DATA ACQUISITION AND ALERT SYSTEM FOR RECIRCULATION AQUACULTURE SYSTEM (RAS) USING FOG COMPUTING

by

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LIST OF ABBREVIATIONS

ADC	Analog Digital Converter
DO	Dissolve Oxygen
FAO	Food and Agriculture Organization of the United Nations
FCR	Feed Conversion Rate
GPIO	General Purpose Input Output
GUI	Graphical User Interface
HDMI	High-Definition Multimedia Interface
HTML	Hyper Text Markup Language
IoT	Internet of Things
IP	Internet Protocol
LED	Light-Emitting Diode
OS	Operating System
RAS	Recirculation Aquaculture System
RaspDAQ	Raspberry Pi Data Acquisition Query Collector
RaspFog	Raspberry Pi Fog Server
Rpi	Raspberry Pi
SMS	Short Message Service
SQL	Structured Query Language
SPI	Serial Peripheral Interface
Vs.	Versus
WiFi	A Wireless Technology

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Sistem Perolehan Data dan Amaran bagi Sistem Peredaran Akuakultur menggunakan Pengkomputeran *Fog*.

ABSTRAK

Kajian ini membentangkan satu pendekatan yang lebih baik dan berkesan untuk sistem perolehan data bagi sistem edaran semula akuakultur. Sistem sedia ada menggunakan kaedah manual untuk mengambil data penting dari sistem itu dan juga mendapat tindakan yang lambat dari penternak ikan jika data tidak berada dalam keadaan yang baik. Sebagai penambahbaikan, teknologi pengkomputeran *fog* digunakan untuk mengatasi semua masalah ini dan bertindak sebagai sistem perolehan data yang menyimpan data dengan selamat dengan berkongsi data yang diproses dalam pengkomputeran *fog* bagi setiap tangki, menganalisis data untuk membuat kawalan yang tepat dalam masa yang sebenar. Di samping itu, teknologi *open source* dan sistem terbenam akan dimanfaatkan untuk kajian ini kerana saiz fizikal yang kecil, ringan, mudah alih, kosnya yang rendah, kecekapan tinggi dan penggunaan kuasa yang rendah. Kajian ini telah mencapai objektif iaitu merekabentuk satu sistem pengumpul data, merekabentuk sistem pemprosesan data menggunakan pengkomputeran *fog* dan mengintegrasikan, menguji dan mengesahkan pengumpulan data secara automatik dan strategi pemprosesan untuk sistem peredaran semula akuakultur. Sistem pengumpul data untuk RAS, RaspDAQ dibangunkan dengan menyambungkan Raspberry Pi 3 kepada sensor suhu (LM35DT) menggunakan penukar analog digital ,MCP3002, sensor paras air (HC-SR04), modul kamera RPi, LED dan penggera. Python dan server Apache digunakan untuk memprogramkan fungsi-fungsi di dalam RaspDAQ. Manakala Raspberry Pi 3 ketiga ditetapkan sebagai sistem pemprosesan data, RaspFog menggunakan PHP, Apache dan server MySQL. Kedua-dua RaspDAQ dan RaspFog menggunakan sistem operasi Raspbian. Selepas itu, RaspDAQ1 dan RaspDAQ2 disambungkan kepada RaspFog menggunakan teknologi WiFi untuk menghantar data sensor dalam masa nyata. Data yang diterima disimpan dan diplot menggunakan graf Highcharts.com. Sistem yang mengumpul data, RaspDAQ dan pangkalan data dan pemproses, RaspFog telah diuji dan disahkan. Pada masa yang sama, pengguna boleh melihat keluaran graf dalam masa yang sebenar sensor suhu dan sensor paras air serta keadaan sebenar menggunakan modul kamera RPi bagi RaspDAQ1 dan RaspDAQ2 melalui laman web RaspFog. Akhirnya, teknologi pengkomputeran *fog* telah diimplementasikan dengan jayanya untuk sistem peredaran akuakultur di dalam kajian ini.

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Data Acquisition and Alert System for Recirculation Aquaculture System (RAS) using Fog Computing.

