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INTELLIGENT CONTROL OF VISUAL TRACKING SYSTEM BASED ON ARTIFICIAL BRAIN

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Abstract

This paper presents a new information processing machine which is called artificial brain(ABrain) and considers the structure of artificial neural networks constructed in a RICOH neurocomputer RN-2000 in the ABrain, in order to track given trajectories which are produced in a microcomputer or a moving light by hand in a recognition and tracking system.

1 Introduction

We have already developed the recognition and tracking system of moving objects[1]-[4]. The system consists of one CCD video camera, two DC motors in horizontal and vertical axes with encoders, pluse width modulation(PWM) driving unit, 16 bit NEC PC-9801 microcomputer, and their interfaces. The recognition and tracking system is able to recognize the pattern and size of a moving object and is able to track the object within a certain range of errors by learning control laws.

In the meanwhile the RICOH neurocomputer RN-2000 has been recently devised for research and development[5],[6]. The RICOH neurocomputer RN-2000 consists of seven RN-200 digital neural network VLSI chips, where sixteen neurons and totally 256 synapeses are integrated in a 13.73×13.73 mm^2 VLSI chips, fabricated by RICOH 0.8 μ CMOS technology. This chip can perform 5.12 giga pluse operations per second. It corresponds to effective neural computing rate of 40M CPS or CUPS. Utilizing the neurocomputer RN-2000, we have developed a new identification technique in order to model linear and nonlinear dynamical systems to be controlled[7],[8].

Utilizing the results obtained from the identification experiments using the neurocomputer[7],[8], we devised a new recognition and tracking system of moving objects[9] called a neurocomputer control system for recognition and tracking of moving objects. The new system consists of the 32 bit microcomputer NEC PC-9801βA, the neurocomputer RN-2000, and the other remaining hardware developed in the former one stated above. The main differences from the former system are:
(1) The 16 bit microcomputer NEC PC-9801 is replaced by the 32 bit microcomputer NEC PC-9801βA in order to use the software(Nadeshiko and Yamato) for operating the neurocomputer on the Microsoft Windows.
(2) In the former one the control laws were produced from the neural network systems programmed in the 16 bit NEC PC-9801 microcomputer so that on-line learning was not possible[8].
(3)The neurocomputer RN-2000(S specification) is newly added to the system. Therefore on-line learning of control laws and patterns become possible because the learning by the neurocomputer RN-2000 is very fast.

On February 2 in 1995, we succeeded in the experiments in order to track both the desired values(sinusoidal, circular, and elliptical movements) of encorders in X and Y axes and a light from electric lamp moved by hand using the new neurocomputer control system for recognition and tracking stated above in our laboratory. We obtained the first experimental results on the control studies for the tracking using the neurocomputer control system. We gave a brief introduction of both the neurocomputer control system and the results obtained from the control studies[10],[11].

Based on the results obtained from the preceding studies, we propose a new information processing machine which is called artificial brain(ABrain) and considers the structure of artificial neural networks constructed in a RICOH neurocomputer RN-2000 in the primitive ABrain[12], in order to track given trajectories which are produced in a microcomputer or a moving light by hand in a recognition and tracking system.

The ABrain consists of
1. various sensors which receive different information.
2. a self-organizing circuit which organizes the structure of artificial neural networks and numbers of both neurons and neurocomputers in the ABrain.
3. several parallel neurocomputers and Von Neumann-type computer.
4. a circuit for generating internal performance criterion in order to optimize the total neural network systems in-

cluding the parallel neurocomputers and a Von Neumann-type microcomuter.

The configulation of an ABrain for robots is shown in Fig.1. This configulation has a general structure and we forcus our attention on the investigation of the structure of the artificial neural network used for generating control signals in the recognition and tracking system.

