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Research paper

Haven-Garden System: an Alternative Garden for Temperate-Plants with Microcontroller Application

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Abstract

Based on the concept of current commercialized greenhouse, a simple system is created to control the modified greenhouse into a "sheltered-garden". This modified greenhouse is made to be different from the conventional ones in terms of its size and control system. The size is designed to fit a normal garden instead of a crop, and the system conceived to be low-cost thus much simpler. Named as Haven-Garden, the system is composed of a PIC16F877A microcontroller via programming language written using PIC Simulator IDE which controls curtain, light sensors, exhaust fan, LCD, LEDs and temperature sensor. All these components are integrated to create a controlled environment in ensuring the necessities of temperature, lighting, humidity, and carbon dioxide (CO2) are delivered adequately to the plants. In this study, the system has the ability to make decisions in providing necessary light intensity needed by controlling the openness of the curtain in the Haven-Garden according to the light radiates by the sun. On the other hand, the conventional light controller does not have the ability to solve this kind of issues, and can only be seen as in big greenhouse project and higher scope of crops to be covered. Therefore, this study identifies a design of a simple and low-cost system integrated with hardware circuit of automated controller using PIC16F877A microcontroller, controlling various parameters inside the "alternative garden". A system was successfully been created as an alternative to a contemporary garden but with far more beneficial as it helps in managing all the plants' necessities thus organizing the owner's time better. In this study, tests cases have illustrated that dynamic control method could be a suitable alternative method compared to conventional control methods that could save electricity consumption and offers ease of use to human being. The input variables were indoor lighting, inference from outdoor lighting, and temperature while the output variables were the required illumination to achieve the standard; presented in LED lighting, an exhaust fan to control the temperature and humidity, curtain to eliminate excessive light from direct sunlight and an LCD to monitor the temperature inside the Haven-Garden for more effectiveness.

Keywords: *greenhouse; greenhouse energy consumption; control system; temperature and humidity; PIC16F877A*

1. Introduction

Gardens are often related to beautiful and peaceful. Having a view of a garden may relieves stress thus helps in the relieving process. A study where stress-relieving effects of gardening were hypothesized and tested in a field experiment which salivary cortisol levels and self-reported mood were repeatedly measured. Positive mood was fully restored after gardening. These findings provide the first experimental evidence that gardening can promote relief from acute stress [1] [17]. An earlier experimental research made in the environmental psychology's field shows that well-beings can be influenced by positive effects of natural environment through restoration of stress and attentional fatigue. In a research conducted by the descriptive epidemiological, a positive relationship is proven between the amount of green space in the living environment and physical and mental health and longevity [2] [18]. Another research by demonstration made has reveals that a mere exposure to views of nature via restoration provision from stress and mental fatigue can improve people's health and well-being. Likewise, this exposure can also lead to decreases in aggression and crime rates while improving the feelings of neighbourhood safety [3],[4]. All previous researches show how gardening can gives massive impact on oneself and society. Therefore, having a garden or a green space is crucial and has to be widely promoted among the Malaysians.

Alas, minimal care for plants requires a continuous maintenance to ensure enough needs in terms of air, lighting, and water as their basics [5][8]. If these basic needs cannot be fulfilled, let alone assuring adequate supplements such as fertilizers, nutrients, minerals, micronutrients and others which helps to hasten vegetative growth, endorse rooting and enhance size and yield during flower, fruit and vegetable production cycle [6]. Growing plants may be easier than raising kids, but these two pursuits have similarities in their own ways. If they are healthy, they can continue making their own food through photosynthesis [7]. Time is a crucial thing in organizing plants as it takes time to grow and care for them. Some plants require more time to grow than others. It is challenging at certain times for plants to flower or fruit [5]. For this reason, only few have the patience to wait and care for their plants. Not to be excluded are those employed persons whom love gardening but found it hard to desegregate it into their hectic life. To the fact that caring for plants is not a simple matter, many people then conclude to let their front yard neither bare without any decorative plants nor garden at all. Due to all the benefits and goodness it brings, a solution was made where the idea of having a "sheltered-garden" was being brought up from the existed greenhouse concept as to alleviate the issue.

