A Study on Navigation of Autonomous Mobile Robot

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ABSTRACT

Autonomous action, which corresponds actively to the change of conditions in complicated circumstances ,is a fundamental function required to an intelligent robot. To develope a control system for a robot having the ability to adapt itself to complicated circumstances, it is necessary to establish self-tracing technology, which recognizes the corresponding position between peripheral objects and itself. So we need to manipulate the moving system with flexibility.

It is effective for solving problem that fuzzy theory is adapted to algorithm on a complicated circumstances. We develope a method to generate a route-map which has not only a course from the present position to the destination but also useful information on surroundings.

1. INTRODUCTION

Up to now, practical industrial robots, what is called, have no mobility in itself, and most of them are moved directly by man or by remote control. We are inclined to make and use practically such robots that are moved not by man's control but by itself. In many cases, we find the robots need the landmark near with which they move , and the robots have problems that they cannot adapt themselves to changing of circumstances. To solve these problems, the mobile robots must have the ability that they can understand a high degree geography [1]. Therefore the robots must have the information of real space circumstances in the form of the map because they are able to understand geography and navigate intelligently. If present state and goal state are given, the robots must find the path from the map and navigate in real time applying themselves to changing of circumstances.

In this paper, we describe the avoidance of obstacles, and the inducing of path by applying fuzzy theory, and by using circumstance information from ultrasonic waves in a flat in order to observe motion in building.

2. SYSTEM CONFIGURATION

Intelligent mobile robots consist of units as below, and function individually. The block diagram of system is shown Fig.2-1.

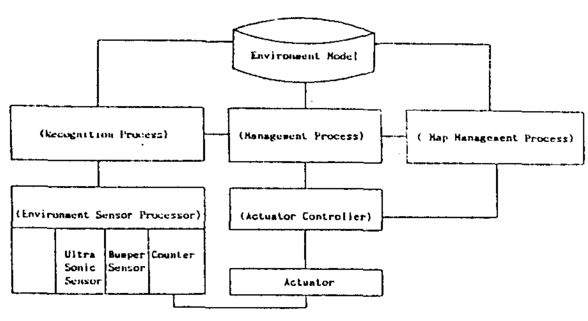


Fig.2-1 Block diagram of system

2.1 Driving Unit

Driving unit of robot has two DC servo motors, a operating control part of PWM and PLL which has the function of driving in a flat. Also it is possible to detect a position and a posture in a flat by pulse encoder which is attached to the wheel of the robot. Having this value accumulated error, it is nessary to correct it.

When the robot navigates along the center line, even if it deviates from the line , fuzzy inference algorithm enables robot to come back automatically to the center line by detecting the error by inner sensor and environment sensor. And when it happens to detect obstacle it awaits obstacle being vanished. If the obstacle vanished, it continue to navigate, otherwise it avoids the obstacle [3,7].

2.2 Environment Sensor Unit

The robot has six range sensors, one is in front, one is in back and the others are in each side respectively. This range sensors consist of ultrasonic sensors and a bumper sensor that block unexpected shock.

The front and back range sensors of this robot are used in order to defect disturbance of path while moving and disturbance of front wall while changing path. And the other sensors are used in order to acknowledge his place and moving direction angle to the wall [6].

2.3 Route-Map Management Unit

With database we make all environmental map in which robot act , if current position and destination , are given , we can find proper path and make the route-map and when that environments are changed we change the map [8] and require the modification of position information of driving unit. the management process which control whole system change of information and state of each unit. such a whole unit is controlled by two CPUs , 80286 and μPD70208, and programed by C-language.

3. FUZZY CONTROLLER

3.1 Control Input

This unit gives the velocity command output if the input data are given from sensor unit. Each command velocity are shown in the following equation.

$$U_L(k) = U_L(k-1) + \Delta U_d + \Delta U_f \qquad (1)$$

$$U_R(k) = U_R(k-1) + \Delta U_d + \Delta U_f \qquad (2)$$

ΔU_d: direction control input

ΔU_f: de- or acceleration control input

Direction control input ΔU_d is derived from the velocity difference ΔV between environment information and driving wheel by fuzzy inference.

$$\Delta V(k) = V_L(k) - V_R(k) = U_L(k) - U_R(k)$$

$$= U_L(k-1) - U_R(k-1) + 2\Delta U_d$$

$$= \Delta V(k-1) + 2\Delta U_d \qquad (3)$$

$$\Delta V(k) - \Delta V(k-1) = 2\Delta U_d \qquad (4)$$

From (4), the direction control input ΔU_d can change the direction if there is no velocity difference, namely $\Delta V(k-1)=0$. In other cases, because the ΔU_d value is an acceleration component, it also contributes to change the direction. Because an acceleration or deacceleration control input ΔU_f has the large value if the path consists of branch,

