LOOSE FRUIT COLLECTION USING A DELTA ROBOT

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A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Mechatronics & Automatic Control)

School of Electrical Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

JULY 2022

DEDICATION

This is dedicated to my parents who fuelled my ambitions with hope and encouragement, who dedicated all their resources to ensure I always make a step forward, and who taught me that there is no dream that is beyond my capabilities if given enough dedication.

ACKNOWLEDGEMENT

First and foremost, I thank Allah SWT who provided me with the strength and dedication to complete this project. In preparing this thesis I was in contact with many people especially researchers, both local and abroad. Their insights and ideas were an essential aspect of my understanding of the topic, and they impacted the methodology and approach of the project, as well as the hypothesis formed and its validity.

I would like to express my deepest appreciation to all those who helped me throughout the project and particularly my project supervisor, Dr. Hazlina Binti Selamat, who helped me immensely by providing the academic guidance and support – whether instrumental or informational – that I needed.

Finally, I would like to thank all Universiti Teknologi Malaysia (UTM) staff who helped me in various ways to complete this project.

ABSTRACT

With the increase of the global demand for palm oil, mechanizing oil palm plantations is becoming more and more significant. Even after almost a century since the first oil palm plantation in Malaysia, these plantations still rely almost-completely on manual labour for many of the harvesting and collection of the fresh fruit bunch (FFB) and the loose fruit (LF). Loose fruits that fall away from the FFB have the highest oil content since they are originally from the outer layer of the bunch. Due to its economic value, collectors have to manually collect these fruits which can result in many musculoskeletal disorders due to the bad back, hip and knee postures they have to endure on daily basis. Increasing the productivity and minimizing these issues of LF collection can be achieved by developing machines that can carry out the collection process seamlessly. Although many mechanisms like vacuum type collecting as well as racking tools have been implemented, each of which comes with constraints and issues like debris filtering and intensive manual labour. With the evolvement of robotics as well as machine vision and their applications in recent years, robotic collection of these fruits became more and more viable. In this work, automatic collection of these fruits using a delta robot along with a vision system for detection and localization is explored. A proof of concept of the collection process using a parallel delta link robot under a controlled environment is simulated. Additionally, a more versatile YOLO based LF detection system is explored. Although the robot displayed a capability of collecting over 50 LFs per minute, the integrated vision system for the delta robot proved incompetent when presented with different variations of LF and hence, a separate YOLO-based LF detection system is introduced.

ABSTRAK

Dengan peningkatan permintaan global untuk minyak sawit, mekanisasi ladang kelapa sawit menjadi semakin ketara. Walaupun selepas hampir satu abad sejak ladang kelapa sawit pertama di Malaysia, ladang-ladang ini masih bergantung hampir sepenuhnya kepada buruh kasar untuk kebanyakan penuaian dan pengumpulan tandan buah segar (FFB) dan buah lepas (LF). Buah gembur yang jatuh dari BTS mempunyai kandungan minyak yang paling tinggi kerana ia berasal dari lapisan luar tandan. Oleh kerana nilai ekonominya, pengumpul perlu mengumpul buah-buahan ini secara manual yang boleh mengakibatkan banyak gangguan muskuloskeletal akibat postur belakang, pinggul dan lutut yang buruk yang perlu mereka tanggung setiap hari. Meningkatkan produktiviti dan meminimumkan isu pengumpulan LF ini boleh dicapai dengan membangunkan mesin yang boleh menjalankan proses pengumpulan dengan lancar. Walaupun banyak mekanisme seperti mengumpul jenis vakum serta alat racking telah dilaksanakan, setiap satu daripadanya datang dengan kekangan dan isu seperti penapisan serpihan dan kerja manual intensif. Dengan perkembangan robotik serta penglihatan mesin dan aplikasinya dalam beberapa tahun kebelakangan ini, koleksi robotik buah-buahan ini menjadi lebih berdaya maju. Dalam kerja ini, pengumpulan automatik buah-buahan ini menggunakan robot delta bersama-sama dengan sistem penglihatan untuk pengesanan dan penyetempatan diterokai. Bukti konsep proses pengumpulan menggunakan robot pautan delta selari di bawah persekitaran terkawal disimulasikan. Selain itu, sistem pengesanan LF berasaskan YOLO yang lebih serba boleh diterokai. Walaupun robot itu memaparkan keupayaan mengumpul lebih 50 LF seminit, sistem penglihatan bersepadu untuk robot delta terbukti tidak cekap apabila dibentangkan dengan variasi LF yang berbeza dan oleh itu, sistem pengesanan LF berasaskan YOLO yang berasingan diperkenalkan.

