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# Lighting System Platform in Smart Home based on Human Density Level

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**Abstract:- Smart control systems are broadly implemented by means of controlling remotely or automatically, however approaches the usage of imagery are nevertheless not often discovered. The goal of this research is to integrate a smarthome with a control platform that controls lights using images as a source of automated control. As input, images are obtained and the Haar-cascade classification algorithm is applied to calculate the number of human objects within the room. however, a light sensor is also used as a parameter in acquiring the light value in the room. If there's a lack of value due to the presence of a human object sitting in a chair, the system will provide extra lighting and regulate the room lighting value to the suitable room light standard. The control and settings interface is made in web form, where several types of control are available. communication between devices inside the system uses the MQTT protocol. From the research outcomes, this control system platform is successful in running and controlling lamp lighting based on image detection input. There are differences in the level of detection accuracy that is influenced by the distance between the camera and the object, apart from that the quality of the camera sensor in capturing images additionally affects detection overall performance. At the same time, objects tend to be easily detected, are objects that do not use facial accessories such as mask, glasses and so on. It was additionally found that the average reduction in light value inside the room became 0.83 lux for each 2-3 humans sitting in the room. This research answers a control system solution for a smart home with an indoor image detection approach. similarly research is needed to precisely calculate the comparison of the accuracy of object detection with other image detection algorithms.**

***Keywords**:- Control System, OpenCV, MQTT.*

## I. INTRODUCTION

### *A. Background*

A smart home system is a technology that connects various equipment, including equipment in homes and residences, that can be connected to each other. Objects in this smart system can produce, receive and process information where the information is used to control, monitor, or provide information to other equipment in a network so that certain actions can automatically move something based on certain situations that are occurring.

Systems that are often used in smart homes are controlling lights and monitoring environmental conditions. Control is carried out remotely wirelessly and can be accessed by smart devices such as smartphones, laptops and tablet computers. This implementation was carried out by Jabbar and colleagues in 2018, where a smart home prototype was created that controls lights and other equipment and also monitors room temperature via an Android application (Jabbar et al., 2018).

Another feature that is also applied to the smart home system is facial image recognition where facial objects are used to recognize occupants in order to gain access to a particular room or place (Pawar et al., 2018). Face recognition through digital image processing which is a process carried out on an image, namely consisting of an array of coordinates where each coordinate maps each pixel in an image. Digital image processing processes are often used in the object recognition process where the output results determine the next action or process. Image processing consists of two types of input, namely still images and moving images.

MQTT (message queuing telemetry transport) is a network protocol that carries messages in the form of information between microcomputer and microcontroller devices. This protocol runs on top of the TCP/IP network protocol suite. The MQTT protocol has two types of network entities, namely message brokers and clients. The broker in the MQTT protocol is a server that receives all messages from clients and then forwards the messages to the appropriate clients (Yuan, 2017). A client in the MQTT protocol is any device (from a microcontroller to a server computer) that runs the MQTT library and is connected to the MQTT broker via a network (Team, 2019).

Until now there are many systems that support the smart home concept. One example is previous research conducted by the author where the author developed the concept of a smart home system using an Android application, but the author only used a Bluetooth connection between devices (Kaunang et al., 2015). In fact, Kumar also developed a smart home system using Android. The system uses the REST protocol to transfer data between devices via a server (Kumar, 2014). However, communication between electronic devices and devices that act as clients via the internet is a challenge for researchers. There are many researchers who try to offer the best communication protocols, and they compare protocols that have specifications that are suitable for smart home concepts and IoT applications, and they show that protocols such as CoAP, MQTT, XMPP, RESTFUL, AMQP and WebSocket are highly recommended for This concept, and among these protocols, the MQTT protocol has been proven to be more efficient with low power consumption which supports the low power consumption smart home concept. The research above also explains that the MQTT protocol uses very little energy compared to other

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protocols, and can operate well in environments that tend to have low bandwidth and high latency (Witthayawiroj & Nilaphruek, 2016).

Based on the explanation above, the title taken in this research is "Lighting System Platform in Smart Home based on Human Density Level ". This system will also integrate a microcontroller and microcomputer where there is an automatic control system for lighting based on human presence using Raspberry Pi as an MQTT broker and client node to capture the presence of objects and NodeMCU as an MQTT client which receives sensing of room light brightness and as a light actuator, where the implementation uses MQTT is a communication protocol between client 1, client 2 and client 3 through a broker in a wireless computer network (WiFi). Client 1 is the NodeMCU which has a number of LEDs installed, client 2 is the NodeMCU which has a light sensor and temperature and humidity sensor installed. Client 3 is a Raspberry Pi with a programmed camera installed to capture the presence of human objects. The broker, namely the Raspberry Pi, is programmed to carry out the publish and subscribe functions, acting as a broker that becomes an intermediary between all clients. It is programmed to carry out the topic subscribe function so that it can obtain information in the form of data with the appropriate topic, where the data is data captured by the previous client 2 sensors. sent to the broker via the publish function, as well as running a web server as a control platform.

*B. Problem Formulation*

Based on the explanation of the background that has been stated, the problem formulation in this research is how to control the lights based on the density of human object detection and the performance capabilities of the hardware and software platform of the system.

*C. Research Objectives*

The aim of this research is to develop an automatic control system based on human presence in a room by utilizing the MQTT protocol.

*D. Research benefits*

Users will be more efficient in controlling lights with this lightweight & low power consumption concept.

## II. RESEARCH METHODS

*A. Research Stages*

There are several phases in this research starting from problem identification, determining research objectives, advantages and limitations, system design, development and system analysis stages.

