An application of ANN to automatic ship berthing using selective controller

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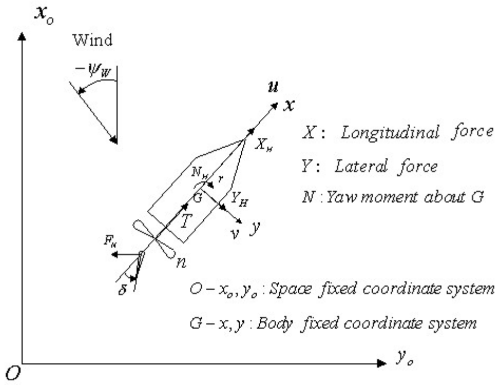
ABSTRACT: This paper deals with ANN(Artificial Neural Networks) and its application to automatic ship berthing. As ship motions are expressed by a multi-term non-linear model, it is very difficult to find optimal methods for automatic ship berthing. When a ship makes its berthing operation, the ship's inertia and slow motion make the ship approach to final berthing point with pre-determined navigation pattern. If the ship is out of the pre-determined navigation pattern, the berthing usually end in failure. 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 different weight 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.

1 INTRODUCTION

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 T 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 unberth the same place, sufficient waters space is needed because of its own turning characteristic and large inertial moment. Therefore a ship usually has a certain berthing pattern, for example, most of ship in certain pier have similar route with each other or the ship should have certain heading angle in advance within certain area for successful berthing. 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 controller that is suggested using ANN controller will guide a ship toward berthing point even the ship approaches from multi-direction. Numerical simulation is 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. The details of the tanker and its particulars are presented in Table 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

Table 1. Particulars of ship

Hull	Ship type	Tanker
	Length	304 (M)
	Beam	52.5 (M)
	Draft	17.4 (M)
	Cb	0.827
Propeller	Rudder Height	12.94
	Propeller Diameter	8.5
	Propeller Pitch	5.16
	Rudder area	98.0
	Pitch ration	1.709

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:

$$(m+m_x)\dot{u}-(m+m_y)vr = X_H + X_P + X_R + X_W \quad (1)$$

$$(m+m_y)\dot{v}+(m+m_x)ur = Y_H + Y_R + Y_W$$

$$(I_{ZZ} + J_{ZZ})\,\dot{r} = N_H + N_R + N_W$$

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.

Total 8 of input items are considered as follows; lateral and longitudinal distance (ξ, η),Lateral and longitudinal speed (), 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

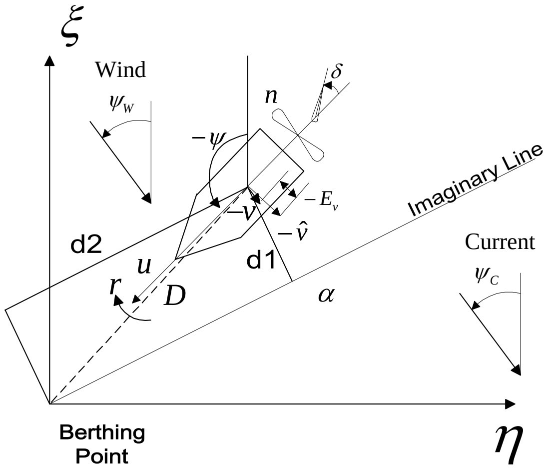


Fig. 2. Berthing concept and its coordinate

$W_{k,j}, W_{j,i}$ indicate links coefficients, I_k, a_j, O_i means input layer, hidden layer and output layrer

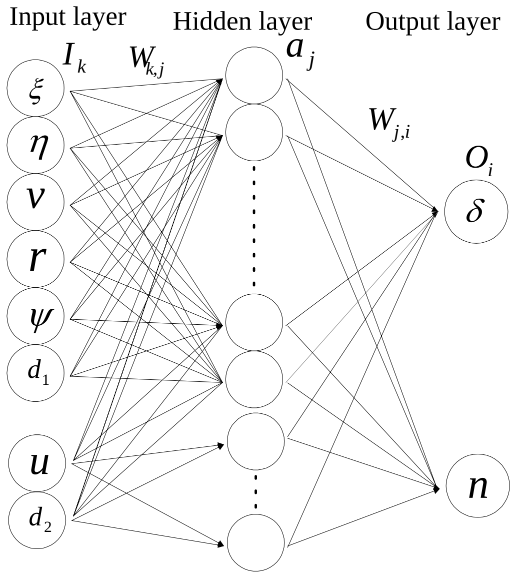


Fig. 3. Construction of berthing controller in ANN

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.

