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Development of a Real-Time Flower Farm Monitoring System for the Utilization of Arduino-Based Artificial Grow Lights

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Abstract: The use of artificial grow lights has been a trend in the modern agriculture sector particularly in western countries. The application of this technology has been introduced also here in the Philippines largely among horticulturists' greenhouses. This study aimed to develop a real-time flower monitoring system for the utilization of Arduino-based artificial grow lights. The aim of the monitoring aspect of the system is to have real-time information about monitors flower farm's greenhouse indoor and outdoor environmental condition such as humidity, temperature, precipitation, and soil moisture, plant growth and the automatic switching of LED-based grow lights thru the use of sensors and relay switch connected to an Arduino microcontroller board and will communicate via a clou system thru built-in Wi-Fi module. The study highlights the systematic identification of software and hardware requirements, the software development method to use, and the quality attributes that will be embodied by the system to be acceptable among stakeholders.

Keywords: real-time flower farm monitoring system, Arduino-based artificial grow lights, software development, waterfall model, ISO-25010:2011, software development life cycle

1. Introduction

Agriculture technologies advanced rapidly in the second half of the 20th century and at the beginning of the 21st century which forever changed the way farmers work.[1] During the onset of the 21st century, software and mobile devices emerged as a successful technology across all nations particularly in the agriculture sector.[2] By the year 2015, digital data have revolutionized farming and gardening potential that allow farmers to use resources more sustainably and plan for better harvests and make decisions that are better for the planet.[2]

Lying as foundation among digital platforms and data collection tools in the agriculture sector is the Internet of Things of IoT.[1] One of the drivers of IoT is the availability of affordable programmable microcontrollers such as Arduino and Raspberry Pi devices in which different sensors can be attached to gather information and record these data in the Internet through Wi-Fi or Bluetooth connections.[3] Arduino and Raspberry Pi devices are among the top microcontrollers being used in plant monitoring systems worldwide either for agriculture or horticulture purposes because of its wide availability, affordability and a vast support.[2]

Emerging IOT technologies that target horticulture is the use of artificial lighting brought about by the decreasing farmlands which is uniform among nations due to progress and expansion of cities and is now becoming one of the foundations of horticulture, indoor gardening, plant propagation and food production, including indoor hydroponics and aquatic plants, practiced in urban farming and vertical farming.[4] For many years, it is known that plants require light for growth, but not until the last hundred years with the development of science and technology that the exact effect of light on plants is fully discovered.[4] In agriculture, the use of artificial lighting or grow light seeks to provide a source of light that is similar to sun light.[5] A grow light or plant light is an artificial light source, generally an electric light, designed to stimulate plant growth by emitting a light appropriate for photosynthesis.[6] The use of artificial light in horticultural applications results in better growth and larger yields due to photoperiod extension (or the exposure to light spectrum that helps plans perform photosynthesis) and increase in the daily light integral.[7]

Here in the Philippines, the Philippine government, through the Department of Agriculture (DA), the agency which also manages horticultural science and technology in our country, poses to promote agricultural development by providing the policy framework, public investments, and support services needed for domestic and export-oriented business enterprises.[8] The DA envisions the agricultural sector of the country to be a competitive, sustainable, and technology-based.[8] Having viewed technology as a vehicle towards achieving its goals, the DA is doing its best in implementing the Philippine Development Plan (PDP) 2017-2022 to empower small farmers by channeling interventions and investments to expand existing opportunities and develop new ones from the computer information and communication field.[9] These mandates and vision of the national government in the agricultural sector is shared with its sub-agencies such as the Bureau of Plant Industry, regional and LGU counterparts.[9]

Most of stakeholders in the Philippine floriculture industry are dedicated on the production of high value ornamental potted plants and cut-flower varieties.[10] Local flower farms believe that monitoring their garden and farm is key in achieving its short-term and long-term goals,[10]] as such, a real-time monitoring system will be highly helpful in their business. With the use of a computerized real-time flower farm monitoring system and artificial lighting through LED-based grow lights, the most common problems encountered by flower farms can be mitigated as it provides integral real-time information on the current factors that directly affect the culture and propagation of ornamental plants being cultured and grown in the farm.

