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# Mobile-based Power Board and Dimmer Light Using Raspberry Pi with Power Monitoring

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***Abstract:*** - **The project is an enhancement from a previous iteration that uses a web application to control the power board. The project composes of a mobile application to control the power board, along with a web application to manage its users, sensors to measure the power consumed, raspberry pi to act as its server, and machine learning to recommend the device identified. The proponents decided to use a hybrid prototype and agile methodology to allow them to deliver early mock-ups, evaluate outcome, and continuously improving through its evaluation. The following were the tests that were conducted: functionality for its user usability; reliability for its hardware; and accuracy for its device identification. Both functional and reliability were successful within acceptable range, meanwhile, the accuracy tests for the device identification couldn't reach the expected outcome and was off with a range of 22% from the calculated evaluation. Nonetheless, the project is fully functional and the possible lacking for the device identification were recommended for its next iteration.**

**Keywords: -Android controlled devices, device identification, enhance version, internet of things, machine learning for device identification, mobile based home automation, power board, raspberry pi**

## I. INTRODUCTION

"With the modern age, electrical fires became a consistent threat"[1] This statement was proven true by a report made by the Bureau of Fire Protection in 2015. The report states that of the 615 fire incidents in Metro Manila, 162 of these were electrical in nature [2]. Reference [3] shows that Bureau of Fire Protection's tally on the number of fire incidents recorded for the first two months of the year 2016 has reached a total of 2,571 nationwide; and among the top three causes of fires were electrical failure, together with open flames, and cigarette butts According to an article published in Manila Bulletin [4], electrical equipment is considered among the top 8 most common causes of fires. This was seen as a major concern for the previous developers and thus came up with the project Web-based Power Board using Raspberry Pi with Power Monitoring. Although deemed as a success by the previous developers, they had listed a couple of recommendations to enhance the power board to which the current developers aim to implement. Thus, the current developers adopted the project and came up with Mobile based Power Board and Dimmer Light Using Raspberry Pi with Power Monitoring. As the title suggests, a mobile app will be used to control the device instead of the previous web application since the use of mobile phones today is so prevalent that you can't see a person without a phone in hand. Internet of Things or commonly abbreviated as IoT, can be defined as simply connecting everyday objects or appliances to the internet to extend its functionalities and gain innovative ways of how people could interact with it. According to Jen Clark of IBM [5], "Smart home technology has been around for quite a while now in forms of home automation devices, software, and applications that generally centers on particular tasks or rooms." Quoted from [6], "With the rapid growth of the internet of things (IoT), this level of home automation has become reality."

A report in [7] forecasts that by 2021, smart home automation and device monitoring would grow up to 770 million globally from an estimated 68 million in 2016. According to [8], "Elderly and disabled are more likely to be exposed to day to day problems. Smart home can be a tool to support elders and disabled people into creating a safe, secure, and empowering environment."The proponent identified that Raspberry Pi board would play a big part in the project. Quoted from [9], "Raspberry Pi boards are fantastic for any project – they are cheap, easy to use, can run a wide range of possible operating systems, and provide programmable GPIO pins as well as multi-core CPU availability and multiple USB ports."

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**1. Project Objectives**

The project generally aims to develop a mobile-based power board and dim-lights using Raspberry Pi with power monitoring to efficiently monitor and control electrical household appliances.
The following are the specific objectives of the project:

• To implement switch control for appliance socket and controller for dimmer light using mobile application;

• To develop a web application for user management and mobile application for control and monitor power board;

• To implement device identification

## II. REVIEW OF RELATED LITERATURE

According to Save on Energy [10], "When you get your electricity bill each month, you may not think a whole lot about what goes into it. But in reality, every appliance or electronic device adds a little something to your bill". At some point a person would wonder how much electricity their appliances use. One way for a person to understand how much money they are spending on electricity is to determine how much electricity appliances and home electronics uses. According to Department of Energy in the US, "Electricity usage monitors are easy to use and can measure the electricity usage of any device that runs on 120 volts.". This device is used to get how many watts a device or appliance is using. Here are some formulas from Energy gov. [11] that would prove helpful in computing the electricity usage:

$$(Wattage \times Hours\ used\ per\ day) \div 100 = Daily\ Kilowatt\ per\ hour\ (kWh)$$

**Find the monthly energy consumption using the following formula:**

$$Daily\ kWh\ consumption \times Number\ of\ days\ used\ per\ month = Monthly\ energy\ consumption$$

