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Marine Technology for Sustainable Development 2017

A FUZZY DECISION SUPPORT SYTEM OF IUU – TRANSHIPMENT IN INDONESIA

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ABSTRACT

Some of isue of IUU – *Illegal, Unregulated and Unreported Fishing and Transhipment* as a major concern in the Ministry of Fisheries and Maritime Republic of Indonesia. One of efforts in proposed of study to overcome the IUU problems is designing of decission support system that will be identify an anomalous of ships movement. The research is identifying an anomalous ships movement using fuzzy logic methods. The inputs are AIS data, which is an electronic information system in almost all ships > 50 GT. The decision system is built on algorithm of ship motion that indicates the IUU transhipment. The system consists of 2 sub systems: fuzzy selection and fuzzy final decision. Input of system is dynamic AIS data. Type of Fuzzy selection and decision is Mamdani. The two of subsytems are series system. Each system is tested and validated in performed according to AIS real data in several areas in Indonesia waters. The result of test and validation of IUU transhipment is shows in accuracy of > 75%.

Keywords: *IUU Transhipment, Indonesia, Fuzzy, Mamdani, accuracy, validation, fuzzy selection, fuzzy decision.*

INTRODUCTION

Indonesia governments is regulating to voyages as suspected in IUU- *Illegal, Unregulated and Unreported fishing*. Some illegal fishing events are Pemerintah Indonesia saat ini melakukan pengaturan terhadap pelayaran yang ditengarai sebagai IUU – *Illegal, Unregulated and Unreported fishing*. Beberapa kejadian illegal fishing occurred in Malaka straits in September 2013 on 2 Malaysian ships (Yogi & Setyadi, 2014), and often occurred in Natuna waters, Sulawesi waters, Aru and Arafura waters (Badan Pemeriksa Keuangan, 2012) (Santosa, 2014). Fish theft is an indication of the loss of competitiveness of Indonesian fishermen, and has caused losses to the state. These losses are include not recorded exports of fishing in Indonesian territory and made a dead activity in the port, in the auction market due to the practice of moving cargo (transhipment) in the middle of the sea (Jenderal, Dan, Internasional, Luar, & Republik, 2013). IUU is a problem in several countries in other than of Indonesia are Malaysia, Thailand, Africa states, and others. International legislation in overcoming the IUU has been in place for a long time, i.e: UNCLOS' 1982 law of the sea convention, FAO Code of conduct for responsible fisheries (CCRC) – 1995, FAO - International Plan of Action (IPOA) to prevent, deter and eliminate IUU fishing – 2001, FAO – compliance agreement – 1993, Fish stock agreement – 1995, UNGA resolution, EC regulation – 2008 (Kusuma, 2014).

The monitoring of illegal fishing activities in Indonesia is conducted by Vessel Traffic System - VTS at the Head Office of the Indonesian Ministry of Marine Affairs or at the nearest port to the sea area. Monitoring was performed using AIS data and long range camera radar. This radar is capable of monitoring up to 40-60 kilometers and monitoring camera (CCTV) as far as 4 kilometers. Indonesia's marine areas are very large, and the number of monitored fleets has not met the adequacy standards. A technology should be used to assist the identification of ships categorized as IUU.

AIS data contains information about the vessel identity, position, speed, and course with Vessel Traffic Services (VTS) stations as well as with other ships (Fiorini, Capata, & Bloisi, 2016). AIS (Automatic Identification System) has used since the 1980s, it is a communication system that works for anti-collision, vessel traffic services and search and rescue, and can be used also to monitor the shipping in the Indonesian ocean. The previous research has been able to propose an information technology for navigation services. This system is called of MCST (Monitoring & Control in Sea Transportation), which is AIS data support information system to manage the shipping traffic in the port (Aisjah et al., 2012). The MCST algorithm has been tested on a laboratory scale in ITS pools, and it is showed of moving ships can be monitored by MCST. Monitor systems can detect the ship movement and also provide navigation services on board. The utilise of AIS data is developed to identify ship movement that is categorized as an illegal fishing and illegal transhipment.

