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Auto GMS: An Automated Greenhouse Monitoring System of Abiotic Factors for Leafy Vegetables Production

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Abstract

"Auto GMS: An Automated Greenhouse Monitoring System of Abiotic Factors for Leafy Vegetables Production" was developed to give ease in terms of monitoring or data logging different natural parameters in the greenhouse that affect the crop growth and most importantly, the system was intelligently engineered to automate the traditional watering system in order to prevent the under irrigation and over irrigation. The system is capable of measuring and data logging the soil moisture content, relative humidity, temperature and the light intensity of the greenhouse.

The system is equipped with highly sensitive sensors-, relative humidity and temperature sensor, light intensity sensor and the soil moisture sensor to obtain the parameter values and send the notification to the registered number of the greenhouse administrator via SMS, save the data on the SD card in.CSV format as back up, display the findings through LCD screen and send the data and the findings over the cloud service, Thingspeaks, for graphical presentation via WiFi module. Automatic irrigation is highly dependent on the soil moisture threshold and water flow is controlled via solenoid valve and relay.

This study employed Developmental, Descriptive Research and Prototyping Model Development.

The developed system was perceived by the end users to be very much important in terms of water conservation, energy conservation, plants growth, manpower and load conservation. The system was very much acceptable in terms of usability, functionality, reliability and connectivity and in terms of implementation. Thus, the respondents were convinced that the system can be implemented.

Keywords: auto gms, greenhouse, abiotic factors, leafy vegetable, monitoring

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1. Introduction

Agriculture has been one of the primary occupations of man since early civilization and even today manual interventions in farming are inevitable. Greenhouses form an important part of the agriculture and horticulture sectors in the country as they can be used to grow plants under controlled climatic conditions for optimum produce. As the application of greenhouse becomes more and more extensive, traditional greenhouse management is far from meeting the requirements [1]. A Greenhouse is a building where plants are grown. Greenhouses are often used for growing flowers, vegetables, fruits, and tobacco plant. Basic factors affecting plant growth are sunlight, water content in soil, temperature, etc. These physical factors are hard to control manually inside a greenhouse and a need for automated design arises. Automatically controlling all the factors that affect plant growth is also a difficult task as it is expensive and some physical factors are inter-related, for example, temperature and humidity are related in a way when temperature raises humidity reduces therefore controlling both together is difficult. [2] Monitoring the basic abiotic factors such as the light intensity, soil moisture, relative humidity and temperature and controlling the irrigation manually is the problem that drove the researcher to propose the innovative project entitled "Auto GMS: An Automated Greenhouse Monitoring System of Abiotic Factors for Leafy Vegetables Production".

All plants and vegetation require certain conditions for their proper growth. Therefore it is necessary to bring the environmental conditions under control in order to make those conditions as close to the ideal as possible. To create an optimal environment the main climatic and environmental parameters such as temperature, humidity, light intensity, ground water etc need to be controlled to create optimal environment [3]. As a plant grows, it undergoes different environmental changes, including formation of tissues and organs such as leaves, stem, flowers and roots. The main source of nutrients used to aid this development process is often found in its surrounding. In other words, the development of the plants is solely dependent on the conditions of the environment in which plants are grown (Vu, 2011). In modern greenhouses, several measurement points are required to trace down the local climate parameters in different parts of the big greenhouse to make the greenhouse automation system work properly. Cabling would make the measurement system expensive and vulnerable. Moreover, the cabled measurement points are difficult to relocate once they are installed [4]. The project will give ease in terms of monitoring the environmental factors for the system will be equipped with highly sensitive sensors to obtain the parameter values and send the notification to the greenhouse-in-charge via Short Messaging Service (SMS), store it in a storage card as back-up, display the findings in the LCD display and send the data and the findings over the cloud service in the graphical format using graphs and gauges for better visualization of data logs of greenhouse natural values. Further, the system will also automatically water the plants once the sensor senses that the soil needs watering.

By using the cost-effective system, the process of managing and monitoring the greenhouse will be easier as the real time parameters will be displayed and will be sent to the LCD screen embedded on the system, to user's GSM phone, and to the cloud service using the Internet of Things (IoT) feature. The automated irrigation will prevent under or over irrigation for it is dependent on the normal parameter threshold values depending on the crop to be grown in the greenhouse to where the system will be deployed. Technology makes things easier and the process less complicated. Accurate and precise data are, likewise, attainable when right technology is applied.

Auto GMS: An Automated Greenhouse Monitoring System of Abiotic Factors for Leafy Vegetables Production is capable of measuring and monitoring the soil moisture content, relative humidity, light sensor and temperature and automatically water the plants whenever needed. The system generally aims for smart data logging and automatic irrigation to help prevent the overwatering and under-watering of the plants that may cause soil corrosion. The system also notifies the farmers or the greenhouse administrator through SMS regarding the parameter status. The system is equipped with memory card wherein the system automatically saves the data logs for back-up which can be shown in tabular form and can be opened through MS Excel. Further, the farmers and the greenhouse administrator could view the parameter status and findings over the web in a graphical view for better analysis.

The system will also be helpful in research studies most especially in comparing different treatments or setups for the sensors are grouped per set and could give data individually.

There will be three different sensors, light intensity sensor, humidity and temperature sensor, and soil moisture sensor used in the system to measure the parameters. All the sensors, the memory card module, Wi-Fi module and LCD screen display are integrated on the Arduino Mega 2560 which will serve as the central microcontroller of the system seconded by another Arduino UNO board to where the GSM module and relay is connected. The system saves the data logs and parameter findings in a memory card in.CSV format that can be opened in MS Excel in tabular form, send it to the registered number in the system through SMS notification and to the web portal for online access of graphical presentations via ThingSpeak.

Solenoid valve which is controlled via relay is responsible for blocking and allowing the water flow to the sprinkler for the automated irrigation.

The introduction of "AUTOMATED GREENHOUSE MONITORING SYSTEM" can bring a green revolution in agriculture. Introducing this system can help in increasing the cultivation in a controlled environment. Greenhouse environment, used to grow plants under controlled climatic conditions for efficient production, forms an important part of the agriculture and horticulture sectors [5].

2. Objectives of the Study

The main objective of the study is to develop an Auto GMS: An Automated Greenhouse Monitoring System of Abiotic Factors for Leafy Vegetables Production.

