DEVELOPMENT OF FUZZY PID CASCADE CONTROL SYSTEM FOR DIFFERENTIAL-DRIVE WHEELED MOBILE ROBOT

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DEVELOPMENT OF FUZZY PID CASCADE CONTROL SYSTEM FOR DIFFERENTIAL-DRIVE WHEELED MOBILE ROBOT

by

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LIST OF ABBREVIATIONS

ECE	Economic Commission for Europe
MAR	Mobile Autonomous Robot
AI	Artificial Intelligence
PID	Proportional+Integral+Derivative
MDARS	Mobile Detection Assessment and Response System
PWM	Pulse Width Modulation
FOV	Field of View
GUI	Graphical User Interface
SIFT	Scale Invariant Feature Transform
VL1	Vertical Line 1
VL2	Vertical Line 2
C	Center Circle
COA	Center of Area
ICC	Instantaneous Center of Curvature
ICR	Instantaneous Center of Rotation
DAQ	Data Acquasition
ZOH	Zero Order Hold
FOH	First Order Hold
FLC	Fuzzy Logic Controller
neglarge	Negative Large
negsmall	Negative Small

possmall	Positive Small
poslarge	Positive Large

LIST OF SYMBOLS

$r(t)$	Reference input
$u(t)$	Input
$y(t)$	Output
ϕ_L	Left wheel rotation per seconds
ϕ_R	Right wheel rotation per seconds
N_R	Numbers of encoder per revolution
x_L	Number of encoder pulses for left wheel
x_R	Number of encoder pulses for left wheel
v	Speed
ω	Angular Speed
$T2$	Low-threshold
$T1$	High-threshold
T	Global single thresholding
σ	Standard deviation of the Gaussian filter
r_H	Normal from the line to the origin
θ_{H}	Angle the normal
(x, y)	Coordinate
C_p	The intensity of the pixel
D_t	Target distance
θc	Circle orientation
n	Constants derived from the camera calibration

c	Constants derived from the camera calibration
x_{center}	x-axis center of circle
$x^{'}$	Diameter of circle
K_p	Proportional Gain
T_i	Integeral Time
T_d	Derivative Time
θ	Angle
u_R	Speed of right wheel
u_L	Speed of left wheel
ω	Angular Speed of robot
u	Speed of robot
d	Distance from center of body to the center of the left wheel or right wheel
$\dot{p}$	Posture of mobile robot
J	Wheel Jacobian Matrix
W	World coordinate system denoted
R	X-axis of robot coordinate system
θ_d	Desired orientation
T_u	Ultimate period
P_u	Ultimate gain
K	Gain
ξ	Damping ratio
ω_n	Natural frequency, rad/s
T_s	Time sampling

