Smart system for future agricultures report:

Arduino based Group Project

Introduction to Modern Agriculture problem:

Figure 1: A farmer in PPE spraying pesticide on crops.

Agriculture plays a vital role in the growth and prosperity of humanity by providing food and resources to humanity. However, in present day, modern agriculture methods are inefficient and do not solve existing problems that contribute to global issues such as global warming, overuses of finite resources and global famine. The first issue of the modern process is that it requires a lot of water usage, most of the water is used on fertilisers and nutrients as well as for moisturising soil where water can be evaporated easily depending on unpredictable weather conditions. Secondly, the traditional process required a tremendous amount of land to grow crops, in the United Kingdom, more than 72% of the land is used for agriculture which means that only 28% are only available for other purposes which are inefficient uses of land. Thirdly, most of the traditional methods are in open space which means that it is prone to environmental and natural factors so there is high uncertainty and risks. For environmental factors, there are seasonal changes throughout the year so it could reduce the yield of the crop and the overall quality. In unpredictable adverse weather conditions can affect all the crops on the field like excessive rain or snow which will significantly affect dominant crops yield. In natural factors, it is undeniable to protect crops from pests and fungal attacks, so chemicals and pesticides have been used more often to protect plants as well as increase yield. However, heavy uses of chemicals contribute to problems to both the natural and human sides. Pests start to develop resistance to a pesticide which then involve more usage of stronger pesticide. On the human side, pesticides can cause acute to chronic health issues for farmers which is the reason why in many developed countries most farmers wear PPE as shown in ***Figure 1****.* However, in developing countries such as Thailand where PPE are costly to local farmers, many unfortunate farmers are left exposed to a chemical directly. For consumers, the consumption of plants contaminated with chemicals will have long-term health effects such as cancer. We tend to not be aware of problems stacked up behind us all the time in all the food we eat which leads us to the development of a system for new agriculture methods.

Literature and technology review:

Figure 2: Vertical farm (top). Smart garden in kitchen (bottom)

Traditional agricultures are inefficient when considering that there are more negative impacts than positive ones. Yet, new ideas and concepts have been proposed such as vertical farming and smart garden as shown in ***Figure 2***. Vertical farming (VF) is the practice of growing plants vertically in a closed and controlled environment. A smart garden is an enhancement in farming or gardening by implementing a computerised monitor and control system. Although some researchers suggest vertical farming does not have computerised and monitoring systems *(Maharashtra, 2018*) many studies demonstrate the benefits of vertical farming towards agricultural industries. For example, research and evaluation on vertical farming in the real-world application have shown that vertical farming can lead to increase production and availability in crops which can reduce the use of pesticides and harmful chemicals (*Garg et al, 2014*). These findings also suggest similarly that with an increase in food supply it can be in the urban area where length transportation is shorted resulted in lower emission of carbon dioxide. Apart from the environmental value, the vertical farm also promotes growth in economies and social improvement among the urban population, there will be more new emerging professional jobs in biochemistry and engineering as well traditional workers which means that there is more growth in the economy by promoting a better quality of life among urbanise population (*Benke & Tomkins, 2017*). These researches have pointed out insight on the benefits of vertical farming toward the environment, economy, and society. Nevertheless, the main limitation of vertical farming in a developing country is the lack of knowledge of development and implementation monitoring and control systems. This is a great opportunity for us as a team to design and create a prototype of the smart garden system for vertical farming.

Madhuri Shrikant Sonawane. Status of Vertical Farming in India. Int. Arch. App. Sci. Technol; Vol 9 [4] December 2018. 122-125.

Garg, Anirudh, and Rekha Balodi. "Recent trends in agriculture: vertical farming and organic farming." Adv Plants Agric Res 1.4 (2014): 00023.

Benke, Kurt, and Bruce Tomkins. "Future food-production systems: vertical farming and controlled-environment agriculture." Sustainability: Science, Practice and Policy 13.1 (2017): 13-26.

Development:

Communication methods in primary and secondary model:

The model for communication that we choose is primary and secondary (master and slave). The primary node will send a command to a secondary node to have the action done in other words primary node is a brain that controls everyone in the lower hierarchy. However, the model required a robust communication medium to carry data along, so we experimented with two methods which are wire and radio communication. Radio communication can be done by using nRF24L01 as shown in ***Figure 3***, but it cannot establish a stable communication line as it is prone to noise. Most of the time, when data is encoded and sent wireless the data integrity decreases which can lead to false communication. Therefore, the approach we take is wired communication in serial using I2C protocol. Serial communication can establish a secure and consistent communication line by maintaining data integrity as it is less prone to noise from EMF with relatively low latency. Therefore, it is more ideal to use primary and secondary model.

