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Automated Air Conditioner Controler and Monitoring Based on Internet of Things

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Abstrak

Kebutuhan listrik untuk air conditioner semakin meningkat dari waktu ke waktu. International Energy Agency (IEA) memproyeksikan bahwa air conditioner merupakan pemicu utama melonjaknya konsumsi listrik di tahun 2050. Melonjaknya konsumsi listrik pada air conditioner disebabkan oleh penggunaan air conditioner yang tidak tepat akibat kesalahan pengguna. Kesalahan yang sering terjadi adalah lupa menonaktifkan air conditioner. Hal ini menyebabkan air conditioner akan bekerja sepanjang waktu. Penelitian ini bertujuan untuk menurunkan kemungkinan kesalahan pengguna tersebut dengan membuat perangkat pengendali dan pemantauan air conditioner otomatis berbasis Internet of Things. Penelitian ini menggunakan sensor passive infrared sebagai input untuk memastikan apakah ruangan yang mengunakan air conditioner sedang digunakan atau tidak dan sensor suhu DHT 11 untuk memastikan kinerja dari air conditioner. Teknologi Internet of Things digunakan untuk memonitor luaran perangkat dan mengendalikannya. Data test menunjukkan bahwa perangkat bekerja dengan baik. Perangkat pengendali air conditioner bekerja seperti skenario dan perintah yang diberikan. Sensor suhu memiliki kesalahan pembacaan sebesar 0,29% dan konfigurasi terbaik untuk sensor passive infrared berada pada radius 90°..

Kata kunci*— Air Conditioner, Kesalahan Pengguna, Internet of Things, Pengendali, Monitor*

Abstract

Air conditioner make electricity demand becomes higher over time. International Energy Agency (IEA) shows that electricity consumption for air conditioner will be the main trigger for the increase in world electricity demand in 2050. Higher electricity demand caused by inefficient usage of air conditioner due to human error factors. Human error that mostly happen is forget to turn off the air conditioner. This condition make air conditioner will be operate all day. This research is aim to reduce human error case that happened by making automated air conditioner controller and monitoring based on internet of things. This research use passive infrared sensor as an input to make sure air conditioner in the room is used or not and temperature sensor DHT 11 to make sure air conditioner operation. Internet of things technology is used to monitor the output from the system and control the device. Data test shows that the device works well. Air conditioner controller device works as the command and scenario that given. Error reading for temperature sensor is 0.29% and best configuration for infrared transmitter and passive infrared at radius 90°.

Keywords— *Air Conditioner, Human Error, Internet of Things, Control, Monitoring*

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1. INTRODUCTION

Machine to machine or M2M communication is two communicating machines that exchange data without human interaction. This process includes serial connections, power line connections, or wireless communications. Development of M2M and Internet of Things (IoT) service businesses in the world has continued and shows a significant increase. The increasing IoTdevelopment has been driven by the demand for remote sensing and monitoring product [1]. Many surveys have been done for reviews IoT application research challenges and area such as IoT hardware, cloud platform technologies, manageable, and intelligent services [2]. The application of the IoT can be utilized for various things such as smart cities, smart public transportation systems, digital payments, manufacturing, and household [3]. IoT gives new paradigm that aimedto providing solutions for integration and communication. Research focus in IoT area comes from monitoring and controlling device for smart home [4]. According to the International Energy Agency (IEA), electricity consumption for air conditioning will be the main trigger for the increase in world electricity demand in the next 2050 [5]. The use of air conditioning becomes inefficient due to human error factors [6]. Biggest problem for this issue because user forget to turn off air conditioner. In addition, how to use AC is one of the triggers for the waste of electricity used. Most people set the air conditioner temperature at 16°C and 18°C when start operating [7]. This condition will cause the air conditioner compressor works at maximum power. In addition, this condition makes the usage room temperature very cold and increase in electricity costs. The proof is data from Badan Pusat Statistik (BPS) shows that highest electricity distribution in Indonesia comes from household [8].

