Smart hydroponic farming with IoT-based climate and nutrient manipulation system

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***Abstract*—the significant incline on environmental awareness in agriculture and the rapid development of technology of food system have brought interest that arises. If done properly hydroponics can produce many benefits, both commercially and environmentally. But there are so many parameters that must be considered in hydroponic systems, which make practicing them, a challenge. In this study an automatic computer-controlled climate and nutrient manipulation system will be proposed. Manipulation will be based on monitoring carried out by a number of sensors that will be processed by computers in an IoT-based system.**

Keywords— IoT, smart hydroponic system, climate manipulation, nutrient manipulation

I. INTRODUCTION

Food security is a very big problem, so the development of technology (conventional and nonconventional) to produce the same food products in quantity and quality without excessive pressure on non-renewable natural resources is an interesting thing to follow. The interest that arises in the food system is the result of various concerns ranging from environmental problems, equity and power, trade, to food health [1]. Many agricultural innovations have emerged in recent years, one of which is urban agriculture that has been applied in various places. For example, Barcelona is a city where urban agriculture has been widely developed. The Barcelona city council recently decided to provide incentives for the development of urban agriculture [2]. Other examples of the provinces of KwaZulu-Natal, Gauteng Province, Eastern Cape (EC) and Western Cape in South Africa have also succeeded in developing urban farming systems at the hobbyist level to commercial level [3]. Urban agriculture is not a homogeneous practice, including among others, small commercial agriculture, community-supported agriculture, community gardens, roof or greenhouse gardens, hydroponic and aquaponic agriculture, and indoor agriculture [4].

II. CURRENT STUDIES

This research will focus on one of the many urban agricultural practices, namely hydroponics. Hydroponics is a system of plant growth in liquid nutrient solutions with or without using artificial media. Media commonly used include clay, coir, pear lite, vermiculite, brick fragments, or wood fiber. At present, there are 17 elements that are considered important to be present in nutrient solutions in hydroponic practice, these elements are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, copper, zinc, manganese, molybdenum, boron, chlorine and nickel. With the exception of carbon and oxygen, which are supplied from the atmosphere, important elements are obtained from the growth medium (nutrient solution) [5].

Hydroponics has been recognized as a viable method for producing vegetables (tomatoes, lettuce, cucumber and chili) as well as ornamental plants such as herbs, roses, freesia and leaf plants [6]. The selection of this practice is the basis of the research as well because it can be concluded that growth without soil media makes it possible to control environmental conditions to be more accurate, which offers the possibility to increase production and improve crop quality. In particular, nutrient solution parameters such as temperature, pH, electrical conductivity, oxygen content can be manipulated. If this parameter is not properly controlled and in the right time, profits can turn into losses [7]. Manipulation of nutrient solutions will be the main focus in this study.

Another method that will be considered is manipulation that relates to the atmosphere including aeration, room temperature and light intensity. This study considers manipulating these parameters by knowing that based on the latest experiments the parameters have an impact on plant growth. The total biomass of cultivars increased under LED lighting, while the root ratio: shoots were more visible under NS1 light compared to fluorescent lighting [8]. In another study it was found that one of the most important and crucial factors in hydroponic practice was aeration of roots and room temperature [9].

III. DESIGN AND ARCHITECTURE

To help the manipulation that will be done, in this study using NodeMCU as a controller and some sensors that we use are water flow, water level, pH meter, EC, humidity meter and lux meter sensor.

A. Water flow sensor

Water flow is a tool to detect the flow rate of fluid through a closed pipeline. The sensor is applied between connecting pipes so that this sensor will detect the rate of water and will read continuously for the speed of water flow through it, if the speed is high then the output produced will also be high and if there is no water flow through it the sensor will produce 0 for the flow rate. We use this sensor to control the flow of water that will flown into hydroponics so that the water content in the growing media can always be maintained [10].

B. Water level sensor

Measuring water levels in a storage container can be measured easily using modern tools such as Water Level. Water Level itself is a set of tools used to measure water

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levels in a place or container. So that we can find out the remaining water in the storage container and provide actual reports to avoid empty water containers which will result in hydroponic plants that will lack water [11].