*B. System Design*

General description of the system offered

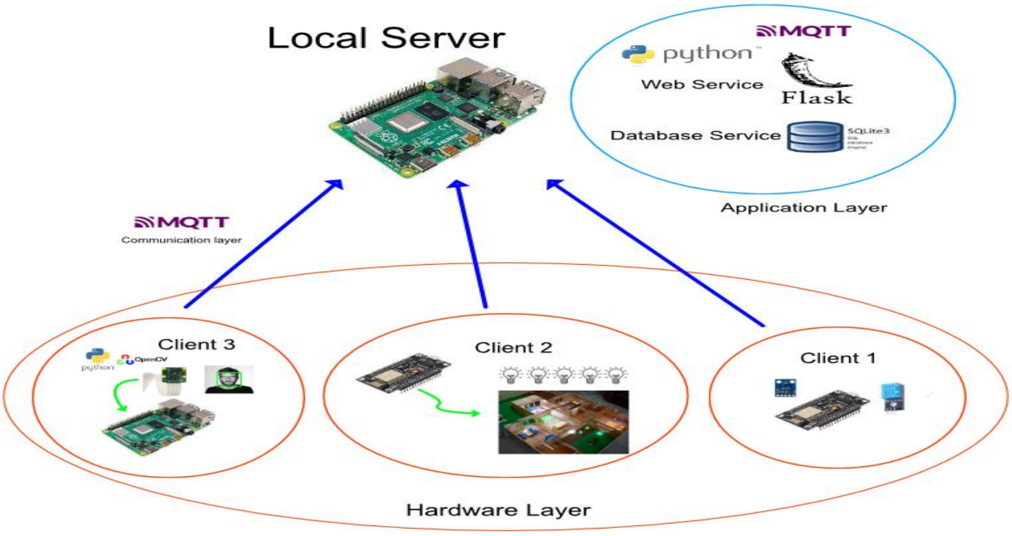



Fig. 1: System Design

In figure 3 above is the control system design where the DHT22 and light sensors (BH1750) are installed on the NodeMCU (client 1). The LED representing the room light is connected to the NodeMCU (client 2). Client 1 will receive DHT22 and light sensor data, then using the MQTT protocol carries out the publish function with a different topic. The Raspberry Pi (broker) in real-time with the subscribe function receives published data from client 1. Client 2 with the subscribe function is connected to the broker via the MQTT protocol, the data is then sent in real-time with the publish function from the broker with the topic "/ eps8266/humidity", "/eps8266/temperature" and "/eps8266/lightmeter". A website was also built to accommodate manual control and make arrangements for client management. The web interface was created using the flask micro-framework. If the temperature sensor data is received with a certain value, the temperature information display will be displayed on the web interface. If light sensor data is received with a certain intensity value, the microcontroller will turn the LED on/off automatically.

The application simulation design of the control system will be applied to a miniature house as a representation of the house building where the lighting system will be applied.

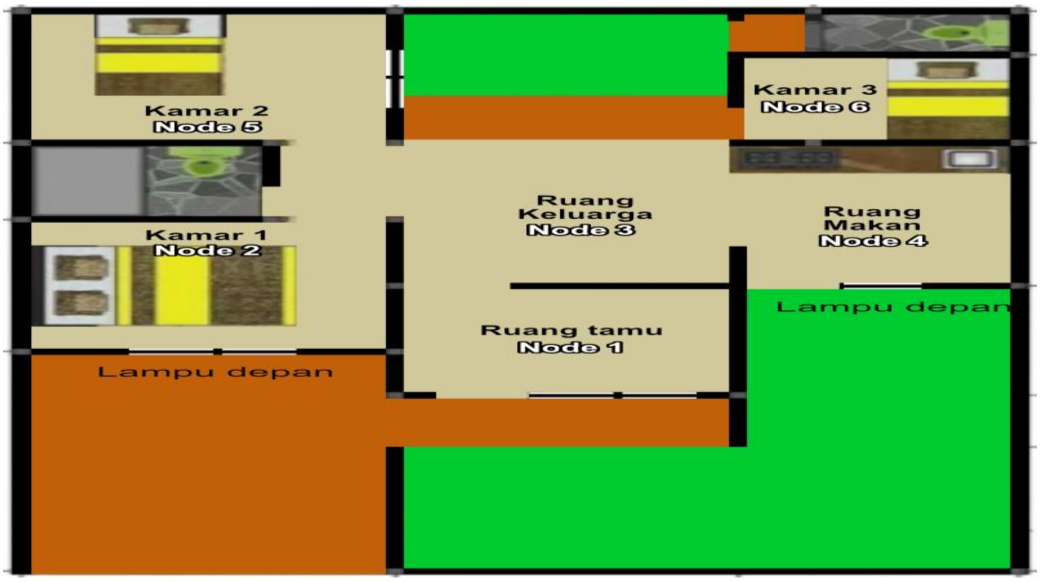


Fig. 2: Miniature house sketch

There are 5 areas where the lights in these areas will be controlled, namely the living room, room 1, dining room, front lights and family room.

Data flow diagram for node 1, broker node, and lights node.

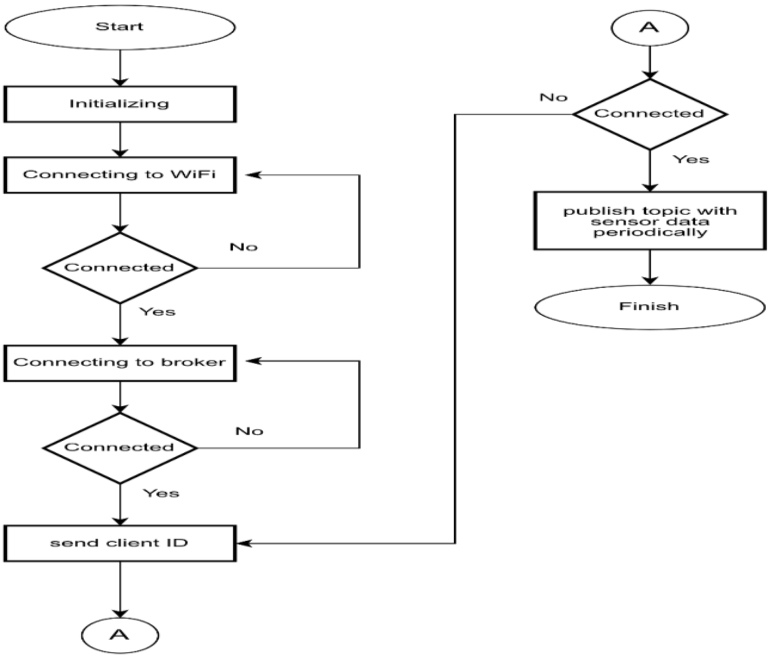


Fig. 3: Data flow diagram client 1

In Figure 3, the data flow begins by initializing the Wifi ID and pins on the NodeMCU which are used as connected pins to receive information from the DHT22 sensor and light sensor. Then the process to connect the NodeMCU to WiFi and then to the broker is carried out. When connecting to a broker, NodeMCU as a client sends a client-ID. If the client-ID is recognized by the broker then information from the sensor is published with different topics, namely "/esp8266/temperature", "/esp8266/humidity" and "/esp8266/lightsensor" in real-time to the broker.

