SIDE BY SIDE SPEED AND DISTANCE CONTROL FOR PERSON FOLLOWING ROBOT

TEOH YEW CHONG

A report is submitted in partial fulfillment of the requirement for the Bachelor of Mechatronic Engineering

Faculty of Electrical Engineering

UNIVERSITY TEKNIKAL MALAYSIA MELAKA

YEAR 2015

I declare that this report entitle “Side by Side Speed and Distance Control Person Following Robot” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……

Name : ……

Date : ……

Acknowledgement

First of all, I would like to express appreciation to Miss Nur Maisarah Binti Mohd Sobran for serving as my supervisor of this project and giving me opportunity to learn and apply engineering knowledge in this project. Her guidance encourages me to accomplish my work on time. With her valuable suggestion and comment that enable me to write a good final year report. Besides, I also would like to thanks to my friend, Koh Guan Keong for technical guidance, sharing his knowledge and advice in this project. Lastly, I would like to thanks to those who are giving me support and motivation to accomplish this project.

Abstract

Nowadays, the elderly in whole world is increasing year by year. Therefore, assistive robot is introduced and applied in many applications such as in hospital and home to help elderly. There are two types of person following robot; robot following behind and human and side by side person following robot. But only side by side person following that has interact more with human compare to robot following behind human. However, the problems will occur when design a side by side person following robot which is the distance between human and robot when robot following target human. Besides, speed control of side by side person following robot is also necessary. There are three objectives in this project which are to develop prototype of a side by side person following, design a fuzzy logic controller of speed control on robot and analysis performance of robot in term of distance and speed control. In methodology, Arduino Mega ATmega1280 as microcontroller, ultrasonic sensor as distance measurement and brushless DC motor with encoder as motor to move robot are used to build a robot. First experiment is to determine the rpm of motor by adjusted the input PWM. Second experiment is to test ultrasonic sensor and speed control on prototype while the third experiment is to determine the performance of side by side person following robot. The result of first experiment is the PWM able to control rpm of motor. Next, the result of second experiment showed that the maximum distance measured by front sensor and back sensor are 301cm and 316cm. Moreover, overshoot occurred in the result of experiment 2.

Abstrak

Pada masa kini, orang tua di seluruh dunia meningkat setiap tahun. Oleh itu, robot bantuan diperkenalkan dan digunakan dalam pelbagai aplikasi seperti di hospital dan rumah untuk membantu warga tua. Terdapat dua jenis robot yang boleh ikut manusia; robot berikut di belakang manusia dan robot yang ikut di sampingan manusia. Tetapi hanya robot yang ikut di sampingan manusia mempunyai lebih berinteraksi dengan manusia daripada robot berikut di belakang manusia. Walau bagaimanapun, masalah akan berlaku apabila mereka bentuk robot yang ikut di sampingan manusia yang boleh menjarakkan jarak di antara manusia dan robot apabila robot sedang ikut manusia. Selain itu, kawalan kelajuan dengan algoritma kawalan robot yang ikut di sampingan manusia juga diperlukan. Terdapat tiga objektif dalam projek ini iaitu untuk membangunkan prototaip robot yang ikut di sampingan manusia, mereka bentuk algoritma kawalan untuk kawalan kelajuan pada robot berkaitan dan analisis prestasi robot dari segi jarak kawalan dan kelajuan kawalan. Dalam metodologi, Arduino Mega ATmega1280 sebagai pengawal mikro, sensor ultrasonic sebagai pengukuran jarak dan brushless DC motor dengan encoder sebagai motor untuk menggerakkan robot. Eksperimen pertama adalah untuk analisis rpm motor diselaraskan oleh PWM input. Eksperimen kedua adalah untuk menguji sensor ultrasonik dan kawalan kelajuan pada prototaip manakala eksperimen yang ketiga ialah untuk mengujikan prestasi robot yang ikut di sebelah manusia. Hasil daripada eksperimen pertama adalah PWM yang dapat mengawal rpm motor. Seterusnya, hasil daripada eksperimen kedua menunjukkan bahawa maksimum jarak pengesanan bagi sensor depan dan sensor belakang adalah 301cm dan 316cm. Selain itu, terlajak berlaku ketika menjalankan experiment kedua.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

RPM	=	Revolution Per Minute
PWM	=	Pulse-Width Modulation

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Motivation

Nowadays, assistive robot is widely developed to assist human in daily life such as use to help patient in hospital or elderly in home nursing. But if the assistive robot can have interacted with human, the robot can assist human more effectively [1]. Besides, assistive robot also is introduced by Japan government for the purpose of assist elderly in daily life, it is due to from the World Bank population aging research Japan has a highest percentage of aging of total population (25%) compare to other country [2] [3]. Moreover, in Malaysia the data show 1.5 million Malaysian are elderly.

