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Urban Farming Prototype Design and Development with IoT System using STEMSEL and Runlinc IDE

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ABSTRACT

Urban farming technology is getting more acceptable with the increase in population. Running urban farming with IoT becomes more important as urban farming has many constraints. This project aimed to design and develop an automated urban farming system operated with an IoT system using Science Technology Engineering Maths Social Enterprise Learning Artificial Intelligence (STEMSEL AI), and Runlinc Integrated Development Environment (IDE) to ease urban farming. The prototype consists of three major components: the structural part, the water piping system, and the IoT operating system. Idea generation was applied to develop various conceptual designs in the structural component. Concept evaluation was performed to choose the final design. The IoT operation system was designed and developed using the STEMSEL module and Runlinc IDE. A few challenges were identified throughout the design process. Overall, STEMSEL is much simpler and easier to set up than other controllers.

1. Introduction

Over the decades, the growth in the worldwide population has brought various challenges to the food production industry, especially the agriculture industry. The population growth resulted in huge demand for land occupation for agricultural food production. It is also reported that most of these populations reside in cities, thus causing another difficulty in transporting of food from rural areas where the agriculture industry is located to the vegetable market and food storage.

The human labour involved in food production in the agriculture industry is another vital issue that must not be neglected. Human labour has limited the growth of agricultural food production. Traditional farming via soil, fertiliser and pesticide is time and resources consuming. It will involve human activities such as ploughing the field, seeding, picking out the weeds, etc. The traditional

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farming method will require a huge amount of labour, in wherein Malaysian context, these labours primarily consist of foreign workers.

The Intergovernmental Panel on Climate Change (IPCC) reported that the warming of the climate system is unequivocal, and climate change will affect the natural human system and biological systems, including plants. Global climate change has also brought negative impacts to the agriculture industry. This issue can be tackled and overcome by implementing an IoT system in the agriculture system related to urban farming technology.

The main aim of this project is to design and develop a small-scale urban farming prototype with IoT implementation. Such an aim can be achieved by designing and building a prototype of urban farming. In addition, the IoT operating system using Science Technology Engineering Maths Social Enterprise Learning (STEMSEL) module and Runlinc Integrated Development Environment (IDE) is to be designed and implemented to realise the automatic control of the irrigation system through sensors and even the use of the internet.

2. Urban Farming

Urban farming is about growing or producing food in a city. Urban farming is regarded as an effort to provide sufficient food for everyone without worrying about the constraint brought by the limitation and availability of land to grow crops. In other words, urban farming can be the potential solution to ensure adequacy and secure food supply in metropolitan cities [1]. Urban farming has been a topic of discussion since the 1990s and with more research presented in the 2000s [2-5].

Urban farming has been shown to affect the city's development positively. In addition to the food supply mentioned earlier, urban farming also improves the landscape of the city, create job opportunities, and improves the environmental quality of buildings [6-8].

There are currently few urban farming technologies available. Aeroponic is popular indoor farming that uses no soil and minimal water [9]. The technology was first developed in the 1940s and became popular because of its efficiency and ability to produce edible crops in small and confined spaces. The method is known for its ability to reduce water consumption. The technique differs from aquaponics and hydroponic as it suspends the plant root to continuous water flow. The suspended roots are exposed to the surrounding air, allowing them to access more oxygen than hydroponic. The tools required for aeroponic farming are sprayers, forgers, and misters to produce a fine mist solution that could transport the nutrients to the roots.

Urban farming is available in various parts of the world. For example, in New York City, Aerofarm LLC runs a business using Aeroponic (Figure 1) [10]. Aerofram LLC applies horticulture technic that intersects with engineering, food safety, data science and nutrition. This aeroponic farm had been reported to be successful in improving harvest time for certain crops from 30-40 days to 12-14 days.

