UNIVERSITI TEKNIKAL MALAYSIA, MELAKA

AUTONOMOUS SUBSURFACE VEHICLE (ASV) FORWARD MANEUVERING CONTROL USING FUZZY LOGIC

Thesis submitted in accordance with the partial requirement of the Universiti Teknikal Malaysia, Melaka for the Bachelor of Manufacturing Engineering (Robotic and Automation)

By

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UNIVERSITI TEKNIKAL KEBANGSAAN MALAYSIA

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DECLARATION

I hereby, declare this project entitled "autonomous subsurface vehicle (ASV) forward maneuvering control using fuzzy logic" is the result of my own research except as cited in the reference.

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APPROVAL

This thesis submitted to the senate of Universiti Teknikal Malaysia, Melaka and has been accepted as partial fulfillment of the requirement for the degree of the Bachelor of Manufacturing Engineering (Robotic and Automation). The members of the supervisory committee are as follows:

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ABSTRACT

This final project purposed to design and compares various methods the forward maneuvering control for ASV (autonomous subsurface vehicle) using fuzzy logic. The comparison methods use are Mamdani method, Sugeno method and ANFIS method. The first part of this project describes about three main fuzzy methods and the forward maneuvering control design. ANFIS method is the adaptive neuro-fuzzy inferences system which the result of combining fuzzy logic and neural network using MLP (multilayer perceptron) type. The result of ASV forward maneuvering using ANFIS method show the structure of rules, input and output through MLP (multilayer perceptron) structures. Controlling the maneuvering has been traditionally handled by experienced helmsmen but for autonomous vehicles, it difficult to design in order to avoid the obstacles which moving or static obstacles. The purpose of this project is to apply fuzzy logic control theory to such maneuvering scenarios in order to show that autonomous subsurface vehicles (ASV) forward maneuvering and avoid the front obstacles. This project simulates using MATLAB R2006 simulation and the forward maneuvering design through fuzzy logic toolboxes. The maneuvering equations of motion are apply during fuzzy logic IF/THEN rules design but only centre line angle and front obstacles distance taking in account.

ACKNOWLEDGEMENTS

Appreciations are expressed to those who have given generous contributions within the period of this thesis development to fulfill the requirement of the Degree of Bachelor of Engineering Manufacturing (Robotic and Automation).

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Both their constant guidance and support during my thesis writing is invaluable to me and continuous direction & opinion regarding the flow of the project has an invaluable contribution to achieve the objective of the project. Furthermore, the guide and help from Mr. Hafidz make this thesis a more effective reference are followed with my sincere gratitude.

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

2D	-	2-dimension
3D	-	3-dimension
4D	-	4-dimension
AGV	-	Automated Guided Vehicles
AND	-	Logical Operation
ASV	-	Autonomous Subsurface Vehicles
AUV	-	Autonomous undersea Vehicles
CMOS	-	Complementary Metal Oxide Semiconductor
CTD	-	Conductivity Temperature and Depth
FLC	-	Fuzzy Logic Control
FLIR	-	Forward Looking Infrared
LADAR	-	Laser Detection and Ranging
MIT	-	Massachusetts International Technology of collage
NOR	-	Logical Operation
OR	-	Logical Operation
PC	-	Personal Computer
PID	-	Proportional Integrated Differentiate
RCS	-	Real time Control System
RGB	-	Red Blue Green
TOF	-	Time of Flight
USB	-	Universal Serial Bus
UUV	-	Untethered Subsurface Vehicles
UXO	-	Unexploded Ordinance
VFH	-	Vector Field Histogram
FIS	-	Fuzzy Inferences System
ANFIS	-	Adaptive Neural Fuzzy Inferences System