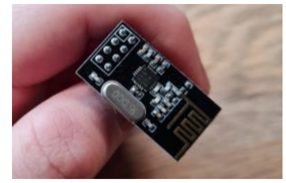

Figure 3: nRF24L01 Transceiver Module.

Shift Register in LCD:

Traditionally, LCD required 6 digital pins to work properly. We decided to save up a digital pin by implementing a 74HC595 shift register which only required 3 digital pins. However, unlike this one the normal LCD connection uses a library called *<LiquidCrystal.h>* but we must use *<LiquidCrystal_74HC595.h>* which is specially written for library LCD with a shift register. We took a very long time to discover the *<LiquidCrystal_74HC595.h>* library and the way it is set up in the code is different as well. Therefore, with previous knowledge of shift register from the first project making this development process went smoothly and successfully.

Electromagnetic field (EMF) Interference:

These are the most complicated problems we encountered. First, we did not realise that the problem is from EMF but instead we suspected it to be a 'bouncing' effect in the circuit when we send a digital signal to a relay to open a water pump but there is fluctuation in analogue value especially on the capacitive soil sensor which the value deviated up to 30 values which make the whole circuit unfunctional. So, we decided to redesign all the circuits by implementing a new layout where we isolate relay with external power into secondary Arduino while primary Arduino is packed with components that are sensitive to noise and EMF interference. When the isolation process is completed, we have decided to remove the relay and implement MOSFET which is a transistor that acts as a switch along with a 100 µf polarised capacitor to make a circuit 'smoother' as shown in ***Figure 4***. Unfortunately, the implementation did not reduce the effect of value fluctuation. At this point we were feeling hopeless about the fluctuation of value, we even decided to add the value up along as the water pump turned on to reduce the fluctuation. The discovery of EMF came by accident when we sperate two Arduino apart as we want to make a change in the circuit while but both are powered by USB and all components were running, the value of soil moisture recovered from the effect so we realised that the water pump has a solenoid inside which create a magnetic field and when placed near to Arduino EMF cause the fluctuation in the circuit resulting in a change in value. Therefore, to suppress EMF, we put a water pump fully submerged in water which greatly reduces interference to zero.

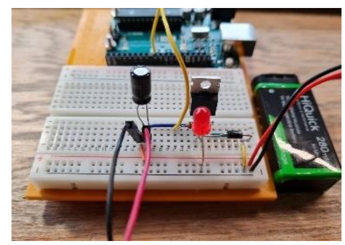

Figure 4: Fail implementation of noise reduction in the circuit using single MOSFET and single 100 µf polarised capacitor.

Light intensity data collection:

In this experimental research process, as shown in ***Figure 5***, we decided to use one standalone Arduino that has no connection to the primary & secondary. We used six ambient light sensor which is special LDR that is safer to use to collect light intensity data throughout the day, the sampling rate is one minute per one data set to prevent overflow of the data in *.csv* file format. We write a special Python script in Visual Studio Code that allows us to collect data from the Arduino and record into *.csv* format so data can be imported to Microsoft Excel to be processed and analysed. Therefore, light intensity data to build a probabilistic model of light intensity using basic Sigmoid function $S(x) = \frac{1}{1+e^{-x}}$ for making basic prediction which can improve prediction in light detection system.

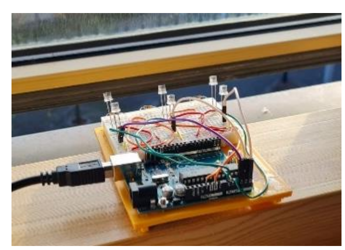

Figure 5: Light collection module made from 6 LDRs at the window to collect data.

Final Prototype Implementation:

Primary Arduino:

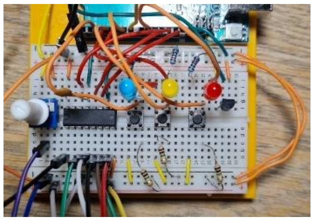

Figure 6: Buttons layout for manual control.