C. Humidity meter sensor

Humidity meter is an electronic device used to measure the amount of water and moisture in a particular object. This tool can measure humidity, air flow, and the temperature level of a substance. Hydroponic plants that grow indoors do require a certain range of humidity to grow and develop [12].

D. pH meter sensor

pH meters are an electronic device that serves to measure the pH (degree of acidity or basicity) of a liquid (there is a special electrode that serves to measure the pH of semi-solid materials). pH meter consists of an electrode (measuring probe) connected to an electronic device that measures and displays the pH value. This tool is very useful for the drinking water, laboratory, aquarium and agriculture industries [13].

E. EC meter sensor

EC meter devices. EC meters or electro-conductivity meters measure the smooth delivery of electricity between cations and anions [14].

F. Lux meter sensor

Lux meter is a tool used to measure the amount of light intensity somewhere. The amount of light intensity needs to be known because basically plants need light to photosynthesize. To find out the magnitude of this light intensity, a sensor that is sensitive and linear to light is needed. The farther the distance between the light source to the sensor, the smaller the value shown by lux meter. This proves that the farther away the light intensity will decrease. Therefore, this sensor is used so that the lighting for hydroponic plants can be arranged more optimally so that when the sunlight is obtained less than additional light or lighting will be given using lights so that it can meet the needs of hydroponic plants as well as too much sunlight the roof panel will close until sunlight is enough [15].

IV. PROPOSED METHOD

The proposed architectural design will require a greenhouse as shown in Figure 1 where the environment inside the building will be manipulated. Parameters that will be manipulated include how much sunlight is needed, how often LED lights are used, humidity, and aeration.

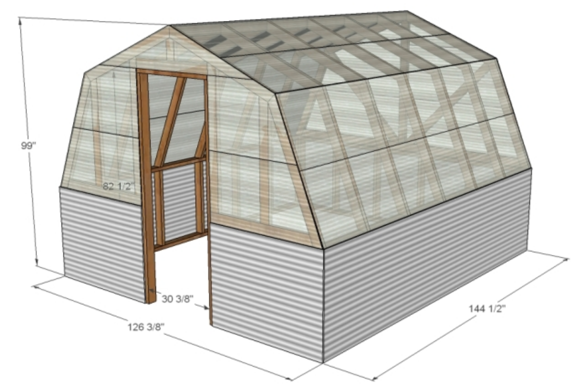

Figure 1: Green House

Manipulation will be based on the results of the calculation of the data generated by the sensors used; the data flow will be divided into 2, namely the data flow for climate manipulation and data flow for manipulation of nutrient solutions as shown in Figure 2.

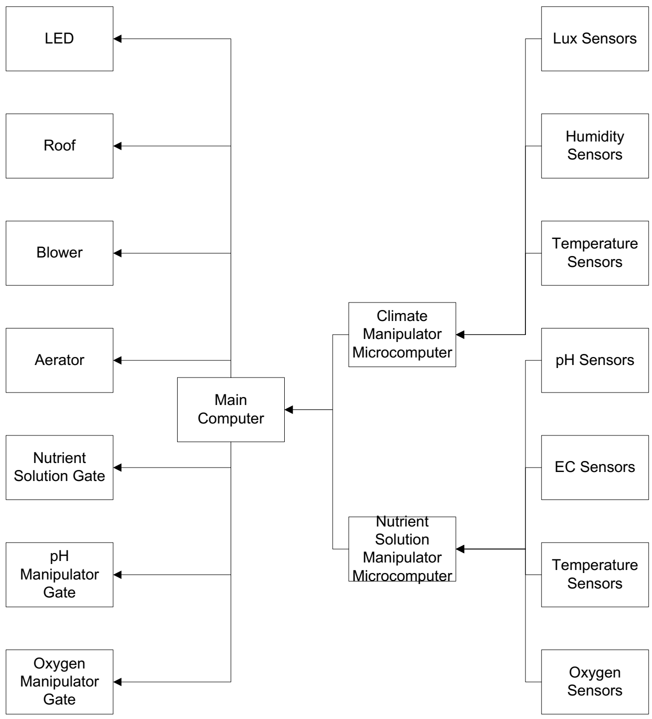

Figure 2: Data flow

Manipulation is by an algorithm that decide whether some gate need to be open or close as shown in Figure 3 and Figure 4.