Specifically, the study aimed to answer the following sub problems: 1.) What is the level of importance as perceived by the end users on the developed system? 2.) What is the respondents' level of acceptance on the developed system in terms of: usability; functionality reliability; and connectivity, 3.) What is the respondents' level of conviction in terms of the implementation of the Auto GMS: An Automated Greenhouse Monitoring System of Abiotic Factors for Leafy Vegetables Production? And 4.) What are the suggested improvements made by the respondents in the developed project?

3. Materials and Methods

This chapter presents the research method used, the respondents of the study, instrumentation, data gathering techniques and procedures, the statistical treatment of data, software development methodology, and the technologies proposed to be used for development.

3.1. Method of research used

This study employed Developmental, Descriptive Research and Prototyping Model Development. It is a problem-oriented and interdisciplinary research methodology. Developmental research, as opposed to simple instructional development, has been defined as the systematic study of designing, developing, and evaluating instructional programs, processes, and products that must meet criteria of internal consistency and

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effectiveness (Richey, 1994). This method is used for development of prototypical software, starting from design, development and evaluation of the software. The descriptive research method is used, as it describes the nature of the situation as it exists at the time of the study (Sevilla, 1992). According to Creswell (1994), it can help in order to show the different facts that are connected with the nature of the status of the current problem or condition as it happens at the time of the study. This is the reason why it is considered as one of the most applied methodology in most studies. It is concerned with conditions of relations or relationships that exist, practices that prevail, beliefs, processes that are going on, effects that are being felt, or trends that are developing. The process of descriptive research goes beyond the mere gathering and tabulation of data. It involves an element or interpretation of meaning or significance of what is described. Thus, description is often combined with comparison and contrast involving measurements, classifications, interpretation, and evaluation.

Through thorough study of the different models of software development, the researcher realized that the best model to use is the Prototyping Model. The Prototyping Model is the System's Development Method (SDM) that suggests and allows the researcher to go backward to the previous phases if changes, revisions and improvements are implemented.

Prototyping is a system development methodology in which a prototype is built, tested, and then reworked as necessary until an acceptable prototype is finally achieved from which the complete system or product can now be developed. In addition, this model is an iterative, trial-and-error process that takes place between the system developers and the end users. The researcher chose to use this model because of several reasons such as, it may provide the proof of concept necessary to attract funding, early visibility of the prototype gives users an idea of what the final system will look like, encourages active participation among users and producers, enables a higher output for user, cost effective (development costs reduced), increases system development speed, assists to identify any problems with the efficacy of earlier design, requirements analysis and coding activities, helps to refine the potential risks associated with the delivery of the system being developed.

Describe the research method used in the study. Discuss comprehensively the sampling technique used in selecting the participants if the study will not use the total population. It is very important to explain the generation and validation of instrument. If the questionnaire or any data gathering instrument used is not standardized, explain further the reliability tests or validation procedures have done in the instrument. The

Data Collection Procedure must also be well defined. The statistical tools used in the study must be well explained in the Data Analysis part. Ethical Considerations (if applicable) is also considered important in informing the participants regarding the purpose of the administration of the instrument or the main purpose of the study. Included here is the proper way of putting sub-headings and its levels.

3.2. Population and sample size

The main respondents of this study were the students, instructors and farmers of MinSCAT Main Campus and Alcate, Victoria, Oriental Mindoro. The respondents were given questionnaires after manipulating and navigating the developed mobile apps and the assembled project. Furthermore, to obtain accuracy of their responses, the project was presented to the respondents before getting their responses to the questionnaire.

3.3. Sampling technique

This study used Slovin's formula in computing for the size of the sample:

$$n = \frac{N}{1 + Ne^2}$$

Where: n = the size of the sample

N = the size of the population

e = the margin of error (3%)

3.4. Research instrument

The researcher prepared a questionnaire to determine the answer of the respondents towards the developed project over the concept being deliberated. Also, the software evaluation instrument used for this project is the standard criteria used in evaluating this kind of project. It determined the usability of the project in terms of functionality, usability, reliability and connectivity. These were also the characteristics and/or subcharacteristics provided by the ISO/IEC 9126.

The Likert scale was used by the researcher in the conduct of the study for the respondent's assessment. It is a psychometric response scale often used in questionnaires and is the most widely used scale in survey research. When responding a Likert questionnaire item, respondents specify their level of agreement to a statement. The researcher used ranks from one to five: five being the highest and one being the lowest rank. Below is the Likert scale that the proponent used in the questionnaire:

To determine the level of importance, level of acceptance and conviction in the implementation of the respondents on the developed project, the scale below was used:

Table 1: Rating Scale Criteria.

Rating	Interpretation	
4.51 – 5.00	Highly Important	Highly Acceptable
3.51 – 4.50	Important	Acceptable
2.51 – 3.50	Partly Important	Partly Acceptable
1.51 – 2.50	Not highly Important	Not highly Acceptable
1.00 – 1.50	Not Important	Not Acceptable

3.5. Data-gathering procedure

Research is one of the most useful tools in gathering necessary information in accomplishing anything.

Information gathering was used to discover business information details to define the information structure. This helped the researcher establish the priorities of the information needs and further led to opportunities that highlight key issues which may have crossed functional boundaries or may have touched on policies or the organization itself. Information gathering is a complicated task especially in a large and complex system. Therefore, this must be organized to ensure that nothing is overlooked and all system details are eventually captured.

Since information gathering is the core of system analysis, the researcher collected the needed information for the operation of the system and for its users, specifically, the information of physical environment of the greenhouse where the experiments was done, and the factors or natural parameters affecting the growth of plants. The researcher also considered conducting laboratory tests and experiments in order to get the default threshold values of the (1) relative humidity, (2) light intensity, (3) soil moisture and (4) temperature. Interviews with the greenhouse administrator and the Agriculture faculty and surveys were also conducted. Joining and participating in several online fora with regards to system programming and automations done by the researcher including watching video tutorials and reading and analyzing related systems and journals. The researcher also interviewed the end users for their recommendations and comments on the system.

In addition, the researchers reviewed existing reports, forms and procedure description, observed and documented the business processes and conducted several meetings to brainstorm.

The researcher used the indirect and direct method of data gathering with open-ended questions as well as close ended questions and gathered data and information from the prospective users of the system which were the greenhouse administrator, garden enthusiasts and the farmers.

Canvassing for the availability of the hardware resources was also done by the researcher such as visiting online shops for the procurement of the hardware.

