UNIVERSITI PUTRA MALAYSIA

SIMULATION AND DESIGN OF AN INTELLIGENT MOBILE ROBOT FOR FIRE FIGHTING

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SIMULATION AND DESIGN OF AN INTELLIGENT MOBILE ROBOT FOR FIRE FIGHTING

By

CHOR KEONG SENG

Thesis Submitted To the School of Graduate Studies, Universiti Putra Malaysia in Fulfilment of the Requirements for the Degree of Master of Science

August 2003

DEDICATION

To my family

who always back me between the rock and the hard place…

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

SIMULATION AND DESIGN OF AN INTELLIGENT MOBILE ROBOT FOR FIRE FIGHTING

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August 2003

Chairman: **Associate Professor Dr. Abdel Magid Hamouda**

Institute : **Advanced Technology**

The application of traditional frangible glass panel and automatic system such as smoke detector or heat detector requires a human response to realise the existence of fire and to perceive and determine its severity. However, fire-fighting system such as sprinkler causes the damage of the property and also injury and panic due to the water sprayed out when the system trigged. Thus to avoid such incident, a mobile robot with fire detection capability and fire fighting system to perform fire-fighting purpose is a new technology to reduce subsequent damage and secure life before the fire engine to attend.

A navigation system base on fuzzy logic controller (FLC) is developed for the mobile robot in an ambiguous situation for fire fighting purpose. A method of Path Recognition Algorithms (PRA) providing robots the autonomous ability to judge purpose of action likes human base on the input sensors from the environment. Multiple fuzzy behaviours by fuzzy logic method have been developed to allow the robot over come some of the possible obstacles and resistances for the robot to navigate in unknown environment. Behaviours have been integrated with arbitration strategy to determine the appropriate behaviours by priority method with preset data.

An ultrasonic sensor and an infrared thermal sensor were mounted on a 360 degree rotated stepper motor to scan distance between the robot and its immediate obstacles and fire source around its environment. A fuzzy base computer animation in virtual reality is developed to simulate a simple in-door environment for fire fighting purpose and a systematic implementation of real-time simulation of the mobile robot is presented. However travelling in such region to the target location, there exist some un-know obstacles for the mobile robot especially in real-world environment with unknown map and unpredictable obstacle location, thus the control algorithms must be able to promptly react upon the unpredictable.

The simulation result of this study indicated that application of FLC in mobile robot could be a suitable system for fire detection and fire fighting task in an unknown environment. More comprehensive study in behaviour coordination will be the major focus to ensure smoother robot navigation and more effective fire detection capability.

Keywords: (Fuzzy logic control, mobile robot, part recognition algorithms)

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

SIMULASI DAN REKABENTUK ROBOT BERGERAK CERDIK UNTUK PEMADAM API

Oleh

CHOR KEONG SENG

Ogos 2003

Pengerusi: **Profesor Madya Dr. Abdel Magid Hamouda**

Institut: **Teknologi Maju**

Penggunaan panel kaca pemecah tradisional dan sistem automatik seperti pengesan asap dan pengesan pemanasan memerlukan manusia bertindak untuk memastikan kebakaran dan menentukan paras kekuatannya. Malah penggunaan system pemadam api seperti sistem spinker akan menyebabkan kemusnahan pada harta benda dan mengujudkan keadaan panik dan kecederaan akibat air yang dipancut ketika system tersebut bertindak. Untuk mengelakkan keadaan ini berlaku, sebuah robot bergerak yang dilengkapi pengesan api dan pemadan api merupakan teknologi yang dimajukan untuk bertindak menggurangkan kerosakan dan menyelamat nyawa sebelum pihak bomba bertindak.

Satu sistem navigasi berasaskan "Fuzzy Logic Control" (FLC) telah ditubuhkan untuk robot bergerak bertindak di suasana yang tidak menentu untuk tujuan pemadaman api. Penggunaan "Path Recognition Algorithms" (PRA) akan memberi robot keupayaan membuat keputusan seperti manusia berdasarkan data persekitaran dari pengesan-pengesan. Pelbagai "fuzzy behaviours" dengan cara "fuzzy logic" telah ditubuhkan untuk mengatasi kemungkinan penghalang dan perintang semasa robot bergerak di persekitaran yang tidak diketahui. Perlaksaan "Behaviours" telah diintegrasikan dengan

cara strategik penentuan untuk membuat pemilihan "behaviour" yang sesuai secara keutamaan berdasarkan data-data yang telah ditentukan.