In terms of the function, primary Arduino is designed to be a medium between a user and functional hardware. There are three buttons dedicated to specific controls of the system on secondary Arduino, each has an individual unique LED which will light to indicate the process. As shown in ***Figure 6***, firstly a button on the left with a blue LED is used for manual dispense of water to the plant, Secondly, a button on the middle with yellow LED is used for turning on UV light on or off. Lastly, the button on the right with red LED is used to activate manual control on water and UV light, a red light will light up to show that the system is in manual control, this system is designed to prevent any accidental control on the system when in automatic which can cause an error from overriding or data collision in the system as well as causing unwanted damage the plant. TMP-36 sensor on the top right of the board is introduced to measure air temperature supplied with 5V. LCD is installed in front of the primary Arduino; LCD will display soil moisture in percentage, air temperature as well as the current model of the system. The intensity of an LCD pixel can also be adjusted using a potentiometer on the middle far left.

In terms of the working principle, in serial communication, when each button is pressed or a value from the sensor relative to the clock signal, a signal is sent along to the Arduino which then encode specific button signal into bytes which then sent along a serial wire to the secondary Arduino, a signal is decoded and then the program will read the bytes to perform a task. Arduino uses the I2C protocol which controls the communication by synchronising the two Arduinos together and trying to prevent data collision. For the LCD we use a shift register that pushes a stream of bits along with the pins in either the least significant bit first (right to left) or the most significant bit first (left to right) to the LCD pins. A ceramic capacitor is added to the shift register on power and output to enable pins to reduce the voltage pulsion in the circuit on LCD. Capacitive soil moisture sensors measure the moisture content in the soil which required constant constraint to get accurate calibration. However, the process is hard to replicate and follow up as it required different soil in different moisture content, so we decided to use the data from the internet. To reduce noise in the circuit we supplied it 3.3 V. TMP-36 uses a diode to measure a small change of analogue voltage and is later processed by a formula. Therefore, both TMP-36 and capacitive uses a formula given in ***Figure 8*** to calculate and output value.

Secondary Arduino:

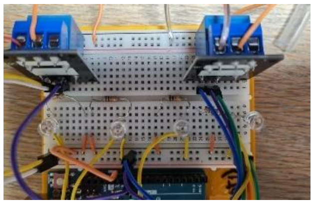

Figure 7: Ambient light sensors layout along with two relays.

In terms of functionality, when in automatic mode a system will act independently by using the data it obtains both from themselves and primary Arduino. The local data that is obtained is an ambient light sensor which is a photoresistor or LDR that does not contain harmful chemicals like a traditional photoresistor. In the light detection system, four ambient light sensors are installed as shown in ***Figure 7***, the system will take values and average them, if the value of light intensity is high then a UV light strip will turn on automatically. For soil moisture, the primary Arduino will send a signal for activating the water pump if the value is below 40%. When a signal is received by the secondary Arduino a relay will turn on so a water pump can dispense water until moisture value is reached more than 40%. In manual mode, secondary Arduino will deactivate all its automatic functions which include light detection system and watering system, and the system will be fully ready for receiving a command from a primary Arduino.

In terms of the working principles, starting from the light detection system. Four ambient light sensors will take in value and average it, then values are inputted into a probabilistic model that has been modelled by data we collected from the light data collection system in ***Figure 5*** which the system can make an accurate prediction on the light environment to produce appropriate action. Each ambient light sensor has a 10k Ω resistor to prevent the ‘bouncing’ effect on the circuit. In the watering system, the reason that we processed moisture value in primary Arduino is to reduce transmission size, The value for encoding moisture value is 8 bits but by building threshold function which only produces a Boolean signal, it only required 1 bit which greatly reduces data trafficking and data collision. A relay is used as a switch that isolates circuits with different power supplies from each other to prevent damage. When a digital signal is sent to the relay it activates an electromagnet inside which completes the circuit on the UV light strip and water pump with a 9V power supply.

$$M = \frac{m_{wet} - m_{dry}}{m_{dry}} \times 100$$

M = moisture content (%)
m_{wet} = weight of aggregate in stockpile condition (g)
m_{dry} = weight aggregate in saturated surface dry condition (g)

$$T = \left(\left(\frac{a \times V_{in}}{1024} \right) - 0.5 \right) \times 100$$

T = temperature (°C)
V_{in} = supplied voltage
a = analogue value

Figure 8: Formula for calculate moisture content in percentage (left). Formula for calculating Celsius from TMP-36 sensor (right).