Fig. 1. Aeroponic farm by Aerofarm LLC [10]

The urban population in Malaysia has increased from 35.9% to 78.2% in 50 years from 1973 to 2022 [11]. Such increase in the population resulted from urban migration, expansion of townships and establishment of new townships, and course, immigration [12]. The rise in the Malaysian population also increased food demand. As the population increases, urban farming is gaining popularity to utilise the land space entirely, but to cater to the food requirement of the urban. Urban farming can help local communities in both economic and social ways. Some various companies and organisations run urban farming in Malaysia.

CityFarm Malaysia is a company that aims to inspire more city farmers to grow vegetables locally [13]. Showing in Figure 2, the company applied an indoor hydroponic method. The vegetables were grown in a confined space that provided a conducive environment for plant growth. HAVVA Agrotech Sdn Bhd is another company based in Penang that fully utilised and optimised space to grow vegetables two times faster [14]. HAVVA Agrotech, shown in Figure 3, integrated hydroponic, aquaculture, vertical farming, fermionic and aeroponic into a single, effective and efficient urban farming technology.

Fig. 2. CityFarm Malaysia [13]

Fig. 3. HAVVA Agrotech [14]

Research has also shown that, despite its popularity, farmers still face challenges in urban framing, such as weather conditions, land availability, and financial issues [15,16]. Certain urban areas are vulnerable to weather changes. For example, Kuala Lumpur would face challenges during bad weather conditions. This is in line with Jega *et al.,* [15], where flood is the most natural hazard affecting the agricultural crop sector, impacting crops, livestock, and agricultural assets. Therefore, urban farmers must incorporate technologies in farming to ensure maximum harvest throughout the year.

3. IoT Systems with STEMSEL Module and Runlinc IDE

Digital urban agriculture, referred to as "a large-scale extension of urban agriculture", is an urban farming system that incorporates digital systems such as software or automation in operation [17].

Urban farming methods such as aeroponic will not be efficient if all the systems are run and controlled manually. There needs to be an automated system to run the urban farming system, such as lighting, irrigation, temperature or humidity measurement and monitoring, and many others. With the current technology, these automated systems can be efficiently designed, configured and executed with the help of IoT. For example, Rafi *et al.,* [18] developed a system for monitoring temperature, humidity and soil moisture using ThingSpeak in combination with Arduino software to program NodeMCU as the controller for the irrigation system.

Runlinc IDE is a webpage-based AI and IoT application platform that works in any browser [19,20]. It supports Science Technology Engineering Maths Social Enterprise Learning (STEMSEL) microcomputer with a microchip that enables the interfacing between the STEMSEL module and Runlinc IDE on the web page. The operation of Runlinc IDE on the webpage provided a new horizon and massive potential for remote control of application devices deployed in IoT networks. Figure 4 illustrates a STEMSEL module and the specific Runlinc IDE webpage.

Fig. 4. STEMSEL module and Typical Runlinc IDE webpage

4. Methodology

The project started with the project definition, information gathering and background research on urban farming using aeroponic and IoT systems and STEMSEL and Runlinc IDE. The project continues with developing a methodology that comprised the conceptual designs, identifying the equipment and components for the prototype and configuration of the working principle for the system via the STEMSEL module and Runlinc IDE. Figure 5 shows the process flow chart throughout the design and development of the automated aeroponic system using STEMSEL and Runlinc IDE.