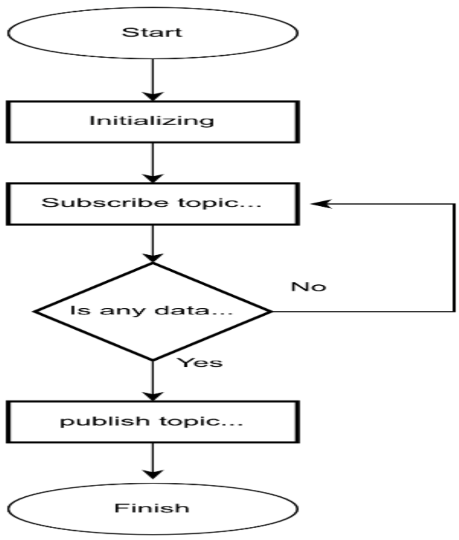



Fig. 4: Data flow diagram for broker node

In Figure 4, the broker starts initializing the library functions that will be used. Next, the subscription process is carried out on several topics. If there is information from the topic, then the publishing process continues with the information from the topic received in real-time for clients who make requests on the same topic.

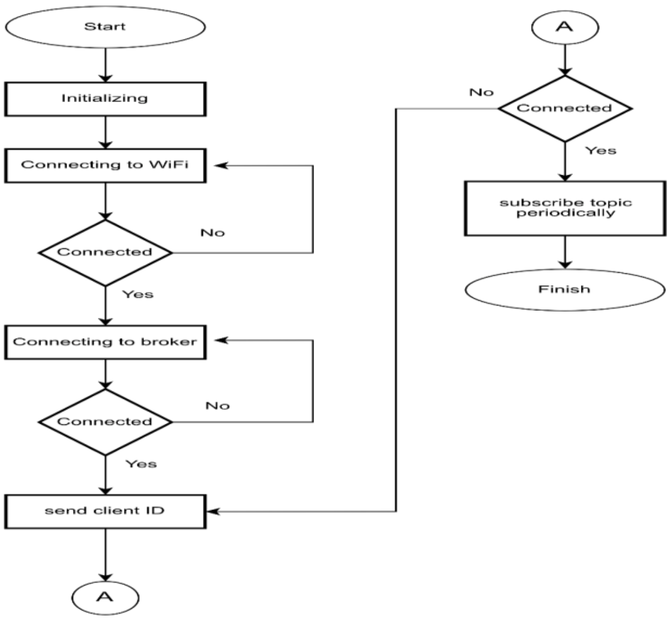



Fig. 5: Data flow diagram for lights node.

In Figure 7, the data flow begins by initializing the Wifi ID and the pin on the NodeMCU which is used as a pin connected to the LED which represents the light as a control output. Then run the process to connect the NodeMCU to WiFi and then to the broker. When connecting to a broker, NodeMCU as a client sends a client-ID. If the client-ID is recognized by the broker then NodeMCU then carries out the subscribe topic process to receive information from the broker in real-time.

## III. RESULTS AND DISCUSSION

Before you begin to format your paper, first write and save the content as a separate text file. Keep your text and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper. Do not number text heads-the template will do that for you.

Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar:

## *A. MQTT Topics*

Table 1: MQTT TOPICS

| Topics Name | Controlled Object |
|---|---|
| /esp8266/rumah/ruangtamu | Lampu ruang tamu |
| /esp8266/rumah/kamar1 | Lampu kamar 1 |
| /esp8266/rumah/kamar2 | Lampu kamar 2 |
| /esp8266/rumah/kamar3 | Lampu kamar 3 |
| /esp8266/rumah/ruangmakan | Lampu Rg. Makan |
| /esp8266/rumah/ruangkeluarga | Lampu Rg. Keluarga |

For each different room, different topics are used. This topic will be set on each device in the system, whether it is on the node that will send or receive information.

## *B. Web Platform*

On the web platform itself, there are control settings that must previously be adjusted, namely adding control objects with appropriate topics. The platform display is as shown in Figure 6. Each control object can be adjusted to a different topic according to the needs of a smart home system.

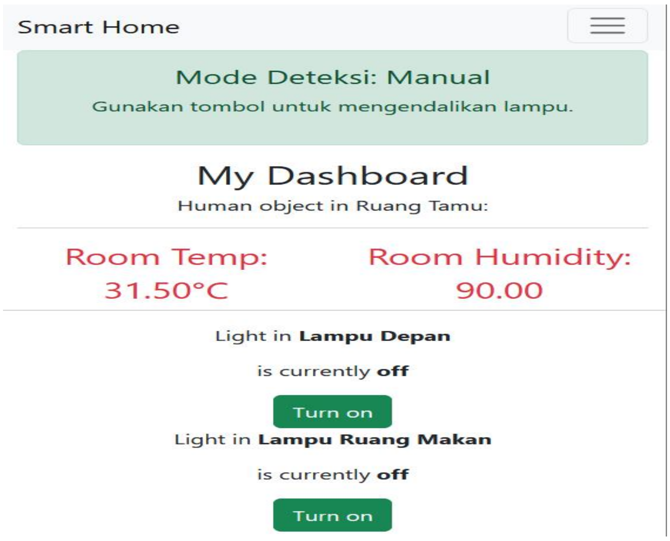



Fig. 6: Platform web view

Each object that is successfully added to the web platform will display a control panel in the form of a toggle-button to turn the light on or off along with a description of the light status. Additional room temperature and humidity information is displayed on this page.

To add a control object by accessing the navigation menu and selecting the add control menu. Next, fill in the object name, board name, and object MQTT topic then press the submit button.

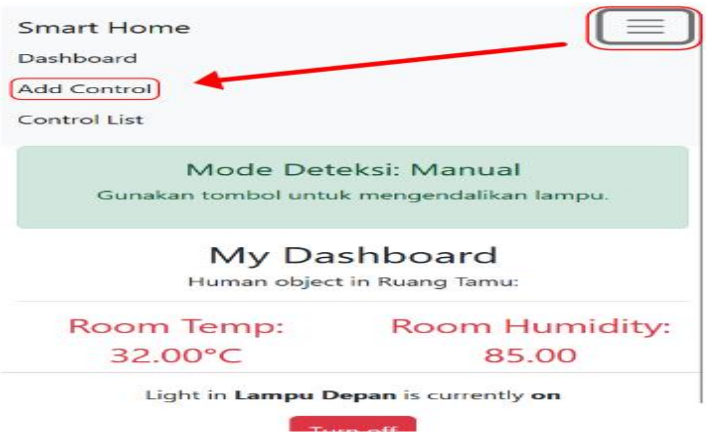



Fig. 7: Navigation access to the add control object menu

After accessing the add control menu (figure 7), then complete the control target details in the form of room name, unit board name, and control topic.

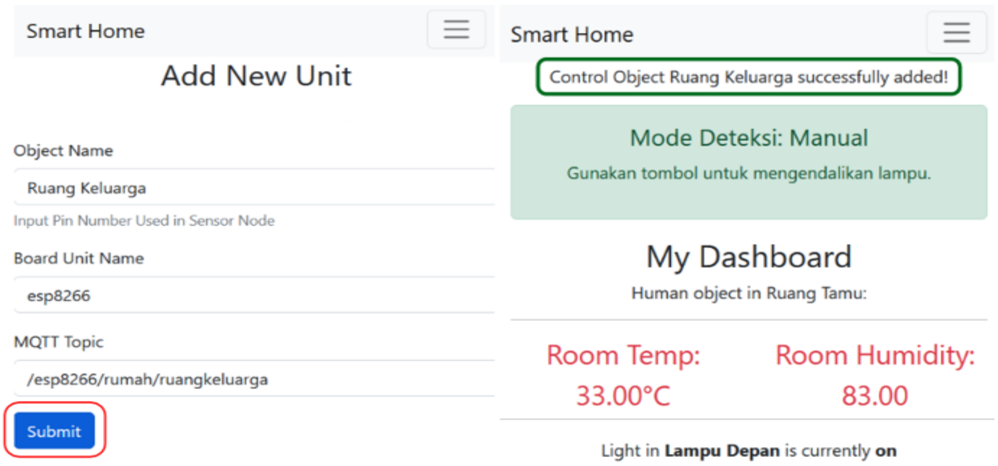



Fig. 8: The control object was added successfully.

After the control object has been successfully added, the display will be redirected to the main page accompanied by information that the control object has been successfully added as in Figure 8. Then all control objects will appear on the main page with buttons to control the room lights as in Figure 9.

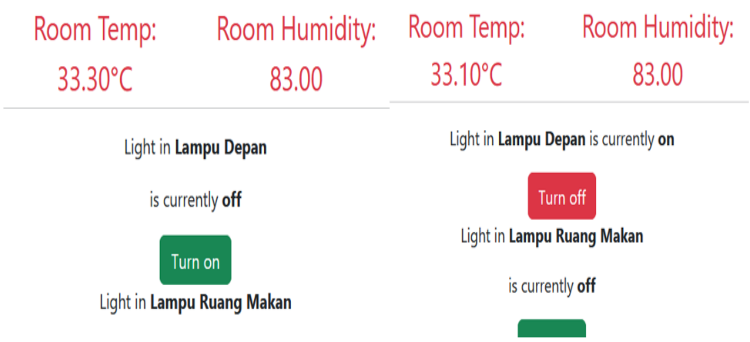



Fig. 9: The condition of the control button when the state light is off and on

From the image above, the condition of the object (light) appears on the web dashboard which represents the actual condition of the light. When the condition is "off" the button will be green and when pressed, the object light will turn on so that the object's status will change to "on", the button will change to red.

In Figure 10, all control objects that have been added also appear on the control object list page by accessing the navigation menu and selecting the control list menu. On this page you can edit or delete control objects.

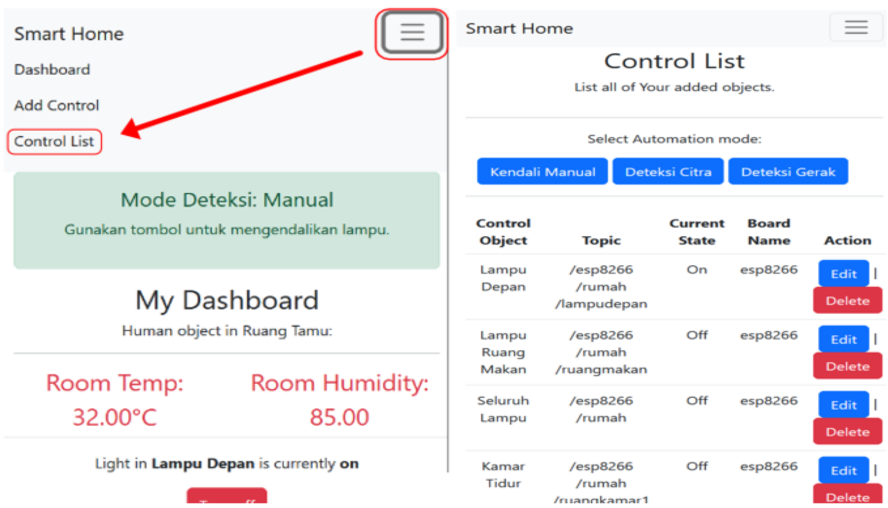



Fig. 10: Access to menus and control object list views

Editable control items include changing object names, MQTT topics and node names. This is done if an error occurs when adding the previous object.

The web also provides a function to change the type of control as desired. The control mode can be manual control, image detection, or motion detection. The mode selection display is as shown in Figure 11 . Sometimes there is a change in the device because we have added a sensor or actuator module so changes to the control parameters need to be made.

