# STUDY ON APPLICATION OF NEURO-COMPUTER TO NONLINEAR FACTORS FOR TRAVEL OF AGRICULTURAL CRAWLER VEHICLES

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## ABSTRUCT

In this study, the NEURAL NETWORK (hereinafter referred to as NN) was applied to control of the nonlinear factors for turning movement of the crawler vehicle and experiment was carried out using a small model of crawler vehicle in order to inspect an application of NN. Furthermore, CHAOS NEURAL NETWORK (hereinafter referred to as CNN) was also applied to this control so as to compare with conventional NN. CNN is especially effective for plane in many variables with local minimum which conventional NN is apt to fall into, and it is relatively useful to nonlinear factors.

Experiment of turning on the slope of crawler vehicle was performed in order to estimate an adaptability of nonlinear problems by NN and CNN. The inclination angles of the road surface which the vehicles travel on, were respectively 4deg, 8deg, 12deg. These field conditions were selected by the object for changing nonlinear magnitude in turning phenomenon of vehicle. Learning of NN and CNN was carried out by referring to positioning data obtained from measurement at every 15deg in turning. After learning, the sampling data at every 15deg were interpolated based on the constructed learning system of NN and CNN. Learning and simulation programs of NN and CNN were made by C language ("Association of research for algorithm of calculating machine (1992)").

As a result, conventional NN and CNN were available for interpolation of sam-

pling data. Moreover, when nonlinear intensity is not so large under the field condition of small slope, interpolation performance of CNN was a little not so better than NN. However, when nonlinear intensity is large under the field condition of large slope, interpolation performance of CNN was relatively better than NN.

Key Word: Non Linear Factor, Neural Network, Chaos Neural Network,
Agriculture Crawler Vehicle

## INTRODUCTION

In recent years in Japan, industrial field has been rapidly developed. On the other hand, the field of agriculture has serious problems of decreasing the population mainly engaged in own farming and increasing the rate of the advanced age. These problems are caused by phenomenon of decreasing child. Introduction of the automatic technology seems to be an effective solution against these problems. This technology is expected saving labor, low-cost products and more safety "Yukimoto (1990)". Crawler system has been adopted for agriculture and construction vehicles due to low ground contact pressure in the world. On the other hand, crawler vehicles have more nonlinear factors than 4-wheel vehicles in travel. In general, to control traveling of the crawler vehicles, motion equations with nonlinear factors must be introduced. However, in practice, nonlinear factors caused by the ground conditions could not be identified easily. In this study, NN and CNN, which have effects for nonlinear factors, were applied to traveling control of the crawler vehicle. The availability of autonomous running system equipped with both NN and CNN for the crawler vehicle was inspected using a small model vehicle.

## COMPARISON BETWEEN CONVENTIONAL COMPUTER AND NEURO COMPUTER

The present Neuman-model computers are used widely. This type of computer needs analytical equations, algorism and data. It can calculate answers effectively and accurately for relative simple problems. However, it is very difficult to solve complex nonlinear problems.

NN imitates neurotic systems of brains by technical method. In other words, NN is constructed by many neuron (cell) and connect cable (synapse). The information process is performed by exchanging each signal in whole network. NN does not need equations and complex algorisms to solve the problems. That is the reason NN enables to solve the problems that the conventional computer processes inefficiently. The process is as follows. At first, sample data are inputted into the network proposed by "Imai (1990) ". The next process is that network is constructed in order to be obtained output data corresponding to target data. Finally, inputting arbitrary data is processed by learned network.

The most important factor for autonomous running system is recognition of position, direction and velocity of vehicles "Noguchi (1993,1994)". The method of positioning is to obtain real time data measured by external sensor like a GPS (Global Positioning System). But this system is too expensive now. We can control the vehicles with interval data if the characteristics of the vehicles for controlling on any condition of ground were obtained. As a result, we might reduce the number of data for positioning with this method by "Inoue et al. (1995,1996)".

## CHAOS NEURAL NETWORK (CNN)

Brain took the form of a high quality expert system concerning to analog-to-digital. To simulate the brain is needed to understand the characteristics of analog and digital. NN with Back Propagation rule (hereinafter referred to as BP) has a dynamics that reduce the sum of square of output error. This dynamics might be settled with local minimum. Characteristic of swing under the restriction of mutual action of CNN dynamics is available for avoiding this local minimum in order to get global minimum. From this point of view, Dr. Aihara proposed chaos neuron model with chaos dynamics and Chaos Neural (1993).

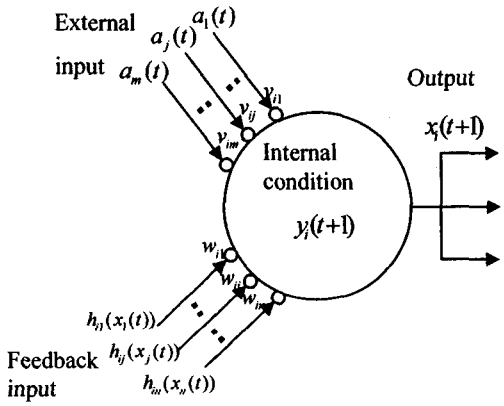


Fig.1 Input/output of chaos neural model

In generally, model of chaos neuron is needed to recognize both external $\alpha_j(t)$

input of the network and feedback input $h_{ij}(x_j(t))$ from other neuron of the network. Model of chaos neuron is shown in Fig.1.

