UNIVERSITI PUTRA MALAYSIA

A VARIABLE RATE PULSED WIDTH MODULATED NOZZLE VALVES ALGORITHM FOR A BOOM SPRAYER SYSTEM

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By

ALI RAFIEISHAHEMABADI

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

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This thesis is dedicated to the author's beloved wife, Seyedeh Zahra Seyed Abrishami, and my parents who are always in the author's mind

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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April 2008

Chairman: Samsul Bahari bin Mohd Noor, PhD

Faculty: Engineering

Agricultural sprayers are used for applying pesticides, fertilizer and other chemicals in the field. A control algorithm to precisely vary the application rate of fertilizer across the fields using low cost components is desired.

A variable rate sprayer control system was developed using a combination of boom flow rate variation and pulse width modulation of solenoid nozzle valves. The combination makes it possible for variable rate broadcast application of chemicals and/or variable rate application over the length of the boom. Matlab 7.1 was used to simulate the performance of the combination. To specify dynamic characteristics of the sprayer components, the sprayer was assembled and its components were calibrated. The given characteristics were used in simulation program. Process identification technique was used to estimate response time of the sprayer flow rate changes to control signals. A look ahead strategy was used for navigation system to minimize misapplication along the direction of travel from a simulated preloaded geographical information map with positioning constantly updated and corrected for variation in forward velocity. This strategy was verified by simulation program used sample GIS data and assumed AGPS coordinates. Misapplication over the width of the boom is minimized by precomputing the pulse width modulation algorithm to use on the nozzle valve when variation in application rate along the boom is desired. The simulation used a 1 second cycle to change control parameters thus effectively minimizing misapplication. The pulse width modulation algorithm was modified to pulse width activation algorithm to compensate for errors due to fall and rise time of non expensive normally closed solenoid shut off valve.

The experiments estimate average dead time and time constant of 0.1095 and 0.4225 for the sprayer. A flow control range of 34:1 was achieved by the given control algorithm. The average estimated flow rate error in manifold for two different random desired application rate data and each four different random range were 1.356% and 1.211% for constant velocity and 2.651% if the velocity changes within a limited range. The simulated results showed that the pulse width activation algorithm reduces average error of non expensive normally closed solenoid shut off valve with opening and closing time of 20 ms and 30 ms to 2.555% for constant velocity and 3.084% if the velocity changes within a limited range compared to ideal expensive shut off valve with response time of zero.

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

ALGORITMA BAGI INJAP KADAR BERUBAH MODULASI LEBAR DENYUTAN BAGI SISTEM BOOM PENYEMBUR

Oleh

ALI RAFIEISHAHEMABADI

April 2008

Pengerusi: Samsul Bahari bin Mohd Noor, PhD

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Penyembur pertanian digunakan untuk aplikasi racun makhluk perosak, baja dan bahan-bahan kimia lain di dalam ladang. Sebuah algoritma kawalan untuk mengubahsuai kadar aplikasi baja dalam ladang dengan jitu menggunakan komponen yang berkos rendah diperlukan.

Sebuah sistem kawalan penyemburan berkadar ubah telah dimajukan, menggunakan kombinasi perubahan kadar aliran pada boom, dan juga dengan menggunakan modulasi lebar denyutan pada injap solenoid yang dipasang pada nozel. Kombinasi ini membolehkan aplikasi kimia pertanian dengan tebaran kadar berubah dan/atau aplikasi kadar berubah bagi keseluruhan panjang boom. Matlab 7.1 telah digunakan untuk simulasi pencapaian sistem kombinasi tersebut. Untuk menentukan pencirian dinamik komponen-komponen penyembur, penyembur tersebut telah dipasang dan komponennya telah dikalibrasi. Pencirian tersebut telah digunakan di dalam pengaturcaraan simulasi tersebut. Teknik pengenalpastian proses telah digunakan untuk menganggar waktu tindakbalas perubahan kadar aliran penyembur terhadap perubahan isyarat kawalan.

Strategi pandang depan telah digunakan untuk sistem navigasi bagi meminimakan ralat aplikasi sepanjang arah pergerakan traktor penyembur, menggunakan kadar yang ditentukan sebuah peta GIS yang disimulasi, di mana kedudukan sentiasa dikemaskini dan diperbetulkan bagi variasi dalam halaju. Strategi ini telah disahkan secara simulasi dengan menggunakan data GIS yang telah disampel, dan koordinat AGPS yang telah diandaikan. Ralat aplikasi sepanjang boom diminimakan dengan lebih awal algoritma modulasi lebar denyutan untuk digunakan pada injap nozel apabila variasi dalam aplikasi sepanjang boom diingini. Simulasi tersebut menggunakan kitar masa 1 saat untuk untuk mengubah parameter- parameter kawalan bagi miminimakan ralat aplikasi. Algoritma modulasi lebar denyut telah diubahsuai kepada modulasi lebar denyutan aktivasi untuk mengurangkan ralat daripada waktu naik dan turun bagi injap solenoid biasanya tertutup yang berkos rendah.

