Exploratory Testing for the Internet

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Exploratory Testing for the Internet of Things in Smart Fertilizer Hydroponic System using Hydropo

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Abstract. Internet of things "Hydropo" was designed for automatic fertilizing in a hydroponic system. It is not only for making sure of working both hardware and software but also the implementation of such products. Therefore, testing is needed for proofing that "Hydropo" can be implemented. Exploratory Testing has already done in order to test the usability and validity of the smart tool in producing vegetable in the hydroponic production system. The result of the research was the Internet of Things "Hydropo" may not still be implemented yet for an outdoor environment. Redesigning "Hydropo" for outdoor implementation is needed including made it more adaptive to temperature and air controlling.

1. Introduction

A product compatibility requirements since its development software is important concerning its implementation. Development Internet of Things (IoT) has many things to consider regarding hardware and software requirements. The fulfilment of the main IoT requirements such as real-time, security, and continuous exploitation of product stated the success key and challenge for IoT, that IoT hardware has an undefined parameter [1]. So, testing should be done to identify that the IoT product has compatibility with requirements.

Cognizant defined the rules of *Quality Assurance*-QA of IoT tools, that it was not only limited to convergence testing for hardware and software of IoT tools testing, but also to make sure that the tools have its functions running well. Implementations of IoT in real-time which apply integrating censors is also a challenge for QA of IoT. One of the Cognizant testing environment was [2] *exploratory*, a testing based on user's perspective and beyond procedure testing had already defined.

Dietmar *et al* states that more than 60% of respondents use ET for usability-critical, performance-critical and security-critical [3] while ET is more efficient by requiring less design effort [4]. Esquiagola et al. identified that the test layer on IoT for user interaction is usability tests (testing the ease of the system for users) [5]. In this paper, ET is used to test the usability of an Internet of things products.

Internet of things which is smart fertilization of hydroponic systems (hydropo) consists of "hydropo hardware" and "hydropo assistant software". Hydropo Hardware is a set of tools consisting of interconnected sensors that can collect data and send it to the hydropo Assistant application. Hydropo

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Assistant software designed as a control function and provides information and user interfaces. The functions that exist on the internet of things consists of monitoring temperature, pH, Rh and EC and also controlling the supply of fertilizer and water.

The aims of Hydropo & Hydropo Assistants were to be able in controlling fertilizer and water, and provide information regarding temperature, pH, Rh and EC in hydroponic systems. Therefore, the IoT devices must be able to run in producing good hydroponic crops compared to its common systems. Thus, ET was carried out to identify the usefulness and performance of smart devices in producing good quality hydroponic crops.

2. Related Works

Exploratory Testing (ET) has been introduced since 1983, as stated by James Bach, "Exploratory testing is simultaneous learning, test design, and test execution". ET covers any test including control by testers for design after the testing was already done, and the use of information obtained during the testing for new designs and better testing [6]. ET will be more effective if it works with limited time [4]. ET can generate product/feature feedback quickly, while coding testing has been done it will be able to find bugs quickly. ET is a reliable testing method, since it can trace the flow of information backward from testing execution until product design [6].

Juha Itkonen defined the characteristics of ET are [7]: 1) Exploration to achieve goals without specific instructions; 2) the test is guided by the results of previous tests and the knowledge obtained by the examiner comes from the information available (for example the user manual); 3) Focus on ET that found defects through exploration systematically in producing comprehensive test cases; 4) ET is simultaneous learning from the system being tested (system under test), test design (test design) and test execution; 5) The effectiveness of testing depends on the knowledge, expertise, and experience of the examiner.

3. IoT Hydropo Exploratory Testing Product

The method of ET testing consists of [8]: **Learning**: anything that can guide what will be tested, how to test or how to identify problems; **Design**: to make, execute, or to build according to plan; **Execution**: test and collect results; **Interpretation**: what can be learned from the product, to define a product pass or fail (Oracle heuristics). Based on the ET stages described above, the testing methodology that will be carried out on IoT Hydropo adopts the following ET stages as follows:

- **Learning IoT Hydropo**, the first stage that describes the knowledge of IoT Hydropo products to be tested, such as: what, the function and method of work.
- **IoT Testing Design**, the second stage identifies the design of the tests carried out: Methods and Techniques, which are used to assess the quality of IoT Hydropo
- **Hydropo IoT Execution and results**, the third stage is the execution/implementation of the methods and techniques that have been described at the design stage.
- **Interpretation of the test results**, is the last stage of the execution results of the method and the testing techniques performed are interpreted.