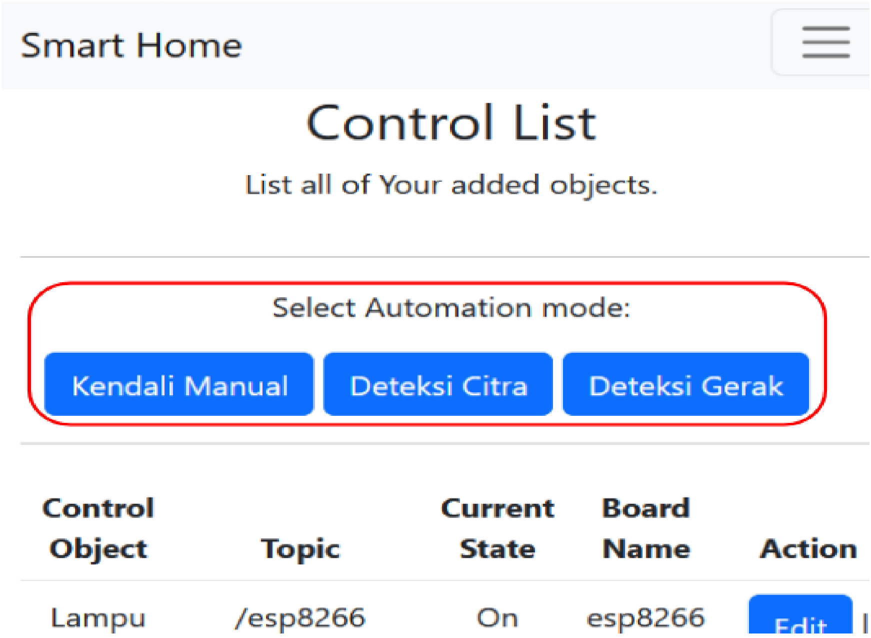



Fig. 11: System control mode selection button.

There is a selection of control modes, namely manual mode, namely controlling lighting conventionally, image sensor mode, namely automatic control of lights based on the number of human objects captured by the sensor in the room. Motion sensor mode is light control based on the presence of objects in the room. Modes can be selected and adjusted to suit your needs.

*C. Testing Method*

A miniature was built at a scale of 1:10 where the actual area of the living room is 2.75 x 2.5 meters and is the room where human density detection will be applied. The living room has 4 LEDs representing 4 manually controlled lights and 6 additional LEDs representing 6 lights which will light up in 3 modes (mode 1: two lights will light up; mode 2: four lights will light up; and mode 3: six lights will light up). The LED circuit in the room is all connected to client 1.

The control mode can be adjusted, namely divided into 3 types, manual control, image detection, and motion detection. This menu can be accessed on the control list page as in Figure 12.

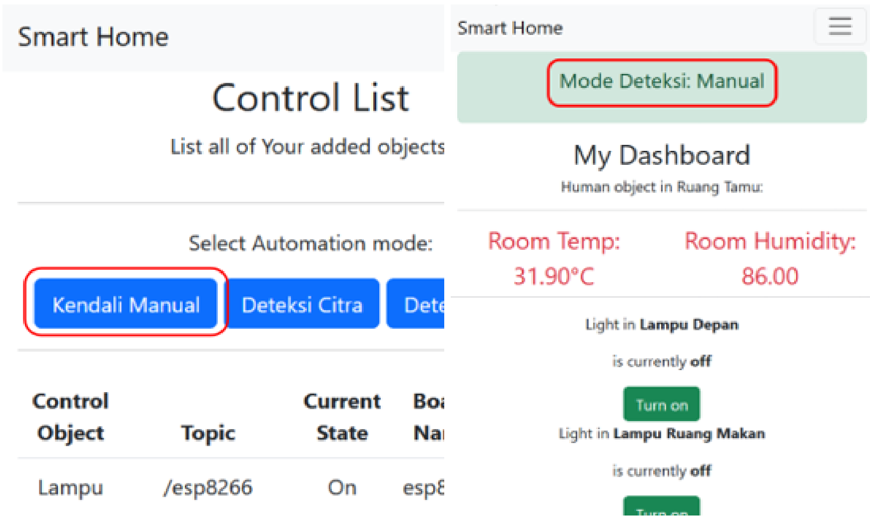



Fig. 12: Activates the control mode and displays the currently active control mode

After accessing the control list menu, there are 3 buttons to select the type of control. When the button is selected, the page will be directed directly to the main page accompanied by information at the top of the control mode that has been selected. The first test was carried out in manual/conventional smarthome lighting control mode via a web application platform.

Figure 13 is a simulation that is carried out when the lights on the miniature turn off or on, controlled from a previously built web application.

Fig. 13: Example of a light control object that is on and off.

The simulation in the picture above was carried out on a miniature house, namely in the front light area (terrace). The LED installed represents a lamp that is generally used in home installations. Control is carried out via the web which is accessed on a smartphone device connected to a web server network which is also run on the broker.

The second test was carried out to see whether automatic control could work using motion sensor mode as a trigger source. Control mode is first activated on the control list page by selecting the 'motion detection' button as in figure 14.

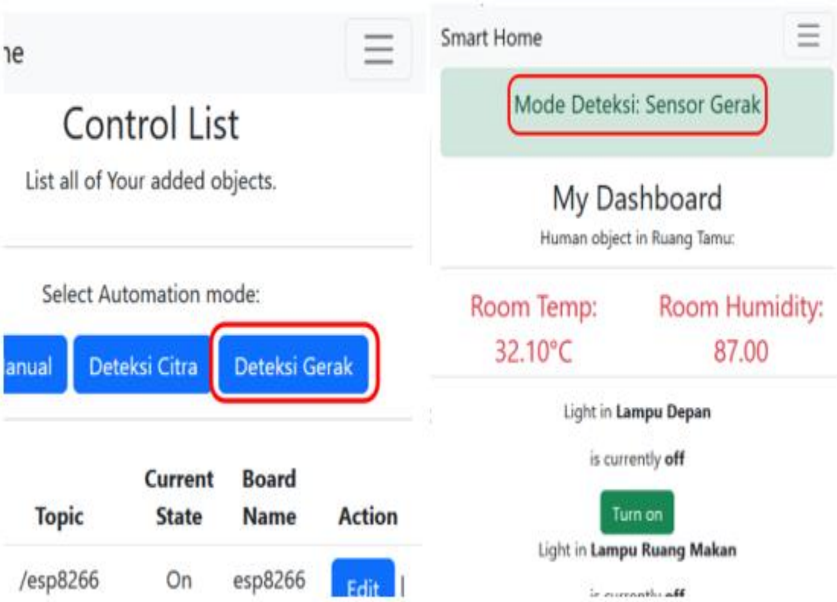



Fig. 14: Selects the motion detection mode and a message indicating that the mode is active

After activating the motion control mode via the selected button, the page will be immediately redirected to the main page accompanied by information at the top of the selected control mode.

