ELEKTRIKA
Journal of Electrical Engineering

Robotic Arm Control using Internet of Things (IoT)

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Abstract: Robotic arm is a reprogrammable and multifunctional manipulator design to assist human in various surroundings. It is able to overcome human inefficiency in performing repetitive task such as pick and place operation. Thus, industrial in assembly and manufacturing have widely integrated robotic arm into their assembling line to overcome the problem of human inefficiency. Internet of things (IoT) allow data to be exchange between devices through the connection of many devices. The integration of internet of things with robotic arm allows smart industry to be realized. The purpose of this research is to design and build a three degree of freedom robotic arm with a mechanical gripper. The robotic arm can be controlled remotely through android mobile device to perform pick and place operation while Matlab provides the graphical movement of the robotic arm as a feedback.

Keywords: Android mobile device, Arduino Yun, Internet of Things (IoT), robotic arm.

1. INTRODUCTION

Robot are used in various environment ranging from homes to industries to provide assistant to human for a range of purpose such as operation in hazardous situations or operation in manufacturing sector [1]. The design of a robot can be varied depending on its function, application and the environment. Robotic arm is most commonly used in industry such as manufacturing and assembling. The use of robotic arm is to overcome human inefficiency in performing repetitive task such as pick and place operation. Robotic arm is a reprogrammable and multifunctional manipulator design to assist human in various surroundings. Robotic arm is able to overcome human inefficiency in performing repetitive task such as pick and place. Thus, industry such as assembly and manufacturing have widely integrated robotic arm into their assembling line to overcome the problem of human inefficiency [2-4].

Internet of things (IoT) allow data to be exchange between devices through the connection of many devices [5, 6]. Internet connection has fundamentally changed the arrangements for monitoring and control and the use of open or public standards and personal computer systems (PCs, tablets, smart phones) bring significant benefits to their users and producers [7]. This concept can be further extended to be integrated into various wearable energy harvesting devices [8] and implantable wireless biomedical applications, such as wireless micropumps, micromixers, and microvalves [9-11].

The capabilities and the functionality of a robot depends largely on the needs and its environment. Robot will then be varied accordingly to suit the needs. For example, robotic arm has been widely integrated into industry or factory to assist human in performing repetitive task. The used of robotic arm in industry promotes better product quality, productivity and increase efficiency [12, 13].

Most of the time, robotic arm is required to be train or teach before it can spring into action. The training or teaching process are normally carried out through teach pendant in a certain distance within the factory. The training or teaching process on the robotic arm will pose a great challenge in the absence of the relevant person in charge or engineer [14-17]. This is due to the fact that the training process on a robotic arm requires an in-depth knowledge not only on the robotic arm but also on the surrounding environment and material that the robotic arm will be handling. The integration of IOT with robotic arm allows smart industry to be realized. The purpose of this research is to design and build a three degree of freedom (DOF) robotic arm with a two-finger mechanical gripper. The robotic arm can be controlled remotely through android mobile device (AMD) to perform pick and place operation [18].

2. LITERATURE REVIEW

2.1 Robotic Arm

Robotic is a fusion of not only electronic, mechanical and electrical engineering but it also includes other engineering fields such as computer science, mathematics, technology and science [4, 19]. In general, robotic arm is a reprogrammable and multifunctional manipulator that resemble a human arm. The movement of robotic arm is driven by actuator which is located at the joint of the robotic arm. Motion of human arm differs from the motion of articulated robot arms.

Although the robot joints have fewer degrees of freedom, they are able to move in larger angles. For example, the elbow of an articulated robot can bend up or down whereas a person can only bend their elbow in one direction with respect to the straight arm position [12]. Actuator is a device or component that converts energy into motion. Example of actuator are AC motor, DC motor, stepper motor, hydraulic piston and pneumatic piston. End effector is the tool that perform work or operation and is usually located at the end of the kinematic chain [20, 21].

2.2 Internet of Things (IoT)

In general, IoT is the connection of devices to the Internet. It allows data to be exchange between devices, and it is able to overcome the limitations of bus topology connection. The "things" can be referred to any sort of devices such as alarm clock, watch, car, kitchen, and even including robotic arm. The booming of IoT allows the realization of managing, monitoring or even controlling of electrical and electronic devices through a 3G mobile phone [21, 22]. IoT can be applied into a variety of fields such as industrial, health-care, military, business and management to form different kinds of applications. This is possible as internet bridge the gap between the physical world and the virtual world by allowing physical raw data to be exchange between devices [5].