Current greenhouses in Malaysia are merely built for massive horticulture. Conventional greenhouses evolved to adapt with the tropical weather in Malaysia which evidenced in the development of a greenhouse suitable for lowland tropics; a collaborative project named as 'Tropical Horticulture in Malaysia'. In terms of climates in the lowland tropics where it has high temperature, radiation and humidity, this project has successfully created a greenhouse suitable and adapts to this type of climate [8]. A standard greenhouse is built from glass or plastic in terms of its design, works as a barrier to airflow and functions as to trap energy within it. All types of plants can be grown in a controlled environment of a well-constructed greenhouse [9]. However many researches were done in order to enable cultivation commercially, known as tropical greenhouses. It controls everything in huge plantation, and no greenhouse was installed personally in each house. As for plant nurseries, they do include the growth of ornamental plants but they need to be supervised manually. Hence, this project is done by integrating both concepts of greenhouse and plant nursery; whereby to create a garden under controlled environment.

Using a microcontroller PIC16F877A, this system gives the plants a sufficient light which is controlled by the movement of the curtain above them. The curtain interacts with the total of lights engrossed inside where for an example, in a condition, it will be fully opened when there is insufficient light received inside the greenhouse. When the light received is at its highest level, the curtain will be entirely closed, protecting the plants from being too much exposed under the direct sunlight.

Reducing humidity is another crucial aspect to be looked upon. Proper watering and adequate plant spacing, having well-drained floors, warming plants, moving air and venting moisture are ways to reduce humidity in greenhouses. Since the main objective is to provide the least expensive method without abandoning its effectiveness, therefore, this system is then been provided with the exhaust fan system where it will be operated when the humidity is high inside the greenhouse. This exhaust fan will be automatically turned on when the temperature reading is set to a certain level.

Reducing humidity via combinations of ventilation and humidity is far more effective compared to the alone usage of either ventilation or heating. There is a high need in the exchange of air moisture inside greenhouse with drier air from outdoors which refers to the ventilation process; whilst in terms of heating process, it is crucial to bring the outdoor air up to an optimum growing temperature thus increases the capacity of the air to carry moisture hence evading any condensation [10]. Neither practice alone is as efficient as both combined. Taking note, heating element can be in any form. In this case, when the outdoor light sensor senses no light, the Light Emitting Diode (LED) placed above each plant individually will be turned ON. This solution was made as to provide the plants inside with artificial light as to enable its photosynthesis process. This gives the plants enough light to produce oxygen and thus retains thermal energy at the same time. Since the wall is partly opaque, some of this energy is trapped inside the greenhouse, which in a way, helps to keep the environment inside to be warm. Commercial greenhouses need a proper watering system to reduce plants' heat stress. There are several techniques used such as dripping irrigation system, overhead watering, sprinkling and misting. But for this project, none of these techniques will be used. The advantage of using these types of techniques is that it allows greenhouses to be damp especially in the dusk time until midnight, as the temperature decreases. During this time, moisture develops rapidly due to the splashes of water done while watering, as well as the evaporation process that happens on any surfaces. Evaporation from the water splashes and puddles will cause the increment of humidity and eliminates energies which supposed to keep temperature inside the house consistent [10]. This is the main reason of why the system does not include any watering system along. Watering plants will be done manually by cultural practices including watering just enough to prevent excess of water on the floor, and watering early enough in the day to allow plant surfaces to dry before evening. Plus, since this non-commercial greenhouse will not be as big as those commercial ones, therefore there is no necessary needs in having the dripping irrigation system, thus doing it manually gives the owner a chance to perceive their plants. No wasting of water usage will minimize the cost.

The temperature inside of the greenhouse will be monitored by the LCD placed by the door. Keeping the temperature to be stayed in correct track is essential as it is included in one of the most important controlled variables in planting inside greenhouse. The LCD will be functioned based on the reading of the temperature sensor LM35 placed inside of the greenhouse.

