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INTELLIGENT CONTROL STRATEGY FOR A MOBILE VEHICLE WITH NEUROCOMPUTER

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Abstract In this paper, an intelligent control strategy for a mobile vehicle, based on the technology of the artificial neural network in a Neurocomputer, is presented. The mobile vehicle learned recognizing and driving knowledge by a neurocomputer. Moment Invariants computation was used to extract the shape of objects. The technologies of both neurocomputer and Neumann-type computer are applied into the control system, and make the mobile vehicle be capable of tracking designated objects and avoiding obstacles.

Keywords Mobile Vehicle, Neurocomputer, Tracking Object

1. INTRODUCTION

The general characteristics of intelligent systems is defined as having an ability to emulate human capabilities, such as planning, learning and adaptation[1]. The field of intelligent control is multidisciplinary and combines techniques from control theory, computer science, psychology, physiology and operations research. The research of navigation of vehicles have lasted for many years. J. Laumond[2] applied three-step algorithm to a mobile robot and solved the problem that how to compute optimal feasible paths in a configuration space(the space in which the motion of rigid bodies amid obstacles in the 3-D dimensional Euclidean space is translated into the motion of point in some space) equipped with the singular metric induced by the nonholonomic constraints. Y. M. Enab[3] build a controller for the unknown nonlinear time invariant dynamic process based on modeling the behavior of its human operator. D. Gorinevsky etc.[4] designed a controller for an automated support system and performed desired features of such a system and parking controller. The navigation problems can be classified into parking problems, motion planners, vehicle sensors, image processing etc. Our research pay attention to two points, the strategies of driving an feasible paths and image processing of information from a CCD camera sensor. The test vehicle in our research is called Neural Mobile Vehicle (denoted by NMV). We will describe the NMV in section 4 in details. The running pattern is shown in Figure 1. The technologies of both neurocomputer and Neumann-type computer are applied into the control system, and make the mobile vehicle be capable of tracking designated objects and avoiding obstacles smoothly and successfully.

The neural network control or the neural controller is a subset of both neural network research and conventional control techniques. The neural networks, and the neurocomputation in general, represent a unique methodology by which knowledge is acquired from the training bases and stored in a distributed manner in the connective structure of the neural network. The distributivity contributes to increased learning capabilities of neural networks because the individual elements in the network are capable of adjusting their connections to achieve near optimal I/O(input/output) map.

Figure 1: Running pattern

The fuzzy logic control(FLC), which is one of the major developments of fuzzy set theory and was primarily designed to represent and reason with knowledge that is hardly to be expressed by quantitative measures, has proven effective for complex, nonlinear and imprecisely defined processes for which standard model-based control techniques are impractical or impossible. So fuzzy controller will also be used in our design, but is not our point in this paper.

In general case, time-optimal paths can be calculated by using the Maximum Principle in the framework of optimal control theory, but it is not easy for an arbitrary nonholonomic system[2]. The goal of this paper is to present an intelligent idea from the practical point of view and a possibility of industrial application. For this reason, the paper assumes that the most desirable practical approach to the typical case of tracking object and avoiding obstacle. The object and obstacle are assumed to be seen at the same time(the object should not be concealed by the obstacle), and are not more than one independently. Some other practical issues considered include 1) boundedness of the steering angle, 2) optimality of control inputs(in sense of minimizing the steering effort required to driving a car).

The outline of the paper is as follows. In section 2, we presents neurocomputer and the moment invirants for recognition of a designated object. Details of our image processing method and our strategy of intelligent control are described in section 3. Finally, we give some experimental discussion and conclusions.