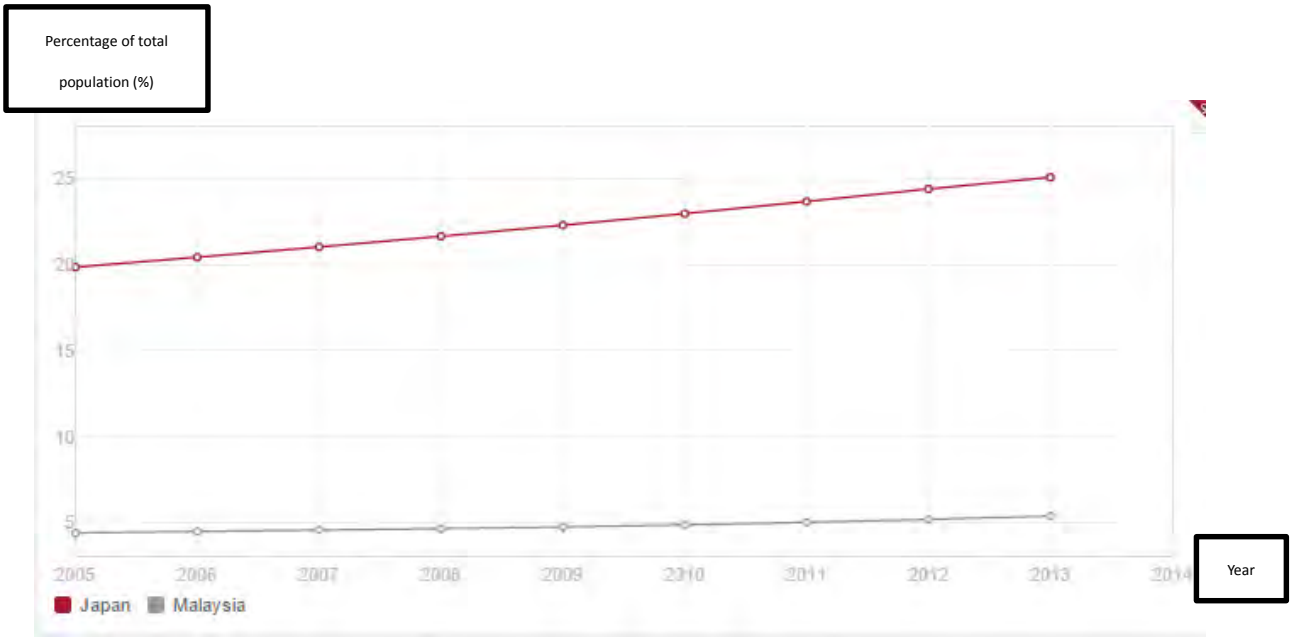

Figure 1.1: Graph of percentage of total population versus year

Person following robot is one of the assistive robot which can follow and assist human. There are 2 types of person following robot; first type is robot following behind human and second type is side by side person following robot. Robot following behind human has the most researches compare to side by side person following robot. But robot following behind human has less interacted with human due to this robot only follow at behind of human and when human walking, human does not know the status of robot whether it is follow or not. So, side by side person following robot is most suitable due to it is following target human beside him/her has more interact with human.

This type of robot can widely develop in many applications such as factories, office and supermarket. Side by side person following robot can be used in office, work as an assistant of human help them record and remind human. Besides, side by side person following robot also can use in the field of tourism such as guide human walking to reach their destination. Furthermore, side by side person following robot as an assistive robot can use as home nursing robot. [4]

1.2 Problem statement

From the previous researches, most only focus on the robot following behind a human, however it seems not much advantage for human since human and robot less interact at all. So to let human and robot have interacted is to design the robot side by side following a human. Then both human and robot can get information from each other easily.

Furthermore, a side by side person following robot that able to follow target human and can always besides target when following target. Therefore the motor speed control is needed to follow target human. This part of speed control is depends on the signal of human tracking sensor. The signal of human tracking sensor sends to microcontroller and then is calculated. Afterward the feedback signal will control speed of motor.

When a side by side person following robot is following a target human, the robot must able to measure distance, d between robot and human. In order to to control speed of robot, a suitable control algorithm is needed with inputs signal from distance sensor, so that output is the speed of both motors, v_m, can be adjusted according the sensors signal. For example, if target is far around 150cm from robot, the robot can speed up due to target may walk away from the view of distance sensor. If the target is near around 50cm from robot, the robot may using medium speed to follow human.

