Design and implementation of ecoholistic vertiminaponic with automated control and internet of things based monitoring system for sustainable urban farming

H Sugeru1*, P Musa2 and M E E Miska3

1Urban and Smart Farming Laboratory, Department of Agrotechnology, Faculty of Industrial Technology, Gunadarma University, Kampus F6 Universitas Gunadarma Taman Puspa, Depok 16451 Indonesia
2Department of Computer System, Faculty of Computer Engineering, Gunadarma University, Kampus D Universitas Gunadarma Pondok Cina, Depok 16424 Indonesia
3Agrotechnology Intermediate Laboratory, Department of Agrotechnology, Faculty of Industrial Technology, Gunadarma University, Kampus F6 Universitas Gunadarma Taman Puspa, Depok 16451 Indonesia

*Corresponding author: herik_sugeru@staffgunadarma.ac.id

Abstract. The urban farming plant system is a type of plant that requires extra monitoring in its maintenance. Internet of Things is a concept whereby an object has ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. In otherwise, optimizing limited spaces in urban areas we can combine several cultivation technique as integrated urban farming consist of plant culture, aquaculture apiary, veterinary, etc. This study aims to create smartly integrated all those cultivations as one cycle system that we called Ecoholistic Vertiminaponic using automated control and monitoring applications on the systems by utilizing the Internet of Things using Android and Cloud smart phones. Applications on Android smart phones are made to be able to know the sensor data that exist on the Cloud and also control the lights, pumps, and fans on the vertiminaponic system through Cloud. Both tasks can be done remotely via an Android smart phone connected to the internet. By using this system, activities that should be done directly can be done remotely via the internet, including in the monitoring and control of plant systems. As the cycle of cultivation system Ecoholistic Vertiminaponic will support urban sustainable farming and its food self-sufficiency.

Keywords: Ecoholistic vertiminaponic, IoT, automated control, monitoring and control system

1. Introduction

Today, environmental problems have became crucial because there are a lot of damage widely found globally. People have to choose safety food for their health and also keep all process ecofriendly. “Back to Nature” has became healthy lifestyle spirit for all aspects included agriculture. Organic farming is one way that choose to support safety food and ecofriendly systems in agriculture. For the urban people there is limited area or field for planting. Therefore one of main problem to urban people is food security [1]. As suburban and urban satelite zone are growing and developing too agriculture field are decreasing slightly and affected agriculture yield in quantity [2]. Therefore urban have to cut
food supply chain dependency from suburban and satellite zone. Food dependency which is related to availability, distribution and consumption can be solved by using limited space in urban area as horticulture cultivation [3]. Then urban farming are advancing now and toward.

One of cultivation technique which can be used in urban farming is verticulture. In verticulture system cultivation is done vertically. It is good to maximize cultivation yield in limited space. We can integrate it with other cultivation techniques such as fisheries, aquaponics, veterinary, apiary, etc. The combination of verticulture and fisheries or aquaponics is called vertiminaponic. Rakocy et al. [4] explained that vertiminaponic cultivation system doesn’t need plant media like hydroponic system. Water can be supplied from water circulation of aquaponics [5]. Plant can absorb organic nutrition from fish ecosystem which is soluted in water circulation. This system production more effective than conventional system production at the same dimension area.

Internet of Things is a concept which is one object has ability to transfer data via internet and doesn’t need direct man to man or man to computer interaction. By using IoT activities can be done directly and remotely via internet. Monitoring is done by upload data from sensor to the cloud, then those sensory data can be read by smart phone application. In other hand, Internet of Things can be used as controlling activity by smart phone application remotely too. Using monitoring and automation systems farmer can monitor and control their planting everytime and everywhere. So this technology can help farmer to do several main activities in their cultivation and efficient in farming labor and time using.

As the implementation of Revolution of Industry 4.0, this is an integrated system for urban sustainable agriculture concept that combine verticulture, aquaponics, veterinary and environment management with Internet of Things based monitoring and control system that we called Ecohoolistic Vertiminaponic. This system is not only developed as limited space area cultivation scale but also can be implemented for wide scale cultivation.

