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NEURAL FUZZY CONTROL FOR A MOBILE VEHICLE

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Abstract A neural fuzzy control strategy, developed in order to make a Mobile Vehicle(MV) run along with the traffic guidelines on the road, is presented. A neurocomputer is used in the control procedure and it learnt the driving knowledge to control the MV's actions. The image information of the guidelines is provided by a CCD camera on the top of the MV. The MV utilize the image information to identify the shape of the road and to decide the position of itself, and control the running actions. A fuzzy controller works on-line. Both of the neural controller and the fuzzy controller make up each other. This control method solve the problem of mechanical and electrical inertia and make the Mobile Vehicle run rapidly and smoothly.

Keywords Neurocomputer, Fuzzy, Control, MV, Run

1. INTRODUCTION

The autonomous control problems have been researched by many people[1][2][3]. These researches have dealt with the motion planners and smoothing trajectories and so on. The differences between our research with them are the controlled object and the working environment of the controlled object. Our controlled object has a structure like a real car[6], is called a Mobile Vehicle(MV). In such a system, a lot of practical problems have to be considered in the overall design, such as the weight, the mechanical and electrical inertia, the nonlinearities of the performing units of the MV etc.. Therefore, the experiments of those simulations are not easy to get the satisfactory practical effect. Our purpose is make the MV run along with the guidelines on the road according to the image information from a CCD camera. Following the research of **the center of the weight**[6], a new neural fuzzy control strategy is presented in this paper. The image information which is gotten by means of the CCD camera and relevant processor is divided into two areas, area1 and area2, according to the distance of the guideline in front of the MV. The area1 is the area from 1.3m to 2.6m in front of the MV, the area2 is 2.6m~5.0m. The standard position is located at 1/2 width of the MV (i.e. 0.35m)[6] to the right edge of the MV. This position is suitable to the angle of view of the CCD camera. A neurocomputer is trained, and is capable of recognizing 12 shapes of the road. A fuzzy controller works on-line. The two controllers are given full play independently and make up each other. This control method solve the problem of mechanical and electrical inertia and make the Mobile Vehicle run rapidly and smoothly.

The problem of running a Mobile Vehicle is given in **Section2**. We will show how to handle the image information to recognize the shapes of the road in **Section 3**. The details of neural fuzzy controller is submitted in **Section4**. The experiment results are in **section 5**.

2. RUNNING PROBLEMS

From the driver's point of view, a car has two degrees of freedom: the accelerator and the steering wheel. The MV is designed to move a smooth locus as shown in Figure 1[5]. We considered the midpoint of the rear wheels as the reference point. As mentioned above, our purpose is to make the MV run along with the guidelines on the road according to the image from the CCD camera rapidly and smoothly.

In Figure.1,

$$\omega = \frac{\mathrm{d}\theta}{\mathrm{dt}} = \frac{\mathrm{d}\theta}{\mathrm{ds}} \cdot \frac{\mathrm{ds}}{\mathrm{dt}} = \frac{\mathrm{v}}{\mathrm{R}} \tag{1}$$

$$(\text{from}: \frac{d\theta}{dt} = \frac{1}{R}, \frac{d\theta}{ds} = v)$$

- ω: turning speed of angle of the car(rad/s)
- R: the curvature of a certain point on the running locus(m)
- ds: running distance in the time dt(s)
- $d\theta$: turning angle of the car(rad)
- dt: smooth running time(s)
- v: running speed(m/s)

In the theory (see Figure 2), the (R,ϕ) has the relationship

$$\mathbf{R} = \mathsf{b}/\tan\phi \tag{2}$$

where ϕ: steering angle, b: the distance between the two shafts. Our final aim is to find the better relationship from R to ϕ and v.

3. IMAGE INFORMATION

All of the image information of the MV's location and the shape of the guideline are caught by a CCD camera which works in the available area of view of itself (see Figure 3). The dark part is the blind area and the blind distance **d=1.3m** in Figure 3. The available viewing angle is 60 degree. The centers of the weight of the guideline, W1=(x_{W1}, y_{W1}) and W2=(x_{W2}, y_{W2}), are extracted from the area1 and the area2 independently. In order to illustrate the basic ideas about how to deal with the image information, we give an example in Figure 4 and Figure 5. The shape of a certain real road is shown in Figure 4 and its image information is in Figure 5. The two points, Ws1=(x_{Ws1}, y_{Ws1}) and Ws2=(x_{Ws2}, y_{Ws2}), are the centers of the weight of the reference position or a direct line which keep pace with the right edge of the MV with a distance of 0.35m. In Figure 5, **O** is the center of the camera. The location is estimated with the center of the weight of the guideline in the area 1. As the image information is divided into two areas, area1 and aera2, the shape of the guideline is estimated with {W1,W2,Ws1,Ws2} or {Φ, Φ_o}. The mathematical relationship is

$$\mathbf{\Phi} = \begin{cases} \mathbf{\Phi}_o - tan^{-1}\frac{y_{w2}-y_{ws1}}{x_{w2}-x_{ws1}} & x_{w2}-x_{ws1} \neq 0 \\ 0 & x_{w2}-x_{ws1} = 0 \end{cases} \tag{3}$$

where Φ_o=$tan^{-1}((y_{ws2}$-$y_{ws1})/x_{ws2}$-$x_{ws1})$.

