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Design and Development of Microcontroller-based Air Conditioning Units Controller as Input to Energy Conservation for University of Batangas

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ABSTRACT

University of Batangas not only aims to provide an effective method of instruction delivery through a conducive learning environment but also aspires to satisfy the needs of its clients. One initiative that could address this goal is thru the installation of Air-Conditioning Units (ACU) in all classrooms in the university. Doing so poses a liability because ACU misuse is widespread in some buildings. Observation showed that considerable amount of energy has been wasted due to ACU misuse. The main objective of this research was to develop an ACU controller that would empower the faculty members in controlling the use of the ACU. Developmental research method was used where each aspect of the process was documented. The developed device was installed in one engineering classroom where it was tested for its functionality, accuracy, and yielded impact in terms of cost savings. With the implementation of the developed device, a 32.3052% average daily savings was observed. If this percentage would be converted to savings, the university would be able to set aside a considerable amount. A longer period of testing would show further improvement and would benefit the institution in terms of cost savings relating to energy consumption.

Key words: Air-conditioning units, controller, microcontroller, energy saving

1. INTRODUCTION

The mission of the University of Batangas (UB) is to provide quality education by promoting personal and professional growth which encompasses diverse aspects. It not only focuses on the effective instruction delivery but also gives attention to other facets of learning needed in the attainment of its objectives. One such facet is the provision of a conducive learning environment where instruction delivery happens. There are two major factors though affecting the goal of providing conducive learning environment: temperature and noise.

Addressing the aforementioned dilemma led to the installation of air-conditioning units in almost all classrooms of the University, but installing these units poses some problems. In maintaining a comfortable temperature in every classroom within a school, teachers typically need to be able to control the temperature in their own classroom. The problem, however, is that the teachers in UB do not have this level of control as far as properly operating the air-conditioning units is concerned. The result is that the teachers, whether deliberately or in haste, leave the air-conditioning units running. Energy consumption for room air-conditioning accounts for about half of the total energy used in the building equipment area. Under this situation, it is clear that a major contribution to energy saving can be made by achieving greater energy efficiency if the air-conditioning systems is controlled more effectively. Energy conservation is important as energy is a requirement for sustainable development for twenty first century [1].

The question now is "how could an improvement in technology be used to implement energy saving for the University of Batangas specifically in terms of improving the operation of air-conditioning units?" Several technologies that perform the aforementioned tasks are already in existence. All of these technologies are centralized in an operating concept that uses microcontrollers as its brain and heart. A microprocessor is actually a computer on a chip with high-density memories that reduce costs and package size dramatically and increase application flexibility [2].

With the many variations of microprocessors in the market, it is therefore crucial to pick what is just right for the intended application. The microprocessor is a multipurpose, programmable device that accepts digital data as input, processes it according to instructions stored in its memory, and provides results as output. It contains both combinational logic and sequential digital logic [3]. One of the most famous microcontroller currently being used is the Arduino. Arduino has many variations to choose from depending on the application where it will be used Arduino is an open source tool for making computers that can sense and control the physical world than the desktop computer [4]. A. Majeed , R. Bhana, and S. Parvez [5] concluded in their paper that Arduino could be used in saving energy consumption in providing a cheap solution for a common living man .

Because of its flexibility, Arduino's applications could be used even in temperature control. The concept of ACU control using Arduino is not new. C. Bustamante, V. Lagahino and M. San Diego [6] used a variation of Arduino that has control of a wifi-module in designing a centralized ACU controller for Asia Pacific College. One contributing factor in the success of their study is the ability of the Arduino microcontroller to accept and execute control commands coming from the program embedded in its built-in memory.

Design and Development of Microcontroller Based Air Conditioning System is a journal article by T. Thein Soe , K. Soe Lwin, Z. Min Naing and A. Soe Khaing [7] utilized PIC 16F877A microcontroller, LM35 Temperature Sensor, Liquid Crystal Display (LCD), and ULN 2003A. They were able to control the air conditioner using the microcontroller. They concluded that the microcontroller based air conditioner prototype can be widely applied to control different kinds of human appliances and industrial applications. Moreover, they found out that it is a smart way to use microcontroller because of its reliability.

A study conducted by T. Sri Vignesh , S. Sudharsan , S. Sweetlin Packiavathi , M. Thangamani , B. Saravana Manikandan [8] entitled, "Design and Implementation of Air Conditioning System based on Temperature Control Device for Power Saving" focused on minimizing the energy consumption and health related issues. The main controller of their device is AT89C52 which belongs to Intel 8051 microcontroller having an IR sensor that detects the obstacle. Moreover, a thermistor and humidity sensors were interfaced to detect the temperature inside the room and to sense the humidity in the air by means of measuring both moisture and air temperature. They concluded that implementation of Air Conditioning System using microcontroller saves power and helps in unwanted run out of air conditioners for a long time.

