MAPPING AGRICULTURE ENVIRONMENT USING VISUAL SIMULTANEOUS LOCALIZATION AND MAPPING (SLAM)

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

Faculty of Electronic and Computer Engineering
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DEDICATION

I am very grateful to my families, supervisor and friends who have helped me a lot throughout my journey finishing this research and completing this thesis paper. Thereby, I dedicate this to everyone that is involved directly and indirectly in completing this research.

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ABSTRACT

Agriculture activity is essential to maintain human life to provide food and nutrients for human body. As the world population increase, there is also a growing demand for food where food productivity need to also increase simultaneously. In the meantime, technologies are also evolving rapidly. Thus, autonomous mobile robots started to be used for a variety of tasks in agriculture activity to increase the productivity. To do so, a robot need to be able to perform localization and mapping the surrounding environment. That is when visual Simultaneous and Localization Mapping (SLAM) was introduced. This project will evaluate and analyze the performance of visual SLAM algorithms for mapping in agriculture environment using agriculture dataset. The dataset used in this project is Rosario dataset as a benchmark to compare the performance of the algorithms. The project will carry out in Ubuntu Linux operating system with Robot Operating System (ROS) where the algorithm will be implemented. By the end of this project, the performance of each visual SLAM algorithm will be compared and proved which is the most reliable for agricultural activity.

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ABSTRAK

Aktiviti pertanian adalah penting untuk mengekalkan kehidupan manusia untuk menyediakan makanan dan nutrien untuk manusia. Peningkatan populasi dunia menyebabkan permintaan terhadap makanan juga semakin meningkat sekaligus memerlukan peningkatan dalam produktiviti makanan. Dalam pada itu, teknologi juga berkembang dengan pesat. Oleh itu, robot mudah alih autonomi mula digunakan untuk membantu dalam melakukan pelbagai tugas dalam aktiviti pertanian untuk meningkatkan produktiviti. Untuk berbuat demikian, robot perlu dapat melakukan penyetempatan dan pemetaan persekitaran sekeliling. Ketika itulah visual "Simultaneous Localization and Mapping (SLAM)" diperkenalkan. Projek ini menilai dan menganalisis prestasi algoritma visual SLAM untuk pemetaan dalam persekitaran pertanian menggunakan dataset pertanian. Set data yang digunakan dalam projek ini ialah dataset Rosario sebagai penanda aras untuk membandingkan prestasi algoritma. Projek ini akan dijalankan dalam sistem operasi Ubuntu Linux dengan Sistem Operasi Robot (ROS) di mana algoritma akan dilaksanakan. Menjelang akhir projek ini, prestasi setiap algoritma visual SLAM akan dibandingkan dan dibuktikan yang mana yang paling sesuai untuk digunakan dalam aktiviti pertanian.

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LIST OF SYMBOLS AND ABBREVIATIONS

SLAM	:	Simultaneous Localization and Mapping
DSO	:	Direct Sparse Odometry
ATE	:	Absolute Trajectory Error
RPE	:	Relative Pose Error
UAV	:	Unmanned Aerial Vehicle
UGV	:	Unmanned Ground Vehicle
ROS	:	Robot Operating System
6DOF	:	6 Degrees of Freedom
BA	:	Bundle Adjustment

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CHAPTER 1

INTRODUCTION

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1.1 Project background

Agriculture activity is essential to maintain human life to provide food and nutrients for human body. By 2050 it is forecasted the world population would reach 9 billion people. As the world population increase, there is also a growing demand for food where food productivity need to also increase simultaneously by increasing the productivity in agricultural activities [1]. In the meantime, technologies are also evolving rapidly. Thus, autonomous mobile robots started to be used for a variety of tasks in agriculture activity to increase the productivity. To do so, a robot need to be able to perform localization and mapping the surrounding environment. That is when visual Simultaneous and Localization Mapping (SLAM) was introduced. This project will evaluate and analyze the performance of visual SLAM algorithms for mapping in agriculture environment using agriculture dataset. The dataset used in this project is

Rosario dataset as a benchmark to compare the performance of the algorithms. The project will carry out in Ubuntu Linux operating system with Robot Operating System (ROS) where the algorithm will be implemented. By the end of this project, the performance of each visual SLAM algorithm will be compared and proved which is the most reliable for agricultural activity.

