ALL DIRECTION APPROACH AUTOMATIC SHIP BERTHING CONTROLLER USING ANN(ARTIFICAL NEURAL NETWORKS)

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Abstract: This research deals with ANN(Artificial Neural Networks) and its application to automatic ship berthing. Due to the characteristic of a ship 's manoeuvre comparing with other moving objects on land, it has been known that the automatic control for ship's berthing cannot cope with various berthing situations such as various port shape and approaching directions For these reasons, the study on automatic berthing using ANN usually have been carried out based on one port shape and predetermined approaching direction. In this paper, new algorithm with ANN controller was suggested to cope with these problems. Under newly suggested algorithm, the controller can select appropriate weights on the link of neural networks according to various situations, so the ship can maintain stable berthing operation even in different situations. Numerical simulations are carried out with this control system to find its improvement..

Keywords: ship, automatic berthing, ANN(Artificial Neural Networks), controller

1. INTRODUCTION[1]

The study on ship automatic berthing control has been one of the most difficult problems in ship control fields. When we take a look on a ship's berthing operation in certain harbour, the captains and pilots consider a lot of factors such as ship's present speed, heading angle and remain distance to pier and so on to control ship's speed and heading angle with engine revolution and rudder angle. Therefore ship berthing control is called as one of MIMO(multi input and multi output) control. In addition to this, because the ship's inertial is large and its motion around pier is slow, the effect of environments such as wind and current has big impact on the safety of ship's operation in a port.

Many researches have been carried out related to ship automatic berthing problems. H. Yamato[2] performed successfully the numerical simulation of automatic ship berthing control using intelligent control method. He applied feed-back control into ship automatic berthing problem and found successful results. Enviromental effects including wind and current was used in input items to overcome disturbance problems in this control. However it was very time-consuming and tedious works to consider all of wind directions. It was found that more dedicated control method was necessary to solve these problems due to complicated and nonlinear characteristic of ship's motion. Another researches[3,4,5] have been performed to solve ship berthing control using artificial intelligent theory and its related fields..

When a ship approaches a pier and un-berths the same place, sufficient waters area is needed, because its turning characteristic and large inertial moment. Therefore all ships usually have a certain berthing pattern, for example, most of ship have similar route in the same pier or the ship should keep certain heading angle toward berthing point when the ship reaches a limit distance to goal point.

When we take a look on existing researches on ship berthing control, most of ship approach berthing point with pre-determined heading angle or route. The reason why that if the ship approaches opposite direction, the berthing operation will end in failure.

In this paper, new approach is suggested to overcome these problems. Even a ship approaches the berthing point with opposite direction, selective controller will guide the ship to 'safe zone' automatically where the ship will make its berthing operation more easily.

The selective controllers are designed using ANN. Numerical simulations are carried out to verify its effectiveness.

2. SHIP DYNAMIC MOTION

A type of tanker was adopted as a model, of which axes coordinates are depicted in Fig. 1. Many mathematical models of a ship motion have been proposed, module type ship motion (6) is adopted in this paper, because it has been known that it is suitable to express ship motion. In order to formulate the equations of ship motion, two systems are

considered where one is the space axes, $O-x_o, y_o$ and the other is the ship body axes, $G-x, y$, or the moving axes which are fixed in the center of gravity of the ship.

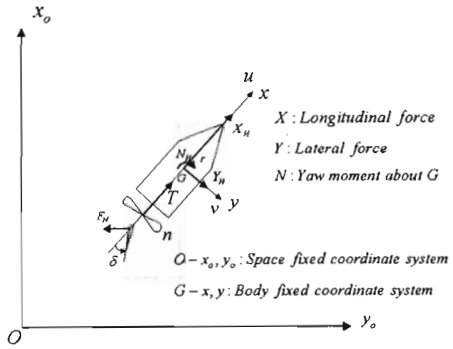

Fig. 1 Coordinate system for ship dynamics

The maneuvering of a ship is usually described in the form of the modular mathematical model, in which the total hydrodynamic forces and angular moment are split into separate parts. Consequently, the ship's dynamical behavior can be described by the equations of motions for three degrees of freedom as follows:

$$\begin{aligned}(m+m_x)\dot{u}-(m+m_y)vr &= X_H+X_P+X_R+X_W\\ (m+m_y)\dot{v}+(m+m_x)ur &= Y_H+Y_R+Y_W\\ (I_{ZZ}+J_{ZZ})\dot{r} &= N_H+N_R+N_W \end{aligned} \quad (1)$$

where;