ABSTRACT

This research presents an improved and more effective approach for data acquisition of recirculation aquaculture system (RAS). In the previous research, the system uses manual methods to take the important data from RAS and it wastes the time because manual system uses human compare to computer. It is also gets late response from the fish farmer if the data is not in the good condition. As a result, fog computing technology is applied to overcome all these problems and acts as advance data acquisition system to keep data safely by sharing the processed data in fog computing for every tanks and analyze the data to make an accurate control/decision in the real time. Besides, open source technology plus embedded system based has been integrated for this research because its benefits such as small size, low cost, lightweight, portable, high efficiency and low power consumption. This research has achieved the objectives which are design and develop data collecting system, data processing system using fog computing for RAS and validate the system. The data collecting system for RAS (RaspDAQ) is developed by connecting Raspberry Pi 3 to temperature sensor (LM35DT) using analogue digital converter (ADC) MCP3002, water level sensor (HC-SR04), Rpi camera module, LEDs and buzzer. Software and program are built using Python and Apache server to run every functions of RaspDAQ. Two RaspDAQ are used in this research which are RaspDAQ1 and RaspDAQ2. While third Raspberry Pi 3 is setup as data processing and server system (RaspFog). Raspfog uses PHP, Apache and MySQL database. Both RaspDAQ and RaspFog are based on Raspbian operating system. After that, RaspDAQ1 and RaspDAQ2 are connected to RaspFog using WiFi technology to send sensors data in real time. The received data are stored and plotted using Highcharts.com graph. Both RaspDAQ, RaspFog have been tested and validated. At the same time, users can see the graph output in the real time for temperature, water level sensor and real condition using Rpi camera module of RaspDAQ1 and RaspDAQ2 by browsing RaspFog website. Finally, fog computing technology has been implemented successfully to RAS in this research.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Food and Agriculture Organization of the United Nations (2014) has reported that human consume more fish is instigated from farms than from wild capture, having reached almost parity in 2012 according to the latest global report. Because of that, the fishery and aquaculture sector have to face a critical defining moment when they need to move with the rapid technology changes, increasing demand, and rising feeding cost. Furthermore, the global projection of fish production is increasing from 2010 to 2030 by 24% which is 35.4 million tons as reported by Siwa Msangi and Miroslav Batka (2015).

High density fish farming with Recirculation Aquaculture System (RAS) is said as key of technology which allows the world aquaculture community to supply the world per capita needs for aquatic species over the coming decades with environmentally and friendly manner. RAS also sustainable, infinitely expandable, environmentally compatible and has the ability to guarantee both safety and the quality of the fish produced throughout the year. On other hand, RAS offers the controlled environment, the permitting controlled product growth rates and predictable harvesting schedule. The heat and water can be conversed through the reused water after reconditioning by biological filtration (Tidwell, J. H., 2012).

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Nevertheless, there are some parameters need to be monitored in RAS that can be divided into two aspects. The first aspect is the parameters of environment control such as temperature, water level, Dissolve Oxygen (DO), PH and Ammonia (NH3) level to control the healthy environment for fish especially DO level which is the first limiting factor in intensive aquaculture system. It can immediately cause the fish fatality if DO is not at the required level. The second aspect is the parameters to be calculated to determine the fish growth and Feed Conversion Rate (FCR) such as the weight of fish, the weight of feed and the frequency of feeding. A real time and efficient monitoring system is really desired for some critical parameters which can improve the quality and determine future projection by using the stored data previously. Additionally, a very low latency is required to response the output device and to alert the stakeholder and aquaculture men if something unwanted condition happens such as temperature going higher. Secure and reliable system also high demanded due to high cost and profit business such as RAS.

Consequently, fog computing technology is suggested in this research to make RAS monitoring system is more efficient. Fog computing offers reduction of network traffic by providing a platform to filter and analyse the data generated by the devices which close to the edge and for local data views. As result, it will automatically reduce the traffic being sent to the cloud. Fog computing also suitable for Internet of Things (IoT) tasks and queries which most of the smart devices need to capture events only about a hundred meters from it and not necessary to access global data from cloud. Low latency requirement also provided by fog computing which critical parameter can be reflected with high speed real time response. Furthermore, it can reduce the scalability issue since fog computing aims the incoming data get closer to the data source itself and reduces the burden of that processing on the cloud and without concern of the increasing number of

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endpoints. (Amir Vahid Dastjerdi, Harshit Gupta, Rodrigo N. Calheiros, Soumya K. Ghosh, and Rajkumar Buyya, 2016).

1.2 Motivation and Problem Statement

Monitoring system is the most important part in Recirculation Aquaculture System (RAS) to provide health environment of fish living because it will affect the quality of the fish growth and life in indoor tanks. It is more challenging in a "controlled" environment like RAS and also in fish production especially when involve with profit, cost and human resources. For that reason, an advanced technology has to be developed in fish production or fish catching and also to increase the awareness on benefits of fish. In the previous research, the system uses manual methods to take the important data from RAS and it wastes the time because manual system uses human compare to computer. It is also gets late response from the fish farmer if the data is not in the good condition.