This kind of structure has many shortcomings, such as complex wiring, the line is very easy to destroy, difficult of maintenance, and etc. [5]. This reinforce the idea of connecting devices to the internet as it is able to overcome the limitations of bus topology connection. On top of that, it is speculated that the booming of IoT will greatly reduce the interaction of humans with computer and other electrical and electronic devices, which results in the increasing of number of "things" and number of active internet user [19]. Finally, the current industry can be transformed to become "smarter" though the integration of IoT with the industry.

3. METHODOLOGY

3.1 Research Overview

The research consisted of three main parts, namely mechanical or hardware construction, circuit development

and software programming. Each part plays an essential role as the integration of each part determines the completion of the research, while the succession of the research is determined when all parts works well when it's been integrated Figure 1 shows the research elements or the research overview.
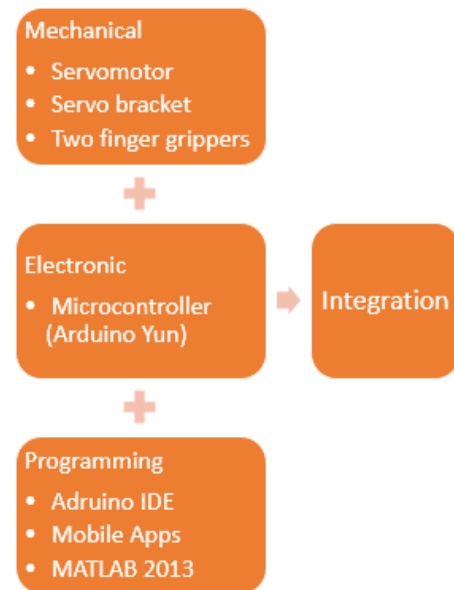

Figure 1. Research overview

3.2 Research Operation Flow

Research operation flow presents on the sequence for controlling the robotic arm remotely through android mobile device using IoT. Figure 2 shows research operation flow presents on the sequence for controlling the robotic arm remotely through AMD using IoT. The research consisted of three main parts, which are hardware construction, circuits development and software-programming.

3.3 Mechanical Part

The structure or mechanism of robotic arm can be break down into three main parts, the base, the links and the end-
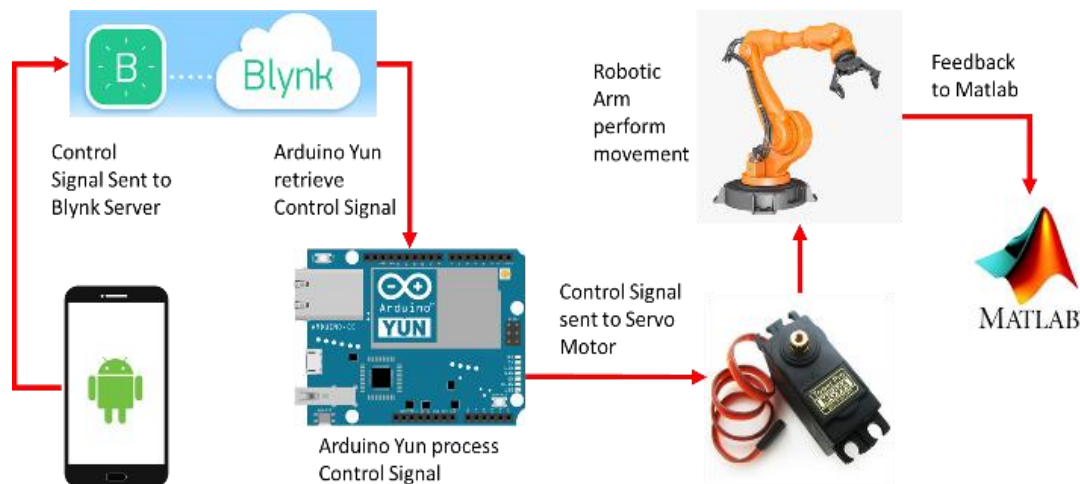

Figure 2. Research operation flow

effector which is a two-finger mechanical gripper. Servo motor bracket will be used to construct the base and the links of robotic arm. RC servo motor such as TowerPro MG995 will be used as the actuators to drive the movement of robotic arm. RC servo motor is chosen due to its simplicity in controlling. The choice of these materials is considered base on the availability, cost and weight.