1.3 Objective of Project

There are three objectives in this project.

i. To develop prototype of a side by side person following robot
ii. To design control algorithm for a side by side person following robot that has speed control.
iii. To analysis the performance of developed side by side person following robot in term of speed and distance control.

1.4 Scope

The scopes of this project are outlines as follows.

1. From this project is to design a side by side person following robot which able to measure distance between human when following human and able to control the speed to follow human.

2. Besides, the path of human walking is straight line only when followed by side by side person following robot.

3. Moreover, there is no obstacle between human and side by side person

following robot when robot is following target human. The side by side person following robot is tested in a room of no obstacle.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Person following robot is a famous research due to it is very useful in assist human future life. The information from the previous research is use as guide to build a better side by side person following robot in this project. This chapter is about review, comparison and summary of previous researches on person following robot.

2.2 Review on previous study of person following robot

A study about side by side person following robot with the objective of able to follow beside target person and can keep a safe distance between target person and robot when both robot and human are moving. In this study, laser range finder with the detection range of 30m is used to detect target human. One unit of laser range finder can cover 180 degree of field of view, so two units laser range finder will built inside the robot which can cover 360 degree means it can detect surrounding of robot. Eight parameters are considered to design a better person following robot such as social relative distance, relative angle, relative velocity, distance to obstacle, sub goal, velocity, angular velocity and acceleration [5].

Besides, the robot is tested in three conditions by using three methods. First method is the standard prediction method which is to guess next position of target by using mathematical methods, linear extrapolation of the velocity. Next, second method is the

self-anticipation. This method is use to plan the next step of robot movement to enlarge its utility with preferred linear velocity, angular velocity and acceleration. After these two methods the next method is the partner and self-anticipation. It plans next step movement of robot to maximize robot utility and target utility. There are few shortcomings in the study [5] such as parameters are not systematically calibrate, standard prediction method and the self-anticipation have the problem of lacks of ability to make the robot take a lead toward the target. Figure 2.1 is shows a success side by side person following robot by considering eight parameters [5].

Figure 2.1: People walking side by side with a mobile robot

Source:[5]

In [6] proposed a person following robot with fuzzy based control system. The paper used Radio-frequency identification (RFID) with antenna is able to detect the position target human by giving the target person with an ID and stereo camera to detect human. But when human is out of the detection range of stereo camera, only can depends RFID detect the position target human. Moreover, two control strategies are used in this study; intelligent control strategy and fuzzy based controller. Intelligent control strategy is to control the robot for turning toward target when target is away from robot, two parameters are used which are the turning gain and linear velocity. The direction and distance from

tracking part is obtained and from these two to do adjustment for turning gain and linear velocity. Then, the turning gain is adjusted online to make sure the target is in the view of camera, as the direction between target and robot is increased the turning gain is also increased while turning radius is decreased. There are two main parts using fuzzy based controller to control the motion of person following robot; reference linear velocity and turning-gain.

Furthermore, in order to get the reference linear velocity, $v_{re,}$ two inputs is considered and there are the distance, $x_{r,}$ between target and robot when both are moving and the vertical velocity of target, v_x. The rules between distance, x_r, and vertical velocity of target, v_x to get reference linear velocity is shown in Figure 2.2 with linguistic term. For example, if the distance, x_r, is very near (VN) and the vertical velocity of target, v_x is very slow (VS), then reference linear velocity, v_{re} is very slow (VS) [6].

TABLE I
LINGUISTIC TERMS FOR REFERENCE LINEAR VELOCITY.

x_r	Linguistic terms	v_x	Linguistic terms	v_{re}	Linguistic terms
VC	Very Close	VS	Very Slow	VS	Very Slow
C	Close	S	Slow	S	Slow
Z	Safe Distance	Z	Normal	Z	Normal
F	Far	F	Fast	F	Fast
VF	Very Far	VF	Very Fast	VF	Very Fast

TABLE II
FUZZY LOGIC FOR REFERENCE LINEAR VELOCITY CONTROLLER.

v_{re}		v_x /m • s^{-1}				
		VS	S	Z	F	VF
x_r /m	VN	VS	VS	S	S	Z
	N	VS	S	S	Z	Z
	Z	VS	Z	Z	F	F
	F	Z	F	VF	VF	VF
	VF	F	VF	VF	VF	VF

Figure 2.2: Table I and II about linguistic term and fuzzy rules for reference linear velocity

Source:[6]

For the turning-gain controller, the absolute direction, y_r and horizontal velocity of

target, v_y will considered as inputs to obtain output turning-gain of robot, k. The rules used to obtain turning-gain, k is shown in Figure 2.3. The example of the rules is if the absolute direction, y_r is negative far (NF) and velocity of target, v_y is negative slow (NS), and then the output turning-gain, k is large [6].