Namely, we discuss which structure of the neural networks in the primitive ABrain, which concists of a Von-Neumann computer, one neurocomputer RN-2000, their interface, and the recognition and tracking system shown in Fig.2, is best from a point of view of control performance. By changing the structure of the neural network, more precisely, the number of neurons in both input and output layers, the control performances of tracking both a predetermined trajectory in Von-Neumann computer and a moving object(light) produced by hand are compared in order to decide the best structure of the neural network in the ABrain. We obtained the guideline of designing more sophicicated ABrain than the primitive ABrain by considering the structure of the neural network for control in it.

2 Neural Network in Artificial Brain

One of the neurocomputer control system in the ABrain of the recognition and tracking system of a moving object is shown in Fig.2 and Fig.3. The elaborate descriptions of the system have been given in [1]-[4]. The configuration shown in Fig.2 is different from the former system[1]-[4] in the point that the neurocomputer RN-2000 is newly connected to the microcomputer NEC PC-9801βA. The general view shown in Fig.3 is the same as before.

At the first stage, in the experiments of the neurocomputer control system in the ABrain simple control laws are desirable for the purpose of checking the control performance of the recognition and tracking system by changing the structure of the neural network. To this end, we used a simple propotional control law and the training data discussed below.

2.1 Neural Network Structure

The one of the structure of the neural network used in the neurocomputer RN-2000 in the ABrain is shown in Fig.4. The number of neurons in the input layer is 4, the numbers of neurons in the first and second intermediate layers are 16 and 16, respectively, and the number of neurons in the output layer is 1. The inputs to the neural network are the errors(deviations) between the center of the CCD camera and the desired values of the encorders in X and Y axes or the highest intensity of a moving light from electric lamp by hand as shown in Fig.5. The teaching signals are the duty ratios of the PWM. The reason why we use 4 neurons in the input layer is the followings.
(1)As the inputs to the neurocomputer RN-2000, the two digits 0(equals 0) and 127(equals 1) are permitted due to the hardware specification.
(2) The maximum error is 10 in the experiments and this value is transformed into the binary number of 4 bits, namely, 4 neurons. On the other hand, the digits ranged from 0 to 127 can be used as the output from the neurocomputer so that one neuron is employed in the output layer. We changed the structure of the neural network in order to investigate the control performance of tracking both a predetermined trajectory and a moving light by hand.

2.2 Learning Data

As the learning or training data for the neural network shown in Fig.4 in order to track a moving object, we use the data produced from a propotional control indicted by the dotted line shown in Fig.6. Both the real training data and the corresponding data used for the neural network in the neurocomputer RN-2000 in the ABrain are shown in Table 1. In this table the input data to the neurons are deviations or errors of e_x and e_y which are equal to 1, 2, ..., 10 and the teaching data are the duty ratios of the DC motors in both horizontal and vertical axes which are equal to 0.1, 0.2, ..., 1.0. The input data are transformed into 4 bit digits by using bit tranformation technique. The teaching signals are normalized such that the maxmum value 1.0 and the minimum values 0 in Table 1 correspond to 127 and 0, respectively.

As one of criterions for the learning of the neural network, we introduce the average error criterion J given by

$$J = \sum_{i=1}^{N} |O_i - T_i|/N, N = 11(patterns), \quad (1)$$

where O_i is the output from the neural network and T_i is the teaching signal. We use the neural network trained until the value of this criterion becomes less than 2.0. The results, which were obtained from the forward processing by the neural network trained, are shown in Table 1 using the same input data where the iteration number per one pattern is 2378 for the learning, total learning time is 1 minute and 7 seconds, and J=1.64. It is seen from Table 1 that the data obtained from the neural network learned are different from the teachnig signals due to the hardware specification, namely, the digital neural network VLSI with on-chip learning using stochastic pulse encording. However, the neural network learned works well for the tracking problems as shown below.

It should be noted that in the experiments for the tracking the control laws indicated by the solid lines in Fig.6 are used in order to compensate the nonlinear characteristics of two DC motors in the recognition and tracking system for improving the control performance. This will be discussed in the next Section.