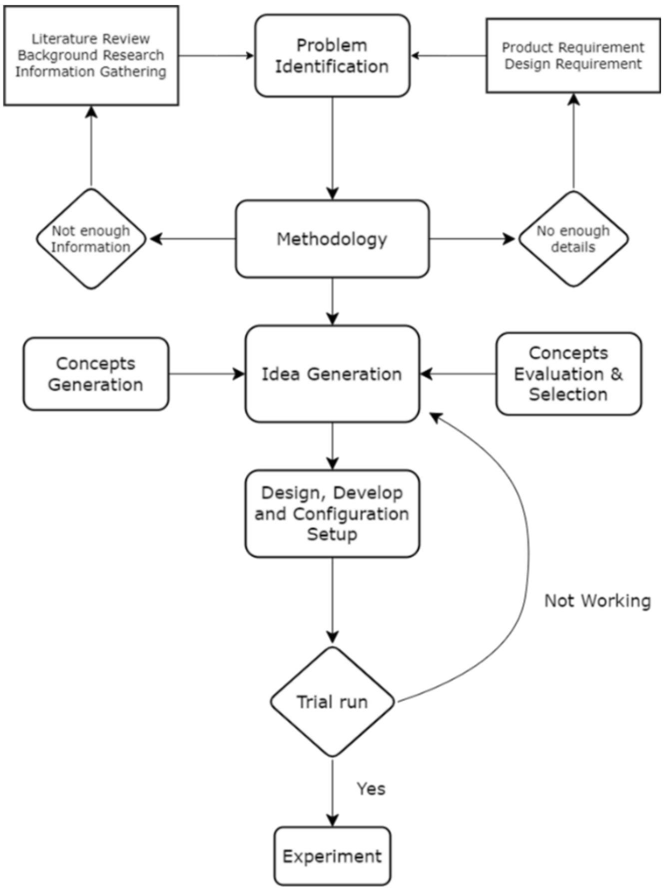


Fig. 5. Design and development of prototype flow chart

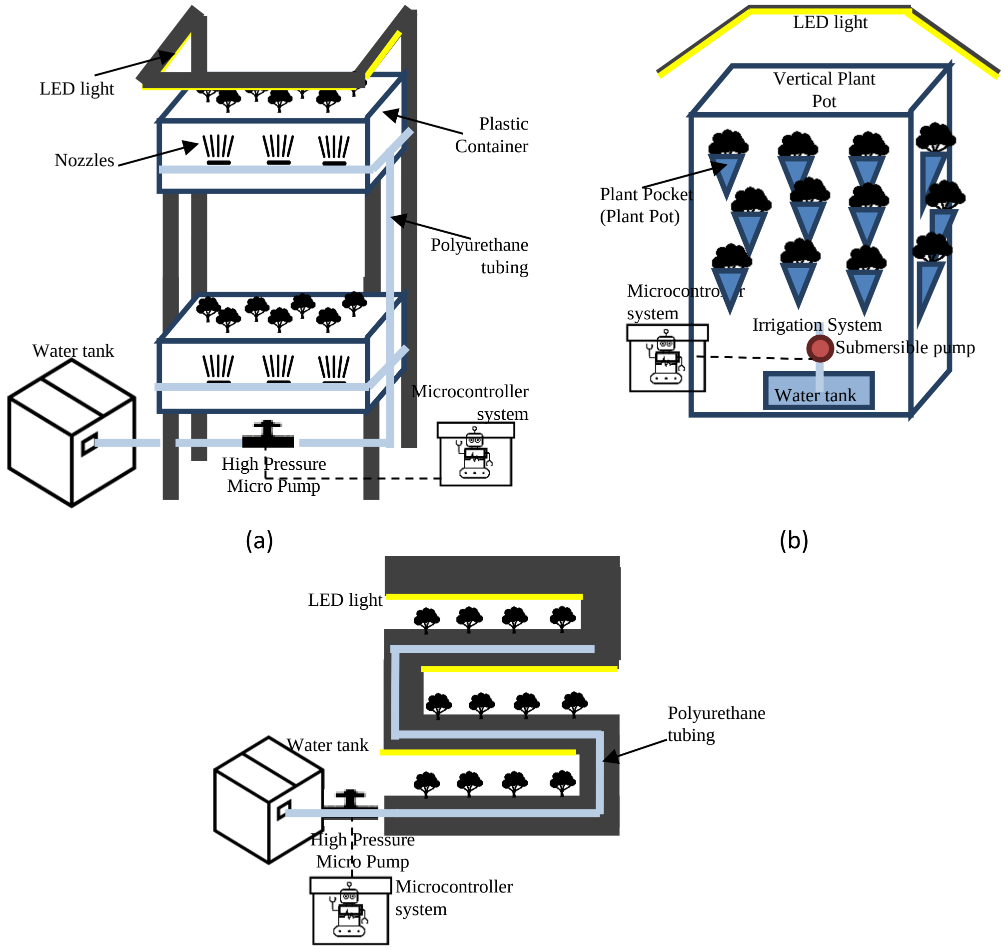
The STEMSEL module functions as the microcontroller for the aeroponic farm, which allows the Internet of Things (IoT) control of farming. The STEMSEL module consists of Light-Dependent Resistors (LDR), Thermistor, a Temperature sensor, a relay, and a Direct Current motor. In addition, light intensity, humidity, temperature, and ultrasonic sensors are also installed in the module.

