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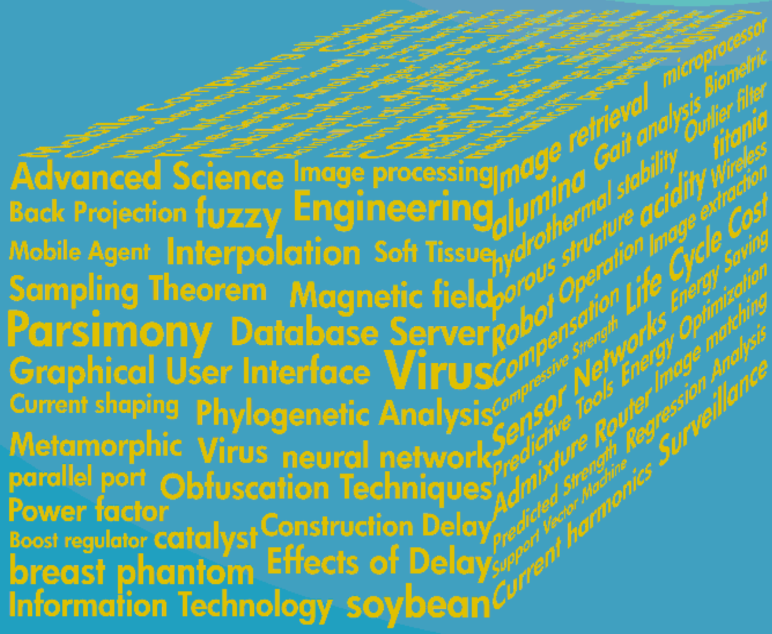

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IoT-Based Air Conditioning Control System for Energy Saving

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***Abstract*—A high portion of electric consumption is air conditioning in householders or offices, reaching 42%. Therefore, it is necessary to automatically regulate air conditioning operations for energy saving using a control system, usually involving its hardware. As another option, the control system also involves electronic devices and software. This research developed an automatic control system using an ESP32 microcontroller integrated into the Blynk-based internet of things (IoT) for energy-saving air conditioning. The ESP32 was programmed using Arduino IDE and combined with a motion sensor to maximize energy saving. The motion sensor was a trigger to turn on the system. The recorded data were current, voltage, power, temperature, and motion detection. Based on the recorded power, the consumed energy was computed using trapezoidal and Simpson's composite rules of numerical integrations and ordinary methods. The testing was conducted in conventional, manual, and automatic operations. The yielded automatic control system operated adequately. The testing results revealed that the automatic operation saved 1.15 kWh (15.00%),0.99 kWh (13.66%), and 1.14 kWh (14.87%) average daily energy compared to the conventional operation, respectively, by using the ordinary, Simpson's composite rule, and trapezoidal composite rule computations. While the automatic compared to the manualmethodssaved1.68 kWh (20.44%), 1.78 kWh (22.14%), and 1.66 kWh (20.24%), respectively, for the same computations. Thus, the automatic system considerably saved energy compared to conventional and manual operations. Moreover, these energy savings were also higher than some previous research on air conditioning energy savings.**

***Keywords*—Air conditioning; energy; ESP32; motion sensor; Simpson; trapezoidal.**

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I. INTRODUCTION

Air conditioning usages focus on comfort and safe [1]. It spent 35%-42% more electricity for householders [2], and even HVAC is utilized to provide grid services [3]. Many efforts on energy saving of air conditioning systems have been conducted, such as dynamic setting temperature, 59.1% of energy consumption saving [4], ventilation and variation law of 30% reducing energy consumption [5], 8.6% of conserved energy of adaptive model [6], 11%-30% extended driving range of utilizing air re-circulation [7], 38% reduced electric energy of M-cycle evaporative cooling [8], 15% potential energy saving of lightweight thermoelectric [9], 50% recover energy of exhausted air [10], PCA-GMMs has 99% fault diagnosis correct rates [11], 6.4% reducing energy consumption with stratum ventilation [12], 12.3%, 38.5% and 221.9% energy efficiency improvements in three cities [13], 4%-12.4% decreasing power consumption using a evaporative cooling of condenser of a split-type AC [14], balance on energy saving and thermal comfort on a BEV by 10% slow down, energy gain reached 2.2 kWh [15], and 20% reducing fuel consumption on home appliances (including ACs) using a hybrid PV, diesel generator and batteries [16].

The energy-saving strategies were also using multiple machine learning methods [17], a high energy efficiency rating inverter [18], a digital scroll compressor of multi-unit AC [19], and an 18% reducing cooling energy by using PCRC [20]. On the other hand, the internet is widely used for various information retrievals, file sharing, and so on [21]. A 26% reducing fan power using raised-floor fixed panels was reached in a data center [22], and a data mining approach is a more accurate simulation of energy-saving [17]. An AC controlling energy consumption focused on either scheduled switching or optimizing [23].

