DESIGN AND DEVELOPMENT OF COOPERATIVE CONTROLLED TWO ROBOTS FOR PIPELINE INSPECTION

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DESIGN AND DEVELOPMENT OF COOPERATIVE CONTROLLED TWO ROBOTS FOR PIPELINE INSPECTION

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DECLARATION

I declare that this thesis entitled “Design And Development of Cooperative Controlled Two Robots For Pipeline Inspection” 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	:	
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Date	:	19 June 2019

APPROVAL

I hereby declare that I have checked this report entitled "Design And Development of Cooperative Controlled Two Robots For Pipeline Inspection" 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 : ....

Date : ....

DEDICATIONS

To my beloved mother and father

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ABSTRACT

Pipeline explosion is the most dreadful incident in the oil and gas industry which cause a huge number of fatality and financial loss every year. The existing pipeline inspection robots is costly and the efficiency and flexibility of the single robot system is low in case the pipeline have 2 ways such as T-branch. Therefore, the affordable cooperative controlled two robots for pipeline inspection are developed where the robots are applicable for the horizontal pipeline which used to transport air or gas. This project also aims to evaluate the performance of the developed mobile robots and develop the communication between the mobile robots. A simple structure wheeled type robot has good performance in T-branch accessibility is stated. Besides, Bluetooth module is the most common tools to develop the communication between the multi robot system due to its ease to use and can communicate with other Bluetooth enabled devices. Few experiments such as performance of mobile robot on various type of surfaces, tracking object using ultrasonic sensor, leader-follower approach and tracking control of mobile robot are designed to evaluate the performance and communication between the mobile robots. A PVC pipe with T-branch is built to verify the mobile robots in T-branch accessibility. Through the experiment, the mobile robot is successfully pass through the pipeline with various type of surfaces. The speed, efficiency and accuracy are also evaluated through the experiment. The master and slave robot are able to perform forward, backward, turning left and right movement without having communication loss or disconnected in the PVC pipe.

ABSTRAK

Letupan saluran paip adalah kejadian paling mengerikan dalam industri minyak dan gas yang menyebabkan banyak kematian dan kerugian kewangan setiap tahun. Robot pemeriksaan saluran paip yang sedia ada di pasaran adalah mahal dan kecekapan serta fleksibiliti sistem robot tunggal adalah rendah sekiranya saluran paip mempunyai 2 arah seperti T-cawangan. Oleh itu, dua robot yang dikawal dengan koperatif dan harga berpatutan untuk pemeriksaan saluran paip dicadangkan di mana robot itu boleh digunakan untuk saluran paip mendatar yang digunakan untuk mengangkut udara atau gas. Projek ini juga bertujuan untuk menilai prestasi robot mudah alih yang dibina dan membangunkan komunikasi antara robot mudah alih. Robot jenis beroda mempunyai prestasi yang baik dalam akses T-cawangan dipilih. Selain itu, modul Bluetooth adalah alat yang paling biasa untuk membangunkan komunikasi di antara sistem multi robot kerana ia mudah digunakan dan boleh berkomunikasi dengan peranti berkemampuan Bluetooth yang lain. Beberapa eksperimen seperti prestasi robot bergerak pada pelbagai jenis permukaan, objek penjejakan menggunakan pengesan ultrasonik, pendekatan pemimpin-pengikut dan kawalan penjejakan robot bergerak telah direka untuk menilai prestasi dan komunikasi antara robot mudah alih. Paip PVC dengan T-cawangan telah dibina untuk mengesahkan robot mudah alih dalam pengaksesan T-cawangan. Melalui eksperimen, robot mudah alih berjaya melalui saluran paip dengan pelbagai jenis permukaan. Prestasi seperti kelajuan, kecekapan dan ketepatan juga telah dinilai melalui eksperimen. Robot pemimpin dan pengikut dapat melakukan gerakan ke depan, ke belakang, mengubah gerakan kiri dan kanan tanpa kehilangan komunikasi atau terputus di dalam paip PVC.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