TABLE III
LINGUISTIC TERMS FOR TURNING-GAIN ADJUSTMENT CONTROLLER.

y_r	Linguistic terms	v_y	Linguistic terms	k	Linguistic terms
NF	Negative Far	NF	Negative Fast		
NN	Negative Near	NS	Negative Slow	S	Small
Z	Center	Z	Zero	N	Normal
PN	Positive Near	PS	Positive Slow	L	Large
PF	Positive Far	PF	Positive Fast		

TABLE IV
FUZZY LOGIC FOR TURNING-GAIN ADJUSTMENT CONTROLLER.

k		v_y /m • s^{-1}				
		NF	NS	Z	PS	PF
y_r /m	NF	L	L	N	N	N
	NN	L	L	N	S	S
	Z	N	N	S	N	N
	PN	S	S	N	L	L
	PF	N	N	N	L	L

Figure 2.3: Table III and IV about linguistic term and fuzzy rules for turning-gain

Source:[6]

Moreover, the other research about person following robot is proposed with goal of ability to follow target person and able to keep safe distance between target and robot when both are moving. The sensor used to track human position is IR based co-ordinate system, while the distance sensor used is ultrasonic sensor. Fuzzy rules is applied in this research which means the inputs of position (Left, Mid and Right) and distance (Near, Locked and Far) to obtain the output, robot velocity. The Figure 2.4 show the fuzzy rule based in the control system [7].

1. If (Direction is Left) and (Distence is Locked) then (Rigth_wheel is incr)(left_wheel is Mild) (1)
2. If (Direction is Right) and (Distence is Locked) then (Rigth_wheel is Mild)(left_wheel is inc) (1)
3. If (Direction is Mid) and (Distence is Near) then (Rigth_wheel is dec)(left_wheel is dec) (1)
4. If (Direction is Mid) and (Distence is Far) then (Rigth_wheel is incr)(left_wheel is inc) (1)
5. If (Direction is Mid) and (Distence is Locked) then (Rigth_wheel is Mild)(left_wheel is Mild) (1)
6. If (Direction is Right) and (Distence is Near) then (Rigth_wheel is dec)(left_wheel is inc) (1)
7. If (Direction is Left) and (Distence is Near) then (Rigth_wheel is incr)(left_wheel is dec) (1)
8. If (Direction is Right) and (Distence is Far) then (Rigth_wheel is dec)(left_wheel is inc) (1)
9. If (Direction is Left) and (Distence is Far) then (Rigth_wheel is incr)(left_wheel is dec) (1)
10. If (Direction is Left) and (Distence is Dangerous_distance) then (Rigth_wheel is Mild)(left_wheel is stop) (1)
11. If (Direction is Right) and (Distence is Dangerous_distance) then (Rigth_wheel is stop)(left_wheel is Mild) (1)
12. If (Direction is Mid) and (Distence is Dangerous_distance) then (Rigth_wheel is stop)(left_wheel is stop) (1)

Figure 2.4: Example of fuzzy rule based used in the study

Source:[7]

From those rules the person following robot is tested in three conditions such as target in centre location of robot, target is in left side of robot and target is in right side of target. At the first conditions, the robot able to follow up human speeds with full power and can keep a safe distance with target. Besides, the robot able to make a curve turn to follow target by controlling left and right motor in the next two conditions [7].

Furthermore, a study about person following Omni-directional vehicle robot is focus more on position of the target. So input of position controller is based on 2 stereo camera sensors and reference position which is X_R, Y_R and Z_R. Typically there are two methods of control to calculate the distance between target human and robot, namely, position-based control and features-based control but this study is focus on the position-based control. Image captured is extracted, geometric model and camera model is used to predict the target pose. The study apply PD controller for the calculation of the position controller, while the position reference is the distance between person following robot and target human. After that the output position controller is derived by using Jacobain matrix, and then will become the input of velocity controller. The RT-Linux is used for calculate the position information from the stereo camera position and control the motion of robot [8].