X_H, Y_H, N_H : Hydrodynamic forces and angular moment acting on a hull

X_R, Y_R, N_R : Hydrodynamic forces and angular moment due to the rudder

X_P : Hydrodynamic forces due to the propeller

X_W, Y_W, N_W : Hydrodynamic forces due to wind

3. SHIP AUTOMATIC BERTHING CONTROL SYSTEM

3.1 Artificial Neural Networks Design.

When a ship is under berthing operation, various factors are considered such as speed and heading and so on for successful ship's berhing. Fig. 2 shows brief ship berthing illumination and items to be considered such as speed and distance. As shown in this figure navigators considers ship's speed, heading angle and remain distance to berthing point and so on as input factor to control ship until a ship arrive final point.

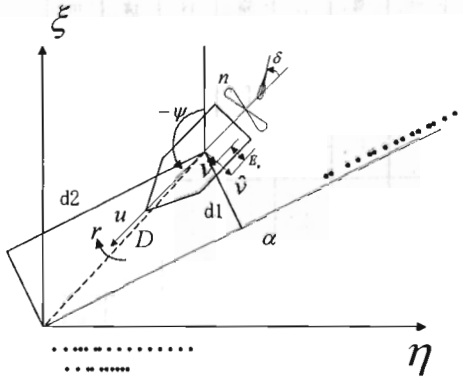

Fig. 2 Berthing concept and its coordinate.

Total 8 of input items are considered as follows; lateral and longitudinal distance (ξ, η),Lateral and longitudinal speed (u.v), turn rate (r), heading angle (ψ), distance to goal point (d_2) and vertical distance with approach line to berthing point(d_1). Two item of output are engine revolution per second (n) and rudder angle(δ). Fig. 3 shows final diagram of neural networks used in this research. Here $W_{k,j}, W_{j,i}$ indicate links coefficients, I_k, a_j, O_i means input layer, hidden layer and output layrer respectively.

The number of neuron in hidden layer was set to 15 that is bigger more than that of input layer. The value of input, output and weight are normalized between 0 and 1. The propagation method is adopted as learning way. Sigmoid nonlinear function also used in neural networks. Matlab 6.0 was used as the programming language for numerical simulation.

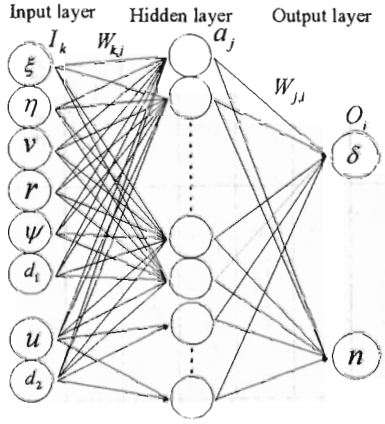

Fig. 3 Construction of berthing controller in ANN

3.2 Structure of ship automatic berthing system

When a ship approaches to pier and is under berthing operation, the ship usually maintains certain heading angle toward final berthing point. It is similar with air plain's landing on the ground. The air plane keep certain angle to ground until its landing. It is to keep the safety of ships and air plains. The mass of ship is larger than other vehicles in a land and it speed is greatly slow under its berthing operation. It requires

spare water space to make it turns and rudder effect extremely down when its speed is under certain limit line.

Therefore when we look at many researches already carried out in last years, general ship approach the berthing point from Area-1. (the reason already have been mentioned in introduction)

In this moment, if a ship approach from area Area-3 or Area-2, it is almost difficult to make safe berthing operation. The reason is that the ship requires sufficient water area to make its turning and keeps heading angle toward berthing point with low speed.