Ujikaji mendapati nilai anggaran purata masa mati dan masa malar sebanyak 0.1095 dan 0.4225 bagi sistem penyembur tersebut. Julat nisbah kawalan aliran sebanyak 34:1 telah dicapai menggunakan algoritma tersebut. Anggaran ralat purata kadar aliran dalam perecik bagi dua data kadar aplikasi pilihan rawak dan empat julat rawak adalah 1.356% dan 1.211% bagi halaju malar, dan 2.651% jika halaju berubah dalam julat yang kecil. Hasil dari simulasi menunjukkan bahawa algoritma aktivasi lebar denyut ini mengurangkan ralat purata bagi injap solenoid biasanya tertutup berkos rendah dengan waktu bukaan dan tutupan sebanyak 20ms dan 30 ms kepada 2.555% bagi halaju malar dan 3.084% jika halaju berubah dalam julat yang kecil, berbanding dengan injap ideal berkos tinggi dengan waktu tindakbalas sifar.

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APPROVAL

I certify that an Examination Committee met on ____________ to conduct the final examination of Ali Rafieishahemabadi on his Master Degree thesis entitled “A Variable Rate Pulsed Width Modulated Nozzle Valves Algorithm for Boom Sprayer System” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher degree) Regulations 1981. The Committee recommends that the student be awarded the relevant degree.

Members of the Examination Committee were as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master Science. The members of Supervisory Committee were as follows:

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Date : 10 July 2008

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

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ALI RAFIEISHAHEMABADI

Date: _____________

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LIST OF ABBREVIATIONS

VRT	Variable Rate Technology
LPM	Litter Per Minute
GPM	Gallon Per Minute
PWM	Pulse Width Modulation
PSI	Pound Per Square Inch
GPS	Global Positioning System
AGPS	Assisted Global Positioning System
GIS	Geographic Information System
DC	Duty Cycle
FOPDT	First Order Plus Dead Time Model
SOPDT	Second Order Plus Dead Time Model
MATLAB	Matrix Laboratory
PTO	Power Takeoff
RPM	Revolutions (or Rotations) Per Minute
gpa	Gallon Per Acre (4046.86 square meter)
CV	Coefficient Value
PRV	Pressure Relief Valve
VRA	Variable Rate Application

CHAPTER 1

INTRODUCTION

1.1 Overview

Precision farming is a farming system concept which involves the development and adoption of knowledge-based technical management systems with the main goal of optimizing profit. This management system will enable micro- management concepts, that is, the ability to appropriately manage every field operation at each location in the field, if it is technically and economically advantageous to manage at that level. The system will likely include the ability to vary or tailor the application rate of all inputs such as seeds, weed, insect, and disease control. It has become feasible because of several new technologies like fast computers, geographical information system, remote sensing, and geographical positioning system. Fast computers and powerful graphical and information management software are among the technologies which are making precision farming a reality.

Variable rate technology (VRT) plays an important role in precision farming. It involves the use of historical and/or real-time site-specific information in applying a desired rate of an agriculture input such as pesticides, herbicides and fertilizers at a specific site within a field.

Technically, one important aspect of the development of precision farming concepts is the development of the hardware and software necessary to vary the rate of the application of agricultural inputs.

Control systems fitted to agricultural boom sprayers should guarantee control of delivered dose rates in order to achieve optimum use of fertilizer, pesticide and herbicide. Precision farming approaches are likely to require application rates to be varied to match the fertilizer requirements of different parts of a field and this will require control systems that have a rapid response to change requirements. Control parts are devices that change the application rate of products being applied real time.

A new development in variable flow rate application is the use of variable flow rate from the nozzle by pulse width modulation. Some shut off valves installed on a boom mounted on the rear of the vehicle, usually tractor, with a control system to make a sprayer apply the desired application rates by pulse width modulation.

1.2 Research Problems in Sprayer

Nowadays, the precision farming is able to access information of agricultural fields by employing new technologies. The micromanagement process in agricultural field management affords ability to extract required application rates of chemical fertilizers with accuracy of less than a meter. However, the technology required to vary application rate of fertilizer across the fields with a given precise micro amounts in each part of the land is a challenge to researchers. The new sprayers play an important role to distribute chemical precisely on the farm.

The PWM (pulse width modulation) sprayer is a new design of sprayer developed by Han et al. (2001). The flow control range of 9:1 was achieved under constant supply pressure for PWM sprayer (Ess et al., 2001) which is not a wide range of control compatible with preload GIS data. The fast-acting electrical solenoid valves with response time of 4 ms and operation frequency of 10 Hz used in given sprayer system. The high speed solenoid valves used in this system is quite costly, adding to the expense of the hardware, especially since the valves are likely to require replacement as they wear out. If lower cost industrial solenoid valves could be used instead, the initial cost of the hardware could be brought down. The penalty in using lower cost valves is their slower opening and closing time compared to high speed valves.

This study offers a control system design for pulse width modulation sprayer with low cost components. This sprayer was assembled by contribution of mechanical and GIS group in instrumentation laboratory of Engineering, University Putra Malaysia.

1.3 Aim and Objectives

The aim of this project is to design and simulate a control system for the sprayer fitted with low cost PWM (pulse width modulation) nozzle valves. In order to have a control system for PWM sprayer that will be able to spray with high accuracy, the following objectives have been set: