Performance Evaluation of Elderly Home Automation Control (EHAC) IoT System

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Summary
As the number of elderly increased rapidly every year, many elderly still choose to stay independent despite of difficulties and challenges faced in their daily routine. Elderly has desperate needs for support for their living. Internet of Things helps to support and improve elderly's life in many ways to meet the needs and requirements. Home Automation Control (EHAC) is a research based system that support elderly with controlled automation solution that control and operates various home electrical appliances based on the measurement of heart pulse rate and environment temperature. This paper works on EHAC system to evaluate the performance of the system in elderly's daily routine. This paper presented experiments conducted with approach of IoT testing and discussion on analysis of the results.

Key words:
Internet of Thing (IoT), Testing, Elderly, Automation, Sensors

1. Introduction

The number of elderly in Malaysia has rapidly increased in every year. According to the department of statistics Malaysia, the population older than 65 years had increased 1.4% from 2014 and accumulative of 7% of the share of the Malaysian population in 2020 [1]. There are numerous issues faced by the elderly due to deceasing ability. Basic tasks such as controlling home appliances become too difficult to perform due to physical condition [2]. Despite of these challenges, many elderly still choose to live independently in their own home. Internet of things helps to support and improve elderly's life in many ways to meet the needs and requirements. Home Automation Control (EHAC) is a research based IoT system which designed for the elderly who wish to live independently. The initial prototype has been developed on a small scale consists of sensors, microcontrollers that allows elderly to control and operates various home electrical appliances based on the measurement of their heart pulse rate and environment temperature.

"Internet of Thing (IoT) was first introduced by Kelvin Aston in 1999 as "we need a standardized way for computers to understand the real world". Aston further described that physical objects can be connected all around the world through internet via sensors at anytime and anywhere [3]. As IoT advances, testing are required to ensure high performance and effectiveness of the operation. IoT testing is described as testing tools to evaluate the overall performance of an IoT based system [4]. An IoT system needs to meet several criteria in order to be usable, such as usability, reliability, data integrity, security and performance [5]. Usability measure the interaction between the system and the elderly, reliability represents the degree of probability the system perform correctly in a certain time of period, data integrity measure the accuracy and validation of the data transmission between microcontrollers and database, security refer to the accessibility of users to the system and performance represents the overall attributes of the system.

IoT testing provides an insight and control over various interconnected IoT devices. According to literature, there are several IoT testing approach has been introduced by researchers [6-8]. These framework aims to identify testing for IoT system that involves device, networks, processors, operating systems, standards and platforms. One of the researcher claimed that there are similarity and contrast between IoT testing and normal software testing as IoT focuses on different fundamentals that connected the user and objects [9]. The IoT testing approach can be different based on the system architecture involve, hence test-as-a-user is often used than test based on requirement in an IoT testing. IoT testing is important to find out all possible bugs and to ensure each of the modules of the system is well function.

In this paper, IoT testing has been adopted to evaluate the performance of EHAC system according to the bench mark of pulse rate per minute by age and pre-set of instructions. Several experiments are conducted to evaluate the performance of EHAC system. The basic element of this IoT testing consists of benchmarking, pilot testing and dataset experimentation. The objective this paper is (1) to identify the defects from the EHAC system and (2) to evaluate the effectiveness of the EHAC system in perspective of Malaysian elderly. This study supposed to significance in enhancement and improvement of EHAC system to benefits Malaysian elderly for quality life in the light of living in an ambient assisted environment and energy conservation. The rest of the articles are as follows, section 2 provides the background studies of

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EHAC system. Section 3 discusses the evaluation of testing approaches carry out in this paper. Section 4 mentioned on the results and discussion and this paper conclude with future work.

2. Elderly Home Automation Control (EHAC)

IoT technology has been heavily used in different industries [10-11], it has proven IoT is able to improve elderly life in many ways. In research methodology, literature reviews has been taken into account to identify the problems and challenged faced by the elderly, the needs and requirements and existing system in this study area. This paper has introduced EHAC (developed in IoT framework) system for elderly to live independent without assistance from third person.

