Auto Berthing – a Solution for Achieving Zero Waiting Time at Harbour

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***Abstract* —Tanjung Perak Port is one of biggest harbour in Indonesia. The shipping start from Karang Jamuang to Naval Base. The moving is use help of scout ships and tug boat. A control system can be applied to anchored ships , to replace the role of tug and scout boat. Movement from the parking position to the anchored involve auto maneuver and auto berthing. Both auto system is designed using fuzzy logic control. Input of control from sensors and guidance according to the path leading to the dock, and to anticipate the environmental disturbance factors (that is ocean currents). Control rules are unique, according to the type and size of vessel. In the case study to AHTS vessels, berthing auto show good ability. The heading error of 0.04° to the direction parallel to the dock, and the range of distances error is 0.16 to 2.16 meters from the desired position. Reduction of processing time leaning point to Jamrud dock is 33 minutes.**

Keywords— **auto berthing, auto maneuver, fuzzy logic, scout ship, tug boat**

I. Introduction

Since Perak Port is one of the entry gates to the flow of goods by sea and the surrounding areas of East Java. Volume transport in the port high. So that the density of loading and unloading ships resulted in the large number of ships queuing to enter the dock. In the current management, to lean processes require tugboat that helped push the boat toward the dock.

The development of science and technology, now it is possible the existence of an automatic navigation system that is able to regulate the movement of the ship. That is can lean automatically without the assistance of tugs. Maneuver the ship is affected by the propeller, rudder and thruster so as to guide the ship to lean automatically [5]. There are previous studies related to the research of ship docked automatically either in simulation or prototype stage vessel. The design Boat Ramp automatically Using Neural Network in the port of Tanjung Perak and r berthing Automatic Control of Ship using Adaptive Neural Network [4] . In both the above studies using the same method, that is a Neural Network, which require training data for the parameters that are used as the rudder angle and speed of the propeller. Research does not stop at the simulation stage but has developed into a prototype. The equipped with advanced equipment such as GPS so the ship can lean automatically according to the trajectory traversed [7].

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Automatic berthing research is the development of a pre-existing research, but using a different method of fuzzy controller.

In this paper a proposed a fuzzy logic method is used as a control system to produce auto berthing. The study was conducted by taking in Jamrud Dock of Tanjung Perak Port, on Air Handling Tug Supply (AHTS) vessels. The result shows the ability of auto berthing to move toward the dock with error heading and error distance are very small.

II. Method

An automated system can move a ship from one to another position, involving multiple control systems: the maneuvering control, position control, trajectory control. To develop the control system, takes some data as a parameter to design the control system

A. The Data

Data collection was conducted in two places, in PT. PELINDO III Surabaya and District navigation class 1. The data required are:

1. The specifications: The length of ship – Lpp, The speed of ship – U, The bread – B, The draft – T, Block Coefficient – Cb, XG-center of gravitation, the rudder areas - Aδ and displacement – m.
2. AIS data: static and dynamics, shipping route.
   The coordinate of trajectory as recommendation Navigation District.

B. Extraction Process

The variables in the Fuzzy Logic Control (FLC) for auto berthing can be seen in Table 1.

C. The Modelling Mathematics

The ability of the control system to drive the motor of stren and bow thruster is depend on the dimension of the vessel. Dimension of AHTS vessel is used to model mathematically. The model is derived based on the approach by Nomoto (1957) as a 2'nd order of mathematical model. These are the data specification of AHTS vessels, L_{pp} (the length, m) = 55, B (The breadt, m) = 13, T (Draft, m) = 5,75, Δ (*displacement*, ton) = 1680, U (speed, m/s) = 10, C_B (*coefficient block*) = 0,4086, X_G (*center of gravity*) = 3,45, A_δ (*rudder area*, m^2) = 2,212.

The dimension of vessel is used to determine the ship hydrodynamic using Clarke regression approach. An AHTS vessel hydrodynamic coefficients (Fossen, 1994) are:

$-Y_{\dot{v}}' = 0{,}029614, -Y_{\dot{r}}' = 0{,}004856, -N_{\dot{v}}' = 0{,}005742,$
$-N_{\dot{r}}' = 0{,}000722, -Y_v' = 0{,}047002, -Y_r' = -0{,}005521,$
$-N_{\dot{r}}' = 0{,}02577, -N_r' = 0{,}007063, Y\delta = 5{,}567525, N\delta = -2{,}783762$

The hydrodynamics coefficient are used to determine the inertia and damping matrices of model maneuvering [5],

$$M' = \begin{bmatrix} 0{,}02963 & 0{,}00486 \\ 0{,}00574 & 0{,}00207 \end{bmatrix}, M = \begin{bmatrix} 0{,}016298 & 0{,}14693 \\ 0{,}003159 & 0{,}06285 \end{bmatrix} \quad (1)$$

$$N' = \begin{bmatrix} 0{,}047002 & -0{,}0053 \\ 0{,}025771 & 0{,}00707 \end{bmatrix}, N = \begin{bmatrix} 0{,}0047 & -0{,}02927 \\ 0{,}00257 & 0{,}038917 \end{bmatrix} \quad (2)$$

$$b' = \begin{bmatrix} 5{,}56752 \\ -2{,}7838 \end{bmatrix} \quad (3)$$

And the constant in the second order Nomoto models, that is time and gain of constant as parameters of ship dynamics, the following [3],

$$T_1 T_2 = 2{,}1685 \quad (4)$$

$$K_R = 106{,}183 \quad (5)$$

$$T_1 + T_2 = 2{,}49077 \quad (6)$$

$$K_R T_3 = 243{,}6932 \quad (7)$$

Transfer function of maneuver is,

$$\frac{\psi(s)}{\delta_R(s)} = \frac{243{,}6932s + 106{,}183}{2{,}1685s^3 + 2{,}49077\, s^2 + s} \quad (8)$$

The transfer function of berthing for stren and bow thruster are as follows:

$$\frac{R(s)}{E(s)} = \frac{0{,}034363s + 1{,}32728 \times 10^{-8}}{s^2 - 4{,}46514 \times 10^{-6}s + 1{,}35787 \times 10^{-12}} \quad (9)$$

$$\frac{V(s)}{E(s)} = \frac{-0.00133s - 1.81413^{-10}}{s^2 - 4.46514 \times 10^{-6}s + 1.35787 \times 10^{-12}} \quad (10)$$

The Rudder is steering that serves to determine the direction of the ship in accordance with the command. The output of FLC is a command rudder (δc) and converted into actuator (δa). The rudder is has a specification of 380 volts Vcc and the time constant of 0.05. The equation of rudder transfer functions as follows:

$$\delta = \frac{0.6/380}{0.05s + 1} \quad (11)$$

The propeller as propulsion ship modeling performed with the approach of Horigome, Hara, Hotta and Hotsu (1990). Modeling of vessel specifications (Ky - gain constant) is 1, and rpm of propeller is 500. The time constant – Ty is obtained from the calculation of 0.339. The propeller transfer function becomes:

$$\frac{Q_m}{Y}(s) = \frac{1}{1 + 0{,}339} \quad (12)$$

D. Determination of Trajectory and Berthing of Ship

The trajectory as a path is determined by the position of the ship reliance upon entering to ship docking area. With the coordinates of dock position as follows: -07 º -11 '-18 "latitude and 112 º 43' 00" East, and represented into XY coordinates of the first quadrant with a point (10, 1,020) m. The position of dock is located at North Jamrud: -07 º -11 '-51 "latitude and 112 º 43' 32" East, and represented into XY coordinates of the first quadrant with a point (0, 990) m.

At the time of the leaning ship, the engine should stop at 3 times of the width of ship before reaching the dock. After the ship's engine stopped, the bow thruster is working slowly to lean the ship to the dock in accordance with the trajectory. Figure 1 is a plot of the position of the cruise ships start to dock.

E. Design of Trajectory Control

The design of the trajectory control at AHTS vessels based on FLC can be seen in Figure 1.

In the design of the ship berthing controls used in this study is divided into two parts, the first is a control of yaw and the second is sway control. From the desired trajectory, the ship is expected to move in accordance with the direction and position. The set point is the yaw direction and position coordinates of the ship. The yaw control is a FLC with input of yaw error and yaw rate. The output of the voltage of bow and stern thruster. The sway control uses FLC with input from the distance of boat dock and output is voltage of bow and stern thruster.

The rule base in FLC is applied to control and the application is alternately bow or stern thruster accordance with a predetermined set point. Development of rule in FLC based on expertise of the designer [1,2].

F. Math and Equations

The rule base on rudder of Stern control and The rule base of FLC in *Bow and Stern thruster* will be shown on Table 2 and Table 3.

G. The Current Model

Modeling of ocean currents in the port of Tanjung Perak Surabaya used Gauss-Markov process, with a maximum current speed varies from 2, 2.25 and 2.5 knots.

III. Result and Analysis

Ship heading changes depend on changes in the voltage of the controller to the actuator. The actuator are bow and stern thruster. Figure 4 shows that the maximum output voltage of 12 V and a minimum of 0 V. When the ship move into the port, the controller gives decreases of the output voltage according to the rule base has been designed. And the ship heading changes affected by changes of the voltage on the stern and bow.

The results of simulation is show in Figure 4. The ship trajectory for berthing can be seen from Figure 4, begin to leave the initial position until the ship reaches way point and then proceed to the dock and ship can reach a set point coordinates and set point of direction. The simulation also shows a few error in the disturbances condition (Figure 5).

IV. Conclusion

This study has been able to develop an automatic control system for a berthing of ship. Fuzzy Logic Control selection (FLC) as a controller with a rule base adapted to conditions in the ocean currents of Tanjung Perak Port of Surabaya. The result of control design can follow the desire trajectory. The moving of ship has been set properly. Design of berthing control by stern and bow thruster can achieve set point well. The maximum value of the vessel trajectory error for current disturbances at 2 knots is 1.26 m, 2.25 knot of current gives error of 0.64 m and for current of 2.5 knots, the error of 2.68 m. As for the berthing ship phase with the ocean currents 2; 2.25 and 2.5 knots gives the error of 0.040; 0.040 and -0.010..

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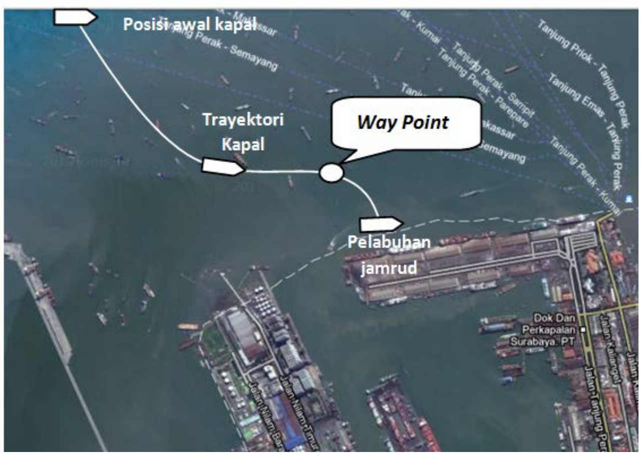