Grasping unto the new principle of growing plants recommended by [16], growing crops in a more protected and controlled environment using the greenhouse concept where there is no light from the sun is required. Being a success, the project only requires the use of semiconductors that emit monochromatic light (LED). Saves energy, water and time are the most apparently common things between this Haven-Garden project and the project recommended by [16], but together with a maximum supervision as an added value in terms of temperature, humidity and lighting. In terms of watering, there will be a narrow gutter built with branches directed to each of the plants' pot. This gutter is made to be narrow as to allow the water to flow downwards regarding the earth's gravity. As far as to concern, this system will be manually done as it saves more in terms of cost and energy. This project is said to be an energy-saving as it requires the LED to be fully operated only when there is none light detected outside. The system has a program that sets the LED to only light at certain times as to save the electrical usage.

2. System Design

This section elaborate the overall Haven Garden system design. First, the architecture and flow of the system are discussed. Next is the explanation of the main hardware components involved. The section ends with the software design of Haven Garden system.

2.1. System Architecture

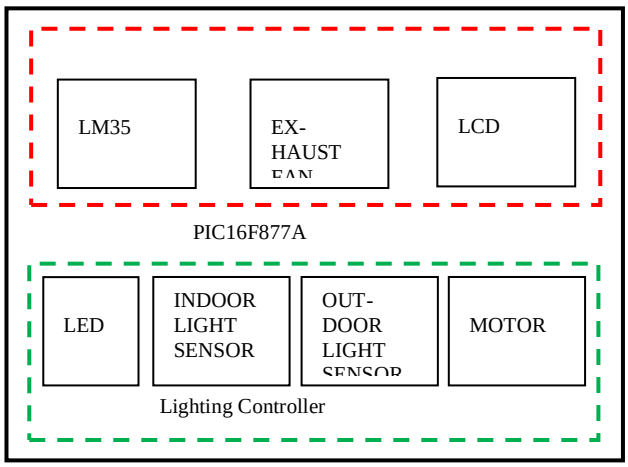

Fig. 1: System Architecture

The system architecture of the design gathers two main components of temperature and lighting controller. Both these controllers are being manipulated by a PIC16F877A microcontroller as the core to mainly control the temperature and lighting of the Haven-Garden. As shown in Figure 1, the temperature controller is integrated with the exhaust fan and displays the readings on an LCD

attached along, while the lighting controller are interconnected with the motor which eventually calibrates the curtain and controls the LED as a response to the luminance measured inside and outside the Haven-Garden via light sensors. For this Haven-Garden system, a PIC Simulator IDE software is used as the platform to create the designated data based on the rule matrix assigned to the sensors. This software is known for its user-friendly graphical development environment with integrated simulator, basic compiler, assembler, disassembler and debugger via assembly language. Thus, it is one suitable software since this program supports the PIC16F877A microcontroller.

A block diagram with its inputs and outputs is created which implies the system. For this Haven-Garden system, the block diagram involves the inputs, the core microcontroller PIC16F877A, and the outputs as illustrated in Figure 2.

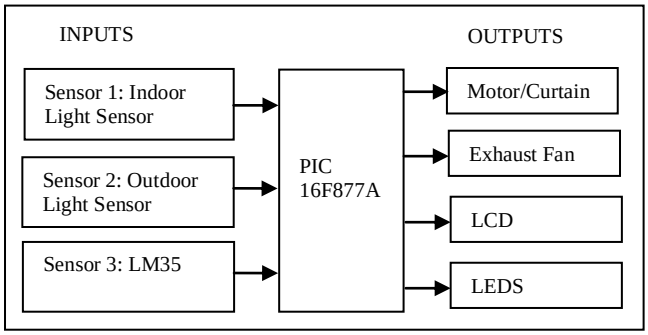

Fig. 2: Block Diagram for Haven-Garden System

A general block process is created to give ideas on how the overall system actually works. Figure 3 shows the general block process for the system, where it initially starts when the Outdoor Light Sensor was evaluated to be either in High (H), Medium (M), and Low (L) whilst the Indoor Light Sensor was eventually done the same. The H, M and L levels are the conditions as being resolved in the Rule Matrix set. At a certain condition, the curtain will be closed regarding to the response of these outdoor and indoor sensors. Only in one condition may the LED be turned ON; when the Outdoor Light Sensor sensed no light at all. In the meantime, the temperature sensor will detects any temperature changes inside the Haven-Garden. This measured temperature will then be displayed on the LCD. When the temperature sensor detects excessive heat, it will then activate the exhaust fan at a particular level of heat. This functions as to reduce the heat inside the Haven-Garden where this excessive heat is the range of heat that cannot be endured by the plants and action must be immediately taken to save the plants from having Heat Stress Syndrome [11]. Augmentation in humidity will also be lessening accordingly. This process is a closed-loop type since each condition is checked individually one-by-one by the PIC16F877A.

