UNIVERSITI PUTRA MALAYSIA

ROBUST POSITION ENCODING AND VELOCITY DEDUCTION FOR REAL TIME WATER LEVEL MONITORING

ABDALLAH S. Z. ALSAYED

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By

ABDALLAH S. Z. ALSAYED

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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DEDICATION

First and foremost I would like to thank Allah, my creator, for giving me the intellectual capacity to learn about His creation. Without His gift and grace to me, I could do nothing. I dedicate my thesis work to my hometown Palestine, and to my loving parents, **SAMIR and MAHA,** whose words of encouragement and push for tenacity ring in my ears. In addition, a special feeling of gratitude to my loving brothers, Tariq, Mohammed, and a reckless brother Yusuf for supporting me entire my life, as long as I was a child. In addition, I would like to call my great sisters in this dedication, Doa, Mariam, and Marah.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman: Muhammad Razif Bin Mahadi @ Othman, PhD

Faculty: Engineering

Precision Farming is concept that emphasis on optimization of input for maximum output. In rice production, Precision Farming has been gradually implemented to improve the rate of production. One of the activities is in the management of water usage, for better sustainability. Otherwise an uncontrolled water management leads to excessive use and in the long run may cause the soil to be damped and too soft for machinery to travel without sinking. Motivated by the problems related to irrigated water management for rice production, this research was conducted as a proposed method to measure the level of water, deducing the rate of rising, and at the same time establishing a wireless connectivity for possible use of remote monitoring.

Specifically, this research presents a proposed technique for linear motion parameters measurement system. The measurement system contains linescan transducer with built in illumination system, grating scale, and ultrasonic sensor. Once the linescan transducer scans the grating scale optically, the displacement of the transducer is measured based on pixel differential method. However, if the time of the travelling is known, then it is possible to deduce the velocity and the acceleration of the transducer movement. Additionally, an ultrasonic sensor is added to the transducer to provide the initial position in proximity.

The design of the linescan transducer basically included the illumination source and the division of grating scale. The accuracy of the measurements were compared to white and infrared lights. Then, the comparison was based on three scale divisions which are 0.5 mm, 1 mm, and 2 mm. Finally, the accuracy was also compared to different travelling ranges of motion. Moreover, the linescan transducer measurements were evaluated comparatively to reference devices. Two ZigBee modules were incorporated into the device, which allowed remote data communication between the transducer to a monitoring station. The wireless connection was tested over different transmission

distances with a view to inform the accuracy of the measurements through ZigBee technology.

The linescan module had low errors, if the grating scale division was 2 mm and the used illumination was infrared LEDs. In this case, the average error was 0.9% and the standard deviation was 11.63 mm over travelling range of 500 mm. However, after adding an ultrasonic sensor to the transducer, the integration of linescan sensor and ultrasonic sensor could measure the displacement over 1 meter with average error of 1.18% and standard deviation of 783 mm. The remote monitoring system could successfully send the data over different transmission distances (1.5m-10m) based in ZigBee modules. As a result, the output of this research is a contribution to knowledge in novel, robust, and simplified method for measurement of displacement, velocity, and acceleration of object in linear horizontal motion.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
Sebagai memenuhi keperluan untuk ijazah Master Sains

PENGEKOD KEDUDUKAN TEGUH DAN PENURUNAN KELAJUAN UNTUK KEGUNAAN PEMANTAUAN MASA SEBENAR PARAS AIR

Oleh

ABDALLAH S. Z. ALSAYED

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Pertanian Jitu adalah konsep yang memberi penekanan kepada pengoptimuman input untuk output yang maksimum. Dalam pengeluaran beras, Pertanian Jitu telah semakin digunakan untuk meningkatkan kadar pengeluaran. Salah satu aktiviti ini adalah pengurusan penggunaan air, untuk kelestarian yang lebih baik. Jika pengurusan air yang tidak terkawal yang membawa kepada penggunaan yang berlebihan maka untuk jangka masa panjang boleh menyebabkan tanah akan teredam dan terlalu lembut untuk jentera untuk melakukan perjalanan tanpa tenggelam. Bermotivasikan masalah yang berkaitan pengurusan pengairan untuk pengeluaran beras, kajian ini telah dijalankan sebagai kaedah yang dicadangkan untuk mengukur paras air, pengurangan kadar kenaikan paras air, dan pada masa yang sama mewujudkan sambungan tanpa wayar untuk kegunaan pemantauan jarak jauh.