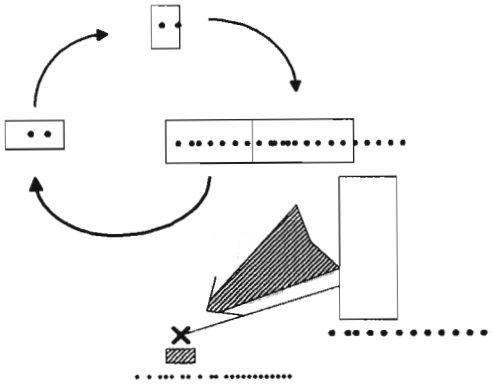

Fig. 4. Berthing concept

In this research, new approach is suggested to overcome these problems. New system is suggested to guide a ship to final berthing point with selective controller even the ship come from multi-direction. The Fig. 5 shows its brief concept.

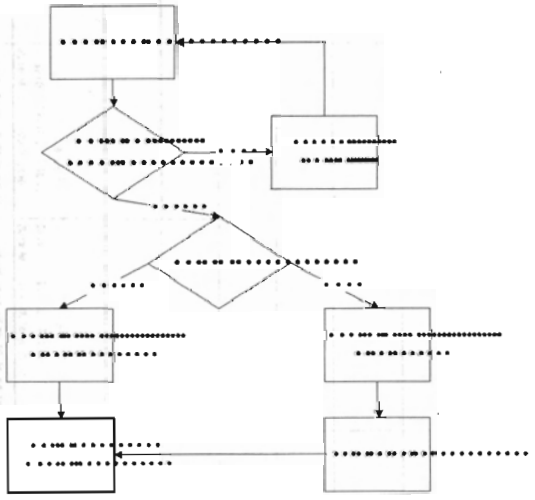

Fig. 5. General flow of berthing control

When a ship approaches goal point from the direction of Area-1, Area-2 and Area-3, the system reasons whether it is possible to make a berthing safely or not. In this reasoning, ship's present conditions such as present location, speed and heading angle are used. If the system estimates that berthing is impossible or it is dangerous, it suggests the ship turning and approaching from new direction. For example, when a ship approaches to Area-3, the possibility of berthing is almost impossible, because the remained distance to final point is too short and the ship have to make turning under slow speed. In this case, the system guides the ship make a turn toward area-B , Area-A and Area –2.

However when a ship approach from the direction of Area-3 like Figure 6, the system determined that safe berthing is impossible or it is dangerous if the ship enforces the berthing work with its present heading and speed.

Then the system guide the ship toward 'safe zone' such as Area-1 or Area-2 using ANN controller.

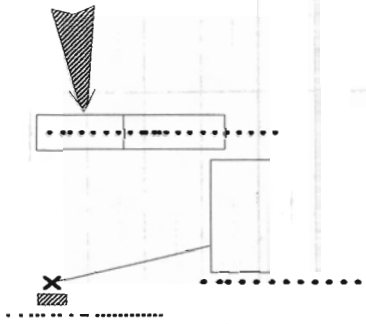

Fig. 6 ,When ship approach from dangerous zone

In other hands, when a ship approaches to Area-1 or Area 2, the assigned controller at this area will guide the ship toward berth point.

4. NUMERICAL SIMULATION

4.1 Automatic control at each zone

The figure 7 shows 4 cases of numerical simulations when a ship advances to berthing point through "Area-3". As shown in this figure, the ship is controlled from Area- 3 to Area-B by the assigned controller of Area-3.

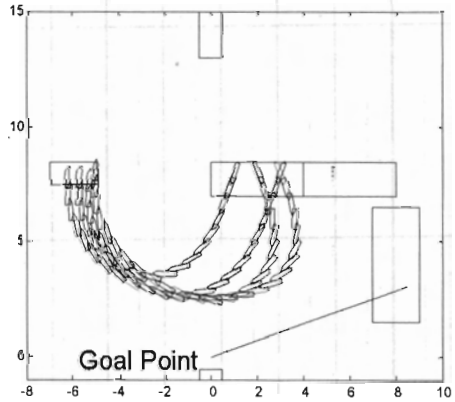

Fig. 7. Simulation Result in Area -3

Fig. 8 shows numerical simulations case when a ship move from Area-A to Area-2 that is safe zone for berthing. Assigned controller to Area-A was used to guide the ship and it is found that all cases made successful shifting of ships.