Improvement:

In term of the hardware, there are some faulty but does not have a significant effect on the primary Arduino is that the power is shared between buttons and LCD display. This means that when a button has pressed the brightness of the LCD will reduce a little bit as the button provides a new complete circuit path which causes a change in voltage. The solution would be to isolate two systems from each other, an LCD will run on a 5V area while buttons and LEDs run on 3.3V with both having their own separate ground (earth). The additional side feature could be added as well. For instance, a battery level indicator could be implemented which required connecting a wire to diode and resistor directly from the 9V lines resistors to analogue pins. Furthermore, a water level indicator could be added as well by using a water level sensor or also known as a rainwater sensor or in simple approach by using an ultrasonic sensor to measure the height of the water in the container but could be faulty if the water level is unstable from shaking or pushing.

Conclusion:

Many problems arise in today's agriculture method that creates many negative impacts either directly or indirectly to everyone. Although new concepts of agriculture have been developed and well researched it is still lacking a system to make this a reality which this opportunity inspires us to develop this project using the knowledge and resources in Computer Science. As a result, we develop a system using an open-source microcontroller called Arduino UNO R3 that can work along with other open-source and common electronic hardware which opens the choices of implementation. We have carefully designed both hardware and software with our best ability by designing circuit layout, communication model which relies on primary and secondary (master & slave) model which allows it to have a robust communication system and pick best hardware choices to produce the best efficient monitoring and control system that creates an optimal environment for plant or crops to grow. Besides the project as a team, we have learned many new technical skills in electronics and programming and sharpened existing knowledge along creating this project. Apart from practical skills, we have learned management skills which include job assignments, time management and team communication. Lastly, as a team, we would like to express sincere gratitude to anyone who read this report and we would like to dedicate this project to the agriculture industries to develop and adopt this technology to start making a change in agriculture for humanity and a sustainable future.

Appendix:

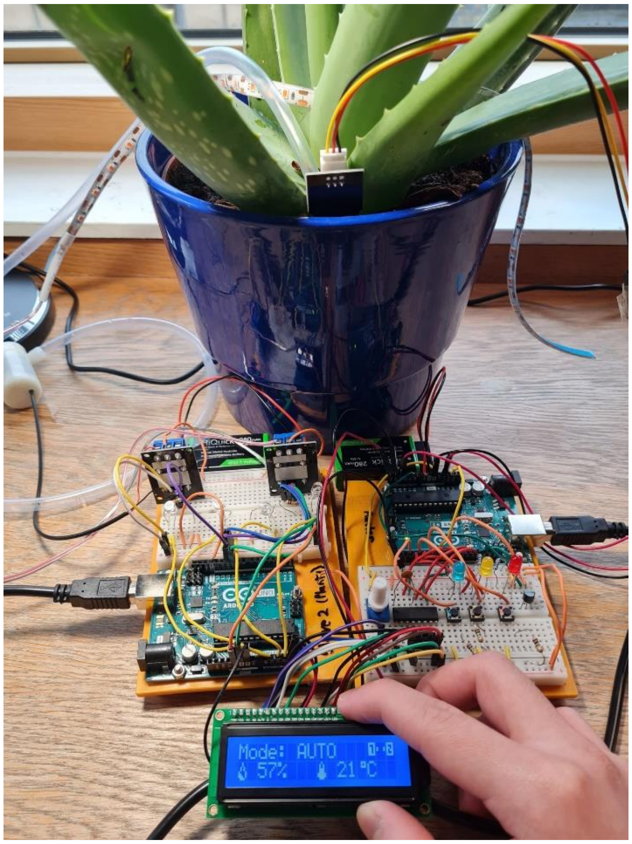

Figure 9: Full view of a system (without water tank) operating in automatic mode during the daytime. All the important data are displayed on the LCD.