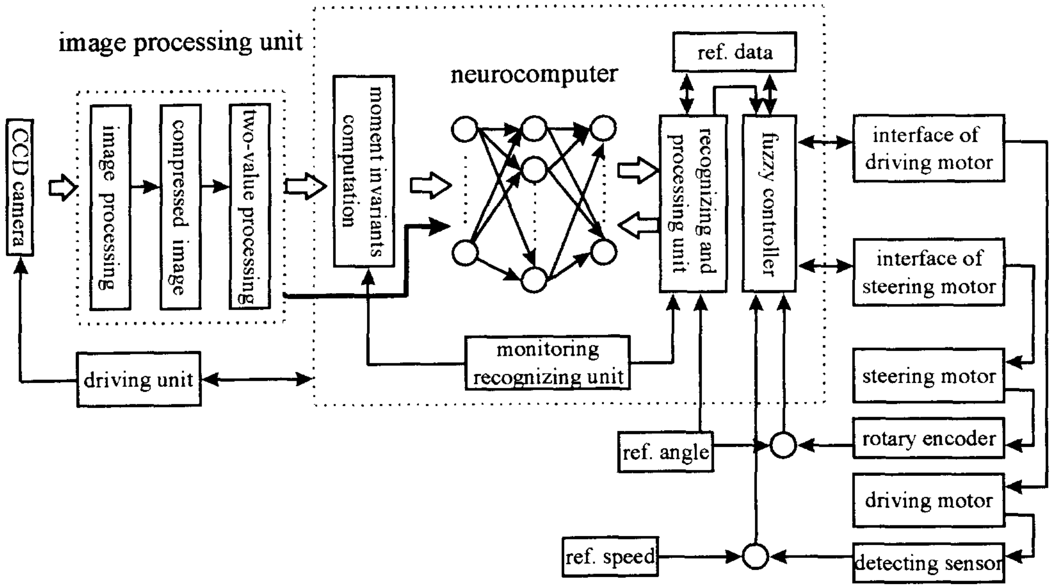

Figure 2: Block diagram for the control system

2. DESCRIPTION OF THE SYSTEM

Then the running problem is equivalent to drive the NMV from an state $q(t)$ into a desired control state or location $q^d(t)$ $(t_0 \leq t \leq t_f)$ with the control inputs v and ϕ. The block diagram of the mobile vehicle control system[5] is shown in Figure 2. Our system consist of three parts. (1) neurocomputer recognition, (2) Moment invirant computation (3) fuzzy controller. The basic idea[6][7] of the intelligent algorithm is make the mobile vehicle recognize the designated objects, then a fuzzy controller drive the NMV from the state $q(t)$ to the desired control state $q^d(t)$. The main idea of fuzzy system or fuzzy controller is to imitate the human reasoning process to ill-defined plants, and is able to realize the imprecision of the reasoning process without using exact quantitative analysis. Details about (3) has been discussed in [8]. The intelligent algorithm of (1) and (2) consist of four steps.

1. Learning the feature of shapes of both the obstacle and the object,
2. The camera rotates to search spatial objects in order to expend its viewing range, if necessary,
3. Deciding whether there are some obstacle between the object and the mobile vehicle,
4. Driving and avoiding the possible obstacles in order to reach the designated object.

2.1 Neurocomputer

The training of the neural network or neural controller based on human expert experience is sometimes very feasible method, especially for those complex and hardly defined processes. The back propagation network(BPN) model change the input-output problem of a set of sample into a nonlinear optimal map[9][10][11]. The steepest descent method, one of the common near-optimal algorithms, is applied. The learning and keeping are realized by weight update with recurrent computation in the inner neural network. We assume that there are N samples $\{\lambda_k,\gamma_k\}$ (k=1, 2, $\cdots$, N). The BPN with m input neurons and n output neurons is the map $\Re$ from $\Lambda = \{\lambda_1, \lambda_2, \cdots, \lambda_m\}$ to $\Gamma = \{\bar{\gamma}_1, \bar{\gamma}_2, \cdots \bar{\gamma}_n\}$. Here, $\bar{\gamma}_k (k = 1, 2, \cdots, n)$ is the real value of the output of the BNP. If $\gamma_i = G(\lambda_i)$ $(i = 1, 2, \cdots, l)$, then $\Re$ is a mathematical approach of the map G.

$$\bar{\gamma}_i = \Re(\lambda_i) \qquad i=1,\ 2,\ \cdots,\ l;$$

The neurocomputer RICOH-2000 is based on the back propagation algorithm. The RICOH-2000 consist of seven RN-200 digital neural network VLSI chips and sixteen neurons in each layer, and whole 256 synapses are integrated in a $13.73 \times 13.73 mm^2$ VLSI chip. This chip can perform 5.12 giga pulse operations per second. It corresponds to effective neural computing rate of 40M CPS[5].

Let $\Lambda = \{\lambda_1(i), \cdots, \lambda_m(i)\} \in R^m$ be a vector containing m measurements representing the process states at time index i, $\Gamma = \{\gamma_1(i), \ldots, \gamma_n(i)\} \in R^n$ be the outputs which response the inputs. The RICOH-2000 realized the map $\Re$: $\Lambda \mapsto \Gamma$ $(m = 7$ and $n = 1)$. Six kinds of objects were used in this paper.

