UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN AND DEVELOPMENT OF A TESTING RIG FOR POSITION LOCALIZATION USING ROBOT OPERATING SYSTEM

This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The members of the supervisory committee are as follow:

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(Dr. Shariman bin Abdullah)

ABSTRAK

Penyelidikan projek ini menumpukan pada mereka dan menghasilkan robot bergerak sebagai platform rig pengujian untuk menjalankan proses penyetempatan dan navigasi kendiri. Robot akan dipasang dengan Sistem Operasi Robot (ROS), yang merupakan pakej yang merangkumi simpul ROS, *independent library* ROS, set data, fail konfigurasi, dan apa sahaja yang secara logik melakukan modul praktikal untuk penyetempatan dan navigasi. Konsep sistem pengangkutan yang tidak terkira banyaknya dalam industri semasa kebanyakannya tetap dan sukar diganti. Keperluan untuk sistem pengangkutan yang fleksibel sangat penting dalam meningkatkan kecekapan industri dan syarikat untuk menangani sistem pengangkutan barang mereka. Idea dengan menggunakan paket ROS, Adaptive Monte Carlo Localization (AMCL) dalam melakukan Penyetempatan dan Navigasi Serentak (SLAM) dan memperbaiki sistem navigasi dan penyetempatan robot bergerak yang digunakan untuk mengatasi masalah sistem pengangkutan industri. Badan rig pengujian robot bergerak akan membuat fabrikasi menggunakan pencetak 3 dimensi menggunakan bahan plastik polylactic acid (PLA) standard. Ia dilampirkan dengan Raspberry Pi 4, sebagai komputer mini utama untuk mengintegrasikan semua algoritma ROS untuk mengawal pergerakan robot, menghasilkan pemetaan, dan membaca pelbagai input data sensor. Fasa terakhir dalam projek ini akan dinilai dalam bab metodologi dengan membuat percubaan untuk mengendalikan robot mudah alih menggunakan perisian RViz yang dijalankan dalam Sistem Operasi Linux untuk robot mudah alih yang melakukan proses pergerakan dari lokasi ke lokasi lain yang dikehendaki menggunakan penyetempatan kendiri dan konsep navigasi. Hasil projek ini menunjukkan semua objektif tercapai kerana robot mudah alih menunjukkan prestasi yang baik dalam menunjukkan ketepatan yang tinggi dalam pemetaan dan melakukan proses pergerakan.

ABSTRACT

This project research focuses on designing and developing a mobile robot as a testing rig platform to carry out self-localization and navigation processes. The robot will be installed with Robot Operating System (ROS), which is a package that includes ROS nodes, a ROS-independent library, a dataset, configuration files, and anything else that logically does a practical module for localization and navigation. Innumerable transportation system concept in the current industry mostly is fixed and difficult to be alternate. The necessitate for a new flexible transportation system is very essential in increasing industry and company efficiency to handle transportation systems for their goods. An idea by using ROS package, Adaptive Monte Carlo Localization (AMCL) in performing Simultaneous Localization and Navigation (SLAM) and improving the mobile robot's navigation and localization system used for resorting to industry transportation system problems. The mobile robot testing rig body will fabricate using a 3-dimension printer using the standard polylactic acid (PLA) plastic material. It is attached with Raspberry Pi 4, as the main minicomputer to integrate all the ROS algorithms to control therobot movement, generate mapping, and read the various sensor data input The last phase in this project will be evaluated in the methodology chapter by experimenting to operate the mobile robot using the RViz software running in Linux Operating System for the mobile robot performing movement process from a location to another desired location using self-localization and navigation concept. The result of this project shows all the objectives are achieved as the mobile robot is performing well in showing high accuracy in mapping and performing movement processes.

DEDICATION

To my family,

My beloved father, Hairudin bin Ahmad

My beloved mother, Zuraina binit Ishak

My respectful brothers, Hafizudin, Ismail,

Muhsin, Rashdan, and Syamil

To my supervisor

Dr. Shariman bin Abdullah

Thank you for giving me moral support,

money, cooperation,

encouragement, and understandings

Thank You So Much & Love You All

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LIST OF ABBREVIATIONS

AGV	-	Automated Guided Vehicle
AMCL	-	Adaptive Monte Carlo Localization
DMR	-	Differential Mobile Robot
EKF	-	Extended Kalman Filter
IMU	-	Inertial Measurement Units
LiDAR	-	Light Detection and Ranging
OS	-	Operating System
PLA	-	Polylactide Acid
ROS	-	Robot Operating System
RGB-D	-	Red-Green-Blue-Depth
SLAM	-	Simultaneous Localization and Mapping

LIST OF SYMBOLS

A	-	Ampere
V	-	Volt
KV	-	Kilovolt
α	-	Angular angle
d	-	Distance
$\circ$	-	Degree
θ	-	Angle
$\boldsymbol{\omega}$	-	Angular velocity
$\boldsymbol{v}$	-	Linear velocity
k	-	Spring constant
ms	-	Millisecond
mm	-	Millimeter
Hz	-	Hertz

CHAPTER 1

INTRODUCTION

1.1 Research Background

Robot localization and navigation denotes the robot's ability to establish its position and do the orientation of movement within the unknown environment. This project's main point is to study similar research and perform robot localization and navigation. Robot navigation refers to the process of robot moving from the starting point to the target point. During this period, the robot determines its position according to the saved map and lidar, and then plans out the optimal path according to its own position and preset target point. Finally, the robot moves to the target point roughly according to this path.