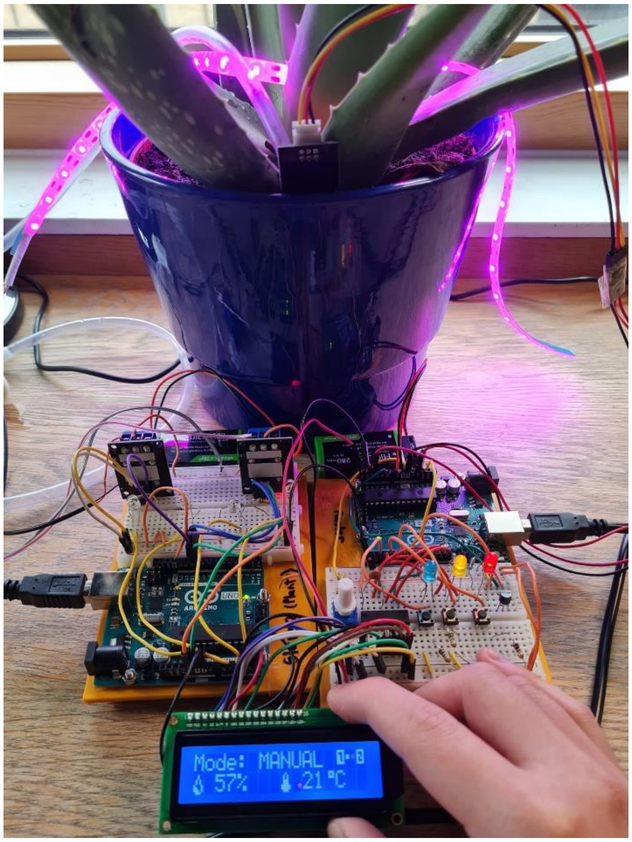

Figure 10: Full view of a system (without water tank) operating in manual mode by turning UV light on only during the daytime.

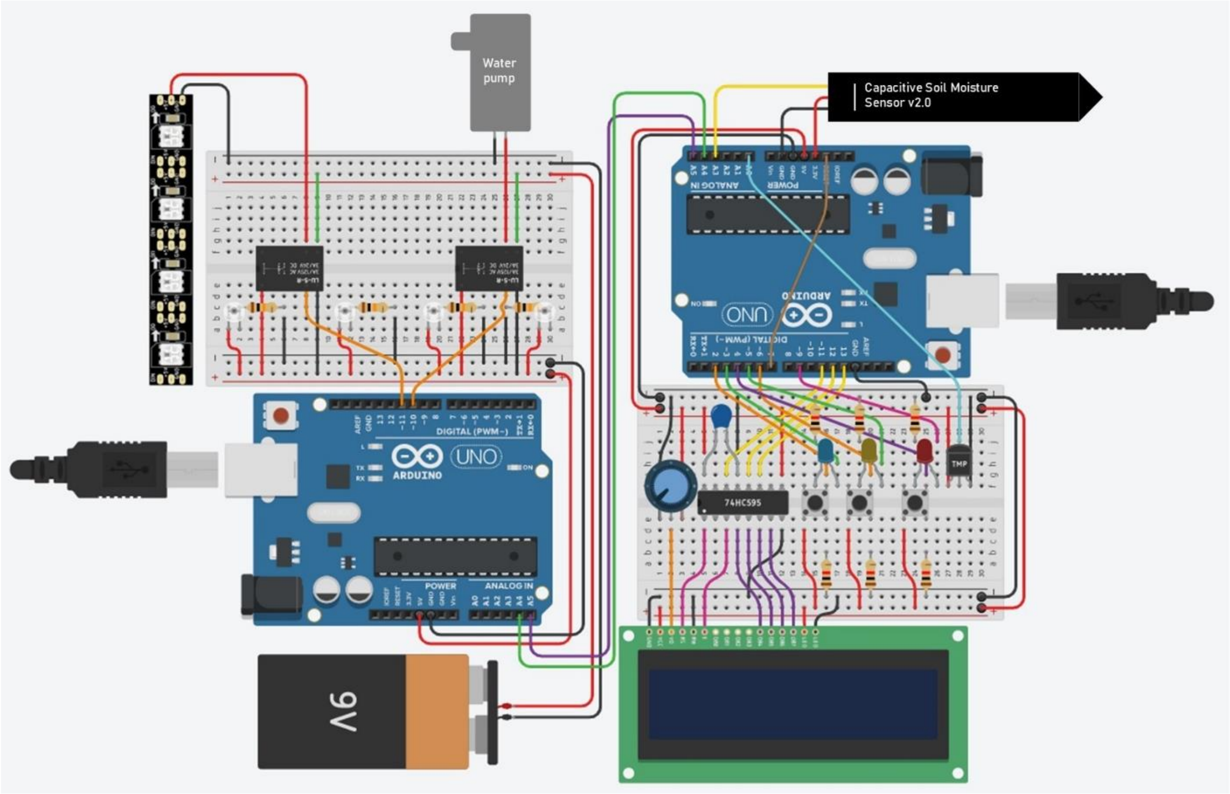

Figure 11: A schematic created by Tinkercad. Secondary Arduino (left) and Primary Arduino (right).