Research about controlling air conditioner based IoT shows increasing trends. Researcher concern about how to control air conditioner, lamp, and projector that show connection between client and microcontroller. The communication between device and platform is quite good with average latency 3 – 8ms without request time out [9]. Another research area aims to implement IoT to control air conditioner automatically in class room and using the technique of calculating the number of people with an ultrasonic sensor to determine the temperature of the air conditioner and remote control using the web. This research shows that air conditioner can be controlled without remote and can be set from website [10]. Research about development an innovative system in air conditioning also done. This research aims to control temperature by making 2 prototypes. First prototype has a function to control air conditioner using a relay and the other prototype is made for measure temperature [11]. Research about control air conditioner for set comfort temperature according to predicted mean vote (PMV) method has been done. This research shows that using air conditioner at the lowest temperature can be interfere user and feel discomfort. PMV method can be used to set best temperature for specific room size and how many users in that room [12]. Other research aims to develop AC control using microcontroller and send the result trough Raspberry Pi as a server. This device uses 2 microcontrollers. One microcontroller for monitoring temperature and the other one for control air conditioner. This research shows that data can be send to server trough internet. AC control and monitoring thermal works well and all the data is saved to server [13]. Air conditioner controller can be very useful to reducing electricity cost [14]. Research about implementing controller such PID and neural network gives good improvement for controlling air conditioner [15]. Not only controller technology but also internet of things technology can be implementing to optimize air conditioner [16]. Adding some sensor to monitor the parameter for air conditioner also gives improvement [17]. Controlling air conditioner from far location anywhere and anytime can solve electricity problem. Internet of thing can make controlling air conditioner from anywhere and anytime possible. From previous research shows that controlling air conditioner is a solution for electricity cost in household. This research will aim to improve air conditioner controller by use low cost and simple method that can be implemented in any area such as household, factory classroom, or office.

From the study literature above controlling air conditioner is important. Controlling air conditioner can decrease the probability of human error when operating air conditioner. This research aims to develop a simple and compact device that can be control air conditioner and monitoring room temperature in one device. Monitoring and controlling can be done using Internet of Thing platform. By using Internet of Things platform, user can be possible to turn off air conditioner from anywhere and anytime. This device has a feature to measure temperature with temperature sensor. This feature is important to make sure temperature room if the system set off for air conditioner but the temperature still low. It means that air conditioner controller device fail to turn off air conditioner. The problem is temperature sensor is very noisy. To reduce noise from reading room temperature from sensor, this research implements moving average filter. Moving average filter is a filter that can be used to sensor for stabilize output measuring. Control air conditioner from anywhere and anytime can be powerful to solve human error. When user forget to turn off air conditioner, user can check status of air conditioner and turn it off anywhere. Although, if user also forget to turn off air conditioner trough internet of thing platform, system will apply automatic turn off is system when system detect any human.

2. METHODS

From the study literature above controlling air conditioner is important to minimize human error. This research aims to develop a simple and compact device that can be control air conditioner room temperature in one device. Monitoring and controlling can be done by using internet of thing platform. User can turn off air conditioner from anywhere and anytime by using internet of things platform. The device development in this research has a feature to measure temperature. This feature is important to make sure that air conditioner is on or off. When IoT platform show air conditioner is turn off but temperature sensor still give low temperature, it means that something wrong with the device. Other issue by using temperature sensor is that temperature sensor can be very noisy. To reduce noise from reading room temperature from sensor, this research use moving average filter. Control air conditioner from anywhere and anytime can solve human error problem and mistakes when operating air conditioner. When user forget to turn off air conditioner, user can check status of air conditioner and turn it off anywhere. Although, if user also forget to turn off air conditioner trough internet of thing platform, system will apply automatic turn off is system when system detect any human.