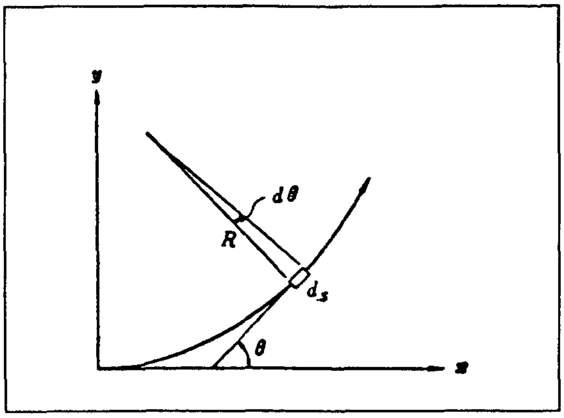

Figure 1: The smooth running track

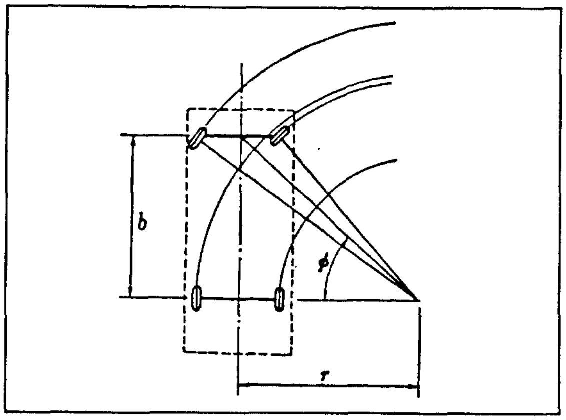

Figure 2: The steering angle of the MV

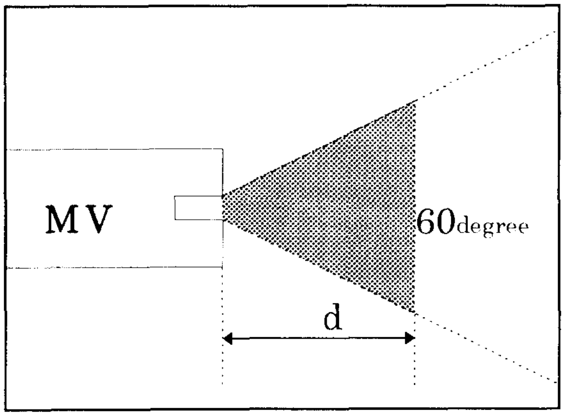

Figure 3: The available area of view of the camera

table 1 The data of the neurocomputer

No.	pattern	Teaching signal	Learnt signal
0	0000000127	10	10
1	0000001270	20	19
2	0000012700	30	31
3	0000127000	40	38
4	0001270000	50	53
5	0012700000	60	57
6	0127000000	70	68
7	1270000000	80	76
8	000000127127	90	92
9	000001271270	100	100
10	000012712700	110	109
11	000127127000	120	115

4. CONTROLLER

For rapid running a MV, the problems which must be solved are that image information change fast and the driving sampling interval of the MV is contrasted with the smoothing feature. What we want to do is to make the MV run smoothly within the sampling interval $[0, t_{min}]$ (t_{min}: the minimum sampling time to make MV move smoothly) as short as possible. Then the problems are changed into the control effect within the interval $[0, t_{min}]$. The neural fuzzy controller solved the problems.

4.1 Neural Controller

A RN-2000 neurocomputer is used in our control procedure. The neural network is operated in back propagation method (**BPM**). Let $\Omega=\{x(i),...x_m(i)\}\in R^m$ be a vector containing m measurements representing the process states at time index i, $\Psi=\{y(i),...y_n(i)\}\in R^n$ be the output which response the input, that is

$$f: \Omega \longmapsto \Psi.$$

The RN-2000 is trained to learn how to run on 12 shapes of the roads. In this controller, $\Omega\in R^8$, $\Psi\in R^1$. The input is from W2 which is the center of the weight in the area2(see Section3), and the output is the driving speed with a homologous steering angle.

The control regulator is

If now location is A
and the guideline shape is B
then running C according to A and B.

It is the neurocomputer that recognize the shapes of the roads and control the running actions. The data are shown in the table 1. The details of the algorithm of **BPM** and the neurocomputer RN-2000 appear in separate papers[4][7].

4.2 Fuzzy Controller

A fuzzy controller is used to control the running action on-line in order to know the location and moving trend of the MV at any time. The output of the fuzzy controller, which has two inputs, is the steering angle.

4.2.1 Variable Selection

The variable of the fuzzy controller are chosen as follows:
(a). One of the two inputs **e(t)** is the location errors between the MV and the guideline.

$$\mathbf{e(t) = e_l(t) - e_s(t)} \tag{4}$$

t: time;
e_l: location of the MV;
e_s: reference location of the MV.