One of the anomaly mode of ship movements that happen in Indonesia waters on 7 September 2017 in South China Sea, Natuna Sea, and Riau Sea. The incident when the patrol boat caught 4 ships from Vietnamese vessels conducting illegal fishing activities in position of (1). KG 93525 TS (GT 139), (2). KG 91490 TS (GT 139); (3). KG 93877 TS (GT 139). Detection of ship movement at coordinates shows no change significantly, at: (1) 05º 22.23 'N / 108º 55.15' E KP; (2) 05º 22.09 'N / 108º 54.53' E, (3) 05º 21.90 'N / 108º 54.03' E. The third example of the movement of the vessel will serve as the basis for developing the rules on IUU Fuzzy Logic. This paper is propose designing decision fuzzy logic system of illegal transipment.

METHODS

AIS as an electronic information system is required to be installed on board with a tonage above 300 by IMO (International Maritime Organization) as a marine safety tool. AIS as a communication system between ships, between ships to the ground station or from land to ship, will be able to provide information and identification of ship movement along the voyage (Mund, Ray A.; Campbell, 2005). AIS serves to identify the location where the vessel sails, and can exchange data electronically including identification, position, activity or state of the ship, and speed, to other nearby vessels and VTS stations.

Illegal transhipment is carry out illegal activity in the middle of the sea and transfer goods from one ship to another at sea. Moving goods should be done at the port. Several studies have been conducted to generate decisions about illegal activities in the middle of the sea. Decision tree to identify critical IUU fishing traceability points in the fish supply chain (Borit & Olsen, 2012).

A predictor system of predicting illegal transhipment is shown in Figure 1 below. The system is composed of two sub-systems, (1) the prediction vessel movement system, and (2) the decision of illegal transhipment system. Both of sub-systems are built using Mamdani's fuzzy logic. The output variables of sub system 1 as variables input of sub system 2. The input variable for both sub systems are expressed ini fuzzy variables in triangle membership function.

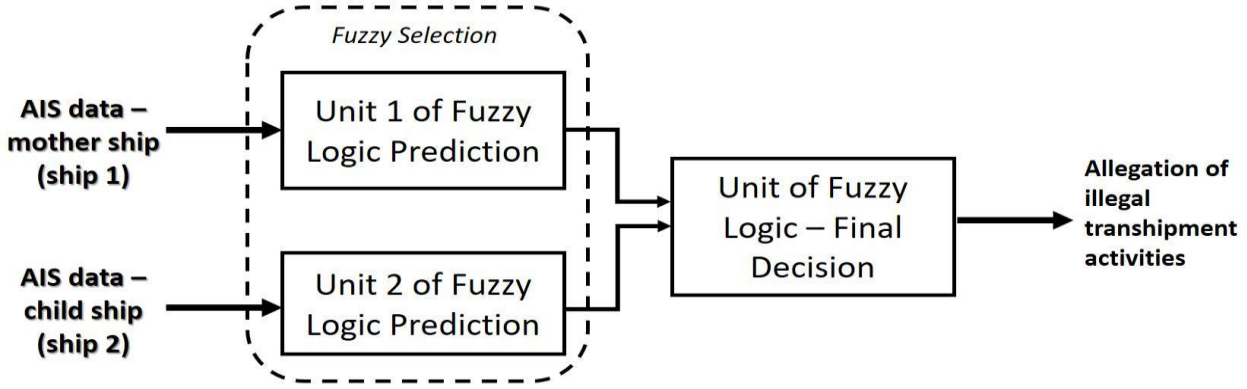


Figure 1 Blok diagram system of Illegal Transhipment Predictors

A. Design a Fuzzy Logic System of Prediction Ship Movement

Ship motion patterns can be predicted using AIS data. The pattern depicted in Fig. 2, based on 4 data pairs: (1) latitude position, (2) longitude position, (3) speed, and (4) heading of ship (Redoutey, Scotti, Jensen, Ray, & Claramunt, 2008). This research was developed the preveiuous research.