Path planning is divided into global planning and local planning according to the scope of action. Local planning is to plan the specific moving speed of the robot according to the local target points and the environmental information obtained by the radar. Robot Operating System (ROS) is a package includes ROS nodes, a ROS-independent library, a dataset, configuration files, and anything else that logically does a practical module for localization. There are lot of others ROS package that free access to anybody that can be utilized if we have the right knowledge and good effort. Mobile robot navigation technology is now increase rapidly with the technology of 2D/3D mapping. Many studies have been done on the implementation of 2D/3D SLAM to determine the goal position respect to the current position of the robot in an area that has not been recognized previously. This research is determined to improving transportation concept system by implementing IR 4.0 for transporting system widely in our industry.

1.2 Problem Statement

Mostly in our current transportation system in industry are not flexible as they tend to be fix and cannot be manipulate or adjusted. In industry sector, people tend to have a carrier system in transporting their goods. Commonly these company will manually transfer and move their components using machinery or in intermediate company, they will transportation system such AGV. The problem came out when the need of changing of factory layout or transportation process. For this old manual transportation method, there will be need huge, fixed cost needed for creating new layout for their industry. In addition, for the AGV and similar sort of this transportation device, they demand for landmark as line guidance, barcode and others figure for performing their movement process to lead them in their path. For that, this study was needed to build and autonomous mobile platform testing rig for position localization analysis in assisting all the stated problem to make in a safer and efficiently.

This research will inquiry the efficiency of a Simultaneous Localization and Mapping (SLAM) based of robot model which are implemented in Robot Operating System (ROS) by measuring how the robot travel to reach their destination set by the operators need to be optimized. Much research from others study stated ROS algorithm that used in autonomous mobile robot platform for localization tend to have shortage and error which become problem for the autonomous mobile robot.

There are many resources needed for completing this task to achieve and meet the localization systems, that allow a robot to locate itself, whether there is a static map available or simultaneous localization and mapping is required. We can use different sensors like LIDAR, RGB-D camera, inertial measurement units (IMU) and sonar to give the sensing power. By using these sensors and mapping algorithms a robot can create a map of the surroundings and locate itself inside the map (Guimarães et al., 2016). The robot will be continuously checking the environment for the any environment changes that could happened.

Mobile robot navigation technology is now increase rapidly with the technology of 2D/3D mapping. Many studies have been done on the implementation of 2D/3D SLAM to determine the goal position respect to the current position of the robot in an area that has not been recognized previously. We need this mobile platform testing rig robot that enable operators to plan outages more precisely and more efficient. This increases the availability of facilities and makes them more profitable, as well as boosting the safety of people and the environment which eliminate human entry in (Priyandoko et al., 2017).

1.3 Objectives

The objectives are as follows:

(a) To develop a mobile robot platform testing rig programming framework and control in Robot Operating System (ROS).

(b) To perform data collection from the surrounding environment in creating mapping through Simultaneous Localization and Mapping (SLAM) process.

(c) To analyze the behavior of the mobile robot when moving from a position to an input desired position.

1.4 Scope

This project limitation is to fabricate the mobile robot platform with the dimension size of 45 cm in width from 3D printer process by standard Polylactide Acid (PLA) material using differential drive locomotive method with additional caster wheel. The Robot Operating System ROS used is Adaptive Monte Carlo Localization (AMCL) package for the Simultaneous Localization and Mapping (SLAM) process which installed in the microcomputer board of Jetson Xavier NX. Dual shaft brush DC motor will be used at both side tire powered with 24-volt Li-Po battery and controlled by Odrive V2.6 board for the movement speed and rotation. Odometry encoder sensor will be utilize increasing accuracy in rotation motor shaft while maneuver by Light Detection and Ranging (LiDAR) sensor to detect the surrounding environment. The speed of this mobile robot platform is determined to be as 0.5 meter per second.

1.5 Summary

This section provides an overview of the research that has led up to the development of the mobile robot. An aim and problem statement that are specific, observable, and attainable are defined. Finally, the project's scope is specified, and the report's structure is constructed to illustrate the report's flow in each of its sections.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses literature of how others journal and study on navigation of mobile robot using the Robot Operating System for navigation and localization. There are few studies that is relate to this topic on developing and design the mobile platform robot such using the mapping, localization, path planning, Simultaneous Localization and Mapping (SLAM) and the robot operating system (ROS). The needs of various sensor in the development of this project as laser sensor, odometry sensor and kinetic sensor is also being discussed in this chapter.