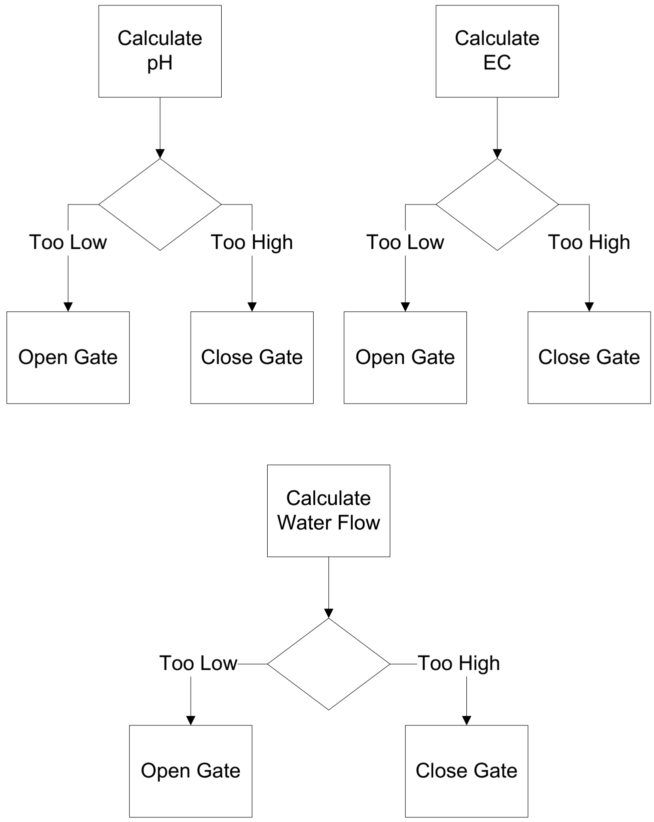

Figure 3: Nutrient Manipulation

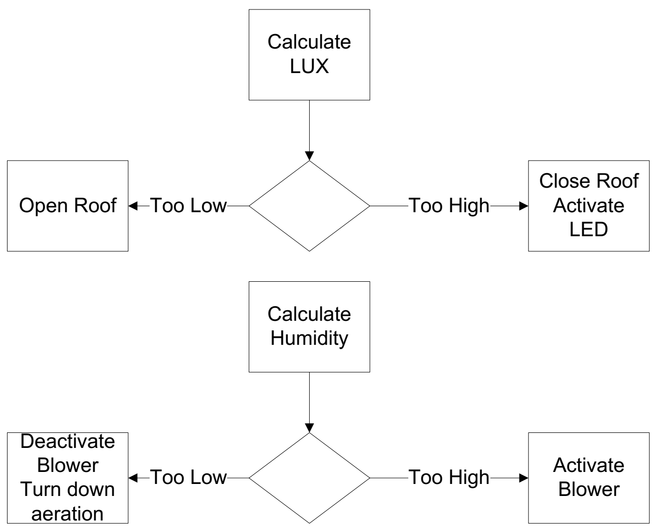

Figure 4: Climate Manipulation

V. RESULT AND DISCUSSION

Anyone who wants to grow crops hydroponically should pay special attention to the design of hydroponic systems. One important element of a functioning hydroponic system is monitoring water quality. In the cultivation of traditional plants they absorb nutrients from the soil. In order for hydroponic plants to get the nutrients they need, water in the hydroponic system must be enriched with nutrients. Water enriched with nutrients must be monitored carefully to ensure that the nutrient level is not too low (inhibits growth) or too high (potentially toxic).

Based on this system design, it shown that it is possible to create fully automatic hydroponic agriculture by manipulating few parameters that need to be controlled. This design can reduce the complexity of carrying out hydroponic farming practices by relying on computer capabilities and sensors. With very good computer capabilities and reliable sensor accuracy, the results of planting of this system are very satisfying, because all these parameters are calculated precisely in a very short time so that the manipulation can be done as soon as possible, which makes the plant get the best care from this system. Which means plants will grow better and produce better profits.