The designing the system in this research is conducted based on 5 pairs of data: ie 4 data equal to mentioned above and (5) turning rate (^{o}/min). A design system for tracking identification and ship maneuvering is performed with a fuzzy logic system in 5 inputs. Block diagram of Figure 1 shows the design architecture fuzzy logic system. There are 5 input variables for tracking identification and actual ship maneuvers of ship 1 as mother ship, namely: (1) Latitude / Δx, (2) Longitude Δy, (3) change of yawrate Δr, (4) change of direction - and (5) change of ship velicity - v. These five data can be obtained from AIS data and / or sea radar.

These five data used to predict position, heading (course), rate of course, speed of vessel, using the following rule:

R(1): If Δx(i) is … and Δy(i) is … and Δr(i) is … and …and y(i+1) is… then Ψ(i+1) is… Ψ(i) is .. and Δv(i) is …and THEN x(i+1) is

…

R(n): If Δx(i) is … and Δy(i) is … and Δr(i) is … and …and y(i+1) is… then Ψ(i+1) is… Ψ(i) is .. and Δv(i) is …and THEN x(i+1) is

The fuzzy unit prediction of ship movement for chil ship as the same algorithm to mother ship.

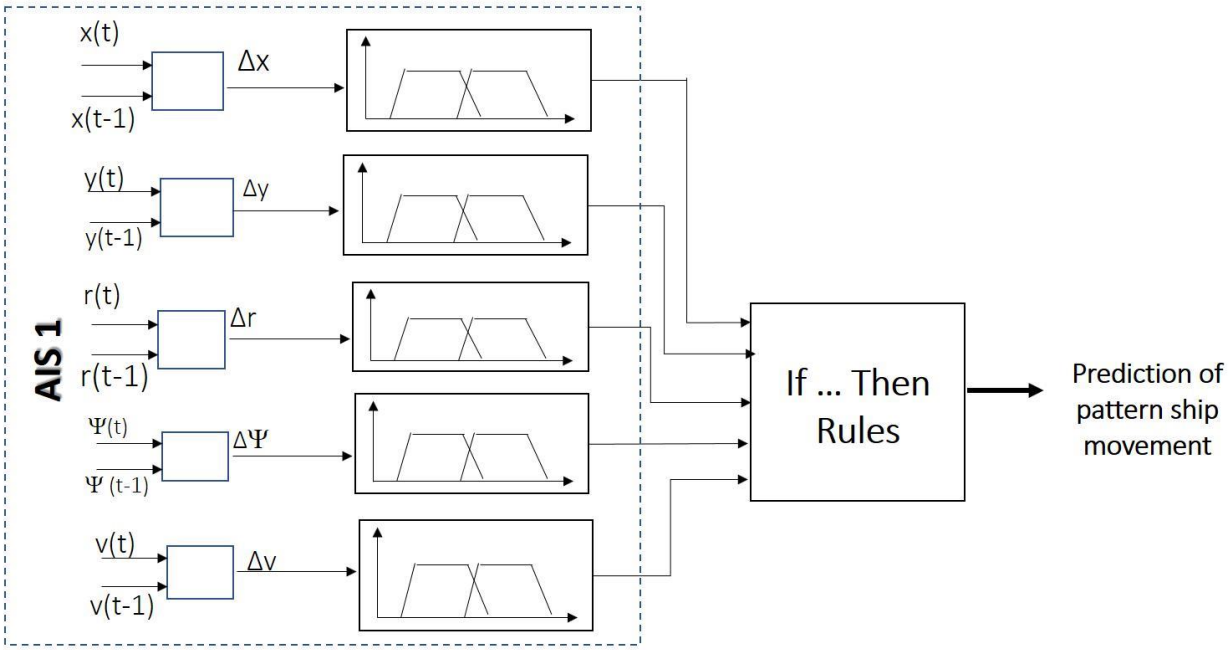


Figure 2 Design of Architecture Fuzzy Logic System of Prediction Ship Movement (Mother Ship)

The output of prediction ship motion pattern of ship 1 and ship 2 are used to determine the difference of the distance, speed of mother and child ships, and difference of heading between two vessels. Both of these variables as input for fuzzy decision logic system. If the distance difference between two ships is 500 - 800 m as wary distance, then most likely will do illegal transhipment. Differences of headings are used to generate a decision whether the possibility of the two ships will be closer to each other or not.