2. Related Works

2.1 Processes in Ornamental Plants Propagation and Cultivation

Floriculture is the discipline of horticulture concerned with the cultivation of flowering and ornamental plants. It deals with cut flowers, bedding plants, houseplants, flower garden, pot plants, cultivated greens for beauty and herbaceous nursery. Floriculture is an important agri-based, labor intensive and business-oriented enterprise.[11] Flower cultivation is generally divided into the following types: amenity, amateur and commercial gardening.[10] The amenity gardening includes the cultivation of ornamental plants or greenery landscaping of the private housings, business plazas, public parks, and other public places. Amateur gardening covers the cultivation of ornamental plants for the enjoyment of individuals as a part of hobby or luxury and not for sales.[10] Commercial gardening is a type of floriculture that covers ornamental plants produced for sale and includes potted plants, seeds, seeding, cut flowers, and bulbs.[11]

Plant propagation is both an art and science because it is the deliberate production of new plants that is achieved by two means – either sexual or asexual, getting basic knowledge of both the types can help growers in selecting the right method according to the plants they grow.[12] Put simply, plant propagation is the process of creating new plants from a variety of sources such as seeds, cuttings, bulbs and other plant parts.[12]

Plant propagation can also refer to the artificial or natural dispersal of plants as plants may be multiplied through both genetic and vegetative methods of propagation.[13] Sexual propagation or also called genetic propagation is the simplest, easiest and the most economical process among various types of plant propagation as this type of propagation leads to better plant species that are stronger, disease-resistant and have a longer lifespan.[13] On the other hand, vegetative or asexual propagation involves the production of species through vegetative parts of the plants such as roots, leaves, stems, bulbs, tubers etc. in which no exchange of genetic information takes place as the offspring is formed through the material of a single parent, thus, the resultant plants formed are identical to the parent plant (also known as clones) as in the case with propagation by cuttings, division, layering and grafting.[13]

Commercial flower farms must invest not only financial capital and skills through employees on the propagation processes, but also invest time in monitoring direct and external factors that boost flower plant propagation and cultivation.[14] Water, light, air, and temperature are the most important direct and external factors for the production of plants from seeds which are in dormant form and that when the favorable environment is created, the dormancy of the seed is broken, typically by soaking seeds in the water. The fundamental conditions for the germination of the seeds are a) the proper environmental conditions must be available; b) the embryo must be alive or viable; and c) any dormancy preventing germination must be broken.[14]

In terms of ornamental plant cultivation, water, temperature and light are the topmost factors that should be considered by commercial flower farms together with ideal soil moisture which can be attained by proper watering, not excessively flooded, not almost dry, but uniformly moist.[10] The proper temperature for soil and air contributes to the speedy germination and cultivation of flowering plants by providing cool air and warm bottom soil.[11] Proper lighting plays a major role to the complete cultivation of plants from their germination phase up to their flowering stage.[13]

Nowadays, the use of grow lights from germination phase up to maturation stage of flowering plants has become a profitable trend and best practices among commercial flower farms as they provide the necessary spectrum of light for the photosynthesis of plants even at night times, thus, halving the necessary time for ornamental plants to flower creating an opportunity for faster return of income.[10]

2.2. Core Functional Requirements of the System

Functional requirements are those which are related to the technical functionality of the system.[15] The core technical functions of a flower farm monitoring system include data sensing, communication, storage and processing.[16]

a. Data Sensing

Data sensing refers to the use of one or more electronic sensors connected to microcontrollers that act as part of Internet of Things whose primary role is to sense relevant direct and external factors that are aimed to be monitored.[16] In a commercial flower farm, most common sensors used are temperature and relative humidity sensor, light sensor, hygrometer or soil moisture sensor, anemometer or wind speed sensor, and ultrasonic sensor to detect plants' height and tank water level.[16] Light sensors are used to detect the presence of sunlight outdoor and is used as trigger to switch on greenhouse grow lights at night times or during dark times.[16]

