VISION BASED ROW GUIDANCE APPROACH FOR NAVIGATION OF AGRICULTURAL MOBILE ROBOTS IN ORCHARDS

NURUL SAKINAH BINTI LAFIDI

BACHELOR OF MECHATRONICS ENGINEERING WITH HONOURS
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

VISION BASED ROW GUIDANCE APPROACH FOR NAVIGATION OF AGRICULTURAL MOBILE ROBOTS IN ORCHARDS

NURUL SAKINAH BINTI LAFIDI

A report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Mechatronics Engineering with Honours

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this thesis entitled "VISION BASED ROW GUIDANCE APPROACH FOR NAVIGATION OF AGRICULTURAL MOBILE ROBOTS IN ORCHARDS is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : 

Name : NURUL SAKINAH BINTI LAFIDI

Date : 5/7/2021

APPROVAL

I hereby declare that I have checked this report entitled “Vision Based Row Guidance Approach For Navigation Of Agricultural Mobile Robots In Orchards” and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

Signature : 

Supervisor Name : DR. HAIROL NIZAM MOHD SHAH

Date : 5 JULAI 2021

DEDICATIONS

First of all, I would like to express my deepest gratitude to Allah, the Almighty. To my beloved mother and father, Pn Habibah binti Taib and En Lafidi bin Mahdan, who always give me emotional support to complete this Final Year Project study.

Special appreciation to my brother and sisters, Muhammad Zuhairi, Nurul Najihah and Nurul Farzana, who willingly share with me their experiences for me to survive during my studies in UTeM.

To my best friends, who have always been with me through the good and bad times, Nur Syafiqah binti Fisal and Wan Najihah binti Wan Mamat, and my partner Nur Azreen Azwa binti Ngahadi who always share important information with me about this subject.

And to my peers who are involved with me, whether directly or indirectly.

ACKNOWLEDGEMENTS

I would like to express gratitude to my project supervisor, Dr. Hairol Nizam bin Mohd Shah, who has played a very important role in guiding and encouraging me during the whole project. I am also very fortunate to have a supervisor who can always inspire me and keep motivating me to complete this project.

I am grateful to my panels, particularly Ir. Dr. Anuar bin Mohamed Kassim and Dr. Saifulza bin Alwi @ Suhaimi, for their honest evaluation and recommendations on how to improve my project during the seminar.

My fellow graduate students should also be acknowledged for their support. My big gratitude also goes to all my friends and those who have provided assistance. Unfortunately, it is not possible to mention all of them in this limited space. I am also very grateful to all my family members for always there with me.

ABSTRACT

Machine vision plays important roles for the development in agriculture to improve the level of productivity. In the present study, this project proposes the development of an automatic guidance system capable of navigating an autonomous vehicle which traveling between the row in orchard. The system focuses on the straight lines recognition of the tree rows by identifying central line for robot navigation in orchard's row using Hough Transform and image processing methods such as Morphological operation, Thresholding and Edge detection by using Canny operator. The system is meant for outdoor use only as it is designed for navigation guider in orchard. The main software used in this project is MATLAB for simulation of the vision-based approach which offers workspace for image processing with different features. A series of images of various types of orchards were used to develop the algorithm. The algorithm was then evaluated using several orchards image with different characteristics and the result showed that the proposed method can successfully detect the central lines as navigation of an autonomous vehicle to travel between the row with various heights of trees and sizes.

ABSTRAK

Penglihatan mesin memainkan peranan penting untuk pembangunan dalam bidang pertanian untuk meningkatkan tahap produktiviti. Dalam kajian sekarang, projek ini mencadangkan pembangunan sistem bimbingan automatik yang mampu menavigasi kenderaan autonomi yang bergerak antara barisan di kebun. Sistem ini memberi tumpuan kepada garis lurus pengiktirafan barisan pokok dengan mengenal pasti garis pusat untuk navigasi robot dalam barisan kebun menggunakan Hough Transform dan kaedah pemprosesan imej seperti Operasi Morfologi, Threshold dan Pengesanan Sisi dengan menggunakan pengendali Canny. Sistem ini bertujuan untuk kegunaan luaran hanya kerana ia direka untuk pembimbing navigasi di kebun. Perisian utama yang digunakan dalam projek ini adalah MATLAB untuk simulasi pendekatan berasaskan penglihatan yang menawarkan ruang kerja untuk pemprosesan imej dengan ciri-ciri yang berbeza. Satu siri imej pelbagai jenis kebun digunakan untuk membangunkan algoritma. Algoritma kemudiannya dinilai menggunakan beberapa imej kebun dengan ciri-ciri yang berbeza dan hasilnya menunjukkan bahawa kaedah yang dicadangkan dapat berjaya mengesan garisan tengah sebagai navigasi kenderaan autonomi untuk perjalanan antara barisan dengan pelbagai ketinggian pokok dan saiz.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