B. Design a Fuzzy Logic System of IUU Decision

The allegations in motion patterns of ships in illegal transhipment activities are based on the motion pattern of COLREGS regulations for anti collision. There are 3 motion patterns shown in Figure 3 is said to be a movement to avoid collisions. It is very unlikely that the two vessels will have a motion pattern in accordance with the OLREGS, unless it will perform illegal transhipment activities, so the three motion patterns are used to determine the possibility of illegal transhipment.

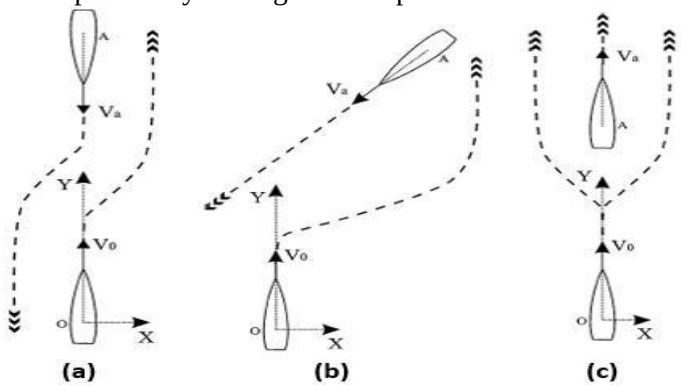


Figure 3 Three patterns of ship movement in avoiding collisions (a) *Head On* (b) *Crossing* (c) *Overtake* (Perera, L P; Carvalho, J.P.; soares, 2009).

The input variable for the second - fuzzy decision system is shown in Table 1 below. 3 variables of input fuzzy decisiona are: (1) The speed changing of ship 1 as a mother ship (knot), (2) The speed changing of ship 2 as a child ship (knot), (3) The distance between 2 ships (m), and (4) The heading differences between two ships (^{o}). The third variables first is divided in 3 membership function of triangulair term: N – Negative, Z – Zero, and P – Positive.

Table 1 The input variables for the second - fuzzy decision system

Input Variables	Unit	Index	Domain	Membership Function
The speed changing of ship 1 (mother ship)	Knot	N	[-0.25 -0.25 0]	Trimf
		Z	[-0.05 0 0.05]	Trimf
		P	[0 0.25 0.25]	Trimf
The speed changing of ship 2 (child ship)	Knot	N	[-0.25 -0.25 0]	Trimf
		Z	[-0.05 0 0.05]	Trimf
		P	[0 0.25 0.25]	Trimf
The distance of 2 ships	Meter	N	[-35 -35 0]	Trimf
		Z	[-5 0 5]	Trimf
		P	[0 35 35]	Trimf
The heading difference of 2 ships	Degree	OT	[-6 0 6]	Trimf
		C	[6 90 174]	Trimf
		HO	[174 180 186]	Trimf

