Internet of Things Technology for Greenhouse Monitoring and Management System Based on Wireless Sensor Network

by

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TABLE OF CONTENT

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LIST OF FIGURES

©This item is protected by original copyright

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LIST OF TABLES

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LIST OF ABBREVIATIONS

ADC	Analog Digital Conversion
AFH	Adaptive Frequency Hoping
AP	Access Point
API	Application Program Interface
CPU	Central Processing Unit
DAN	Desk Area Network
DVD	Digital Video Disk
dBm	Decibels
ES	Electromagnetic Spectrum
EDR	Enhanced Data Rate
FHSS	Frequency Hopping Spread Spectrum
GSM	Global System for Mobile communication
GUI	Graphical User Interface
HCL	Human Computer Interaction
HS	High Speed
IC	Integrated Circuit
IDE	Integrated Development
IoT	Internet of Things
IP	Internet Protocol
ISM	Industrial, Scientific and Medical
IT	Information Technology
LAN	Local Area Network
LCD	Liquid Crystal Display
LDR	Light Dependent Resistor
LED	Light Emitting Diode
LTE	Long-Term Evolution
MAC	Media Access Protocol
MQTT	Message Queue Telemetry Transport
OSI	Open System Interconnection
PAN	Personal Area Network
PAR	Photo-synthetically Active Radiation

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PC	Personal Computer
PIC	Peripheral Interface Controller
PLC	Programmable Logic Control
PLR	Packet Loss Rate
RX	Receiver
RF	Radio Frequency
RSSI	Received Signal Strength Indicator
SMS	Short Message Services
TX	Transmitter
USB	Universal Serial Bus
UV	Ultra Violet
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network
WSN	Wireless Sensor Network
6LoWPAN	IPv6 over low-power Wireless Personal Area Network

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LIST OF SYMBOL

CO_2	Carbon Dioxide
H_2O	Water
CH_2O	Carbohydrate
O_2	Oxygen

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Teknologi Internet Benda bagi Pemantauan dan Pengurusan Rumah Hijau Berdasarkan Rangkaian Penderia Tanpa Wayar

ABSTRAK

Perkembangan dalam teknologi pertanian memainkan peranan yang amat penting dalam pengeluaran hasil tanaman dari rumah hijau khusus bagi penanaman buah-buahan, bunga-bungaan atau sayur-sayuran yang mempunyai nilai komersial yang tinggi. Memantau dan memastikan tumbuhan mendapat nutrien yang secukupnya pada setiap fasa dalam kitaran pertumbuhan tanaman adalah amat penting untuk mengekalkan hasil dan kualiti pengeluaran yang terbaik. Walaubagaimanapun, pemantauan secara konvensional terhadap tanaman rumah hijau berskala besar adalah tidak efisien, melibatkan kos yang tinggi dan pengunaan tenaga buruh yang yang ramai. Projek ini memperkenalkan konsep penjadualan mengikut keperluan tanaman di setiap fasa pertumbuhan untuk meningkatkan keberkesanan penghasilan dan pengeluaran yang optimum. Konsep penjadualan ini juga merupakan satu sumbangan bagi projek penyelidikan yang dilaksanakan dan dipercayai tiada lagi kajian khusus berkaitan sistem automasi dalam konsep penjadualan mengikut kitaran dan fasa-fasa tertentu dalam tanaman. Beberapa pengukuran keadaan persekitaran rumah hijau perlu di cerap bagi melaksanakan sistem automasi pengurusan rumah hijau di dalam projek ini. Penggunaan rangkaian kabel di persekitaran rumah hijau berskala besar yang terdedah kepada faktor luar akan meningkatkan kos pemasangan dan ianya lebih berisiko selain daripada pemasangan yang lebih rumit dan kesukaran dalam penyelenggaraan. Oleh itu, rangkaian penderia tanpa wayar (WSN) yang terdiri daripada nod sensor tanpa wayar yang bersaiz kecil menggunakan teknologi ZigBee merupakan pilihan yang terbaik dan menjimatkan kos untuk membina sistem yang dicadangkan. WSN digunakan bagi mengesan dan memantau suhu, kelembapan, cahaya, kelembapan tanah dan karbon dioksida. Parameter ini dipilih kerana ianya adalah komponen penting di dalam proses fotosintesis tumbuhan. Jadual bagi sistem automasi ini dibangunkan menggunakan bahasa pengaturcaraan Visual Basic C# untuk melakukan penganalisaan maklumat dan memaparkannya dalam masa nyata (real-time). Apabila WSN mengesan keadaan persekitaran tumbuhan di luar kondisi optimum yang diperlukan mengikut fasa-fasa yang telah ditetapkan, maka sistem ini akan mengaktifkan penggerak (actuator) untuk menstabilkan kembali keadaan persekitaran agar tumbuhan kekal berada di tahap optimum. Projek ini juga mengkaji prestasi WSN dengan melaksanakan ujian kedudukan dengan jarak yang bersesuaian antara nod dan ujian keboleharapan data. Sistem automasi pengurusan rumah hijau ini memperkasakan Internet Benda (IoT) dengan penggabunggan teknologi deria elektronik, rangkaian tanpa wayar serta pengaturcaraan komputer. Sistem yang dibangunkan ini dijangka akan dapat meningkatkan pengeluaran hasil tanaman dari rumah hijau, memaksimakan keuntungan dan seterusnya menjadi pemangkin kearah pengurusan perladangan yang cekap (precision farming).