Moreover, Kevin Ashton proposed IoT in 1999 has the potential to improve energy efficiency [24]. Recently, most models of released AC have been IoT-enabled [25]. The IoT technology controls set-point temperatures improving energy-saving potential in reducing the energy consumption of ACs [26].

Using an IoT basis, a preference map reduces 57.38% energy consumption [25], A PMV-based temperature control system saved 33%-44% of consumed energy [27], and an IoT-based computer room achieved 16.64% energy-saving [28]. The IoT prototype saved up to 20% of energy in HVAC systems [29]. The IoT framework and Blynk Application Programming Interface (API) for monitoring the achieved data of 0.9 kWh HVAC energy saving [30]. The use of CoAP of IoT in an intelligent building could save energy by 30.86% [31]. An air-handling process and chilled water loop achieved an energy saving of 16.4% [32].

Nevertheless, the energy-saving efforts on air conditioning involved in IoT are limited. Therefore, a new design, implementation, and testing method for IoT-based energy-saving monitoring and automatic control should be investigated. It also used motion-sensing as existing human detection. The research objective was to find out an IoT-based automatic system for an air conditioning operation to maintain thermal comfort. In comparison, the purpose of the research was to acquire electrical energy savings consumed by an air conditioner compared with previous similar research and other methods; conventional and manual.

II. Material and Method

Generally, conventional temperature-controlled air conditioning ignores the occupants in a room. Even though the air conditioner operates based on temperature sensing, this is still wasteful, and consumption savings can still be made based on the presence of occupants in a temperature-controlled room. Thus, two sensors were needed, namely temperature and motion sensors, hoping the electrical energy consumed could be saved further. For example, above the setting value, the air conditioning will continue to work in extreme conditions when the temperature is high. However, the air conditioner will turn off if there are no occupants. Thus, electrical energy consumption can be saved more when compared to only based on temperature sensing, which will turn on continuously if the set temperature value has not been reached.

Fig. 1 shows the system block diagram of the designed monitoring and control of the air conditioning based on IoT. The main input quantities, temperature, and adult human movement were sensed by LM35 temperature and motion passive infrared (PIR) sensors. In this case, the mean temperature was the conditioned room's temperature. Although the outside temperature, number of occupants, and presence of opened window influence the room temperature, the occupant comfort is determined by the room temperature itself. In comparison, the PIR sensor sensed the presence of occupants regardless of the number of occupants. Equipped with this PIR sensor, the system will save further electrical energy consumption rather than just a temperature sensor. The signals from the sensors entered into the ESP32 microcontroller. The main output equipment was a relay, transistor, liquid crystal display (LCD), and modem.

The programmed control system used Arduino IDE software inserted into the ESP32 microcontroller. The program read a room temperature. The program measured voltage, current, and power using PZEM-004t, connected to the ESP32 microcontroller. The automatic system operated when the motion sensor detected an adult human movement, so the air conditioning was turned on. It was also remotely monitored and controlled by the Blynk software, installed on a smartphone, and integrated into the ESP32 microcontroller.