IPE	-	Impacting people and environment
AI	-	Artificial Intelligent
MRS	-	Multi Robot System
USV	-	Unmmaned Surface Vehicle
UAV	-	Unmmaned Aerial Vehicle
HRI	-	Human Robot Interaction
ILI	-	In-line Inspction
MFL	-	Magenetic Flux Leakage
PIR	-	Pipeline Inspection Robot
CCD	-	Charge Coupled Device
CMOS	-	Complementary Metal Oxide Semiconductor
DC	-	Direct Current
IDE	-	Integrated Development Environment
Mbps	-	Megabytes per second
RPM	-	Rotations per minute
PVC	-	Polyvinylchloride
RC	-	Remote control
RMSE	-	Root Mean Square Error
AT	-	Attention Command
PWM	-	Pulse Width Modulation

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Mobile robot is an integration of different type of physical and computational components which are controlled automatically to solve the task given by human being. Basically, the mobile robots are designed and used in three major type of environment which are air, land and underwater. Mobile robots are widely used in industrial plant to solve the task which can't be solve by human being. Normally, the tasks are dangerous work and the environment is inaccessible by human being.

Pipeline inspection is one of the dangerous work that can be solved by the mobile robots. The purpose of pipeline is used for the movement in transporting the liquids and gases from one place to another place. Basically, the pipeline is used to transport the natural gas, fuel oils and drinkable water. The transporting activities are carry out every day. After a period of time, the pipes are exposed to the chance of break, leak or crack due to the rusting, pressure and aging [1]. These defects can cause the time to complete the transportation become longer. As a result, the business activities of the company will be effected and decelerate and it is a serious impact to the oil and gas industry. This is the main reason that pipeline inspection needed to carry out frequently to reduce the chance of incidents happen.

1.2 Motivation

The serious pipeline incident such as pipeline explosion which will cause fatality or injury due to corrosion failure, equipment failure, incorrect operation, material pipe failure and others incident causes [2]. In recent years, the case of pipeline incidents has been decreased due to the latest technology of pipeline inspection. However there are some case of pipeline incidents happen due to the weakness of the technology. Pipeline incidents cause destruction in terms of economy and fatality. Table 1.1 shows the total number of pipeline incidents that impact the people and environment (IPE) that occur in worldwide from 2013 to 2017 [2].

Table 1.1: Total number of IPE case by cause (2013-2017)

Total IPE incidents by cause (2013-2017)	
Factor	**Total Case**
Corrosion Defeat	168
Equipment Defeat	105
Material Pipe/ Weld Defeat	61
Mistaken Operations	60
Excavation incidents	47
Natural Force incidents	30
Other Causes	26
Outside Force incidents	23
Total	**520**

Based on Table 1.1, there are total 520 cases of IPE incidents that happen in the world. In other words, it is almost 100 cases of IPE incidents are happen every year. Main causes of the IPE incidents are corrosion and equipment failures.

Recently, a natural gas pipeline explosion has been happened in southeast New Mexico at 20 August 2018. The explosion has caused fatality which five adults and five children are killed in the incidents [3]. Besides, the explosion also caused two people in critical injury. The 30 inch pipeline exploded and left a crater about 86 feet long, 46 feet wide and 20 feet deep [3]. The investigator of the incidents said that the explosion could have been happened because of some leakage of the pipeline and ignited by anything.

In terms of percentage of occurs, Malaysia is considered as a country with low percentage of pipeline incidents occurred. However, this should not be ignored because there is a pipeline incident that has been happened in Miri Sarawak at 11 Jun 2014. A pipeline explosion ripped apart a section of the Sabah-Sarawak interstate gas pipeline located in between Lawas town and Long Sukang in the northernmost district of Sarawak [4]. Although there are no fatality in the incident, but the incident causes a temporary business activity shut down. A RM4 billion project that owned by Petronas is shut down for a period of time [4]. The investigator of the incidents said that there must be some serious faults to have ignited the explosion.

In conclusion, an efficient mobile robots is needed in the field of pipeline inspection due to pipeline incidents bring a big impact to human being and environment. Although occurrence of pipeline incidents in Malaysia is less than other countries, however Malaysia should have an effective pipeline inspection robot to reduce or avoid the chance of pipeline incidents happening.

1.3 Problem Statement

The current technology for pipeline inspection robot is very advanced. With this current technology, many pipeline explosion incident can be avoid. The pipeline inspection robot that developed by the JETTY Robot company can even maintenance or repair the pipe which is defect [5]. However, these extremely advanced pipeline inspection robot is not been ordinary to the others country especially Malaysia because of its high cost. One fully equipped pipeline inspection robot costs around 20,000 - 35,000 dollars [6]. Therefore, an affordable pipeline inspection robot with high efficiency should be develop to meet the demand of the countries which have low percentage of pipeline explosion incident.