**Find the monthly cost to run the appliance using the following formula:**

$$Monthly\ energy\ consumption \times utility\ rate\ per\ kWh = Monthly\ cost\ to\ run\ the\ appliance$$

[1] assumed that throughout the years, the number of electrical devices being used has increased. Quoted from [1] "It is prevalent in the Philippines especially in the residential areas of the National Capital Region (NCR). These electrical fires usually stem from extensions that either short circuit or overload due to a user plugging in too many electrical devices in the extension.". Internet of Things or commonly abbreviated as IoT, can be defined as simply connecting everyday objects or appliances to the internet to extend its functionalities and gain innovative ways of how people could interact with it. Smart homes are one of the many applications of Internet of Things. According to [5], "Smart home technology has been around for quite a while now in forms of home automation devices, software, and applications that generally centers on particular tasks or rooms. Home automation task could range from scheduling to automatic operations of tools and/or home appliances [12], either onsite or remotely. Quoted from [6] about internet of things and home automation, "With the rapid growth of the internet of things (IoT), this level of home automation has become reality.". Automating tasks greatly affect a household as activities within the house can be monitored. This gives household owners the sense of security as Internet of Things gives its users the ability to be informed and updated on the currently events inside their home.

A report from Hampshire, UK forecasts that by 2021, smart home automation and device monitoring would grow up to 770 million globally from an estimated 68 million in 2016 [7]. This means that people are rapidly adapting Internet of Things as part of their lives and to make their home living as easy and comfortable compare before. According to [8], - "Elderly and disabled are more likely to be exposed to day to day problems. Smart home can be a tool to support elders and disabled people into creating a safe, secure, and empowering environment.". Using devices, Internet of Things, and home automation, the proponents proposed to create a project that utilizes the beforementioned. Quoted from [13] regarding 'What is Internet of Things?', "A 'thing' is any object with embedded electronics that can transfer data over the network – without any human interaction. The Internet of Things can make life easier and reinvent the way we interact with the physical world.".

The proponent identified that Raspberry Pi board would play a big part in the project. Quoted from [9], "Raspberry Pi boards are fantastic for any project – they are cheap, easy to use, can run a wide range of possible operating systems, and provide programmable GPIO pins as well as multi-core CPU availability and multiple USB ports.".

Raspberry Pi board are amazing, as they can be used as components for all kinds of automation. Note that one should be careful in developing projects that would include the raspberry pi connected to the network, otherwise the raspberry pi would become a vulnerability

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to the user rather than as an asset [14].

Quoted from [15], "It is critical to keep in mind that the Raspberry Pi is a fully functional computer. All of the security considerations associated with network connected desktops and laptops equally apply to the raspberry pi unless proper precautions are taken.".

Having gaps in the security of Raspberry Pi is dangerous. One should take care and be cautious with its security. If its security was left alone as it is, the raspberry pi would be open to hackers with bad intent to take advantage of the system. Although, the raspberry pi can be secured if it has a firewall that is connected within the local home network. "However, if you wish to expose your Raspberry Pi directly to the internet, either with a direct connection (unlikely) or by letting certain protocols through the firewall (e.g. SSH), then you need to make some basic security changes." [16].

