A Study on Autonomous Driving Mobile Robot by using Intelligent Algorithm

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Abstract: In this paper, we designed a intelligent autonomous driving robot by using Fuzzy algorithm. The object of designed robot is recognition of obstacle, avoidance of obstacle and safe arrival. We append a suspension system to auxiliary wheel for improvement in stability and movement. The designed robot can arrive at destination where is wanted to go by the old and the weak and the handicapped at indoor hospital and building.

Keywords: ARV, ultra sonic sensor, nonholonomic, kinematic model, suspension system

1. INTRODUCTION

Due to increment of the demand of the nursing facilities and hospital in the advanced age society, it is expected the necessary of the assistants. In accordance with that, in this paper, we designed a guide mobile robot for an old man. The robot is made of two parts. The one is electro signal process part for the operating control. The other is the signal process part for the lever and laser scan sensor.

The Fig1 is the block diagram that shows the signal flow of the system. The user who wants to receive the service of the robot inputs the his location to the main controller at first. Then the main controller sends the digital signal to the MMC. The signal passes interface card and drives the motor, which send the user to the place where the user wants to go. And giving a pressure to the lever including the sensor (Load cell), MMC gets analog signal then main controller calculates it to react the power of the signal. If the calculated value is included in the range which is related with the speed control, the main controller controls the robot's speed.

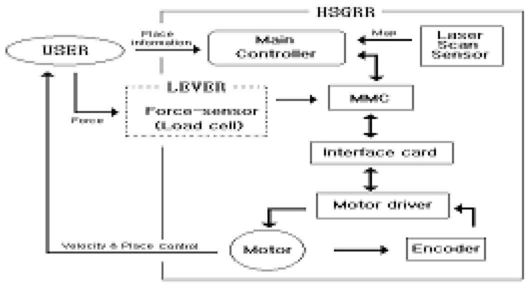

Fig. 1 Signal block diagram of the whole system

2. SYSTEM MODELING

2.1 The design of the mobile robot's operating part.

To design a controller, we explain the physical mechanism of the mobile robot. Fig2 shows schematic diagram of the mobile robot to design controller. In the Fig2,

To get the simple the physical mechanism of the mobile robot, we assume that there is no slide of the side. Under the assumption, we can get the followed equations.

$$\dot{x}_M = \frac{r}{2}(\dot{\theta}_1 + \dot{\theta}_2)\cos\psi \quad (1)$$

$$\dot{y}_M = \frac{r}{2}(\dot{\theta}_1 + \dot{\theta}_2)\sin\psi \quad (2)$$

$$\dot{\psi}_M = \frac{r}{2}(\dot{\theta}_1 - \dot{\theta}_2) \quad (3)$$

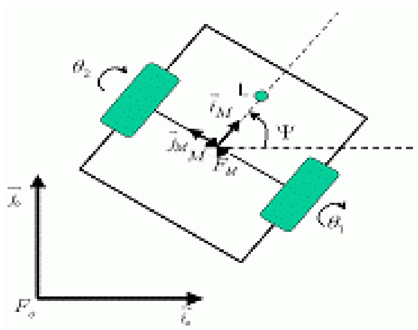

Fig.2 Schematic diagram of mobile robot

- M : Center of Gravity Point (CG Point)
- FO : The standard frame which is fixed
- FM : The standard frame included to the moving car

These equations are the mechanism equations of the most popular two-wheeled vehicle. But it is not easy to control. Because, equation(1) and equation(2) are Nonholonomic so can not be integral. To make control easy, we make the equation of the vehicle. At first, we make vector like as

$$X = [x \quad y \quad \psi]^T \quad (4)$$

And the assistant control vector is

$$U = [v \quad \psi]^T \quad (5)$$

The control vector, U, is expressed that

$$U = E\begin{bmatrix}\dot{\theta}_1 \\ \dot{\theta}_2\end{bmatrix} \quad (6)$$

$$E = \begin{bmatrix}\frac{r}{2} & \frac{r}{2} \\ \frac{r}{2R} & -\frac{r}{2R}\end{bmatrix} \quad (7)$$