CNN	-	Convolutional Neural Network
EKF	-	Extended Kalman Filter
GPS	-	Global Positioning System
LiDAR	-	Light Detection and Ranging
ROS	-	Robot Operating System
RGB	-	Red, Green and Blue
SLAM	-	Simultaneous Localisation and Mapping

CHAPTER 1

INTRODUCTION

1.1 Introduction

Agricultural industry has become the most significant industry in the world as it provides food supply for the living. The food demand has been risen every day due to the increment of world population each day that required extra attention from the sector. Malaysia's global agricultural trade reached $43.5 billion in 2019, with exports of $25 billion and imports of $18.3 billion according to International Trade Administration. Machine vision has been increasingly utilized in precision agriculture to provide automated solutions to activities that were previously done manually [3]. A lot of research has been done to develop mobile robotic systems for greenhouses, orchards and farm land [2]. Precision agriculture research attempts to develop a decision support system for farm management that maximizes input returns while conserving resources. Machine vision and image recognition has been widely used in agriculture in recent years as a method to facilitate process automation and improve productivity. Therefore, wheeled-mobile robots have been used widely for agricultural tasks, such as automated irrigation with the purpose of reducing water consumption, extensive crop inspection, seeding and harvesting [1].

One of the most critical challenges in mobile robot applications is autonomous navigation. The navigation task is to guide the robot safely and autonomously across various environments. Complex sensing systems and smart control algorithms are used to help the robot navigate [5]. Hence, vision-based row guidance approach for navigation of agricultural mobile robot in orchard consist of designing the systems for obstacle detection and central path planning for the mobile robots to move correctly and more efficient. In this paper, the main proposes is the development of an automatic guidance system capable of navigating an autonomous vehicle which traveling between the row. The system focuses on the straight lines recognition by detecting line between the row and tree for robot's navigation in orchard using Hough Transform. The system is meant for outdoor use only as it is designed for navigation guider in

orchard. The algorithm was then evaluated using several orchards image with different characteristics to navigate of an autonomous vehicle to travel between the row of various heights of trees and various sizes.

The research offered in this paper is an expansion of the latest technical developments currently being explored in the agricultural, where it is important to restructure agricultural equipment in order for the industry to keep pace with modern innovation in order to be able to supply advanced field machinery that can perform its increasingly expanding roles convincingly.

1.2 Motivation

The shortage of labours and obsolete technology in the industry has become the issue today. To overcome this matter, advanced technology such as automation and robotics was introduced to this industry also known as smart farming or precision agriculture, aimed for faster with more quantity and quality product can be produced at one time. These robots play a significant role in many agricultural applications, as they minimize human labour and improve operational protection [3]. Figure 1.1 shown below is the vehicle travel between rows in orchard.

Figure 1.1: The Vehicle Travel Between Row in Orchard

Therefore, the vision-based row guidance approach for navigation of agricultural mobile robots in orchards was studied to help the farmers to obtain more accurate path especially bigger size orchard that needs more time to manually measured and has to recheck to gain better results. To measure the line manually, usually it takes minimum two person to hold the measuring tape from start to end of the line. Thus, farmer need to hire more worker for the line-making alone. To make the row line, ones need to have sufficient experience to make the line consistent and align or else the worker have to redo the task.

By using vision-based approach, farmer can always monitor the end result without having to attend the orchard because this project used the threshold selection, morphological operation and canny edge detector and also Hough Transform to develop an automatic guidance system capable of navigating an autonomous vehicle which traveling between the row. Farmer also can save for labour cost yet can obtain more effective outcomes. Figure 1.2 shown below is the traditional method used in orchard's row.