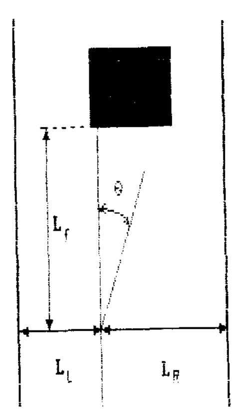


Fig.3-1 Input variables

namely, in go straight mode, and has the small value if the path consist of node, namely, in obstacle avoiding mode, we can control efficiently.

3.2 Method of Fuzzy Inference.

The i-th fuzzy control rule is expressed with variables x_1, x_2 and y in the following manner [4].

R^i: if x_1 is A_{i1} and x_2 is A_{i2} then y is B_i (5)

where A_{i1}, A_{i2} and B_i belong to one of fuzzy labels of x_1, x_2 and y, respectively.

Given x_1^o and x_2^o as input data, the degree of adaptability for the i-th fuzzy rule is defined for the measured data x_1 and x_2 in the following manner.

$$w_i = A_{i1}(x_1^o) \wedge A_{i2}(x_2^o) \quad (6)$$

For each i-th rule, the membership function of the implied fuzzy subset for variable u is calculated by the following equation.

$$B_i^*(y) = w_i \wedge B_i(y) \quad (7)$$

The membership function of fuzzy subset inferred from the overall fuzzy control rule

$$B^o(y) = \vee [w_i \wedge B_i(y)] \quad (8)$$

Finally, the overall control action y^o for the controlled system is calculated as the center of gravity of $B^o(y)$ in the following manner.

$$y^o = \frac{\int B^o(y) y \, dy}{\int B^o(y) \, dy} \quad (9)$$

Go Straight Mode is used at branch on route-map, and the control ruleis as following.

R_s^1: if d is left and θ is middle then U is PB
R_s^2: if d is right and θ is middle then U is NB
R_s^3: if θ is left then U is PS
R_s^4: if θ is right then U is NS

Table 3-1 Fuzzy control rules

		θ		
		Left	Middle	Right
d	left	PS	PB	NS
d	right	PS	NB	NS

PB : Positive Big
PS : Positive Small
NS : Negative Small
NB : Negative Big

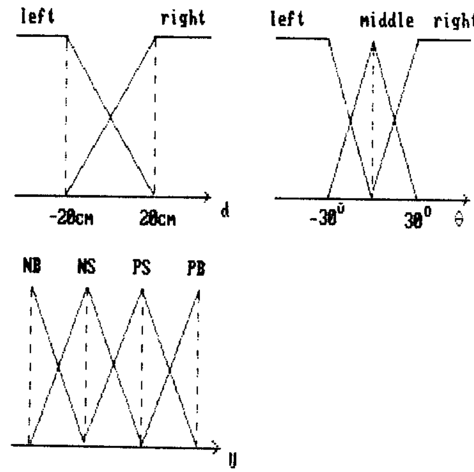
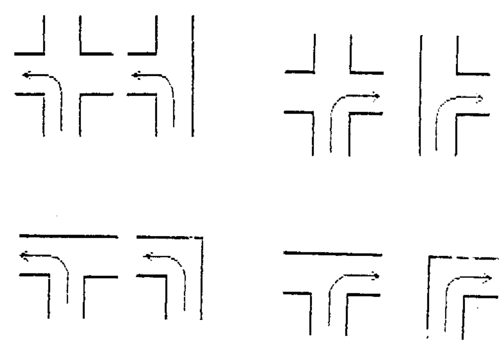


Fig.3-2 Fuzzy sets for " go straight "

Turning Mode is used at node on route-map, and turning type at node are divided in 8 cases as like Fig.3-3. At large, there are two types: left and right turning.

Fuzzy inference rules are constructed at the basis of the characteristic that it is possible for us to have the information about the wall at turning point.