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 that is about to take on the ground. The phnomiem is maintained for the safety of ship and air plain. 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 take a look at previous researches on neural networks controller, most of them show such as study that a ship approaches the final berthing point from very limited direction. In other words, when we take an example like Fig. 4, the ship approaches the berthing point through "Area-1" in many study case. This is the reason that it is physically impossible to make a ship turn or to maintain the ship with desired heading angle with slow speed within certain distance to berthing point.

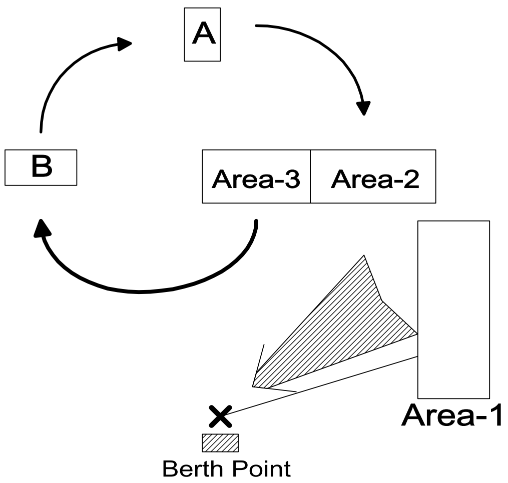


Fig. 4. Berthing concept

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.
When a ship approaches goal point, the system reasons whether it is possible to make a berthing or not. At this moment ship's present conditions such as present location, speed and heading angle are used. If the system estimate berthing is impossible under present conditions, it suggests the ship make turn and approaches new areas.
If the present conditions are clear, assigned controller at each area is used to make the ship

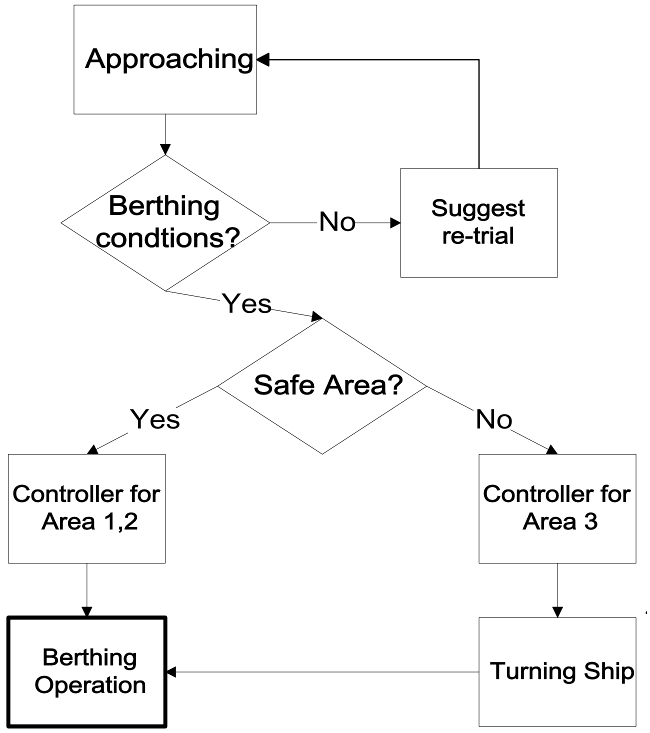


Fig. 5. General flow of berthing control

berth. 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 3, area-B, Area-A and Area-2. If a ship enters into Area-2 that is safe zone for berthing, assigned controller will guide the ship to final berthing point.
In other hands, a ship approached from Area-1 or Area 2 originally will be guided toward berthing point by assigned controller in each area because these areas are safe zone for berthing.