2.2 Moment Invirant

The moment invirant computation have been applied into recognition of shapes successfully[12]. We will give the result in this paper. Details is shown in reference[12]. The 16×16 two-value compressed image were used to calculated the moment inviants Q_i $(i=1, \ldots, 7)$.

$$Q_1 = \mu_{20} + \mu_{02} \qquad (1)$$
$$Q_2 = (\mu_{20} - \mu_{02})^2 + 4\mu_{11}^2 \qquad (2)$$
$$Q_3 = (\mu_{30} - 3\mu_{12})^2 + (3\mu_{21} - \mu_{03})^2 \qquad (3)$$
$$Q_4 = (\mu_{30} + \mu_{21})^2 + (\mu_{21} + \mu_{03})^2 \qquad (4)$$
$$Q_5 = (\mu_{30} - 3\mu_{12})(\mu_{30} + \mu_{12})[(\mu_{30} + \mu_{12})^2 - 3(\mu_{21} + \mu_{03})^2] + (3\mu_{21} - \mu_{03})(\mu_{21} + \mu_{03}) \cdot [3(\mu_{30} + \mu_{12})^2 - (\mu_{21} + \mu_{03})^2] \qquad (5)$$
$$Q_6 = (\mu_{20} - \mu_{02})[(\mu_{30} + \mu_{12})^2 - 3(\mu_{21} + \mu_{03})^2] \qquad (6)$$

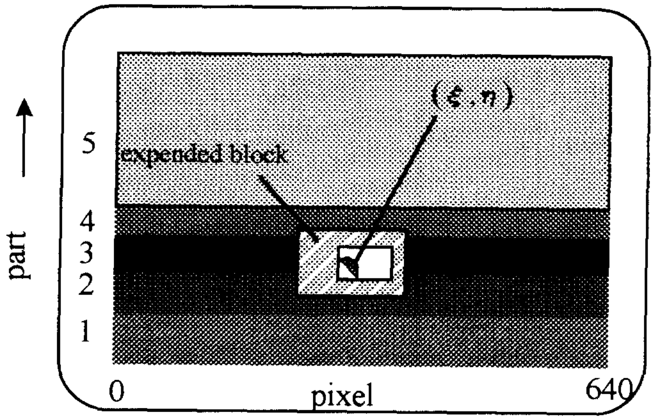

Figure 3: Imaging Information Divided

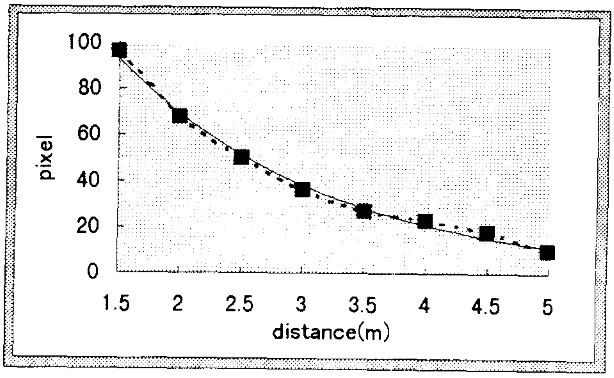

Figure 4: The relationship of distance and pixel

$$+4\mu_{11}(\mu_{30}+\mu_{12})(\mu_{21}+\mu_{03})$$

$$Q_7 = (3\mu_{21}-\mu_{03})(\mu_{30}+\mu_{12})[(\mu_{30}+\mu_{12})^2 - \quad (7)$$

$$3(\mu_{21}+\mu_{03})^2] + (3\mu_{12}-\mu_{30})(\mu_{21}+\mu_{03})$$

$$\cdot[3(\mu_{30}+\mu_{12})^2 - (\mu_{21}+\mu_{03})^2] \quad (8)$$

where

$$M_{pq} = \sum_{x=1}^{16}\sum_{y=1}^{16} x^p y^q P_{xy} \quad (9)$$

$$\mu_{pq} = \sum_{x=1}^{16}\sum_{y=1}^{16} (x-\bar{x})^p (y-\bar{y})^q P_{xy} \quad (10)$$

in 9 and 10, P_{ij}=0 or 1, $\bar{x}=M_{10}/M_{00}$ and $\bar{y}=M_{01}/M_{00}$.

3. CONTROL PROCESS OF THE SYSTEM

The information of NMV CCD camera is divided into 256 grades. There are 640×400 pixels in the available viewing range of the camera. Five parts included 43 blocks (see Table 1 and Table 2) were established on the based of the regular pattern between real distance and pixels distance shown in Figure 3 and Figure 4) in the 640×400 pixels, where Δx_b is searching pixel interval in x direction, Δy_b is searching pixel interval in y direction. The objects were recognized according to their colors and shapes. The color was distinguished by means of graded-stage way ($r_l \leq r/s \leq r_h, g_l \leq g/s \leq g_h, b_l \leq b/s \leq b_h, s = r+g+b$). r, g, b are called image units. p_l and p_h ($p = r, g, b$) are the parameters. The parameters in common circumstance are shown in Table 3. If the image units of a object is caught, the center of gravity (ξ, η) of the object caught in the concerning block will be calculated and an expending block as shown in Table 4 which center is (ξ, η) will be formed. Therefore, compressed image for recognition using moment invirant computation are finished.