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LIST OF ABBREVIATIONS

GDP	-	Gross Domestic Product
FFB	-	Fresh Fruit Brunches
LF	-	Loose Fruit
OER	-	Oil Extraction Rate
MBOP	-	Malaysian Palm Oil Board
WIPO	-	World Intellectual Property Organization
GPS	-	Global Positioning System
CNN	-	Region-Based CNN
SSD	-	Single Shot Detector
YOLO	-	You Only Look Once
ACE	-	Automation Control Environment

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CHAPTER 1

INTRODUCTION

1.1 Problem Background

Malaysia is the second biggest producer and exporter of palm oil in the world. In 2019, with over 5.74 million hectares of land, palm oil was the major contributor to the value added to the agriculture sector, contributing around RM38.3 billion to the Gross Domestic Product (GDP) [1, 2]. These huge prospects of the palm oil industry showcase the importance of it to the Malaysian economy and how crucial it is to integrate sustainable solutions for problems that arises to ensure economical security as well as its future potential value.

The process of harvesting in the majority of oil palm plantations is consisted of six stages namely: branches cutting, fronds stacking, fresh fruit brunches (FFB) collection, loose fruit (LF) collection, and finally the transportation to the mill [3]. The loose fruit collection stage stands out compared to the rest of the stages as they contain the highest amount of oil extraction rate (OER). FFBs alone can turn out an OER of around 25%, which can be significantly increased – up to 40% – with careful LF collection [4]. Therefore, careful collection of the loose fruit without any debris involved is significant for palm oil industry.

It is clear that aspects like harvesting procedure, efficiency of the oil mill, and plantation practices can impact the total OER [3]. Many commercial plantations now have long harvesting round in order to increase the overall collection of the leftover LFs. This behaviour is an indication of how crucial LF collection is and how improper implementation of this task can be the reason bring about huge loss of potential income. In order to ensure the highest possible OER, it is important to make sure the LF collection is handled properly, meaning that LF integrity and lack of debris is ensured.

1.2 Problem Statement

Harvesting for palm oil industry is a process that is carried out all-year round. The cycle consists of multiple stages as the FFBs as well as the subtending fronds have to be cut first, then the fronds are stacked. Next, the FFBs are collected then later the LFs are collected. Finally, both are sent to the mill. LFs are typically scattered in the field and collected manually either by picking or raking.

Multiple studies have shown that more than 70% of the harvesting labor time us dedicated just for collecting LF. additionally shows that 30% of the total fruit handling time is just time spent in LF collection [3]. Hand picking of LF is still the preferred method of collection as it ensures that the least number of debris is involved. Palm oil industry in Malaysia is a labor-intensive industry that is dependent on foreign labor. In April 2020, 337,000 migrant workers, worked on Malaysian plantations, which constitutes 80% of the workforce [5]. With the COVID-19 pandemic and the closure of international borders, labor shortage hit the palm oil industry harshly as the supply dropped by around 30% in 2021 [6].

Manual LF collection is a very laborious work that exposes the collectors to ergonomic risks because of the awkward and repetitive posture they have to endure especially when hand picking the LF is the method of collection. In 2021, a study investigated possible musculoskeletal disorders the collectors might be facing, and the result showed that collectors displayed poor and discomfort posture during both LF and FFB collection [7].

The heavy dependance on manual labor for physically demanding tasks like LF collection has a negative effect on the production due to its inefficiency. Due to a multitude of economic and social factors, it is believed that Malaysia's reliance on foreign workers should not last for long term [8]. Manual LF collection is also time consuming and exposes workers to musculoskeletal disorders due to the bad back, hip and knee postures they forced to endure on daily basis. Thus, mechanizing the century long industry is a consistent problem that now attract many businesses that want to utilize the financial prospects of an efficient and reliable process.

1.3 Project Objectives

This project serves as the first stage in the development of a mechanized solution that can carry out LF collection by utilizing a robotic system (a parallel delta robot). Thus, this project's objectives are simply:

1) To simulate a proof-of-concept (POC) of a robotic loose fruit collection system based on a delta (parallel link) robot.

2) To test out the efficiency of the robot's integrated vision system and explore other LF visual detection methods.

1.4 Project Scope

A robotic LF collection system involves a lot of subsystems that all need to work together effectively and efficiently in scenarios similar to that in the field. This indicates that solution requires a detailed research and development process for each of the subsystems which is carried out on a timeline that exceeds that of this project. Thus, the project has a limited scope where only a proof of concept is simulated, one that shall discover the challenges presented for the given task in terms of the robotic application for mechanical picking as well as the visual detection and localization of the LFs themselves. The robot selected for the simulation is the Omron Hornet 565 (3-axis) as it is present and available for future experimentation in Centre for Artificial Intelligence & Robotics lab in Kuala Lampur. Unfortunately, since the robot lacked the equipment and software needed to implement the integrated vision system during the project timeline, the trials were emulated on the OMRON software which has a feature where the emulation can be used to program the robot using a single click. Although the robot is a fixed robot which differs from the mobile collaborative robotic solution that suits the proposed overall collection system, the Hornet 565 is suitable for the objectives of this project where a simulation of picking and visual detection is explored to understand the challenges that need to be overcome and refine the overall solution accordingly in order to achieve an efficient robotic LF collection solution.

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