K_i	Integral gain
K_d	Derivative gain

PEMBANGUNAN SISTEM KAWALAN ALIRAN KABUR-PID BAGI PERBEZAAN PEMANDUAN BERODA ROBOT MUDAH ALIH

ABSTRAK

Kajian ini memberi tumpuan kepada pelaksanaan sistem kawalan robot autonomi mudah alih pintar yang dipanggil Mobile Autonomous Robot (MAR). Robot disasarkan untuk penggunaan tertutup, memainkan peranan sebagai panduan atau kakitangan keselamatan di kilang-kilang, gudang, muzium dan pejabat. Ia mempunyai dua roda memandu dikuasakan oleh dua motor yang bebas untuk memandu dan stereng masing-masing. Setiap AT motor dikawal oleh modulasi lebar denyut (PWM) motor pengawal. Satu sistem kawalan aliran telah dilaksanakan untuk mengawal pergerakan robot, dan ia terdiri daripada pengawal induk dan dua pengawal hamba bagi setiap AT motor. Pengawal induk adalah Pengawal Logik Kabur (FLC) untuk mengira kelajuan dan kelajuan sudut yang diperlukan oleh kedua-dua motor. Satu sistem penglihatan digunakan sebagai pengesan untuk gerakan robot. Logik kabur digunakan untuk menjana sasaran gerakan trajektori dengan maklumat yang diekstrak daripada sistem penglihatan seperti jarak sasaran dan orientasi sasaran. Penanda yang dipilih adalah pintu kerana pintu adalah satu objek yang sangat biasa dalam persekitaran tertutup dan pengesanan pintu membolehkan robot untuk melakukan tugas-tugas seperti navigasi dan laluan perancangan. Kerja ini membentangkan pendekatan yang menggunakan penglihatan pengkomputeran yang mengaplikasikan teknik Penjelmaan Hough dan teknik Penyamaan Sifat selepas imej tersebut diproses menggunakan pengesan pinggir Canny. Kedua-dua pengawal hamba adalah Kadaran - Kamiran - Terbitan (PID) pengawal yang memastikan kelajuan yang diingini diperoleh oleh roda. Dua kaedah telah digunakan bagi pengiraan nilai-nilai yang betul bagi PID. Iaitu menggunakan kaedah eksperimen dan kaedah model. Kaedah eksperimen menggunakan kaedah Zigler-Nichols talaan automatik tanpa mengetahui sifat loji yang hendak dikawal. Dalam kaedah berasaskan model, model matematik bagi motor diterbitkan terlebih dahulu dan ia digunakan untuk mereka bentuk pengawal PID. Parameter pengawal PID telah ditala mengikut empat julat kelajuan. Parameter pengawal PID bagi kedua-dua AT motor ditalakan secara automatik menggunakan *Gain Scheduling* yang berasaskan kepada empat julat kelajuan. Perbandingan telah dibuat untuk melihat prestasi robot mudah alih yang menggunakan parameter PID yang ditala oleh kedua-dua kaedah. Dalam kajian ini, logik kabur juga digunakan untuk menjana teknik mengelakkan halangan dengan maklumat yang diekstrak daripada pengesan ultrasonik. Prestasi keseluruhan robot apabila berpindah ke sasaran menunjukkan bahawa purata ralat relatif adalah kurang daripada 0.03 meter bagi jarak dan ralat relatif purata untuk orientasi adalah kira-kira 20^{o} apabila tiba pada robot mencapai sasarannya. Purata masa yang diambil oleh robot untuk tiba di sasaran dalam 1 meter kira-kira 23 saat.

DEVELOPMENT OF FUZZY-PID CASCADE CONTROL SYSTEM FOR DIFFERENTIAL-DRIVE WHEELED MOBILE ROBOT

ABSTRACT

This study focuses on the control systems implementations of an intelligent autonomous mobile robot called Mobile Autonomous Robot (MAR). The robot is targeted for indoor usage, assume the role of a guide or security personnel in factories, warehouses, museums and offices. It has two driving wheels powered by two independent motors for drive and steering respectively. Each DC motor is controlled by a pulse width modulation (PWM) motor controller. A cascade control system has been implemented to control the movement of the robot, and this consists of a master controller and two slave controllers for each DC motor. The master controller is a Fuzzy Logic Controller (FLC) which computes the required speed and angular speed needed by the two motors. A vision system is used as the sensor for the robot motion. Fuzzy logic is applied to generate target trajectory movement with the information extracted from vision system such as the distance of target and the orientation of target. The landmark selected is a door because the door is a very common objects in indoor environments and the detection of a door allows a robot to do tasks such as navigation and path planning. This work presents an approach using computer vision which applies Hough Transform and Feature Matching technique after the image has been process using Canny edge detector. The two slave controllers are Proportional-Integral-Derivative (PID) controllers which ensure the desired speeds are obtained at the wheels. Two methods are used in calculating proper values of the PID. These are experimental method and model based method. The experimental method uses the Zigler-Nichols autotuning method without any knowledge about the plant to be controlled. In the model based method a mathematical model of the motors are first derived and this is used to design the PID controller. PID controller parameters were tuned according to four ranges of speeds. The PID controller parameters for both DC motors are auto-tuned using Gain Scheduling based on four ranges of speeds. Comparison was made to see the performance of the mobile robot using the PID parameters tuned by the two methods. In this study, fuzzy logic is also applied to generate obstacle avoidance techniques with the information extracted from ultrasonic sensors. Overall performance of the robot when moving to the target shows that the average relative error is less than 0.03 meter for distance and the average relative error for orientation is about 20^o when arrived at the robot achieves its target. The average time taken by the robot to arrive at the target in 1 meter is approximately 23 seconds.