## III. METHODOLOGY

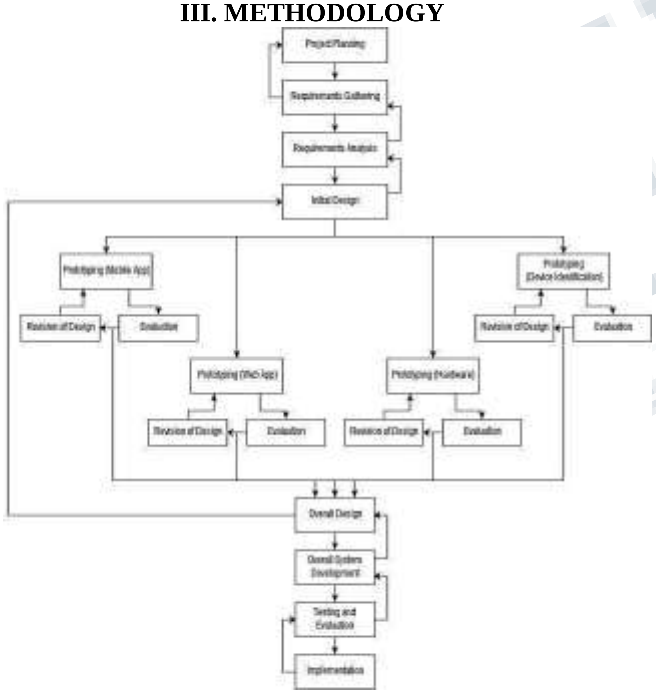


*Fig. 1 Hybrid Agile and Prototype Model research methodology*

For the methodology that the proponents used for this project is the hybrid between Agile and Prototyping. Agile method focuses on early delivery with scope, flexibility, and continuous improvement of project's product and processes [17], meanwhile prototyping, according to [18], displays the functionality of the product at an early stage and evaluates the product to help the developers understand what exactly is expected from the product. As shown in Fig. 1, combining these two model allows the proponents to slice up the whole system into tiny modules by identifying the initial requirements needed in the system and combining them later for the total and whole system.

## IV. RESULTS AND DISCUSSIONS

### A. Discussion

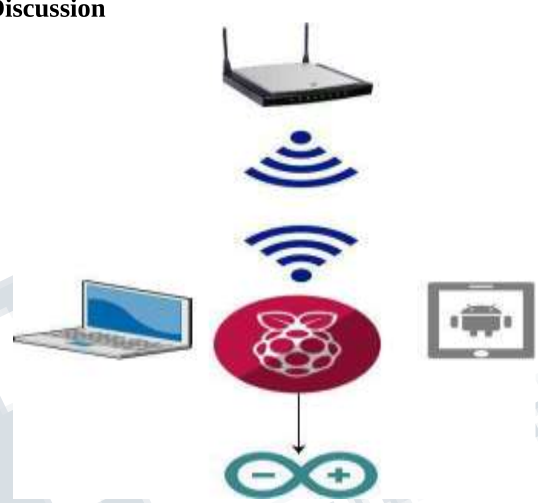

*Fig. 2 Network Diagram*

The proponents came up Fig. 2 as their network diagram for the device's network capabilities. User management can only be done by the admin through the website https://socketsandlight.tk/. Regular users can control the device given that the application has given them permission to use the internet. All devices must be connected to the same network otherwise a functionality is not met and the system will not work. The Raspberry Pi is connected to the Arduino UNO via USB-to-Serial. The 6 terminal relay board is connected to the Raspberry Pi's Vcc, Grd, and pins 7, 11, 13, 12, 16, and 18. Each terminal of the relay is provided 220V of AC by the contactor which is directly connected to the mains. The five ACS712 Sensors are powered on using the Raspberry Pi's Vcc and Grd pins, while its outputs are connected to the analog pins of Arduino. Relay terminals are connected to their own sensor, fuse, and receptacle. The fifth terminal is connected to the sensor and the power line from the sensor is connected to the dimmer circuit, and it then gives power to the light bulb when operating. For the device identification, the proponents needed to analyze the data that was gathered by controlling and **monitoring** the output given by the sensors. The proponents gathered data from the following device/s: desk lamp, monitor, electric fan, phone charger,

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and laptop charger. The data gathered are exported with the averages of the first five seconds and the next five seconds, with the total of ten seconds represented by the name of the appliance. After gathering data from the sensors, the proponents cleaned the datasets for clearer results for machine learning. For the machine learning, the proponents used Scikit Learn [19]
machine learning model SVC (Support Vector Classification) from its parent SVM (Support Vector Machines). SVC is a popular machine learning model that is used for predicting categorical data. The dataset is divided into training dataset and testing dataset which has the ratio of seven to three. The training dataset is for the machine learning model and the testing dataset is for the model to be evaluated. The classification report has the numerical analysis of the model, it has scores for precision, recall, f1-score, and support. The precision is the correctness of the predicted values, while the recall is the actual positive that was identified correctly, the f1-score is the average of the precision and recall, and the support is the supporting test data that was used in the evaluation. As shown in Fig. 3, the monitor and phone charger is expected to have more false predictions with each other since their data are close to each other compare to other devices that has an f1-score >95%. The model has an average of 89% for its precision, recall, f1-score with a total of 1041 data for testing.

```
In [253]: print(confusion_matrix(y_test, prediction))
          print("\n")
          print(classification_report(y_test, prediction))

[[210   0   2   2   0]
 [  0 194   3   0   0]
 [  0   6 207   0   0]
 [  2   0   3 140  50]
 [  0   0   0  42 180]]

                precision    recall  f1-score   support

      Desk Lamp       0.99      0.98      0.99       214
   Electric Fan       0.97      0.98      0.98       197
 Laptop charger       0.96      0.97      0.97       213
        Monitor       0.76      0.72      0.74       195
  Phone Charger       0.78      0.81      0.80       222

    avg / total       0.89      0.89      0.89      1041
```