3 Tracking Experiments

In the experiments for tracking, we used various structures of the neural networks. One of the structures was shown in Fig. 3 in the nerocomputer RN-2000 in the ABrain, which is constracted by the software called Nadeshiko. The configulation of the neurocontroller using the neural network is illustrated in Fig.7. The duty ratios for two DC motors in X(horizontal) and Y(vertical) axes are produced from one neural network sequentially. In other words, at first, the error between the desired value in X axis(denoted $X_{desired}$ in Fig.7) and the value of encoder of DC motor in X axis(denoted X motor in Fig.7) is processed by the neural network in order to get the duty ratio of X motor. Secondly the same processing is performed in order to get the duty ratio of Y motor.

In the whole experiments, the sampling time employed is 100 ms by taking account of hardware specifications in the various parts. The procedures stated above[1]-[4] are repeated at each sampling time for the tracking experiments. The results are given below.

3.1 Tracking for Desired Values

We performed the experiments for tracking the desired values(sinusoidal, circular, and elliptical movements) of the encorders in X and Y axes using the outputs from the neural network.

At first the neural network shown in Fig.4 is set in the neurocomputer RN-2000 in the ABrain and is learned or trained as stated above by using the software Nadeshiko. Thereafter the duty ratios for the X and Y motors are produced from the neural network by using the softwares Yamato and the control programs written by C language developed in our laboratory. The compensated propotional control laws were used in the programs to produce the duty ratios as indicated by the solid lines in Fig.6.

For the reason of space, we show only the results for tracking the desired values of the encorders obtained from the elliptical movement in two dimensional space given by

$$X_{desired} = 40sin(5\pi t/(180 \times 100)), \quad (2)$$

$$Y_{desired} = 30cos(5\pi t/(180 \times 100)), \quad (3)$$

where the unit of time t is ms.

The locus of X and Y coordinates in the elliptical movement is illustated from 1 second to 25 seconds by the solid line in Fig.8(a) where the the dotted line is the desired value or trajectory. The values of the encoders in X and Y axes are shown in Fig.8(b), where the dotted lines are desired values.

3.2 Tracking for a Moving Light by Hand

The procedure for tracking a moving object is shown in Table 1 in [4] and the elaborate explanations are also given. Therefore, we show briefly how to detect the position with the highest intensity of the light from a lamp moved by hand and then explain how to track it. The detection procedures are as follows.

(a) Read 6 bits image data of the light with 15×12=180 pixels, which is moved by hand, from CCD video camera.
(b) Write the image data into the memory in NEC PC-9801βA.
(c) Detect the position with the highest intensity of the moving light.

The tracking procedures are as follows.

(d) Calculate the duty ratios using the neural network, which has been trained beforehand in the neurocomputer RN-2000, for both X and Y motors sequentially.
(e) Move the system in oder to coincide the center of the CCD video camera with the position of the hightest intensity using the duty ratios calculated above.

We show one of results for tracking a moving light by hand in Fig.9 where the distance between the moving light and the CCD video camera in the system was approximately 60 cm. In this figure the loci from 8 seconds to 25 seconds are illustrated. The locus of X and Y coordinates in tracking the highest intensity of the moving light is shown by the solid line in Fig.9(a) where the dotted line is the locus of the highest intesity. The corresponding values of the encoders in X and Y axes are shown in Fig.9(b).

The results obtained from tracking both the desired values and a moving light by hand are quite satisfactory. The followings are considered as the reasons.

⋆ The neural network structure constructed in the neurocomputer RN-2000 is simple as shown in Fig.4.
⋆ The control law used for training the neural network is a simple propotional law as shown in Fig.6.
⋆ The control law used for calcurating the duty ratios for both X and Y motors is simply compensated as shown in Fig.6.

The results obtained using the simple propotional control law as indicated by the solid line in Fig.6 were also satisfactory although they are not shown in this paper. The other structure of the neural network in the ABrain were also investigated and were not illustrated in this paper for the reason of space.