Dynamics of chaos neuron in Fig.1 is shown as following Eq. (1).

$$x_i(t+1) = f_i\Big(\sum_{j=1}^{m} v_{ij} \sum_{d=0}^{t} k_e^d a_j(t-d) + \sum_{j=1}^{n} k_f^d h_{ij}\big(x_j(t-d)\big) - \alpha \sum_{d=0}^{t} k_r^d g_i\big(x_i(t-d)\big) - \theta_i\Big) \tag{1}$$

$x_i(t+1)$ : output of neuron $i$ at time of $(t+1)$

$f_i$ : the function of output for neuron $i$

$m$ : the total number of external input

$v_{ij}$ : the coefficient of synapse from external input $j$ to neuron $i$

$a(t-d)$ : external output $j$ at time of $(t-d)$

$n$ : the total number of neuron

$w_{ij}$ : the coeffcient of synapse from neuron $j$ to $i$

$h_{ij}$ : the convertible function for propagation of electric potential from neuron $j$ to $i$

$\alpha$ : unresponsive scaling parameter

$g_i$ : the function characterizes responseless neuron $i$

$k_e$ : the timely stabilized for external output

$k_f$ : the timely stabilized for feedback input

$k_r$ : the timely stabilized for responseless

In Eq. (1), if $k_e \to 0$, $k_f \to 0$, $k_r \to 0$, $\alpha \to 0$

$$x_i(t+1) = f_i\left(\sum_{j=1}^{m} v_{ij} a_j(t) + \sum_{j=1}^{n} w_{ij} h_{ij}\big(x_j(t)\big) - \theta_i\right) \tag{2}$$

Analog neuron model that is widely used for NN with BP rule is obtained by Eq. (2). Where, under $k_e = k_f = k_r = \alpha = 0$, CNN equals to conventional NN and further, the CNN can be introduced into the dynamics of NN by inputting these parameters.

Neuro computer is known that it can solve the problems of a complex nonlinear data because all problems are recognized as a pattern. But it is not effective to solve the

complex problems if huge sample data are required. Therefore, we experimented to estimate an effect of NN and CNN in case of turning phenomenon of crawler vehicles.

## OUTLINE OF EXPERIMENT

### 1.Device of experiment

In this experiment, model crawler vehicle was assembled with aluminum alloy. The width of crawler was 30mm, crawler length which contacted on the ground was 280mm, tread was 186mm. Stepping electric motors were used for power units of this model. These stepping motors were controlled by pulse signal from personal computer. The schematic diagram of experiment device is shown in Fig.2. The specifications of the stepping motors are shown in Table 1.

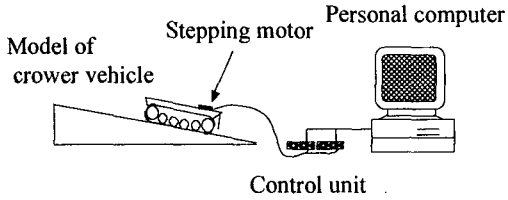


Fig.2. An illustration of experiment

Table1. the specifications of stepping motor

| | |
|---|---|
| Maximum exciting fixed torque N/m(kgcm) | 0.24 (2.4) |
| Rotor of moment of inertia $kg/m^2(gcm^2)$ | $68\times10^{-7}(68)$ |
| Rated electric A／phase | 0.75 |
| Stepping angle | 0.72deg |
| Output of electric | 0.75 |

### 2. Experimental Method and measurement items

This experiment was carried out on November 26~28, 1996 at faculty of agriculture of Kyushu University. In this experiment, the vehicle was set on every 15deg and turn with constant rotation of driving wheel on the slope. The wooden board (coefficient of kinetic friction: 0.485) was used for road surface in this experiment. The inclination angles of the road surface which the vehicle travel on, were respectively 4deg, 8deg, 12deg. The nonlinear factors were excited by the inclination angle. These conditions were adopted to change the turning characteristic and increase nonlinear factors in turning phenomenon of vehicle.

### 3.Learning method of NN

NN simulation was performed by the Neuman-model computer and BP rule was introduced to learning method of the network. It was consisted of one input unit, two

units in two hidden middle layers and one output unit. The experimental data was encoded for this network. In learning process, we removed some data and used the remainder in every condition (inclination angle: 4,8,12deg). The removed data was used for inspecting the network. Turning angle of expectation would be outputted at respective direction of vehicle by using these data.

## 4. Results and Consideration

The results of turning experiment and calculated results by NN and CNN were shown in Fig.3~Fig.5. In these figure, results were indicated by distance from the center on every setting angle line. From these results, as the inclination angle increases, turning angle was inclined to increase. It seems that turning angle was been effect on nonlinear factors by differences of the inclination angle. Considering result, those experiments almost could be followed by NN and CNN. NN and CNN could be made up for the data at 4deg, 8 deg from Fig.3, Fig.4. The errors between experiment results and simulation results were less than 1deg under these inclination angles. When we compared NN to CNN under 12deg inclination angle condition, the making up for the data by CNN could be relatively more accurate than NN. The errors were less than 1deg except the set vehicle direction in range of 240deg~270deg or 340deg~360deg under 12deg.

