Monitoring and Control of Sea Traffic based on Improving AIS Data

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Abstract: Modern management of sea transportation which are integrated is needed, the system consist of system improvements based on shipping traffic demand, policy and safety cruise, cruise business management modernization and development of related industries. In the last 5 years, the marine accidents are clusterred into ship collision, fire, engine problems, and leakage of the ship. This paper propose an integrated monitoring system with control system for the direction, position and maneuver of the ship that make up a system at any time can provide information about the position, trajectory and direction of the ship. The control strategic is developed based on fuzzy logic. In this control using rules in the form of If ... Then..... The mechanism control system is fulfilling the trajectory in shipping line from Karang Jamuang – Tanjung Perak and vice versa.

Keyword: *Smart* ***Control****, Fuzzy, Monitoring*

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I. INTRODUCTION

Indonesia is an archipelago country which is geographically located between 6^o.08, LU and 11^{o}15, LS and between 94^{o}45, BT and 141^{o}05, BT. (+) Marine accidents occured in Indonesia territoti according Directorate General of Sea Transportation can be clusterred into sank of ship (41%), ship collision (11%), fire (14%), problems in machinery (3%), and leakage. In the year 2005, 125 accidents were happened, and in 2007 there were 159 accidents, this means that in every two days there is one marine accident. 41% of these accidents are caused by human error, 38% by natural disasters (*force majeure*) and 21% by the structure of the ship (*hull structure*). Based on the IMO (*International Maritime Organization*) data, indicated that Indonesia as a country with frequent accident at the sea / *high risk country*.

In order to improve quality in maritime transport management, the AIS (*Automatic Identification System*) technology was installed in several type and size of ships. However, there are weaknesses encountered in this technology:

(i) The AIS can be used only up to 20 characters with restrictions on the name and navigation status of ship.
(ii) The display of AIS usually shows several errors, 30% in ship status information, 4 % in ship power and about 47% in ship dimension (length, beam, draught)
(iii) 49% ETA – *estimated time to arrival* indicates inconsistency, either displaying the word “not available” or “null”.
(iv) The AIS could not properly handle heading information, COG – course over ground, SOG – speed over ground and ship position.
(v) The AIS can show latitude values that are more than 90^o, and longitude values that are more than 180^o or position error at 0^o N/S, 0^o E/W.
(vi) The AIS is integrated with other components, which depends on other components accuracy.

Ship navigation status is necessary in order to avoid accident. Some of disadvantages of AIS were reported in designing a monitoring and control system (M&C) for marine transportation [1].

Specifications and performances of M&C design system are:
(a) It can be accessed by means of wireless at the frequency of 2,4 GHz,
(b) It indicates position, heading, speed, distance between the ship and the ground, as well as distance between the ships,
(c) The above mentioned data were shown according to the sea map coordinates digitally.
(d) The system could give recommendation about direction and speed of the ship to avoid accident (crash, sail, or at the forbidden zone).
(e) Recommendations were given in linguistics, such as slow down the speed of ship, change ship direction, etc.

The above performances are outputs from several control modules, which are designed according to If.. Then rule. This rule is build upon the ability of ship’s maneuver dynamics, which are derived mathematically.

II. THEORETICAL BACKGROUND

Autopilot system can be stated in two automatic control systems, i.e. *Course keeping* and *track keeping* [2]. Both controllers play an important role in preventing collision between ships of other floating elements. Several control systems have been designed to avoid collision by using many systems such as expert system, artificial intteligent, etc. The method used in designing a safe ship tracking was incorporating the ship’s direction and speed.

2.1 Ship Maneuvering Control

There are 4 methods in designing ship maneuvering control, i.e. conventional, adaptive, modern and expert-based [3].The weakness in the conventional method which did not fully accommodate to a disturbance at high frequency [4]. Interference from environment cause changes in system parameters. Two of the strategies are MRAC (*Model Reference Adaptive Control*), and ARMA (*Auto Regressive Moving Average*) [5].

Modern control system design is one of method that is designing based on state space equation. In this method, mathematical model of dynamic ship maneuver in controllable and observable. In this method, there are ILQ (*Inverse Linear*

Quadratic) [6, 7], H_2, LQG (*Linear Quadratic Gaussian*) [6], H~ [8, 9], MPC (*Model Predictive Control*) and LQR (*Linear Quadratic Regulator*) [8].