In motion control mode, the sensors used are PIR (passive infrared) sensors which are positioned in three room zones. Each sensor position covers zones one, two and three where the sensor's line of sight is parallel to the seating position. Each sensor will capture the presence of objects in the zone that has been set. The light will light up to illuminate the zone where the object is captured by the sensor, so that the lighting will turn on according to where the presence of the object is detected in a zone. An overview of the sensor detection of the room is as in Figure 15.

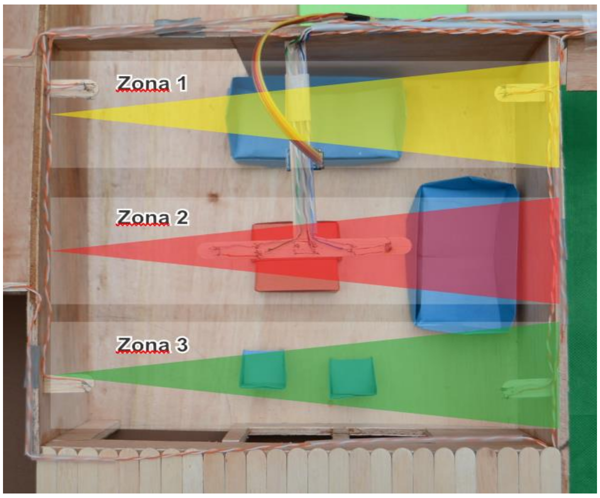



Fig. 15: Sensor coverage scheme

From this second test, using motion detection mode, the system succeeded in detecting the presence of objects and was able to control the lights automatically. Set an initial delay after detecting an object for 2 seconds before the light is turned on. The light will then turn off after approximately 1 minute of the object leaving the sensor coverage zone. The maximum distance that can be detected by the sensor is 20 cm to 5 meters, while the effective distance for detection is 20 cm to 3 meters. However, during the testing process it was also found that the sensor performance sometimes did not detect if the object had not moved for a long time. The sensor also cannot provide information regarding the number of objects and confirm whether the objects within the detection range are humans.

Next, the third test is automatic control with image detection. Via the control list page the image detection mode is first activated. The second test was carried out to see whether automatic control could work using image mode as a trigger source. Control mode is first activated on the control list page by selecting the 'image detection' button as in Figure 16.

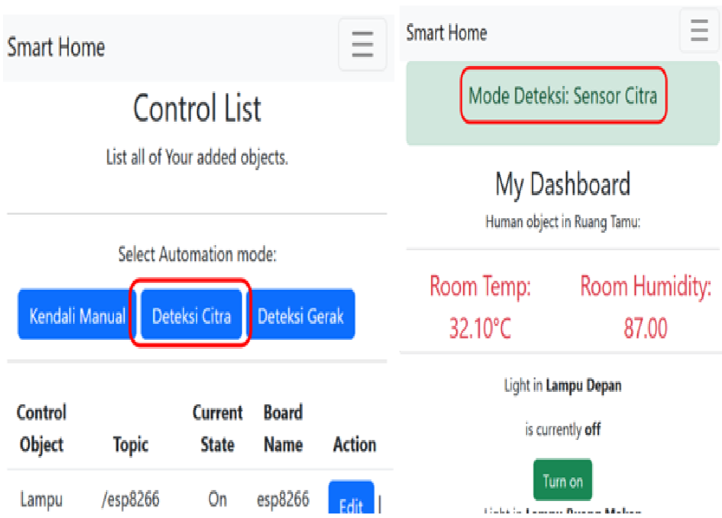



Fig. 16: Selecting the image sensor detection mode and a message indicating that the mode is active

After activating the image control mode via the selected button, the page will be immediately redirected to the main page accompanied by information at the top of the selected control mode.

The test was carried out where the target light being controlled was the light in the living room. The lights will turn on according to the lighting mode that has been determined based on the density of people in the living room. If the human density is less than or equal to two, then mode 1 will be executed. If the human density is more than two and less than four, mode 2 is executed. For human density greater than or equal to four, mode 3 is implemented. There is a delay to turn the lights on and off when an object is detected and after the object leaves the room. Pause for about 10-15 seconds when an object is detected then the light will be turned on according to the mode. When the object leaves the detection range, pause 60-90 seconds until the light is turned off.

In the miniature in figure 17, there is a manually controlled lamp where the lamp will provide a standard lighting value for a guest room, namely 300 lux. If there is a reduction in the light value then the additional light will turn on and adjust the lighting to the proper value.

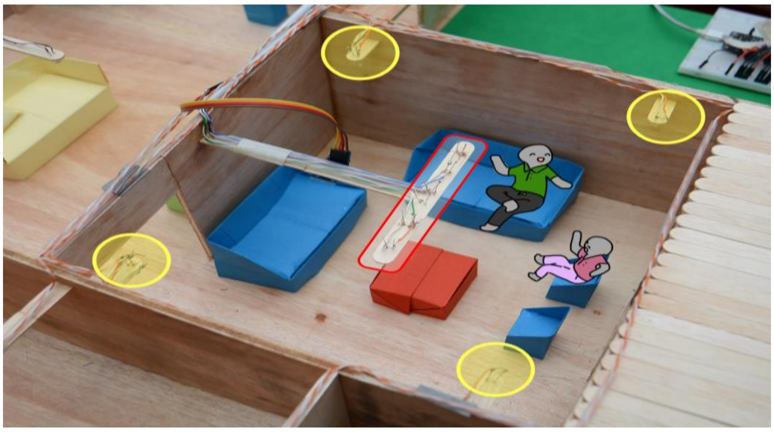


Fig. 17: Red line (automatically controlled lights) and yellow line (manually controlled).

The chairs are placed around the room with each chair on the side of the wall. A light sensor is also installed above which will monitor the light intensity in the room which will have an effect on automatic light control.