Figure 1. The trajectory of berthing to the Jamrud

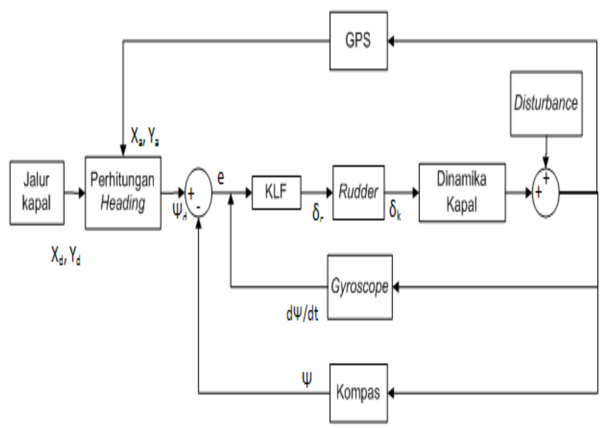

Figure 2. Block diagram of design of The Trajectory Control

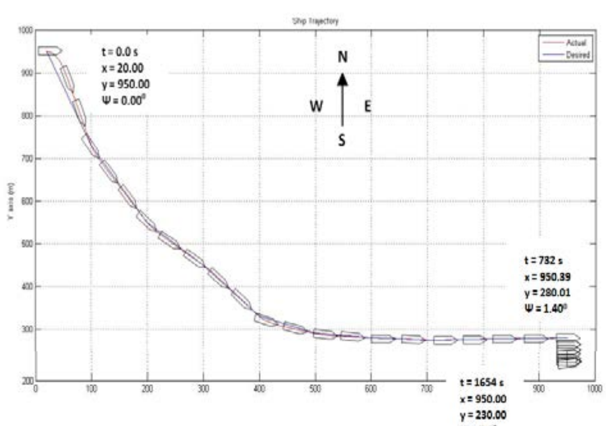

Figure 3. The result of simulation of auto berthing in the un disturbance

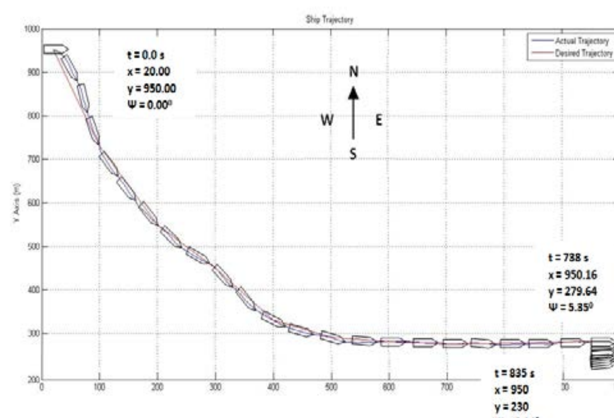

Figure 4. The result of auto berthing in the condition of current sea

TABEL 1
THE RELATIONSHIP OF INPUT AND OUTPUT OF FLC

Kontrol Logika Fuzzy	
Input	Output
Error ψ	1. δc (*rudder command*)
dψ/dt	2. The Voltage of stren thruster
Eror of distance	3. The Voltage of bow thruster

TABLE 2
THE RULE BASE ON RUDDER OF BOW CONTROL

r e	**NB**	**NM**	**NS**	**Z**	**PS**	**PM**	**PB**
NB	Z	M	M	B	B	B	B
NM	Z	Z	M	M	B	B	B
NS	Z	Z	Z	M	M	B	B
Z	Z	Z	Z	Z	M	M	B
PS	Z	Z	Z	Z	Z	M	M
PM	Z	Z	Z	Z	Z	Z	M
PB	Z	Z	Z	Z	Z	Z	Z

TABLE 3
THE RULE BASE ON RUDDER OF STERN CONTROL

r e	**NB**	**NM**	**NS**	**Z**	**PS**	**PM**	**PB**
NB	Z	Z	Z	Z	Z	Z	Z
NM	M	Z	Z	Z	Z	Z	Z
NS	M	M	Z	Z	Z	Z	Z
Z	B	M	M	Z	Z	Z	Z
PS	B	B	M	M	Z	Z	Z
PM	B	B	B	M	M	Z	Z
PB	B	B	B	B	M	M	Z

TABLE 4
THE RULE BASE OF FLC IN BOW AND STERN THRUSTER

Input of Distance	Output	
	Vbow	Vstren
S	B	B
M	M	M
L	Z	Z