The theory of fuzzy logic was invented by Zadeh in 1965. This theory logic mimics human reasoning in making decisions on various matters, and was able to be used as a control in various household products such as washing machines, air-conditioning machines, rice cooker and etc. Application of fuzzy logic is not only growing in the using of household products, but also in some Japan industries since the beginning 1980. Similarly maneuvering systems that have been proposed by Noguchi and Mizoguchi (1998) from the company Ishikawa Jima – Harima Heavy industries which maneuvering devoted to safe ship passage. The position and category of secure position of ship are expressed in fuzzy variables. The simulation demonstrated maneuverability of vessels with fuzzy logic is able to avoid another vessel.

In fuzzy logic control system (FLC) , mechanisms of control is acquared from the procces of fuzzification, inference and defuzzification. In inference, rule base depends on the determination of the FLC design that has been done with two inputs and three inputs of fuzzy [10], shows the result obtained with three inputs of fuzzy provide performance for deviation trajectories is better than two fuzzy inputs, and also performance of it is more stable than fuzzy PI strategy [11].

In dealing in sea disturbances is stochastically disturbances, require the fuzzy controller is able to overcome this causes. The rule bases have needed to modify. On the condition of international waters can be overcome by preparing rules of fuzzy is developed from another robust control reference [12]. The robustness controller used to disturbances due to wind, ocean currents and waves obtained in the Froude number of significant ranges.

A control system is used to drive the ship steering system that is able to work in accordance with expected performance, it's design has been widely performed both in scale and applied computer simulation minilab scale . Among them is the tracking control of ships at sea conditions of uncertainty, this is not apart from some previous research in terms design intelligent autopilot [13,14].

2.2 Ship Dynamic Models

In general, the dynamic of ship in sea, there are six moving kinds: yaw, heave, roll, surge, sway, and pitch. The general form equation maneuvering ship expressed in the form,

$$\mathbf{M}\dot{\nu} + \mathbf{D}\upsilon = \tau_L \quad (1)$$

Where, $v = [u, v, r]^T$ is the velocity vector. **M** and **D** is the matrix of inertia and damping, it's obtained from the linearized the forces and moment equations on the surge, sway and yaw.

The equation 1 is dynamics model ship. This mathematics is used as a model that is controlled by a FLC. Two alternative models that describe the steering system on the ship are Davidson and Schiff (1946) and suggested by Nomoto, Taguchi, Honda and Hirano (1957). This model is obtained by eliminating the sway velocity v to obtain the transfer function between yaw rate and rudder angle, expressed in equation.

$$\frac{r}{\delta_R}(s) = \frac{K_R(1+T_3 s)}{(1+T_1 s)(1+T_2 s)} \quad (2)$$

Where is K_R, T_3, T_1, T_2 are constants obtained from the matrix equation of (1) based on ship hydrodynamic coefficients of the regression clark [Aisjah, A.S, 2009].

2.3 AIS

AIS – Automatic identification system as a monitoring system at the sea transportation , which is not available inside a recommendation against setting the direction and speed automatically on shipping information system. The weaknesses in the system can be developed through several design modules – an integrated control module to provide advice on the captain.

2.4 Designing of Monitor and Control Systems Sea Transportation

Maritime transport model covering several aspects related with monitoring and control system in transportation. There are two systems in propose: monitoring system and control system. Such as describe in Figure 1, the monitoring system is a system that serves as a monitoring of the position, speed, direction and trajectory of certain cruise ships in the shipping. Information from data obtained from the monitoring station based on GPS. GPS is a navigation system that utilizes satellites. GPS receiver obtains signal from multiple satellites orbiting on the earth and provide position and time information in high accuracy. The mechanism design is a working system of GPS to provide information about the position and time. From these data can be calculated a speed and direction of the ship and giving the information to the monitoring station on land. The information is about position, direction and speed of the ship. Data stored in the monitoring station is used to process in determining the performance of controllers [15].

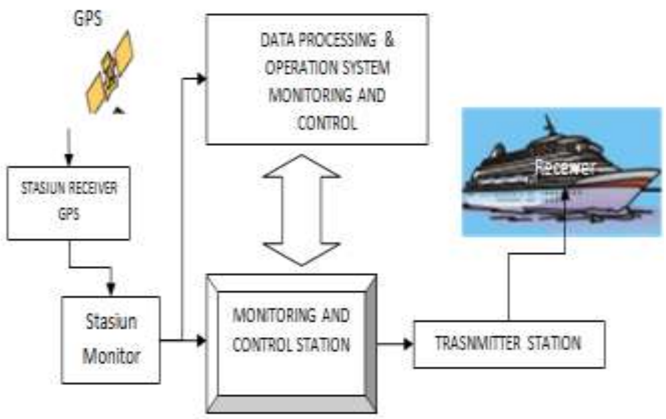

Figure 1. Block Diagram of M&C System

III. METHOD

In designing the monitoring and control system such as shown in block diagram in figure 2, consists of several modules, that are

(i) module of searching input data
(ii) collision avoidance module
(iii) vessel movement dynamic module , and

(iv) Control module heading.