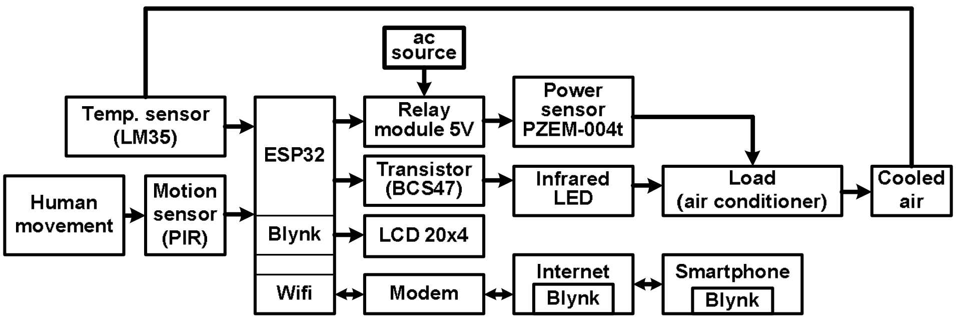


Fig. 1 Automatic system diagram

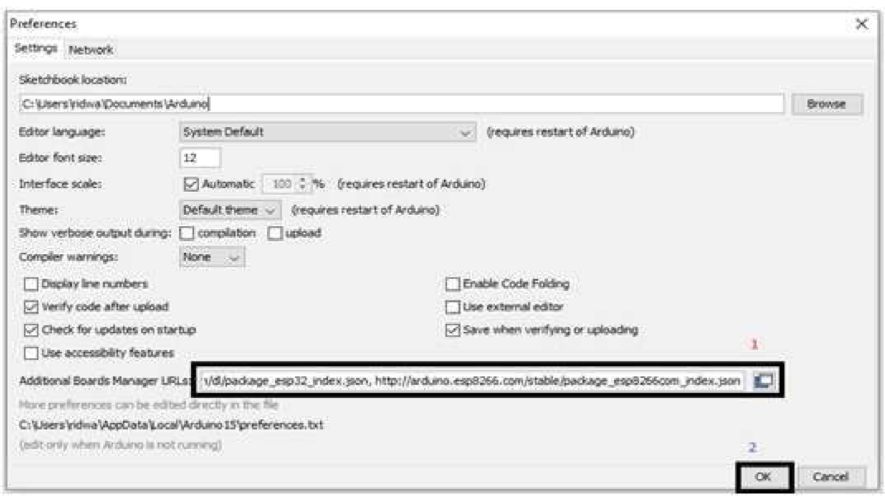


Fig. 2 Display on Preferences Settings

The Arduino IDE was run by entering the File into the Preferences menu. Furthermore, it was displayed in the dialog window, and copying of the link was then entered in the Boards Manager and running, as shown in Fig. 2. The Arduino IDE downloaded data from a particular address.

The application of the AC should be able to send an infrared signal, like a standard AC remote. However, the unique pattern of an infrared signal received by the AC could not be changed because it could only accept the particular designed infrared signal set by the factory. Nevertheless, the unique infrared signal could be achieved using the ESP32 microcontroller. The ESP32 circuit, connected to the TSOP1738 IR Receiver, was linked to an Arduino IDE installed computer. The program was created for the infrared signal pattern reading and uploading to the Arduino ESP32. The remote button for the AC infrared signal included the switch to turn on at 20°C to 32°C in a 1°C step. The unique pattern of the infrared signals was visible in the numerical forms on the Arduino IDE software monitor. The button on the AC remote was directed to TSOP1738, which was connected to the Arduino.

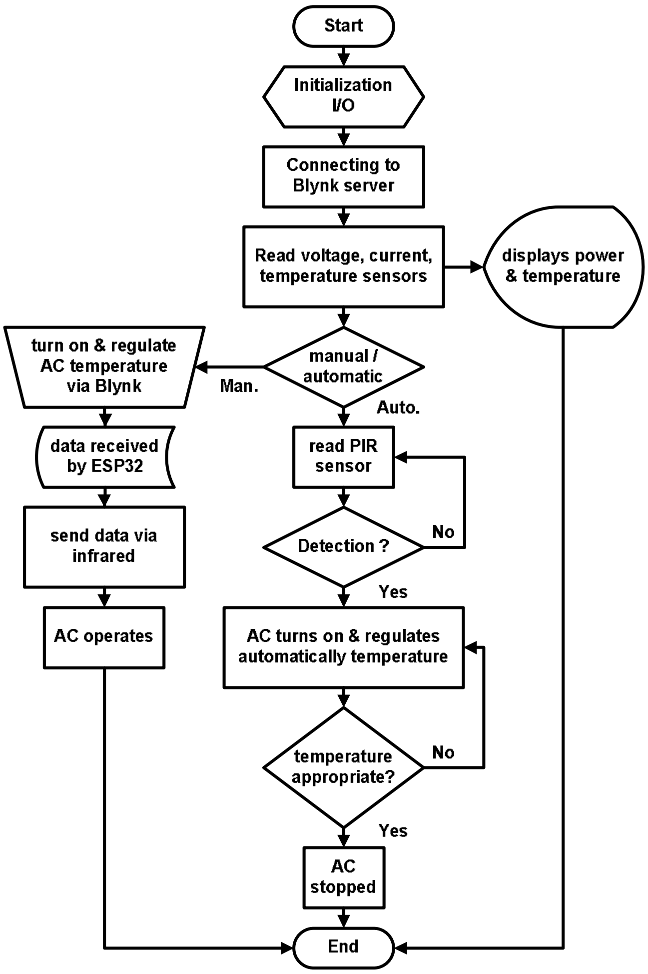


Fig. 3 Automatic system flow chart

The first step of designing Blynk software was creating an account on an Android and logging in. Furthermore, a new project should be done. All necessary features were added, including a control and monitoring system. In the automatic system, initially, the PIR sensor was placed near a door to detect the presence of an adult human. Therefore, the microcontroller ordered the infrared transmitter to turn on the system and vice versa. Fig. 3 shows the flow chart of the complete automatic system.

The system was turned on to initialize the input and connect to the Blynk server. The reading voltage, current, and temperature were displayed on the LCD. It used manual and automatic methods. The manual method used the Android-installed Blynk application. The ESP32 sent the data via the infrared LED to the load. While the automatic method used a PIR sensor. If an adult human movement was detected, the system automatically controlled the room temperature; as the temperature followed the program, the air conditioning turned off, although a human was still detected. The air conditioning system was continuously turned on if the room temperature was not achieved yet.

Fig. 4 shows the block diagram of the ESP32 microcontroller and Android system integration. The controlling process sets the air conditioning to room temperature, programmed in the Arduino IDE software. The system commanded the automatic and manual methods via Android. The ESP32 microcontroller was connected to a modem via Wi-Fi, an internet network, and Android.

