IUU fishing and transhipment identification with the miss of AIS data using Neural Networks

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Abstract. Exploitation of maritime natural resources in Indonesia is still widespread. Efforts to monitor illegal fishing and transhipment practices are still less than optimal due to the limited ability of monitoring instruments. The loss of automatic identification system (AIS) data has an impact on weakness in the ship's motion monitoring system. The weakness of the system in the previous research, without regard to data losses so that in real identification of illegal fishing and transshipment, it becomes less accurate and valid. Losses data it means as missing of some the data in along ship trajectory. This research designs system integration with predictor to identify the occurrence of illegal fishing and transshipment in the presence of missing AIS data. Predictor are designed using recurrent neural networks (RNN) and system integration is designed using artificial neural networks (ANN). Predictor and system integration are simulated, tested and validated using data of real ship that committed illegal fishing and transshipment. Data achieved from the marinetrack.com and NASDEC-ITS data centers. The validation results show results from the predictor can be used as input for system integration and system integration, and it has a high accuracy.

1. Introduction
Indonesia has geographic potential in a marine area of 77% of the total area of Indonesia. This geographical potential is what makes Indonesia a maritime country. Unfortunately, in the Indonesian seas there are still many exploitations of biological resources. Illegal, unreported, and unregulated (IUU) fishing and transshipment practices are both threats and challenges that arise amidst Indonesia's fishery potential. In the current monitoring of illegal fishing and transshipment activities in Indonesia is carried out through Vessel Traffic System (VTS) at the Head Office of the Ministry of Marine Affairs in Jakarta or from the nearest port. The monitoring is based on automatic identification System (AIS) data information and a long-range radar camera. The capable of monitoring up to 40-60 kilometers, as well as monitoring cameras (CCTV) as far as 4 kilometers [1]. Indonesia's marine area is very large, but the number of monitoring fleets has not met the adequacy standard, for this it needs to be supported by technology that is able to identify shipping as IUU fishing and Transshipment categories.

The existence of AIS technology since the 1980s, as a communication system that functions for anti-collision, vessel traffic services and search and rescue. AIS can also be used to shipping monitor, and very helpful in monitoring shipping activities at sea [2]. The International Maritime Organization (IMO) made a regulation requiring every ship to install AIS equipment in 2000. AIS as an electronic
AIS is very helpful in navigation throughout the shipping. AIS also can be used to show events around the location of a ship / several ships are located [2]. Several studies in the utilization of AIS data, linking it to avoid collisions, maintain the course, etc. Several methods are offered in designing an automatic anti-collision system based on AIS data. AIS is able to provide information on the density of sea transportation, which allows collisions or navigation diversions along the busy shipping. This shows that AIS is able to support technology in e-navigation and various uses for security and safety in marine transportation [4].

Research on AIS technology with system integration to identify vessels indicated to be carrying out IUU fishing and Transshipment has been previously designed. However, in the previous research there were still weaknesses due to of AIS data available [5]. In the real conditions of illegal fishing and Transshipment occurred, there are loss of AIS data which resulted in inaccuracy and invalidity of the results of the identification of vessel movements categorized as illegal fishing and transshipment. In real conditions, sometimes we find that AIS data is missing for a long time. This becomes a serious problem if the loss of data indicates an IUU incident.

Therefore, this research was conducted to design a system integration with the addition of predictor to identify IUU fishing and transshipment with the loss of AIS data using neural networks. The use of neural networks in the design of system integration for identification. In this study neural networks are able to produce more general identification results than other expert system methods such as fuzzy logic. In the previous study, a fuzzy logic system is only able to identify based on predefined rules. In many cases fuzzy logic is unable to identify something that is outside the rules that have been set in the fuzzy logic. In contrast to neural network, which is able to produce general identification [3]. Neural networks are always able to learn new things as long as there is new data [6].

In this study, a predictor and identification system is proposed to be integrated into one system. The system has two functions, namely (i) a trajectories predictor, and (ii) identifier a shipping related to IUU. The two sub systems, namely the sub system predictor and the sub system identifier. The predictor system works when there is missing data, and the identifier system works to identify one of the following forms of events, that are: normal shipping, shipping that is categorized as an IUU fishing, and categorized as an IUU transportation.