As a result, fog computing technology is applied to overcome all problems and acts as advance data acquisition system to keep data safely by sharing the processed data in fog computing for every tanks which will be extended to the cloud and analyse the data to make an accurate control/decision in the real time. Besides, open source technology plus embedded system based will be integrated for this research because its benefits such as small size, low cost, light weight, portable, high efficiency and low power consumption. Finally, this research focuses on data acquisition and alert system for recirculation aquaculture system using fog computing technology to overcome the existing problems.

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1.3 Aim and Objectives

The aim of this research is to design a data acquisition and alert system for recirculation aquaculture system (RAS) using fog computing.

To achieve the aim, the main objectives of the research are:

1. To design and develop a data collecting system for RAS.
2. To design and develop a data processing system using fog computing.
3. To validate data acquisition and alert system for recirculation aquaculture system using fog computing technology.

1.4 Research Scope

This research aims to design and develop a data acquisition and alert system for recirculation aquaculture system (RAS) using fog computing. It focuses on a system contains data collection, data analysis, data sharing in the server by using fog computing technology and decision making to control RAS. Two Raspberry Pi units are used to collect data from RAS. The data is collected from two sensors which are temperature and water level sensor converting to digital data using analogue to digital converter (ADC) channel and also real time camera view from each collector. After that, the data is sent to another Raspberry Pi through fog computing which function as server that keeps the data in MySQL database and as a processor to do the analysis and decision maker to control output tools which are LED, buzzer, email and SMS. Furthermore, the important and analyzed data will be display in web based using PHP, Apache service and an interactive graph tool, Highcharts.com. So that, the analysis can be monitored through the web browser from anywhere in the world as the internet is there.

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1.5 Thesis Outline

This work is organized as follows:

1. Chapter 2 introduces the existing work and concept related to data acquisition and alert system for recirculation aquaculture system (RAS) using fog computing. It contains related study of the recirculation aquaculture system (RAS), fog computing, embedded system and operating system.

2. Chapter 3 describes this research methodology consists of the hardware setup, software configuration and integration of the sub systems.

3. Chapter 4 informs the system test results, the work done and discussion for data acquisition and alert system for recirculation aquaculture system (RAS) using fog computing at client and server side.

4. Chapter 5 covers the conclusion and recommendation which concludes this research by summarizing the important ideas for the contributions and future works.

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CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter explains more detail about the theory of recirculation aquaculture system (RAS), fog computing, previous works and also the specification of some hardware and software which related to this research. In subtopic of RAS, important parameters and the system procedures of RAS are explained. Next, the important benefits and the development of fog computing are explained in subtopic of fog computing. Similar study with this research is also described in this chapter to see the methods, scopes, strength and the weakness of the works done. Lastly, the description of Raspberry Pi 3 and some softwares such as Raspbian, MySQL, PHP and etc.

2.2 Recirculation Aquaculture System (RAS)

Recirculation aquaculture system (RAS) is a technology utilizes reusing water in production for the rearing of fishes or others aquatic organisms. This technology uses mechanical, biological filters and methods can basically be applied for any aquaculture species such as clams, fish and shrimp. However mainly RAS is used in fish farming and field of aquaculture (Jacob Bregnballe, 2016).

RAS grows hurriedly in various fields of fish farming and systems used in the production units in generating many tons of fish per year. It is used with a complicated

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system to save insufficient species. RAS can be ran at different amount depends on the water usage is recycled or reused. Some new super intensive farms are installed in a building that closed and insulated uses minimum 300 litres of water to produce kilos of fish each year. Another system is outside the traditional farm that has been reconstructed into systems using recirculated water $3m^3$ for every kilo of fish produced each year. Traditionally, trout species use water flow through systems about 30 m^3 per kilo of fish produced each year. For example, the new water is used will be $17m^3$ / hour (h), $171m^3$ / h and $1712m^3$ / h, which is a big difference in a fish farm producing 500 tonnes of fish a year (Jacob Bregnballe, 2016).

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2.2.1 Parameters in RAS

Recirculation allows fish farmers to fully control all parameters in production and also the farmers' skill. Those are very important to take care of the fish. Control parameters such as oxygen levels and water temperature (Refer to Figure 2.1) provide a stable and optimum condition for fish. That gives better growth and less stress. Stable conditions can cause a steady growth pattern and good expectation to allow farmers to predict the level or size of fish precisely. As result, the proper production plan can be created and the exact time of the fish sale availability can be predicted. That helps the farm management and strengthens the ability to market the fish competitively (Jacob Bregnballe, 2016).