CHAPTER 1

INTRODUCTION

ASV stands for Autonomous subsurface Vehicle under AUV (autonomous undersea vehicles) class and the term of UUV or Untethered Underwater Vehicle is also used. ASV's are unmanned or robotic vehicles that are using state-of-the-art technology to bring new capabilities to work in the sub-sea environment. In the past 30 years, nearly 200 AUV have been built (R. Camilli, 2002). Most of these systems have been experimental. However, they have achieved impressive results and this record of success is creating a demand for their use in operational settings. The ASV's purpose is to carry a payload. The specific composition of the payload will be determined by the mission of the vehicle but can include instrumentation to measure ocean water characteristics, map the seabed or inspect sub-sea installations such as pipelines. In addition to gathering data, ASV's can be used to lay underwater cable or to deliver equipment to remote destinations. Refer figure 1.0 for information.

1.1 Objectives:

The objectives of ASV (Autonomous Sub-surface Vehicles):

1. Design the intelligent system for ASV forward manoeuvring for using fuzzy logic IF/THEN rules.
2. Compare the intelligent control system development of forward manoeuvring for ASV using different fuzzy method such as Mamdani, Sugeno and ANFIS (Adaptive Neuro Fuzzy Inferences System).

1.2 Problem statement:

Water pollution is extremely bad in certain place and conditions. Cleaning operations can be extremely dangerous for human response if the environmental containing hazardous materials such as lead or radioactive materials. Human task forces carrying necessary tools and equipment and having the required skills and techniques are deployed for cleaning and detection purposed after disaster such as tsunami or oil cleaning task on sea operations. Instead of sending human expertise into such dangerous structures or environments, it is hoped that autonomous robots will one day meet the requirements to perform such tasks so that human are not at risk of being hurt or worse.

1.3 Project Scope

This project report is intended to:

1. Provide information for guiding ASV projects development.
2. Review about ASV & AUV research that was focused mainly on the autonomous vehicle system using intelligence system such as Fuzzy Logic and Neural Network.
3. Propose an intelligent system (fuzzy logic) for ASV purposes.

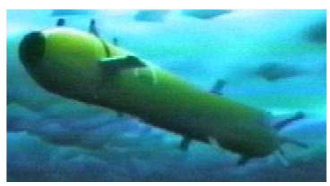

Figure 1.0: ASV laying cable in the Arctic (R. Camilli, 2002)

CHAPTER 2

LITERATURE REVIEW

The first section briefly discuss about the following specific aspects:

- Pressure Hull.
- Hull Form.
- Energy
- Vehicle control

The second section discuss about artificial intelligence in general term such as:

- Artificial Neural Network.
- Rule-based Expert System.
- Neuro-Fuzzy.
- Neural Expert System.
- Fuzzy logic.

The third section contained the explanations about Fuzzy logic methods:

- Mamdani Method.
- Sugeno Method.
- ANFIS (Adaptive Neuro-Fuzzy Inferences System).

The last section explained about ASV maneuvering from specific aspect such:

- Hydrodynamic model.
- Mathematical model.