This study aimed to come-up with a microcontroller-based ACU controller for UB and specifically aimed to: (1) design and develop a system that would automatically turn-on/turn-off air-conditioning units using the faculty ID; (2) test the developed system in terms of functionality, accuracy and reliability; and (3) estimate the impact on the financial operations of UB

2. METHODOLOGY

A systematic study of designing, developing, and evaluating instructional program, processes, and products that must meet criteria of internal consistency and effectiveness was employed in this study [9].

A research model that includes three stages: design and development, testing, and implementation was utilized. The first stage encompasses the process of identifying the software and hardware requirements and then transforming it into a working prototype. Then a ten (10) trial testing was done on all components and on the prototype. The finished prototype was then installed in the two ACU at one class room within a period of two months for functionality and performance testing.

3. RESULTS AND DISCUSSSION

The system was focused on controlling the usage of ACU with the Arduino Uno as the main controller, push buttons for controlling the settings of ACU, barcode scanner for scanning the faculty ID and infrared (IR) LED for transmitting the IR signals from the main controller to the ACU. The system was installed and tested in a classroom of UB.

3.1 Design and Development

The design concept for the hardware is shown in the Figure 1.

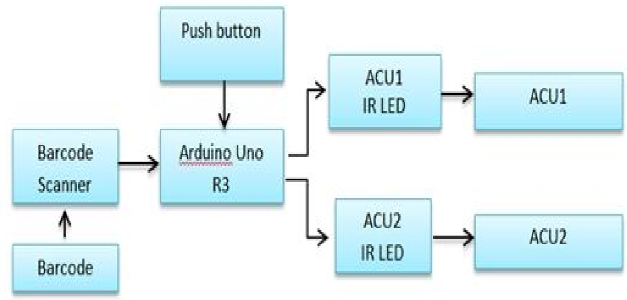

Figure 1: Block Diagram

The control card for the ACU was constructed using the Arduino Uno which is a microcontroller board based on the ATmega328P chip.

The initial step is the scanning of the ID of the faculty assigned in the room by the barcode reader. A barcode is simply a simple way of encoding characters in a simple machine readable format of black bars, normally printed onto a white background [10]. If the faculty barcode read is authorized according to the program embedded in the system, the barcode will enable the Arduino Uno to execute the command of turning ON and OFF the ACU. Aside from turning ON and OFF, other control operations such as temperature setting, air swing, and air direction setting can also be done. These additional inputs impose more control to the ACU giving faculty members freedom to identify the settings needed and required by the room. The outputs of these buttons are then fed into an infrared (IR) unit that is secured on the surface of the ACU. The infrared sensor signals then sends the commands to the ACU's infrared signal detector.

Though infrared signaling is best to implement this particular application, there are inaccuracies in the infrared signal reading by the receiving units signal detector. S. Johnson [11] cited that infrared detectors are modern technology used to pick up an area of the light spectrum that the eyes are not capable of seeing. A. D. Africa and C. F. Uy [12] stated that infrared technology plays an important role in wireless applications, especially in the areas of sensing and remote control. Today's newest products such as remote controls for every market sector depend on IR sensing and control devices.

However, infrared detectors cannot detect differences in objects that have very similar temperature range. Thus, although it is feasible for infrared detectors to receive signals even a few meters away, placing the infrared unit that would send signals to the detector a certain distance away might cause disturbances in the signals. It is therefore best to attach the infrared unit directly on the surface of the ACU.

The system was then developed following the concepts presented in the block diagram.

The researchers see it fitting to use a flowchart in presenting the general concept of how the system works. Fig 2 shows the step-by-step operation of the Arduino Uno - based control of ACU. Initially, the faculty (authorized person) will have his ID's barcode scanned by the barcode reader. If the barcode read is authorized, a signal will be sent to the ACU's signal receiver for it to be turned on. Switches are provided for selecting which of the two ACUs, labeled as AC1 and AC2, will be controlled. There are also switches for the control of the settings for the selected ACU labeled as temp down, temp up, air direction and swing. A switch is also provided to simultaneously turn
off the two ACUs.