2. Literature study

2.1. Verticulture
Verticulture term adapted from English which comes from the word vertical and culture which means the technique of plants cultivation vertically so that the planting uses a multilevel system. In the beginning this technique came from the idea of a vertical garden that was launched by a seed company in Switzerland around 1945 [6].

According to Andoko the main goal of applying verticulture techniques is how to use narrow land as optimally as possible [6]. Where by applying this verticultural technique the increase in the number of plants in a particular area can be multiplied by 3-10 times, depending on the model used. Sutarminingsih added that verticulture can be applied to areas with narrow land, especially in urban areas which are now on average become dense settlements [7].

Planting with verticulture techniques can provide aesthetic aspects because plants that appear in rows vertically can display shades of beauty. Therefore generally verticultural techniques are mostly carried out by retired housewives or adolescents for hobbies. Verticulture buildings in the yard of the household with various types of plants that line up indeed really captivate the eye and cause feelings of satisfaction and pride in the owner. Besides being able to display the beauty it does not mean that planting with verticulture technique cannot be applied for commercial purposes. With the premise that verticulture can multiply the number of plants and production, this technique can be economically accountable for commercial purposes. Investment is needed for the application of this verticulture technique is much higher than the conventional method [7].

2.2. Aquaponics
According to Diver [8], aquaponics is a combination of aquaculture and hydroponics to maintain fish and plants in a system that is interconnected. The waste produced by fish is used as fertilizer for
plants [9]. The interaction between fish and plants produces an ideal environment to grow so it is more productive than traditional methods [4].

Research on aquaponics was started by Virgin Island University since 1971, research began with the difficulty of maintaining freshwater fish and vegetables on semi-arid islands, Australia. The results of the study were then used as a basis for aquaponic systems for commercial purposes but the efforts to develop this system still experienced many new obstacles in the 1980s the aquaponics system began to expand [10]. Until the 1980s all efforts to combine aquaculture and hydroponics were not all successful, but a variety of innovations carried out have transformed aquaponic technology into one system for producing food ingredients [8]. Because aquaponics is energy efficient, prevent the discharge of waste into the environment, produce organic fertilizer for plants (better than chemicals), reuse wastewater through biofiltration and ensure food production through multi-culture, making aquaponics one of the role models for green technology [9].

On Aquaponic systems, nutrient-rich water flow from fish rearing media is used to fertilize hydroponic plants. This is good for fish because plant roots and rhizobacteria take nutrients from the water. Nutrients derived from urine, feces, and the rest of fish feed are contaminants that cause increased toxicity in maintenance media, but this waste water also provides liquid fertilizer to grow plants hydroponically. Conversely, hydroponic media functions as a biofilter, which absorbs ammonia, nitrate, nitrite and phosphorus so that clean water can be returned to the maintenance medium [8] Nitrifying bacteria found in hydroponic media have an important role in the nutrient cycle, without these microorganisms the entire system will not work. Ammonia and nitrite are toxic to fish, but nitrates are safer and are a form of nitrogen recommended for plant growth such as fruits and vegetables [4].

2.3. Organic fertilizer

Organic fertilizers are organic materials that generally come from plants or animals, added to the soil specifically as a source of nutrients, generally containing nitrogen (N) derived from plants and animals [11]. Minister of Agriculture Regulation No. 28 / Permentan / SR.130 / 5/2009 states that organic fertilizers are fertilizers derived from plant residues and animal waste that have been through an engineering process, in the form of solid or liquid and can be enriched with natural mineral materials or microbes that are beneficial in enriching nutrients, soil organic matter, improving physical, chemical and biological properties soil. Organic fertilizers have an elemental content, especially nitrogen (N), phosphorus (P), and very little potassium (K), but have other roles that greatly influence plant growth, development and health. At present most farmers still depend on inorganic fertilizers because they contain a number of nutrients in large quantities, whereas if inorganic fertilizers are used continuously it will have a negative impact on soil conditions [6]. Organic fertilizers are in solid and liquid forms.

Liquid organic fertilizer in addition to being able to improve the physical, chemical and biological properties of soil, also helps increase crop production, improves the quality of plant products, reduces the use of inorganic fertilizers and as an alternative to manure [10]. Plants absorb nutrients especially through the roots, but the leaves also have the ability to absorb nutrients. So there is a benefit if liquid fertilizer is not only given around the plants, but also in the leaves. The advantages of liquid organic fertilizer are nutrients contained in it more easily absorbed by plants [12].