b. Data Communication

The data communication functional requirement of common flower farm monitoring systems refers to how electronic sensors and microcontrollers communicate with a base station computer or online hosting server to transfer sensed data.[17] Data communication from these sensors and microcontroller devices can be transferred to base stations or online host computer through cable communication, usually through computer serial cable, or via wireless communication technologies such as Bluetooth, Wi-Fi or GSM or SMS. The base station or online host program then captures, interprets and classify transferred sensed data.[17]

c. Data Storage

Once sensed data are captured, communicated to base station, interpreted and classified, they are then stored in a database as part of the data recording functional requirement of the flower farm monitoring system.[16] The selection of the type of database to be used depends on how flower farms would want to consume sensed data as some flower farm monitoring systems prefer a real-time and dynamic data to be processed immediately while other systems prefer a batch-type of processing.[17] Currently, Google Firebase is a contender for dynamic data storage for mobile and web applications while Oracle MySQL is still the preferred free online database by most developers of flower farm monitoring systems.[16]

d. Data Processing

Data processing refers to how flower farm sensed data would be consumed by stakeholders and end-users of the flower farm monitoring systems.[17] Sensed data can be processed by means of showing historical data through graphs or can be used for forecasting by adding artificial intelligence algorithms to the data processing function.[17]

2.3 Core Non-Functional Requirements of the System

Non-functional requirement is a requirement or feature that specifies criteria that can be used to judge the operation of a system in particular conditions, rather than specific behaviors.[15] The most common non-functional requirements for a flower farm monitoring system include adaptability, backup, data integrity, durability, reliability and usability.[16]

Adaptability, in general, refers to the ability to change a part of entirety of the system to fit to occurring changes.[15] Flower farm monitoring systems should continue to function and adapt regardless what type of ornamental plant it is monitoring or whatever plant stage.[16]

Backup is defined as the ability of the system to create a duplicate of its stored data and make it available during the times they are needed.[15] Meanwhile, data integrity, refers to the maintenance of and the assurance of the accuracy and consistency of data over its entire life-cycle.[3] A good flower farm monitoring system sense, communicate, store and process data with accuracy and consistency in order to land to reliable information, the state in which data processed or forecasted are near to reality or truthfulness and can be used as basis for conclusion.[16]

Lastly, a great flower farm monitoring system must have a high degree of usability and durability or the easiness to use and learn the system and its corresponding long-lasting components, parts, devices, and operational procedures.[16]

2.4 Software and Hardware Tools

Two of the most commonly-used microcontroller boards in developing Internet of Things devices and systems are Arduino and Raspbery Pi devices.[17] Both of these devices are affordable, easy to assemble, support a wide variety of electronic sensors and both have Integrated Development Environment (IDE) where ready-made and customizable classes per electronic sensors are freely available providing great information support for professionals, students and hobbyists. The IDEs as well as their respective dedicated online web logs (blogs) and forums offer easy to understand step-by-step assembly, coding, testing, and simulation which enables even those non-programmers to learn to build IoT devices and programs.[17]

Because Arduino and Raspberry Pi devices are programmed using the C/C++ programming languages and because these devices provide communication ports and software support libraries, projects from these devices can be easily integrated to other programming languages and IDEs such as Microsoft Visual Studio for Visual Basic.NET or C#, Eclipse, Android Studio, NetBeans for Java and PHP.[17]

Meanwhile, in terms of circuit design and simulation, a number of free online or downloadable circuit design software are available and support both Arduino and Raspberry Pi boards.[16] These circuit design software does not only offer a visual drag-and-drop design approach, but also provides an automatic creation of standardized electronic circuit design and printed circuit board (PCB) design.[16] Among the most common and free to use electronic circuit design software are EasyEDA, FreePCB, Proteus Design Suite, Fritzing, EAGLE, PROTEL, PADS, and CircuitMaker.[17]

2.5 Acceptability of the System

The last test action before deploying and implementing a software is to test its acceptance among its stakeholders.[18] The main goal of this test is to analyze if the software is ready to be used and can really perform the tasks and functions it is created for.[19] There are three strategies to test acceptability, these are formal acceptance, informal acceptance or alpha test and the beta test in which acceptability test is a "contract" between the developer and the customer in which the conditions and terms of the contract relate to the features and functional requirements of the system.[18]