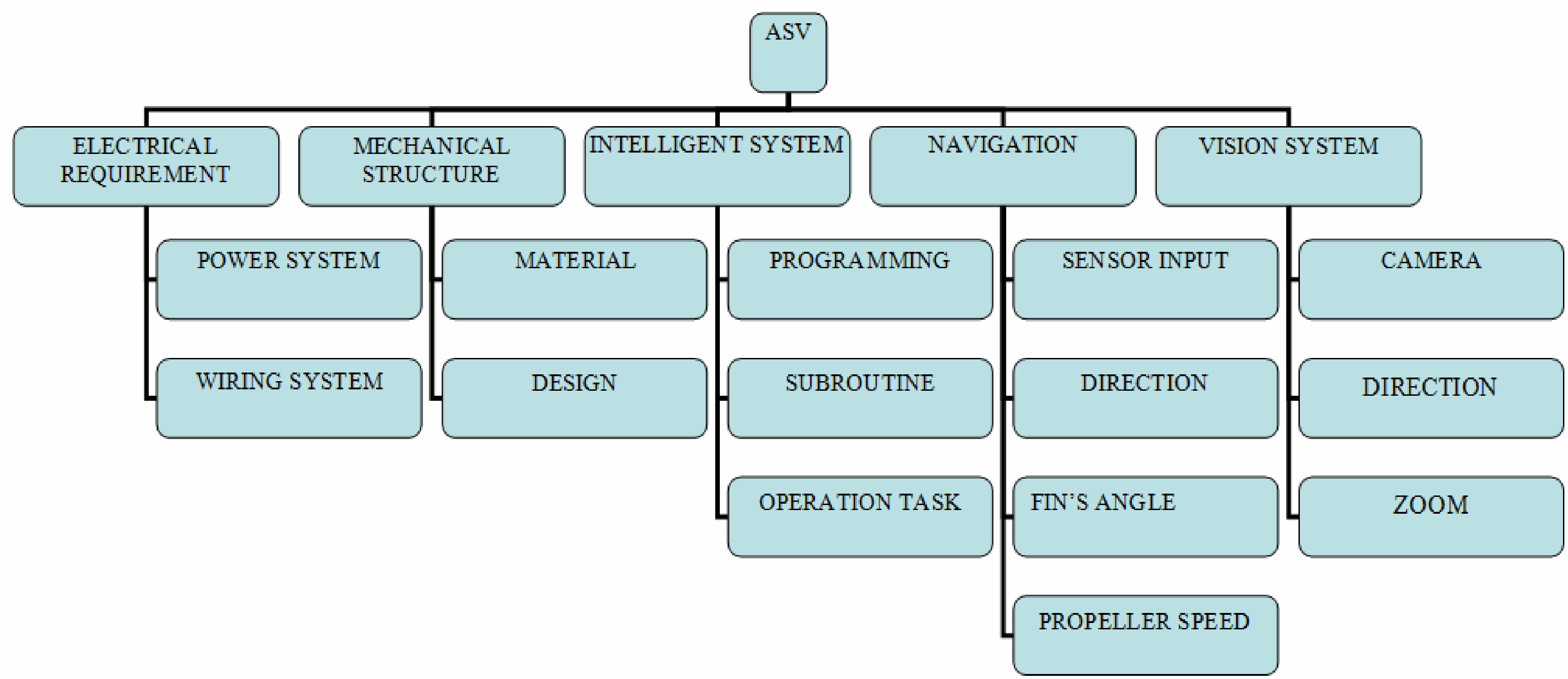

Figure 2.1: Structural chart for ASV's component systems.

2.1 Intelligent Vehicle Research

Vehicle intelligence has been advancing for many years, mainly in sensing, intelligences system and navigation. Researchers have developed much key advancement in vehicle navigation including this small subset:

- R. Camilli (2002) – Massachusetts International Technology Collages has been develops autonomous underwater vehicles (AUVs) are small, easily deployable, low component cost survey platforms, which have been used in numerous missions throughout the world. These AUV uses an embedded autonomous control system capable of adapting its mission directives and sampling regimes to better monitor its environment. Operation of the instrument onboard an autonomous underwater vehicle enhances the advantages of in-situ analysis. This research is the main references for my project.
- N. C. Tsourveloudis et al (2006) - The thesis discuss about the technology of unmanned vehicles in all its aspects especially since it holds the promise of saving human lives by letting machines do dull, dirty or dangerous missions into high-threat environments or just unknown environments. This thesis also shows the core research on fuzzy logic affects the advances in unmanned vehicles navigation technology and the way it can be applied to a variety of robotic vehicles, operating on ground, air or underwater. Moreover, three key attributes for a vehicle to be considered as capable for performing autonomous navigation have been identified. *Perception* is the ability of the vehicle to acquire knowledge about the environment and itself. *Intelligence* is the knowledge of a vehicle to operate for a considerable amount of time without human intervention and *action* is the ability of the vehicle to travel. This research architecture proven the effectiveness in almost all types of robotic vehicles. Refer to figure 2.3.