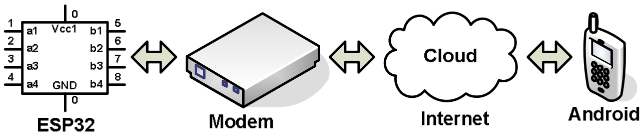


Fig. 4 ESP32 integration to Android

The 20x4 LCD integration to the Android allowed recording of temperature, voltage, power, and current data, which were sent to the Blynk application. The recorded data could also be sent via email using Microsoft Excel format.

The conditioned room size is 4 m (13.12 ft), 3 m (9.84 ft), and 3.3 m (10.82 ft), respectively, for length, width, and height. It is on the top floor (4th floor) and the south of the longest wall. Therefore, the minimum necessary air conditioning capacity was 8381.22 Btu. The closest air conditioning capacity was 9000 Btu or 1 PK based on the conversion. Meanwhile, in this study, the portable AC capacity was 1.5 PK. This value exceeded what should be used following the calculation. By using that capacity, it should be able to condition the room.

The data analysis used box plots, where narrow boxes correspond to more constrained conditions. A box plot middle line corresponds to a data set median value. In comparison, the lower and upper lines correspond to the first and third quartile values, respectively [33].

The analysis also used PCA (principal component analysis), which transformed all information of the sample set into little comprehensive information [34]. If a sample set matrix X_{nxp}, the zero mean is shown in equations (1), (2), and (3).

$$AVG = [avg_1 + avg_2 + \dots\dots + avg_3] \quad (1)$$

Where

$$avg_j = \frac{1}{2}\sum_{i=1}^{n} x_{ij} \;;\; j = 1,2,\dots,p \quad (2)$$

And

$$Z_{nxp} = X_{nxp} - repmat(AVG, n, 1) \quad (3)$$

The covariance matrix R with element r is as equation (4)

$$r_{ij} = Cov(z_i, z_j); i, j = 1,2, \ldots, p \quad (4)$$

The eigenvalues are obtained by using equation (5) [34]

$$|\lambda E_p - R| = 0 \quad (5)$$

Where avg_j, AVG, repmat(AVG,n,1), $\lambda_1, \lambda_2, \ldots, \lambda_p$, E_p are j-column average values, 1xp dimension matrix AVG, eigenvalues and identity matrix respectively. Usually, a principal component analysis uses two dimensions so that the plot uses the first two components to represent the data. The more the PCA plot represents the actual data, the greater the first eigenvalue is greater than the other eigenvalue. Negative and positive correlated parameters are indicated by opposite and grouped positions, respectively. The consumed energy was computed by using Simpson's composite rule, trapezoidal composite rule, and ordinary methods. The first two methods are revealed in equations (6) and (7), respectively[35].

$$W_S = \frac{\frac{b-a}{3}\left(f_{x_0} + 4\sum f_{x_{odd}} + 2\sum f_{x_{even}} + f_{x_n}\right)}{3600} \quad (6)$$

$$W_T = \frac{\frac{b-a}{2}\left(f_{x_0} + 2\sum f_{x_{n-1}} + f_{x_n}\right)}{3600} \quad (7)$$

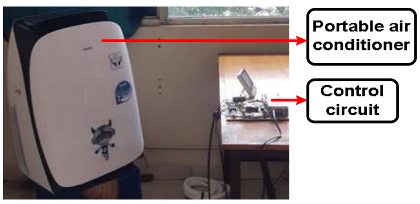
Where a, b, f_{x_0}, f_{x_n} and 3600 are lower limit, upper limit, initial power data, last power data, and hour-to-second conversion, respectively. While the ordinary method is shown indicated in equation (8), where P and Δt are power and interval time, respectively.

$$W_o = \sum P x \Delta t \quad (8)$$

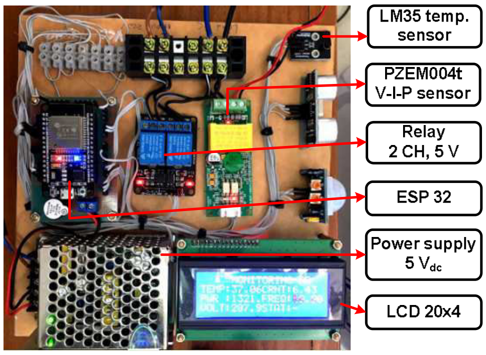
For comparisons, the testing was conducted using conventional, manual, and automatic methods. The first test was run smoothly without being managed by an adult human. The AC was set at 20°C and ran from 08:00 until 17:00 time range every day, on a weekday. In other weeks, it was assumed that the patterns of consumed powers were the same on the same day. The second test was run manually according to the human felt. The air conditioning was turned on and turned off if it was too cold, which was also carried out on weekdays, from 08:00 until 17:00 for four weeks, with data retrieval at the interval of 30 minutes. The third test was run according to the yielded automatic system, which was carried out on weekdays, too, from 08:00 until 17:00 for four weeks, with data retrieval at the interval of 30 minutes. According to the standard, the temperature sensor was set to maintain a comfortable condition.

