2017 International Conference on Information Technology Systems and Innovation (ICITSI)
Bandung, October 23 – 24, 2017
ISBN: 978-1-5386-3100-3

# Hydroponic Smart Farming Using Cyber Physical Social System with Telegram Messenger

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***Abstract*—In the Cyber Physical Social System (CPSS), collaborative work between hydroponic farmers is now possible. With this new concept, hydroponic smart farming system that can be monitored online via Telegram Messenger is developed. The design that is created can monitor important parameters in the hydroponics system, such as light intensity, room temperature, humidity, pH, nutrient temperature, and Electrical Conductivity (EC). The prototype is designed using Raspberry Pi 3 that connects directly with sensors such as DHT11 module, LDR, pH sensor module, and EC sensor. Telegram BOT that allows to monitor sensors online via Telegram is also made. With the integration of the Physical System (Raspberry Pi, sensor) and Social System (Telegram Messenger) connected online via internet or cyber, the hydroponic system monitoring becomes more flexible.**

***Keywords*—cyber physical social system; smart farming; hydroponic; raspberry pi; internet of things; telegram messenger; telegram bot**

## I. Introduction

Smart farming is an application of information and communication technology for monitoring farming system. It contains sensors for sensing the environment parameters. A study aimed to investigate an establishment using an Intelligent System which employed an Embedded System and Smart Phone for farming management and problem solving using Raspberry Pi and Arduino Uno [9]. There is also a study that developed a sensor-based automatic control mobile application for hydroponics [5]. The application enables automatic environment monitoring for hydroponics with different types of sensors including temperature and humidity sensor, water temperature sensor, and light sensor. Another study showed about new aspect for organic farming through hydroponics [8]. That research noticed the adoption of technology is open for productive organic farming practices. A breakthrough of technology is the concept of CPSS. CPSS is a combination between physical system and social system delivered through cyber or internet connection [23]. Physical system contains sensors, actuators, and computer systems that do computation [24],while social means society that doescommunication to each other. In a hydroponic system there are some factors that affect from growing of hydroponic plant. Light, temperature, humidity, pH, and nutrition are essential matter for growing plants in hydroponic system. Solution conductivity and temperature measurement are also an important factor to monitor in hydroponic system. In the green house, light can be suppliedartificially using LED lamp or other light source besides sun light. The useof Raspberry Pi is needed to integrate all sensors. Implementing CPSS concept made hydroponic farmers possibleto work in a group.

Smart hydroponic farming system is the solution. Monitoring of the hydroponic environment parameters can be taken remotely. Also,monitoring activities can be done anytime and anywhere by its farmers. Some systemsare needed to make the smart farming system work. The first is its own hydroponic system with the Nutrient Film Technique (NFT). The second is the physical system that consists of Raspberry Pi as a single board computer to do computation, sensors and actuators. The sensors that are used are light sensor, temperature and humidity sensor, and nutrition sensor. The third is Telegram messenger as social media to take communication activities between farmer to farmer and farmer to a Bot. A Bot is Telegram Bot based on Python script for communication between sensors and human or farmers.

In conventional hydroponics systems, monitoring plant environment conditions is done manually. Farmers manually still need to come to the hydroponic garden. Then manually the farmers must also continue to monitor the condition of the plants. This becomes difficult if the farmer is not near his hydroponic garden,or weather conditions that do not allow the presence of these farmers. The design of a prototype that uses the concept of CPSS technology allows farmers to monitor the condition of the hydroponic system environment remotely and real time.

This research triesto integrate between physical system and social system. The physical system consists of Raspberry Pi version 3 and the sensors. The social system is by using Telegram messenger. A Telegram-Bot is created in python programming language for communication between physical system and it users. Raspberry Pi, a single board computer, is used to integrate sensors that are connected. Telegram is a cloud-based messaging application with a focus on speed and security. It is fast, simple, and free, including its API.

The purpose ofthis research is prototyping hydroponic smart farming which could monitor the system through telegram messenger as CPSS. Prototype that is designed usesTelegram messenger for CPSS implementation. Following the scenario, a group of farmers set up a group on telegram.