- Teoh Eam Khwang et al (1999) - The development of techniques for autonomous navigation and control of vehicles have become an important and active research topic in the face of emerging markets for advanced Autonomous Guided Vehicles (AGVs) and mobile robots. There are four major aspects to the development of this system. They are the sensor module, vehicle and controller module, navigation module and system integration module. (Refer Figure 2.2)

- Philip Redleaf Kedrowski (2001) - The purpose of autonomous vehicles range from Unexploded Ordinance (UXO) detection and removal for planetary exploration application. Virginia Tech has been developed autonomous vehicle named Navigator. For navigation, Navigator uses a local obstacle avoidance method known as the Vector Field Histogram (VFH) (Refer Figure 2.4 & 2.5)

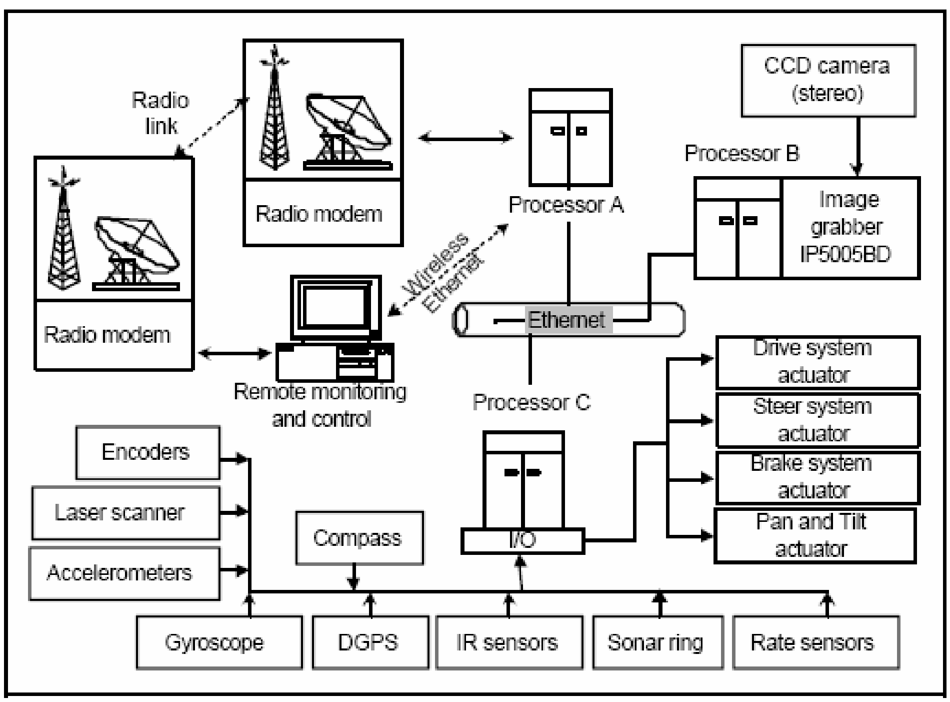

Figure 2.2: Computer Architecture for the Navigation System (Teoh, E.K. et al 1999)