So the state equation is

$$\dot{X} = B(X)U \tag{8}$$

Equ7 is expressed that

$$\begin{bmatrix} \dot{x} \\ \dot{y} \end{bmatrix} = \begin{bmatrix} -1 & y \\ 0 & -(d+x) \end{bmatrix} \begin{bmatrix} v \\ \dot{\psi} \end{bmatrix} + \begin{bmatrix} \cos\psi & \sin\psi \\ -\sin\psi & \cos\psi \end{bmatrix} \begin{bmatrix} \dot{x}_P \\ \dot{y}_P \end{bmatrix} \tag{9}$$

If the point, P, is relocated O, the Equ8 is expressed that

$$\dot{x}_P = \dot{y}_P = 0 \tag{10}$$

The input of the controller, B(x), is that

$$B(x) = \begin{bmatrix} -1 & y \\ 0 & -(d+x) \\ 0 & 1 \end{bmatrix} \tag{11}$$

At this time, we confirm stability of B(x). At first, if d is zero, that it is set that the location of controller is located the center of the vehicle, we can do the feedback control by using Lyapunov's stability theory. The input of the control is that

$$U = \begin{bmatrix} v \\ \dot{\psi} \end{bmatrix} = \begin{bmatrix} k_1 x \\ k_2 y \end{bmatrix} \quad , \ k_1 > 0 \ , \ k_2 \neq 0 \tag{12}$$

We can see the result at Fig3.

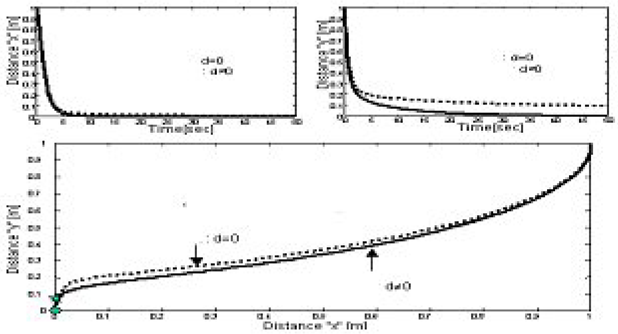

Fig.3 Stability of feedback control

In the simulation, it cannot reach to the zero when d is zero. The reason is that the B(x) is to be singular matrix when zero point. So, we locate the d near to zero to avoid the singular point.

2.2 The modeling of the assistant wheel.

To apply to the path algorithm, we need the mechanism of the operating system which satisfy the slide of the side. So we apply the mechanism of the suspension to the system. To setthe capacity of the suspension we are modeling the suspension.

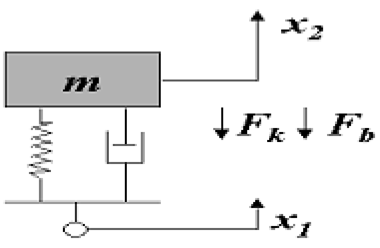

Fig.4 Modeling of a suspension

Fig.4 describe the modeling of the suspension. The assistant wheel uses the precise caster to absorb the vibration percussion and is installed the suspension. The suspension helps the motor's operation and absorb the percussion of the ground. Especially, it improves the operating wheel's ability of the grounding. If the wheel loses the ability of the grounding, the controller cannot steer the vehicle. And it is very dangerous. The equation of the modeling of the suspension is that

$$m\ddot{x}_2 + B(\dot{x}_2 - \dot{x}_1) + K(x_2 - x_1) = 0 \tag{13}$$

where, x_1 : movement of mobile robot

F_b : damping power

F_k : elasticity-transformation power

x_1 : displacement

3. THE DESIGN OF THE CONTROLLER.

Fig.5 is the block diagram of controller which is designed to this system. As you see, thus controller is composed with two feedback loops. The one is inner loop which is made of the PID controller following in the desired velocity which is made by Fuzzy controller. The other is outer loop(main controller) which decides velocity of the vehicle and steering angle depending on the location of the object and the input of the sensor. The value of the outer loop' output is changed to the velocities of the two wheels.