They can communicate each other and also communicate with the telegram-bot that is connected with physical system. Commands sent by the member of farmer through telegram request condition of environment in hydroponic system and replyback to the sender.

From some other researches, generally system design to monitor the condition of android-based environment and its nature for single user. Therefore, in this research, it is attempted to design a hydroponic smart farming system that can be monitored by a group of p

eople or groups of hydroponic farmers. The social system here uses Telegram messenger as its communication medium.The communication between group members and communication with Telegram-Bot can be directly done. Telegram-Bot is an application based on telegram messenger API for communication between users with sensors.

## II. Methodology

This research used system engineering as its methodology. Systems engineering is a guide to a complex system [25]. System engineering not only focuses on the design of a system, but also external factors of the system. The general definition of a system is a collection of interconnected components, working together for a common purpose. The function of system engineering is as a technical guide of complex systems. The guidance here is defined as a guide, organizing or directing, usually based on a superior experience in following the given direction and to point the way. The dictionary-based engineering definition is the application of scientific principles to practical, construction and operation design of efficient, economical structures, tools and systems [25]. In this definition, efficient and economical terminology is a particular contribution of good systems engineering.

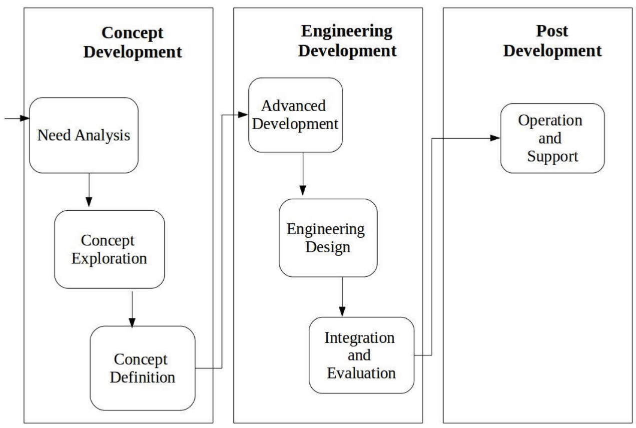


Fig 2. Phases in System Engineering [25]

The picture in figure 1 shows the stages and phases in a system engineering methodology consisting of three phases and six phases. Each phase will be divided into steps.

Figure 2 illustrates the monitoring process in current hydroponics plants. The process is done manually, startingfrom coming to hydroponic garden, measuring humidity and room temperature, measuring pH, measuring EC and the temperature of nutrition. The process of turning on or off the lights is also still done manually.

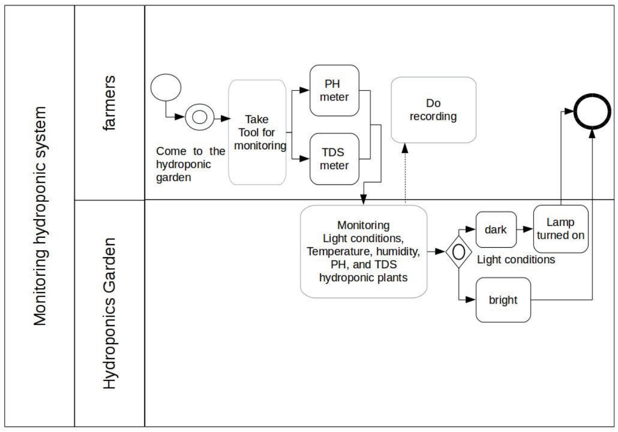


Fig 3. Process as-is in monitoring hydroponic

## III. Results and Discussion

### A. Concept Development

Concept development is an early stage in this research using system engineering methodology. Concept development is the process of identifying problems, analyzing needs, and proposing solutions to problems. Concept development consists of three phases, namely need analysis, concept exploration and concept definition.

#### A.1. Need Analysis

The purpose of the need analysis phase is to ensure the need for system engineering. Itis mainlygetting a valid operational requirement as the basis of system development. Below is the need analysis table, that indicates steps, activities, inputs, outputs, and analysis techniques used. In the validation step used evaluation of hydroponic farmers' perceptions of the system to be designed. Several analytical techniques were used in this need analysis phase, including Strengths Weaknesses Opportunities and Threats (SWOT) analysis and Technical Economic Legal Operational Schedule (TELOS) analysis. TELOS analysis is used to ensure system feasibility. This analysis is based on observations of operational conditions and interviews with stakeholders.