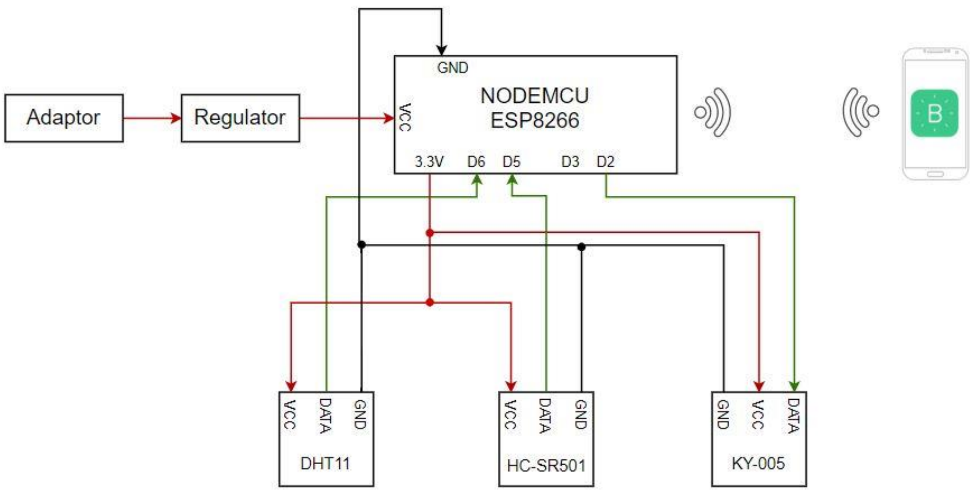

Figure 1 Block Diagram System Air Conditioner Controller

The device consists of temperature sensor DHT11, passive infrared sensor HC – SR501, infrared transmitter KY – 005, and NODEMCU ESP8266 according to figure 1. NODEMCU ESP8266 is a main microcontroller. It used to read output from temperature sensor DHT11, passive infrared sensor HC – SR501, and control infrared transmitter KY – 005 for sending command to air conditioner. NODEMCU ESP8266 already equipped with Wi-Fi module to connectwith internet network. According to datasheet specification, NODEMCU ESP8266 can be powered with 7 – 12V input voltage, 16 digital pins, 1 ADC pin, compatible with serial communication such as UART, I2C, and SPI. NODEMCU ESP8266 is already have antenna that embed in the board [18]. DHT11 is a temperature sensor. According to datasheet specification, this sensor can be powered with 3.3 – 5.5V, 16-bit resolution when reading temperature, and accuracy ± 2°C. This sensor can communicate with NODEMCU ESP8266 through pin digital D6 [19]. Passive infrared sensor HC – SR501 function is to detect human activity in room and inform if the room still used by user or not. According to the datasheet, HC – SR501 can be powered 5 – 20V with current consumption 65mA, sensor TTL output 3.3V or 0V, sensing angle range less than 120 degree, and sensing object distance range less than 7m [20]. Infrared transmitter KY – 005 basically is an infrared blaster at remote controller. The advantage of KY – 005 is this module iscompatible for microcontroller application. According to the datasheet, KY – 005 can be powered with 3.3V and consume 20mA to operate [21].

2.1 Moving Average Filter

Basically, moving average filter is a low pass filter in finite impulse response that can be used to reduce noisy signal [22, 23]. Moving average filter can be applied in many filed such as to reduce noise in sensor response, sensor fusion, high frequency signal, and piezo electric sensor [24, 25, 26, 27]. According to the reference, this study use moving average filter for reducing noise for temperature sensor. DHT11 have the same issue with other sensor in the reference. DHT11 temperature reading is very noisy and give higher error rate when measure temperature. Moving average filter can be expressed by:

$$y\,(i) = \frac{1}{M}\sum_{j=0}^{M-1} x\,(i-j) \qquad (1)$$

Formula 1 shows that moving average filter equation. According to formula 1, y is an output filter, x is an input filter, M is a window for averaging, i is a present state, and j is previous state. Moving average filter works according to window M. If M is high, then output sensor can be more stable but the response will be very slow with temperature changing. If M is too low, output sensor maybe not as stable as higher M but the filter response is faster. The key to use moving average filter is set efficient window M according to the usage. This research will be investigating about moving average filter for optimize sensor reading.

$$err = \left|\frac{RD - SD}{RD}\right| x\,100\% \qquad (2)$$

Formula 2 is used to measure error reading temperature sensor before using moving average filter and after using moving average filter. According formula 2, err is an error value when sensor reading temperature in the room, RD is a real temperature data that obtained from room temperature sensor in class room, and SD is a system sensors data that obtained from DHT11 temperature reading. This research use Formula 2 to measure improvement for error reading temperature sensor. All sensor such as IR sensor performance cannot be measure by using Formula 2.