3.6. Statistical treatment of data

All the data were evaluated with the use of SPSS software. Thus, in order to come up with the results and findings of the study, frequency percentage and weighted mean was calculated. The following were the formulas used:

1. Percentage – was calculated to determine the magnitude of the responses to the questionnaire.

2. Weighted Mean – is similar to an arithmetic mean (the most common type of average), where instead of each of the data points contributing equally to the final average, some data points contribute more than others.

$$\overline{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

Ranking was also used as a statistical tool with 1 as the highest value rank and 5 as the lowest value rank. This was used for the evaluation of problems of the survey questionnaire.

3.7. System architecture

Auto GMS: An Automated Greenhouse Monitoring System of Abiotic Factors for Leafy Vegetables Production automatically monitors the different abiotic factors in the greenhouse such as the relative humidity, light intensity, soil moisture and the temperature. The system is equipped with automatic watering system that responds to the needs of the soil. The pump automatically powers on and off if the soil moisture sensor finds out the irregularities of the default parameter threshold.

For the system's irrigation, the flow of water to the plots is controlled via solenoid valve. The pump turns on, only if one or both of the solenoid valve are turned on. On the other hand, the solenoid valve automatically opens only if the soil moisture sense that the soil moisture content intended for the crop planted falls down to 35% or less and the irrigation stops if the soil moisture reaches the 60% soil moisture content or greater than that. Each plot has its own set of sensors consisting of soil moisture sensor, light intensity sensor and the humidity and temperature sensor. Further, each plot also has its own sprinkler wherein water flow is regulated via solenoid valve.

The system is also capable of showing the findings via LCD display, SMS notification, MicroSD saved in CSV format and over the web, thus permitting the ease of access to greenhouse abiotic factors.

The system is integrated with the ThingSpeak Cloud Service for the farmer to view the graphical representation of the findings.

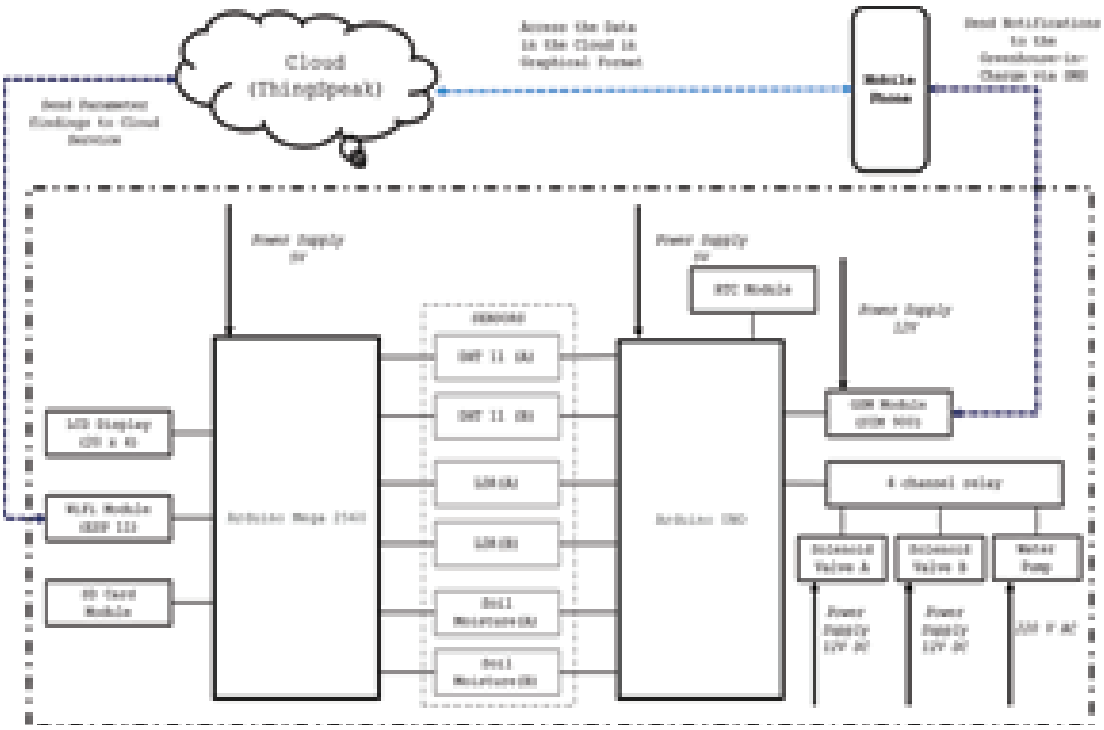

Figure 1: Auto GMS: An Automated Greenhouse Monitoring System of Abiotic Factors for Leafy Vegetables Production Architecture.

Shown in Figure 1 is the overview of the system and the system process. The figure shows that the system sends data to the cloud service (IoT platform) via the ESP 11 Wi-Fi Module which can be accessed via mobile phone. Moreover, the system is also capable of sending data to the mobile phone via GSM module.

Auto GMS: An Automated Greenhouse Monitoring System of Abiotic Factors for Leafy Vegetables Production composed of several hardware, the Arduino Mega 2560

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and Arduino Uno serve as the central microcontroller where all the sensors and modules are attached.

System also has data logging module which can be inserted with MicroSD in order to store the findings with regards to the greenhouse environmental factors. There is a data module or GSM module in order for the system to communicate with the user through SMS notification. On the other hand, for the display of the parameter findings, LCD screen is installed.

3.8. Software design and development tool

Systems design is the process of defining the architecture, components, modules, interfaces, and data for a system to satisfy specified requirements. It is similar to a set of blueprints used to build a house. It is also called physical design. Thus, while systems analysis emphasized the business problem, systems design focuses on the technical or implementation concern of the system. This phase is where the technical blueprint of the system is created. The primary objective of the design phase is to design the solution system based on the requirements defined and decisions made during the analysis phase.

In the design phase, the researcher used the information gathered during analysis and then converted them into models that represented the solution to the proposed system.

Meanwhile, coding is the process where the physical design specifications developed by the analysis team are converted into computer codes by the programming team. It can be an involved and intensive activity that depends on the size and complexity of the system. No matter what development methodology is used, once the coding starts, the testing process can begin and proceed in parallel. With each program module produced, it can be tested individually, then as part of a larger program, and then as part of a larger system.

The researcher planned on designing a system that was pleasant and easy to use and that used codes that made the application a whole lot easier to operate and access. Specifically, the researcher also considered the hardware resources because codes follow its connection where being integrated.

In addition, the researcher provided an appropriate design and hardware housing for the device. Also, the researcher used an accurate input-process-output of the system code and syntax. The system enhanced, structure and design with reference to the schematic diagrams and with the use of the Arduino programming software. For the web graphical representation of data, ThingSpeak was used and proper designing was done.