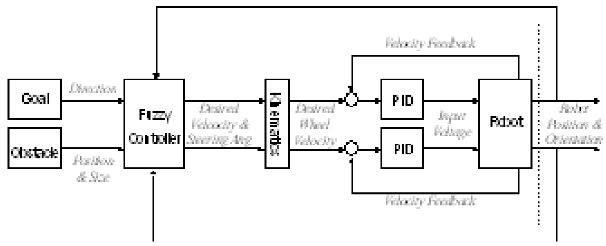

Fig.5 Diagram of Control Syste

3.1 Algorithm of the Route recognition

The mobile robot is applied by the algorithm which determine the location and attitude of mobile robot using the laser sense scan for inner the surface of the wall. Fig.6 shows the surface of the wall related to the mobile robot.

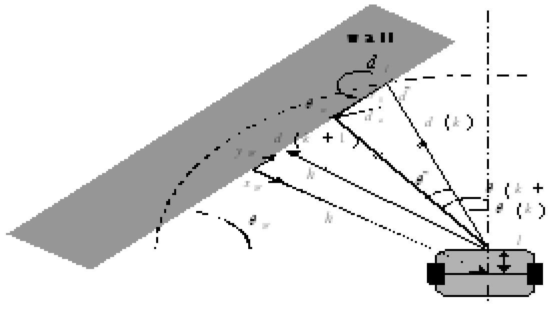

Fig. 6 Sensor frame in scannin

Above the model, the mobile robot recognize the coordinates of the attitude and the distance from the surface of the wall. The polynomials about recognizing the coordinates of the attitude and the distance from surface of the wall is then given as .

$$\theta_w = \frac{\pi}{2} - \cos^{-1}\left(\frac{d_a^2 - \tilde{d}^2 - d_l^2}{2\tilde{d} \cdot d_l}\right) - \theta(k) \quad (14)$$

$$h = h' - \cos\theta_w \cdot l \quad (15)$$

where,

$$d_1 = \sqrt{d(k)^2 + d(k+1)^2 - 2d(k) \cdot d(k+1)\cos\tilde{\theta}} \quad (16)$$

$$\tilde{\theta} = \theta(k+1) - \theta(k) \quad (17)$$

$$\theta_1 = \cos^{-1}\left(\frac{d_a^2 - \tilde{d}^2 - d_l^2}{2\tilde{d} \cdot d_l}\right) \quad (18)$$

$$\tilde{d} = d(k+1) - d(k) \quad (19)$$

$$d_a = d(k+1) \cdot \tilde{\theta} \quad (20)$$

where, . θ_w is the attitude of the mobile robot, h is to be the distance toward x axis from the surface of the wall. The mobile robot travels by the algorithm of the route recognition to minimize the distance from the surface of the wall to the mobile robot.

3.2 The fuzzy Algorithm.

fuzzy theory is proposed by professor Zadeh , 1969 in Unite State America initially. The fuzzy theory recovers from the imitation of math of existing dividing tow parts and expresses well the real natural siturations.

Fig. 7 shows that the Fuzzy controller is based on the knowledge base designed IF – Then types as the obscure natural language , the interface system resulted from preresented input of the fuzzy and the regulations of fuzzy, the defuzzifacation system consisting of the crisp value resulted from the conclusion of the fuzzy theory.

3.2.1 Fuzzy variable

In this paper, we propose that the mobile robot achieve the Function of the route creation and avoidance of the obstacle. Desired results. The fuzzy controller is designed by the purpose which the direction of the target and the location of the obstacle and the load shell accepted the variable input. The mobile robot is designed to determine the speed and the steering angle using the input variable of the fuzzy set. The fuzzy value of the fuzzy input and output variable are proposed that they hold the value of Table. 1 and Table.2 , respectively.