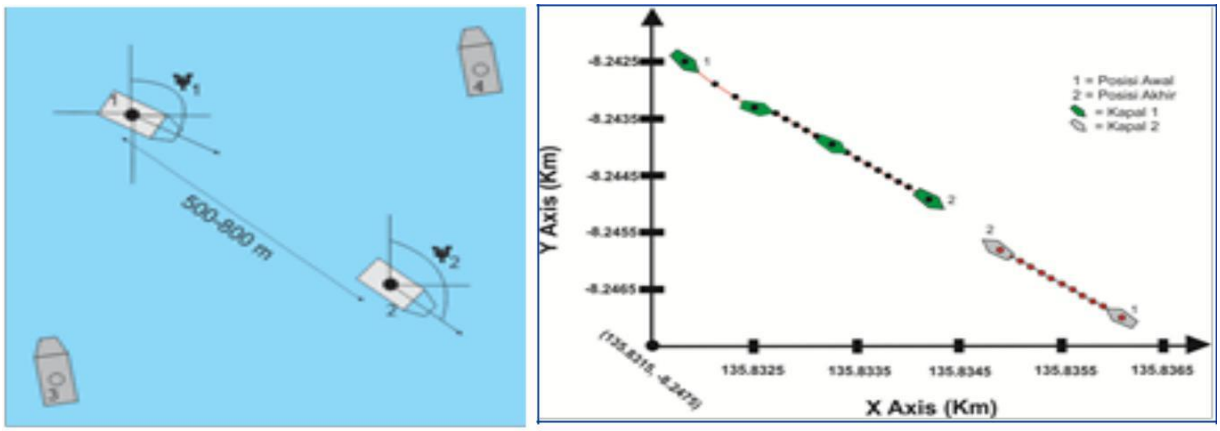
Remark: OT: *Overtake*, C: *Crossing*, HO: *Head On*, N: Negatif, Z: *Zero*, P: Positif

RESULT AND DISCUSSION

The system design is tested with some data, to ensure that the rules can provide the decision results in high accuracy. The test is performed by generating the position data of 2 vessels in region of 08°0'S 134°15'E to 09°45'S, 136°0'E. The coordinate point is area of Arafura Sea, Aru Islands. The testing data in variation as there were illegal transhipment activities. The variation values used in system testing are in many trajectories of heading, speed, and position of mother and child ships. The analysis was conducted in 4 different ship movement in transhipment patterns.

A. Testing of Fuzzy Decision Systems of Illegal Transhipment

One test was performed by providing an AIS data of two vessels. The system is able to sort the ship 1 in position -8.2418^{o}S, 135.8317^{o}E, 123^{o} heading angle, and speed of 4.4 knots. Ship 2 is in position -8.2468^{o}S, 135.8348^{o}E, 127^{o} heading angle, and speed of 3.2 knots. The prediction result of sub system selection is the Heading Difference is 4^{o} and the distance between the two vessels of 656.73 meters. The heading increment is categorized as an overtake and the distance of two ships is categorized as Medium. Both values of these variables in fuzzy selection given the possibility of illegal transhipment is 20.9%. The value less than 50% and the heading differences is 4^{o} are categorized as overtake and No Illegal Transhipment in fuzzy decision. Figure 3 (a) below shows the predicted ship motion in first test.



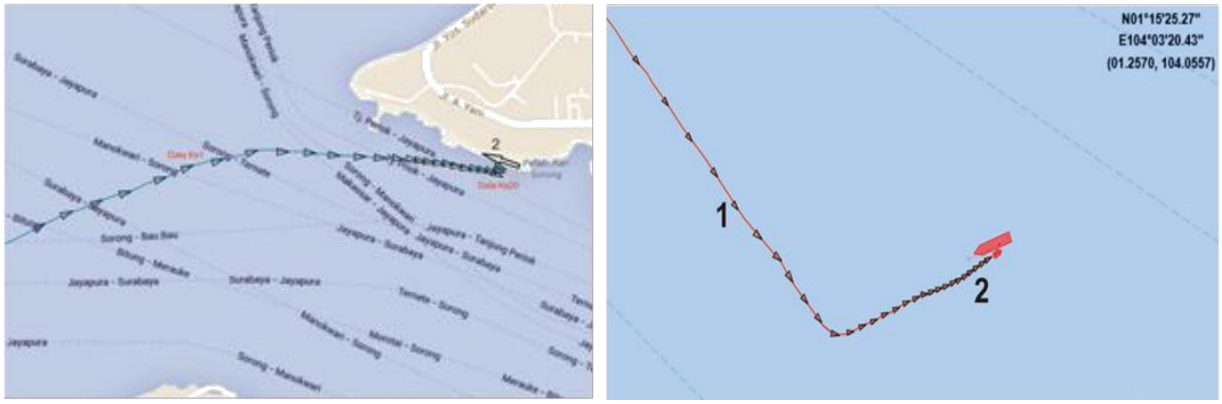
(a) (b)