Acceptability of software follows the ISO 25010:2011 quality in use model in which an I.T. product or computerized system is acceptable if quality if part of its overall characteristics.[18] ISO 25010:2011 standard relates to the degree to which a product or system can be used by specific users to meet their needs to achieve specific goals with effectiveness, efficiency, freedom from risk and satisfaction in specific contexts of use.[20] The properties of quality in use are categorized into five characteristics: effectiveness, efficiency, satisfaction, freedom from risk and context coverage.[20] Usability is defined as a subset of quality in use consisting of effectiveness, efficiency and satisfaction, for consistency with its established meaning.[20]

3. Methodology

3.1 Method of Research

The researchers utilized the developmental method of research which requires a tangible output rather than informational concepts contrary to descriptive methodology as it is a systematic study of designing, developing, and evaluating instructional programs, processes, and products that must meet criteria of internal consistency and effectiveness.[18] The developmental method is used by the researchers in planning, designing, creating, evaluating and testing of the actual flower farm monitoring system.

3.2 Use of Iterative Waterfall Model

The researchers have chosen to pair the developmental method of research with the Iterative Waterfall Model as the System Development Life Cycle (SDLC) method. The waterfall model is a sequential, iterative, design process, used in software development processes, in which progress is seen as flowing steadily downwards (like a waterfall) through the phases of requirements analysis, system design, implementation, testing, deployment and maintenance.[21]

The Waterfall Model is observed by the researchers in the development of the Flower Farm Monitoring System by strictly following its phases, establishing a schedule or timeframe for each phase, and moving on to the next phase when the current phase has been successfully conducted. Accordingly, the Iterative Waterfall Model should be used when requirements are stable and do not change frequently, the requesting organization is stable or fixed in terms of overall structure and will change frequently, and the tools, technology and resources that will be used are stable.[22] Since most of the requirements and resources in developing the proposed Flower Farm Monitoring System are already available and will not change often, the researchers utilized the Iterative Waterfall Model.

Likewise, the Iterative Waterfall Model has been widely used among software companies developing different systems used in the fields of banking and finance, communications, transportations, engineering, research, and education,[19] as such, the researchers implemented it in the development of the proposed system together with the developmental method of research.

The following are the phase-by-phase description of the Iterative Waterfall Model and how each phase is used by the researchers:

a. Requirement Analysis

In this phase, all possible requirements of the system to be developed are captured in this phase and documented in a requirement specification document.[21] Requirements of the system are pieces of information that will form part of each system's features. It can be gathered using survey, interview, gathering of transaction forms or office forms, documents and reports, personnel expected procedures and outputs that should be generated.[19]

The researchers conducted an interview and work observation at the Insular Botanicals International, Inc., the subject institution of this research, to gather the required data and information relevant to the development of the proposed Flower Farm Monitoring System. The researchers were provided by sample forms and documents by the flower farm to provide visual representation of data and information that will be handled by the proposed system. Aside from the interview and observation, the researchers performed similar system review and monitoring device assembly available on the Internet to fully grasp the functional and non-functional requisites of the proposed system

b. System Design.

The requirement specifications from first phase are studied in this phase and the system design is prepared. This system design helps in specifying hardware and system requirements and helps in defining the overall system architecture.[23]

In this phase, the researchers enumerated the major modules of the system and then divided each module into each respective components and processes. The features that will be covered by the proposed system were also enumerated and linked to the modules, components and processes involved in each feature.

Once the foundations and structure of the system were set, different diagrams were drawn to easily have a preview of how each module, process, and component of the system are interrelated with other processes, modules and components. The researchers used the following diagraming tools: Flowcharts for the graphical representation of the step-by-step execution of the system; Entity-Relationship (ER) Diagram to visualize the interrelationship of each database table and their corresponding fields to other database tables, exhibit how each actor, process, database entity, required input and expected outputs will be working simultaneously; Class Diagram to display how each data are classified into a group to create a record together with their corresponding functions and procedures; and Use Case diagram to show the processes owned and will be handled by each stakeholder of the proposed system.