The types of organic waste that can be processed into liquid organic fertilizer are new vegetable waste, leftover stale vegetables, leftover rice, leftover fish, chicken, eggshells, fruit waste such as grapes, orange peels, apples and others [13]. The raw material for liquid fertilizer is very good from organic waste, which is wet organic matter such as leftover fruit and vegetables. Besides being easily decomposed, this material is also rich in nutrients needed by plants. The higher the cellulose content of organic matter, the decomposition process will be longer [14].
2.4. Internet of things

The general definition of the Internet of Things is a network of several physical objects. The internet is not only a network of computers, but has developed into a network of devices of all types and sizes, vehicles, smart phones, household appliances, toys, cameras, medical instruments and industrial systems, animals, humans, buildings, all connected, all communicate & share information based on established protocols to achieve reorganization, positioning, tracking, secure monitoring & control & real-time online personal monitoring, online upgrades, process control & administration [15, 16].

Internet of Things (IoT) is a concept and paradigm that considers the widespread presence in a variety of things through wireless and wired connections with unique addressing schemes that can interact with each other and work with other things to create applications / new services and achieve common goals. In this context the challenges of research and development to create a smart world are enormous. A world where reality, digital and virtual converge to create smart environments that make energy, transportation, cities and many other regions smarter [15].

The Internet of Things is a new revolution of the Internet. Objects make themselves recognizable and acquire intelligence by making or activating context-related decisions because they can communicate information about the objects themselves. They can access information that has been collected by other things, or can be a complex service component. This transformation is in line with the emergence of cloud computing capabilities and the Internet transition to IPv6 with almost unlimited addressing capacity [15, 16].

As shown in figure 1, many things covered in Internet of Things which covered almost things as a part of human activities today and future. There are numerous real-world applications of the internet of things, ranging from consumer IoT and enterprise IoT to manufacturing and Industrial IoT (IIoT). IoT applications span numerous verticals, including automotive, telecom, and energy. In the consumer segment, for example, smart homes that are equipped with smart thermostats, smart appliances and connection of heating, lighting and electronic devices can be controlled remotely via computers and smart phones.

![Figure 1. Things covered in the Internet of Things](image)

2.5. IOsA (Internet of smart Agriculture)

The forms of internet use for agriculture include:Green House: Control micro-climate conditions to maximize fruit and vegetable production and quality, Compost: Control humidity and temperature
levels in alfalfa, straw, straw, etc. to prevent fungi and other microbial contaminants, Animal Husbandry/Animal Tracking: Location and identification of animals grazing on open grasslands or locations in large stables, Study of ventilation and air quality in livestock and detection of harmful gases from manure, Hereditary Care: Control of growing offspring conditions in animal farms to ensure continuity and health, Field monitoring: Reducing decay and plant waste with better monitoring, accurate data acquisition, and management of agricultural land, including better fertilization, electricity and watering control.

IoT has many applications, but today we will cover top 11 IoT Applications with uses. As we can see on figure 2, there are several uses of IoT. IoT are now become widely used for smart cities, smart health, smart industry, smart energy, smart transportation, smart agriculture, smart home, animal tracking and others application. And this research has conducted to develop one application for smart agriculture or smart farming.

![Application Areas of the Internet of Things](image)

**Figure 2. Application Areas of the Internet of Things**

2.6. Engineering design concept
Designing is a part of engineering activities which is an intellectual effort to fulfill certain demands in the best possible way. While the notion of engineering is the application of science and mathematics to utilize objects and energy in this nature, so that it is useful for humans in building activities, machinery, products, systems, and processes [17]. Conceptually design activities can be divided into (1) product design, (2) process design, and (3) engineering design.