Figure 4 Pattern of ship movement, (a) First Test, (b) Second Test

In the second test is done by generating data in the same area in the preveious. The speed and heading of ships in vaiuous values and different with the first test. The calculation results as follows: the difference heading of 177^{o}, the distance between the two ships is 692.88 m. The heading difference is categorized as head on, and the distance between the two vessels is categorized as medium. The result of the sub system of fuzzy prediction shows that the difference of heading is 179^{o}, the change of speed of ship 1 (mother ship) -0.15 knots, the change of speed of ship 2 (child ship) is -0.06 knots, and the change in the distance of two ships is -29.78 m. The four values as predicted results are categorized, head on, and negative for changes in speed of ship 1 and 2 (both of mother and child ship), as well as negative for the change of distance of 2 ships. The numerical value of fuzzy selection is 80.8%. The value is > 50%, then proceed by entering all fuzzy selection output variables into fuzzy decision. The result of fuzzy decision is 78.1%. From both fuzzy selection and fuzzy decision results showed that both ships are suspected of illegal transhipment.

B. Validating of Fuzzy Decision Systems of Illegal Transhipment

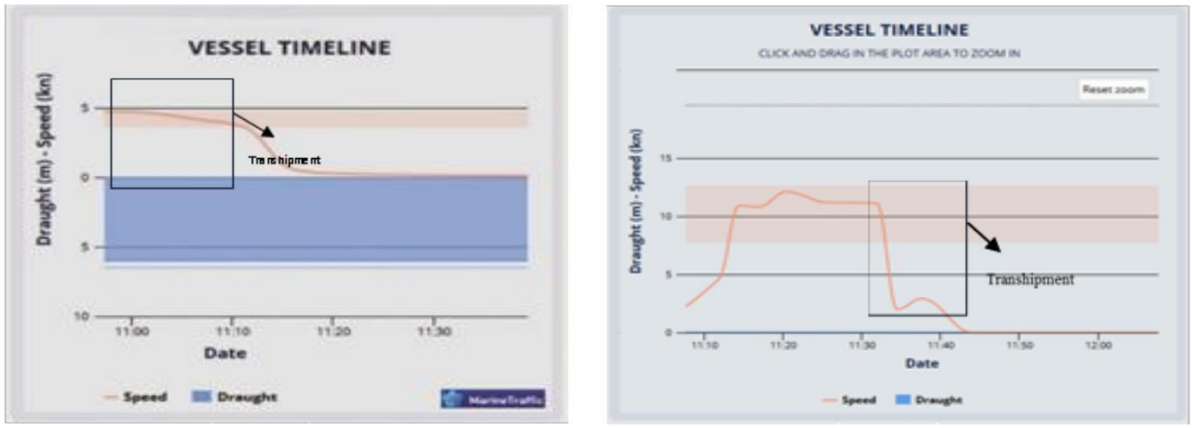
Validation is done by entering the real AIS data into the fuzzy system. The data used for validation are shipping data of Nurdic Bahari in Sorong Ports, and two shipping of Eagle Seville and Lurongyuaanyu 105 in Batam waters. Data obtained from online AIS (http://marinetraffic.com) of 30 data. The Nordic Bahari ship will conduct transhipment at Sorong ports, on April 16, 2016 at 11.00 AM to 11.15 AM. Transshipment at the port means that the port as the 2nd ship (child ship) in a state of standstill position, and Nordic Bahari as ship 1 (mother ship) will move closer to the child ship.