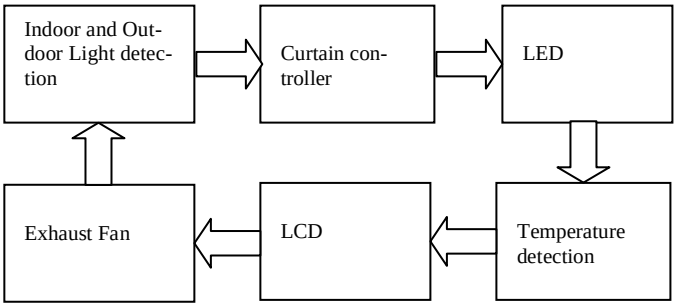

Fig. 3: General Block Process for Haven-Garden System

2.2. The Hardware Components

This Haven-Garden system is implanted inside a house where its construction's idea was formulated from a greenhouse's edifice. A rule was created as to show connections between each component. From Figure 1, the system architecture was divided into smaller sections of seven (7) decisive components listed as LM35, LCD, Exhaust Fan, LED, Curtain/Motor, Indoor Light Sensor and Outdoor Light Sensor. Figure 4 shows the overall circuit of the system which is then separated its each important component to get better understandings.

1) Temperature Sensor (LM35): There are several types of heat sensors available to measure the temperature. Some may deal with large temperature changes whilst some are more precise in detecting particularly small temperature ranges variations. Several temperature/heat sensors that have been done researched for their functionality and characteristics are like Resistance Temperature Detectors (RTDs), Thermistors, Thermocouples and Bimetallic Strip are among the listed sensors commonly used in building controllers that requires temperature detection. RTDs is an electrical resistors whom the resistance changes as a correspondence to the temperature variation. Since its temperature range is too big; from -200 to 850 ^{O}C and works on a basic relation between metals and temperature [12], it is not a very suitable sensor to be used for this project. A thermally sensitive resistor, called a Thermistor, is manufactured by metal oxides which can exhibits high coefficient of resistivity. This type of temperature sensor has its own disadvantage where it may have a great resistance at low temperatures but its resistance will eventually decrease once it is in a warmed condition. With a big temperature range around -50 to 200 ^{O}C [13], this Thermistor is yet doubtfully satisfied to be used in the system. Another type is Thermocouples which built based on Seebeck Effect, has a junction between two metals that can produce a voltage which functions as a temperature. Regardless its characteristics, it is more useful for measuring a very high temperature such as used in furnace applications [14]. Finally, a Bimetallic Strips are ones made from two types of metals bonded together, and the metal with high rate of expansion will tend to bend faster when being heated. This Bimetallic Strips usually have the temperature range of -30 to 130 ^{O}C [15]. Thus, there is only one most suitable temperature sensor that is suitable for this project; the LM35Dz. This component produces increase in voltage conjointly with the temperature rising. The readings are far better because of its output's precision changed by 10mV per ^{O}C and since it is produced by National Semiconductor, it can be operated up to 150^{O}C from -55^{O}C and been already proportional to Centigrade Temperature Scale. With a Zero-Offset voltage, it is easier as when the output reads none (0V), it measures 0^{O}C. Since in this lowland tropical climate of Malaysia, plants can only bare a temperature in a range of 25^{O}C-35^{O}C averagely [10]. Therefore, when the LM35 sense a temperature higher than the range, the exhaust fan will be operated promptly. Alas, the program can actually be altered depending on types of plants inside the Haven-Garden.