5. Results and Discussions

The results are discussed based on two areas: the development of the prototype and the development of the IoT operating systems. The prototype design consisted of three major categories: the structural design, the water pipe structure, and the IoT automated system design with STEMSEL module and Runlinc IDE.

5.1 Structural Design

The idea generation phase involved conceptual designs, evaluation, and selection. In the conceptual design generation phase, three different designs were generated via sketching, shown in Figure 6.



(a) (b)

(c)

Fig. 6. Concept 1 to Concept 3 (a, b and c) developed via Sketching

These conceptual designs were later evaluated using the Pugh matrix. Table 1 illustrates the Pugh matrix, and the results indicated that Conceptual Design 1 is the best of all three designs. All three designs addressed the need for vertical farming and LED lights as the source for photosynthesis. The microcontroller is strategically placed in the design to control the system. In terms of the ease of installation, and cost, Conceptual Design 1 seems to be better than the other two, as the components are not built on top of each other, which causes additional design considerations in terms of dimension, materials and supports. More importantly, Conceptual Design 1 is relatively lightweight compared to the other two, where more weight contributes to the Vertical Plant Pot and the housing to the Polyurethane tubing. Therefore, the first objective is achieved.

Table 1
Pugh matrix for Concept Evaluation and Selection

Selection criteria	Concept 1	Concept 2	Concept 3
Space Optimisation	0	+1	-1
Lightweight	0	-1	-1
Cheap	+1	-1	-1
Easy to disassemble	+1	0	-1
Vertical	+1	+1	-1
LED Lights	+1	+1	+1
Outdoor	+1	+1	+1
Total	+5	+2	-3

Figure 7 illustrates the aeroponic prototype in complete structure 3D view and the corresponding engineering drawing of the complete assembly.