### 2. Method

#### 2.1. Data gathering

The AIS data used are dynamic ship data and partly static data, as well as the validation data for IUU fishing and transshipment criteria obtained from NASDEC-ITS and the marinetraffic.com website. The data used for predict the longitude and latitude position, heading, and ship speed. Categorized of ship speed when casting, towing, houling, and ship position of longitude and latitude are used for identification od IUU fishing. If there are two adjacent ship data, namely the latitude, longitude, different headings and speed differences, which are used to identify IUU transshipment [5].

The block diagram of the design system drawing is shown in Figure 3. Sub system 2 of ANN selection used k-fold cross-validation technique [4]. This technique was used in the both of ANN selection and ANN decision. There are of 4515 observations the dataset, which were divided into five sets. Four sets of 80% data or 3612 observations are used to train the neural network. The remaining sets of 20% of observations or 903 observations are stored to test model performance.

In ANN decision Transshipment used of k-fold cross-validation with 4500 observations the dataset. Data divided into five sets. Four sets of 80% of observations or 3600 observations are used to train the neural network, and the remaining sets of 20% of observations or 900 observations are stored to test model performance. In ANN decision fishing design used of 4745 observations dataset, which are divided into five sets. Four sets of 80% observations or 3796 observations are used to train the neural network, and the remaining sets of 20% of observations or 949 observation are stored to test model performance. Several other studies used a percentage amount of data for training approximate 70% and
the rest of 30% for validating. The definite provisions of this comparison have not been disclosed by many previous researchers [7].

2.2. Design predictor when the losses of longitude and latitude data

Some of data are missing in time series and statistically modeled, for example Autoregressive (AR). The AR models is widely used in the real world [8]. The existence of missing data will have an impact on the predictor accuracy. As shown in Figure 3 below, there are 3 sub-systems, namely (i) predictor unit, (ii) selection unit, and (iii) identification unit. Predictors function to predict data: longitude and latitude position, direction and speed of ships, due to missing trajectory data. The selection unit is used to select data in categorized as a single data for one ship or multi-ship data. Single data will be sent to the IUU fishing identification unit, while multi-ship data will be sent to the IUU transhipment unit. The identification unit for both IUU fishing and transhipment uses recurrent neural networks (RNN).

Several algorithms were developed to get the best predictor parameters. The best parameter chosen, is the one that will result in high accuracy. The algorithm model with the highest accuracy, in follows:

- Number of LSTM layers: 1
- Number of neuron units in LSTM layers: 5
- Learning rate: 0.005

Flow chart to predict the ship position data when missing data occurs, is shown in Figure 1 below. The target parameter set is Mean Square Error (MSE), and use the Adaptive Moment Estimation (Adam) optimizer. The predictor model is trained with 100 epochs. The performance of the RNN model for predict the missing AIS latitude and longitude data is 0.055% of MAPE and time step is 2.

![Figure 1. RNN model for predicting the latitude and longitude when missing of AIS data](image)

2.3. Test and validation of heading predictors

The test and validation of predictor of illegal fishing and transhipment vessels is divided into two. In testing, the number of real data used of 10 AIS data as perpetrating illegal fishing and 10 AIS data as perpetrating illegal transhipment. RNN predictor give the results of high accuracy or MAPE value ≤ 10%, while for the speed predictor it can be said to have been successful [7].

Test of predictor of AIS heading data have been carried out, the optimal parameters are obtained which can be used to predict the missing AIS heading data. These parameters are:

- Number of LSTM layers: 1
- Number of neuron units in LSTM layers: 10
- Learning rate value: 0.1

Apart from using the above parameters, the network is trained and tested using batch size 2, in addition the input and output layers are dense layers (fully connected). The loss function used is Mean Squared Error, the optimizer used is Adaptive Moment Estimation (Adam), and the model is trained in 100
epochs. The flow chart of From the results of this training and testing, the best model is obtained for the prediction of missing AIS heading data as shown in Figure 3. The performance of the RNN model is MAPE of 8.01% and time step is 2.