Secara khusus, kajian ini membentangkan satu teknik yang dicadangkan untuk parameter gerakan linear sistem pengukuran. Sistem pengukuran mengandungi transduser imbasan garisan (linescan) yang dibina bersama dalam sistem pencahayaan, skala garisan, dan sensor ultrasonik. Setelah transduser linescan mengimbas skala garisan secara optik, anjakan transduser diukur berdasarkan kaedah perbezaan piksel. Walaubagaimanapun, jika masa perjalanan diketahui, maka nilai untuk halaju dan pecutan pergerakan transduser boleh dikira. Selain itu, sensor ultrasonik ditambah untuk memberikan kedudukan awal transducer.

Reka bentuk transduser linescan pada dasarnya terdapat sumber pencahayaan dan pembahagian skala garisan. Ketepatan ukuran dibandingkan dengan lampu putih dan inframerah. Kemudian, perbandingan itu dibuat berdasarkan tiga bahagian skala yang 0,5 mm, 1 mm, dan 2 mm. Akhir sekali, semua ketepatan juga dibandingkan untuk julat gerakan yang berbeza. Selain itu, ukuran transduser linescan dinilai untuk peranti rujukan. Dua modul ZigBee telah dimasukkan ke dalam peranti ini, yang membolehkan komunikasi data untuk jarak jauh antara transduser ke stesen pemantauan. Sambungan

tanpa wayar diuji pada jarak penghantaran yang berbeza dengan tujuan untuk memberitahu ketepatan ukuran melalui teknologi ZigBee.

Modul linescan mempunyai ralat yang rendah, jika bahagian skala garisan adalah 2 mm maka pencahayaan yang digunakan ialah LED inframerah. Dalam kes ini, purata ralat adalah 0.9% dan sisihan piawai ialah 11.63 mm pada julat gerakan 500 mm. Walaubagaimanapun, selepas menambah sensor ultrasonik pada transduser, integrasi sensor linescan dan sensor ultrasonik mampu mengukur anjakan lebih 1 meter dengan purata ralat 1.18% dan sisihan piawai 783 mm. Sistem pemantauan jarak jauh berjaya menghantar data pada jarak penghantaran yang berbeza (1.5m-10m) seperti di dalam modul ZigBee. Konklusinya, kajian ini adalah satu sumbangan kepada pengetahuan yang baru, kretif, teguh dan memudahkan untuk mengukur sesaran, halaju dan pecutan objek dalam gerakan mendatar.

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I certify that a Thesis Examination Committee has met on (date of viva voce) to conduct the final examination of Abdallah Alsayed on his thesis entitled "Robust Position Encoding and Velocity Deduction for Real Time Water Level Monitoring" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS

CNC	Computer Numerical Control
CMOS	Complementary Metal-Oxide Semiconductor
ISR	Interrupt Service Routine
CAN	Controller Area Network
USB	Universal Serial Bus
IEEE	Institute of Electrical and Electronics Engineers
GND	Ground
LED	Light Emitting Diode
SI	Serial Input
FFT	Fast Fourier Transform
CCD	Charge Coupled Device
RS232	Recommended Serial 232
Wi-Fi	Wireless Fidelity Alliance
RF	Radio Frequency
DSSS	Direct Sequence Spread Spectrum
A/D	Analog/Digital
CCTV	Closed Circuit Television
CLK	Clock
AO	Analogue Output
GUI	Graphical User Interface
OLM	OPTIV light measurement
API	Application Programming Interface
PWM	Pulse Width Modulation
I/O	Input/Output
UART	Universal Asynchronous Receiver/Transmitter
VB6	Visual Basic 6
RMS	Root Mean Square
WiMax	Worldwide Interoperability for Microwave Access
ISM	Industrial, Scientific, Medical
ANOVA	Analysis Of Variance

CHAPTER 1

INTRODUCTION

1.1 Background

Sustainability in farming requires the efficient use of resources. This is the core concept of Precision Farming. In rice production, high yield achievement is significantly affected by the management of water in paddy field. In conventional practice, the fields are simply flooded and drained. If the flows are not precisely controlled the inner layer remains damp although the top soil has dried out. Hence the soil would gradually lose its strength capacity to sustain heavy loads on the surface and thus preventing the use of heavy machinery. This situation has been experienced at Muda Agriculture Development Authority (MUDA) in Kedah [1]. In paddy field, management of water level that includes the measurement of rate of rising and falling are important factors for irrigation systems [2], soil and water management [3], water productivity, and flood control systems [4].

1.2 Problem Statement

Rice production in paddy field is strongly affected by water. Water should be supplied continuously in paddy fields throughout the growth stages. In Asia, 90% of total irrigated water is used for rice crops [5]. In Malaysia, a total of 775 mm is needed for irrigation of 1.82 hectares of paddy plot area [6]. Water level during the growing period varies from 25 mm to 100 mm [7]. In some cases, such as floods, irrigation system troubleshooting, and rainfall patterns, the level of water goes more than the desired level. Hence, management of water level is of prime importance.