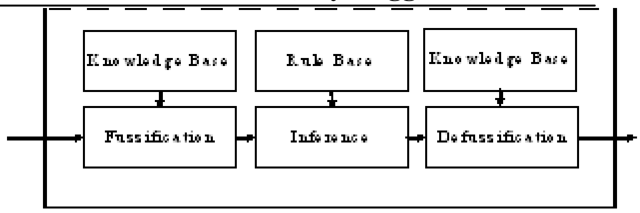

Fig. 7 Diagram of Fuzzy Controller

Table. 1 Input Variables and Fuzzy Sets in Them

Variable	Fuzzy Sets in the university
Velocity of Robot Body	SM BG
Steering angle	NE ZE PO

Table 2. Output Variables and Fuzzy Sets in Them

Variable	Fuzzy Sets in the university
Velocity of Robot Body	SM BG
Steering angle	NE ZE PO

3.2.2 The regulation base.

The regulation of the mobile robot determined the speed is Then given as :

- When the mobile robot is close and in front of the obstacle, it is slowly moves.
- When the mobile robot is far , it is fast moves.

Table 3. Control Rules for Velocity

NAR	NBG	ANY	ANY	BG
	NMD	ANY	ANY	BG
	NSM	ANY	ANY	SM
	ZER	ANY	ANY	SM
	PSM	ANY	ANY	SM
	PMD	ANY	ANY	BG
	PBG	ANY	ANY	BG
MED	ANY	ANY	ANY	BG
FAR	ANY	ANY	ANY	BG

The steering angle determined from the regulation is then given as:

- IF the mobile robot isn't behind the obstacle but close , it is avoid the obstacle.
- If the mobile robot is far from the obstacle, it is move the target.
- If the mobile is behind the obstacle, it is move the target.
- If the mobile robot is in middle of the obstacle and

the size of the obstacle is small, it is move the obstacle.

4. A SIMULATION RESULT

4.1 The avoidance of the obstacle

Fig. 8 shows that the simulation that the mobile robot recognizes the signal of the obstacle from the laser scan sensor.

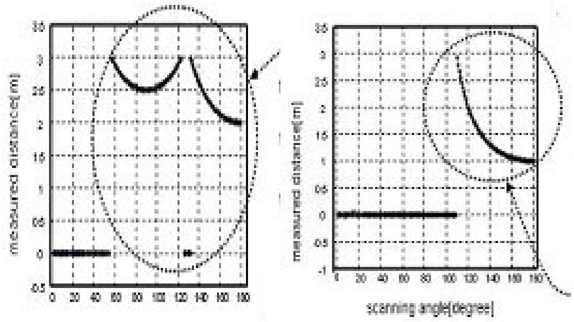

Fig. 8 Simulation of navigating the recognized path

4.2 SUSPENSION

From Fig. 9 to Fig. 10 show that the simulation results of the suspension system in case of the the obstacle on the road. The dotted line shows the obstacle of the road, the solid line shows the assimilation of the suspension. Likewise, From Fig. 11 to Fig. 14 show that the result from the simulation in case of the disturbance applied the road.