***Fig. 3 Confusion Matrix and Classification report***

**B. Results**


***Fig. 4 Functional Testing Pie Chart***

Fig. 4 shows the result of tests that were conducted on both web and mobile application. These tests included functionalities like login, logout, and socket control through the web and mobile application. Also included in the functional testing were: user management (add, edit, delete), navigation and viewing functionalities, turning on/off the sockets (manual and scheduled), and adjusting the brightness of dimmer light. There is a total of 75 test case scenarios that was conducted and out of all the test conducted, no failure was encountered

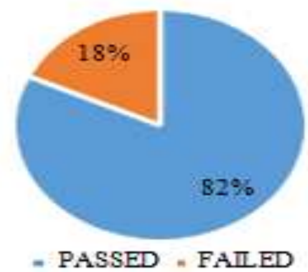


***Fig. 5 Reliability Testing for Individual Module Testing Pie Chart***

Fig. 5 shows the result of the individual module testing done by the proponents. There are 14 individual hardware modules that are tested to check if they work individually and they work with the entire system connected all-together. The proponents tested the following modules that earned a passed: Raspberry Pi, Arduino UNO, five ACS712 sensors, electrical relay, and fuses. A button was included in the device but through the testing phase, it was identified by the developers that it was not working properly as intended. Although it passed two (2) out of four (4) of its test cases. The developers decided to remove it from the device.

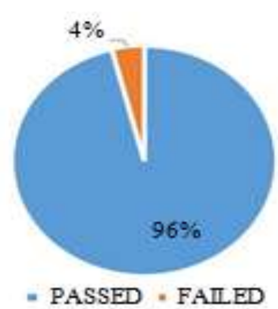


***Fig. 6 Reliability Testing for Load Testing Pie Chart***

Fig. 6 shows the result of the load testing done by the proponents. Four (4) sockets are available that can be used as a power source for appliances. The proponents loaded these sockets and tested if the power board is built well to hold four different appliances at the same time with different control for it. The proponents tested the timer-based control for load testing, the first two tests for timer-based resulted in fail, the proponents checked the script in handling the scheduling of sockets. After fixing the error, the testing went smoothly for time-based control for load testing. Load testing for standard control has no problem in testing and passed all the test cases provided.

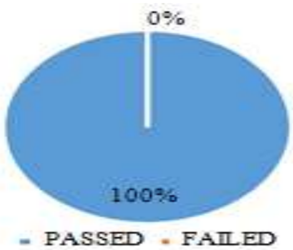


*Fig. 7 Reliability Testing for Stress Testing Pie Chart*

The stress testing made use of high powered everyday appliances like flat iron, refrigerator, toaster, and etc. To get more out from the testing, the proponents used the flat iron that has the highest wattage (1200W) from all of the available appliance to test each socket. The purpose of this test is to know if the device would be able to handle the electricity requirements of the appliances. The test was conducted in two scenarios: first is that the device would power on the appliance, and second power off the appliance. Fig 7 shows there were no recorded failures. The test for the accuracy of the device was conducted with the appliances being plugged and identified by each socket. The accuracy test for the appliance identification was conducted in two situations: first it was tested in a situation where only one of the socket is in use (the appliance to be identified is into plugged, and second with all sockets in use while the appliance is being identified. 13 iterations were conducted for each test for the identification

*Table I Table for Accuracy Testing for Unit Testing*

| Device | Number of tests planned | Number of tests executed | Passed | Failed | % |
|---|---|---|---|---|---|
| Monitor | 104 | 104 | 67 | 37 | 64.42 |
| Electric fan | 104 | 104 | 86 | 18 | 82.69 |
| Charging laptop | 104 | 104 | 100 | 4 | 96.15 |
| Desk lamp | 104 | 104 | 100 | 4 | 96.15 |
| Phone charger | 104 | 104 | 55 | 49 | 52.88 |
| Dimmer light | 5 | 5 | 5 | 0 | 100 |
| OVERALL | 525 | 525 | 413 | 112 | 78.67 |