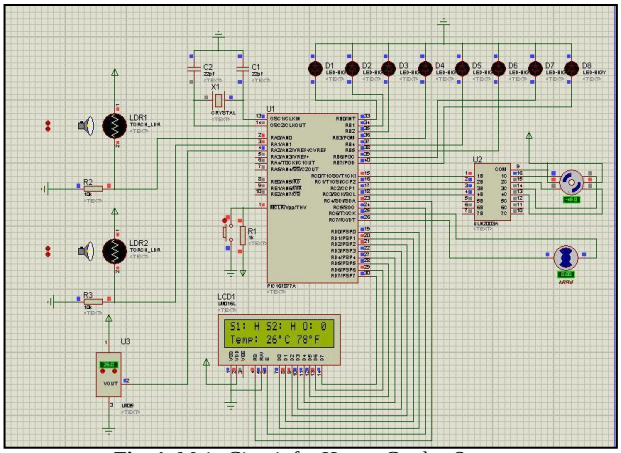

Fig. 4: Main Circuit for Haven-Garden System

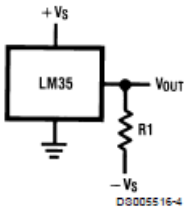

Fig. 5: The LM35 Temperature Sensor

2) Exhaust Fan: An exhaust fan is one of the most important components in this project as it helps cooling down the Haven-Garden thus eliminates the heat and humidity. In previous research [10], the humidity proven to be increases as the heat inside the Haven-Garden increases. Maintaining the temperature inside the greenhouse is challenging as to ensure the plants are not kept in a too over-heated environment. Thus, this system helps to supervise the environment to be in a controlled temperature ranged. For this prototype, a type of cooling fan pad which usually used to cool laptops was used.

Fig. 6: The Exhaust Fan used

3) LCD: In general, a Liquid Crystal Display (LCD) is used to display any data set by users. In this project, an LCD is connected to the output port of the PIC16F877A, where this LCD will show the measured temperature taken through the airborne inside the Haven-Garden in Celsius (^{O}C). The purpose of having an LCD is to ease the owner in supervising any slight change in the temperature. Though the temperature sensor responds independently with the system, the LCD can be a saviour when there is error in the system which disable it to function automatically corresponds to each other.

Fig. 7: 16X2 LCD Panel

4) LED: During daylight, plants receive their energy from the sun. Plants require heat and light as a source of energy, to produce food. During night times where there is no lights served as source of energy, the plants will be in their inactive states. Many conventional greenhouses do provide their plants and crops with lighting system during night times as to ensure productive outcomes. But the lighting system provided is mainly directed using the Alternating Current (AC) via the fluorescent or incandescent lights. This system is actually requires a lot of energy consumption, depending on the size of the plantation inside the greenhouse; the bigger the crop, the higher the cost in terms of bills payment. Hence this project is created to have a system of which the LED will be controlled its ON/OFF conditions based on the rule created.

5) Outdoor Light Sensor: This light sensor circuit is placed outside the Haven-Garden. This circuit is used to detect the intensity of the sunlight. This intensity is divided into three groups of intensity level; Low (L), Medium (M) and High (H). Using the PIC Simulator IDE, the sensor is set to be able to recognize the types of intensity level and the motor which controls the curtain will be automatically corresponds to this readings accordingly. A Light Depending Resistor (LDR) is used in the prototype of this project. This sensor can be referred as in Figure 8.

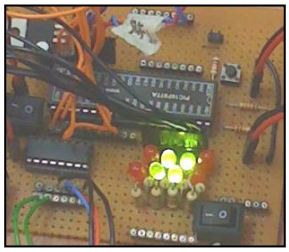

Fig. 8: Tested LEDs on The Hardware

6) Indoor Light Sensor: Same as the Outdoor Light Sensor, this Indoor Light Sensor circuit functions as to detect the intensity of the light but since it is placed inside the Haven-Garden, it will detect the light level inside. In correspondence to this sensor output, the PIC will compare these two readings measured between the Outdoor and the Indoor Light Sensors based on the rules made. Then, the motor that drives the curtain will then be moved based on the rules. Same, this sensor also used an LDR as prototype (refer Figure 9)

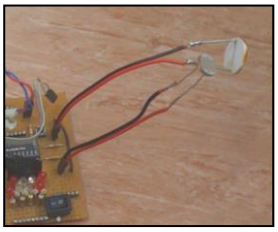

Fig. 9: The Prototyped Lighting Sensors (Indoor and Outdoor)

7) Motor/Curtain: A stepper motor is used in this project as it is the most suitable in controlling the openness of the curtain whereby its angle is manipulated according to the analogue input readings obtained by the Outdoor and Indoor Light Sensors.