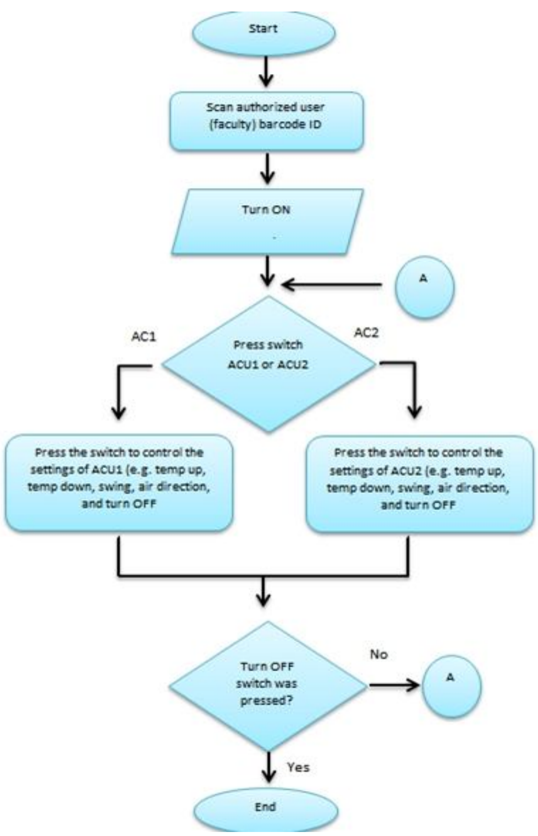

Figure 2: System Flowchart

Figure 3 shows the pin connections of barcode scanner and switches as the inputs and IR LEDs as the outputs to the Arduino Uno. It can be seen from the figure that a barcode scanner serves as input into the Arduino Uno. This provides the means for the faculty member to input information through the barcode embedded in his ID. This information is then processed by Arduino Uno and enables access–to the ACU controller. The inputs determine what process is to be performed by the ACU's based on the program embedded into the microcontroller unit. The indicator lights represented by the LEDs help the user to determine the status of the system operation.

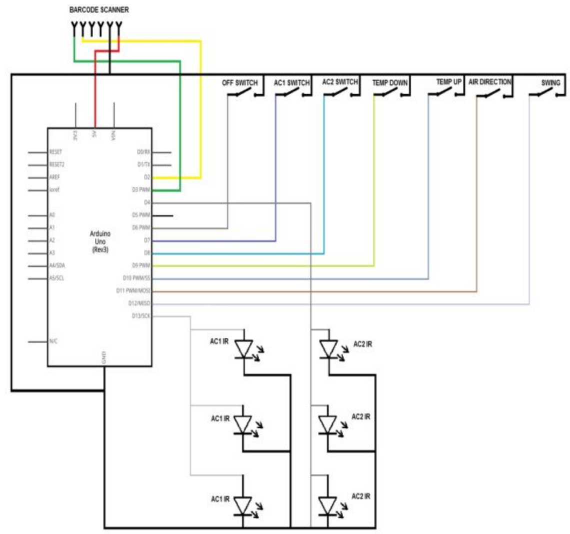

Figure 3: Schematic Diagram

The prototype was installed and tested in D-208, the Computer Engineering laboratory room of the University of Batangas. Fig. 4 shows the actual system indicating how to turn on the two ACUs. As is shown, the barcode from the faculty ID is to be scanned by the barcode reader. Once this is done, the AC units will be turned on with the default settings. To alter the setting that suits the current requirements of the room, the AC1 and AC2 switches must be used

(a) Barcode (b) Barcode Scanner and ACU Controller (c) ACU1 (d) ACU2

Figure 4: Prototype of the Design

3.2 System Testing

The following tables present the result of evaluation in terms of the functionality of the barcode scanner and remotely controlling the ACUs.

Table 1: Functionality of Barcode Scanner

Trials	Input	Expected output	Actual Output	Remarks
1	Scan Barcode ID	Barcode ID was scanned	Barcode ID was successfully Scanned	Successfully scanned barcode
2	Scan Barcode ID	Barcode ID was scanned	Barcode ID was successfully Scanned	Successfully scanned barcode
3	Scan Barcode ID	Barcode ID was scanned	Barcode ID was successfully Scanned	Successfully scanned barcode
4	Scan Barcode ID	Barcode ID was scanned	Barcode ID was successfully Scanned	Successfully scanned barcode
5	Scan Barcode ID	Barcode ID was scanned	Barcode ID was successfully Scanned	Successfully scanned barcode
6	Scan Barcode ID	Barcode ID was scanned	Barcode ID was successfully Scanned	Successfully scanned barcode
7	Scan Barcode ID	Barcode ID was scanned	Barcode ID was successfully Scanned	Successfully scanned barcode
8	Scan Barcode ID	Barcode ID was scanned	Barcode ID was successfully Scanned	Successfully scanned barcode
9	Scan Barcode ID	Barcode ID was scanned	Barcode ID was successfully Scanned	Successfully scanned barcode
10	Scan Barcode ID	Barcode ID was scanned	Barcode ID was successfully Scanned	Successfully scanned barcode

Table 1 shows the data obtained from the test conducted on the functionality of the barcode scanner. Testing if the barcode reader was functional is important since all the other operations of the system were dependent on the performance of the barcode scanner. Should the barcode fail to function as expected, the entire system would fail. The researchers scanned the barcode to find out if the scanner would recognize the barcode present on the ID of the faculty. Ten (10) trials were done and the data show that 10 out of 10 trials, equivalent to 100%, were all successful which means that the barcode scanner was functioning accurately.