The fourth modules are making a system that gives the decision, which will be used by users.

In monitoring and control transportation, it takes some data information such as:

(1) port infrastructure
(2) limit the territorial waters and the mainland
(3) the occurence of the marine environment factor :average of the speed and direction of ocean currents, wave height, speed and direction of wind.
(4) parking area, shallow area , mine area , the area planted pipe, anchor area, anchored prohibited area, planted area gas pipelines, fisheries areas, safe areas , and other
(5) the hierarchy of priority of ship entering and going the harbor area
(6) specification of ship: type, name, dimensions , speed and age of vessel
(7) the date of incident, location, type of ship, the causes and consequences of collision, regulatory aspects of coordination in the response to a collision on the ship .
(8) the coordinates of the position of the dock

Some agencies involved in building M & C system are: PT . PELINDO III – Tanjung Perak branch, office of navigation, office of maritime, NSTC – National transportation safety committee, BMKG – Meteorology, climatology and geophysical agency, Syahbandar, BKI – Indonesian Bureau of classification

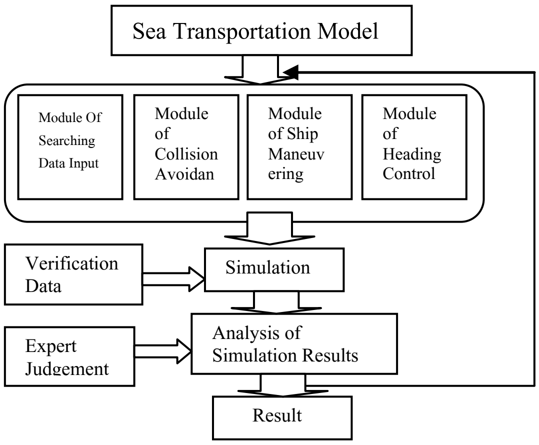

Figure 2. The control modules in designing system

3.1 Developed Program

Process of developed program, in the stages described below,

- *Creating a splash screen form to display the name of the software*
- *Creating main page form. first page contains a map of Madura strait waters and the view on the right layer monitoring that serves to provide information such as pointers (locations) , monitor, reset button , and button run*
- *Creating a form for data base weather*
- *Creating boundaries form*
- *Creating database form vessel specification*
- *Creating a form target / destination*

3.2 Sea Transportation Model

Marine transport model consist of several related mathematics models:

- Dynamics of several types of ships
- Track shipping in the harbor area

In this model performed to obtain a data base on the parameters of a heading control system, the setting time, time constant and other parameters that correspond to the speed of the ship. The parameter is used for verification and validation of the rule in fuzzy control system.

IV. ANALYSIS AND DISCUSSION

The result of monitoring and controlling system design on the sea transportation when was accessed by users as shown in figure 3 and Figure 4. Figure 3 describes map of navigation channel in area of Tanjung Sawo and Figure 4 describes The simulation results, there are two vessels approaching each other, if not take actions such as the recommendations given there will be a collision between them. From image display shows that the ability of the system design in providing information and recommendations on the movement of ships along the west line of Tanjung Perak:

(i) M & C systems provides information on the position of all ships that can access this system
(ii) M & C systems provide information about the area : safe / forbidden anchor, danger areas , etc .
(iii) M & C system provides information about speed, direction, trajectory of the voyage.

The numerical analysis has been done to the performance of the system design. Analysis based on performances of control system, both of control the direction and trajectory and also the parameter of control responses ie: settling time, time constant [15].