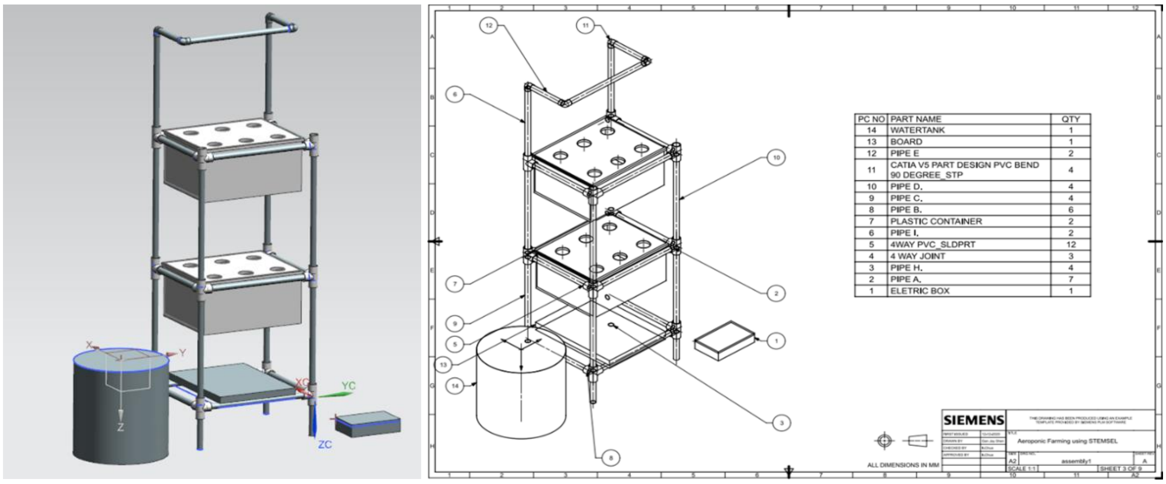


Fig. 7. Aeroponic prototype 3D view and engineering drawing

5.2 Water Piping System

The water piping system is another crucial design part of this automated aeroponic prototype. The primary role of the water pipe is to deliver the water to the plant. The water piping schematic diagram is shown in Figure 8. When the power is turned on, the pump will transport the water from the tank, which will be sprinkled out by the misting nozzles indicated by the red circles. The distance between the nozzles is 12 cm. The yellow arrows indicated the water flow direction.

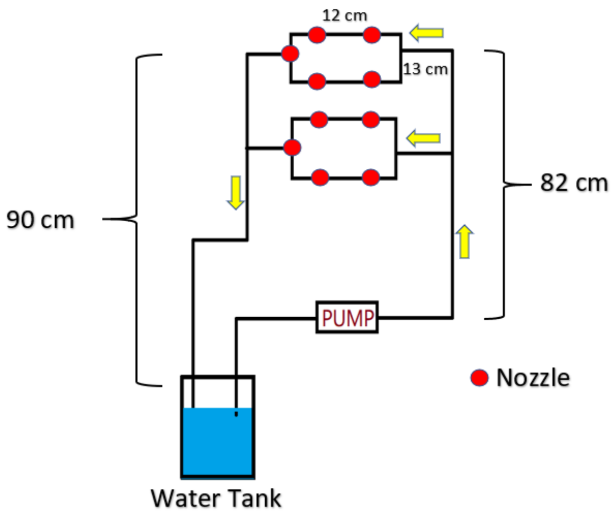


Fig. 8. Schematic diagram of water pipe and pump

The various IoT automated systems need to be installed and configured after designing the overall prototype body structure and water piping structure. This includes the LED lighting system, water pump and irrigation system, water level detection and alarm system, and temperature and humidity measurement system. The idea is illustrated in Figure 8 and Figure 9.