4 Summary

In this paper we presented a new information processing machine called ABrain for tracking a moving object using the RICOH neurocomputer RN-2000. The resutlts obtained from the tracking experiments revealed that the neural network of simple structure developed in the neurocomputer RN-2000 in the ABrain have desirable features such that they are able to track both the desired values and the moving light by hand satisfactory by using a few training data. In other words, the information processing machine proposed in this paper for tracking a object has artificial knowledge or brain.

The other experimental data obtained by changing both the structure and the training data for the neural network could not be shown in this paper for reason of space. They are quite interesting and will be presented in a forthcomming paper. We are now developing the applications of our hardware and software obtained from the experiments for various engineering fields.

Acknowledgements

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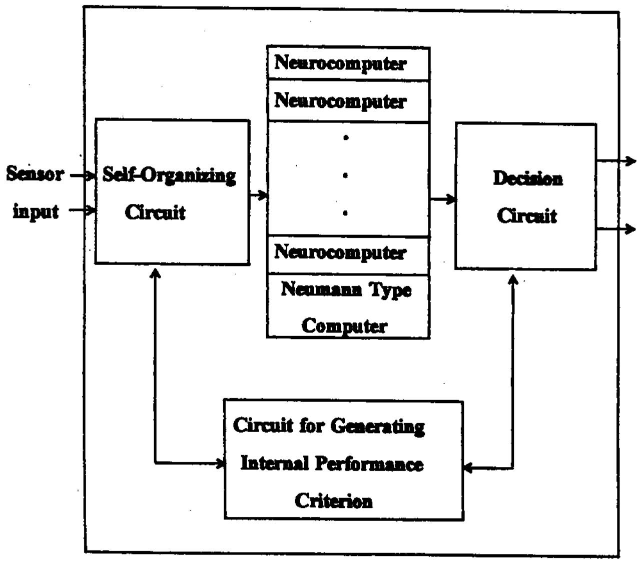