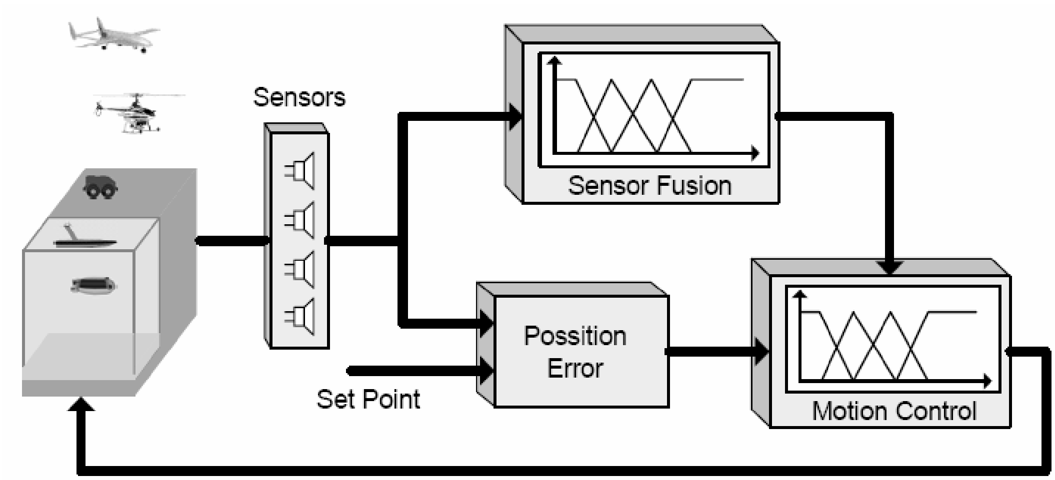

Figure 2.3: FL navigation scheme Architecture (N. C. Tsourveloudis et al, 2006)

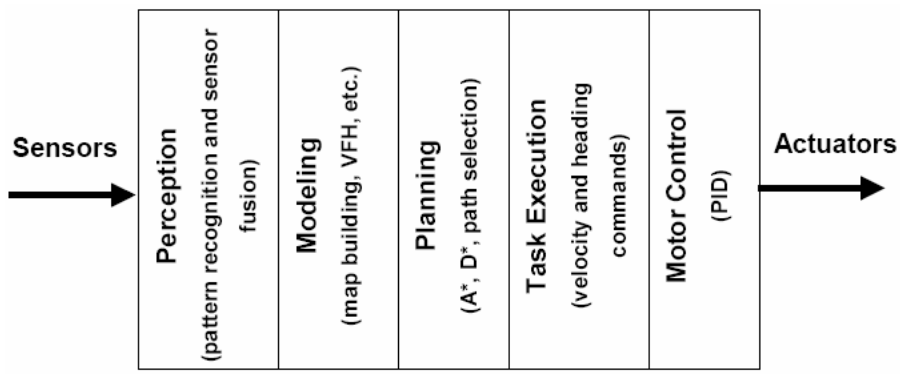

Figure 2.4: Linear decomposition of functional modules in a mobile robot control system (Philip Redleaf Kedrowski, 2001)

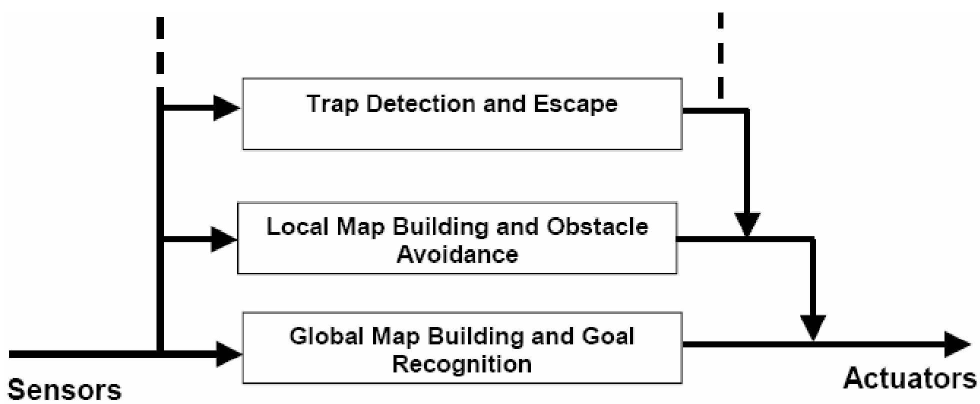

Figure 2.5: Intelligent consumption control architecture for an autonomous vehicle (Philip Redleaf Kedrowski, 2001)

- D. Richard Blidberg et al (2000) – The technologies of solar module performance, energy transfer issues to include charge control device technology and energy monitoring devices such as fuel gauges. It will also consider energy management strategies being developed. Solar energy systems allow the endurance of AUVs to be increased dramatically thereby allowing sampling systems to acquire needed scientific data over large volumes of ocean and across long time scales and to overcome the burden of recovering and recharging vehicles on a daily basis. These systems can store only a limited amount of energy therefore they must be efficient in terms of energy utilization.