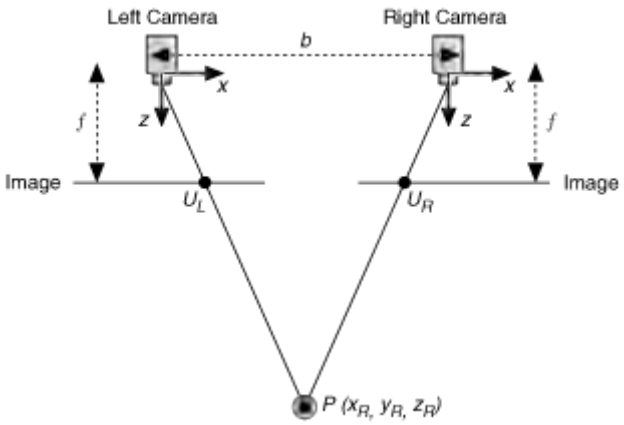

Figure 2.5: Baseline of stereo vision system

Source:[8]

The speed control of person following robot is mention in [9]. Speed control of this study is set according to three conditions such as death zone, speed control and adaptive deceleration. Death zone is a zone of errors occurs in robot like the distance control is different from the desired value. This is very important due to error is needed to consider building a better side by side person following robot. Furthermore, speed control is same as death zone where it also considered the response time of robot speed up and motion robot is slower than human walking speed. At the same time, adaptive deceleration algorithm is also considered depends on the speed decrease stage.

Three speed stages was introduced in the paper [9] and there are speed increase stage, speed saturation stage and speed decrease stage. These three stages are about the categories of robot speed and robot speed will changed according the output signal from the Kinect sensor. In order to find the error of human relative angle, PD controllers is used and apply on the servo motors control of robot. After the person following robot is done, few experiments is needed to test;

1. Target human move forward and reverse only for examining speed control.
2. Target human turn around the robot with constant distance is for testing angle control.
3. Target human walk along a straight path for speed control and angle control

testing.

4. Forward and reverse path.

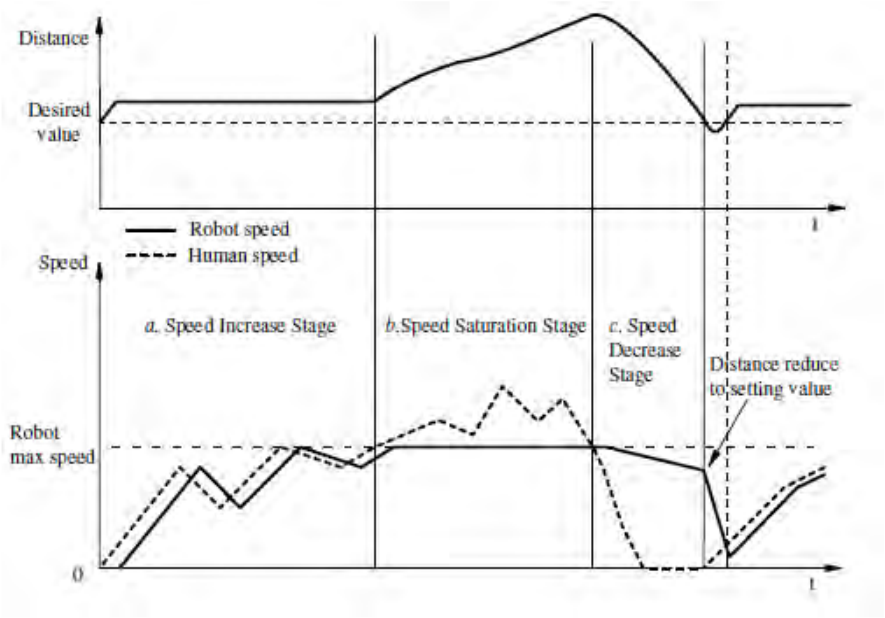

Figure 2.6: Three speed stages of human and robot

Source:[9]

2.2.1 Comparison of previous study

Table 2.1: The details of previous study

Title	Tracking algorithm	Distance algorithm	Control algorithm
How Do People Walk Side By Side? – Using a computational model of human behaviour	Laser range finder : Leg detection	Laser range finder: Distance detection	-
Fuzzy-based intelligent control strategy for a person following robot	Stereo camera: human tracking RFID: Position tracking	RFID: Position tracking	Fuzzy inference system
Modelling and Robust analysis of a fuzzy based person following robot	IR with co-ordinate: human detection	Ultrasonic sensor: Distance detection	Fuzzy inference system
A controller design on person following omni-directional vehicle robot	Stereo vision sensor: position tracking	Stereo vision sensor: position tracking	PD controller in position control
Robot human-following limited speed control	Kinect sensor: human joints detection	Kinect sensor: Distance detection	PD controller in angle control