2.2 System Device

Air conditioner controller and monitoring device has 5 condition mode to operate. First condition is “ON” mode. This condition can be triggered by sensor HC – SR501 or internet of things platform. When PIR sensor HC – SR501 detect human activity or Internet of Things platform send "ON" command trough internet network this condition will be triggered. Second condition is "OFF". This condition also can be triggered by sensor HC – SR501 or Internet of Things platform. When HC – SR501 sensor do not detect any human activity in 5 minutes or Internet of Things platform send "OFF" command trough internet network this condition will be triggered. Condition "ON" will make air conditioner start operating and "OFF" condition will make air conditioner stop operating. Third condition is "Cold". This condition is initial condition after air conditioner is start operating. Condition "Cold" will set air conditioner temperature at 21°C. Fourth condition is "Medium". This condition can be triggered by sending "MEDIUM" command trough Internet of Things platform. When this condition is triggered, air conditioner will set temperature to 22°C. Fifth condition is "Cool" This condition can be triggered by sending "COOL" command trough Internet of Things platform. When this condition is triggered, air conditioner will set temperature to 23°C. Air conditioner controller and monitoring rules can be represented by flowchart system below.

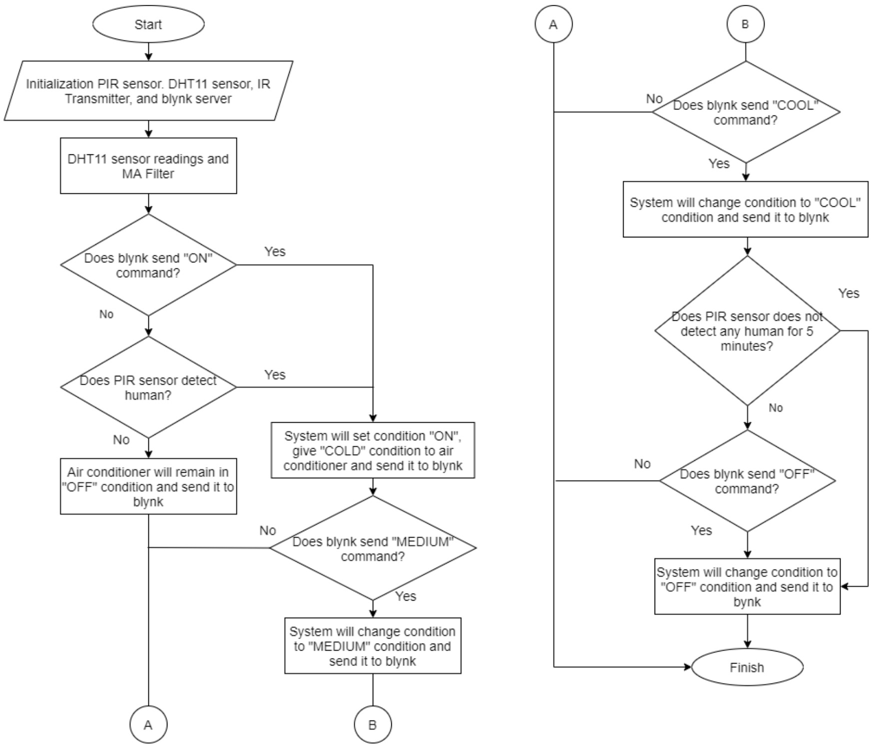

Figure 2 Flowchart System Rule

3. RESULTS AND DISCUSSION

The results of this study are the results of tests carried out from several sensors such as the results of DHT11 sensor readings, distance and radius testing on passive infrared HC – SR501 sensor, infrared transmitter KY – 005, and system scenario testing.

3.1 DHT 11 Sensor Reading

This test is show to determine the performance of the moving average filter applied to theDHT11 sensor. This test uses 6 different temperatures to measure, namely 21.00 ° C, 21.80 ° C, 22.10 ° C, 23.00 ° C, 24.00 ° C, and 25.10 ° C. The six temperatures are read with the DHT11 sensor by comparing the output before and after using a moving average filter. This research compare output from DHT11 with temperature and humidity room sensor for household.