Meanwhile, the researchers also used a Gantt chart in creating the timeframe of each phase of system development together with each phase's subsequent development goals and the corresponding requirements in fulfilling each goal. The researchers used Fritzing to design simulate the electronic circuit schematics and the design of the printed circuit board.

c. Implementation.

With inputs from the system design, the system is first developed in small programs called units, which are integrated in the next phase. Each unit is developed and tested for its functionality, which is referred to as Unit Testing. The complete design is now translated into program code.[22]

During this phase, the proponents converted all output diagrams of the previous phase into functional units of the proposed system. The system's schema and its corresponding database tables and fields, triggers, procedures and functions were created in MySQL using MySQL WorkBench. Meanwhile, the developers used Microsoft Visual Studio 2010 as IDE to develop the base station software using Microsoft VB.Net. For the corresponding online program of the system, PHP, JavaScript, HTML, Ajax, and CSS have been selected and utilized by the developer as programming languages to develop the proposed system's browser-based and

Android mobile device user interface, scripts, and source codes using Eclipse as IDE. Finally, to program each sensors, wireless communication modules and their integration with one another and with the Arduino board, the researchers used C++ programming language using the Arduino IDE.

d. Integration and Testing

In this phase, all the units developed in the implementation phase are integrated into a system after testing of each unit. Post integration the entire system is tested for any faults and failures.[24]

The developers performed system compilation every time the source code of a large process or a module has been made. The developers immediately tested the system using the corresponding IDE to immediately resolve functional, non-functional, syntax and parameter errors. Once a module of the system is created, an integration test is conducted to evaluate process flow, logic, and input validation errors.

For the User Acceptance Test (UAT), fifty (50) randomly selected employees and farmers of the subject institution were set to be the study's primary respondents in answering a work interview and the acceptability survey questionnaire utilizing a four-level Likert scale composed of 4 criteria as quality indicators: Graphical User Interface (GUI) Design, Usability, Efficiency and Reliability, as prescribed by Quality-In-Use model of ISO 25010:2011.

Answers of randomly selected employees and farmers in the UAT survey questionnaire will be statistically treated using Frequency, Percentage Distribution, and Mean Absolute Deviation. Frequency refers the number of occurrences of a repeating event per unit of time. It is important in any survey as it directly identifies the quantitative representation of respondents for a particular answer in a survey question.[25] Meanwhile, percentage distribution or percentage frequency distribution is a display of data that specifies the percentage of observations that exist for each data point or grouping of data points. It is a particularly useful method of expressing the relative frequency of survey responses and other data.[26] The formula for percentage distribution is:

$$Percentage\ Distribution\ \% = \frac{frequency\ count}{number\ of\ respondents}\ x\ 100\% \qquad \textbf{(1)}$$

The researchers used the frequency and percentage distribution formula in order to represent data visually through graphs and chart and identify what percentage among all the respondents is constitute by a certain observation.

Lastly, the researchers utilized Weighted Mean in assessing the system end users rate in terms of the degree of effectiveness, efficiency and satisfaction.[26] The formula for the weighted mean is as follows:

$$Weighted\ Mean = \frac{w_1x_1 + w_2x_2 + \ldots + w_nx_n}{w_1 + w_2 + \ldots + w_n}\ x\ 100\% \qquad \textbf{(2)}$$

where w refers to the weights or equivalent to the specified Likert score and x represents the set of mean values.

Meanwhile, in order to collect and gauge technical feedback on the technical design and architecture of the software and devices, the researchers opted to acquire the services of five (5) I.T. experts who will review and evaluate the proposed flower farm monitoring system using another set of UAT survey questionnaire. These I.T. experts will provide in-depth technical assessment following the PIECES rubrics (performance, information, economics, control and security, efficiency, and service). At the end of the survey questionnaire, each I.T. expert will write down their overall evaluation and recommendation of the proposed system.

e. Deployment.

Once the functional and non-functional testing is done; the product is deployed in the customer environment or released into the market.[19] The developers installed the latest build of the system, its corresponding electronic

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sensors and wireless communication devices, and its system database into the designated test server, test database server, client computer and Android mobile device in one of the greenhouses of the subject institution. After the installation, the developers presented the system to the stakeholders and I.T. experts and conducted the acceptability test to measure the users' satisfaction and system readiness for deployment.