Fig.1 Configulation of Artificial Brain

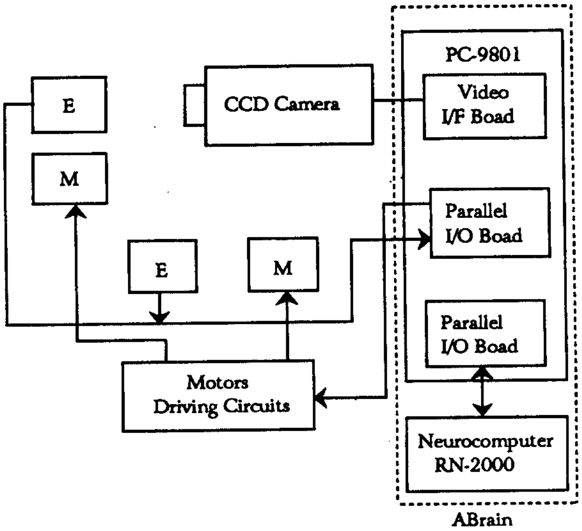


Fig. 2 Recognition and Tracking System with ABrain

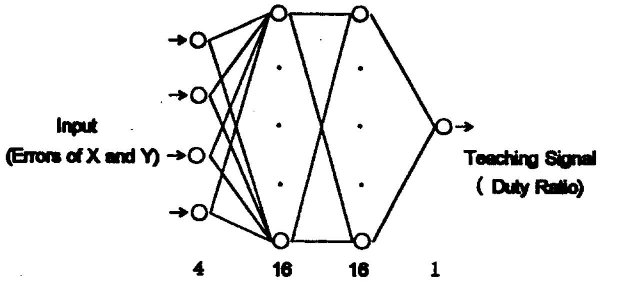


Fig.4 Structure of Neural Network in RN-2000

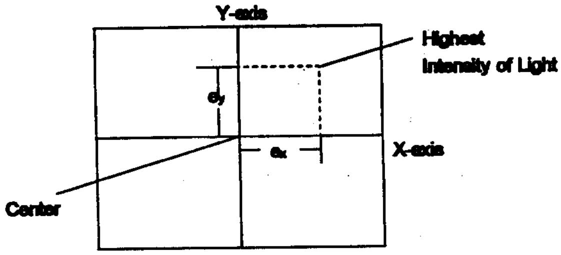


Fig.5 Errors

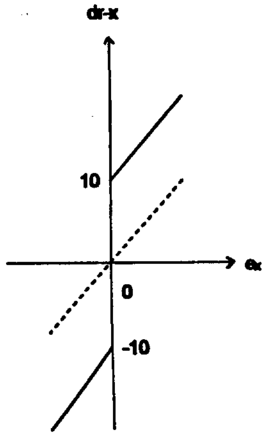


Fig.6a Nonlinear Propotional Control(X_{axis})

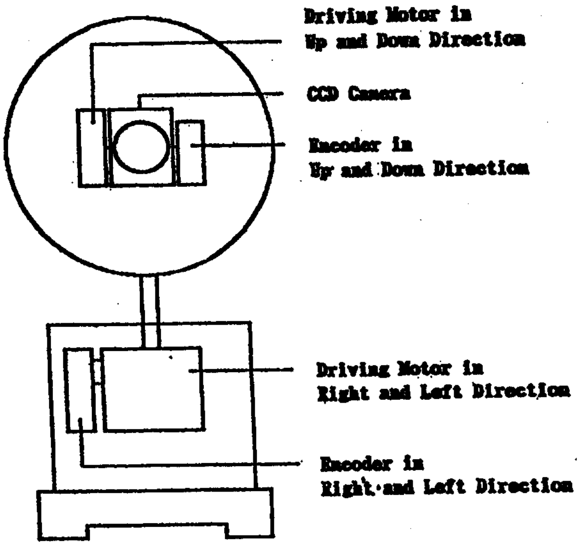


Fig.3 General View of Recognition and Tracking System

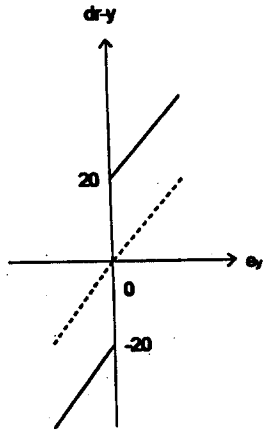


Fig.6b Nonlinear Propotional Control(Y_{axis})

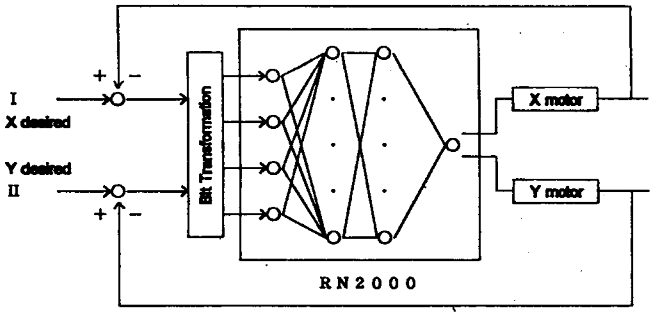
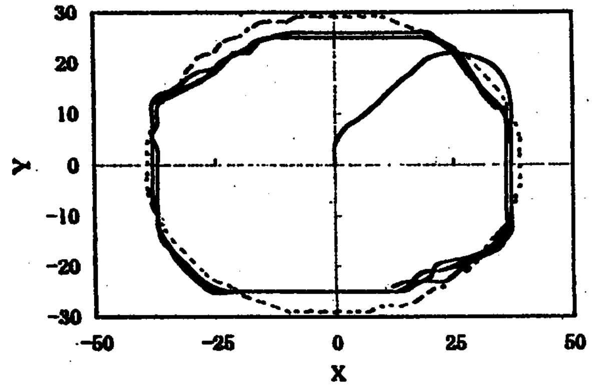