Next, efficiency is one of the main concerns of a pipeline inspection robot. In current technology, humans are not only need a robot that can perform the physical task but also chasing the high efficiency of the robot to solve the task in a shorter time. However, the evolution of the robotics field has been focused on the single robot systems which consume more time in solving a task compared to multi robot system. The move from single robot system to multi robot system is very important to develop a new era of technology. Multi robot system brings many benefits over single robot system in terms of efficiency, completion of time, and flexibility. Basically, a pipeline inspection robot is move slowly along the pipeline to check and monitor along the pipe. The robot need extra time especially the pipeline have a two ways like T branches. Therefore, the speed and accuracy of the mobile robot must be considered to improve the time efficiency of the pipeline inspection robot so that the inspection work can solved in a shortest time.

Besides, flexibility of the robots also is a main concern issue. In current technology, most of the multi robot system perform the homogeneous action mechanism. Homogeneous action mechanism means that a team of follower robots follow exactly the task that have done by the leader robot. The flexibility of the robots are low if compared to the heterogeneous action mechanism robot. There is a slightly different between two mechanisms. Both mechanism consist of a main robot but the slave robot in heterogeneous action mechanism can perform different task with the master robot. Some pipeline have a two ways like T branches pipeline. In this case, heterogeneous action mechanism robot can perform well by perform the pipeline inspection simultaneously but different direction. Thus, flexibility of the robots must be considered to improve the efficiency of the pipeline inspection process.

In summary, this research will focus on developing a communication system between two mobile robots to perform the pipeline inspection with high efficiency and flexibility with the aid of low cost cooperative controlled robots.

1.4 Objectives

In this project, there are three objectives going to achieve:

1. To develop two affordable mobile robots that are cooperative controlled for pipeline inspection.

2. To evaluate the performance of the mobile robots in terms of speed, accuracy and efficiency.

3. To develop a communication system between the ‘master and slave’ robots by using the Bluetooth module for real time data transmission.

1.5 Scope

1. The robots consist of ultrasonic sensors, infrared sensors, Bluetooth module and the Arduino Uno board as the controller.

2. The size of the robots is 19cm x 13cm x 12cm.

3. There are two of the cooperative controlled robots is developed.

4. The mobile robots are applicable for the pipe where the diameter of the pipe is in the range of 20cm to 30cm.

5. The pipe is set up in horizontal.

6. The distance of the pipe to the junction is fixed to 2m.

7. The robots consists of camera which is specialized for data monitoring only. Robots are performed the task of live streaming in the pipe and capture image without image processing.

8. The mobile robots are applicable for the pipes which use to transport air or gas.

1.6 Summary

Overall, there are 4 subtopics are discussed which are motivation of the project, problem statement, objectives and scope of the research. The objectives of this project is to design two affordable mobile robots that are cooperative controlled for pipeline inspection by using a camera to monitor the environment of the pipeline. Besides, this project also aims to develop a communication system between the master-slave robots by using the Bluetooth module for real time data transmission. Last but not least, to evaluate the performance of the pipeline inspection robots in terms of efficiency, speed and accuracy. The next chapter will discuss and summarizes the findings on previous journal related to the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the theoretical background which related to this project such as theories on multi robot system and pipeline inspection are presented. Many previous journals, conference papers and articles which related to this project are studied and analyzed. A summary table is then constructed to summarize the findings based on few specific criteria.

2.2 Cooperative Controlled Robots

The phrase cooperative controlled robots also defined as multi robot system (MRS). MRS means a group of two or more mobile robots working together as a team to solve the tasks in the same environment [7]. Actually multi robots system is not a new technology. Since the late 1980s, researchers have been inspired to design and construct a set of robots which can working together to solve certain tasks [7]. At the beginning, researchers are motivated by observed the natural behavior of a swarm of ants and bees. From the observations, researchers are studied how a group of organism can working together to solve the problems. These early studies is important in contribution to develop the multi robot system nowadays. The studies also led to multi robot system being applied in different field such as surveillance, rescue, exploration, coordinate navigation, cooperative manipulation and among others [7]. The description of the application of MRS is summarize in Table 2.1.