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ABSTRACT

The rapid development of agrotechnology is playing an important role in the production of greenhouse plantation for cultivating high value fruits, flowers or vegetables. It is imperative to constantly monitor these high value crops optimal requirements at every phase of the plant growth cycle to maintain the best quality production. However, traditional manual inspection, data collection and control method for large-scale greenhouse plantation deemed inefficient with high costs, time consuming and laborious. This project introduces a scheduler to enhance greenhouse management by taking into considerations the different phases of plant growth. The scheduling concept is also a contribution to this research projects implemented and it is believed there is no specific study on scheduling concepts in the automation system according to specific cycles and phases in the crop. Measuring several points in a greenhouse are required to trace down the local climate parameters to ensure the automation system works properly. Cabling would make the measurement system expensive and vulnerable in a large greenhouse plantation. Moreover, the cabled measurement points are complicated and difficult to maintain and relocate once they are installed. Thus, a Wireless Sensor Network (WSN) consisting of small-size wireless sensor nodes based on ZigBee technology is an attractive and cost-efficient option to build the required system. The system is used to sense and monitor the temperature, humidity, light, soil moisture and carbon dioxide which are essential in the photosynthesis process. The scheduler is build using Visual Basic C# to analyse, display and control the actuators in real-time. The system through the scheduler will sense the climate conditions, analyse it and trigger the actuator should the measurement is not within the specified region. These tasks are performed to ensure optimal conditions at different phases of plant growth are achieved. The system performance is also measured to confirm efficient deployment and data reliability in this project. The convergence of embedded electronic sensing, wireless networking and computer science promotes Internet of Things (IoT) in the system. It is expected that the developed system will increase greenhouse production efficiency, profitability and concurrently realising precision greenhouse management.

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CHAPTER 1

INTRODUCTION

In the future, the climate change, population growth, increasing of food prices, and environmental stressors will have significant impacts on food security. Food security, as defined by the United Nations Committee on World Food Security, is the condition in which all people, at all times, have physical, social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2006).

In order to ensure and sustain food security that able to feed around 9.1 billion world population by 2050 (FAO, 2009), agrotechnology will play an important role in maximizing the production and quality of high value crops and sensitive plants. Conventional method of agriculture in open field is susceptible to extreme sunlight (solar radiation), high or low rainfall, weed competition, pest and disease. Greenhouse has been widely used in precision agriculture to acquire the best quality for production of fruits or vegetables (Rezuwan, 2008; Smith et al., 2010; UKCES, 2011). However, a fully automated system taking into considerations the different phases of plants growth and the optimal requirement by the plants during these growth period and cycle is not fully designed and available. The optimal plant growth depends on several parameters which are temperature, soil moisture, humidity, radiation of light and carbon dioxide (D.D.Chaudhary et al., 2011).

In the last decade there have been tremendous advancements using WSN (WSN) technology for agriculture (D.D.Chaudhary et al., 2011). WSN enabling technology for efficient and inexpensive precision agriculture includes collecting, storing and sharing

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sense data. In general it consists of a large number of low-cost and low-power multifunctional sensor nodes that are deployed in the area of interest. In WSN, the nodes communicate wirelessly over short distance and are capable of organizing themselves in an autonomous multi-hop mesh network. Thus, WSN is proposed as part of the technology to be deployed in this system. The sensor nodes collect information about the greenhouse parameter and communicate over a network to a computer system which is called a base station or sink (Kodali et al., 2014). Then the system will respond according to the threshold limit set by the scheduler that has been designed.

This research project proposed a scheduling method for monitoring and management of greenhouse crops in real-time. The system ensures the crops maintains its optimum condition by introducing interventions based on the selected parameters of the growth phases. This concept of scheduling realizes a fully integrated and automated greenhouse monitoring and management system. This system is also flexible to suits to many types of plants in the greenhouse.

