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AN EXPERIMENTAL STUDY ON THE ACTIVE CONTROL OF THE MOTION OF A MODEL SHIP CABIN

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INTRODUCTION

Desire for the stable and comfortable cabin of the high speed passenger ship is increasing. The study on the shipboard comfort has been mainly concentrated on the motion control of whole hull body. In this study, however, a new control system operated by hydraulic actuators, such as the active suspension system of motor vehicle is proposed. This system installed between cabin and hull structure is a device to control the motion of the cabin which is isolated from the hull structure of the passenger boat.

Because the ship motion characteristics are time-variant, nonlinear, and dynamically uncertain, the linear control theory is not appropriate as main control algorithm. So, a neural network, which can allow the solution of the complex time-variant equations without modelling of the ship dynamics has been applied, and a linear feedback controller has been used in parallel with the feedforward neural network to train the system state as well as linear feedback error.

In order to investigate the effectiveness of the applied control algorithm, the experiment was carried out for the simplified 1 DOF (heave) and 2 DOF (heave and pitch) models. In this experiment, the optimal controller for the proposed system was designed. With this optimal controller, to verify the possibility for the motion control of this system in the sea wave, 3 DOF (heave, pitch, and roll) model experiment using the twin hull model was carried out in the basin.

CONTROL ALGORITHM

As shown in Fig. 1, the system controller is a hybrid type that a Proportionl Integral (PI) feedback controller is used in parallel with the feedforward neural network to train the system. The output of PI controller is used as the error function of neural network and control signal for this system. So, at the beginning of control, the cabin motion is mainly controlled by PI controller. As the controlling and learning is going on, however, the control portion by neural network is gradually increasing, whereas the contribution of PI controller

decreases.
Two kinds of neural network, based on the least-square-error approximation formulation, were applied to the simplified 1 DOF and 2 DOF model experiments. One is linear approximation network with single layer and the other is backpropagation network with multilayer. Fig. 2 shows architectures of these networks.

EXPERIMENT MODEL AND EQUIPMENT

The simplified 1 DOF and 2 DOF models utilized in the model experiment consist of two isolated masses, which are corresponding to cabin and hull respectively. The controlling and the exciting actuators are operated by the oil flow from the proportional valve as shown in Fig. 3. The cabin mass is supported and controlled by the hydraulic actuators installed between cabin and hull, whereas the hull motion was excited by the other actuators. Fig. 4 shows 3 DOF model which consists of the twin hull model (3470×940×400mm) as main hull body, the acrylplate(1000×500×50mm) as cabin, and the device operated by three hydraulic actuators to control the motion of the cabin. The experiment for the twin hull model was performed in the basin (5400×2450×1850mm).

RESULTS AND DISCUSSION

A series of model experiments have been carried out for the simplified 1 DOF and 2 DOF models in order to investigate the effectiveness of the proposed control algorithm. Experimental models have been excited in the condition of Table 1 to generate the hull body motion.

Table 1. Exciting frequency range and interval of model experiment

Model	Range(Hz)	Interval(Hz)	Phase difference*1(deg.)
1 DOF	2.0 ~ 8.0	0.2	
2 DOF	1.0 ~ 5.0	0.2	240

*1 : Phase difference between two exciting actuators

Fig. 5 shows experimental results in three cases of a PID controller alone, a linear approximation network with PI controller, and a back propagation network with PI controller. These results state that linear approximation network is more effective than backpropagation network in the controlling of cabin motion. It comes from the different learning architecture(Fig.2). Although the multilayered backpropagation network can identify the relation of function between input and output layers better than linear approximation network with single layer, it requires much learning time due to the complex architecture. Whereas, linear approximation network has the advantage that the optimal selection of input variables obtained from hull motion in the sea waves can give the required control effect within the desired learning time. So, linear approximation network has been applied to the 3 DOF model experiment as main control algorithm. This experiment was carried out in the basin. Hull body has been excited by the simulated signal of sea wave. From this experiment, it has been found that this developed control system gives the remarkable reduction of cabin motion as shown in Fig. 6.