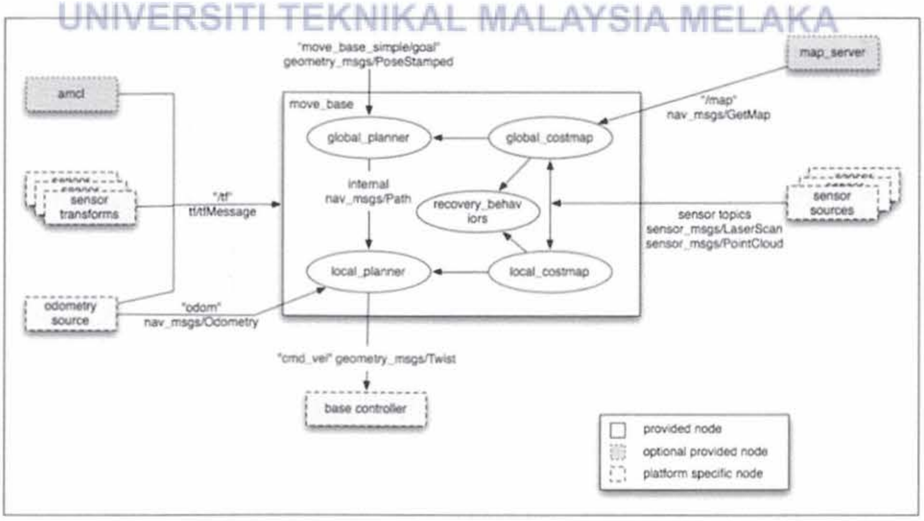

Figure 2.1: Navigation Stack (Guimarães et al., 2016)

Figure 2.1 shows the system overview of the navigation stack in the autonomous navigation system to operate. All the items block stated in this figure will be explain and analyze one by one in this sub chapter.

2.2 Autonomous Navigation Technologies

Autonomous navigation for a robot is achieved when the robot could do a moving task by its own by using mapping the environment process and plotting the odometry process (Akash et al., 2019). These two applications are important as a particle filtering algorithm which will resulting in Simultaneous Navigation and Mapping (SLAM) to work for the robot. Akash et al., (2019) said, by only use this filtering algorithm assist the robot to find the moveable way and path for moving to the input position inserted while avoid collision on surrounding.

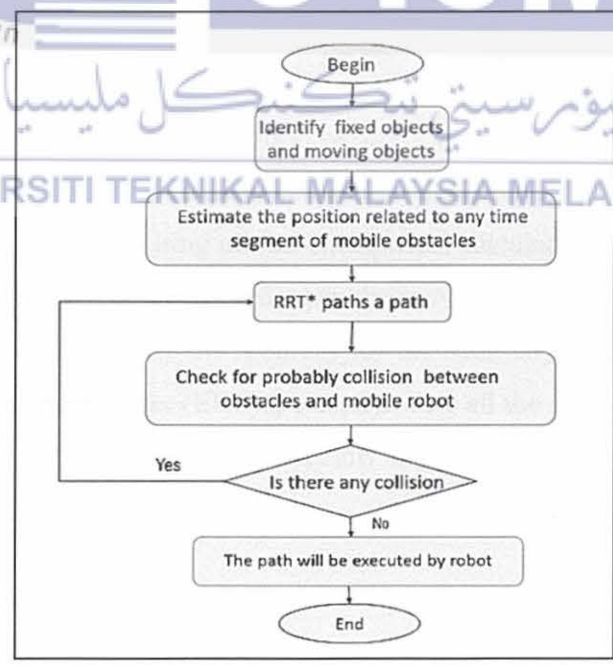

Figure 2.2: Autonomous Navigation Flow Chart (Akash et al., 2019)

The flow chart in figure 2.2 shows how the sequence process for the autonomous navigation process. As stated, the process starts by identifying surrounded object using attached sensor until then it could create mapping for localization process. Next process by undergoing algorithm filtering to process the input and output using the ROS libraries to move to the desired position.

2.2.1 Extended Kalman Filter (EKF)

In assisting local localization system process to works, EKF is used to help to operate in higher frequency to fuse the different sensors data obtained combined with odometry measures sensors. Robot localization package provided by ROS implement the EKF for use in this autonomous navigation application by developing such 2D mode concept, environment parameters as frequency and sensor timeout for tuning process(Valera et al., 2021).

The problems occurs when integration process of parts and the software implementation during autonomous navigation which is error in the odometry calculation. Köseoğlu et al., (2017) stated that odometry calculation in the navigation algorithm was just based on encoder ticks which resulting all the odometrical calculations were made through position change of motor shaft data obtained when the movement occurs. So, the solution to overcome this errors and to increase the accuracy for the odometry calculation to get more reliable, the Extended Kalman Filter (EKF) are used to fuse all the data obtain and solve the problem (Köseoğlu et al., 2017). Figure 2.3 below shows an example how graph when plotting position using EKF concept.