3.4 Circuit Design

The electronic circuit used in this study is Arduino Yun. Arduino Yun is chosen as it has embedded ATmega32U4 microcontroller. This microcontroller is suitable for the controlling of servo motor. Moreover, Arduino Yun has
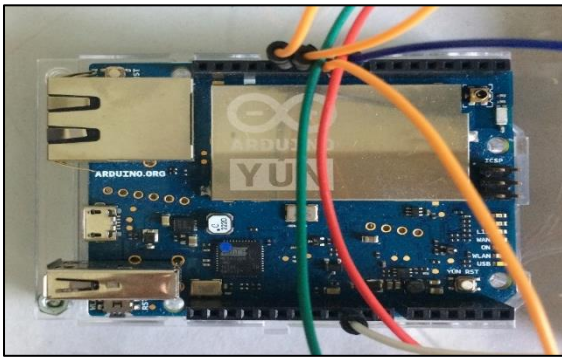

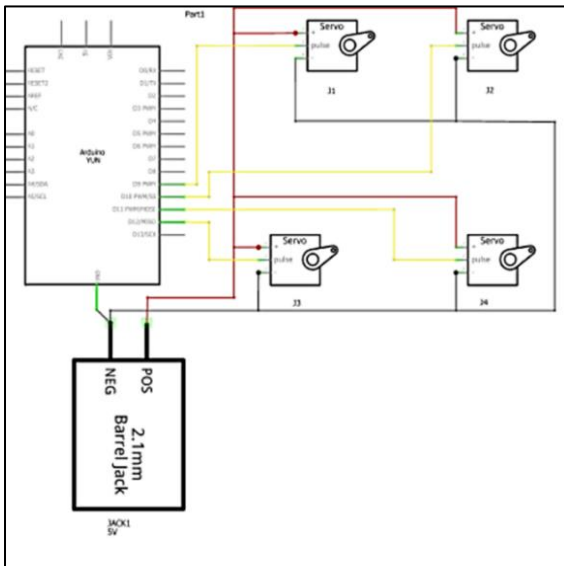Figure 3. Complete electronic circuit.

Figure 4. Schematic diagram.

embedded Wi-Fi module which providing it the capabilities to access over the internet. This allows the implementation of IoT application.

On the other hand, Arduino Yun is unable to supply enough current to the RC servo motor. Thus, power circuit is needed to ensure that RC servo motor is able to draw sufficient current from a 5V 2A adapter. Figure 3 shows the power circuit. Figure 4 shows the schematic diagram of RC servo motor with Arduino Yun while Figure 5 shows the breadboard circuit design. Arduino Yun act as the brain in controlling the movement of RC servo motor by receiving commands from android mobile device.

3.5 Software Design

Software programming involves the use of computer language to develop a sequence or a set of instructions that will carry out a specific task. It plays a significant role by providing the necessary platform in controlling the action and the movement of the robotic arm.

3.5.1 Flow Chart for Programming

Figure 6 shows the flow chart for robotic arm control using IoT. During automatic mode, the robotic arm picks an item from the first position and release the item in the second
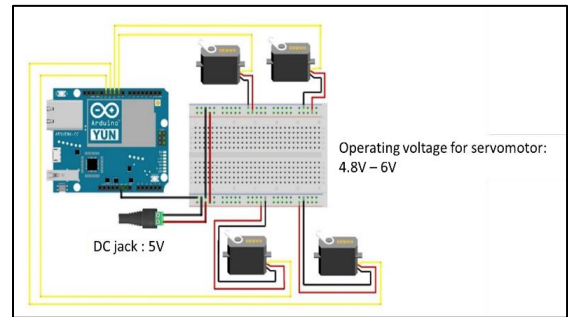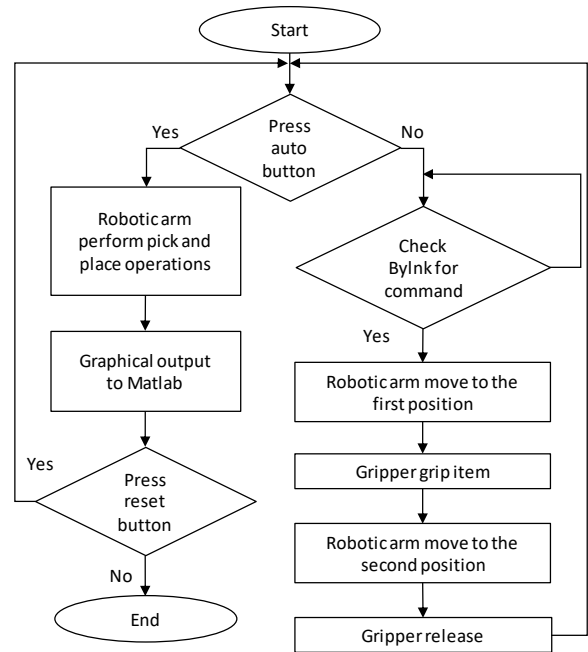

Figure 5. Breadboard circuit design.