In order to manage the water level, the key component for control is a water level measurement device, which usually consists of transducers for reading the values. Selecting a proper transducer for measurement water level is often difficult because of several factors. Cost is a major limitation factor for farmers to acquire such a system. The cost includes the price of the transducer as well as the costs for installation and maintenance. Another factor is accuracy. Although some transducers or devices could achieve high accuracy for short travel, the result is reverse for long travel. The site condition can also influence the suitability of a measurement device, for example, sonic devices cannot work well when the surface of the target shape is irregular [8].

There is a lack in amount of researches which are proposed for water level measurement system in precision farming. This lack is a result of some factors which hinder the desired proposed techniques. Factors such as sensitivity of the transducer, sensitivity to the physical perturbations (vibration, magnetic, temperature, etc.), and the construction of the transducer assess the sensing techniques to be used on the fields [9, 10]. The displacement transducers have been developed and investigated for water level measurements. There are two types of displacement transducers; contact sensing and non-contact sensing transducers. In contact sensing, the problems of corrosion, short lifespan, high absolute error, and vibration are examples of restrictions for capacitive, inductive, and resistive sensors [11, 12]. These restrictions can be overcome with non-contact sensors. But, it has been reported that non-contact sensors have low accuracy over long range of measurements as in magnetic sensor. In addition, it have high power consumption (digital camera), high cost (laser interferometer), complicated algorithm (optic fiber sensor), and difficulties with installation on the fields [13]. Therefore, a robust, low cost, real time measurement system, and preferably high accuracy for long span measurements is needed for implementing water level measurement system.

Recently, the demand for wireless communication in agriculture activities is rapidly growing. It is used to optimize the production by controlling and monitoring the agriculture activities [14]. In wired communication, cables and wires have been reported as a source of noise, failure, and escalating cost for future design of monitoring systems [15]. The most used standards are IEEE 802.15.1, IEEE 802.11, and IEEE 802.15.4, which are generally known as the Bluetooth, Wi-Fi, and ZigBee respectively. Integration of wireless communication and precision farming requires a high efficient technology which has low cost, long battery life, low power consumption, low latency, and operates in most jurisdictions worldwide [16]. However, every one of them has advantages and disadvantages based on the application. In this research, wireless communication technology is integrated into the measurement system, hence allowing for real time water level monitoring.

1.3 Research Objectives

Efficient measurement system for water level prediction relies on specific sensing technique, whereas theoretical and instrumental framework is built to realize the measurement concept. For precise displacement, velocity, and acceleration measurements, the transducer capability affects the system significantly. Therefore, this research embarks on the following objectives:

i. To derive the theoretical framework for robust measurement system based on non-contact sensing technique.

ii. To establish instrumentation for robust encoding of displacement and deduce the velocity and acceleration for water level transducer based on optical and ultrasonic sensors.

iii. To assess remote data communication between the transducer and a monitoring room.

1.4 Research scope and limitation

This research concentrates on linear motion parameters measurement, applied in a horizontal platform in lab environment. In our analysis for motion parameters, the effect of gravitational acceleration is not included. The aim is on establishing the groundwork for the development of a transducer based on non-contact sensing. The maximum resolution of the linescan sensor is 63.5 µm, and 1 mm for ultrasonic sensor. The proposed transducer was tested for displacement over 1000 mm.

1.5 Thesis Layout

In this chapter, the introduction that motivates this work is presented. It shows the main problems in current issues which are going to be taken into consideration in this research. The critical tasks have been developed and identified into the objectives of this research. The limitations and scope of this project are also discussed in scope section. The rest of the chapters are organized as follows:

Chapter 2: This chapter reviews the current and previous researches, which emphasis on the linear motion parameters measurements. It concentrates on displacement sensors, displacement transducer design, water level measurements, and wireless communication in precision farming.

Chapter 3: This chapter describes the methods of sensors transducer design, platform design, and build of monitoring system. Additionally, the linescan sensor based on pixel differential is discussed for displacement tracking and deduction of velocity and acceleration.

Chapter 4: This chapter includes the results of the experiments, and discusses the quality of the results with respect to reference devices.

Chapter 5: This chapter concludes the previous chapter, and investigates the achievement of the objectives based on the methodology. For further work, it gives some recommendations for future work in this research scope.

1.6 Summary

A comprehensive introduction is introduced to provide a novel, robust, and simplified method for determination of displacement, velocity, and acceleration. The previous approaches, as in the problem statement, have suffered from some difficulties in this field, which lead this study to propose a new approach that can be implemented to overcome the current weakness. To complete this proposed method, a number of investigations with real analysis were implemented so that the outcome of this research can overcome the previous and current problems.

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