III. Result and Discussion

Fig. 5(a) shows the portable air conditioner and automatic control circuit as the main equipment of the research. While Fig. 5(b) shows the hardware of the control circuit. It consisted of the temperature sensor, V-I-P sensor, relay, ESP32 microcontroller, power supply, and LCD.



(a)



(b)

Fig. 5 (a) Actual conducted research implementation, (b) control circuit hardware

Fig. 6 shows the Blynk software display, which has added a logger recording feature for the data retrieval process. The data could be sent through an internet network to email and in Microsoft Excel format. The automatic system has successfully operated.

Fig. 6 Blynk logging display

A. Conventional Testing

The conventional testing was carried out by operating the AC according to the specified setting at the manufacturer's default and monitored using the Blynk application. Fig. 7 reveals the typical daily consumed power. The power tended to increase due to increasing temperature in the morning. While, in the time range of 12:00-13:00, the power was zero due to occupants leaving, and the air conditioner was turned off. After this time range, the consumed power rose again due to higher room temperature. Furthermore, Table 1 lists the weekly typical consumed power. The typical powers were similar, except for Friday; the power quartile range was higher due to probably longer left.

Table 2 lists the weekday consumed energy based on the Ordi(ordinary), Simp(Simpson's composite rule), and Trap (trapezoidal composite rule) methods. Usually, the ordinary method has the highest computed energy, followed by the trapezoidal and Simpson's composite rule methods. The ordinary method is the coarsest, whereas Simpson's composite rule method is the finest. The daily consumed energy was typical. It only experienced a slightly decreasing trend in energy consumption on the days of the week. Monday and Tuesday were probably caused by heat deposition on weekend days, so it takes much energy to condition the room.

Meanwhile, for Wednesday and Thursday, the temperature conditions depended on the previous temperature conditions; Tuesday, where the room temperature has been previously conditioned, so the energy required to condition the room is relatively lower. Finally, energy was required to condition the room on Friday, where energy consumption was the lowest. This case was probably caused by, besides being determined the day before, the occupant also praying Friday prayers, so the duration of occupying the room was shorter than the remaining days.

B. *Manual Testing*

The second manual operation test followed an adult human sense in the room. Normally, the air conditioner was turned on. However, if it was too cool, the AC was turned off. The modes depended on the occupants. This testing was carried out from 08:00 until 17:00 on weekdays for four weeks.

The typical daily consumed power of the manual operation is also revealed in Fig. 7. The consumed power increased slightly due to adjusting to occupants' comfort in the morning. The range of typical consumed power was between 1013 W and 1051 W, as listed in Table 1. However, the air conditioning was turned off between 12:00 and 13:00, so the power consumption was zero. The air conditioning was turned on again in the afternoon and adjusted to the occupant's comfort. Therefore, the consumed power decreased slightly as a time to the evening.

Fig. 9 shows the typical room temperature of the manual operation. In the morning, the temperature decreased because the air conditioning was slightly more comfortable. At noon, 12:00 until 13:00, the room temperature even reached 30°C because the occupant left it, and the air conditioning was turned off. After 13:00, the temperature decreased because the air conditioning turned on.

Fig. 8 reveals the typical daily humidity. The humidity tended to decrease considerably in the morning. This case occurred due to air blowing from AC, besides the probable increasing outside temperature. From 12:00 until 13:00, the air conditioning was turned off so that the humidity slightly increased. After this time, the air conditioning turned on again so the humidity decreased.

Figs. 8 also shows the manual operation's weekly room temperature and humidity. The typical values did not change considerably. The typical temperature and relative humidity ranges were 26 (C - 27 (C) and 61 % - 65 %, respectively. Therefore, the days did not influence those quantities considerably. While Table 2 lists the average weekly manual consumed energy. Generally, it did not change considerably every day, and it ranged from 7.8 kWh up to 8.5 kWh.

C. *Automatic Testing*

The last test used the automatic system of the ESP32 basis. This test aimed to save the air conditioning consumed energy. It ran when the motion sensor read a human movement in the room. This system operated when an internet connection was connected to the ESP32 in wireless.

Fig. 7 shows the daily typical consumed power of the automatic operation. In the morning, visually, the typical consumed power tended to decrease. The average typical power was 986 W, and the average decreasing power was -296 W/h. While, at noon, the consumed power was zero because the PIR of the system detected an adult human leaving the room. At around 13:00, the occupant entered, and the automatic system started to turn on. In the afternoon, the consumed power decreased considerably from that in the morning. This case was probably caused by the fact that the rate of outside temperature was lower, to decrease, than that in the morning, which increased. The average typical consumed power was 807.6 W, and the decreasing rate of the power was -672 W/h. In the afternoon, the average consumed power was lower, and the power decreasing rate of -672 W/h was higher than that in the morning.