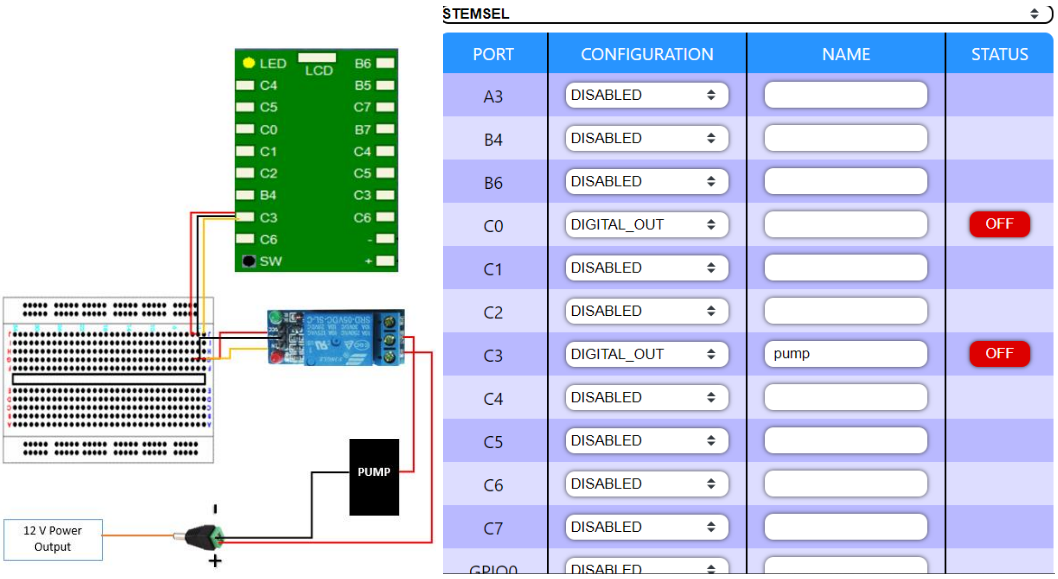


Fig. 9. Water pump configuration and Runlinc IDE configuration

The aeroponic system has a system to alert the user about the water level. The water used in the irrigation system is circulated, where the additional water from the plant watering will be channelled back to the water tank. Hence, the water level drops due to the absorption of water by the root only. The water level sensing is completed with a transmitter (at the bottom of the tank) and a receiver (at the middle of the tank). As the receiver is not wetted by water, the system recognises that the water level drops to the level needed to be refilled. Such coding is completed and incorporated into the STEMSEL system.

Apart from this, the automated system will include an automated LED operating system as part of the thermistor sensor system. Such a design is used to observe the surrounding temperature, as long hours of LED lighting may cause the LED to be overheated, which may affect the growth of the pants. Hence, as the ideal temperature for growing is between 15°C and 30°C, the thermistor sensor system, which is programmed in Java and HTML, is set to turn on a fan when the temperature is over 30°C [20]. Figure 10 and Figure 11 depict the prototype's final structure, including the STEMSEL Module and Runlinc IDE.

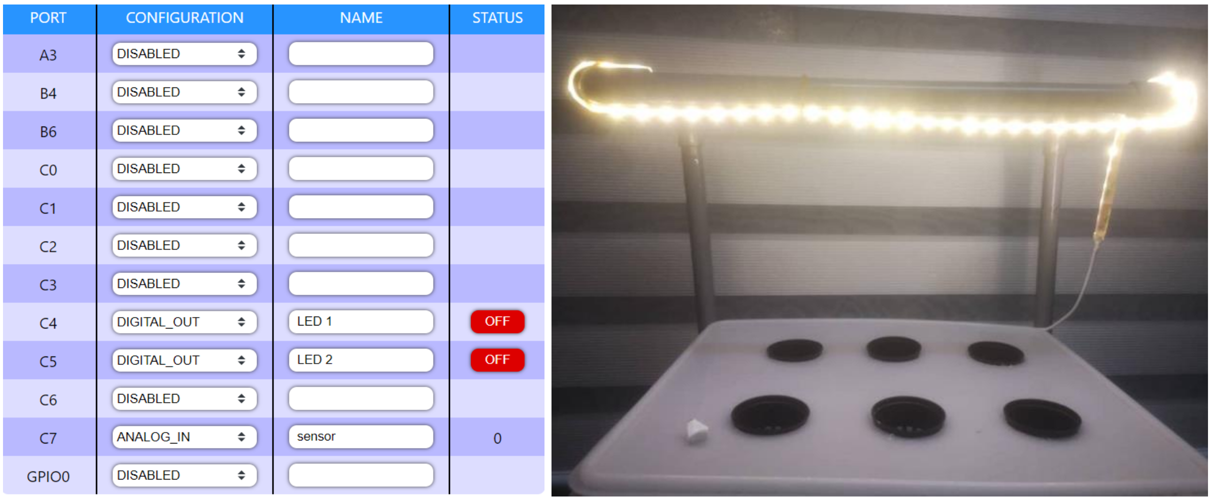


Fig. 10. Configuration of LED lighting system via Runlinc IDE and actual LED operating during low light environment