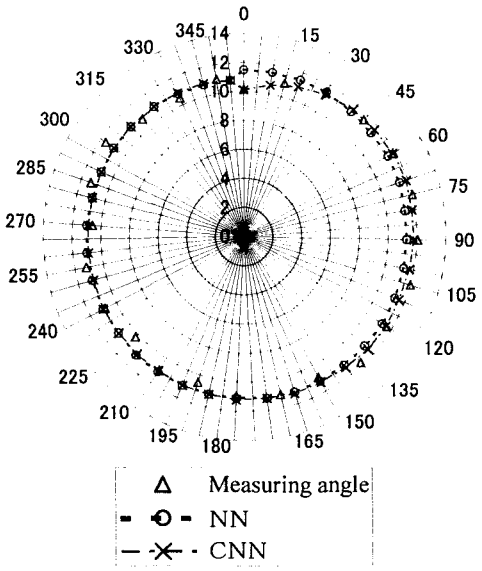


Fig.3. the results of turning experiment and calculated results by NN and CNN :inclination angle 4deg

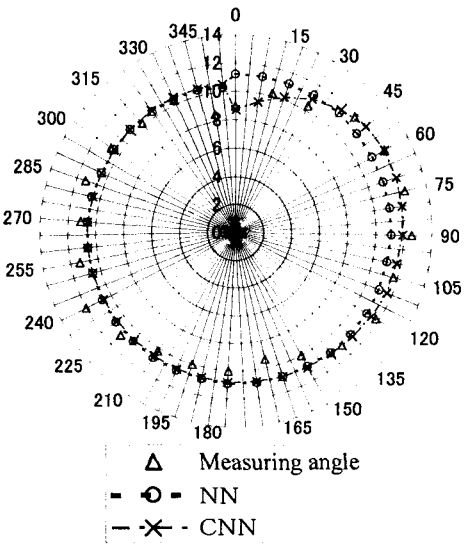


Fig.4. the results of turning experiment and calculated results by NN and CNN :inclination angle 8deg

## CONCLUSIONS

NN and CNN were effective for estimating the characteristics with nonlinear factors. The errors of experiments were almost less than 1deg on condition of inclination angle 4 or 8deg. There were a few errors more than 1deg on condition of inclination angle 12deg. That condition included the largest nonlinear factors. But CNN was relatively better than NN for estimating characteristics with the strong nonlinear conditions. From these results, the efficiency of making up for data of NN and CNN were recognized and it seems that the NN and CNN can use not only model vehicle but also real one.

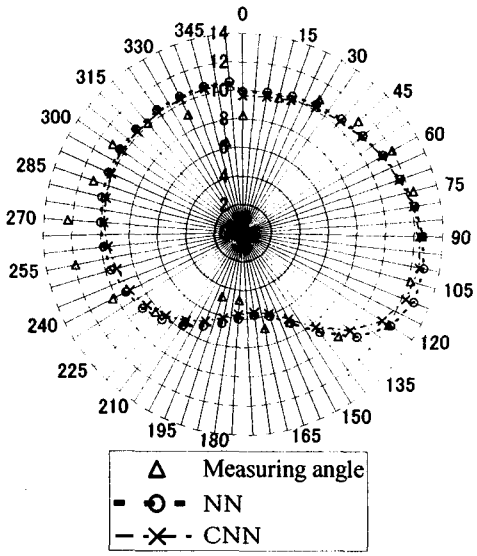


Fig.5. the results of turning experiment and calculated results by NN and CNN :inclination angle 12deg

## REFERENCES


1) Imai,K., 1990. Neural Network -collection-. Kyoritsu Publishing Company
2) Noguchi,S. et al., 1993. Optimal control of agricultural vehicle by Neural Network (Part 1). Journal of JSAM. Vol.55, No 2:83-92
3) Noguchi,S. et al., 1994. Optimal control of agricultural vehicle by Neural Network (Part 2). Journal of JSAM, Vol.56, No 2: 83-92
4) Yukimoto,O., 1990. Autonomous vehicle (1). Agriculture and horticulture, Vol.65, No1:143-148
5) Yukimoto,O., 1990. Autonomous vehicle (2). Agriculture and horticulture, Vol.65, No1:271-274
6) Aihara,K., 1993. Neuro, fuzzy and chaos. Ohm Publish Company: 187-199
7) Association of research for algorithm of calculating machine 1992. Practical neuro computing by C language, Russel Publishing Company
8) Inoue,E. et al., 1995. Study on the autonomous agricultural crower vehicle. Journal of

Agricultural Machinery in Kyushu, Japan, Vol. 44

9) Inoue,E. et al., 1996. Study on the autonomous agricultural crower vehicle. Journal of Agricultural Machinery in Kyushu, Japan, Vol. 45