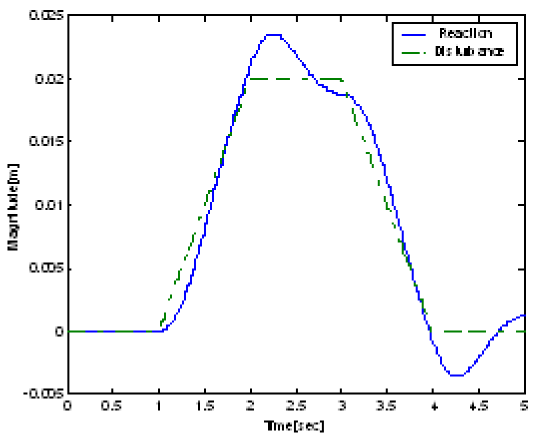

Fig.9

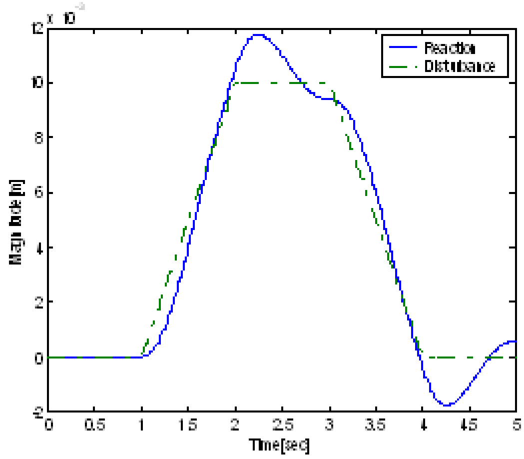

Fig. 10

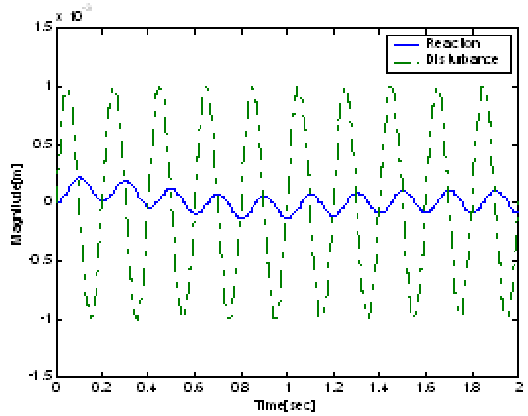

Fig. 11 5HZ(Magnitude : 0.001)

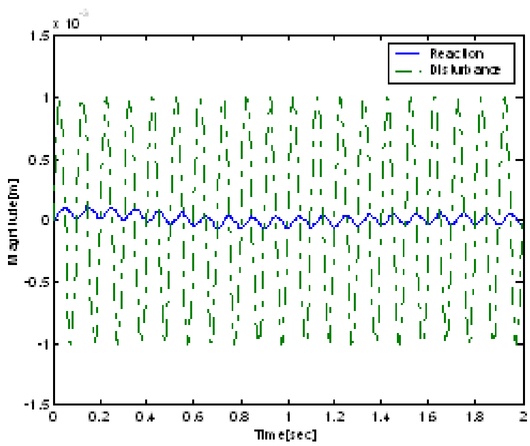

Fig.12 10 HZ(Magnitude : 0.001)

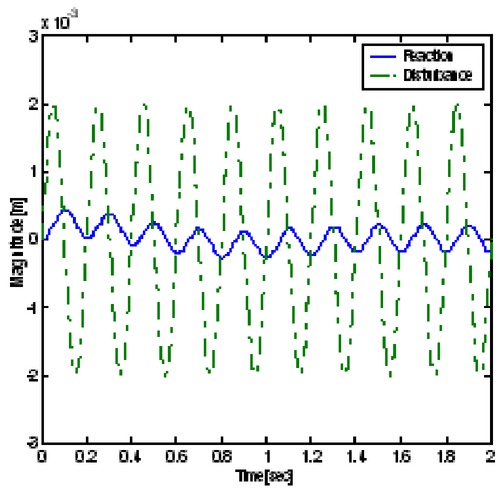

Fig.13 5HZ(Magnitude : 0.002)

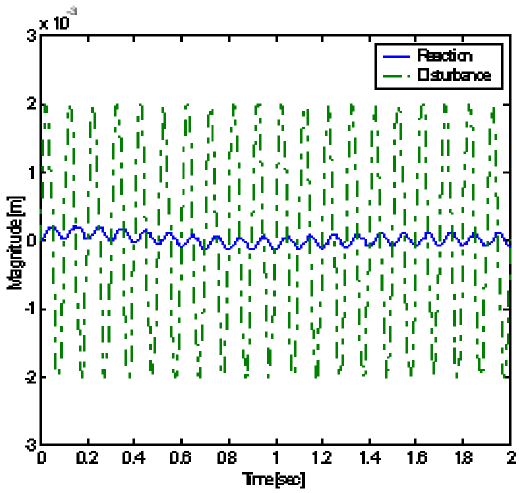

Fig.14 10HZ(Magnitude : 0.002)

5. CONCLUSION

In this paper, on the assumption the kinetics of the mobile Robot we conclude the simulation that the propriety of the control algorithm applied the mobile robot.

The result of the research contents in this paper is then given as :

1. Using the fuzzy control algorithm the mobile robot for the service of the guidance tracks the a route well.
2. The algorithm of recognizing the route and the obstacle are synthesized each other, we propose the algorithm for the tracking the route by the fuzzy logic controller.
3. We make out the superior suction for the obstacle on the road due to equip the suspension system in the assistance wheel.

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