The CCD camera is in the middle of the head and has total 60° viewing range. During the driving, firstly, the NMV search the designated object from part 1 to part 5 block by block, and from left to right in each part. Secondly, if definite color is found, the searching action will be paused to form a expending block which center is (ξ, η)shown in Figure 3. Finally, compressed image is obtained from the expending block which has 16×16 pixels. The moment invirants which are the inputs of the neurocomputer were computed on the basis of the two-value 16×16 pixel units. If the shape is identified as the designated object by the neurocomputer, the mobile vehicle will use the image information to build a near optimal path to tracking the object by fuzzy controller, else the NMV will continue to search paused action. The available viewing range of the CCD camera was expended to 140° with aid of its rotation in the horizontal and vertical directions. The NMV will utilize the guide map(see Figure 4) to make a round way to avoid obstacle and track designated object.

Remark: The searching blocks in part 5 is larger than others because the searching block were decided according to the relationship between real distance and pixels distance. If a object is located in part 5, most possible things is a object with some height over the road, for instance, a landmark etc.. In the present stage, we assumed the designated object were not concealed by any obstacle.

4. EXPERIMENTS AND DISSCUSIONS

The NMV consists of a microcomputer NEC PC9821Ap, some I/O boards including a video interface SUPER CVI. The NMV's two rear wheels can rotate forwards and backwards about the axle shaft and are driven by a 24V DC motor using cross helical gears. The NMV's front wheels are driven by a 24V DC stepping motor for motion to the left or right, with transmission being via gear wheels. Two 6V DC motors are employed to rotate the CCD camera in the horizontal and vertical directions. The location of the front wheels and camera are detected by three encoders.

Figure 5 give a trajectory including an obstacle, the initialized statement is (0.5, 1.0, 0°), the obstacle S is located in (3.5, 1.5) and object in (6, 1.75, 0°). The dash line is

Table 1: Distribution of block units

part	block width	block height	Δx_b	Δy_b
1	128	100	4	3
2	80	50	3	2
3	64	50	2	2
4	32	50	1	1
5	128	150	4	3

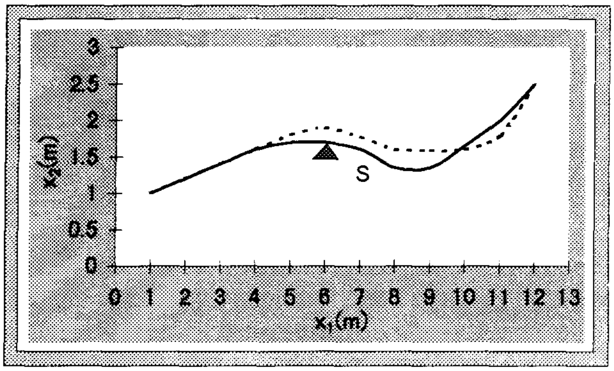

Figure 5: Driving path of the mobile vehicle

human knowledge and dark line is the NMV's way. The smooth motion was accomplished by installed NEC PC9801 series interruption control. The interruption inputs, IT0 and IT1 in i5822, were used because of the structure of the mobile vehicle. The sampling time was 20ms. In the driving process, the NMV adjusted the control inputs v and ϕ to decrease the position errors, and realize near optimal path. The errors resulted from the following facts: (1) It is an approximate method to decide the location of a object by using the centers of gravity of the image data of the object which were caught by a CCD camera, (2) the driving map is experimental one, (3) there were some errors between the membership functions used in the fuzzy controller and the real one, (4) the mechanical and electrical inertia etc..

5. CONCLUSIONS

The technologies of both neurocomputer and Neumann-type computer are applied into the control system, and make the mobile vehicle be capable of tracking designated objects and avoiding obstacles smoothly and successfully. The precision is depended on compressed image. Moment Invariants computation was used to recognized the shape of objects. This image processing strategy can also be adaptable to other case for example navigating transport in plants, parking problem by the aid of landmarks, a curve way in farm field etc.[13]. Our research will focus on recognizing more than one objects and obstacles and applied the developed technique into a electrical car which maximum speed can up to 60 km/hour.

Table 2: Height of block units

part	block start y_1	block end y_2	$\Delta y_p = y_1 - y_2$
1	300	400	100
2	250	300	50
3	200	250	50
4	150	200	50
5	1	150	150

Table 3: Parameters of pixel units

color	r_l/s	r_h/s	g_l/s	g_h/s	b_l/s	b_h/s
red	0.41	0.56	0.20	0.30	0.22	0.31
white	0.28	0.32	0.33	0.40	0.28	0.34

Table 4: Compressed Image

pixels	x-pixels	y-pixels	Δx	Δy
16×16	16×3	16×4	2	4

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