Table 2 : Controlling the ACUs

Trials	Input	Expected Output	Actual Output	Remarks
1	Receive Command from switches	Send signal to ACU sensors	Signal was sent but was not received by the ACU sensors	Adjust distance between IR LEDs and ACU sensors
2	Receive Command from switches	Send signal to ACU sensors	Signal was sent but was not received by the ACU sensors	Adjust distance between IR LEDs and ACU sensors
3	Receive Command from switches	Send signal to ACU sensors	Signal was sent but was not received by the ACU sensors	Adjust distance between IR LEDs and ACU sensors
4	Receive Command from switches	Send signal to ACU sensors	Signal was sent but was not received by the ACU sensors	Adjust distance between IR LEDs and ACU sensors
5	Receive Command from switches	Send signal to ACU sensors	Signal was sent but was not received by the ACU sensors	Adjust distance between IR LEDs and ACU sensors
6	Receive Command from switches	Send signal to ACU sensors	Signal was sent and was received by ACU sensors	Successful sending of control signals
7	Receive Command from switches	Send signal to ACU sensors	Signal was sent and was received by ACU sensors	Successful sending of control signals
8	Receive Command from switches	Send signal to ACU sensors	Signal was sent and was received by ACU sensors	Successful sending of control signals
9	Receive Command from switches	Send signal to ACU sensors	Signal was sent and was received by ACU sensors	Successful sending of control signals
10	Receive Command from switches	Send signal to ACU sensors	Signal was sent and was received by ACU sensors	Successful sending of control signals

A ten (10) trial performance testing revealed that the 5 initial testing determines the effective distance between the IR LEDs sending the signal from the device to the ACU controllers. Upon identification of this distance, further testing showed that remotely controlling the ACU's was possible and effective thus indicating that the system was performing as expected.

3.3 Estimate the impact on the financial operations of UB

The system was tested during the special semester of academic year 2016-2017. To measure the daily energy consumption, a sub-meter was installed inside the room. The normal electric consumption for 16 days was recorded and the electric consumption for another 16 days with the implementation of the system was also recorded.

Table 3: Daily Power Meter Readings

Without the System			With the System		
Date	*Meter Reading*	*Daily Consumption (kwh)*	*Date*	*Meter Reading*	*Daily Consumption (kwh)*
05/18	00014	Initial reading	06/19	00704	Initial reading
05/19	00045	31	06/20	00724	20
05/22	00088	43	06/21	00750	26
05/23	00125	37	06/22	00772	22
05/24	00155	30	06/23	00792	20
05/25	00186	31	06/26	00833	41
05/26	00219	33	06/27	00853	20
05/29	00294	75	06/28	00873	20
05/30	00333	39	06/29	00897	24
06/01	00364	31	06/30	00920	23
06/04	00408	44	07/03	00965	45
06/05	00441	33	07/04	00988	23
06/07	00479	38	07/05	01010	22
06/09	00536	57	07/06	01030	20
06/13	00601	65	07/07	01054	24
06/14	00608	7	07/10	01099	45
06/15	00630	22	07/11	01121	22
Average Daily Consumption		38.5	Average Daily Consumption		26.0625

To measure the daily energy consumption, a sub-meter was installed in the room. The normal electric consumption for 16 days without the system was recorded. It was then followed by another 16 days recording of electric consumption with the system implementation. The completion of this 16-16 days monitoring and observation showed energy saving is possible. Energy Saving was computed as follows:

Average daily power meter reading without the device		38.5 kWh
Less : Average daily power meter reading with the device		26.0625 kWh
Average Daily Energy Saving	=	12.4375 kwh
Daily cost saving	=	$\text{Energy saving} \times \frac{P12}{kWh}$
	=	$12.4375\ \text{kwph} \times \frac{P12}{kWh}$
Daily Cost Saving	=	P 149.00
Monthly Cost Saving	=	P 149.00 x 20 days
	=	**P 2,980.00**

Based on the computations, a single room with two ACUs can save as much as P149.00 per day which was equivalent to P2,980 monthly savings with the implementation of the Arduino Uno -Based ACU controller. Considering that the study was implemented and tested on a single room only, the computed savings could be deemed significant especially since the College of Engineering houses at least 22 air-conditioned classrooms with the same problem.