4. Results and Discussions

Figure 1 exhibits the overall design of the developed Flower Farm Monitoring System. It highlights the major components of the system which communicates via a router device and Internet data connection. These components are the: 1) Farm Environment Sensors connected to an Arduino Microcontroller board composed of 6 digital sensors that will monitor greenhouse soil moisture, outdoor and indoor humidity and temperature, and outdoor level of rain or precipitation; 2) Plant Growth LED Light and Sensors connected to another Arduino Microcontroller board composed of 2 sensors that will monitor the growth of plants and outdoor sunlight level to automatically switch on or off the attached LED light panel through an electronic relay; 3) Online Flower Farm Monitoring System Cloud Application that is composed of a Mobile application API, a Browser-based API and the MySQL cloud database; and 4) End User System Interface composed of Web-based browser application interface for desktop or laptop computers and an Android application interface for mobile

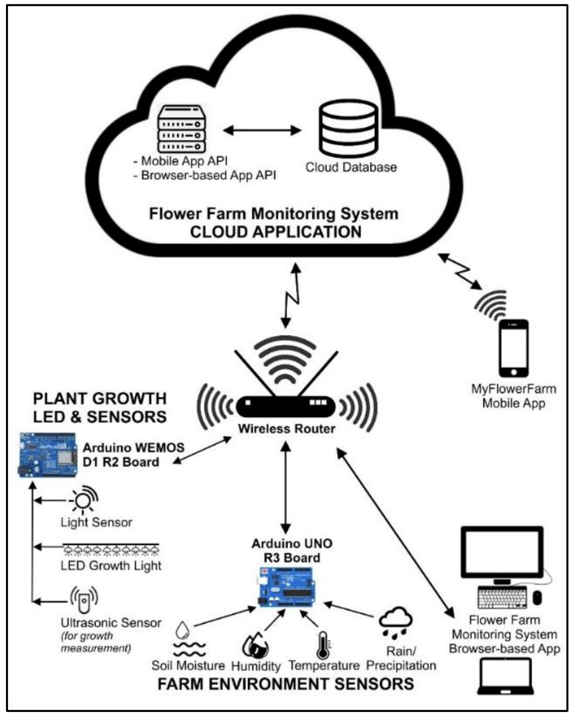

Figure 1. System Design of the Real-Time Flower Farm Monitoring System for the Utilization of Arduino-based Artificial Grow Lights

devices where system end-users can view real-time and historical sensors readings and perform system administrative operations such user account creation and updating and database backup.

Figure 2 shows the screenshot of the System Dashboard Module of the developed Real-Time Flower Farm Monitoring System for the Utilization of Arduino-based Artificial Grow Lights.

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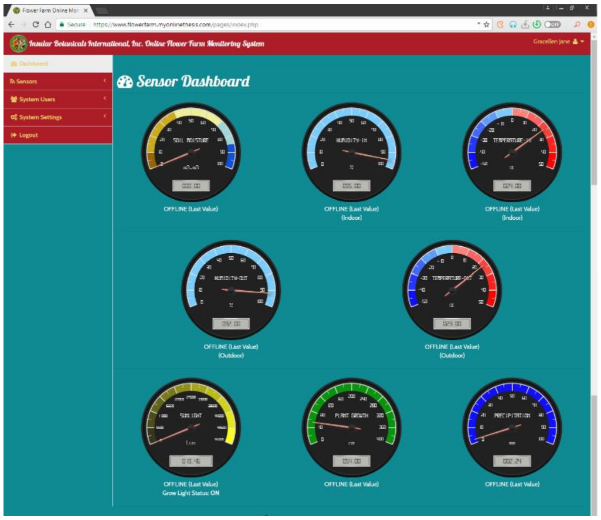

Figure 2. Screenshot of the Sensor Dashboard of the Real-Time Flower Farm Monitoring System for the Utilization of Arduino-based Artificial Grow Lights

The Sensor Dashboard is composed of the Top-page Navigation Bar that displays the currently logged in system end-user and available top-down system account menus, the Sidebar Navigation Menu that displays all system menu, and the System Dashboard page which exhibits 8 graphical gauges of all the sensors and their real-time or last-value sensor readings. The real-time gauges displayed on the System Dashboard are: 1) Soil Moisture; 2) Indoor Humidity; 3) Indoor Temperature; 4) Outdoor Humidity; 5) Outdoor Temperature; 6) Sunlight; 7) Plant Growth; and 8) Precipitation.