4. Results and Discussion

This chapter presents the presentation, analysis and interpretation of data according to the statement of the problem, as well as the description, features and structure of the system.

The table below shows the results of evaluation in terms of the level of importance perceived by the end users on the developed system.

Table 2: Interpretation of the Computed Weighted Mean of the Level of Importance perceived by the end users on the Developed System.

Indicator/ Statement	Mean	Rank	Verbal Interpretation
1. The prototype conserve the use of water. (Water Conservation)	4.75	4	Highly Important
2. The prototype conserve the use of electricity. (Energy Conservation)	4.62	5	Highly Important
3. The prototype have a big effect in the growth of the plants. (Plants Growth)	4.97	1	Highly Important
4. The prototype lessen the work or task of farmer in monitoring the greenhouse. (Manpower)	4.95	2	Highly Important
5. The prototype conserve the use of SMS load in sending SMS. (Load Conservation)	4.92	3	Highly Important
Overall Mean	4.84		Highly Important

Table 2 illustrates the level of importance perceived by the end users on the developed system in terms of water conservation, energy conservation, plants growth, manpower and load conservation.

When the respondents were asked to assess the level of importance of the developed system, indicator 1 “Water Conservation” got a mean of 4.75 with a verbal interpretation of highly important that implies that the prototype conserves the use of water. Indicator 2 “Energy Conservation” got a mean of 4.62 with a verbal interpretation of highly important which means that prototype conserves the use of electricity. Indicator 3 “Plants Growth” got a mean of 4.97 with a verbal interpretation of highly important which implies that the prototype have the big factor in the growth of the plants. Indicator 4 “Manpower” got a mean of 4.95 with a verbal interpretation of highly important which means the prototype lessens the work or task of a farmer in monitoring the greenhouse. Indicator 5 “Load Conservation” got a mean of 4.92 with a verbal interpretation of highly important which means the prototype conserves the use of SMS load in sending SMS.

The assessment of the respondents in the level of importance on the developed system in terms of water conservation, energy conservation, plants growth, manpower and load conservation got an overall mean of **4.84** with a verbal interpretation of **highly important**. This only shows that the prototype is highly important to the greenhouse and to the end users.

Tables 3, 4, 5 and 6 shown in the next pages show the results of evaluation in terms of the respondent’s level of acceptance on the developed system in the following criteria: Usability, Functionality, Reliability and Connectivity, respectively.

Table 3: Interpretation of the Computed Weighted Mean of the Respondent’s Level of Acceptance on the Developed System in Terms of Usability.

Usability	Mean	Rank	Verbal Interpretation
1. The system meet the needs of the target-users.	4.88	3	Highly Acceptable
2. The system uses appropriate hardware components for the automation of the irrigation.	4.85	5	Highly Acceptable
3. The system helps the farmer in monitoring the greenhouse.	4.97	1	Highly Acceptable
4. The system is easy to install and maintain.	4.87	4	Highly Acceptable
5. The system is user friendly and easy to understand by the end users.	4.90	2	Highly Acceptable
Overall Mean	4.89		Highly Acceptable

Table 3 shows the assessment of the respondent’s level of acceptance on the developed system in terms of usability.

When the respondents were asked to assess their level of acceptance on the developed system in terms of usability, indicator 1 “The system meet the needs of the target-users” got a mean of 4.88 with a verbal interpretation of highly acceptable. Indicator 2 “The system uses appropriate hardware components for the automation of the irrigation” got a mean of 4.85 with a verbal interpretation of highly acceptable. Indicator 3 “The system helps the farmer in monitoring the greenhouse” got a mean of 4.97 with a verbal interpretation of highly acceptable. Indicator 4 “The system is easy to install and maintain” got a mean of 4.87 with a verbal interpretation of highly acceptable. Indicator 5 “The system is user friendly and easy to understand by the end users” got a mean of 4.90 with a verbal interpretation of highly acceptable.

The assessment of the respondent’s level of acceptance on the developed system in terms of usability got an overall mean of 4.89 with a verbal interpretation of highly acceptable. This only indicates that the respondents agreed that the developed system is usable.

Table 4: Interpretation of the Computed Weighted Mean of the Respondent’s Level of Acceptance on the Developed System in Terms of Functionality.

Functionality	Mean	Rank	Verbal Interpretation
1. The system is well-structured according to the needs of the users.	4.85	5	Highly Acceptable
2. The syss running according to its uses and functions.	4.92	3	Highly Acceptable
3. The system can be easily operated by a given user in a given environment.	4.93	2	Highly Acceptable
4. The system are secured and protected in terms of data transmission.	4.97	1	Highly Acceptable
5. The system is capable of generating measurements/data through SMS and Web based.	4.88	4	Highly Acceptable
Overall Mean	4.91		Highly Acceptable

Table 4 shows the assessment of the respondent’s level of acceptance on the developed system in terms of functionality.

When the respondents were asked to assess their level of acceptance on the developed system in terms of functionality, indicator 1 “The system is well- structured according to the needs of the users” got a mean of 4.85 with a verbal interpretation of highly acceptable. Indicator 2 “The system is running according to its uses and functions” got a mean of 4.92 with a verbal interpretation of highly acceptable. Indicator 3 “The system can be easily operated by a given user in a given environment” got a mean of 4.93 with a verbal interpretation of highly acceptable. Indicator 4 “The system are secured and protected in terms of data transmission” got a mean of 4.97 with a verbal interpretation of highly acceptable. Indicator 5 “The system is capable of generating measurements/data through SMS and Web based” got a mean of 4.88 with a verbal interpretation of highly acceptable.

The assessment of the respondent’s level of acceptance on the developed system in terms of functionality got an overall mean of 4.91 with a verbal interpretation of highly acceptable. This only indicates that the respondents agreed that the developed system is functional. This shows that the system is well-structured according to the tasks needed to be executed.

Table 5 shows the assessment of the respondent’s level of acceptance on the developed system in terms of reliability. When the respondents were asked to assess their level of acceptance on the developed system in terms of functionality, indicator 1 “The system achieves its expected output” got a mean of 4.88 with a verbal interpretation of highly acceptable. Indicator 2 “The system is free from errors” got a mean of 4.72 with a verbal interpretation of highly acceptable. Indicator 3 “The system gives/sends relevant information to the user” got a mean of 4.90 with a verbal interpretation of highly acceptable. Indicator 4 “The system facilitates recovery procedures in the event of system failure” got a mean of 4.93 with a verbal interpretation of highly acceptable. Indicator 5 “The system generates more effective results of data from the prototype” got a mean of 4.92 with a verbal interpretation of highly acceptable.