(b). The other input is the change of the errors Δe between the interval $\mathbf{t}-\Delta t$ and **t**

$$\mathbf{\Delta e = e(t) - e(t - \Delta t)} \tag{5}$$

(c). The output of the fuzzy controller is the steering angle.

4.2.2 Fuzzy Control Procedure

In Figure 5, $Ws1=(x_{ws1},y_{ws1})$ and $Ws2=(x_{ws2},y_{ws2})$ are the centers of the weight of the reference position. During a certain running procedure at the time **t**, the center of the weight of the guideline in the areal is W1(see Section3). Because the distance between the MV and the guideline is in 0m~0.35m, $\mathbf{e(t)}=e_{W1}(\mathbf{t})\text{-}e_{Ws1}(\mathbf{t})< 0$. If Δe is less than a certain negative value, the system is thought working well and nothing is modified. Else the steering angle ϕ(in the equation (2)) will be changed to ϕ_{new}. ϕ_{new} is a new steering angle.

4.3 Example

If $\{\Phi, \mathbf{e(t)}\}=\{15^\circ,-100\}(\mathbf{e(t)}=x_{w1}(\mathbf{t})\text{-}x_{ws1})$ is obtained after a running action of the MV at the interval $[t-\Delta t, t]$, The MV will found that the location of itself is on the left side of the guideline within a distance of 0m~0.35m. The result of Φ=15° shows the trend of the guideline is near the standard position within a distance of 2.6m~5.0m in the front. So the MV will be controlled to run according to the knowledge "**the guideline is a closed one and the location is in a little left** " by the neural fuzzy controller.

5. EXPERIMENT

The experiment road is shown in Figure 6. The guideline type is red with 50mm in width. The road include direct lines, smooth turning and urgent turnings. On the direct lines, things is simple. The MV go easily. Though it is not easy for MV to pass the urgent round curves, the MV has learnt running ways and is capable of check the actions

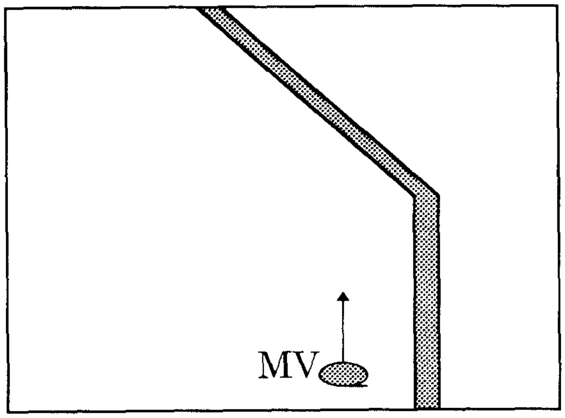

Figure 4: The shape of the real road

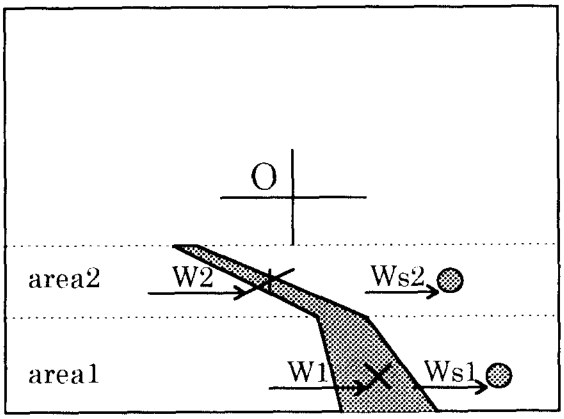

Figure 5: The image information of the MV

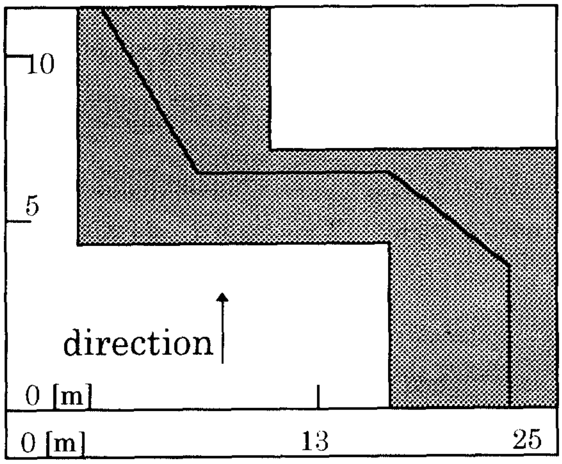

Figure 6: The guideline of the experiment

of itself and modify the operations on-line, therefore the designed purpose are practiced. The minimum speed is not less than 1.0m/s.

6. CONCLUSION

A new neural fuzzy control strategy is applied to make a Mobile Vehicle run along with the guidelines successfully. The neural controller and the fuzzy controller play the roles independently and compensate each other. The neural fuzzy controller not only learnt what should be done but also know to make the actions of itself better. If an intelligent system is defined as "A system is capable of learning, remembering, executing actions and checking the effect of the actions according to some rules and making the effect better", then our Mobile Vehicle is a primary one. An advanced intelligent control is developing in our laboratory.

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