On the other hand, the development cost which includes the programmer's professional fee, installation and maintenance cost for the single device was P11,519.00 which may still significantly drop if the device would be developed in bulk. Moreover, it was expected that the amount to be invested in the device development would be regained from the savings to be generated by the device in just three months and twenty-six days. Payback period was computed as follows:

$$\text{Payback period} = \frac{\text{Initial Investment}}{\text{Cash Inflow per Period}}$$

$$= \frac{P\ 11{,}519.00}{P\ 2{,}980.00/\text{month}}$$

$$= 3.865\ \text{months}$$

$$\text{Payback period} \approx \textbf{3 months and 26 days}$$

4. CONCLUSION

Based on the analysis and findings, the following conclusions were derived:

1. The researchers were able to come up with a viable design that is deemed to be an effective aid in energy conservation as indicated by the testing and evaluation conducted.
2. Testing shows that the system is functional and is performing as is expected.
3. Cost savings measured is significant considering that the study was limited to a single room for testing.
4. Implementation of the same device to all air-conditioned classrooms in the College of Engineering could further increase the university's cost savings in terms of energy consumption.

REFERENCES

[1] Kreith, F., and Goswani, D. Y.Energy management and Conservation Handbook. CRC Press Taylor and Francis Group, 2008.
https://doi.org/10.1201/9781420044300

[2] Dilawari, J., Sandhu, G A review paper on microprocessor based controller programming. International Journal of Advanced Research in Computer Science and Software Engineering.2(8), ISSN: 2277 128X, 2012.

[3] Journal of Electrical Engineering and Electronics Technology. About microprocessor, 2017.
https://www.scitechnol.com/scholarly/microprocessor--microcontroller-journals-articles-ppts-list.php

[4] Krishnamurthi, Thapa, Kothari, and Prakash. Arduino-based weather monitoring system. International Journal of Engineering Research and General Science. Vol. 3, p. 455, 2015.
http://pnrsolution.org/Datacenter/Vol3/Issue2/64.pdf

[5] A. Majeed , R. Bhana and Shaheed Parvez. Controlling energy consumption by internet of things (iot) applications . International Journal of Advanced Trends in Computer Science and Engineering. Vol. 8, No. 1.1, p. 10, 2019.
http://www.warse.org/IJATCSE/static/pdf/file/ijatcse0281.12019.pdf
https://doi.org/10.30534/ijatcse/2019/0281.12019

[6] Bustamante, C. V. , Lagahino, D. D., San Diego, M. G. The development of centralized air- conditioning unit control using arduino with wi-fi module. Asia Pacific College School of Engineering Journal, Vol. 2 p. 14, 2017
https://www.apc.edu.ph/sites/default/files/upload/SoE%20Journal%20Vol2%20No1.pdf

[7] T. Thein Soe , K. Soe Lwin, Z. Min Naing and A. Soe Khaing. Design and development of microcontroller based air conditioning system. International Journal of Scientific Engineering and Technology Research, Vol. 3 pp. 2000-2004, 2014.
http://ijsetr.com/uploads/614523IJSETR1252-341.pdf

[8] T Sri Vignesh , S. Sudharsan , S Sweetlin Packiavathi , M Thangamani and B Saravana Manikandan. Design and implementation of air conditioning system based on temperature control device for power saving. International Conference on Systems, Science, Control, Communication, Engineering and Technology, Vol. 2 , p. 438, 2016.
https://edlib.net/2016/icssccet/ICSSCCET2016084.pdf

[9] R. Richey Developmental research: The definition and scope. Educational Research Center, 2004.

[10] Hashim, N.M.Z., Ibrahim N.A., Saad, N.M., Sakaguchi, F., and Zakarias, Z. .Barcode recognition system. 2013
http://citeseerx.ist.psu.edu/viewdoc

[11] S. Johnson. Advantages and disadvantages of infrared detectors. 2017
https://sciencing.com/advantages-disadvantages-infrared-detectors-6151444.html

[12] A.D. Africa and C.F. Uy. Development of a cost-efficient waste bin management system with mobile monitoring and tracking. International Journal of Advanced Trends in Computer Science and Engineering. Vol. 8, No.2, p. 321, 2019.
http://www.warse.org/IJATCSE/static/pdf/file/ijatcse35822019.pdf
https://doi.org/10.30534/ijatcse/2019/35822019