The assessment of the respondent’s level of acceptance on the developed system in terms of reliability got an overall mean of 4.87 with a verbal interpretation of highly acceptable. This only indicates that the respondents agreed that the developed system is reliable. Table 4 shows the result of the evaluation in terms of reliability which implies that the system achieved its expected output. This could be attributed to the ability of the system to provide the expected output that the user expects from the system such as the measurement of parameter status including light intensity, humidity and temperature and soil moisture content. The system is able to display parameter findings in an LCD screen, save it in an SD card for back up, send SMS of greenhouse environmental values and display results in graphical format that is accessible via web. Further, it has also met the objectives of automatic irrigation with water flow being controlled via solenoid valve.

Table 5: Interpretation of the Computed Weighted Mean of the Respondent's Level of Acceptance on the Developed System in Terms of Reliability.

Reliability	Mean	Rank	Verbal Interpretation
1. The system achieves its expected output.	4.88	4	Highly Acceptable
2. The system is free from errors.	4.72	5	Highly Acceptable
3. The system gives/sends relevant information to the user.	4.90	3	Highly Acceptable
4. The system facilitates recovery procedures in the event of system failure.	4.93	1	Highly Acceptable
5. The system generate more effective results of data from the prototype.	4.92	2	Highly Acceptable
Overall Mean	4.87		Highly Acceptable

Table 6 shows the assessment of the respondent's level of acceptance on the developed system in terms of connectivity.

When the respondents were asked to assess their level of acceptance on the developed system in terms of functionality, indicator 1 "The system is capable to handle multiple connections to the hardware" got a mean of 4.95 with a verbal interpretation of highly acceptable. Indicator 2 "The system is accessible using different devices" got a mean of 4.88 with a verbal interpretation of highly acceptable. Indicator 3 "The system can send measurements to the registered numbers" got a mean of 4.92 with a verbal interpretation of highly acceptable. Indicator 4 "The data acquired by the system can be sent online via ThingSpeak, through Wi-Fi module provided that there is Wi-Fi point with Internet connection" got a mean of 4.98 with a verbal interpretation of highly acceptable. Indicator 5 "The system only notifies the end users based from the default value of the standard measurements or parameters" got a mean of 4.93 with a verbal interpretation of highly acceptable.

The assessment of the respondent's level of acceptance on the developed system in terms of connectivity got an overall mean of 4.93 with a verbal interpretation of highly acceptable. Table 6 indicates the result of the evaluation conducted to test the system in terms of connectivity. The results imply that the system is capable of handling multiple connections of the hardware. The system is connected and integrated to each

Table 6: Interpretation of the Computed Weighted Mean of the Respondent's Level of Acceptance on the Developed System in Terms of Connectivity.

Connectivity	Mean	Rank	Verbal Interpretation
1. The system is capable to handle multiple connections to the hardware.	4.95	2	Highly Acceptable
2. The system is accessible using different devices.	4.88	5	Highly Acceptable
3. The system can send measurements to the registered numbers.	4.92	4	Highly Acceptable
4. The data acquired by the system can be sent online via ThingSpeak, through Wi-Fi module provided that there is Wi-Fi point with internet connection.	4.98	1	Highly Acceptable
5. The system only notifies the end users based from the default value of the standard measurements or parameters.	4.93	3	Highly Acceptable
Overall Mean	4.93		Highly Acceptable

other via Arduino Mega 2560 and Arduino Uno. Sensors, LCD display, Wi-Fi module and SD card module is connected to Arduino Mega 2560. The GSM module, on the other hand, handles connections of GSM module and 4-channel relay. The relay is used to control the pump and the solenoid valve that makes automatic irrigation possible.

The table below shows the respondents' level of conviction in terms of the implementation of the Auto GMS: An Automated Greenhouse Monitoring System of Abiotic Factors for Leafy Vegetables Production.

Table 7 shows the assessment of the respondent's level of acceptance on the developed system.

When the respondents were asked to assess their level of acceptance on the developed system for indicator 1 "The system can monitor light measurements in the greenhouse" got a mean of 4.95 with a verbal interpretation of highly acceptable. Indicator 2 "The system can monitor the temperature measurements in the greenhouse" got a mean of 4.88 with a verbal interpretation of highly acceptable. Indicator 3 "The system can monitor the humidity measurements in the greenhouse" got a mean of 4.93 with a verbal interpretation of highly acceptable. Indicator 4 "The system can control and

Table 7: Interpretation of the Computed Weighted Mean of the Respondent's Level of Conviction in terms of implementation of the Developed System.

Statement	Mean	Rank	Verbal Interpretation
1. The system can monitor light measurements in the greenhouse.	4.95	3	Highly Acceptable
2. The system can monitor the temperature measurements in the greenhouse.	4.88	5	Highly Acceptable
3. The system can monitor the humidity measurements in the greenhouse.	4.93	4	Highly Acceptable
4. The system can control and monitor the watering of the plants.	4.97	2	Highly Acceptable
5. The system can water the plants automatically.	5.00	1	Highly Acceptable
Overall Mean	4.95		Highly Acceptable

monitor the watering of the plants" got a mean of 4.97 with a verbal interpretation of highly acceptable. Indicator 5 "The system can water the plants automatically" got a mean of 5.0 with a verbal interpretation of highly acceptable. The assessment of the respondent's level of acceptance on the developed system got an overall mean of **4.93** with a verbal interpretation of **highly acceptable**. This implies that the system can monitor the light, temperature, humidity and soil moisture in order to automatic water the plants.

Table 8: Summary of Suggestions for Improvements in Auto GMS: An Automated Greenhouse Monitoring System of Abiotic Factors for Leafy Vegetables Production.

Suggested Recommendation	Votes	Rank
Integrate the system to renewable energy source such as solar panels or solar batteries.	46	1
Adding automation process of artificial lighting, cooling system and humidifiers.	9	2
Include integration to other system of the organization.	3	3

Table 8 displays the summary of suggestions for improvement in Auto GMS: An Automated Greenhouse Monitoring System of Abiotic Factors for Leafy Vegetables Production. It can be seen that the suggested statement “Integrate the system to renewable energy source such as solar panels or solar batteries” had 46 of the total votes and ranked first. “Adding automation process of artificial lighting, cooling system and humidifiers” had 6 of the total votes and got the second rank. “Include integration to other system of the organization” had 3 of the total votes and is in the third rank. “Availability of the proposed system to all the staff” had 2 of the total votes and ranked fourth.