3. Methods

3.1. Model design and assembly
This research consists of three part, namely: planning, analysis and design, implementation and testing. Design of Ecoholistic Vertiminaponic scheme is shown as figure 3. For monitoring and control of whole system first we did research planning and we analyzed everything we needed to build the system. Design was made as integrated system of vertiminaponic complex system, renewable energy system, biofertilizer processing system and IoT based monitoring and control system as shown in figure 3.
Figure 3. Monitoring and Control System Design for Ecolistic Vertiminaponic Scheme

3.1.1. Block diagram of ecolistic vertiminaponic (vertiminahol). Figure 4 shown Block Diagram of Vertiminahol System for urban farming. There are four main blocks of Vertiminahol System. The first block is Control System which consist of Sensing System and Plant/Process System. The function of those systems are sensor value reading and pump, lamp and fan controlling. The second block is Transmit Data and Main Control System, to adjust interblock communication media, trasmiting sensor value to the Cloud and to read control value and adjustment value from Cloud. The third block is Monitoring and Remote System which consist of Monitoring System (Android) and Remote System, to view sensing data and to control the system using Android smart phone application. The fourth block is Monitoring System (Website), to view data sensor, chart and database of sensing and controlling data.

Figure 4. Block Diagram of Vertiminahol

The mechanical design of hydroponic control system as part of ecolistic vertiminaponic (Vertiminahol) as shown in figure 5 consist of nutrients flow technique (NFT) complex system and its
monitoring and control system. This mechanical design was made to ensure that nutrients stock can be distributed to whole plants by its flow system. Monitoring and control system which is integrated to the NFT system was design and tested to operate the culture system running automatically or manually controlled system.

![Figure 5. Mechanical Design of Hydroponic Control System Part for Ecoholistic Vertiminaponic](image)

For the Control System we use microcontroller with electrical conductivity (EC) and temperature sensor for the nutrient stock. And for the actuator which can be controlled automatically or manually are lamps, pumps and fans. figure 6 shown mechanical design of whole schematic control system placement which has used in this research.

![Figure 6. Mechanical Design of whole Control System Placement](image)
3.1.2 Electronic circuit of EC and temperature sensor with client. Based on the circuit which is shown in figure 7, EC Sensor is connected to pin Analog A1, and connecting the sensor vcc (common collective voltage) to 5V electrical voltage. And also sensor ground to the microcontroller. Temperature sensor is connected to pin Digital 2, and connecting sensor vcc to 5V electrical voltage and sensor ground to the microcontroller ground.

![Figure 7. Circuit of EC and Temperature Sensor with Client.](image)

3.1.3. Electronic circuit of client and server communication server interface. Figure 8 shows the Arduino Yun (Client) Connection System to the Server via Wireless Serial Network. This circuit is made for Client in order to be communicable peer to peer (PTP) to the Server. Then Server is connected using Wi-Fi to the Router so it can communicate peer to peerly.

![Figure 8. Client and Server Connection Circuit.](image)
3.2. Block diagram of internet of things based monitoring and control system

In this research, system block which will be made are Monitoring and Remote System block. The Internet of Things based monitoring and Control system design is only done in the software subsystem. Software subsystem discuss how to make all elements in the system communicable in the program. Below is the application block diagram design of sensing data monitoring and pump, lamp and fan control system.

The figure 9 is block diagram of Internet of Things based monitoring and control system for Vertiminahol. The diagram show three main blocks, namely Android smart phone monitoring and control system application, Cloud service (ThingSpeak) and Information Provider and Control System using Raspberry PI. The application in the smart phone has function to read and send data to the Cloud service (ThingSpeak). The Cloud service (ThingSpeak) has function to receive and save data and also as the connector between monitoring and control system application to the information provider and control system. Information provider and control system function is sensory data sending and data reading in the cloud service (ThingSpeak) for actuator command for the pump, lamp and fans. Notice: in the red block, the system is made and has run or worked well in other research so will not be discussed here.

![Figure 9. Block Diagram of Internet of Things Based Monitoring and Control System](image)

3.2.1. Data storage in the thingspeak. In this research, ThingSpeak Service has function as Cloud base data storage. The result of sensory data reading will be saved in the ThingSpeak Service and then read by Android smart phone application for monitoring purpose. ThingSpeak also has function as control value saver which is sent from Android smart phone application, those control value will be read by microcontroller to control pump, lamp, and fans.