The continuous water treatment is essential to add oxygen and keep the fish alive and healthy. It also disposes the waste produced by the fish in RAS. RAS is a simple system. Water flows from the fish tank outlet into the mechanical filters. Then, flow to the biological filter.

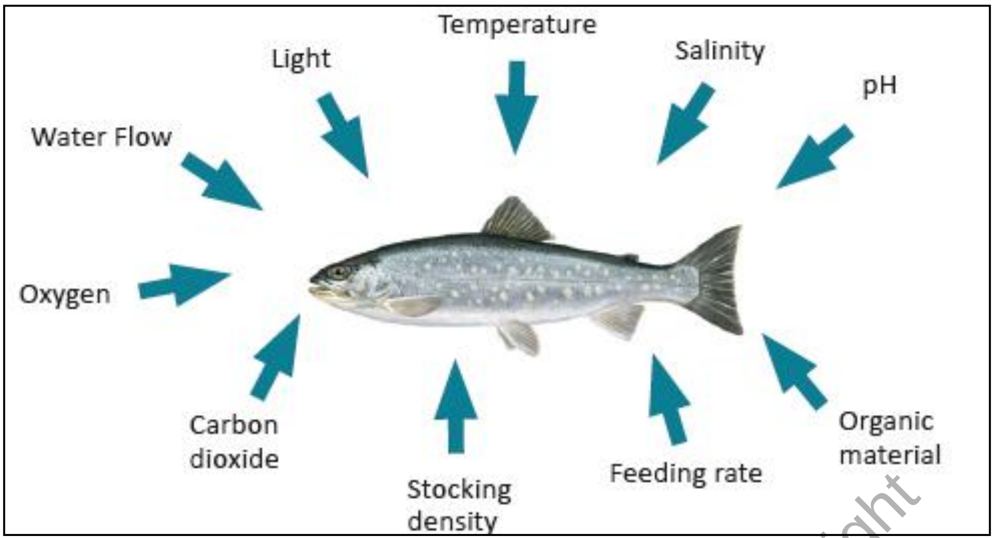

Figure 2.1: Parameters affecting the growth of a fish (Jacob Bregnballe, 2016).

After that, it is aerated and deprived of carbon dioxide and go back to the fish tank. That is the RAS basic principle. Besides, other features can be added such as ultraviolet light or ozone disinfection, oxygen with pure oxygen, heat exchange, automatic pH regulation and denitrification as required as shown in Figure 2.2. Mechanical filtration, biological treatment and aeration/stripping are the basic of water treatment system (Jacob Bregnballe, 2016).

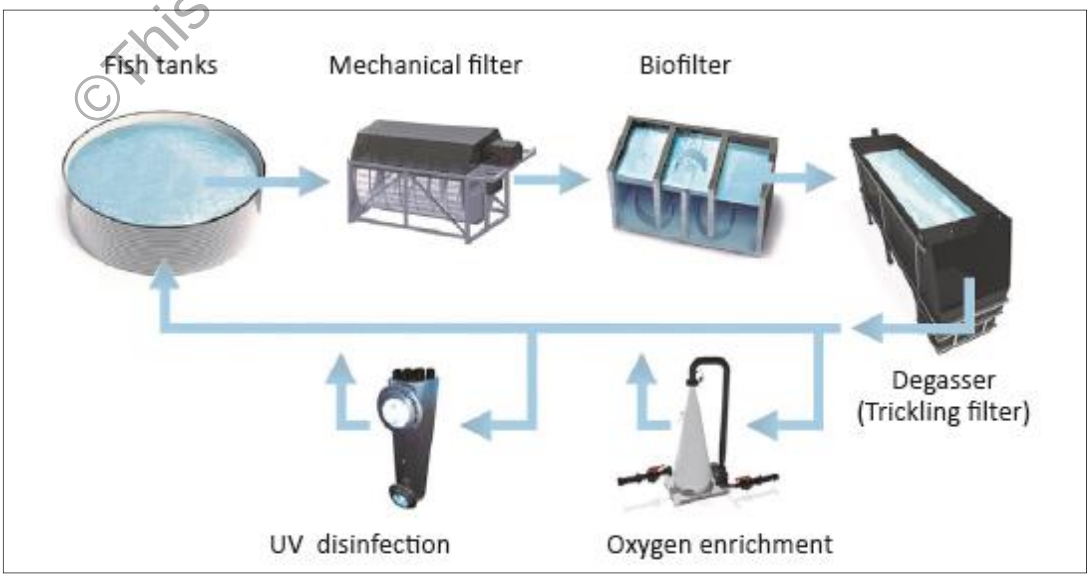

Figure 2.2: Principle drawing of a recirculation system(Jacob Bregnballe, 2016).