Fig 9 and Fig 10 show simulation results when the ship approaches the goal point from the direction of Area-1 and Area-2. The system calculated whether it is safe to enforce the berthing using ship's speed and heading angle. If it is acceptable, ANN automatically controlled the ship toward berthing point and made successful berthing operation.

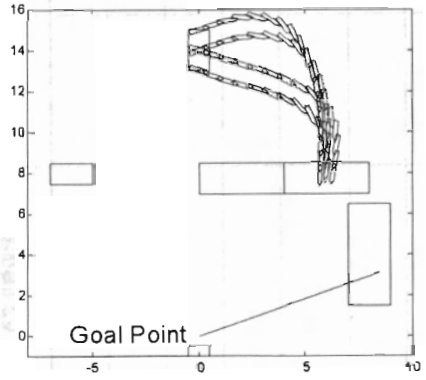

Fig. 8. Simulation Result in Area –A

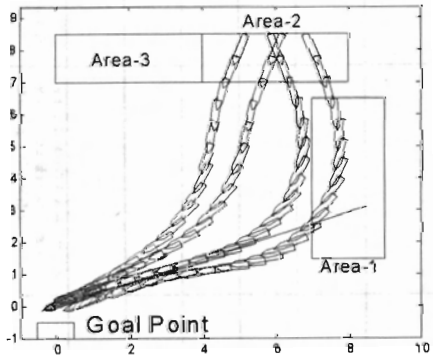

Fig. 9. Simulation Result in Area –2

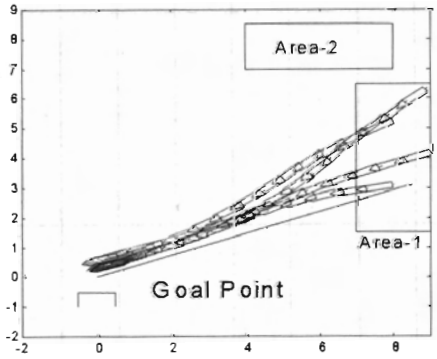

Fig. 10. Simulation Result in Area –1

4.2 Automatic control for all of zone

Numerical simulations also were carried out when a ship approach from non-safe zone. The main purpose is to confirm that the suggested selective controller can guide the ship from dangerous zone to safe zone, Area2 and Area-1.

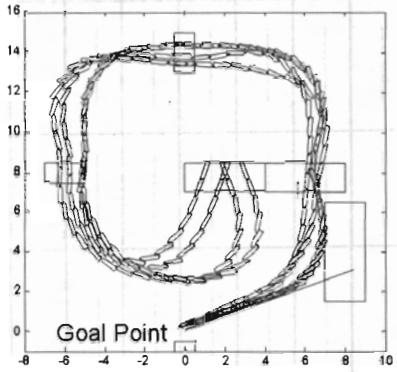

Fig. 11. Simulation Result of all- direction- approach case

The fig. 11 shows simulation results when four ships approach from the direction of Area-3. In this case the control system reasoned that it is dangerous to make a berthing with present heading angle and speed. So the system suggests the ship making a turning and re-approaching. As shown in this figure, the ship was guided to Area –2 where the ship was controlled by ANN automatically. When the ships are passing Area-2, the system reasons whether it is safe to enforce the berthing operation or not. If it is acceptable, ANN controller will control the ship toward the goal point.

As shown in this figure, all simulation results end in successful berthing. All ships were guided to make a turning and they made the re-approach from safe zone and they ended in successful berthing.

5. CONCULSIONS

This research deals with automatic system for ship berthing. The controller of artificial neural networks was adopted as a tool. When we take a look on existing researches on ship berthing control, most of ship approach berthing point with pre-determined heading angle or route. In this paper, new approach is suggested to overcome these problems. Selective controllers are designed at each area and guided a ship toward berthing point even the ship approaches from multi-directions. It was found that new system makes a ship turn and guides it toward berthing point in safety. .