EHAC presents a new approach to utilize IoT integrated with pulse sensor and environment temperature sensor to support elderly with controlled automation solution that control and operates electrical home appliances based on the measurement of pulse rate, environment temperature and instructions. EHAC embedded decision making instructions where it makes decision based on specific conditions for elderly to remote control their home appliances without having any physical interaction with the On/OFF switch [13]. EHAC aims to reduce elderly's movement by eliminating the use of remote controller use. According to Ananda et al, the authors had proposed a solution that control the home appliance based on voice recognition, however the lack of accuracy and misinterpretation shows the downside of the system [14]. The system design of EHAC is developed based on the IoT architecture [15].

In the idea of IoT architecture, three layers architecture was proposed in the early stage of IoT and then develop into four and five layers to fulfill the requirements of IoT. Based on findings, the author had proposed a new version of architecture from modification of the previous architectures which later use in the development of EHAC system. The new architecture consists of five layers; sensor, network and internet, data storage, data processing and application and cover by a security layers. In the new architecture, the processing layer is spitted into data storage and data processing layer which serves as a temporary storage layer that provides storage functionalities such as data replication, distribution and storage and provides a diverse set of services to the lower layer.

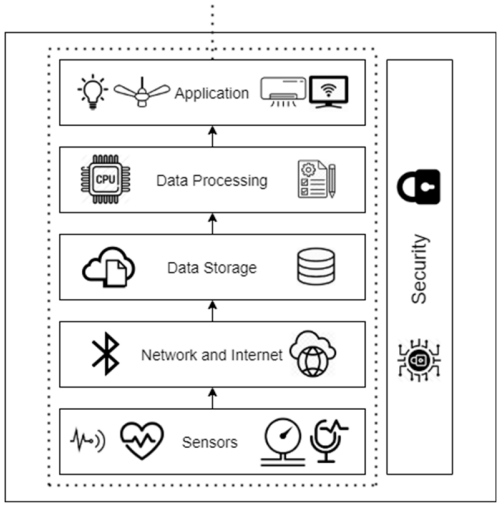

Fig. 1 EHAC System Architecture

EHAC system consists of sensors, microcontrollers and controllers. The back-end of the system has been developed using Arduino. Arduino is an open source cross platform that offers C and C++ programming language focuses on IoT projects [12]. The communication and configuration has been managed through the Blynk server and HTTP RESTful API [16]. Data such as elderly's pulse rate and environment level is store into Firebase database and real time data monitoring can be done through EHAC mobile application.