Pengunaan satu pengesan sonar dan satu pengesan panas "infrared" yang berpusing 360 darjah dengan motor stepper adalah untuk mengesan jarak antara penghalang di sekeliling persekitarannya. Animasi komputer pada "virtual Reality" berdasarkan fuzzy telah ditubuhkan untuk menyimulasi satu contoh persekitaran bilik untuk tujuan pemadaman api dan simulasi masa sebenar secara sistematik. Disebabkan pergerakkan di dalam kawasan tanpa peta ke lokasi sasaran akan menghadapi perlagai halangan yang tidak menentu, maka algorithms mesti berupaya bertindak cepat mengatasi segala kemungkinan.

Keputusan simulasi pada kajian ini menunjukan penggunaan FLC pada robot bergerak adalah sistem yang sesuai untuk pengesanan api dan pemadam api di dalam persekitaran yang tidak diketahui. Pengajian yang lebih komplihensif pada kordinasi behaviour menjadi fokus yang utama untuk memastikan pergerakan robot yang lebih kemas dan keupayaan pengesanan api.

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FLC	Fuzzy Logic Control
PRA	Path Recognition Algorithms
FLS	Front Left Sensor
FMS	Front Middle Sensor
FRS	Front Right Sensor
LS	Left Sensor
RS	Right Sensor
MF	Membership Function
Al	Artificial Intelligent
COG	Centre of Gravity
3D	3 Dimensions
2D	2 Dimensions
PlD	Proportional-Integral-Derivative
CAD	Computer Aided Design
VVF	Very Very Far
VF	Very Far
F	Far
N	Near
VN	Very Near
SVVF	Speed Very Very Fast
SVF	Speed Very Fast
SF	Speed Fast
SL	Speed Slow
ST	Stop
NTSC	National Television Standard Committee

CHAPTER ONE

INTRODUCTION

Since its inception in the early 1960s, the robotics research and development such as Cartesian trajectory, robot programming language, off line programming systems, compliance devices for the assembly, vision system for part assembly and welding robot are developed rapidly in the industry [1]. Yet there are a large variety of robot applications such as military, scientific, household and humanitarian in which robot will operate in large and unstructured domains. Recently, the application of mobile robot is use in maintaining nuclear plats, inspection and repairing underwater structures and etc are a new request in this modern technology to replace human. Thus the development of the mobile robot which operating in such large, un-structure domains must be able to cope with significant uncertainty in the position and identification of objects, It can say that the mobile robots are not expected to follow the path as robot manipulator in the industry because of the large input and complex and dynamic environment.

People and animal have no trouble moving around in a complex environment with sensing, interpreting and responding to new information by their eye and brain. But the development of such natural intelligent system is still far away from our current technology, thus the development of the human-like navigation behaviour orientated is a new challenge to the autonomous robot with the application of artificial Intelligent.

General principle remain the same whether the vehicle is intended to be driven, flown, floated or submerged, all the autonomous vehicles must navigate within an environment [1] . In order to achieved this, the vehicle must be capable of (1) sensing its environment, (2) interpreting this sensor information to refine its knowledge of its position and the environment's structure and (3) planning a route from the initial to a goal position in the presence of known or perhaps unknown obstacles.

Figure 1.1 shows the basic components of the robot. By using the external sensor, like sonar sensor or camera to observe the environment, and the modelling of the workspace are tasks that the robot will perform. By this model, a planning program builds a plan that will perform the given task in the given environment. Then this planning will pass to the control program for the execution. This execution is "blindly" proceeding, but it may use the feed back sensor such as encoder to monitor the state of the robot actuator. What we are going to focus is the Modelling and Planning module that will take care of analysing the execution environment to be executed by the controller.