TABLE I. NEED ANALYSIS PHASE

| Step | Activity | Input | Output | Technique |
|---|---|---|---|---|
| Operational Analysis | Operational analysis, Define operational approach | Laws, government regulation, local regulations, to review agricultural related rules; available data sources | Operational objectives of the system | Operational analysis, Document analysis |

| Step | Activity | Input | Output | Technique |
|---|---|---|---|---|
| Functional Analysis | Functional requirements, allocation of requirements | List of interview topics with hydroponic farmer and government | Hydroponic farmer need | Stakeholder interviews |
| Feasibility Definition | Visualization of system technology, system definition | Hydroponic farmer need | Eligibility from the internal and external side in realizing the system | SWOT Analysis, TELOS Analysis |
| Needs Validation | Model of system effectiveness, Validation of needs | Hydroponic system questionnaire , Operational Purposes system, Hydroponic farmer needs | Valid system operating requirements, Valid system operating objectives | Surveys of public perceptions, Validate needs to stakeholder |

One of the important activities in the need analysis phase is to conduct interviews with stakeholders to find out the needs of the hydroponic farmers. The end result or the main output of the need analysis phase is the operational needs and operating objectives of the system.

TABLE II. ULTIMATE OUTPUT OF NEED ANALYSIS PHASE

| SYSTEM OPERATING REQUIREMENT | SYSTEM OBJECTIVES OPERATIONAL |
|---|---|
| 1. Use of easy techniques in hydroponics systems (tabelnya 2 x2).<br>2. Utilization of quality seeds for hydroponics plants.<br>3. Farmers can interact with members of their group anytime and anywhere<br>4. Farmers can monitor the light conditions in the hydroponics system, whenever and wherever.<br>5. Farmers can monitor the room temperature in the hydroponics system, whenever and wherever.<br>6. Farmers can monitor the humidity of the room in the hydroponic system, whenever and wherever.<br>7. Farmers can monitor the pH conditions of nutrients in the hydroponics system, whenever and wherever.<br>8. Farmers can monitor the condition of EC nutrition in the hydroponics system, whenever and wherever.<br>9. Farmers can monitor the temperature of nutrients in the hydroponics system, whenever and wherever. | 1. Implement the mandate of Law No. 18 of 2004 on Plantations which states the use of growing media other than land through technological innovation.<br>2. Improving the quality of plants for consumption because they do not use pesticides.<br>3. Improving the quality of plants for consumption because they do not use pesticides.<br>4. Suppressing the need for water due to the hydroponic farming system needs less water.<br>5. Suppressing the need for water due to the hydroponic farming system needs less water. |

Table II shows that the operational needs of the system is that farmers can monitor the light conditions, room temperature, humidity of the room, pH, EC, and the temperature of nutrients.

A.2. Concept Exploration

The second phase of the concept development is a conversion to change the needs that have been obtained in the previous stage. This phase tries to find the alternative technology that meets the needs of the system.