(a) (b)

Figure 5 The shiping real based on AIS online (a) Nordic Bahari in Sorong Port, Papua, and (b) Eagle Seavle and Lorongyanyu 105 in Batam waters.

Figure 5a shows the position of ship 1 which does not over change in the heading difference with Sorong port which is considered as ship 2. Difference of headings in this position is head on, where the difference of the previous is crossing. The ship that will perform transhipment, it is will meet in a certain distance and it have the difference heading of head on or overtake. The change in the speed of the Nordic Bahari during transhipment is shown in Figure 6a.



(a) (b)

Figure 6 Speed graphic (a) Nordic Bahari in Sorong ports (http://marinetraffic.com), (b) Lorongyuanyu 105 in Batam waters (http://marinetraffic.com)

The speed graph of ship detected on AIS per time units and it appears that there is a cycle operating in reduced of ship speed. At 11:05 AM, the position of the ship has a distance of 634.63 meters from the Sorong ports. This distance is already eligible criteria of illegal transhipment, in this case as suspected to be docked to move the goods. The calculation result is heading difference is 199^{o} or $19\ ^{o}$, the distance between two ships is 634.63 meters. The heading increment is categorized as crossing, and the distance is medium. The two values as inputs of fuzzy selection and the output of 77.1%. This value indicates the possibility of ship will commit in illegal transhipment, and can proceed to the next process of fuzzy

decision. The result of fuzzy decision is: heading of 183^{o} (Head on), speed changes of ship 1 of -0.22 knot (Negative), speed changing of ship 2 is 0 knot (Zero), and distance changing of 2 vessels is -32.57

(Negative). Based on the 4 variable values gives a numerical output of the fuzzy decision is 83.4%. The value of 83.4% indicates the suspicion of illegal transhipment, in this case it is the transfer of goods
The second validation was carried out by providing shipping data from two ships in Batam waters, that is Eagle Seville (child ship) and Lorongyanyu (mother ship) on 02 May 2016 at 11.30 AM to 11.45 AM. The Eagle Seville ships are at coordinates of Latitude and Longitude of 1.24960^{o} S, 104.0626^{o} E, ship speed of 0 knots, and heading of 261^{o}. The Eagle Seville ship has been at that point 2 since 09.30 AM. The movement of Lurongyanyu 105 is shown in Figure 5b, and the graph of speed change is shown in Figure 6b. Position 1 of Figure 5a is the position of the Lurongayuanyu ship at 11.34 AM, and 10 minutes later at 11:44 AM the ship is at position 2. The data at position 1 is used for sorting, and position 2 is 10 minutes is later later after sorting time. The data at position 2 is used for fuzzy selection of data input.
The result of the calculation of the heading difference and the distance between of Lurongyuanyu 105 (mother ship) and Eagle Seville (child ship) is the Heading Difference is 1160 (Crossing), the distance is 648.06 meters (Medium). Both of these values are used as input variables of fuzzy selection. The output of fuzzy prediction is follows: Heading is 177^{o} (Head on), the changing speed of ship 1 (mother ship) is -0.12 knot (Negative), the speed changing of ship 2 (child ship) is 0 knot (Zero) and the distance changing is -33.52 m (Negative). The output of fuzzy selection is 80.5%. This value supports the next process in fuzzy decision, and gives the numerical output of 80.6%. This value indicates that both ships are doing an illegal transhipment.

CONCLUSION

Based on the results and discussion, it can be concluded that:

1. Fuzzy logic system designed in series unit as a fuzzy selection and fuzzy decisions as a Fuzzy System to suspect of illegal transshipment incidences.
2. Fuzzy logic selection that works on the results of the calculation of two fuzzy predictors to predict in well ship movements in the later.

AKNOWLEDGEMENT

Thanks to:

1. Ministry of Research, Technology and Higher Education who has funded in the research of "Penelitian Unggulan Perguruan Tinggi" in 2017
2. NASDEC ITS, and LPPM ITS

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