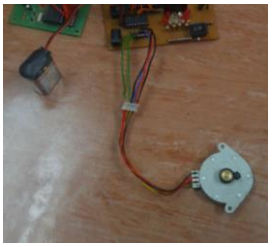

Fig. 10: Stepper Motor being tested

2.2. The Software Design

The programming part is a crucial part in creating the software for this system. The foremost important thing in starting a program is to firstly initialize all ports and interface them to related components. It is easier when the programmer knows how to write the coding using suitable language for the PIC16F877A. For this PIC16F877A, the PIC Assembly Language is used to write and compile the program. A programmer is the device that must be connected with a computer in order to burn the program by placing the PIC16F877A onto the programmer. The programmer will then send the program unto the PIC16F877A's ROM. As for this system, the PIC Simulator IDE is used as the platform to build the program.

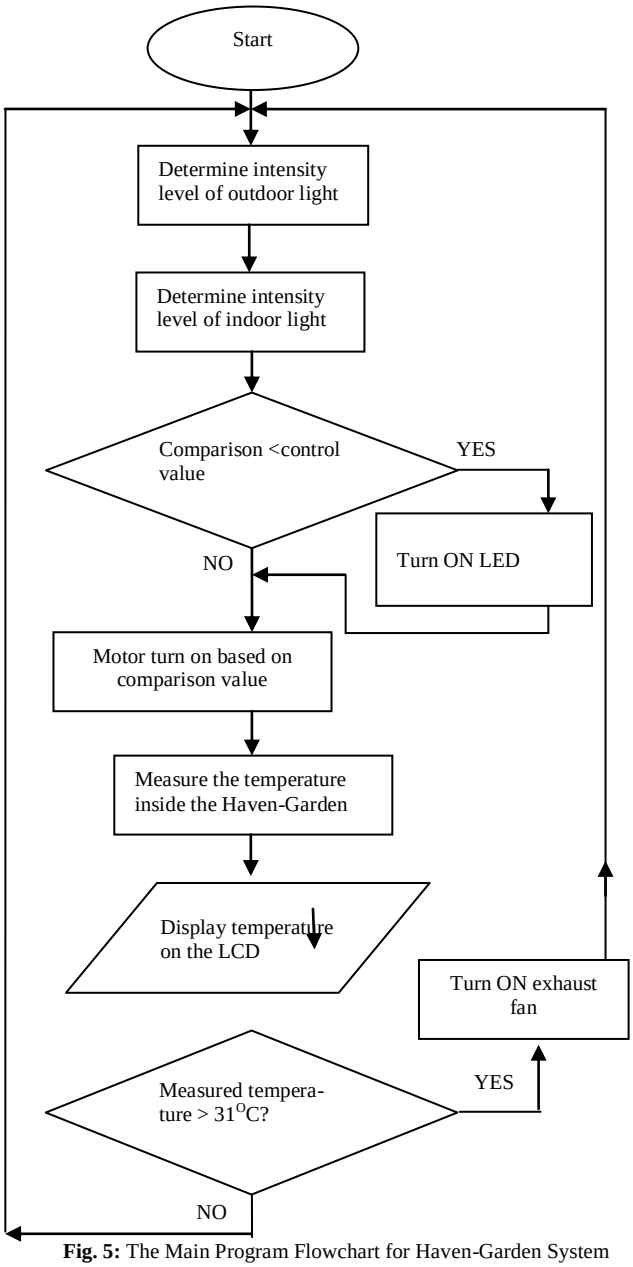

Fig. 5: The Main Program Flowchart for Haven-Garden System

Fig. 5 shows the main program flowchart for the Haven-Garden system. The system starts by determining the intensity measured by the Outdoor Lighting Sensor thus comparing it with the intensity level measured via the Indoor Lighting Sensor. As the result, the LED and motor will then be turned ON and controlled its degree of openness based on the rule they satisfy. The temperature inside the Haven-Garden will then be measured by the LM35, and displays the value on the LCD. The value of the temperature measured will be checked either it exceeds the range or not. It yes, the system will activates the exhaust fan. The system will go in a loop, checking all the conditions to satisfy conditions and rules.