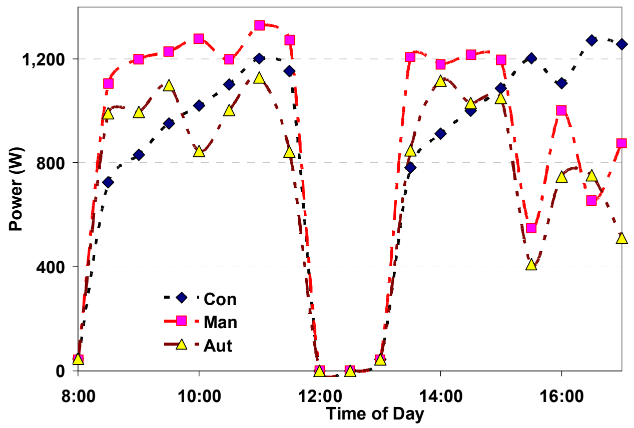


Fig. 7 Daily typical consumed powers

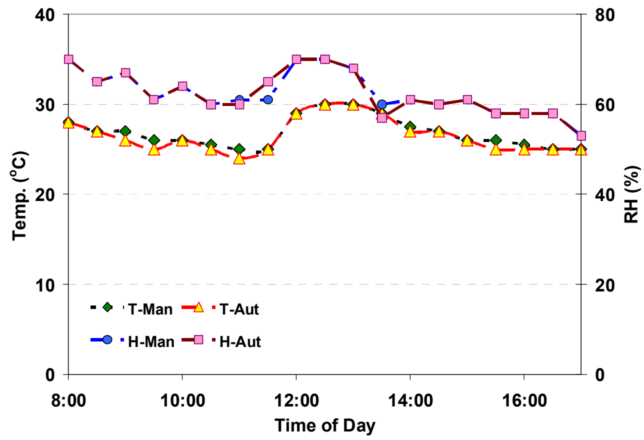


Fig. 8 Daily typical temperature and humidity

Fig. 8 reveals the typical daily temperature pattern in the automatic operational method on the last chart. In the morning, the temperature tended to decrease, and the system turned off at around noon because the occupant left, detected by the PIR sensor, until around 13:00. In this range, the temperature suddenly highly increased to the value of 30°C. At around 13:00, the occupant entered the room so that the air conditioning system started to turn on automatically. Therefore, the room temperature decreased again to be more comfortable, around 25°C, until 17:00. Fig. 8 also shows the typical daily humidity due to automatic operation. Due to the blowing air conditioner, the humidity decreased considerably in the morning and afternoon. At noon, the humidity was relatively high due to no air blowing.

Table 1 also lists typical weekly temperature, humidity, and consumed power for the automatic operation. The typical temperature was fairly constant, at 26°C. While the typical relative humidity experienced slight variations, between 61% and 64.5%, and the typical consumed power experienced considerable variations, 735 W up to 835 W. This case is reasonable because the detected quantity of the automatic was temperature.

TABLE I
WEEKLY TYPICAL POWER, TEMPERATURE, AND RELATIVE HUMIDITY

Op.	Day	Power (W)	Temp. (°C)	RH (%)
Con	Mon	1,001	-	-
Con	Tue	1,014	-	-
Con	Wed	934	-	-
Con	Thu	1,012	-	-
Con	Fri	925	-	-
Man	Mon	1,020	26	61
Man	Tue	1,049	26	65
Man	Wed	1,051	27	64
Man	Thu	1,020	26	61
Man	Fri	1,013	26.5	61
Aut	Mon	735	26	64.5
Aut	Tue	835	26	63
Aut	Wed	773	26	64
Aut	Thu	788	26	61
Aut	Fri	769	26	61

TABLE II
WEEKLY AVERAGE CONSUMED ENERGY

Op.	Day	Method of computation		
		Ordi.	Simp.	Trap.
Con	Mon	8.02	7.91	8.01
Con	Tue	8.08	7.94	8.07
Con	Wed	7.39	6.66	7.39
Con	Thu	7.73	6.98	7.72
Con	Fri	7.25	6.76	7.23
Man	Mon	8.50	8.45	8.42
Man	Tue	8.19	8.24	8.18
Man	Wed	8.27	7.83	8.26
Man	Thu	8.14	7.79	8.13
Man	Fri	7.98	7.96	7.97
Aut	Mon	6.30	6.22	6.29
Aut	Tue	6.96	6.90	6.95
Aut	Wed	6.57	6.04	6.55
Aut	Thu	6.48	6.03	6.46
Aut	Fri	6.29	6.23	6.28

The average energy consumed by the automatic system per day is listed in Table 2. The charts show the computation energy using the ordinary, Simpson's composite rule, and trapezoidal composite rule methods. Generally, it was proven that the consumed energy of the automatic method was lower than those of conventional and manual operational methods. Therefore, there was energy saving using the automatic operational method. It was also proven that the output power was following the presence of occupants because this system detected movement.

Fig. 9(a) shows the temperature and relative humidity scatter plots and exponential regressions as a function of the consumed power. The temperature was pretty constant, as indicated by the power of the exponent was very small, only -3×10^{-6}. While, the humidity slightly increased as the consumed power rose, with the exponential constant of 5×10^{-5}. This case is also confirmed by the increasing humidity as the temperature increases, as shown in Fig. 9(b). It is also supported by principal component analysis (PCA), as shown in Fig. 10, where the temperature and humidity are on one side vertically. Thus, the humidity slightly increased as the temperature rose. While the humidity and power are on one side horizontally. Therefore, the humidity slightly increased as the power rose.