4. Learning IoT Hydropo

Generally, the smart fertilization method works by mixing two levels of fertilizer in the form of granules with water automatically (application of fertilizer and water). After mixing, then it flows into hydroponic crops through pipes. In detail the working procedure of the device from the start (sensor reading by the microcontroller) until finally the fertilizer is dropped is as follows:

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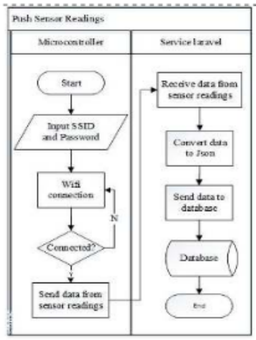

Figure 1. Microcontroller flow of process in doing the Push Reading Sensor Data to service laravel

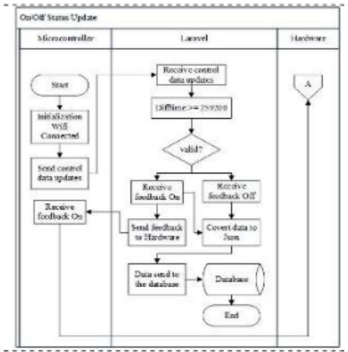

Figure 2. The microcontroller updates the ON/OFF status.

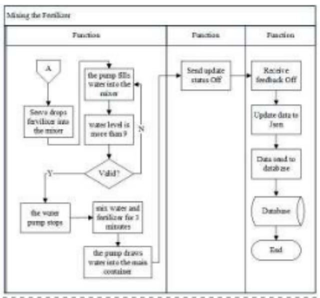

Figure 3. Hardware when doing fertilizer Mixing

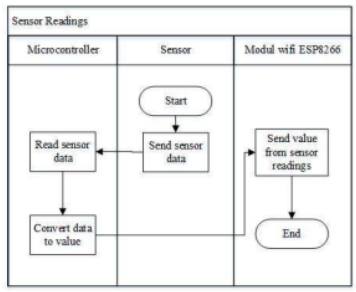

Figure 4. Microcontroller when doing sensor Readings

5. IoT Hydropo Testing Design

Hydropo IoT testing has been carried out for the Software and Hardware interaction layer as follows: 1) Device Android; 2) Vue.js and Firebase; 3) Ultrasonic Sensor Reading/Distance Sensor; 4) Testing Data Sent from Arduino to web Vue.js (pH, EC, Height of container and temperature) were all valid. The test was undertaken on a lab scale, while the Hydropo IoT product development was initiated (indoors condition).

This paper was intended to find out the result of crop production by the assistance of the application (by mixing water and fertilizer automatically) roughly similar to the real environment. Meanwhile, IoT Hydropo testers are those who have knowledge related to crops production using the hydroponic system. Usability tests, that was intended to identify the ability of the software, was easily learned and understood, and furthermore attracted to customer attention. Usability Testing is one type of black box testing, which not only used for application and web software, but also can be used for various types of products [9]. IoT-based applications need to be tested for the usefulness of the application (usability) in order to get the value of efficiency, effectiveness, satisfaction, and ability to learn from the application to achieving its goals [10]. IoT Hydropo test aims to find out the requirements related to user needs, by using a test case/scenario experimental design testing. It was also carried out by Frederic Goncalves et al. to obtain the adaptability of the product configuration and feedback from users [11] and Maria Fernanda Granda to evaluate the completeness of requirements from the user's point of view [12].

Scenario testing in the form of this experiment was tested by the user since the device used to ensure that, the user applies the system can produce crops with sufficient nutrients. This experiment was

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undertaken on two hydroponic systems simultaneously, which were planted the same crops seeds with the same seeding age. The first hydroponic systems would be installed with an IoT device (mixing fertilizer and water automatically controlled via Hydropo Assistant) and the second hydroponic system using common method (mixing involves the human hand with the knowledge the user has).

The crops used use in this experiment consist of 2 types of vegetables, namely pakcoy and lettuce. The two crops as chosen were easily seen physically if they get sufficient nutrients or not. Moreover, the crops have also a short growing period of time (approximately 3 weeks) including the nursery period of 10 days to 2 weeks (a total of 5 weeks).

Before using the IoT device, users were given the following information:

- Users were given a device usage guide (Hydropo and Hydropo Assistant Manual's book), so users could use the device correctly
- Users get information from the team related to how the IoT device works and how to control it.

6. IoT Hydropo Testing Design

The implementation of this test is as follows:

- Installation of 2 hydroponic systems. Based on the testing conditions similar to the hydroponic cropping system, the IoT device was wrapped in a portable box and has a security system. The following is a description of the hydropo device:
  Planting pakcoy and lettuce.
  Each hole was coded as: P = Pakcoy; S = lettuce; m = manual/common system; o = automatic (with hydropo device); b = big seed; k = small seeds; the codes would be Pmb01, Pob01, etc. The total numbers of crops in each hydroponic system were 49, as of the total number should be 98 crops.
- The observation was approximately 3 weeks (until harvest). The IoT Hydropo product is valid, as seen from the physical crops appearance.