Figure 3 shows a screenshot of sample sensor historical data user interface of the flower farm monitoring system.

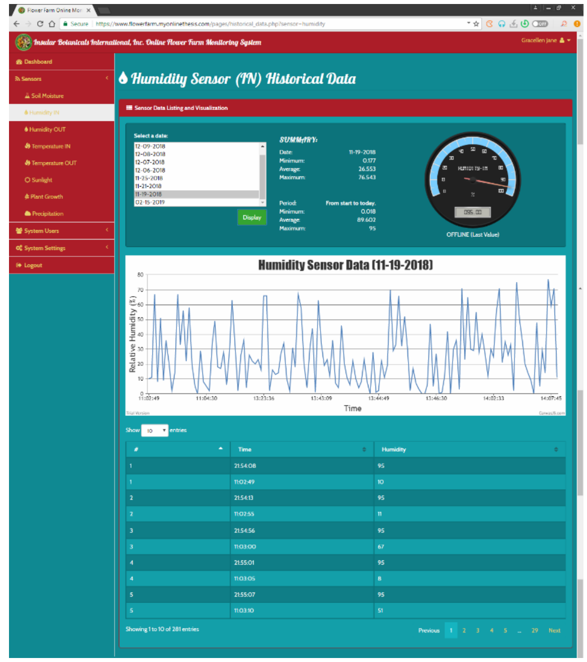

Figure 3. Screenshot of Sample Sensor Historical Data User Interface of the Real-Time Flower Farm Monitoring System for the Utilization of Arduino-based Artificial Grow Lights

Sensor historical data UI exhibits all the dates in which the particular sensor inside the greenhouse has performed readings and submitted values to the online database. Once a date is selected and the Display button is clicked, it will display sensor data readings inside the greenhouse on that particular date on graph and on the table. The graph visually shows sensor data inside the greenhouse by using a line graph while the table lists the numerical values of sensor readings on each particular time that the sensor has read humidity data. Aside from the actual sensor readings, the UI also displays a numerical summary of monitored sensor data inside the greenhouse. A numerical summary consisting of Minimum, Maximum and Average sensor readings are displayed for the selected date and for the period from which the sensor has started its monitoring duty up to the selected date. Meanwhile, a graphical sensor gauge also shows the real-time status of the sensor. If the sensor is switched on and online, an "ONLINE" status will be seen underneath the sensor, otherwise, an

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"OFFLINE" status will be seen and will display on the gauge the last recorded value of the sensor.

Table 4.15 exhibits the Summary of User Acceptance Test (UAT) conducted among the five randomly selected farmers and staffs of the subject institution.

Table 1: Summary of User Acceptance Test conducted among randomly selected Flower Farmers & Staff

Quality Descriptors	WM	DESC
1. Graphical User Interface (GUI) Design	3.45	A
2. Usability	3.68	SA
3. Efficiency	3.15	A
4. Reliability	3.73	SA
Overall Weighted Mean	**3.50**	**SA**

Legend: SA-Strongly Agree (3.50-4.00); A-Agree (2.50-3.49); D-Disagree (1.50-2.49); SD-Strongly Disagree (1.00-1.49); WM-Weighted Mean; DESC-Description;

The overall weighted mean of 3.50 with a description of Strongly Agree is indicative that the flower farm monitoring system has an acceptable quality as a software product in terms of overall graphical user interface (GUI) design, usability, efficiency and reliability. Specifically, according to survey respondents, the GUI of the system embodies an agreeable appropriateness, understandability, simplicity, and basic functionality of each UI element utilized while the efficiency has an agreeable efficient energy consumption, human resource utilization, microcontroller utilization, Internet data bandwidth, and web-browser or mobile app page loading. Meanwhile, respondents strongly agree that the system, in terms of usability, is usable in its intended real-world application, will yield significant benefits among system stakeholders, can be used in monitoring other varieties of ornamental plants and that the mobile device Android is easy to use and install without the need for any further technical expertise, and in terms of reliability, its components provide reliable or calibrated data, computing data according to standardized formula or methods, storing and retrieving, using secured data transmission and storage protocols, and implementing multi-level system user security.