This case is the opposite of what happens in general conditions without air conditioning, where when the temperature increases, the humidity will decrease. In the air-conditioned room, this is since the temperature will increase the blower's work so that the air that contains water vapor will be blown too.

Moreover, the temperature opposites slightly with the consumed power, and the consumption increased in the conditioned room so that the temperature decreased. This case is also in line with the temperature versus power chart, in which the temperature slightly decreased as the consumed power increased, as shown in Fig. 9(a).

Based on the principal component analysis, the first, second, and third eigenvalues are 1.67212, 0.80128, and 0.52660, respectively. Thus, the sum is three, and the absorbed information of the data set was 82.45% which indicated that data were highly enough representatives.

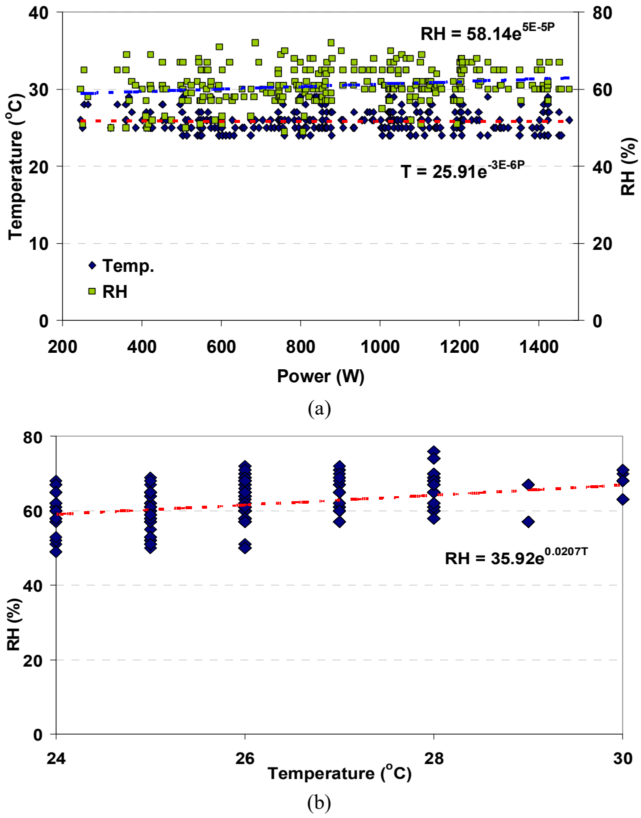
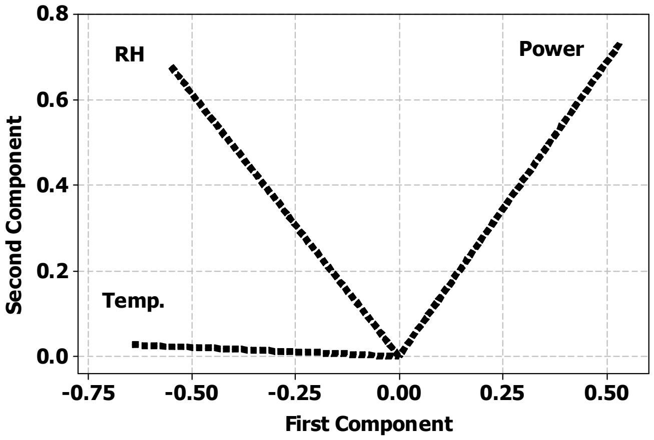


Fig. 9 (a) Temperature and humidity versus consumed power, (b) humidity versus temperature

As long as the testing, the room was still influenced by the outdoor temperature. This case was probably caused by the room facing south, leaning west, and on the top floor, which is always the hottest among remaining floor rooms, due to the sun radiation during the afternoon and is exposed to direct heat from the roof. Therefore, the air conditioning capacity is not always determined by the AC capacity.



(c)

Fig. 10 Principal component analysis on temperature, humidity, and consumed power

Table 3 lists the average energy per day comparison among tests and computations. The consumed energy of the manual operation and ordinary computation methods occupied the highest, and while the automatic operation occupied the lowest consumed energy.