Table 1 DHT11 Sensor Test Results before Using the Moving Average Filter

No	Thermometer Readings	Sensor DHT11 readings	Sensor reading error before using filter
1.	21.00°C	21.60°C	2.85%
2.	21.80°C	22.90°C	5.04%
3.	22.10°C	22.90°C	3.60%
4.	23.00°C	23.80°C	3.48%
5.	24.00°C	24.70°C	2.92%
6.	25.10°C	25.30°C	0.80%
Average Error Value			3.11%

Table 1 shows DHT11 sensor temperature testing before using moving average filter. The data is taken by obtain 20 data for each measuring parameter and average the 20 data into one parameter. According to the data test, DHT11 temperature reading give a quite high error. Highest error occurs when reading 21.80°C with 0.80% error rate, the lowest error occurs when reading 25.10°C with 5.05% error rate, and average error value at 3.11%. High percentage of error can cause system error in making decision for automated temperature setting. Average of error rate in this system is 3.11%. This value is quite high and need to be optimize. This research proposes moving average filter to optimize sensor reading.

Table 2 DHT11 Sensor Test Results after Using the Moving Average Filter

No	Thermometer Readings	Sensor DHT 11 readings	Sensor readings error after using filter
1.	21.00°C	21.00°C	0.00%
2.	21.80°C	22.00°C	0.91%
3.	22.10°C	22.00°C	0.45%
4.	23.00°C	23.00°C	0.00%
5.	24.00°C	24.00°C	0.00%
6.	25.10°C	25.00°C	0.40%
Average Error Value			0.29%

Table 2 shows DHT11 sensor temperature testing after using moving average filter. The data is taken by obtain 20 data for each measuring parameter, average 20 data, and write it to sensor DHT11 readings. According to the data test, implementing moving average filter for DHT 11 temperature lowered error rate while sensor reading temperature. Highest error occurs when reading 21.80°C with error rate at 0.91%, the lowest error occurs when reading 23.00°C and 24.00°C with error rate at 0.00%. Comparing data test result in Table 1 and Table 2 indicate that moving average filter lowered error reading for DHT11 temperature sensor. The average error reading lowered by 2.82%. The averaging error rate after is 0.29% and quite small compare to data system before implementing moving average filter. 0.29% error rate can be accepted to read temperature system and moving average filter was successful optimize error reading in temperature sensor DHT11.

3.2 Passive Infrared Sensor Test

Passive infrared sensor testing is carried out to obtain data about how far the signal capture by the passive infrared sensor. This test is done by using 10 different distances which is 0.5m, 1m, 1.5m, 2m, 2.5m, 3m, 3.5m, 4m, 4.5m, and 5m with a various angle radius of 30°, 60°, 90°, 120°, and 150°. This parameter testing is adjusted according to information from datasheet of passive infrared sensor. According to the datasheet, maximum distance for passive infrared sensor reading is 7m and maximum radius angle is 120°. This test goal is to know best configuration to set position of passive infrared sensor to the device. If the position is wrong, then several scenarios cannot work properly because passive infrared sensor cannot detect human activity in the room.

Table 3 Result Passive Infrared Sensor Testing

Angle / Distance	30°	60°	90°	120°	150°
0.5m	4x	5x	5x	5x	4x
1m	5x	5x	5x	5x	4x
1.5m	4x	5x	5x	5x	3x
2m	3x	5x	5x	4x	2x
2.5m	1x	5x	5x	5x	4x
3m	0x	5x	5x	3x	0x
3.5m	0x	5x	5x	3x	0x
4m	0x	5x	5x	5x	0x
4.5m	0x	5x	5x	5x	0x
5m	0x	4x	5x	4x	0x

Table 3 is the result of the passive infrared sensor test to detect human. This test shows that from specification from datasheet and data from testing quite different. Datasheet shows that sensor cannot work properly when the radius is above 120° but according to test result passive infrared sensor HC – SR501 still can work properly if the distance is close. Datasheet shows that sensor still work properly if the distance is below 7m but according to test result passive infrared sensor HC – SR501 still cannot work properly when the distance is 5m with radius 30° and 150°. According to the test result, the best configuration for passive infrared sensor HC – SR501 to detect human is in angle radius 90° and with maximum distance is 5m. This result provides information that infrared sensor works well for detecting user and can be implemented for air conditioner controller.