TABLE III. ULTIMATE OUTPUT OF CONCEPT EXPLORATION PHASE

| No. | Requirement | Alternative System Solutions |
|---|---|---|
| 1 | Use of easy techniques in hydroponics systems. | Using the NFT technique in the hydroponics system Using the Deep Water Culture (DWC) technique |
| 2 | Utilization of quality seeds for hydroponics plants. | Using certified seeds Using seeds from Seed Center of the Ministry of Agriculture |
| 3 | Farmers can interact with members of their group anytime and anywhere | Designing an integrated CPSS with hydroponics system Using Telegram Messenger's social media platform for smartphones Using Telegram Messenger web version Using Telegram Messenger application version |
| 4 | Farmers can monitor the light conditions in the hydroponics system, whenever and wherever | Utilizing the API of Telegram Messenger Designing integrated CPSS with hydroponics system using Raspberry Pi 3 which is connected with Light Dependent |
| 5 | Farmers can monitor the room temperature in the hydroponics system, whenever and wherever | Utilizing the API of Telegram Messenger Designing an integrated CPSS with hydroponics system using Raspberry Pi 3 that is connected with DHT11 sensor module |
| 6 | Farmers can monitor the humidity of the room in the hydroponic system, whenever and wherever | Utilizing the API of Telegram Messenger Designing an integrated CPSS with hydroponics system using Raspberry Pi 3 that is connected with DHT11 sensor module |
| 7 | Farmers can monitor the pH conditions of nutrients in the hydroponics system, whenever and wherever | Utilizing the API of Telegram Messenger Designing an integrated CPSS with a hydroponics system using Raspberry Pi 3 that is connected with a pH sensor module |
| 8 | Farmers can monitor the condition of EC nutrition in the hydroponics system, whenever and wherever | Utilizing the API of Telegram Messenger Designing an integrated CPSS with a hydroponics system using Raspberry Pi 3 that is connected to the EC sensor module |
| 9 | Farmers can monitor the temperature of nutrients in the hydroponics system, whenever and wherever | Utilizing the API of Telegram Messenger Designing an integrated CPSS with a hydroponics system using Raspberry Pi 3 that is connected with the DS18B20 sensor module |

The final outcome or outcome of the concept exploration phase is an exploration of alternative solutions to system requirements. The table above shows an alternative system solution based on needs. The needs here include some of the existing hydroponics systems, the selection of good hydroponic plant seeds, and some of the technologies that can be used.

A.3. Concept Definition

The next phase is the concept definition phase. In the concept definition phase, the selection of system concepts based on the alternatives that have been explored in the previous phase. By defining the concept of the system, the engineering process proceeds to a more specific design stage.

The final outcome or main output of the concept definition phase is to generate functional requirements and perform alternative selection of systems that have been explored in the previous phase. For the concept validation, PIECES (Performance, Information, Economic, Control, Efficiency, and Service) matrix analysis is used. PIECES analysis technique is used to find problems and deficiencies in the existing systems and ensure the achievement of the system requirements.

TABLE IV. ULTIMATE OUTPUT OF CONCEPT DEFINITION PHASE

| No. | Requirement | Selected System Solutions |
|---|---|---|
| 1 | Use of easy techniques in hydroponics systems. | Using the NFT technique in the hydroponics system |
| 2 | Utilization of quality seeds for hydroponics plants. | Using certified seeds |
| 3 | Farmers can interact with members of their group anytime and anywhere | Designing an integrated CPSS with hydroponics system Using Telegram Messenger's social media platform for smartphones |
| 4 | Farmers can monitor the light conditions in the hydroponics system, whenever and wherever | Utilizing the API of Telegram Messenger Designing integrated CPSS with hydroponics system using Raspberry Pi 3 which is connected with Light Dependent Resistor (LDR) module |
| 5 | Farmers can monitor the room temperature in the hydroponics system, whenever and wherever | Utilizing the API of Telegram Messenger Designing an integrated CPSS with hydroponics system using Raspberry Pi 3 that is connected with DHT11 sensor module |
| 6 | Farmers can monitor the humidity of the room in the hydroponic system, whenever and wherever | Utilizing the API of Telegram Messenger Designing an integrated CPSS with hydroponics system using Raspberry Pi 3 that is connected with DHT11 sensor module |
| 7 | Farmers can monitor the pH conditions of nutrients in the hydroponics system, whenever and wherever | Utilizing the API of Telegram Messenger Designing an integrated CPSS with a hydroponics system using Raspberry Pi 3 that is connected with a pH sensor module |
| 8 | Farmers can monitor the condition of EC nutrition in the hydroponics system, whenever and wherever | Utilizing the API of Telegram Messenger Designing an integrated CPSS with a hydroponics system using Raspberry Pi 3 that is connected to the EC sensor module |
| 9 | Farmers can monitor the temperature of nutrients in the hydroponics system, whenever and wherever | Utilizing the API of Telegram Messenger Designing an integrated CPSS with a hydroponics system using Raspberry Pi 3 that is connected with the DS18B20 sensor |

In the PIECES matrix analysis in table 5, visible system proposed based on the analysis of conditions that existed before design. Here, the proposed technology is CPSS that allows farmers to work interactively, either with other farmers or with their hydroponic systems.