- Sanjiv Singh (1995) - The thesis describes an approach to synthesizing plans for robotic excavators. Excavation tasks range from loading a pile of soil to cutting a geometrically described volume of earth for a trench or foundation footing. The excavation task stated in terms robotics and artificial intelligence: Transform the world from its current state to another state (Refer Figure 2.6 & 2.7)

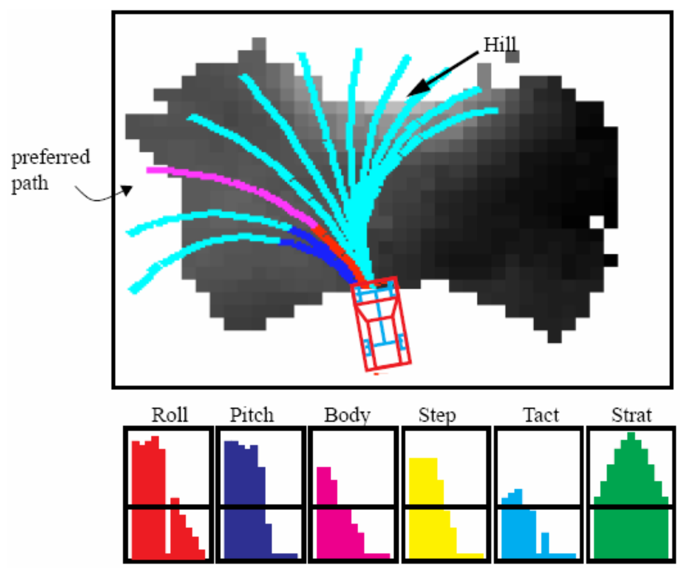

Figure 2.6: Planning for a mobile robot with non-holonomic constraints and multiple optimizations (Sanjiv Singh, 1995)

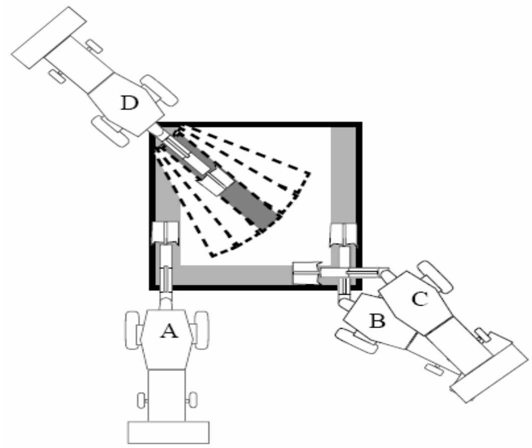

Figure 2.7: Plan view of an excavator backhoe digging a footing. The machine starts at A and digs one side of the footing to a desired depth. Second, the machine moves to B from which a second side can be excavated. A third setup (C) is achieved by rotation of the base. Excavation of the centre is achieved by a fan-like pattern of digs from (D) (Sanjiv Singh, 1995)

- X. Cui, T. Hardin et al (2004) - The paper describes a swarm-based FLC mobile sensor network approach for collaboratively locating the hazardous contaminants in an unknown large-scale area. The mobile sensor network is composed of a collection of distributed nodes (robots) has limited sensing, intelligence and communication capabilities. An ad-hoc wireless network is established among all nodes and each node considers other nodes as extended sensors. Gathering other nodes' locations and measurement data, each node's FLC can independently determine its next optimal deployment location. Applying the three properties of the swarm behaviors' such as separation, cohesion and alignment, the approach ensure the sensor network attains wide regional coverage and dynamically stable connectivity. (Refer Figure 2.8 & 2.9)