Figure 2: Actual of the System Prototype at the MinSCAT Greenhouse.

The Figure 2 shows the actual setup of the system as well as the hardware integration. The water pump and solenoid valve are controlled by a system. The figure also shows the two setups, two plots which were used during testing. There are two sets of sensors for these two plots. Each set of sensor consists of one soil moisture sensor, one DHT11, humidity and temperature sensor and one photo resistor. The system is powered by a 220V for water pump, 12V for solenoid valve and Wi-Fi module and 5V for microcontrollers such as Arduino Mega 2560 and Arduino Uno. The system Wi-Fi module must be connected to the Wi-Fi station with Internet connectivity in order for the system to send data to the IoT Platform, ThingSpeak. The automatic irrigation which is highly dependent on the set soil moisture threshold is controlled via 4-channel relay. The water pump must also be connected to a water source.

The figure shown is a prototype for Auto GMS: An Automated Greenhouse Monitoring System for Abiotic Factors of Leafy Vegetables Production that is fully functional and operational. The Arduino house of the prototype is coated with plastic to make it water resistant, somehow.

Figure 3: Irrigation System Layout of the prototype in MinSCAT Greenhouse.

Figure 3 shows the layout sample of the automated irrigation. The water pump is connected to a water source via 10m hose. On the other hand, the sprinkler is connected to a water pump via 18 inches ¾ rubber hose. The flow of water is controlled via solenoid valve which is connected to a relay. The setup used the lettuce crop, thus, using the required soil moisture content of the crop. The automated irrigation will persist if the soil moisture falls down to 35% or lesser. On the other hand, the system will stop the automated irrigation or will turn off the water pump if the soil moisture reach 65% or greater than that. Solenoid valve blocks and allows the flow of the water to the different plots. Size of the plot which has been used, was 1 x 2 m. In the figure, each plot has one soil moisture that will measure the soil moisture content of the soil which will trigger automated irrigation. On the other hand, different plants require different soil moisture contents.

Shown in the figure above is the soil moisture sensor planted in the plot. The soil moisture sensor measures the quantity of water contained in a material, such as the soil. To obtain an accurate measurement, a soil moisture sensor was calibrated. Once the soil moisture content became absent, the reading will fall to 0% and if there's so much water, the maximum measurement of the soil moisture sensor is 100%. The soil moisture sensor including other sensors are connected to Arduino Mega 2560 and

Figure 4: Soil Moisture Sensor for measuring the needed parameters to automatically irrigate.

Arduino Uno. Sensors are responsible for gathering the measurement of soil moisture content, light intensity, humidity and temperature.

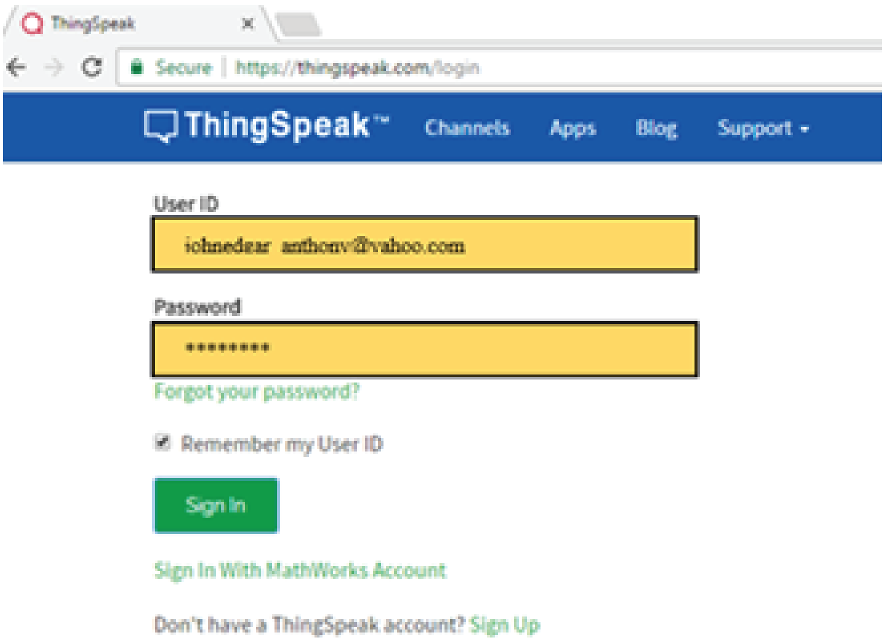

Figure 5: Log In Interface for ThingSpeak.

The log in interface of the ThingSpeak, IoT Platform is shown in the figure above. The user needs to provide the username and the password. The platform is accessible to different devices as long as it has a web browser and is connected to the Internet. On the other hand, the system Auto GMS: An Automated Greenhouse Monitoring System

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for Abiotic Factors of Leafy Vegetables Production also needs to be connected to the Wi-Fi point with Internet connection. The ThingSpeak is an IoT platform that enables the user to collect, store, analyze, visualize, and act on data from sensors or actuators, such as Arduino®, Raspberry Pi^{TM}, BeagleBone Black, and other hardware.

Figure 6: ThingSpeak (IoT Platform) – Graphs per Plot.

Figure 6 shows the graphical representation of data per plot. In the figure, all the parameter values summary are displayed per plot, the green line indicates the soil moisture content measurement, the red line represents the light intensity present in the greenhouse over time, temperature and humidity measurement are shown by the blue and violet lines, respectively.

Figure 7: ThingSpeak (IoT Platform) – Graphs and Gauges per Sensor.

The system is also capable of sending data to the IoT Platform per measurement of each sensor. Shown above are the graphical presentations of all the data measured by the light intensity sensor and temperature sensor. On the other side is the Google Gauges that show the measurement in a clock like representation.