There is two channels with different function will be made in the ThingSpeak. The first channel consist of fields from sensory data from microcontroller. The second channel consist of fields from control value, system adjustment value and user e-mail with the password who send those control value.

The ThingSpeak is used because this platform provide free service for user who try to make system about sensory data and high capacity of data storage facility. Data storage capacity reach to 3,000,000 data with minimum data sending interval is 15 seconds. The advantage of ThingSpeak are uploaded data result appearance and access data using API with HTTP method.

3.2.2. Monitoring and control system application in the android smart phone. In this research, Android smart phone application has function to view sensory data in the ThingSpeak Cloud for user. The application will take data in the ThingSpeak Cloud periodically so the sensory data can be viewed continuously and real time. Others, Android smart phone application also has function to send control value to the ThingSpeak. In the application there is a part which give control command to the pump, lamp, and fans manually or automatically based on microcontroller.

Beside those two main functions above, the application in the Android smart phone also give notification according to the sensory data value which is received. For example if the ppm value is
very low then notification will appear at the Android smart phone monitor. Or other case, if the water temperature is overheated then notification will appear at the Android smart phone too. The application also has a part to set the system, such as pump timer function regulator, maximum temperature detection sensing so the fans will be turned on, or minimum and maximum ppm value limit so the notification will be appeared. The application also has log in form when it just opened before the user log in to the system. If the user has made user account so the user can log in to the system directly. But if there is no user account yet, user can register first and made the user account. Log in is needed to send the user e-mail and its password to the ThingSpeak, so we can know the person who has sent control command or has changed the system setting. The chart of ppm value, EC, water temperature, battery, and environment temperature will be viewed at the different menu so the user can check the last value of data in the system.

According to those application functions above, the application has six main parts or activities, namely:
1. Log in activity, it is used by user to log in to the system before they can monitor or control the Vertiminahol system.
2. Register activity, it is used by user to register and make new user account then they can log in to the system later.
3. Monitor activity, it is used by user to view sensory data from the ThingSpeak.
4. Control activity, it is used by user to control the pump, lamp, and fans manually or automatically as user like to do.
5. Configuration activity, it is used by user to set the system such as pump timer function regulator, maximum temperature detection sensing so the fans will be turned on, or minimum and maximum ppm value limit so the notification will be appeared.
6. Chart activity, it is used by user to view the chart of ppm value, EC, water temperature, battery, and environment temperature.

4. Results and discussion

In this part we will discuss the Internet of Things based monitoring and control system testing. Testing was done for the both two system block, namely Cloud block in the ThingSpeak and application block in the Android smart phone.

4.1 The result of internet of things based monitoring and control system

4.1.1 The result of data validity and accuracy testing. This testing was done to check data validity and accuracy which is obtained from ThingSpeak Cloud to the data view at the activity monitor in the Android smart phone application. Testing was done by viewing channel feed from channel 1, which consist of sensory data then compare it to the application view data. This testing was done five repetitions with five randomize sampling data to check if application view data correct or not, even its value or its field location. The Vertiminahol application appearances are shown below.

The Vertiminahol system interface appearance consist of register page, log in page, tools/option bar, monitoring page, and control button page. figure 10 shows Vertiminahol system interface appearance in simple. Data validity and accuracy testing was tested for the hydroponic and fertigation system. The next testing will be done to integrated system of urban farming. The result of data validity and accuracy testing are shown as figure 11 and 12 below. All variables which is monitored in this system can be displayed well.

In the fertigation monitoring system there are several variable are monitored, namely: temperature of water and micro climate, soil humidity, electrical conductivity (EC), water volume, nutrients stock pH, water pump status, nutrients pump status, agitator and its real time monitoring data record. In the figure 4.2 also shows that the system can display the graphic of each monitoring data as other appearance. In the fertigation control system we can adjust the minimum and maximum water level as
the range of pump activation signal. Others, we can also control or adjust the PPM control value, lamps and fans.

