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 clustered 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

I. INTRODUCTION

Indonesia is an archipelago country which is geographically located between 6°08’LU and 11°15’LS and between 94°45’BT and 141°05’BT. (+) Marine accidents occured in Indonesia territori according Directorate General of Sea Transportation can be clustered into sinked 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 position ship.
(v) The AIS can show latitude values that are more than 90°, and longitude values that are more than 180° or position error at 0° N/S, 0° 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 intelligent, 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], H2, 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 Naguchi 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 acquired from the process 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 outputs of fuzzy [10], shows the result obtained
with three inputs of fuzzy provide fuzzy 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 with 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,

\[ \mathbf{M} \ddot{\mathbf{v}} + \mathbf{D} \mathbf{v} = \tau_L \]  

(1)

Where, \( \mathbf{v} = [u, v, r]^T \) is the velocity vector. \( \mathbf{M} \) and \( \mathbf{D} \)
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.

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 occurrence 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

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].

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

![Figure 2](image-url) The control modules in designing system

![Figure 3](image-url) Map of navigation channel in area of Tanjung Sawo
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

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

<table>
<thead>
<tr>
<th>Nama Kapal</th>
<th>Lpp (m)</th>
<th>U (knot)</th>
<th>Setting Time of FLC (sec)</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWB Ewis lady</td>
<td>63.90</td>
<td>12.5</td>
<td>96.0</td>
<td>Stable</td>
</tr>
<tr>
<td>BG Lintas Samudra</td>
<td>60.508</td>
<td>12.5</td>
<td>92.3</td>
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<tr>
<td>Bitumen Perkasa</td>
<td>63.00</td>
<td>14.6</td>
<td>95.0</td>
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</tr>
<tr>
<td>Brotojoyo MT</td>
<td>238.80</td>
<td>16.1</td>
<td>234.0</td>
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<tr>
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<td>99.00</td>
<td>12.5</td>
<td>121.0</td>
<td>Stable</td>
</tr>
<tr>
<td>King Tiger 2501</td>
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<td>15.0</td>
<td>104.0</td>
<td>Stable</td>
</tr>
<tr>
<td>KM Kudanil</td>
<td>65.30</td>
<td>15.0</td>
<td>96.0</td>
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<tr>
<td>LCT Golden 7</td>
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<td>15.0</td>
<td>68.9</td>
<td>Stable</td>
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<td>Putra Jaya Mojopahit SV</td>
<td>91.50</td>
<td>12.5</td>
<td>109.4</td>
<td>Stable</td>
</tr>
<tr>
<td>Samudra - 1TB</td>
<td>28.58</td>
<td>11.5</td>
<td>42.1</td>
<td>Stable</td>
</tr>
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<td>Sinar Banyu MT</td>
<td>83.08</td>
<td>12.7</td>
<td>103.2</td>
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<td>13.8</td>
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<tr>
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<td>15.0</td>
<td>62.0</td>
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<tr>
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</table>

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

REFERENCES