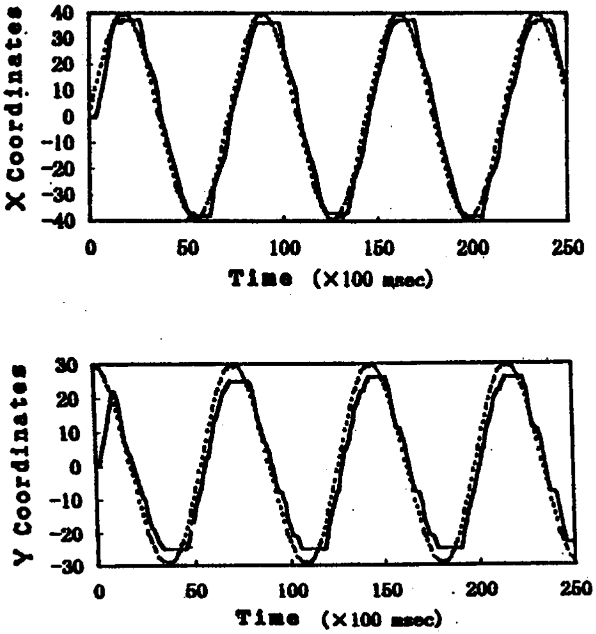
Fig.7 Configulation of Neural Network.
(I and II show the order of processing)

Errors(Deviations)		Teaching signals		Learned results
0	0000	0	0	0
1	0001	10	13	15
2	0010	20	25	27
3	0011	30	38	31
4	0100	40	51	53
5	0101	50	64	63
6	0110	60	76	72
7	0111	70	89	85
8	1000	80	102	108
9	1001	90	114	112
10	1010	100	127	120

Table 1 Data for Training

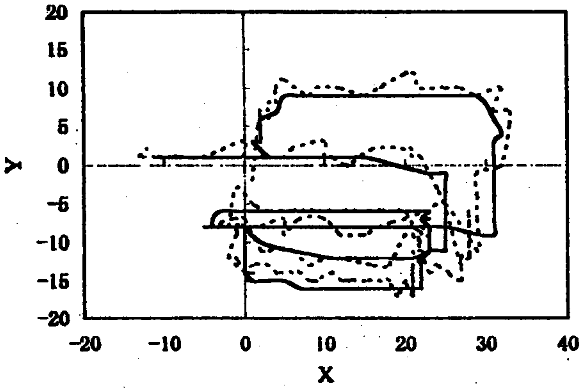


(a) Loci of desired value and X and Y coordinates.

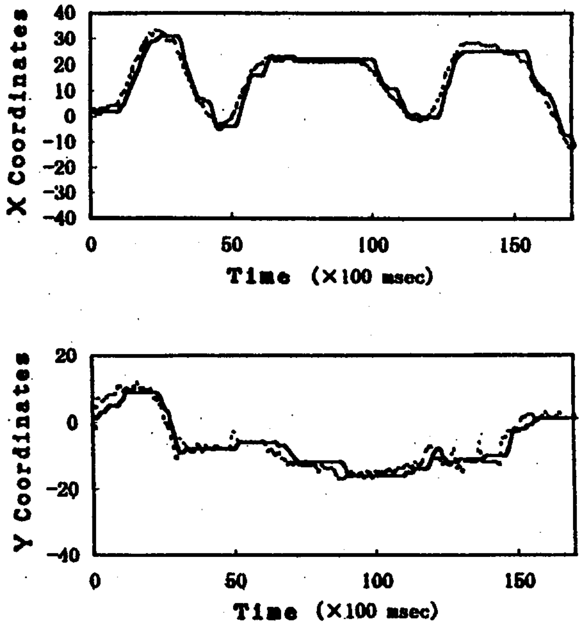


(b) Values of encoders in X and Y axes.

Fig.8 Results of Tracking Given Trajectory(1-25 sec)



(a) Loci of light and X and Y coordinates.



(b) Values of encoders in X and Y axes.

Fig.9 Results of Tracking A Moving Light(8-25 sec)