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2.3 Internet of Things (IoT)

By year 2020, the devices connected to the internet exceed to 50 billion as show in Figure 2.3. This led to the development of electronic technology and advances in telecommunications in recent years is causing a variety of tools that are very strong in networking and communications capabilities. Industry is very attractive to apply this technology into the daily business to improve the efficiency. In addition, there are other sectors have a great demand for the development of Information and Communication Technology such as life, public services and others which. Therefore, a demand of new paradigm in machine to machine (M2M) communication called internet of things (IoT) can enable "Things" connects to the Global Internet Network (Ahmed Banafa, 2015).

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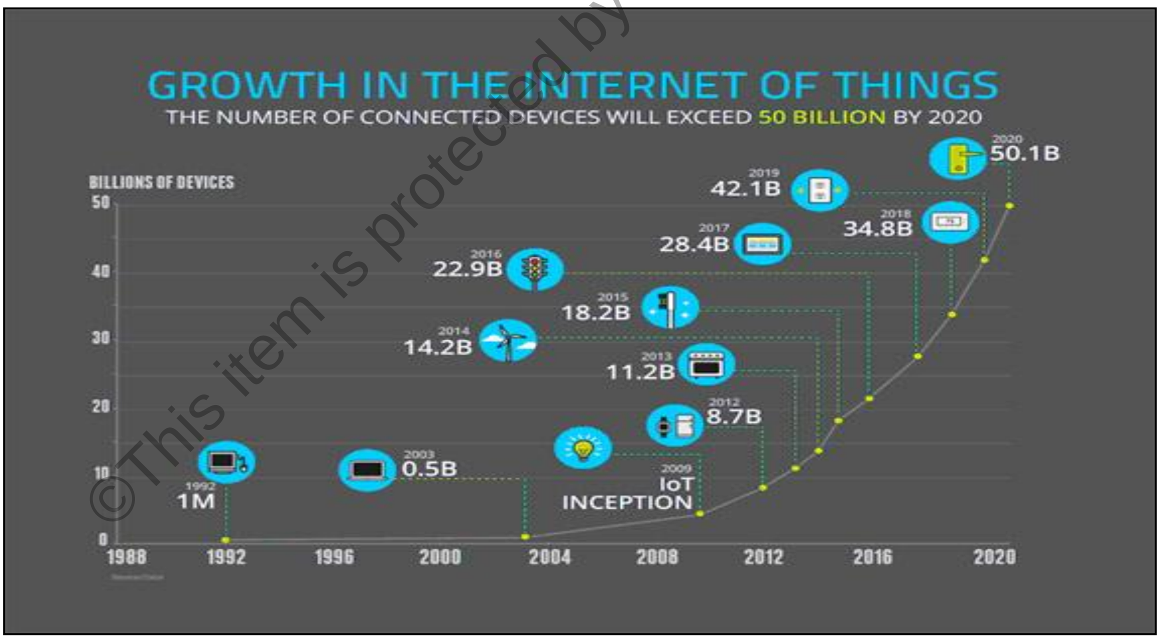

Figure 2.3: IoT growth by 2020 (Ahmed Banafa, 2015).

IoT is a physical objects network or "thing" with sensors, embedded electronics, SW and connection to exchange data with manufacturers, operators and / or other devices connected via a communications protocol developed without human operation. The information communication technology-based environment and social infrastructure make the development of IoT technology and the evolution of IoT technologies is very important in the future (Maher Abdelshkour, 2015).

There are many applications that are used by industry, the government and the public by connecting billion or more devices to the Internet. For example, the traffic in a city monitored by Intelligent Transport System (ITS) application using video surveillance or wireless sensors. Then, the information is sent to the users' mobile devices using Global Positioning System (GPS) transceiver which can avoid the users from accidents and traffic jam. Besides, there are many others examples like smart home and e-Health which generated and transfer large data across the network to the Internet. So that, fog computing can help to emerge network paradigms that require faster processing with less delay and delay jitter while cloud computing can serve the business community meeting their high end computing demands lowering the cost based on a utility pricing model(Maher Abdelshkour, 2015).

2.3.1 Fog Computing as IoT Platform

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Fog computing is paradigm of distributed computing. It covers the cloud service until the edge of the network, can be referred in Figure 2.4. It simplifies the management, computation, networking and data centres and end devices storage. Basically, fog computing involves application components which run both in the cloud and in the edge device between the cloud and the sensors. For example, routers, dedicated fog devices or smart gateways. Mobility, communication protocols, computing resources, cloud integration, interface heterogeneity and distributed data analytics until applications'