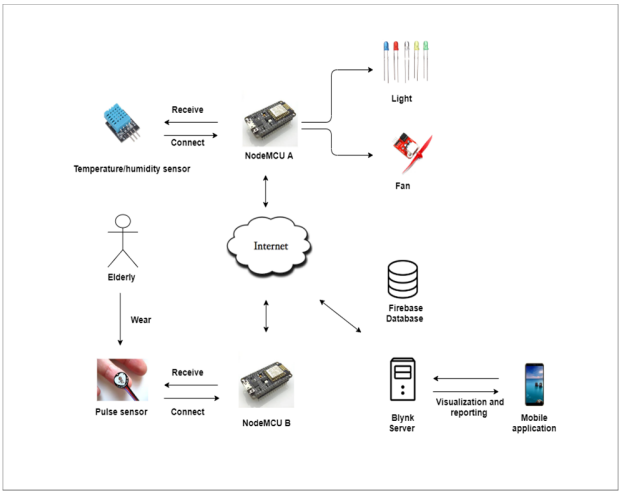

Fig. 2 EHAC system design

2.1 Elderly Home Automation Control (EHAC) algorithms

EHAC's algorithm was developed to eliminate the use of remote control use and allow automation to do its work. For instance, the microcontroller that read the elderly's heart pulse rate will trigger the instructions to the microcontroller that are connect and activate the electrical home appliance through the internet when condition is meet. The following describe the coding for EHAC's solution.

```
program start
initialize variable Heart_rate = 0
initialize function Heart_rate();
initialize variable B
set Heart-rate sensor to virtual pin v3 (D1 to V3)
start infinite loop
call function read variable Heart_rate
if
  (Heart_rate >= 63 && Heart-rate < 97) //example
    set V3 as value 1
  else
     set V3 as value 0
```

```
program start
initialize variable trigger = 0
initialize function temp();
set variable trigger = param.asInt() in v3 (V3)
start infinite loop
call function temp();
if
  (temp == 30 && humidity == 60)  //example
    turn D3 light on
    turn D6 fan on
      else
         turn D3 light off
         turn D6 fan off
receive signal from Nodemcu A
if(trigger == 1)
  turn on D2 light
    else
    turn off D2 light
```

The pseudo code shows the algorithms trigger the home electrical appliance based on the pulse measurement. The code used the "if else" conditional statement, using **if** to specify a block of code to be executed, if the statement is true and **else** to specify a block of code to be executed, if the statement is false. In this case, the statement is reading the heart rate value. For instance, if the heart rate value is above 63 and below 97, data analysis measurements will assume that the elderly is awake, hence the light will be trigger by the command to switch on, and if the heart rate value is below 60, the light will be switch off itself assuming that the elderly is sleeping.

3. Evaluation on EHAC Performance

This section discuss on the evaluation of EHAC performance. The assessment of the system aims to meet the testing criteria such as usability, reliability, data integrity, security and performance. Several IoT testing has been carried out to evaluate the performance of EHAC system. IoT testing has been according to the bench mark of pulse rate per minute by age and pre-set instructions. Table 1 shows the elderly pulse per minute and Table 2 demonstrates the pre-set instructions. These data plays significant role to perform accurate results in the experiment.

Table 1: Average pulse rate based age [17]

Age in years	Average max heart rate in beats/minutes	Target rate range in beats/minutes
40 – 44	180	90 – 153
45 – 59	175	88 – 149
50 – 54	170	85 – 145
55 – 59	165	83 – 140
60 – 64	160	80 – 136
65 – 69	155	78 – 132
70 - 74	150	75 – 128

Table 2: EHAC pre-set instruction

	Scenarios	Actions
1	If temperature < 28	Turn off fan
2	If temperature > 38	Turn on fan
3	If heart rate value > 60	Turn on light
4	If heart rate value < 60	Turn off light
5	If heart rate < 60 && temperature < 28	Turn off fan and light
6	If heart rate > 60 && temperature > 38	Turn on fan, turn off light

3.1 Bench Marking

Bench marking is referred as a process to determine the best processes to achieve the project aim. Benchmarking is adopted to measure the accuracy of elderly's heart pulse rate. This benchmark follows the method of accuracy test [18]. EHAC database receive real-time data such as elderly's pulse rate and environment level. The input is in form of numerical Int and output is in the form of action to be complete in the system flow. In this test case scenario, the benchmark aim to address the questions of how accurate is the data. Two mathematical formulas were used during the test to first gather the average of pulse rate, and then proceed to calculate the percentage of error. On the setting, the value of 70 is set as the accepted pulse rate value. The benchmark test will be run for 3 hours and it is estimated to gather 10800 values as pulse rate per second.

$$Avg\ of\ pulse\ rate\ = \frac{R1 + R2 + R3 + R4 \ldots Rn}{\mathrm{N}}$$

$$\%\ error = \frac{\mathrm{R} - \mathrm{A}}{\mathrm{A}}\ x\ 100\%$$

3.2 Pilot Test

The pilot test was conducted with 3 elderly as experiment participants that meet the experiment requirement such as age and are physically challenged. The numbers of participants are affected due to outbreak of Covid-19 and restriction of MCO. This pilot test aim to validate the EHAC algorithms in an actual environment and the results will be used to validate the effectiveness of EHAC system. The pilot test was continuously conducted in time frame of one week. The pilot test involves capturing elderly's pulse rate and environment temperature. The functionality of electrical home appliances; on and off are controlled by the instruction from the microcontrollers hence were also tested during the experiment. Pulse sensor was placed on elderly's hand wrist as a wearable device during the experiment period to gather pulse rate and the main microcontroller that connects the electrical home appliance were placed at the elderly home. The pilot test monitors real-time condition and scenarios such as system usage, power usage and temperature of the system. All data were stored into Firebase database during the experiment. Fig 2 and Fig 3 shows the dataset collected during the experiment.