4 NUMERICAL SIMULATION

4.1 *Automatic control at each zone*

The figure 6 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 assigned controller of Area-3. Additional 4 cases of numerical simulations were carried out to verify the controller from Area-B to Area-A, the results are shown in fig. 7. It is found that all cases are successful to move a ship between two areas. It is peculiar that even all ship departs from different point they arrived at almost same point in Area-A.
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. When the ship is controlled safely from other zone to safe zone, Area-2, successful berthing control could be expected Fig 9 and 10 shows similar simulations results when ships start from safe zone, Area-1 or Area-2 toward final berthing point. As shown in figure 9, all ships maintain similar heading angle around final berthing point with slow speed, even they departed different point with different heading angle. In addition to this, other cases when ships approach to Area-1 are shown in Fig. 10.

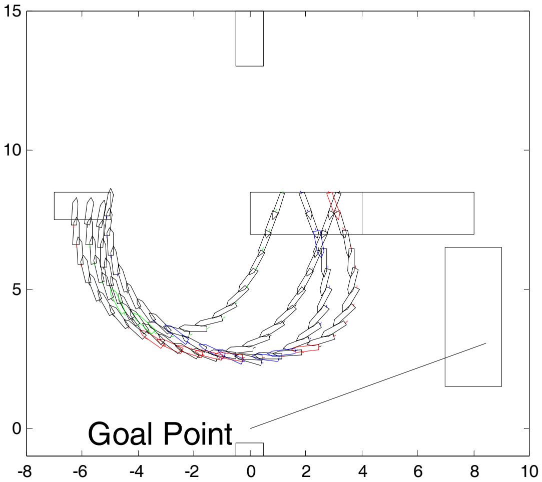


Fig. 6. Simulation Result in Area-3

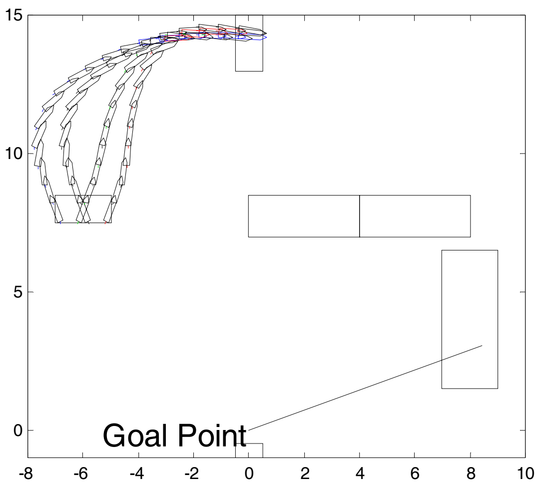


Fig. 7. Simulation Result in Area-B

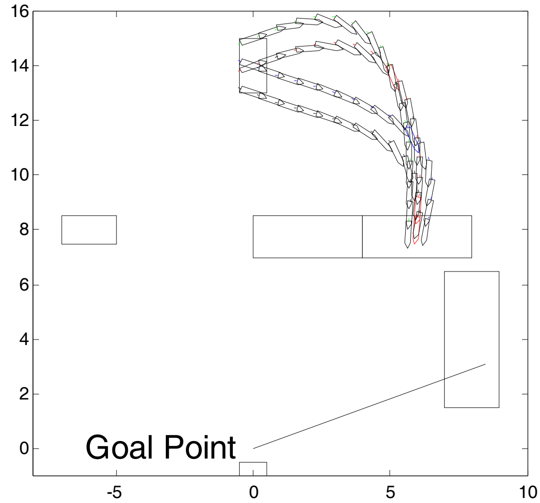


Fig. 8. Simulation Result in Area-A

Generally speaking when a ship is under berthing operation the ship approach the berthing point from side direction as shown in the figure and maintains certain heading angle toward the point with decrease of speed, it is typical pattern in ship berthing process. This figure shows even ships approach from different direction with different heading angle, their berthing operation finished in successful pattern.