Hydroponic nutrient solutions are prepared from mineral salts dissolved in water. The strength of nutrient solutions can be determined by manipulating the electrical conductivity (EC). The conductivity of a solution (K) is given by the sum of the conductivities of ions in solution calculated with formula below (1).

$$K=c(Km,1+Km,2) \qquad (1)$$

Where c is the concentration, and Km,1 and Km,2 are the respective molar conductivities of the two ions. Higher EC values indicate higher ion concentrations (salt). The optimal level of conductivity to support growth depends on the device type. Different hydroponics systems react better to different nutrient solutions. On the other hand, different nutrient solutions produce different conductivity values because they dissociate into ions in ions.

pH in hydroponic systems can also affect plant health significantly. Plants absorb nutrient solutions through their roots; The ability of plants to absorb solutions, as a rule, depends on the pH of the solution. For example, acid solutions promote the absorption of aluminum, hydrogen, and manganese. To calculate the pH of an aqueous solution, you need to know the concentration of hydrogenation ions in moles per liter (molarity). pH is calculated using the expression in (2).

$$pH = - \log [H3O+] \qquad (2)$$

If the solution is too acidic, the super-absorption of these nutrients may be toxic to plants. Calcium and magnesium, on the other hand, are less easily digested at low pH. This can cause this nutrient deficiency. The same applies to alkaline media, which increases the availability of molybdenum and macro-nutrient solutions and reduces the availability of phosphorus, iron, zinc, copper and cobalt.

To install a hydroponic manipulating system, conductivity and pH sensors must be installed in a water tank that will be used to supply the plant nutrient medium. Based on measurements from sensors, pH manipulator, and control signal conductors for opening and closing gates or pump operation. For example, the concentration of solution in the water tank has become too high; the conductivity manipulator can turn on a fresh water pump to supply nutrient solutions. Conversely, the concentration of solution became too low; the conductivity manipulator could turn on the feed pumps. Similarly, if the pH becomes too high, the pH manipulator can open the solenoid gate, allowing carbon dioxide to flow into the water tank. Carbon dioxide reacts with water to form carbon dioxide, which lowers the pH of the solution.

Nutrient solutions are important to the success of hydroponics, there are six fundamental nutrients that a plant needs, and the right amount of these nutrient solutions must be manipulated for each particular type of plant. Important factors are light, temperature, aeration and carbon dioxide. Insects like bees, moths, butterflies, and mosquitoes play a key role in pollination and pest control. When all these factors combined, creation the manipulated environment needed for a hydroponic greenhouse.

Hydroponic systems provide increased crop productivity and efficiency, high yield per plant per square meter and fresh produce, regardless of the season or the soil temperature. Today, there are many different types of plants that serve various market segments, including farms, super markets, restaurants, and institutions. Hydroponic operations can range in size from small operations to large operations that take many hectares.

VI. Conclusions and Future Works

In this research there are few conclusions that appeared. Computer or even microcomputer can be very versatile in term of application. Knowing full well that computing power is not an issue in this particular case the first conclusion is that professional, hobbyist, or ordinary people can have a hydroponic farm relying on IoT based system. Second conclusion is how far sensors have progressed from the past, they are actually reliable and accurate on calculation making task in hand, which is getting data as manipulation basis, can be so much easier. And the last conclusion that this research found is that IoT in application is a very good concept to do menial task that human need to be hands on before, for instance nutrient solutions is not easy to manipulate but with this system nutrient manipulation can be done in no time because sensors will capture the calculation and send data to computer wirelessly in almost no time at all, means calculation and action can be done immediately making this system of hydroponic farming virtually doesn't need labor.

For future research it is recommended to add addition of parameters that need to be manipulated, the most likely to be done immediately is the use of cameras and image processing to find out how healthy the plants are being cultivated. So that preventive measures can be carried out when the plants are in a bad condition. Besides image processing can help determine the harvest period, especially for fruits.

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