1.2 Problem statement

Crop monitoring, watering, weed removal, pest control and harvesting could be found as the most frequent and time-consuming process. This has brought to the application of intelligent and automated system or famously known as mobile robots to assist in agricultural operations. For the robot to aid in all these activities, it needs to know the map of the surrounding area and localize itself in its current position. Thus, visual SLAM is used. Visual SLAM has been widely used in urban landscaping, indoor, and outdoor mapping, and tracking. There are also a lot of algorithms developed to suit the application of the visual SLAM. However, the application of visual SLAM in agriculture activity is in early stage and there are a lot of limitations and drawback in this application because of the repetitive and diverse pattern of the agriculture environment. Researchers are still studying the best algorithms to be used in agricultural activities in terms of performance and robustness of the algorithm.

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So, in this project, a few visual SLAM algorithms are going to be used and compared. There are a lot of visual SLAM algorithms developed which consist of feature-based method such as ORB-SLAM3, OpenVSLAM and direct method visual SLAM such as Direct Sparse Odometry (DSO) and Semi-direct Visual Odometry (SVO). These algorithms will be compared using agriculture dataset which is Rosario dataset as a benchmark to prove which is the most reliable SLAM algorithm that can

be used in agriculture activity. This dataset consists of 6 sequences. This dataset can help to determine the performance and robustness of each algorithm so that it can be implemented on a mobile robots to map the surrounding and localize itself in agriculture environment and aid in various agriculture activity.

1.3 Objectives

1. To compare the performance between feature-based and direct method visual SLAM algorithms for mapping in agriculture environment using agriculture dataset.
2. To analyse the performance of the algorithm for mapping and localizing in agricultural activities using absolute trajectory error (ATE) and relative pose error (RPE).

1.4 Scope of Work

This project is an experiment on the visual SLAM algorithm for mapping in agriculture environment which consists of feature-based method and direct method based on an agriculture dataset. There are a lot of visual SLAM algorithms developed suit to the application of the system. The algorithm will be implemented in Robot Operating System (ROS) running inside Ubuntu Linux operating system. Besides that, there are also a lot of dataset available for urban, terrain, indoor and outdoor mapping. The dataset is used as a benchmark to evaluate the performance of the algorithms. The most famous dataset used in agriculture activity is Sugar Beets dataset and Rosario dataset. This project will only use data from Rosario dataset. From the dataset, the performance between the algorithm is analyzed and compared to determine which one is the best visual SLAM algorithm to be used in agricultural activity. The experiment will be conducted solely through online dataset.

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1.5 Thesis outline

This thesis is structured into five chapters which are introduction, background study, methodology, results, and discussion, and finally followed by conclusion and future works. References, list of publications and paper presented, and appendices for each related works also included in the thesis.

The first chapter provides a quick outline of the theory of the project, related works, and findings from previous research. Apart from that, the issue definition, aims, and scopes of the research activity are all covered in this chapter.

The second chapter touches about the background study of this project where the theory about visual SLAM is explained in detail and the important literature review related to the research work is discussed. The chapter begins with detail introduction about visual SLAM, elements, and methods of visual. Next, it covers about the evaluation of SLAM using ATE and RPE. Then, it continues with literature review of related works. Each literature is briefly explained and concluded at the end of the review. The table of comparison between these literature is provided to give an overview of each literature that has been studied.

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In the third chapter, the methodology of this project is shared. It starts with the flowchart of this project. Then, the explanation of each visual SLAM algorithms used in this project and step by step installation instruction for each algorithms is shown. Finally, this chapter touches briefly on the agricultural dataset that is used in this project to compare the performance of the visual SLAM algorithms.

The fourth chapter shares the results from the experiment and discussion on the findings of this project. The results are presented and explained in detail to share and analyze the performance of the visual SLAM algorithms tested in this project.

Finally, the fifth chapter covers the conclusion obtained from this project and discuss the potential future works and recommendation based on the outcome of this project.

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CHAPTER 2

BACKGROUND STUDY

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2.1 Visual SLAM

Autonomous robot is now widely used to aid human in various task without being controlled. To make the robot move without being controlled by human, it needs to have a sense of direction. However, there are a few problems in autonomous robot navigation which can be divided into three main areas which is localization, mapping, and path planning. Localization is a process of determining the current position of the robot in the environment. Mapping is the robot observation of the surrounding to know the scenery and landscape layout. Path planning is a way of the robot to determine and navigate the best route to a given location. For an autonomous robot to map and planning the path precisely, it needs to properly localize itself in the environment. That is when SLAM was introduced. SLAM stands for Simultaneous Localization and Mapping. As the name suggest, it is a method to localize and map surrounding area of