TABLE V. PIECES MATRIX ANALYSIS IN CONCEPT DEFINITION PHASE

| | Current system | System proposed |
|---|---|---|
| **Performance** | Hydroponic system monitoring is still done manually, Other farmers in one group still have to wait for monitoring results | Hydroponic system monitoring is done remotely and real time, Farmers in one group can directly know the results of monitoring |
| **Information** | Information is available only in manual tools, Recording information is done manually | Information is available directly via Telegram Messenger, Information can be known directly by other farmers |
| **Economic** | Farmers need cost to come to the hydroponic garden site to monitor the condition of their hydroponics system, Utilization of technology has not been done for monitoring hydroponic system | Monitoring can be done through internet, Implement CPSS technology |
| **Control** | Control of the hydroponics system is difficult to do, Arrangements for the addition of nutrients are still done manually | Control of the hydroponics system is easy to do, Nutritional parameters can be read in the realtime |
| **Efficiency** | Farmers need to come to the hydroponic garden to monitor, Submission of information to other peasant members takes time | Monitoring can be done anytime and anywhere as long as there is internet connection, Submission of information via Telegram Messenger |
| **Service** | The monitoring information service is still manual, The interaction between hydroponic systems and farmers is inflexible | The monitoring information service is done through Telegram Messenger, The interaction between hydroponic systems and farmers is flexible |

B. Engineering Development

The next stage or the second stage is the engineering process to design and build prototype system based on the concept of system that has been made. The system prototype is built as a proof of concept from the design of the system that has been created. With the prototype, it is possible to test the system to relevant stakeholders. This stage consists of three phases, namely engineering design, advanced development and integration and evaluation.

B.1. Advanced Development

The initial phase in the engineering development stage is the advanced development phase that focuses on system components that are considered critical or are important in the system. In each component it is necessary to analyze and design the technology used. The final outcome or main output of the Advanced Development phase is the functional requirements of the system components. CPSS here plays a role in integrating the physical system consisting of sensors connected to a single board computer, and social systems that utilize the Telegram Messenger platform.

B.2. Engineering Design

The next phase is the engineering design phase. In this phase, thedetailed design of the system componentsaredone to meet system requirements. The design is then implemented in prototype form in the next phase. The end result or main output of the engineering design phase is the system architecture, the functional design of the system components, and the interaction of the system components.

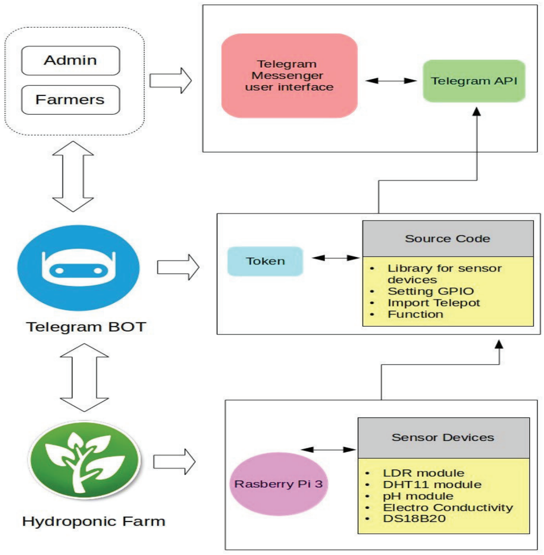


Fig 5. System Architecture of hydroponic smart farming

In the system architecture seen there are three main components, namely hydroponic farm, Telegram BOT, and Telegram Messenger. The hydroponic farm consists of sensors such as the LDR module, the DHT11 module, the pH module, the Electro Conductivity module, and the DS18B20 module. As for Telegram BOT contains source code in which there is token, library for sensors, GPIO settings, import Telepot as main module BOT, and also defined functions. Meanwhile, the Telegram Messenger consists of Telegram user interface and Telegram API that serves as support applications and services made outside Telegram.