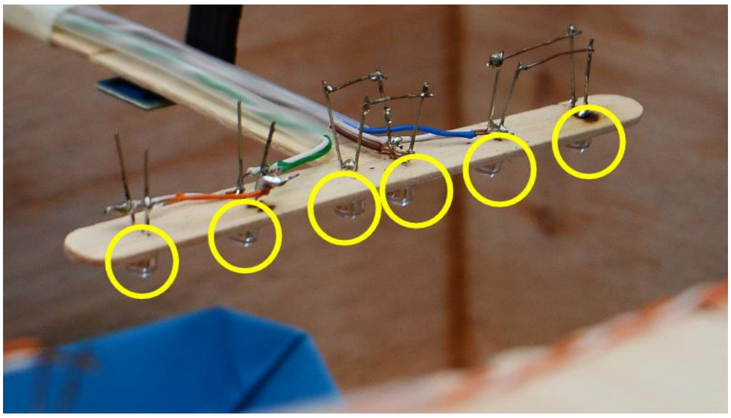


Fig. 18: six LEDs that can be controlled automatically

Lights that are controlled automatically are represented by LEDs as in Figure 18. Each light will light up according to the light requirements in the room. If you don't need a high value, there will only be 1 additional light that will turn on automatically. If the need for light decreases drastically, all additional lights will automatically turn on.

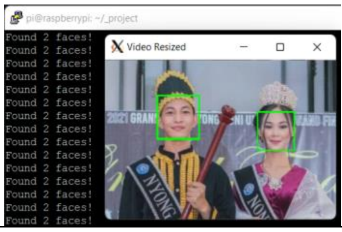
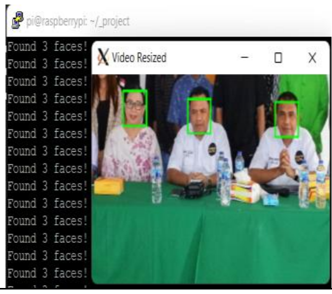
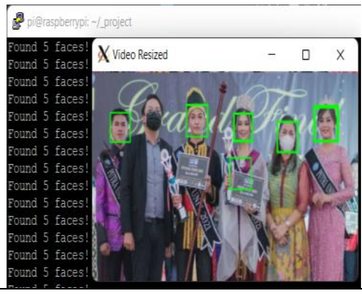
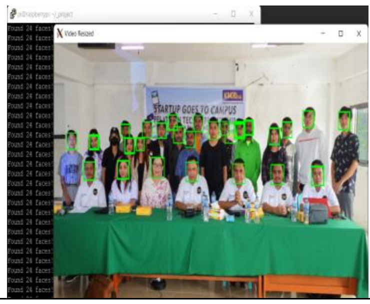
Raspberry pi 4 as a human density object detector which will count the number of objects by running the OpenCV machine learning process with the Haarcascade detection model. The type of haarcascade classifier used is haarcascade face detection. Human objects will be detected based on faces captured on camera. Light control occurs when a number of object faces are detected. The following are the human density conditions that have previously been determined.

Table 2: Automatic light control conditions based on object detection

| Number of Detected Objects (faces) | Light Control | Note |
|---|---|---|
| 0 | Off | Lights off |
| 1 <= 2 | Mode 1 | 2 lights are on |
| 2 >= 4 | Mode 2 | 4 lights are on |
| > 4 | Mode 3 | 6 lights are on |
| 0 | Off | Lights off |
| 1 <= 2 | Mode 1 | 2 lights are on |

Light control testing based on human object density was carried out using several scenarios. First, testing is carried out using images as an input source with the aim of seeing whether the object detection program code is successful in recognizing faces and controlling lights based on the conditions in table 4 above. The first scenario applies five images, each of which has an image with a number of human objects with clear faces, namely two objects, three objects, four objects, five objects with several people using masks and images with more than four objects.

Table 3: First scenario test results

| No. | Number of facial objects in the image | Sucessfully detectetd | Control mode | Keterangan |
|---|---|---|---|---|
| 1. | 2 wajah | 2 wajah | Mode 1 | 2 faces detected<br><br> |
| 2. | 3 wajah | 3 wajah | Mode 2 | 3 faces detected<br><br> |
| 3. | 6 wajah | 5 wajah | Mode 3 | 5 faces detected but 1 face not detected..<br><br> |
| 4. | >10 | 24 wajah | Mode 3 | Almost all faces are detected. Faces using masks are not detected.<br> |

From testing with the first scenario the program code succeeded in detecting faces and succeeded in controlling the lights based on the number of densities based on the number of objects in the image. The positions of objects that are successfully recognized are all facing straight towards the camera. However, objects with additional attributes (such as masks) reduce detection accuracy.

In the second scenario, testing using moving images (video) was carried out to see whether the object detection program code was successful in recognizing faces and controlling lights by applying video as the image source. Previously the settings on the web platform were changed to automatic control mode based on the image. All video conditions place the camera higher than the human object in a sitting position. With a vertical tilt angle of 10-20° facing downwards, with different situations starting from the distance of the camera to the object, position and lighting (dark, medium, bright). The definition of light in this test is that the lighting can clearly show the face of the object.

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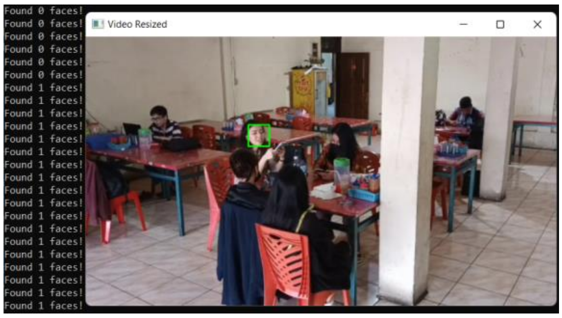
Table 4: Second scenario test results

| No. | Number of facial objects in the image | Sucessfully detectetd | Control mode | Notes |
|---|---|---|---|---|
| 1. | > 4 | 1 | Mode 1 | The distance between the object and the camera ranges from 1 meter to 5 meters. The direction of the object's face varies   |
| 2. | 3 | 1-2 | Mode 1 -mode 2 | The camera is positioned higher than the height of the object. The distance between the object and the camera ranges from 2 meters to 5 meters. The direction of the closest facial object only shows the side of the face.   |
| 3. | > 4 | 0 | Off | The camera is positioned higher than the height of the object. The distance between the object and the camera ranges from 0.5 meters to 5 meters. The direction of the face of the nearest object is facing away from the camera.   |
| 4. | > 4 | 1 | Mode 1 | The camera is positioned higher than the height of the object. The distance between the object and the camera ranges from 1 meter to 5 meters. The direction of the object's face varies.  |

