung EAR rata-rata dari kedua mata
    average_ear = (left_ear + right_ear) / 2

    # Map EAR ke intensitas LED (EAR 0.2 - 0.3 -> Intensitas 0 - 255)
    intensity = int(max(0, min(255, (average_ear - 0.2) / (0.3 - 0.2) * 255 )))

    # Kirim intensitas ke Arduino melalui serial
    arduino.write(f'{intensity}\n'.encode())  # Mengirim nilai intensitas

    # Debugging untuk memantau intensitas
    print(f"Adjusting light intensity to {intensity} (EAR: {average_ear:.4f})")
```

Figure 9. Coding of lamp intensity

In Figure 9, there is a program that functions to control light intensity automatically using two eyes by calculating the average EAR by providing the function "intensity = int(max(0, min(255, (average_ear - 0.2) / (0.3 - 0.2) * 255)))" gives the results of calculating the Eye Apect Ratio (EAR), the distance between the centers of the two eyes and the distance between the heights of the eyes. EAR serves to provide an indicator of how much the eyes are open. Then the EAR value is changed to a light intensity range of (0-255), then the "arduino.write(f'{intensity}\n'.encode())" function will send the value to the microcontroller connected to the second light. Function "print(f"Adjusting light intensity to {intensity} (EAR: {average_ear:.4f})")" to display the average Ear value that will be displayed at the command prompt.

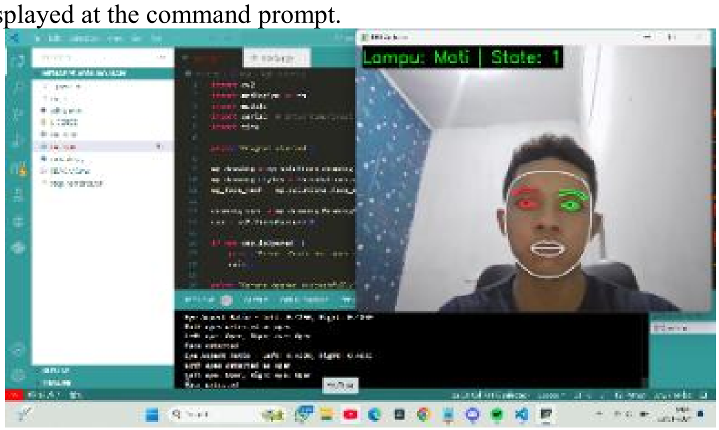

Figure 10. State 1 lamp off

In Figure 10, there is a software design using a Python program where there are white landmarks on the participant's face, eye landmarks in different colors, and landmarks on the participant's mouth. Not only that, there is a state 1 indicator and the condition of the light going off is because the left eye is blinking, which will give an "off" indicator in the software. And there are several indicators in the command prompt, namely the detected face indicator, the Eye Aspect Ratio for each eye with a value showing the left eye as 0.870 and the right eye as 0.1319.

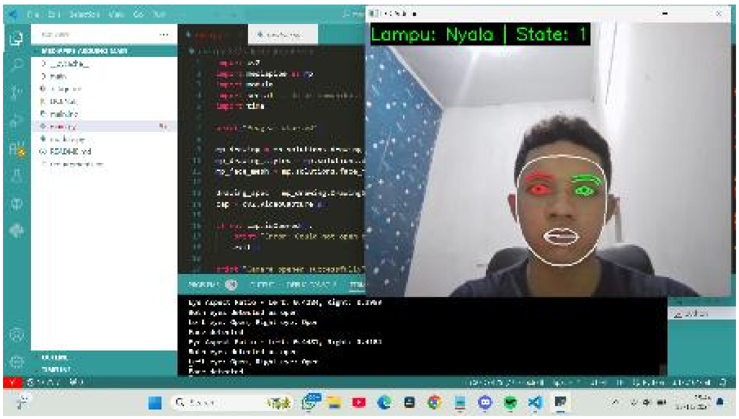

Figure 11. State 1 lamp on

In Figure 11, there is a software design using a Python program where there are white landmarks on the participant's face, eye landmarks in different colors, and landmarks on the participant's mouth. Not only that, there is a state 1 indicator and the condition of the light being on because the right eye is blinking will provide an "on" indicator in the software. And there are several indicators in the command prompt, namely the detected face indicator, the Eye Aspect Ratio for each eye with a value showing the left eye as 0.3227 and the right eye as 0.3809.

Figure 12. State 2 intensity lamp

In Figure 12, there is a software design using a Python program where there are white landmarks on the participant's face, eye landmarks in different colors, and landmarks on the participant's mouth. Not only that, there is a state 2 indicator and the light condition is on because the right and left eyes are open with it. The participant's eyes will automatically control the light intensity of the lamp, in state 2 there are several indicators in the command prompt, namely the detected face indicator, the condition of the right and left eyes being open or closed, the light intensity indicator on the lamp is 165lux with the Eye Aspect Ratio for each eye showing the value for the left eye is 0.2551 and the right eye is 0.2768.

3. RESULTS AND DISCUSSIONS

The results of the research on the system of turning on and off the lights and regulating the intensity of the light using the eye tracking method for right, left blinks and the opening of both eyes which will be processed by the program system will be discussed in detail. This data collection was carried out on 2 participants with different backgrounds, namely, a male participant with normal eye conditions and 1 female participant who had eye problems and was required to wear glasses. The distance between each participant and the camera has been determined, namely 30 cm, 40 cm, 50 cm, 60 cm. With predetermined facial positions, namely right, left, center.

In this data collection stage, participants were asked to carry out predetermined eye activities. Blink the right eye to turn on the light, blink the left eye to turn off the light, and open two eyes to adjust the intensity of the light. With this, the software will record the participant's eye movements, the activities carried out by the participant will be given a table as in Table 2, namely the light condition Table 3, namely the blinking of the participant without

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wearing glasses, Table 4 namely the blinking of the participant's eyes using glasses, and Table 5, namely the aperture both eyes.

Table 2. Condition of lamp

No	Condition
1	easy
2	medium
3	hard
4	error

In Collecting this data, we used an indicator table for participant activity with 4 indicators to calculate how precisely the system can process participant eye activity. These indicators consist of "Easy" which means the system can respond to participant movements in 1 trial, two "Medium" which means the system can respond to participant movements in 2 trials, three "Hard" which means the system can respond to participant movements in 3 trials, Four " Error" which means the system can respond to the participant's movements in 4 trials.

Participant Without Glasses

After collecting data of the participants to control 2 lights using eye tracking without using glasses, the results are written in table 3.

Table 3. Participant's eyes without glasses

Without Glasses					
No	Gender	Distance (cm)	Eye Movement Accuracy		
			Right	Left	Center
1	Male	30	Easy	Medium	Easy
2		40	Easy	Easy	Easy
3		50	Medium	Easy	Easy
4		60	Easy	Easy	Easy
5	Female	30	Easy	Easy	Easy
6		40	Easy	Easy	Easy
7		50	Easy	Easy	Easy
8		60	Easy	Easy	Easy

The results of collecting data on eye blinks of participant without glasses, the system can detect eye activity carried out by participants. It can be seen from the results of table 3 that all participants are categorized as "Easy" with a lamp power of 10W. Factors that influence these results are the quality of the camera and the distance of the participant to the camera.

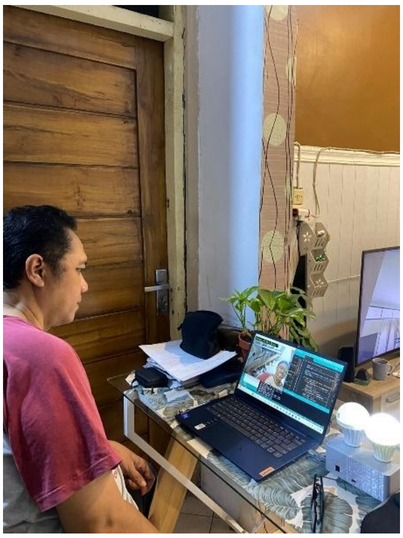

Figure 13. Male participant without glasses

Figure 14. Female participant without glasses

Participant Wearing Glasses

After collecting data of the participants to control 2 lights using eye tracking using glasses, the results are written in table 4, the system was able to detect eye activity but was hampered by several things that the participants did.