With the monitoring system through this CPSS, it allows hydroponic farmers wherever and whenever to know the condition of plants in real-time. Telegram-Bot made python-based using the Telegram Messenger platform. Monitoring conducted in this research includes monitoring of light, room temperature, humidity, pH, EC and the temperature of solution or nutrients.

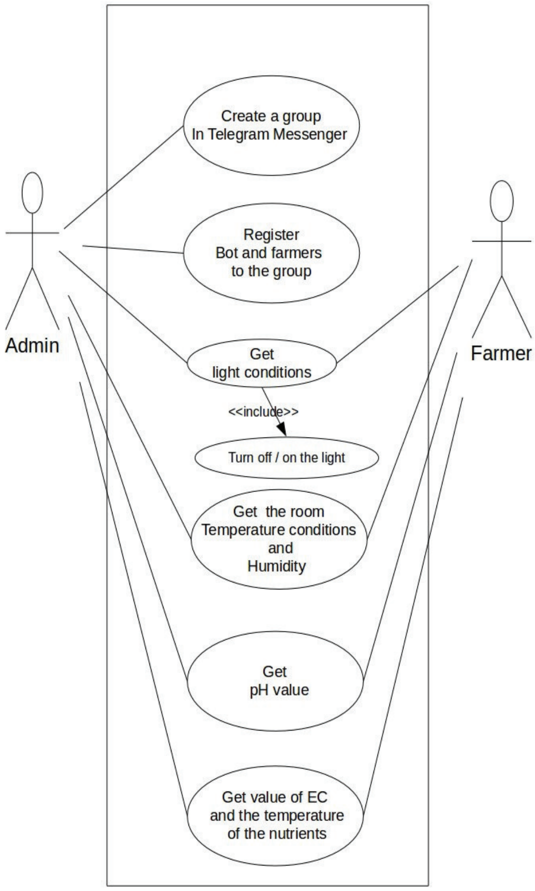


Fig 4. Use case diagram

The design begins by connecting Raspberry Pi to the sensors used in accordance with the prototype design. It is then proceededbymaking Bot in Telegram Messenger by utilizing Bot maker facility, called BotFather. After Bot making, BotFather will provide Token which is a unique combination of numbers and letters. The next step is to copy the Token to the script program that has been created and stored in Raspberry Pi. The Token function is for communication between Messenger Telegram and Bot that has been created. Python-based program codes are capable of reading input from already-installed sensors. This program code is at the heart of the Bot created.

The diagram in figure 4 is a use case diagram that illustrates the actors involved in the hydroponic plant monitoring process. Actors involved here are admins and farmers. Admin has an authority to create groups and include farmers and BOT into groups. In addition, the admin also has the authority in hydroponic plant monitoring,while farmers can only monitor hydroponic plants only.

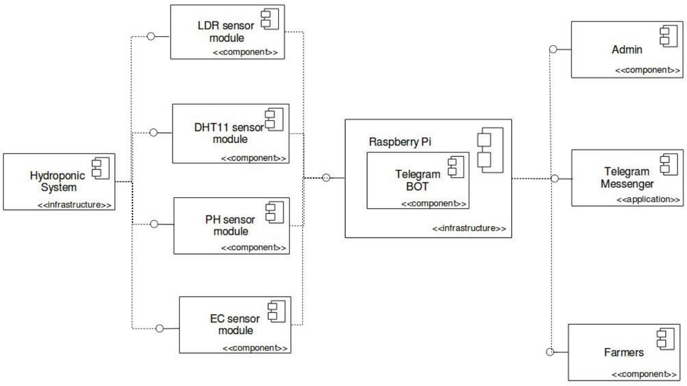


Fig 5. UML Component diagram

In figure 5 is a component diagram thatdescribessome of the components involved in this design, like admin, farmers, telegram messenger, Raspberry Pi, telegram bot, LDR sensor module, DHT11, pH, and EC, and hydroponic system itself.