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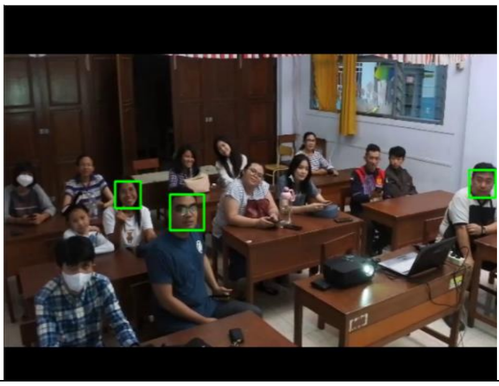
In the third scenario, testing is carried out to obtain an idea of the differences in image input quality which influence the results of object detection for recognizing faces. Testing using video taken at a height of 2 meters from the floor with a vertical slope of 10-20° facing downwards where the room lighting conditions are set to 300lx with the help of variable lights so that the lighting can clearly show the face of the object.

Table 5: Third scenario test results

| No. | Number of facial objects in the image | Sucessfully detectetd | Image Resolution (pixel) | Notes |
|---|---|---|---|---|
| 1. | 13 | 7-9 | 1920x1080 | The distance between the object and the camera ranges from 1 meter to 5 meters.  |
| 2. | 14 | 1-3 | 640x480 | The camera is positioned higher than the height of the object. The distance between the object and the camera ranges from 1 meter to 5 meters. The direction of the closest facial object only shows the side of the face.  |
| 3. | 3 | 1-2 | 720x480 | The camera is positioned higher than the height of the object. The distance between the object and the camera ranges from 3 meters to 5 meters.  |

From testing in the third scenario, it can be concluded that the reliability of object detection (in this case detecting faces) is also influenced by image resolution. Images with a large resolution of 1920x1080px are able to recognize and detect more facial objects compared to images with resolutions of 720x480px and 640x480px. A large image resolution has a longer detection distance than a small image resolution, namely 5 meters.

Table 6: Second scenario test results

| Number of people | Initial illumination | Decrease in Illumination | Final illumination | Number of additional lights that are on |
|---|---|---|---|---|
| 1 | 15.00 | 0 | 15.00 | 0 |
| 2 | 15.00 | 0 | 15.00 | 0 |
| 3 | 15.00 | 0 | 15.00 | 0 |
| 4 | 15.00 | -0,83 | 14.17 | 1 |
| 5 | 15.00 | -0,83 | 14.17 | 1 |
| 6 | 15.00 | -0,83 | 14.17 | 1 |
| 7 | 15.00 | -0,84 | 13.33 | 2 |
| 8 | 15.00 | -0,84 | 13.33 | 2 |
| 9 | 15.00 | -0,84 | 13.33 | 2 |
| 10 | 15.00 | -0,83 | 12.50 | 3 |

From testing with the second and third scenarios, the system succeeded in detecting faces with an effective distance of 1-3 meters for images with low resolution, and detection capabilities can be reached up to 5 meters with greater image resolution. Faces can be detected if the face is straight facing the camera with a tilt tolerance of 100-200 towards the camera and the head is in an upright position. Apart from image quality (resolution), lighting on objects (in this case faces) affects detection accuracy, and at moderate to bright lighting levels faces can still be detected. Additional accessories on the face in the form of a mask reduce the accuracy of object detection.

Testing of the illumination values in table 7 was carried out by experimenting in a room by placing 10 chairs arranged in a circle around the room. One by one the chairs will be occupied by people and the reduction in the lux value of the room will be monitored, starting from when the chairs are empty until they are all filled. The light value in the room has been set to 15 lux with the light sensor facing downwards directly above the head (equal to 300 lux in conventional light measurements). Three additional lights are also prepared, each of which when lit will provide an additional lux value of 0.8 lux.

From the test results, it can be concluded that if there are 1-3 people in the room it does not affect the illumination value in the room, namely 15 lux, so the additional lights are not active. The lux value starts to decrease when there are 4-6 people occupying chairs in the room with a decrease in value of 0.83 lux and 1 lamp will automatically turn on until the room lux value returns to 15 lux by increasing the lighting by 0.8 lux. The reduction in lux value occurs again when there are 7-9 people occupying chairs in the room with a decrease value of 0.84 lux and 2 lights will turn on automatically and increase the room lighting back to 15 lux. Meanwhile, when all the chairs in the room were full, there was a decrease in light of 2.49 lux. This condition will activate 3 additional lights to light up, so that the lighting value returns to 15 lux.

## IV. CONCLUSIONS AND SUGGESTIONS

### A. *Conclusions*

The conclusions from the results of this research are as follows:

- Test results show that images with greater resolution are more effective in recognizing objects and controlling lighting automatically.
- The distance detection capability becomes shorter when using images with smaller resolution.
- The average decrease in light intensity when a person is detected is 0.83 lux.
- The decrease in light intensity begins to occur when there are 4 people occupying chairs in the room.
- There was another decrease in light of 0.84 lux when 7 to 9 people were detected.
- Every time there is a decrease in the light value, the additional light will turn on automatically to adjust the light intensity back to 15 lux.
- The image test results show a false detection rate of 15.8%, but this does not have a significant impact on the lighting control process.

### B. *Suggestions*

Below are some suggestions for this research, namely as follows:

- It is recommended that this research be applied to larger systems involving human presence with varying lighting conditions that support various types of indoor activities.
- System performance will be influenced by device specifications, therefore it is recommended to use a device that has faster computing power so that the system will work better.
- A camera sensor with higher sharpness is recommended to increase detection accuracy.
- The use of motion sensors to detect human presence is recommended for use in rooms with short periods of human activity.

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