Figure 1.2: The Traditional Method Used in Orchard

1.3 Problem Statement

Nowadays, most farmers are using typical existing method where they need to have sufficient experience and visual abilities in order to estimate the difference between rows and trees. This conventional approach regularly lacks of precision in term of spacing. If error occurs, farmers will have to redo the row and this would waste time and cost a lot of money. Hence, by using machine learning techniques, it allows rapid and accurate analysis of large amounts of data and allowing the deployment of machine vision applications in agriculture. Therefore, farmers are able to obtain accurate path along the row by using vision-based row guidance for navigation mobile robots as the system captured colour image and convert to grey scale image. It operated by Threshold and edge detection using Canny operator for image segmentation. In addition, Hough transform is also applied to extract the features required to detect central line for robot navigation in orchard row. A series of images of various types of orchards were used to develop the algorithm. Then, the outcome would also demonstrate that the algorithm can detect the central lines as navigation of an autonomous vehicle to guide the orchard with various heights and sizes continuously without farmers have to monitor it directly.

1.4 Objectives

1) To develop vision-based row guidance system capable of navigating an autonomous vehicle which traveling between the row.

2) To identify central line for robot navigation in orchard's row using Hough Transform.

3) To evaluate the effectiveness of the algorithm by using several orchards image with various heights of trees and sizes.

1.5 Scope of the project

1) This project algorithm will be tested on a group of trees in rows.

2) Only straight line will be considered in line recognition.

3) The algorithm is not in real time.

4) The algorithm only works on well-structured orchard.

1.6 Report Outline

The paper is divided into five chapters. The current Chapter 1 is detailed explanation of the introduction of the project, motivation, problem statements, objectives, and scope in order to present the observations and analysis of vision-based row guidance approach for navigation of agricultural mobile robots in orchards. Chapter 2 is discussion of the literature review and the best method for line detection and path recognition for mobile robots. Chapter 3 is the methodology and the overview of the project, including the design system and equipment used in the analysis. The results obtained from the simulation that was tested are discussed in chapter 4. Lastly, the conclusion and recommendation for future work in chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The purpose of Chapter 2 is to address the literature review and the approach for detecting a line for a novel navigation guidance for mobile robot navigation in orchards as the primary focus. In order to design the novel-based algorithm, computational method and edge detection are being discussed.

2.2 Overview of Research Field

This project is to develop a line recognition algorithm based on image processing to guide the robot in-between tree rows. A compilation of images of various types of orchards has been used to develop the algorithm, and this made it possible to create a system capable of identifying pathways between trees of various heights and sizes. Image processing algorithms have been implemented to orchard's row images in order to identify central line as a pathway for the mobile robots to follow. The algorithm was tested using several images with various characteristics and the result showed that the proposed method would effectively recognize path in straight line rows. The objective of this chapter is to provide analysis and general information on vision-based vehicle guidance systems by grouping or comparing methods from relevant research articles. In order to guide an autonomous vehicle along the path, a vision-based line detection system, Hough transform and Extended Kalman Filter (EKF) are also considered to extract main elements from the environment. Figure 2.1 shown below is the major categories for autonomous navigation system for agricultural mobile robots.