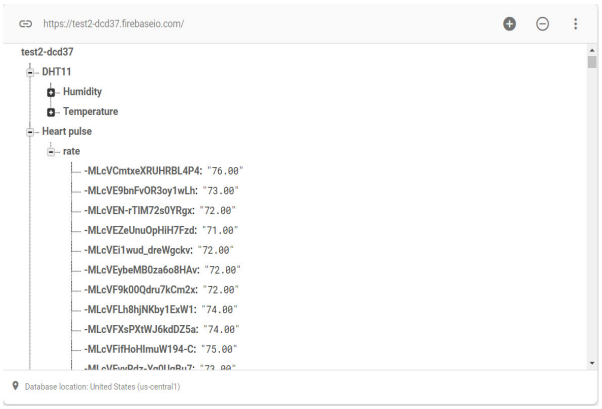

Fig. 3 EHAC Database

3.3 Dataset Experimentation

The dataset experimentation is conducted through the Firebase database to ensure the scalability of the proposed system. EHAC algorithm goal is to control home appliance through dataset of pulse rate and environment temperature to trigger the pre-set instruction. Multiple experiments were conducted after pilot testing to identify how variables of pulse sensor and environment temperature are able to combine to influence the outcome of the results. Adjustment had been done to eliminate unwanted data. The final dataset was identified throughout multiple round of experiment and EHAC's Pre-set instructions with accurate range are finalized.

4. Discussion and Results

On the benchmark testing, the average of pulse rate shows 71.67 from 10800 set of data. The value then used to measure the % error of the data accuracy. The results reveal that there is 0.0239 % of error on the accuracy of pulse rate. The % error occurs due to some undefined data. This is affected by the quality of sensors, such as sensor unable to read the pulse rate when user is moving. Based on the investigation, assumption can be made that better sensors can significantly affect the % error of data accuracy.

On the other side, there are total of tests conducted throughout the experiment and each of this experimentation was categorized into three iterations. Each result was generated based on the EHAC pre-set instruction and were divided into the following group; 1 and 0 which represents pass and fail respectively. The verification is determined by the accuracy of the index

results and the primary findings from the testing show the significance of the study.

Table 3: Experimentation Validation Index

Experimentation	Verification	Functionality	Accuracy index
Experimentation 1	Pulse rate sensor	• Fan: on and off • Light: on and off	1
Experimentation 2	Environment temperature sensor	• Fan: on and off • Light: on and off	1
Experimentation 3	Pulse rate sensor + environment temperature sensor	• Fan: on and off • Light: on and off	1

This paper shows the importance of the IoT testing for the study of the EHAC system. It is proven EHAC system is able to perform effective with automation of home electrical appliances control through elderly's pulse sensor with accurate data transmission and instructions between microcontrollers, electrical home appliances and database. However, through experiment observation, there are several barriers faced by the elderly during the experiment, such as elderly finds it difficult to understand the operation and to wear a device on hand for the whole day is inconvenience for them.

5. Conclusion

The living quality of elderly to stay independent without assistance from third person can be improved from the help of IoT. From the experiment it has been found that tech support is needed for the improvement and support of the elderly daily routine. Based on the IoT testing, it has also be found that EHAC system can expands it connectivity towards more home appliance such as rice cooker and television. In addition, the testing demonstrated that EHAC system is also suitable for the disabilities as they share similarity problems and challenges of physically challenged. Another future plan is to implement emergency detection into EHAC system to avoid and decrease the rate of further physical damages for the elderly during emergency state.

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