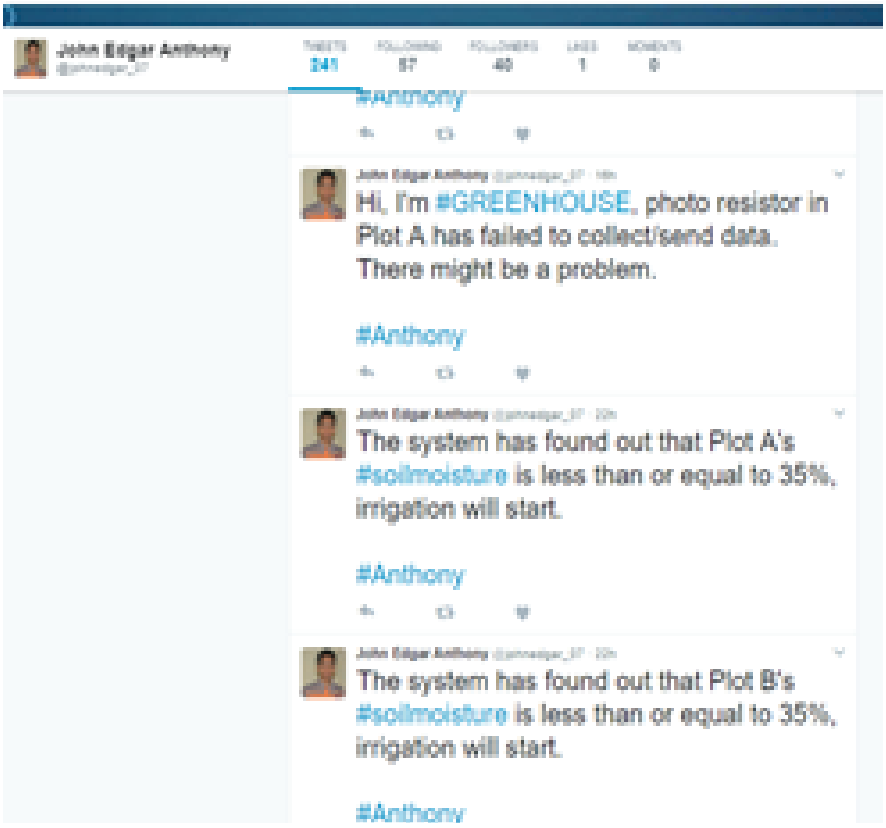

Figure 8: Twitter Account – System Tweets.

Once the system sends information to the ThingSpeak, through the IoT platform, the user could be updated regarding the status of the system. For example, if the sensor has failed and is not able to send data, the user could be notified regarding this via Twitter account. In that manner, the user or greenhouse administrator could take necessary actions to repair the sensors of failed components.

Whatever the system posted on Twitter, will be directed on the Facebook Page intended for the system, thus it will lead to a better and more efficient notification procedure of the system regarding its current state or the current status.

Shown in the figure above is the SMS notification from the system. Upon powering up the system, it will initialize for 30 seconds and after that, a notification indicating that the system is ready will be sent to the registered number. In order to send SMS, the system is equipped with GSM module with SIM card. The data card also needs load for the system to send SMS notification. In order for the user to maximize the feature

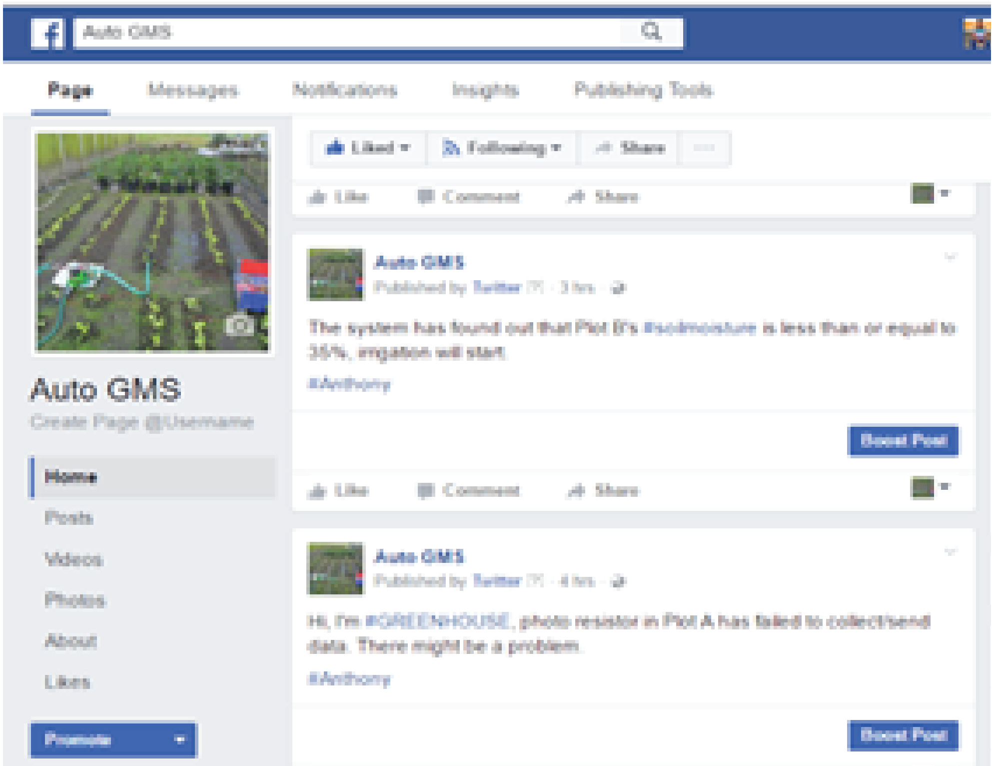

Figure 9: Facebook Page of the System.

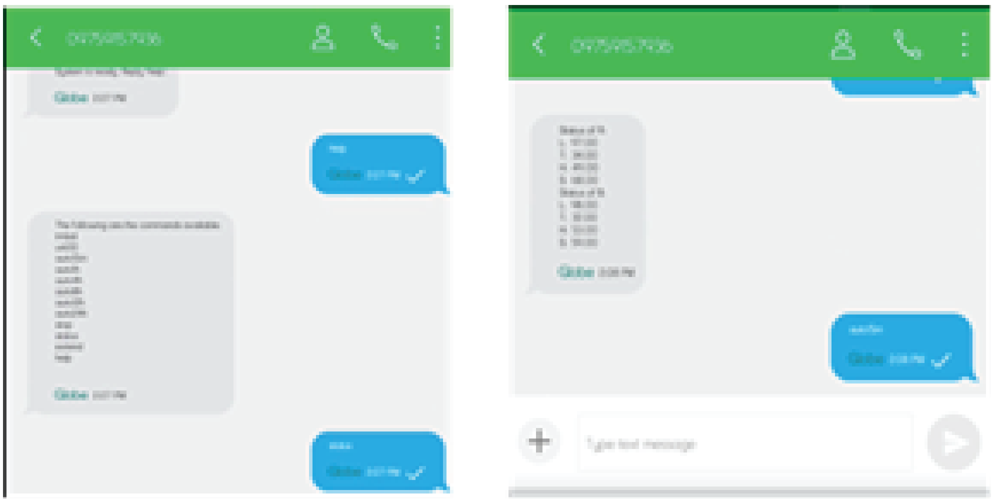

Figure 10: SMS Notification.

of SMS, the user can reply to the system with the "help" keyword and the system will text back all the lists of the available commands such as the tmbal – to check the SIM's load balance, unli30 to register the SIM's load to unli-text 30, the auto commands are used to automatically update the parameter status for 15 minutes, 1 hour, 4 hours, 8 hours, 12 hours and 24 hours and in stop command the system will stop auto-update. To check the parameter status of the greenhouse, the user needs to send "status" as a

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keyword and the system will update the real time readings. To extend the load promo, the user can just send text “extend”.