Figure 10. The Vertimahol System Interface Appearance

Figure 11. The result of data validity and accuracy for the fertigation system

Figure 12. The result of data validity and accuracy for the hydroponic system

Figure 12 shows the appearance of the hydroponic monitoring and control system. All of functions of this system are almost the same as the fertigation monitoring and control system. Plants, fishes and other objects condition in this system are shown as figure 13, 14, 15 and 16 below. Figure 13 shows one of vertiminaponic model that we can choose as plant integrated culture. Mainly, it consists of
aquaculture and plant culture complex system. Water from aquaculture is distributed to whole plants by its flow system and it will run to the main aquaculture box again. Figure 14 shows design of manure decomposer drum. The organic fertilizer, which is produced will be granule or liquid fertilizer. Figure 15 shows fishes condition in aquaculture. Fishes can grow normally. We can choose any fish for this culture but catfish is the most adaptive to the water condition. Figure 16 shows design and model of carriable vertiminaponic system that we can create for indoor or outdoor culture. We can also adjust the dimension of the model fit to the space area that we want culturing there.

Figure 13. Plants in the vertiminaponic system model

Figure 14. Organic waste or manure decomposer

Figure 15. Fish which is cultured in the vertiminaponic system model

Figure 16. Variation of the vertiminaponic system model
5. Conclusion

The Ecoholistic Vertiminaponic (Vertiminahol) has been designed as limited space agrocultivation solution in urban farming. System model design can be implemented well to integrate waste decomposition to be organic fertilizer (granule or liquid), verticulture, aquaponics, etc. This model can also be implemented for wide scale farming. Vertiminahol also designated with 4R concept (Reduce, Reuse, Recycle and Renewable) so it is relevant to the Green Policy. Integrated system of Internet of Things based monitoring and control system has been made and worked well and help user/farmer to monitor and control their cultivation remotely. Furthermore, it is needed to advance the research to specific nutrient sensor to control and set any plant nutrients especially for the essential elements even macro or micro elements.

References

[1] Indraprahasta G S 2013 Procedia Environmental Sciences 17 11 – 9
[2] La Rosa D, Barbarossa L and Privitera R and Francesco 2014 Land Use Policy 41 290–303
[3] Purwaningsih Y 2008 Jurnal Ekonomi Pembangunan 9(1) (in Indonesian language)
[4] Rackocy J E, Bailey D S, Shultz K A and Cole W M 2006 Development of an Aquaponic System for the Intensive Production of Tilapia and Hydroponic Vegetables (Kingshill, U.S Virgin Island: University of the Virgin Island Agricultural Experiment Station)
[5] Nugroho R A, Pambudi L T, Chilmawati D and Haditomo A H C 2012 Jurnal Saintek Perikanan 8(1) 46 – 51 (in Indonesian language)
[6] Andoko A 2004 Budidaya Cabai Merah Secara Verticulture Organik (Jakarta: Penebar Swadaya)
[7] Sutarningsih L 2007 Verticulture (Yogyakarta: Kanisius)
[8] Diver S 2006 Aquaponics – Integration of Hydroponics with Aquaculture (Australia: National Sustainable Agriculture Information Service)
[9] Wahap N, Estim A, Kian A Y S, Seno S and Mustafa S 2010 Producing Organic Fish and Mint in an Aquaponic System (Sabah, Malaysia: Borneo Marine Research Institue)
[10] Yuanita D 2010 Cara Pembuatan Pupuk Organik Cair http://staff.uny.ac.id/sites/default/files/pengabdian/dewi-yuanita-lestari-ssi-msc/carapembuatan-pupuk-organik-cair.pdf [2nd October 2016]
[11] Sutanto R 2002 Penerapan Pertanian Organik (Yogyakarta: Kanisius)
[12] Murbandono 1990 Membuat Kompos (Jakarta: Penebar Swadaya)
[13] Hadisuwito 2007 Membuat Kompos Cair (Jakarta: PT. Agromedia Pustaka)
[14] Purwendro dan Nurhidayat 2006 Mengolah Sampah untuk Pupuk Pestsida Organik (Jakarta: Penebar Swadaya)
[15] Patel K and Patel S 2016 Gujarat: International Journal of Engineering Science and Computing
[16] Vermesan O and Friess P 2013 Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems Norway: River publishers’ series in communications
[17] Bagiasna K and Yoewono S 1992 Proses-proses Nonkonvensional (ITB: Diktat Kuliah Mekanik II. Jurusan Teknik Mesin)