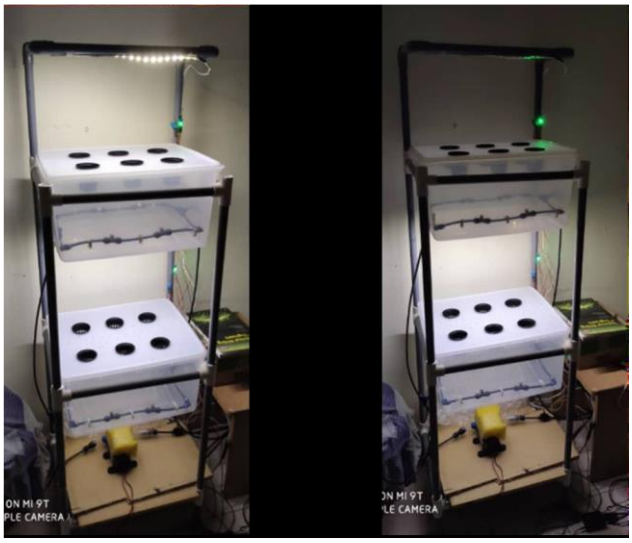


Fig. 11. Complete prototype with LED and water pump system supported by STEMSEL module and Runlinc IDE

The design and development of the structural and water piping system follow the normal engineering design process. The difference is in the IoT system setup and configuration. The STEMSEL module's setup process and configuration using Runlinc IDE is much easier and not so complicated than many other controllers. The programming of the STEMSEL module can be easily accomplished without much difficulty. The STEMSEL module can also be controlled via the Wi-Fi chip installed on the STEMSEL module. The designer can configure the settings and control the STEM module easily at any location as long as a Wi-Fi connection is available.

It should be noted that STEMSEL is relatively new in the market, and hence some of the features were incompatible with the STEMSEL [19]. For instance, the temperature and humidity sensors used in this project could not be connected directly due to the different pin configurations. Compared to

Arduino, where the sensors read the codes using the library, the data from this project's sensors were only taken once during the program's running. Nonetheless, such data reading also provided relatively descriptive information, with the only drawback that recursive running of the program was needed. Compared to Arduino, STEMSEL is observed to be more straightforward in the set-up process, with simpler coding and faster running time. Moreover, STEMSEL allows online control, which is yet to be available in other microchips, demonstrating the purpose of designing the objectives of this project.

6. Conclusion

Although Malaysia has vast land for the agriculture process, it should be noted that urban and vertical farming should also be paid attention to for potential future development. Such development is crucial to ensure the food chain sustainability in the country, as the country not only produces food for domestic use but also exports food to other countries.

STEMSEL module was applied as the controller for the system, and Runlinc IDE was used to configure the setting for the IoT system. The research demonstrated that STEMSEL was easier to be implemented based on its simplicity in coding and shorter set-up time. A complete operational prototype with an automated LED and water irrigation system is developed. The prototype could be further improved using a better pump to reduce noise and vibrations and LED light with higher Daily Light Integral values for a better photosynthesis process. The next step is to choose the appropriate vegetable to execute the farming. Implementing aeroponic farming in Malaysia yields a significant advantage in profit, country development and food supply sustainability and is worth further research and development.

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References
[1] Krishnan, Sarada, Dilip Nandwani, George Smith, and Vanaja Kankarta. "Sustainable urban agriculture: A growing solution to urban food deserts." *Organic Farming for Sustainable Agriculture* (2016): 325-340. https://doi.org/10.1007/978-3-319-26803-3_15
[2] Bryant, C. R., P. Deslauriers, and C. Marois. "Diversification strategies in agriculture in the rural-urban fringe." *New Dimensions in Agricultural Geography. Volume 5: Spatial Dimensions of Agriculture* (1992): 95-112.
[3] Lovell, Sarah Taylor. "Multifunctional urban agriculture for sustainable land use planning in the United States." *Sustainability* 2, no. 8 (2010): 2499-2522. https://doi.org/10.3390/su2082499
[4] Orsini, Francesco, Remi Kahane, Remi Nono-Womdim, and Giorgio Gianquinto. "Urban agriculture in the developing world: a review." *Agronomy for Sustainable Development* 33 (2013): 695-720. https://doi.org/10.1007/s13593-013-0143-z
[5] Thebo, Anne Louise, Pay Drechsel, and E. F. Lambin. "Global assessment of urban and peri-urban agriculture: irrigated and rainfed croplands." *Environmental Research Letters* 9, no. 11 (2014): 114002. https://doi.org/10.1088/1748-9326/9/11/114002
[6] Shamsudin, Mad Nasir, Golnaz Rezai, and Phuah Kit Teng. "Public attitude toward urban agriculture in Malaysia: Study on values and knowledge in Klang Valley." *Journal of Food Products Marketing* 20, no. sup1 (2014): 35-48. https://doi.org/10.1080/10454446.2014.921873
[7] Tiraieyari, Neda, and Azimi Hamzah. "Predictors of Youth Voluntary Participation in Urban Agriculture Programme in Malaysia: A Review." *Modern Applied Science* 9, no. 1 (2015): 1-11. https://doi.org/10.5539/mas.v9n1p1
[8] Tsuchiya, Kazuaki, Yuji Hara, and Danai Thaitakoo. "Linking food and land systems for sustainable peri-urban agriculture in Bangkok Metropolitan Region." *Landscape and Urban Planning* 143 (2015): 192-204. https://doi.org/10.1016/j.landurbplan.2015.07.008