B.3. Integration and Evaluation

The sixth phase is the integration and evaluation phase. In this phase, the implementation of system components in the form of prototypes can meet the operational needs that have been defined. This phase consists of five steps, activities, inputs, outputs, and techniques used. After doing the design, performed functional test using white box testing method. White box testing is a test based on checking for design details, using the control structure of the procedural program design to divide the test into several test cases.

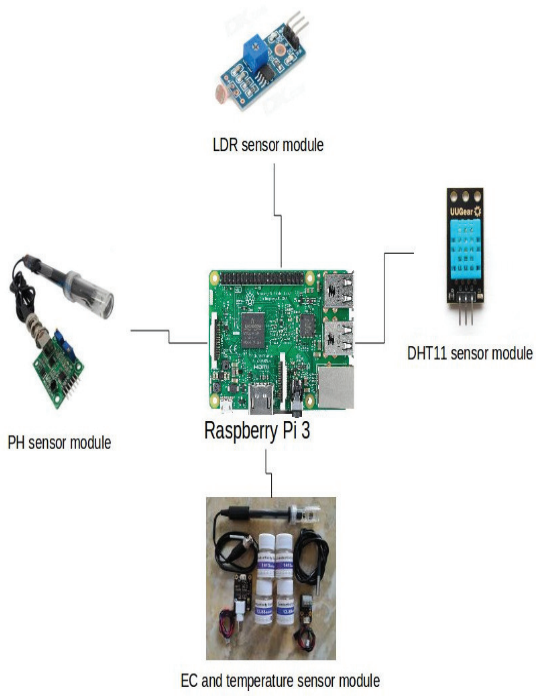


Fig 6. System Prototype

The picture in figure 6 shows that system prototype consists of Raspberry Pi 3 and connected sensors such as LDR, DHT11, pH, EC, and temperature sensor modules for nutrition.

TABLE VI. RESULT OF WHITE BOX TESTING

| No. | Test Case in Source Code | Input / Command | Output | Status |
|---|---|---|---|---|
| 1 | Displaying dark or light environmental conditions | /sunlight | Sunlight condition is “bright” or “dark” | Correct / Success |
| 2 | Reading temperature and humidity data via pin 22 | /dht11 | Time valid input: Temperature: Humidity: | Correct / Success |
| 3 | Provides an automatic command to view the status of lights that have been turned on or off automatically | /light_automatic | Sunlight condition is bright and Lamp turned off Sunlight condition is dark and Lamp turned on | Correct / Success |
| 4 | Gives command to turn on the light | /light_on | Lamp turned on | Correct / Success |
| 5 | Gives command to turn off the light | /light_off | Lamp turned off | Correct / Success |

The final output or outcome of the integration and evaluation phase is the system prototype and test result as described in figure 6 and table 6. The test is done by white box testing method. White box testing is a test based on checking for design details, using the control structure of the procedural program design to divide the test into several test cases.

C. Post Development

Post development is the last stage in system engineering. At this stage the system is tested to ensure that the system meets the needs and objectives of system development based on the point of view of all users involved in the system. The end result or main output of operation and support phase is user acceptance test and system usability scale. User acceptance test was conducted on Hydroponics farmers at Balai Besar Penyuluh Pertanian in Lembang, Bandung. The System Usability Scale (SUS) methodis used for usability test . This method examines three main aspects according to ISO 9241-11, like effectiveness, efficiency, and user satisfaction.

## IV. CONCLUSION

With the monitoring system through this CPSS, it allows hydroponic farmers wherever and whenever to know the condition of plants in real-time. Telegram-Bot made python-based using the Telegram Messenger platform. Monitoring conducted in this research includes monitoring of light, room temperature, humidity, pH, EC and the temperature of solution or nutrients.

## V. LIMITATION AND FUTURE RESEARCH

In this paper, the installed sensors have two of about four sensors planned. The attached sensor is the LDR sensor module and the DHT11 sensor module,while the sensors not installed yet are pH sensor module and EC sensor module. However, this study has several limitations, including the need for an internet connection to monitor hydroponic crops, and the need for additional output from relays such as humidifier to increase moisture. Some things that can be done for future research is the addition of camera modules to get the visual appearance of the plant.

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