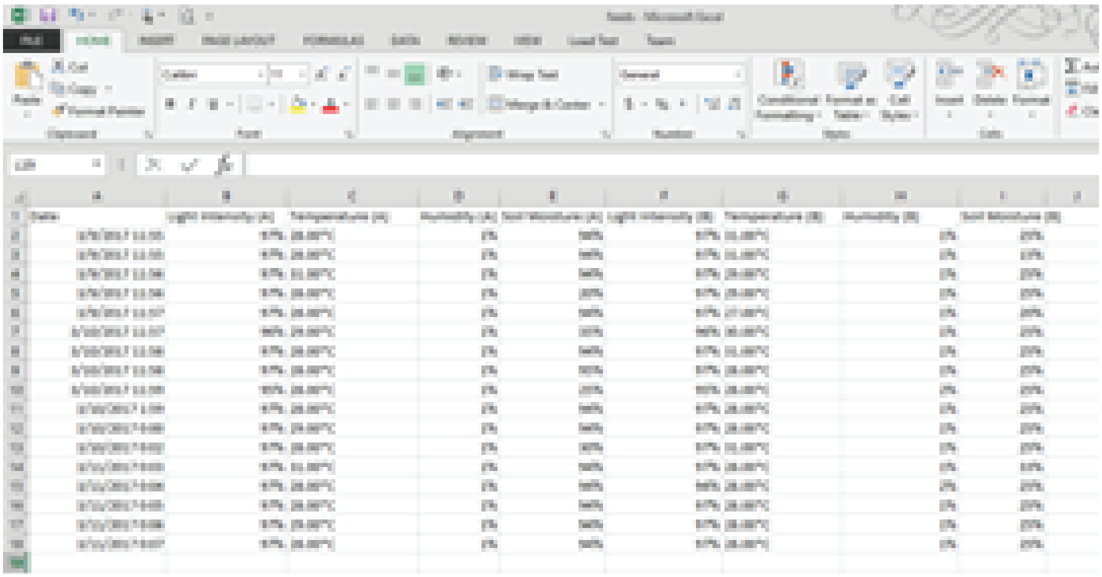

Figure 11: CSV Data on MS Excel.

The system is equipped with memory card wherein the system automatically saves the data logs in.CSV format for back-up which can be shown in tabular form and can be opened through Microsoft Excel. Shown in the figure is the print screen of the saved data logs from the system obtained by the sensors.

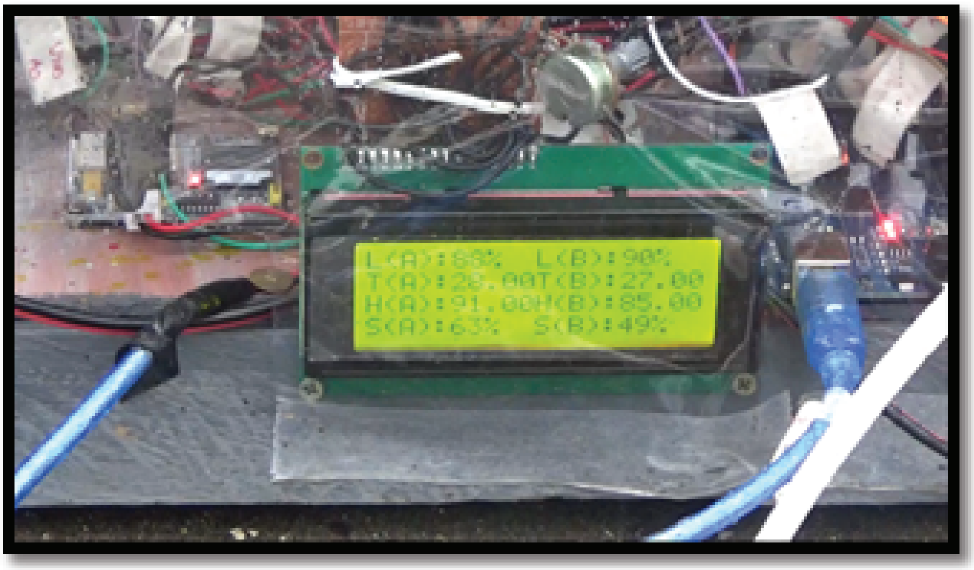

Figure 12: Real-time Measurements Displayed in LCD Display.

The real-time measurements from the greenhouse abiotic factors such as light intensity, temperature, humidity and soil moisture are displayed on the LCD screen built-in on the system. Sensors are grouped per set as seen on the figure above. All the measurements with A are understood to be the sensors for the Plot A and so on.

5. Conclusion and Recommendation

Based on the results of the study and the evaluation of the system, the following conclusions were derived: the developed Auto GMS: An Automated Greenhouse Monitoring System of Abiotic Factors for Leafy Vegetables Production system was perceived by the end users to be very much important in terms of water conservation, energy conservation, plants growth, manpower and load conservation. The prototype system was very much acceptable in terms of usability, functionality, reliability and connectivity. The prototype system was rated very much acceptable in terms of implementation. Thus, the respondents were convinced that the Auto GMS: An Automated Greenhouse Monitoring System of Abiotic Factors for Leafy Vegetables Production can be implemented. The suggested improvements made by the respondents should be considered for the prototype to work perfectly and ideally for it future utilization in the greenhouse. A conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

Hardware casing or the microcontroller house must be waterproof to protect the different devices and components of the system. System must be connected to a Wi-Fi point with Internet connectivity in order to send data to ThingSpeak for graphical presentation of different findings. On the other hand, the user must have a mobile device with Internet access and web browser, a ThingSpeak account. They must log in to the account and select the channel to where the system data is saved and sent. Future researchers could expand the scope of the study such as adding automation process of artificial lighting, cooling system and humidifiers. The greenhouse must have a well-equipped and efficient water source/supply in the implementation of the project.

Author's Note

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