[9] Maximum Yield. "Aeroponics." *Maximum Yield*. May 17, 2021. https://www.maximumyield.com/definition/137/aeroponics.
[10] AeroFarms. "Agriculture, Elevated." *AeroFarms* (2021). https://www.aerofarms.com/.
[11] Knoema. "Malaysia - Urban population as a share of total population." *Knoema*. Accessed March 28, 2023. https://knoema.com/atlas/Malaysia/Urban-population.
[12] CityFarm. "CityFarm" *CityFarm Malaysia,* accessed March, 2022. https://cityfarm.my/
[13] HAVVA. "HAVVA Redefines Farming." *HAVVA Agrotech* (2021). https://havva.my/?v=0f177369a3b7.
[14] Ishak, Norziha, Rosazlin Abdullah, Noor Sharina Mohd Rosli, Hazreenbdul Majid, Nur Sa'adah Abdul Halim, and Fazilah Ariffin. "Challenges of Urban Garden Initiatives for Food Security in Kuala Lumpur, Malaysia." *Quaestiones Geographicae* 41, no. 4 (2022): 57-72. https://doi.org/10.14746/quageo-2022-0038
[15] Jega, Abdussalam Adamu, Norsida Man, A. I. Latiff, and Kelly Wong Kai Seng. "Assessing agricultural losses of 2014/2015 flood disaster in Kelantan, Malaysia." *Journal of Agricultural Economics and Rural Development* 4, no. 1 (2018): 407-415.
[16] Zakaria, Siti Fairus, Rosli Mohamad Zin, Ismail Mohamad, Saeed Balubaid, Shaik Hussein Mydin, and E. M. Roodienyanto M. D. R. "The development of flood map in Malaysia." In *AIP Conference Proceedings*, vol. 1903, no. 1, p. 110006. AIP Publishing LLC, 2017. https://doi.org/10.1063/1.5011632
[17] Runlinc ."The runlinc IDE" *Runlinc, accessed March, 2022,* https://www.runlinc.com/
[18] Rafi, Mohamad Syafiq Mohd, Nur Irwany Ahmad, Diyya Hidayah Abd Rahman, Nazrul Azril Nazlan, Wan Azani Mustafa, Habibah Mokhtaruddin, Nurhafiza Azizan, and Norhanisa Kimpol. "Monitoring and Controlling Water Pumping System Using IoT for Agriculture Purpose." *Journal Of Advanced Research In Applied Mechanics* 62, no. 1 (2019): 1-15.
[19] Gopi, E. S., ed. *Machine Learning, Deep Learning and Computational Intelligence for Wireless Communication. Proceedings of MDCWC 2020*. Vol. 749. Springer Nature, 2021. https://doi.org/10.1007/978-981-16-0289-4
[20] Kuncoro, C. Bambang Dwi, Tandi Sutandi, Cornelia Adristi, and Yean-Der Kuan. "Aeroponics root chamber temperature conditioning design for smart mini-tuber potato seed cultivation." *Sustainability* 13, no. 9 (2021): 5140. https://doi.org/10.3390/su13095140