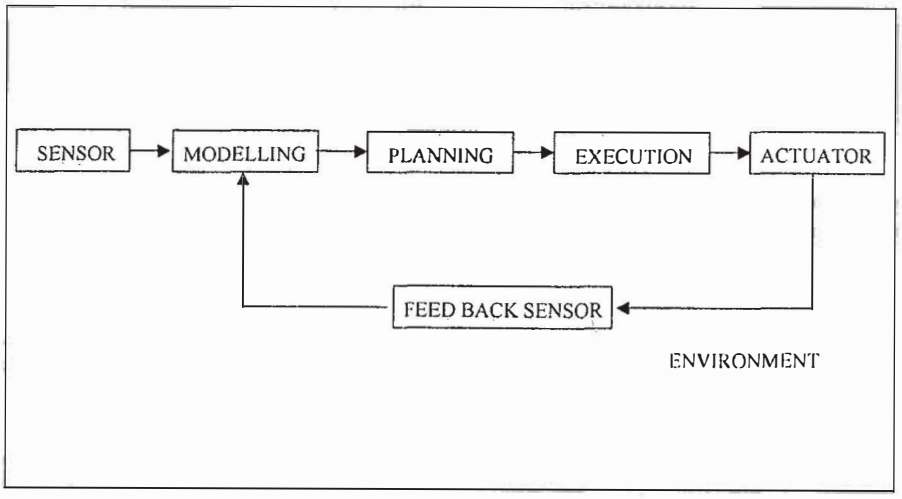

Figure 1.1: Autonomous robot component

1.1 Problem Statement

In sensitive area, automatic fire-fighting devices initiated either manually or by the fire detection system installed. Such automatic devices will vary depending on the type of fire to be expected but they generally operate by smothering fire with denying the fire source location. Thus the prevention of the fire to be spread to un-control condition is always the necessary safety step in fire safety engineering, and it has already been noted that the general cause of deaths is asphyxiation, i.e. being overcome by smoke and gases, or being trapped and being unable to escape and then being exposed to the effects of heat to overcome the problem [2]. Although various of mobile robots have been developed in navigation system, but the application in such field as fire fighting is not yet fully applied for the benefit of mankind. Further more the simulation of the fire behaviour and fire fighting technique is another challenge for the current technology. Thus the development of the mobile robot with the fire fighting capability and navigation ability to perform fire-fighting task to minimize the risk of the fire damage or loss of life has been studied as beginning state for the future research.

1.2 Research Objectives

This research is an effort to develop a fuzzy logic approach mobile robot with navigation ability in unknown environment for fire detection and fire fighting task. A virtual world has been built to simulate the robot navigation and fire detection capability prior a conceptual robot build. The objectives of the research can be summarised as follow;

i. To develop a simulation system for an intelligent mobile robot.

ii. To develop a fuzzy control mechanism for the unknown environment navigation task.

iii. To design the fire fighting robot for the simulation purpose.

iv. To simulate the robot navigation ability and fire detection capability for fire fighting purpose.

1.3 Scope of Research

To build an intelligent fire fighting robot is a huge task. The combination of the mechanical, electrical and programming engineering is the basic knowledge of the research. However this study is to develop an intelligent control system to navigate a mobile robot in an unknown environment to reach fire source with the aid of the multiple type of sensors. Secondly is the development of the FLC for the robot navigation and fire detection capability and finally is the development of the virtual world for the robot simulation purpose. The scope of this research is only a small portion of the fire fighting robot development, it involve only the conceptual design without considering the material analysis and robot dynamic. The simulated environment have been taking into account for the following parameter:

- The navigation of the robot only in 2D environment although the virtual environment generated is in 3D.

- Only the robot kinematics is involved in the robot navigation simulation. Robot dynamic is not taking into consideration.

LIST OF ABBREVATIONS

FLC	Fuzzy Logic Control
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SVVF	Speed Very Very Fast
SVF	Speed Very Fast
SF	Speed Fast
SL	Speed Slow
ST	Stop
NTSC	National Television Standard Committee

- The Encoders are installed in the robot to position the robot in the environment with respect to the home of the robot.

- The sonar sensor is generated by the single line since the sensor is rotating in 360 degree, and it do not have any echo back and with the maximum sensing distance 1200mm.

- The heat sensor is receiving the heat transfer from the fire, the nearest distance to the fire is consider the hottest point to identify the fire location.

- The error of the sensors is expressed as a percentage of the real values, which are, assume from the existing reference.

- The Numerical Modelling Lab is taking as platform for the robot environment. The rooms are considering without the door to allow the robot to enter the room.

- The smoke detector is simulated to generate fire signal is installed in pre-define location.

1.4 Thesis Layout

This thesis is divided into seven chapters. Following this preliminary chapter, which is introduction to this research, chapter two is the literature review of showing the previous work about the application of the fuzzy logic in the mobile robot. Beside this, the reference of the simulation software is also discussed. The methodology of