(a)left (b)right

Fig.3-3 Turning type

Table 3-2. Left Turning Rules

		ΔV		
L_L	L_R	Negative	Zero	Positive
S	S	PS	Zero	NS
S	M	PS	Zero	NS
S	B	PB	PS	Zero
M	S	Zero	NS	NB
M	M	Zero	NS	NB
M	B	Zero	NS	NB
B	S	NS	NB	NB
B	M	NS	NB	NB
B	B	NS	NB	NB

S : Small

M : Meduim

B : Big

PB: Positive Big

PS: Positive Small

Zero: Zero

NS: Negative small

NB: Negative Big

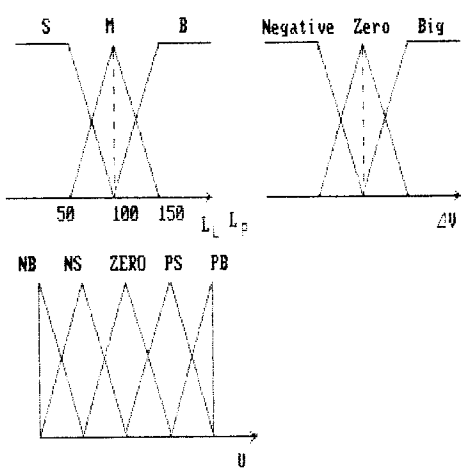


Fig.3-4 Fuzzy sets for " left turning "

4. SIMULATION

The NAS-1 (Fig.4-1), mobile robot made by NAS Lab., is tested in the 3rd floor of the engineering building by the method mentioned above.

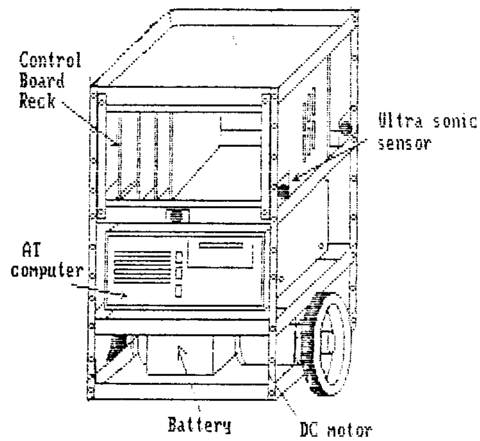


Fig.4-1 NAS-1

The experiments about each basic operations such as Left-turning in T-course, Obstacle avoidance are shown in Fig.4-2 and Fig.4-3.

Obstacle is placed on the right of the center in the experiment of Obstacle avoidance. When the mobile robot senses an obstacle, it stops for a moment and if there is not change, it will take avoidance action by the change of its direction after it considers the

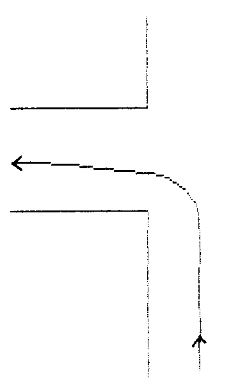


Fig.4-2 T-type

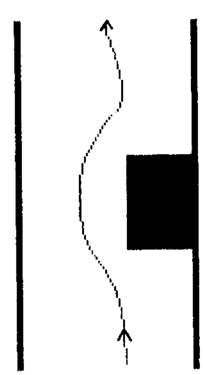


Fig.4-3 Obstacle-avoidance

possibility to move to the left or right. The experiment about navigation in the world map is shown in the Fig.4-4.

As the destination is given in this case, the route map is made by choosing the appropriate route to the destination and the remote control is taken by the route map, environment information and direction change. The map is represented by a graph consisted of nodes and branches, and the node is expressed by type and the branches contain environment information.

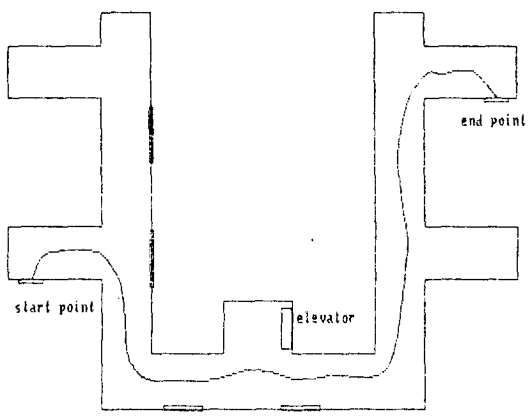


Fig.4-4 The experiment in the world map

5. CONCLUSION

Navigation and path-planning are the most important problem of an intelligent mobile robot. Therefore, we perform the research of moving control method adapting irregulary environment. The method is not only easier than the previous one in light of uncertainty of information from the sensor and exception-deal of the error but also proper to simulate a human action in the piecewise interval.

It is expected that the continous researches on the route-map generation algorithms in the more complex environments and the penception of these environments with the multi-sensor are eventually achieved.

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