TABLE III
COMPARISON AMONG TESTS AND COMPUTATIONS OF ENERGY

Methods	Trap. (kWh)	Simp. (kWh)	Ordi. (kWh)
Conventional	7.68	7.25	7.69
Manual	8.20	8.04	8.22
Automatic	6.54	6.26	6.54

Moreover, the comparisons between automatic and conventional operations and automatic and manual operations yielded energy savings. The automatic operation saved energy compared to the conventional one as 1.154 kWh (15.00%), 0.99 kWh (13.66%), and 1.142 kWh (14.87%), respectively, for the ordinary, Simpson's composite rule and trapezoidal composite rule methods. While the automatic-to-manual operation saved 1.68 kWh (20.44%), 1.78 kWh (22.14%), and 1.66 kWh (20.24%), respectively, for the ordinary, Simpson's composite rule, and trapezoidal composite rule methods. These values of the energy-saving were lower than that of the dynamic setting temperature, 59%.1% [4], ventilation and variation law, 30% [5], M-cycle evaporative cooling, 38% [8], exhausted air recovering energy, 50% [10], preference map, 57.38% [25], 33%-44% energy saving of the PMV-based temperature control system [27], and remote computer room, 40% [28]. However, these values of percentage energy saving are more significant than that of the adaptive model, 8.6% [6], with stratum ventilation, 6.4% [12], and 4%-12.4% power saving using the condenser evaporative cooling of split-type AC [14]. Nevertheless, these values were in ranges or around utilizing air extended driving range re-circulation, 11%-30% [7], lightweight thermoelectric, 15% [9], 12.3%, 38.5%, and 221.9% energy efficiency improvement [13], IoT for computer rooms, 16.64% [28], IoT prototype in the HVAC system, 20% [29], and 16.4% energy saving utilized chilled water loop and air handling process [32].

The manual air conditioning system consumes more energy because of several factors. The manual system operated as a human would. If it felt hot, the air conditioning worked heavier, so the electricity consumption was more significant than the automatic system. The set of the evaporator fan was high. Because when the fan rotated at the high (maximum), it was still complex for the air conditioning to reach the expected temperature. The fan continued to distribute the cool air from the system to the room so that the temperature on the evaporator rose again. On the other hand, the fan of the automatic system rotated automatically according to the stable temperature. Thus, the fan operated at a low (minimum), and when the fan operated in a high state at a high temperature.

In comparing the conventional and automatic systems, the difference in energy was not so significant because the conventional system worked at the setting of 21°C AC temperature. This case was not according to the manual system because it used the human-felt comfort level. However, this manual method was often forgotten to use air conditioning efficiently, which resulted in higher consumed energy than the automatic method. Therefore, the automatic operation method has saved the consumed electrical energy compared to conventional and manual operations. Besides room temperature-based detection, this system detected an adult human movement in the room.

IV. CONCLUSION

The processing system of Arduino ESP32 commanded the automatic system, which was integrated through the Blynk application on an Android, to yield the quantity reading on the LCD properly. The data transfers from the Arduino ESP32 to the Blynk application were electric current, voltage, power, and temperature. As the first contribution of the research, the recording data based on the internet of things could be done anywhere using a computer or smartphone as long as there is an internet network. In comparison, the second contribution is that the system detected an adult human movement, besides that temperature sensing, for AC turning on.

The comparisons of average daily consumed energy-saving between automatic and conventional systems using the trapezoidal composite rule, Simpson's composite rule, and ordinary methods were 1.142 kWh (14.87%), 0.99 kWh (13.66%), and 1.154 kWh (15.00%) respectively. While the comparisons of average daily consumed energy-saving between automatic and manual systems using the same computation methods were 1.66 kWh (20.24%), 1.78 kWh (22.14%), and 1.68 kWh (20.44%), respectively. Furthermore, these energy savings were higher than the adaptive model conserved energy, 8.6% [6], stratum ventilation, 6.4% [12], split-type AC evaporative cooling of condenser,4%-12.4% [14], and BEV balance on energy-saving and thermal comfort, 10% [15]. Nevertheless, these energy savings were in ranges to extended utilizing air re-circulation, 11%-30% [7], 15% on lightweight thermoelectric, [9], energy efficiency improvements in three cities, 12.3%, 38.5%, and 221.9% [13], AC included home appliances using a hybrid PV, diesel generator and batteries, 20% [16] and using PCRC, 18% [20]. Thus, it is no doubt that the automatic operation system saved consumed energy which was the third contribution.

NOMENCLATURE

AC	Air conditioner
API	Application Programming Interface
Aut	Automatic
BEV	Battery-powered electric vehicle
Btu	British thermal unit
CoAP	Constrained application protocol
Con	Conventional
GMM	Gaussian mixture model
Fri	Friday
HP	Horsepower (745.7 watts)
HVAC	Heating, ventilation, and air conditioning
IDE	Integrated development environment
IoT	Internet of things
kWh	kilowatt-hour
LCD	Liquid-crystal display
LED	Light-emitting diode
Man	Manual
Mon	Monday
Ordi	Ordinary method (= Ordi.)
PCA	Principal component analysis
PCRC	Personalized cooling radiant cubicle
PIR	Passive infrared sensor
PK	Paard Kracht (735.5 watts, 0.986 HP)
PMV	Predicted mean vote
PV	Photovoltaic
RH	Relative humidity
Simp	Simpson's composite rule (= Simp.)
Temp	Temperature (= Temp.)
Thu	Thursday
Trap	Trapezoidal composite rule (Trap.)
Tue	Tuesday
V-I-P	Voltage-current-power

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