Table 4. Participant's eyes wearing glasses

Wearing Glasses					
No	**Gender**	**Distance (cm)**	**Eye Movement Accuracy**		
			Right	**Left**	**Center**
1	Male	30	Easy	Medium	Easy
2		40	Hard	Easy	Hard
3		50	Error	Easy	Easy
4		60	Error	Easy	Easy
5	Female	30	Easy	Easy	Easy
6		40	Easy	Medium	Easy
7		50	Easy	Easy	Easy
8		60	Easy	Easy	Easy

It can be seen from the results of the table above that all participants were categorized as "Hard" with a light power of 10 W. Even at a distance of 40 cm the results were still Hard. However, at different distances the results show Easy status. This shows that the system is more sensitive to certain distance and lighting conditions. It can be concluded that the light factor and the distance to the participant's eyes can influence the system.

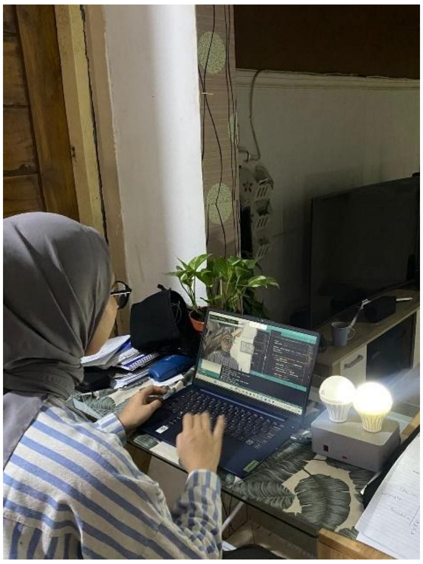

Figure 14. Female participant wearing glasses

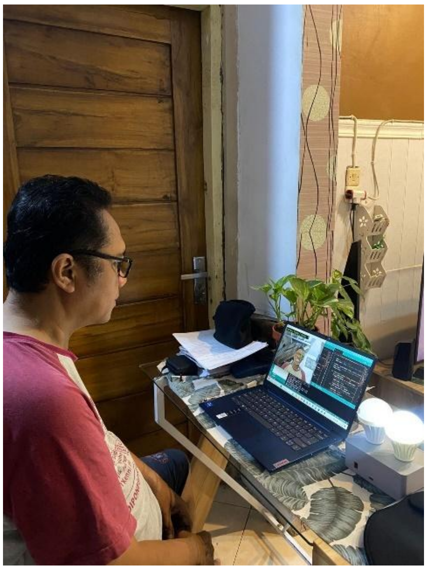

Figure 15. Male paericipant wearing glasses

Move both eyes to regulate the intensity of the light

Data collection this time is to control the intensity of light using eye tracking which only utilizez the lighting from the lamp that has been assembled without using room lighting. To measure the intensity of the light, a mesuring instrument called a lux meter is needed to obtain the minimum value and maximum value.

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Table 5. Intensity Measurement Result

Minimum Setting	Maximum Setting
86 lux	159 lux

Which can be seen in table 5, the results of data collection to control light intensity using a lux meter measuring instrument based on Table 5 have an accuracy of ± 4% +10 with a resolution of 1 lux, a temperature of 0.1 °C which has a measurement range of 0-200,000 lux that can be operated uses AAA x 3 batteries. With the specifications of the measuring instrument, after trying to measure the lamp, it gets a minimum lux value of 86 lux with a temperature of 29.9°C and the maximum value is 159 lux with a temperature of 29.6°C.

Figure 18. Minumum value of intensity

Figure 19. Maximum value of intensity

4. CONCLUSION

Research on a lighting control system using the eye tracking method with an image processing system has been successfully carried out. All data generated is based on activity, distance, eye position on the camera and differences in participant backgrounds. Apart from that, a system that can work well means consistent results are obtained. However, based on distance, the system can read with precision at distances of 50 cm and 60 cm. The effect of eye position on the camera did not show a significant difference in results. For further research, testing can be carried out with a large number of participants with several variations in participant conditions and the development of a system that can be adjusted by the user.

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