CHAPTER 1

INTRODUCTION

Mobile robot has received much attention from scientists and academics over the past two decades. The increased processing capacity and the availability of inexpensive electronic components have contributed to the advancement of mobile robotics to a level of maturity that allows further development. This is especially true since the expected demands for service robotics are increasing.

A robot is autonomous systems used are able to sense its environment and act accordingly to achieve the goals. The main defining characteristic of an autonomous robot is the ability to act on their own decision, and not through the control of a human being (Mataric, 2007).

Navigation is the mechanism in a precise position to identify, plan and follow a path. In robotics, navigation refers to the technique of a robot made its way into the environment (Mataric, 2007) and is a common need and a requirement for almost all mobile robots.

Robot navigation is a vast and can be divided into subcategories for a better understanding of the issues. Leonard and Durrant-Whyte, 1991 outlines the general problem of navigation of mobile robots to three questions, each on a sub-category:

- Where am I?

This issue is the problem of the location can be express as follows: A robot is an unknown position in environment in which it has a map. It "sees" on its position, and based on the observations must infer the place on the map where it could be located (Guibas and Motwani, 1995).

• Where do I go?

The assignment problem consists of a robot living in an unfamiliar environment that has no map, and navigating through it allows the creation of a map display. The robot must identify the specific characteristics of the landmarks of the environment, to recognize that the obstacles are.

• How to get there?

The problem of path planning indicates a general desired to find paths between different locations in an environment based on objective and constraints.

One of the main drivers of the market for robotic automation service is the inner core. As the 2005 World Robotics surveys prepared by the Economic Commission for Europe (ECE) (International Federation of Robotics, 2005) - estimated that the projected sales of domestic robots for the next period 2004-2007 to 4.5 million units. For the same period, the survey also reports a similar trend also in robotics solution for professional use. A figured 50 thousand the number of new facilities. Robotics professional applications with strong growth include underwater systems, medical systems, defense and rescue and security applications.

The world of robotics is one of the most interesting areas that have gone through constant innovation and evolution. Robotics is interdisciplinary and has become increasingly a part of our lives. Many reasons justify this sudden increase in the use of robotics. Among those is the quest for increase productivity, the transfer of dangerous and laborious tasks from man to machine, as well as improving quality of life (International Federation of Robotics, 2005). The increase is also in part attributed to the international climate and the need for improving security of airports, public institutions, and private facilities such as factory and utility plants.

Autonomous navigation is the most important topic of study periods of artificial intelligence, various approaches have been tried to solve navigation problems (Brooks, 1986). The researchers have done studies to both holonomic and nonholonomic mobile robots. Autonomous navigation is related to the ability of a mobile robot to move in an environment that is available to achieve a goal, without interacting with humans. The mobile robot is guided by the information obtained during the online navigation is running. To do this task requires a different ability to perform actions that lead to goal achievement. A mobile robot, competent to avoid contact with objects, traveling without hitting things, exploring the world, places to see in the distance and voice seem to reach for them, building the environment map and plan routes from one place to another. The system is in its surroundings. It is directly related to the problem domain through sensors and effectors. The system can change and the effect of its environment through effectors reacts instantly. The problem domain can be a dynamic environment and the system can react in a limited time. The system environment is a complex real-world environment. No assumption is made for the environment. The system is fully autonomous. It must monitor the problem domain, the real world and determine what the problem is solved, and how to solve it. Moreover, the system must handle multiple issues simultaneously.