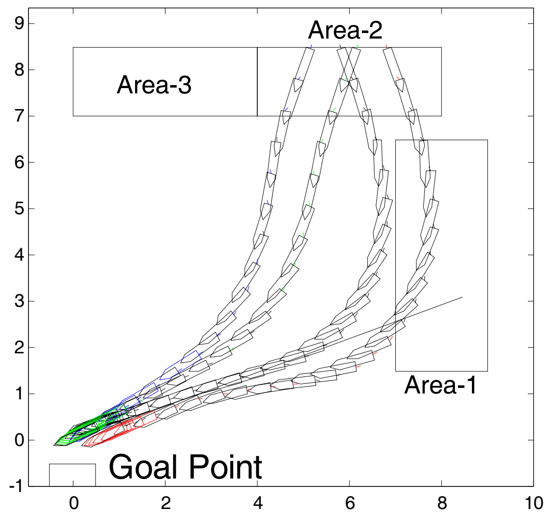


Fig. 9. Simulation Result in Area-2

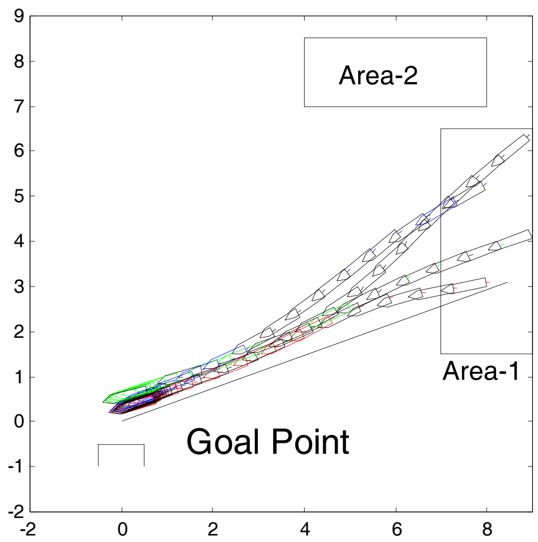


Fig. 10. Simulation Result in Area-1

4.2 *Automatic control for all of zone*

Numerical simulations also were carried out when a ship approach from non-safe zone. The many purpose is to confirm that the suggested selective controller can guide the ship from dangerous zone to safe zone, Area-2 and Area-1. The results are shown in Fig. 11.

As shown in the figure, total 4 cases of simulation scenario were planned. All ship start from Area-3 that is recognized as dangerous zone for safe berthing. In real world, a ship usually does not berth

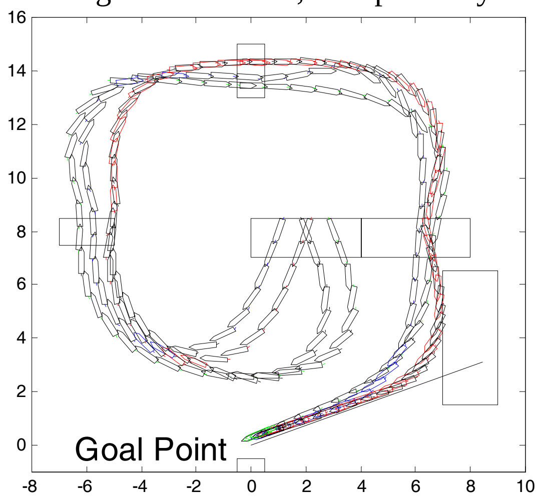


Fig. 11. Simulation Result of all- direction- approach case

in this pattern, because the ship require spare water area to make a turn and slow down its speed around final berthing point. Therefore in this scenario a ship need to make a turn and approach to safe zone such as Area-2 or Area-1. All simulation results show that ships approach to safe zone of Area-2 via midterm areas, Area-A and Area-B. It means that all ships are controlled with safety from dangerous zone to safe zone even they started at undesirable zone for safe berthing.

5 CONCULSIONS

This paper deals with automatic system for ship berthing. The controller of artificial neural networks 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. Numerical simulations were carried out to verify its effectiveness. Selective controllers are designed at each area and guided a ship toward berthing point even the ship approaches from multi-direction. It was found that new system makes a ship turn and guides it toward safe zone for berthing.

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