The rules assembled in the Table 1 are the result of having the best condition of system where to provide adequate temperature, lighting and humidity for the plants. For example, in a case where the lighting sensors where both placed inside and outside of the Haven-Garden read a value of "Low" for both, therefore, the motor that runs the curtain will then be closed and the LED inside the Haven-Garden will lit brightly. Whereas, when both the lighting sensors inside and outside the Haven-Garden are read as both "High", the motor will keep the curtain open, and thus the LED will be in its OFF state. The rule base shown in the Table 1 will be applied to the inputs of lighting sensors and their corresponding conditions for the outputs. For the temperature sensor, there is no rule matrix done as this sensor may only responds to a temperature higher than the fixed value set by programming of the PIC16F877A.

Table 1: The Tabulated Rule Matrix For The Haven Garden System

Inputs (IF)		Outputs (THEN)	
Indoor Lighting Sensor	**Outdoor Lighting Sensor**	**Motor/ Curtain**	**LED**
Low	Low	Close	High
Low	Medium	Close	High
Low	High	Middle	Medium
Medium	Low	Close	High
Medium	Medium	Middle	Medium
Medium	High	Open	Off
High	Low	Middle	Medium
High	Medium	Open	Off
High	High	Open	Off

3. Result and Discussion

The Haven-Garden system was run so as to test the hardware and the programming of the system. Based on the results obtained, both the hardware and software are functioning well without any problem, just as wanted. The Indoor Light Sensor reacts effectively with the Outdoor Light Sensor which resulting in the curtain moving promptly just as what have been stated as the rule in Table 1. The LED also responds to the sensors effectively, following the rule precisely. The LCD shows the displayed temperature of the environment inside the Haven-Garden which is being measured by the temperature sensor LM35. When the system detects the environment to be "too-hot" for the plants to handle which is exceeds 35˚C, the exhaust fan will be automatically activated and will only be shut-off when the temperature stay balanced within the range of 25 ˚C -35 ˚C.

The resulted data is important as a method for confirmation to the theories made and to prove the system is useful and practicable. Selecting components gathered and compiled into the system has also been proven to be suitable since the resulted data is tally to the simulation results. All the components integrated has successfully created a controlled environment which delivers adequate necessities to the plants in terms of lighting, temperature, humidity, heat, and water. ‘

Based on the results, this Haven-Garden system is a dynamic system where all the inputs and outputs can be varied and not attached to one condition only. The system is said to be dynamic as it can responds well to the rules created exactly as listed in Table 1. Compared to other conventional designed control system, this system saves energy the most where it only requires about 5V of energy consumption unlike systems that uses fluorescent and incandescent lamps as their light sources which requires a maximum of 100V.

4. Conclusion

The aims and objectives of this project has successfully achieved. The design has been successfully identified as simple and low-cost system compared to other system embeds inside conventional greenhouses. With the hardware circuit being integrated into a system, all the various parameters are successfully been controlled using the PIC16F877A microcontroller. The accomplished system of the Haven-Garden proven to be that a contemporary garden with shelter and minimum human-supervision is easily achievable and gives more advantage by helping to provide all plants' necessities besides making the owner's time more organized. However, future design of Haven-Garden will integrate with IOT element to

send information to the users on the measurement of the system via internet. Haven-Garden also can be upgraded into several other designs such as efficient in saving much energy, trapping more CO2, lessening the humidity to a required level, improving the air circulation and other features that may give more benefits, the made available. Several features may be added in the future design such as bottom heat, anti-drip plastic, ventilation-and-heating elements and others so as to reduce the relative humidity due to the bad air-circulation. By having currently-existing controlled environments, all the parameters of light, humidity, temperature and water are well-supervised under the use of this system.

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