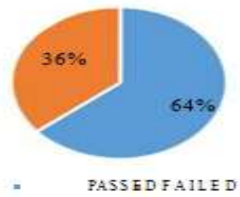


*Fig. 8 Accuracy Testing for Unit Testing for Device Identification of Monitor*


*Fig. 9 Accuracy Testing for Unit Testing for Device Identification of Electric fan*

The device was only able to identify the monitor 64.42% of the time and the electric fan 82.69% of the time. The device identification for the monitor had received 67 passes and 37 failures after testing. The device equally failed to identify the monitor in both situations, with only one socket is in use and all sockets are in use. While testing the device identifies the monitor frequently as a laptop charger and seldom as a desk lamp. On the other hand, the device identification for the electric fan had received 86 passes and 18 failures after testing. The failure encountered in this test was caused by the device identifying the electric fan as a laptop charger. Most failures encountered during the testing for the electric fan was in the first socket of the device. The third (3rd) socket was able to identify the electric fan more frequently than the other sockets.

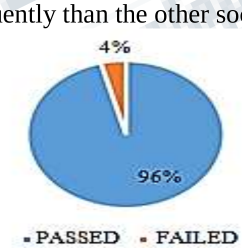


*Fig. 10 Accuracy Testing for Unit Testing for Device Identification of Desk Lamp*


*Fig. 11 Accuracy Testing for Unit Testing for Device Identification of Charging Laptop*


*Fig. 12 Accuracy Testing for Unit Testing for Device Identification of Phone Charger*


*Fig. 13 Accuracy Testing for Unit Testing of Dimmer*

The proponents received minimal failures in the device identification of both desk lamp and laptop charger. Both were identified by the device ninety-six percent (96%) of the time. The phone charger was identified fifty-three percent (53%) of the time with the phone charger frequently identified as a monitor or a desk lamp. The next test cases were for the capabilities of the device to dim the brightness of a bulb. The bulb was first turned on at 25% brightness, then 50%, then 75% up to 100%. Then the bulb was tested if it could dim from 75% to 25% etc. The tests were successful and was given a pass by the proponents. Overall, the accuracy testing gave off a 71% pass rate being able to identify some of the appliances correctly. The 29% fail rate can be attributed by the lack of data as more testing is required.

## V. CONCLUSION

Mobile-based Power board and Dim Light using Raspberry Pi with Power Monitoring is a project that can control the power board using a mobile application, and view its socket's power consumed by preparing data to its user like graphs and numerical data. Based on the test results conducted by the proponents, the power board could power an appliance and control its socket, schedule the socket for turn off, dim a dim-light, and display its power consumed to its user. All the socket can be loaded with appliance that cannot exceed the maximum allowed power. It also has a functioning user management to control the amount of user that can control the power board.

The device identification has a total of 520 tests made for 5 different appliances, 408 of these tests were marked as passed with a percentage of 78.46%. Expecting a result of its precision to be near the average evaluation of the machine learning model which is 89%, the proponents hypothesize the following to be its lacking: 1) accuracy of the sensor; 2) variables that are used in testing; and 3) variable to support the machine learning model is insufficient. The first hypothesis which is the accuracy of the sensor is not that relevant to the device identification since the current that was measured by the power board is alternating current, its equation has a third variable which is the pf (power factor) which acts as the real power needed by the appliance. Since the sensor cannot measure the power factor of the appliance, the accuracy of the sensor is minimal to none factor to the device identification. The second hypothesis which are the variables that are used in testing, the variables that are used in testing is different to the actual device that are used in creating the dataset of the machine learning model. The same appliance with different brand (e.g. electric fan x and electric fan y) has different pf (power factor) even if it has the same wattage consumption in its description. It holds as one of the factors for the error of the device identification. The third hypothesis holds the most factor in device identification which is the variables needed to support the machine learning model. Since the data took from the power board is from a single sensor that reads the alternating current, its suspected to have a bias since it is the sole origin of all the data that the dataset came from, collecting data from the device for ten second from a single sensor is not enough for the device identification. To conclude the device identification, even though it has an increase in accuracy from the previous proponents, it is far from complete and is still lacking in the before mentioned hypothesis. Although there was an issue in a functionality like the conflict with the power button, the whole system is working aligning to its objectives and scope.

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