M0 is the week the seed is sown and Hydropo was installed into a hydroponic system. At the M0 period fertilizer has been stored in a container accommodated as an initial supply which will be channeled to the hydroponic system pipeline.

The result of Test Case The Mixing Fertilizer workflow is as follows:

Table 1. Test Case Results of IoT Hydropo

No	Test Case	M0	M1	M2	M3	Expected Results
T01	Input SSID and Password	✓	✓	✓	✓	Input SSID and password has been succeed
T02	Wifi Connection	X (2day)	✓	✓	✓	Wifi connect
T03	Servo drops fertilizer into the stirrer	✓	✓	X (imperfect amount)	X (imperfect amount)	Servo drops fertilizer to the stirrer according to the specified amount
T04	The pump fills water with the mixer pump	X (2day)		X (imperfect amount)	X (imperfect amount)	water flows to the mixer
T05	More water level from 9	✓	✓	X (2day)	X (not accurate)	The pump fills the water stops
T06	Mixing water and fertilizer for 3 minutes	✓	✓	✓	✓	Water and fertilizer mix

No	Test Case	M0	M1	M2	M3	Expected Results
T07	The pump draws water into the main tub	✓	✓	✓	✓	Water flows into the main tub for 30 seconds
T08	Send Reading Data From Sensor to Server per 5 minutes	X (2day)	✓	✓	✓	Data is stored in the database
T09	Floating switches float because the water the water level reaches the limit	✓	✓	✓	✓	The pump stops filling the water
T10	Reading the status of the on / off nutrition provider	X (2day)	✓	✓	✓	The on / off status of the device was detected
T11	Read temperature (Sensor DS18B20)	✓	✓	✓	✓	The temperature of the plant can be read
T12	Read pH (Sensor SKU: SEN0161)	✓	✓	✓	✓	pH crops can be read
T13	read EC (Sensor SKU: DFR0300)	✓	✓	✓	✓	EC crops can be read (in voltage)

The experimental results show the plant quality is seen based on the parameters shown in the following table 2:

Table 2. Crop Growth Using Hydropro vs. Manual on Hydroponic Systems

Compared Parameter	Hydroponic System			
	Lettuce (m)	**Pakcoy (m)**	**Lettuce (o)**	**Pakcoy (o)**
Crop weight	79.6	144.1	64.1	119.9
Widest Leaf	13.5	10.8	12.8	9.9
Canopy diameter	29.5	27.9	27.5	26.4
Number of leaves	8.2	12.3	6.8	12.1
Crop height	17.7	13.5	18.7	16.3

*big seedlings (seedlings July 30 planted August 14 2018) and
*Small seedlings (2 August seedlings planted August 14, 2018)
*Hydroponic Fertilizers spend one package
* Average of pH: m = 6.64; o = 5.85 and * Average of EC: m = 2.30; o = 9.91 (conversion)

At week 0 (M0-Hydropo Installation), various obstacles were discovered, 1) Modems are not connected, a provider role was needed to correct modem settings; 2) Components could not move too hard, either the pump could not draw water in a specified amount.

Based on the experimental observations from the first week (M1) until the third week (M3) it has been identified that M2 and M3 have formed fertilizer in place of fertilizer A. Fertilizer A containing Calcium Nitrate cannot be stored in conditions exposed to air and heat. It resulted in that amount of dropped fertilizer not in accordance with the specified. The amount of unsuitable fertilizer has affected the number of nutrients present in the container, and in the end the water + fertilizer applied to hydroponic crops was not in accordance with the amount of needed crops. In this stage, the results of crop quality were not satisfying enough, with the implication of improving the hydropo performance.

Outdoor testing indicates that a modification of the equipment is needed for more adaptive tools to outdoor conditions, such as controlling the temperature and humidity of the air so as to prevent fertilizer clumping. A blower is needed to cool the temperature in the box used as storage for the hydropo component.

7. Interpretation

Based on the findings of the experimental results, it can be interpreted that: IoT Hydropo was consistent with what was designed. Meanwhile, it was not adaptable when applied in outdoor environments. Therefore, modification of the hydropo device is needed for more adaptive to air temperature and humidity. Based on the knowledge of the testers, it is necessary to re-design the hydropo IoT with an injection system and use a liquid fertilizer that is not susceptible to the influence of air humidity and temperature.

8. Conclusion

The result of the exploratory testing of IoT Hydropo using experimental design was that IoT Hydropo was still not adaptable to changes in the outdoor environment. Redesigning of Hydropo is needed for in order to make related to more adaptive air temperature and humidity. The discussion of design with the new system will be the next topic of discussion.

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