CONCLUSIONS

The optimal controller for the system proposed in this study was designed from the simplified 1 DOF (heave) and 2 DOF (heave and pitch) model experiments. From 3 DOF (heave, pitch, and roll) model experiment carried out in the basin, it was verified that the control system developed here can be applied to motion control of the passenger cabin in the sea wave.

REFERENCES

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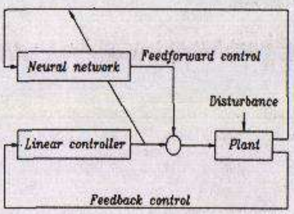

Fig.1 Schematic diagram of control with neural network

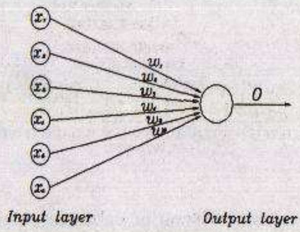

Fig. 2(a) Linear approximation network architecture

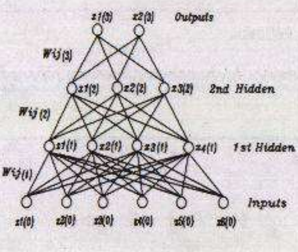

Fig. 2(b) Backpropagation network network architecture

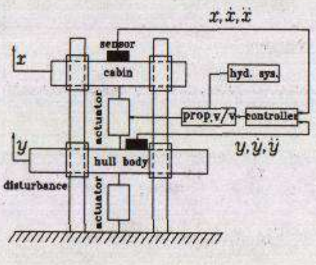

Fig. 3(a) 1-DOF model

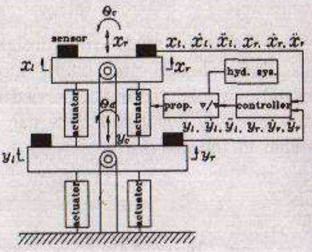

Fig. 3(b) 2-DOF model

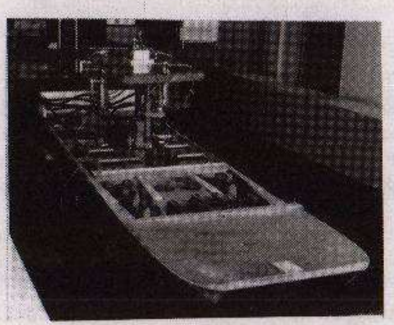

Fig. 4 3-DOF model

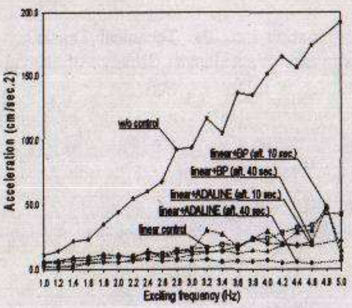

Fig. 5 Comparisons of cabin responses (2-DOF)

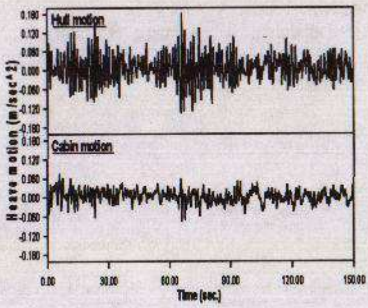

Fig. 6(a) heave motion

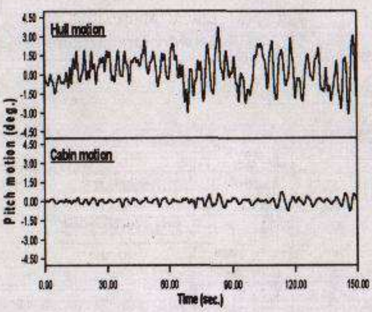

Fig. 6(b) pitch motion

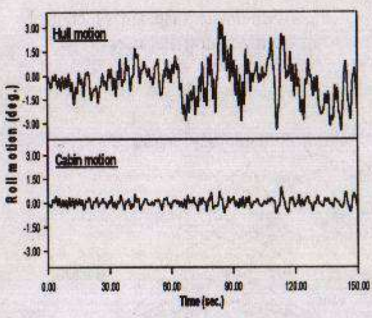

Fig. 6(c) roll motion

Fig. 6 Measured time hitory (3-DOF)