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1.1 Problem Statement and Proposed Solution

Three (3) main problems identified in the current greenhouse monitoring and management system are:

a) Engaging in large scale greenhouse requires many labor to work at the fields by way of traditional approach of agriculture. Rigorous automated scheduling according to each phase of the plant growth cycle is still not designed and available, in order to ensure the plant receive optimal requirement. By promoting automated scheduling, any problems, irregular conditions or unwanted scenarios within the greenhouse environment can be monitored and managed effectively. Human intervention only occur when it is required, hence improving labor productivity and resource utilization.

b) Deploying wired network in outdoor environment and in large scale greenhouse ground is complicated and requires cables to be laid around the fields which can create trip hazards and exposure to moisture and severe weather conditions. These risks may lead to sensing and actuator unreliability issue. Wireless networks have much less cabling which leads to better field working environment and simple to deploy with conscientious network planning.

c) Information and data collection to measure against farm yield in the traditional way is troublesome as it is done manually. Manual keying in the data may lead to human error. Loosing datasheets, analyzing and plotting the data can be a lengthy process. Limitations to access latest update from the greenhouse in real-time will lead to early action cannot be taken if there is unreliability issues occurred. Automation with efficient data storage and real-time visualization in Internet of Things (IoT) environment can highly assist in supporting new formula in precision farming. Moreover with real-time data and control, enable the user to realize a true remote monitoring system.

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1.2 Objectives

This research propose a precision agriculture system and scheduler management in greenhouse by applying IoT and WSN. In order to design a Graphical User Interface (GUI) system, Visual Studio C# is used. Based on the problem statement, four (4) main objectives have been identified:

1. To deploy WSN for local data and control signal transmission.
2. To develop and manage a scheduling method of plant monitoring in real-time for every phases of its growth cycle.
3. To develop a cloud based remote monitoring system using IoT technology and design a user experience dashboard for greenhouse monitoring and management system.

1.3 Scope of Study

The goal of this research is to develop an automated system that can monitor the plant growth from a selected parameter to ensure the plant received optimum requirement for higher quality production. This system consists of; sensor base, main base, actuator base and client base to display output. This study is bounded for greenhouse crops in a control environment and Harumanis Mango plant has chosen as a subject. This project involve input from agricultural practitioners and the farmers to obtain the best agricultural practices such as the threshold limit for each parameter and information on crop requirements for each phase of the plant growth.

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1.4 Thesis Organization

This thesis is organised as follows; *Chapter 2* presents the literature review on agrotechnology and similar project carried out by other researchers. This chapter explains the plant physiology focussed on environmental factors and plant growth development. It provides the fundamental characteristic, components, and possible application of IoT. This chapter then discusses on various technologies of wireless information, comparison and applications.

Chapter 3 describes about the methodology of the research and the design on the experimental setup. This chapter also provides methods of analysis used to evaluate the collected data obtain through experimental study.

Chapter 4 presents the experimental test for the scheduler conducted under different conditions. This chapter also presents the results and discussion for test conducted from the WSN and system performance test. In this chapter, the utilisation of IoT and GUI final design are discussed in detail.

Finally *Chapter 5* presents the conclusion of this thesis. Research limitation and recommendations for future research directions.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides information about the plant physiology in detail, specifically on the plant development, plant growth, and enviromental factors affecting each phases of the plant growth. Section 2.3 in this chapter present related research work and also the fundamental characteristic, components and application in IoT. Apart from that, existing wireless technologies, comparison, and application of WSN are introduced in detail under Section 2.4; wireless technologies.

2.2 Plant Physiology

A plant that grow on soil and on water, or on other plants, usually has a stem, leaves, roots, and flowers and produces seeds. Plant provide human and animal with food, oxygen, fibre, shelter or habitats, medicine and fuel. The basic food for all organism in this world is produced by green plants. Green plants are the primary producers of food for the rest of the biological world, food that is subsequently converted to growth energy nutrients from the soil and carbon dioxide from the atmosphere in a process called photosynthesis process.

Photosynthesis is defined as the process by which light energy is absorbed by green plants and produced carbohydrate are synthesized from carbon dioxide (CO_2) and

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water (H_2O). It is essentially an energy transfer reaction and this process is occur in the chloroplast of leaves. This process nourishes almost all entire living world directly or indirectly. To show the overall process of photosynthesis, the simplified equation is use (Campbell et al., 2014):

$$nCO_2 + 2nH_2O \rightarrow (CH_2O)n + nO_2 \qquad (2.1)$$

Where *n* is the number of molecules of CO_2 carbon dioxide that combine with H2O water to form carbohydrate (CH_2O)n, releasing *n* molecules of oxygen (O_2) to the surrounding.

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2.2.1 Plant Development vs. Plant Growth

Growth is the manifestation of life for all living things. Plant growth refers to a quantitative increase in size of volume of a cell, tissue, or organism. It occurs because of metabolic energy and cell division is accompanied by an increase in cell size. While development is a summation of all activities leading to change in a cell, tissue, and organism (Parker, 2009). The differentiation between plant development and plant growth explained in Table 2.1 (Bareja, 2015).

All type of plant has its own cycle according to a specific time period divided into certain phases according to the respective parameters requirements. UniMAP is the pioneer university for Harumanis projects to improve the quality and quantity of products through greenhouse technology and research development (Saari, 2015). Therefore, the review of the crop in this research project is mostly related to the cultivation of Harumanis based on the cycle and parameter requirements according to certain phases.