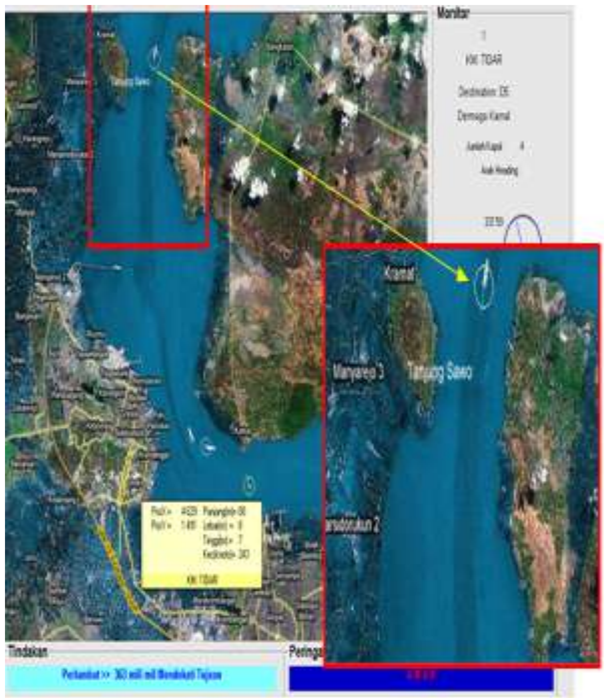

Fig. 3. Map of navigation channel in area of Tanjung Sawo

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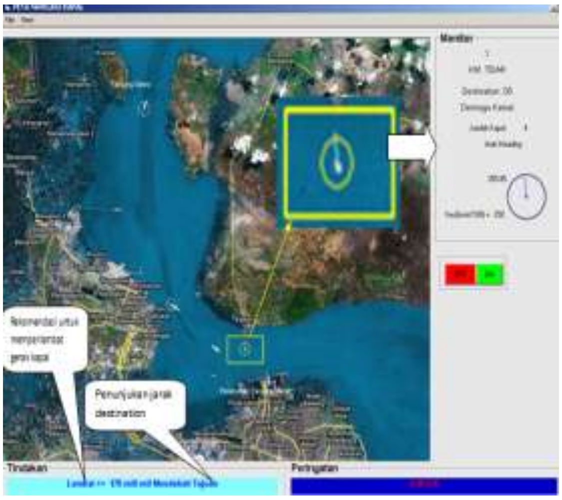

Fig. 5. The simulation results: ship movement as it moved from Pier I go to destination Kamal

The performance of control modules installed in the software design is based on criteria:

- settling time for the fulfillment of the heading and track targets
- steady state error of heading
- tracking error
- robustness of control due to environmental disturbances

(b)

Fig. 4. The simulation results

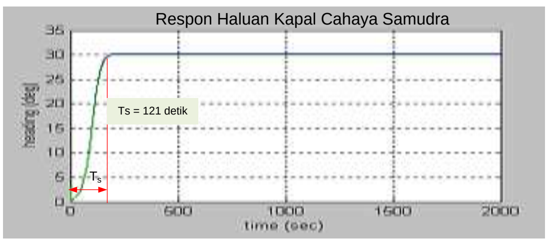

Fig. 5. Time respons of Chemical Tanker Ship

The performance of some types of ships is shown in Figure 5. Where Figure 5 describes Time respons of Chemical Tanker Ship with main dimension Lpp = 99 m, 12,5 knot, dwt = 713.265, Ts = 121 sec. Using control system design for these ships shows that the respon oh heading is stable such as describes in Figure 6.

Fig. 6. Time respon of Chemical Tanker Ship due to wind disturbance

A number of 38 specification ship data base have filled in the system M & C design. The performances of FLC are shown in Table 1. When in environmental without disturbance, all of ships are stable. The differences of sea transportation model in one ship and other. This model is suitable with optimum speed in ship that causes reflection wave to environment.

Table 1.Performance of FLC in Heading Module control

Nama Kapal	**Lpp (m)**	**U (knot)**	***Settling Time* of FLC (sec)**	**Remark**
AWB Ewis lady	63.90	12.5	96.0	Stable
BG Lintas Samudra	60.508	12.5	92.3	Stable
Bitumen Perkasa	63.00	14.6	95,0	Stable
Brotojoyo MT	236.80	16.1	234.0	Stable
Cahaya Samudra	99.00	12.5	121.0	Stable
King Tiger-2501	76.00	15.0	104.0	Stable
KM Kudanil	65.30	15.0	96.0	Stable
LCT Golden 7	36.20	15.0	68.9	Stable
Putra Jaya Mojopahit SV	91.50	12.5	109.4	Stable
Samudra - 1TB	28.58	11.5	42.1	Stable
Sinar Bunyu MT	83.08	12.7	103.2	Stable
Soechi Pratiwi MT	95.61	13.8	119.0	Stable
Sykur 16 TB	26.50	11.5	73.0	Stable
TB Alamanda	31.20	15.0	62.0	Stable
TB Bomas Gemilang	29.05	12.5	54.1	Stable
Tirta Samudra - X – VI	94,29	11,5	118.0	Stable
Tirta Samudra - X – VII	93,30	11,5	103.4	Stable
TK-SSM-IID	70,15	12.7	98.3	Stable
Tunas Tiga	93,60	13.2	116.2	Stable

V. CONCLUSION

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The performance of monitoring and controlling sea transportation in west sea line of Tanjung Perak have a stable for many types of ship.

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