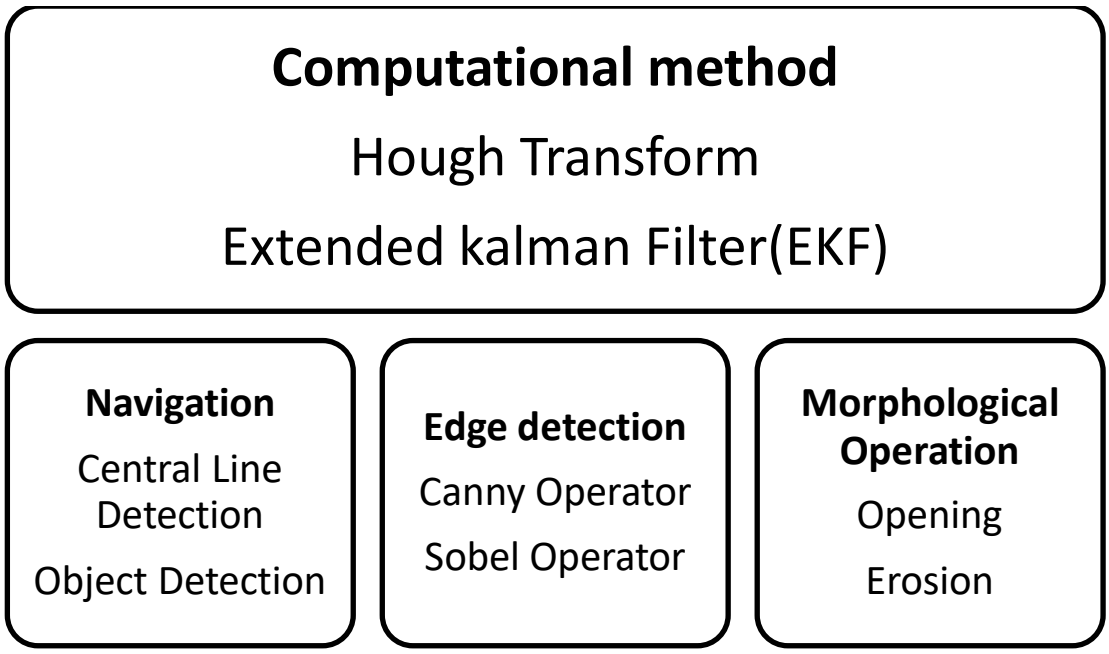

Figure 2.1: The Major Categories for Autonomous Navigation System for Agricultural Mobile Robots

2.3 Computational Methods

2.3.1 Hough Transform

The Hough Transform application is typically used as a line detection method through mathematical transformation [4]. Effective algorithms and methods are needed to extract main elements from the environment to move vehicles automatically. Various computational techniques are used to deal with the data fusion of sensor in order to provide adequate information for the autonomous navigation of agricultural vehicles [1]. Hough transform is a feature extraction method used in the images processing, computer vision, and digital images processing. It is used to isolate the features of a specific shape within an image [1]. Hough transform also an effective method of image segmentation can be used to map the environment and to detect rows. The benefit of it is that the pixels should not be on one line and the neighbours should be able to detect the straight line so that they can extract very effectively the lines that have gaps in them created by noise [2]. As most crops and trees are cultivated in commonly straight line rows, most of the image processing algorithms for row detection are based on Hough transform. Hough transform has been used successfully in a variety of experiments for the straight line identification of crop or tree rows in [1,2].

Figure 2.2: The line Detection using Hough Transform [2]

2.3.2 Extended Kalman filter (EKF)

EKF can be identified as the best fusion data sensor technology that offers reliable estimate of the direction and orientation of the mobile robot. Kalman Filtering is a common technique used to approximate reliable sensor data, including noise and inaccurate data over time [5]. Extended Kalman Filter (EKF) was adapted to find a solution of nonlinear systems. It can be considered to be the most widely used algorithm to solve the SLAM problem. However, EKF-SLAM has disadvantages in terms of processing time and computational specifications according to [5]. Table 2.1 shown below is the comparison in term of advantage and disadvantage between Hough Transform and Extended Kalman Filter (EKF).

Table 2.1 The Comparison between Hough Transform and Extended Kalman Filter (EKF)

	Hough Transform	Extended Kalman Filter (EKF)
Advantage	Integrates details across a variety of rows, making the technique tolerant of missed plants.	Adapted to solve the complexity in non-linear processes.
Disadvantage	Limited to situations where plants are put in rows.	Usually integrated with various optimization techniques and control strategies to boost performance.

2.4 Edge detection

Edge Detection is a method in which the points where the brightness of the image varies sharply or formally are identified. This points where the brightness of the image varies strongly are arranged in line segments called edges.

2.4.1 Canny operator

Canny edge detection technique is used for object recognition and pattern matching purposes where it is important to preserve the features even in the case of a noisy image [6]. Canny operator can clearly detect the edge with better accuracy. Any essential features can be removed from the edges of any image. Of all these edge detection methods, the canny edge detection algorithm is the best, most efficient and frequently used form of edge detection since it consists of a variety of customizable parameters that can influence the speed and efficiency of the algorithm [6].

2.4.2 Sobel operator

The operator used in [1] is the Sobel operator to detect the edge. This operator calculates the gradient of the intensity function derived from the input image and suppresses the noise in the image by specifying a weight that grows in the direction of the central point of the mathematical representation that enables the detection of undesired information [1]. Table 2.2 shown below is the comparison between Canny Operator and Sobel Operator.

Table 2.2 The Comparison Between Canny Operator and Sobel Operator

	Canny Operator	Sobel Operator
Advantages	Can clearly detect the edge with better accuracy. Most efficient as it has customizable parameters. Excellent detection of noise environments.	Suppresses the noise in the image.
Disadvantage	It may be hard to set a common threshold that performs well on all image.	Enables the detection of undesired information.