Figure 6. Flow chart.

position. The process of pick and place operation is then repeated. During manual mode, the robotic arm is train through android mobile device.

3.5.2 Graphical Display

MATLAB R2013a is used in this study to show the graphical movement of robotic arm. The graphical movement of robotic arm is projected in a three-dimensional space. Moreover, MATLAB R2013a also displayed the number of positions received during the operation of robotic arm. Additional toolbox such as Robotics Toolbox is required to be added into MATLAB

R2013a before it is able to present the graphical movement of the robotic arm. Figure 7 shows the graphical display of robotic arm.
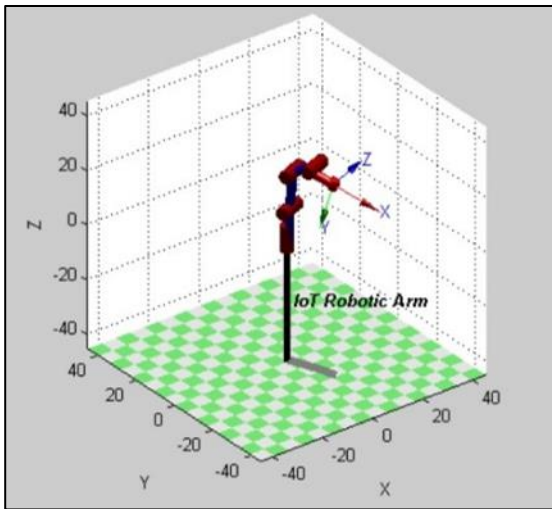

Figure 7. Graphical display of robotic arm.

4. RESULTS AND DISCUSSION

The complete hardware mechanism is integrated with the software programming to form a complete system. With the complete system, pick and place routine process is able to be carried out. A three DOF robotic arm with two finger mechanical gripper is successfully developed, and it is able to be controlled remotely though AMD as shown in Fig. 8.

Figure 9 shows the completed pick and place operation. Upon start up, the robotic arm will move to the initial position or pre-defined position. Once the robotic arm is ready, it will then move to the desired position or the first position. Next, the robotic arm will grasp the desired object at the first location by closing its mechanical gripper. The robotic arm will then lift the object and move to the second position. The base has the ability to rotate up to 180°, thus allowing the position of the object to be changed during the process.

Next, the robotic arm pick and place the object to the second location. Upon placing the object, the robotic arm will release the object by opening its mechanical gripper. Finally, the robotic arm return to its initial position and the pick and place routine will then be repeated.

The pick and place process will only be interrupted or stopped if the robotic arm operation mode is switch from automatic mode to manual mode. The reset command allows the pick and place memory of the robotic arm to be cleared, at the same time moving the robotic arm back to the pre-defined position.

4.1 Limitation

The robotic arm has a limitation of 180° angle of rotation. This is mainly due to the limitation of angle of rotation of RC servo motor. The obstacle sensing ability of the robotic arm is greatly limited as obstacle sensor avoidance is also not being implemented. The transmission speed of command from Blynk app to Blynk server and the retrieving speed of command for microcontroller from Blynk server depends on the reaction time of the
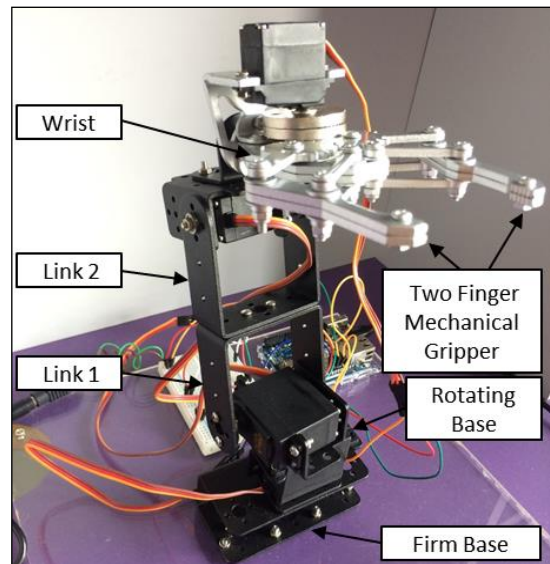

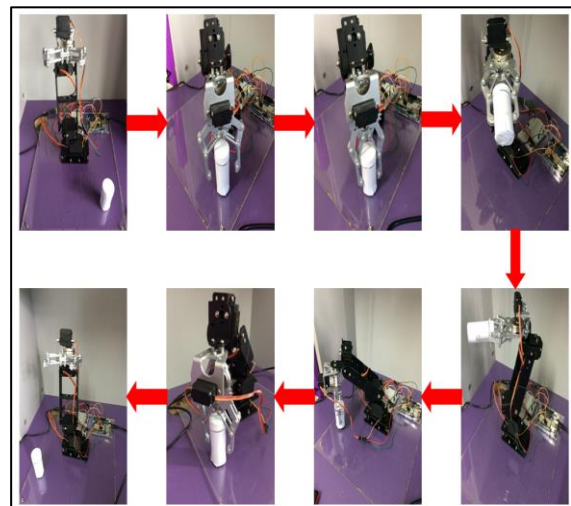
Figure 8. Actual structure of IoT robotic arm.

Figure 9. Complete pick and place operation.

connection of Wi-Fi or cellular data. The speed of graphical display of the robotic arm is limited by the processing speed of MATLAB R2013a.

5. CONCLUSION

Although research on robotic arm has been conducted in the past, the lack of technology applied has given the chance to conduct this research by implementing IoT for the robotic arm. Android mobile device is utilized as the platform to remotely controlled this robotic arm to perform the pick and place operations. Arduino Yun is used as the brain of the system, which will process the control signal and output modulation signal to the servo motor.

Future research needs to examine the effects of other types of sensor and actuator. Radio control servo motor with greater angle of rotation can be used to improve the reachability of the robotic arm. Moreover, more advance motor such as stepper motor can be used to offer more accurate and precise movement. This future research could help in the review of available robotic arm in the industries and make recommendations for future editions. Finally, future research and development in this research is greatly

encourage to bring benefits and advancement in industrial automation field.

ACKNOWLEDGMENT

REFERENCES

[1] A. Kumar, A. Mishra, P. Makula, K. Karan, and V. K. Mittal, "Smart Robotic Assistant," in *IEEE Reg. 10 Symp.*, Ahmedabad, India, 2015, pp. 25-28: IEEE.

[2] A. Shukla and H. Karki, "Application of Robotics in Onshore Oil and Gas Industry - A Review Part I," *Rob. Auton. Syst.,* vol. 75, pp. 490-507, 2016.

[3] S.-H. Kim, Y. J. Shin, K.-S. Kim, and S. Kim, "Design and Control of Robot Manipulator with a Distributed Actuation Mechanism," *Mechatronics,* vol. 24, no. 8, pp. 1223-1230, 2014.

[4] H. A. F. Almurib, H. F. Al-Qrimli, and N. Kumar, "A Review of Application Industrial Robotic Design," in *9th Int. Conf. ICT Knowl. Eng.*, Bangkok, Thailand, 2012, pp. 105-112: IEEE.

[5] P. Suresh, J. V. Daniel, V. Parthasarathy, and R. H. Aswathy, "A State of The Art Review on the Internet of Things (IoT) History, Technology and Fields of Deployment," in *Int. Conf. Sci. Eng. Manage. Res. (ICSEMR)*, Chennai, India, 2014, pp. 1-8: IEEE.

[6] I. Ungurean, N. Gaitan, and V. G. Gaitan, "An IoT Architecture for Things from Industrial Environment," in *10th Int. Conf. Commun. (COMM)*, Bucharest, Romania, 2014, pp. 1-4: IEEE.

[7] M. A. Islam, N. H. Sharif, M. S. P. Tameem, S. M. H. Chowdhury, M. C. Kumu, and M. F. Hossain, "IoT-Based Robot with Wireless and Voice Recognition Mode," in *Emerging Technol. Data Min. Inf. Secur.*: Springer, 2019, pp. 743-752.

[8] A. A. Badrul Hisham, S. A. Saad, M. R. R. Ahmad, R. A. Rahim, N. H. Idris, and M. H. I. Ishak, "Review of Safety Evaluation of Thermal Wearable Power Harvesting Device " *Int. J. Integr. Eng.,* vol. 9, no. 4, pp. 76 - 84, 2017.

[9] P. S. Chee, M. Nafea, P. L. Leow, and M. S. M. Ali, "Thermal Analysis of Wirelessly Powered Thermo-Pneumatic Micropump Based on Planar LC Circuit," *J. Mech. Sci. Technol.,* vol. 30, no. 6, pp. 2659-2665, June 01 2016.

[10] M. Nafea, A. AbuZaiter, S. Kazi, and M. S. Mohamed Ali, "Frequency-Controlled Wireless Passive Thermopneumatic Micromixer," *J. Microelectromech. Syst.,* vol. 26, no. 3, pp. 691-703, 2017.

[11] M. Nafea, A. Nawabjan, and M. S. Mohamed Ali, "A Wirelessly-Controlled Piezoelectric Microvalve for Regulated Drug Delivery," *Sens. Actuators, A,* vol. 279, pp. 191-203, 2018/08/15 2018.

[12] M. A. K. Yusoff, R. E. Samin, and B. S. K. Ibrahim, "Wireless Mobile Robotic Arm," *Procedia Eng.,* vol. 41, pp. 1072-1078, 2012.

[13] M. K. Ishak, M. I. Roslan, and K. A. Ishak, "Design of Robotic Arm Controller based on Internet of Things (IoT)," *J. Telecommun. Electron. Comput. Eng.,* vol. 10, no. 2-3, pp. 5-8, 2018.

[14] A. A. Badrul Hisham, M. Nafea, A. B. Aujih, M. H. I. Ishak, and M. S. Z. Abidin, "Racer: A Simulated Environment Driving Simulator to Investigate Human Driving Skill," in *Modeling, Design and Simulation of Systems: 17th Asia Simulation Conference, AsiaSim 2017, Melaka, Malaysia, August 27 – 29, 2017, Proceedings, Part II*, M. S. Mohamed Ali, H. Wahid, N. A. Mohd Subha, S. Sahlan, M. A. Md. Yunus, and A. R. Wahap, Eds. Singapore: Springer Singapore, 2017, pp. 534 - 547.

[15] A. A. Badrul Hisham, A. B. Aujih, M. H. I. Ishak, and M. S. Z. Abidin, "Accuracy and Quickness Criterion-based Driving Skill Metric for Human Adaptive Mechatronics System," *J. Teknol. (Advances on Intelligent Control and Robotic),* vol. 78, no. 6 - 13, pp. 9 -16, 2016.

[16] A. A. Badrul Hisham, A. B. Aujih, M. H. I. Ishak, and M. S. Z. Abidin, "Car Position and Orientation based Driving Skill Metric for Analytical Driving Skill Index Evaluator," *J. Teknol. (Sensor and Its Applications),* vol. 78, no. 7 - 4, pp. 27 - 33, 2016.

[17] M. H. I. Ishak, M. Mazni, and A. A. Badrul Hisham, "Human Driving Skill for Human Adaptive Mechatronics Applications by using Neural Network System " *J. Teknol. (Bioengineering and Ergonomics),* vol. 76, no. 7, pp. 97 - 101, 2015.

[18] K. Gawli, P. Karande, P. Belose, T. Bhadirke, and A. Bhargava, "Internet of Things (IOT) based Robotic Arm," *Int. Res. J. Eng. Technol.,* vol. 4, no. 03, 2017.

[19] A. A. Badrul Hisham, M. H. I. Ishak, C. K. Teik, and N. H. Idris, "Bluetooth-Based Home Automation System using an Android Phone," *J. Teknol. (Sciences & Engineering),* vol. 70, pp. 57 - 61, 2014.

[20] A. A. Badrul Hisham, W. L. Xuan, M. H. I. Ishak, N. H. Idris, and A. M. Nawi, "Mobile Inspection Robot for Heating, Ventilation and Air Conditioning (HVAC) Ducting Systems," *J. Teknol. (Sciences & Engineering),* vol. 73, no. 6, pp. 89 - 93, 2015.

[21] X. Feng and X. Huang, "The Research of Smart Home Robots Based on 3G Mobile Network," *Appl. Mech. Mater.,* vol. 631–632, pp. 184–187, 2014.

[22] M. Nafea, A. A. Badrul Hisham, N. A. Abdul-Kadir, and F. K. Che Harun, "Brainwave-Controlled System for Smart Home Applications," in *2nd Int. Conf. Bio Signal Anal. (ICBAPS 2018)*, Kuching, Malaysia, 2018, pp. 75-80: IEEE.