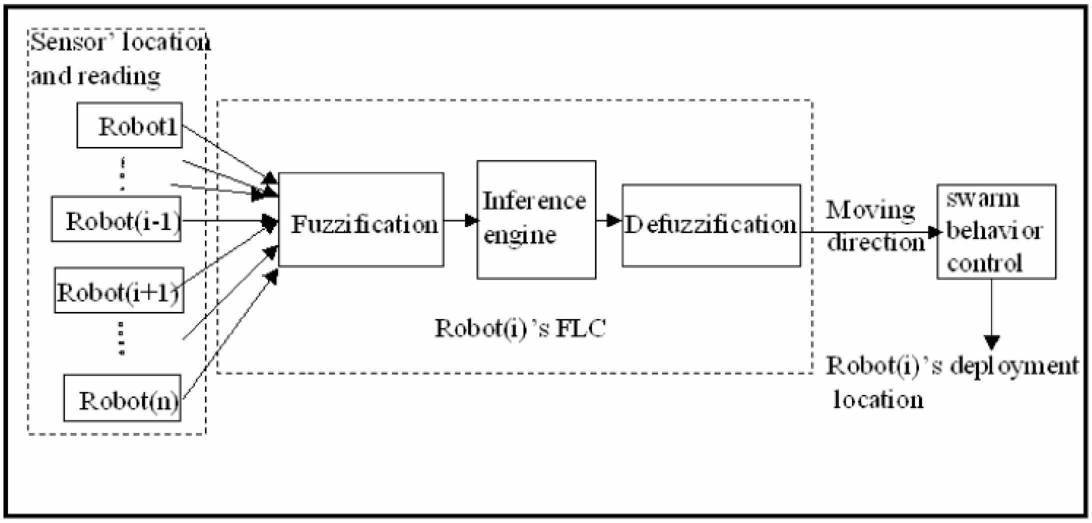

Figure 2.8: Block diagram of the swarm-based FLC system

(X. Cui, T. Hardin et al 2004)

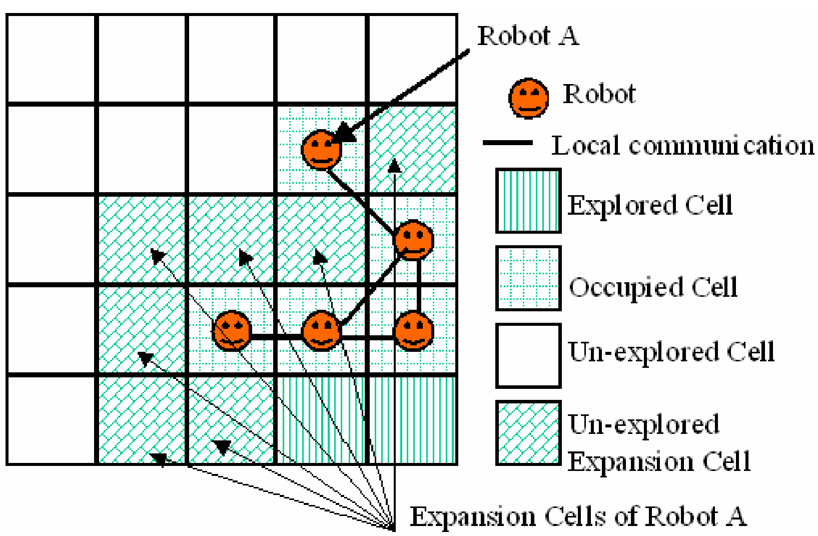

Figure 2.9: The environment grid map and expansion cells

(X. Cui, T. Hardin et al 2004)