3.3 Infrared Transmitter Testing

IR transmitter transmit power test is carried out twice and is used to determine the right position to place the IR transmitter. This test uses 6 different distances with a radius of 90° to make sure that IR transmitter can works well with the right distance and angle. Table4 shows the results of the IR transmitter test.

Table 4 Infrared Transmitter Test Result

Angle / Distance	90°
2.1m	OK
2.5m	OK
3.3m	OK
4.7m	OK
5.2m	OK
7.6m	OK

Table 4 shows IR transmitter testing result. According table 4 IR transmitter that operate with radius 90° has a 100% success rate to send command to air conditioner. That means if the placement of the IR transmitter facing the AC with a radius of 90° is best position to send command. Different angle will occur different result and make the command that IR transmit will not accepted to air conditioner.

3.4 Scenario Testing

Scenario testing is carried out to ascertain whether the expected scenario is suitable or not with the execution results. Table 5 is the test result of controlling and monitoring air conditioner device performance when using passive infrared sensor scenario. Table 6 is the result of the room condition test by using Internet of Things platform command. This research used Blynk as an internet of things platform to send command trough internet network to the device.

This test is must be done for ensure that research concept is work properly and all scenario concept is resolved.

Table 5 Results of Scenario Testing Via Passive Infrared

No	Condition Name	Expected results	Execution Results
1.	There are people in the room	IR Transmitter sends ON command code to turn on the AC	AC ON
2.	No one in the room	IR Transmitter sends OFF command code to turn off the AC	AC OFF

According data from table 5 shows that passive infrared sensor works properly to do automatic controller air conditioner. Air conditioner will automatically operate when sensor detect human activity and air conditioner will automatically turn off when sensor detect any human activity in the room. This data test is obtaining by using best position according to the passive infrared sensorwith radius angle at 90° and 5m distance.

Table 6 Result of scenario testing via Internet of Things Platform Blynk

No	Condition Name	Expected results	Execution Results
1.	Condition "OFF"	IR Transmitter sends OFF command code	AC OFF
2.	Condition "ON"	The IR Transmitter sends the ON command code	AC ON
3.	Cold Mode Condition	The IR Transmitter sends a command code to a temperature of 21 ° C	Set AC 21°C
4.	Medium Mode state	The IR Transmitter sends a command code to a temperature of 22 ° C	Set AC 22°C
5.	Cool Mode state	The IR Transmitter sends a command code to a temperature of 23 ° C	Set AC 23°C

Based on the results of the tests carried out, Table 5 and Table 6 show that in these conditions it reaches a success rate of 100%. This means that for this AC control system automatically using the PIR and remotely using the Blynk application platform, the system can work properly as expected. This result only can be obtain by using same parameter such as distance, angle, component, and method.

Figure 3 Inner Section Device

Figure 4 Device Position in Classroom

Figure 3 shows inner section of the device. The device consists of NODEMCU ESP8266, passive infrared sensor HC – SR501, temperature sensor DHT 11, infrared transmitter KY – 005, and 9V battery. Controller and monitoring device dimension is 160mm x 130mm x 40mm. Figure 4 shows position device while operating in the classroom. The red circle means the device with passive infrared sensor facing out. All test shows that the scenario is works properly and well implemented. This test proves that controlling and monitoring air conditioner device work as a scenario in figure 2. All the possibility human error such as forgetting to turn off air conditioner when air conditioner is not in use or set 16°C when start the air conditioner can be minimize by using this device.

4. CONCLUSIONS

From several testing results this research concludes that overall system is work properly and ready to implement. System can do the task in all scenario testing to reduce human error when operating air conditioner. Moving average filter is useful filter for DHT11 sensors to reduce error from 3.11% to 0.29%. Infrared transmitter position radius is 90° direct to air conditioner to maximize transmitting command trough air conditioner. Passive infrared best radius to operate at 90° direct to user. By using this configuration, remote control and monitoring device using internet of things platform can be done well. Sending mode "ON", "OFF", "COLD", "MEDIUM", and "COOL" can be received and executed properly by the AC control device. Overall, the deviceworks properly and can be implemented.

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