Table 2 exhibits the Summary of User Acceptance Test (UAT) conducted among the five selected I.T. experts in connection with the flower farm monitoring system.

Table 2: Summary of UAT by I.T. Experts

Quality Descriptors	WM	DESC
1. Functional Stability	3.52	SA
2. Performance Efficiency	3.40	A
3. Compatibility	3.65	SA
4. Usability	3.70	SA
5. Reliability	3.35	A
6. Security	3.42	A
7. Maintainability	3.68	SA
8. Portability	3.70	SA
Overall Weighted Mean	**3.52**	**SA**

Legend: SA-Strongly Agree (3.50-4.00); A-Agree (2.50-3.49); D-Disagree (1.50-2.49); SD-Strongly Disagree (1.00-1.49); WM-Weighted Mean; DESC-Description;

The overall weighted mean which resulted to 3.52 with a description of Strongly Agree clearly signifies that the flower farm monitoring system has an acceptable quality as a software product in terms of functional stability, performance efficiency, compatibility, usability, reliability, security, maintainability and portability.

Specifically, the I.T. experts agree that the flower farm monitoring system has performance efficiency in terms of utilizing minimal number of microcontroller boards, internet data bandwidth other system-related implementation resources. Further, experts also agree that the system's components provide reliable or calibrated data, computing data according to standardized formula or methods, storing and retrieving, using secured data transmission and storage protocols, and implementing multi-level system user security. Furthermore, the I.T. experts agree that the developed system is secured in terms of its keeping data with high integrity by following data storage and transmission security standards and protocols, implementing multi-level user security controls, and utilizing system logs to document data processing and system user activities.

Meanwhile, the I.T. experts strongly agree that the developed system has functional reliability in terms of having a complete and appropriate core and advanced functionalities and features for monitoring a greenhouse's physical conditions, compliance with standardized protocols and objective-based methods. I.T. expert-respondents also strongly agree that the flower farm monitoring system is compatible to run among web browsers installed computers with either 32-bit or 64-bit processor architecture, web browsers of mobile devices (either iOS or Android), compatible to transmit data over WiFi form any routers, access points or mobile phone hot spots, and microcontroller devices are compatible to run and be operated using either 110V or 220V power supply.

In terms of usability, the I.T. experts who assessed the system strongly agree that it is indeed usable in its intended real-world application, that it will yield significant benefits among system stakeholders, it can be used in monitoring other varieties of ornamental plants and that the mobile device Android is easy to use and install without the need for any further technical expertise. The expert-respondents also strongly agree that the system has an acceptable degree of maintainability as it utilizes modular programming/ development that limits faults to particular modules only and does not damage the entirety of the system, test data can be implemented without affecting production-level data, and integration/repair of system units/parts or modules will not cause total system stoppage. Finally, the selected I.T. experts strongly agree that the developed system is portable in terms of implementing one (1) APK installer that will work for most Android mobile devices, using the system to other varieties of plants in other flower farms, and the servicing microcontroller components without affecting other sensors or the entirety of the system.

5. Conclusion

The researchers are firm in its stand that in developing systems for greenhouses and flower farms in relation to cloud computing, Internet of Things (IoT), mobile computing, and process automation, the developmental method of research paired with the Iterative Waterfall model of Software Development Life Cycle methodology is an effective software prototyping model.

Meanwhile, the use of Arduino microcontroller boards, complete with WiFi module, is a less expensive means of developing IoT devices as it is capable of handling several digital and analog sensors simultaneously for the automation and betterment of greenhouses and flower farms.

Finally, the implementation of user acceptance test (UAT) patterned to the ISO 25010:2011 standard can really be used to gauge and measure quality in developed software.

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