**Figure 2.** RNN model for predicting the missing heading data of AIS

2.4. Design a system integration for identification (ANN selection and ANN decision)

The input and output design of the system integration for identification designed using artificial neural networks with input from the predictor output (RNN Predictor and Speed Predictor) is shown in Figure 1.

**Figure 3.** System integration block diagram for identification with input from predictor prediction results.

System integration for identification designed using artificial neural networks is divided into two subsystems, the first is ANN selection and the second is ANN decision. The input from the ANN selection is the output of the predictors, namely AIS data from two ships, in the form of a variable distance between two ships and the difference in the headings of two ships. ANN selection is used to sort vessels suspected of carrying out IUU transhipment or IUU Fishing. ANN selection output is used as input for ANN decisions which include IUU transhipment or IUU Fishing.

ANN decision is divided into two subsystems, namely ANN decision of illegal transhipment and ANN of decision illegal fishing. The input variables used in ANN decision transhipment are the difference in headings, the distance between 2 ships, and the difference in speed between the two vessels. Meanwhile, the input variables in ANN decision fishing are the speed of the ship at the time of casting, the speed of the ship during towing, the speed of the ship during hauling, the rate of change in the position of the latitude and longitude of the ship. The output of both is the result of the decision making
it is stated that they are suspected of committing IUU transhipment or IUU fishing or not carrying out the two illegal practices.

2.5. Test results of prediction AIS data
In the process of testing of prediction on illegal fishing and transhipment when the missing AIS speed data, in various of AN architectures. In some test data, both real data and generated data, it shows the characteristics of the predictors, namely the amount of error at ship speed, longitude and latitude position, as well as heading error and average speed as shown in Table 1 below. In this method, predictor works in constant time intervals.

Table 1. The characteristic of predictor

| No | Parameter system       | Value          |
|----|------------------------|----------------|
| 1  | RMSE speed             | 0.83 knot      |
| 2  | MAPE longitude (%)     | 0.00015        |
| 3  | MAPE latitude (%)      | 0.00296        |
| 4  | MAPE heading (%)       | 1.26           |
| 5  | RMSE speed (knot)      | 1.08           |

2.6. Test and validation of integration system
Integration system consist of predictor, selection and decision units. In the selection and decision units, validation of both used of k-fold cross validation. The optimal parameters in the selection and decision units are in Table 2 below, and architecture of selection unit in figure 4 (a) and (b).

Table 2. The characteristic of selection and decision units

| Parameter Design | Selection Unit | Decision Unit of IUU Transhipment | Decision Unit of IUU Fishing |
|------------------|----------------|-----------------------------------|-----------------------------|
| Number of hidden layers | 1              | 1                                 | 1                           |
| Number of neurons in hidden layer | 10             | 10                                | 5                           |
| Activation function | rectified linear unit (ReLU) in input and hidden layer, sigmoid in the output layer | rectified linear unit (ReLU) in the input layer and hidden layer, sigmoid in the output layer | rectified linear unit (ReLU) in the input layer and hidden layer, sigmoid in the output layer |
| Optimizer        | adaptive moment estimation (Adam) | adaptive moment estimation (Adam) | adaptive moment estimation (Adam) |
| Learning rate    | 0.01           | 0.005                             | 0.001                       |
| Number of epochs | 100            | 100                               | 100                         |
Figure 4. ANN of (a) selection unit, (b) Identification unit of IUU transhipment and (c) Identification of IUU fishing

The system integration that has been designed is tested with a various of ship motion patterns that have been generated. The generation of data on the position of two vessels to test the movement patterns of illegal transhipment. In variety data of heading, speed and position of ships are input of system. Testing is done to see whether the system designed is in accordance with the desired target. In testing the movement of illegal fishing vessels is carried out by varying of pattern in casting, towing, hauling, and rate of change of latitude and longitude. The result of system will identify of trajectory pattern in illegal fishing vessels or not.

Validation is done to test whether the system that has been designed can be said to be valid or appropriate. Validation for the occurrence of illegal transhipment is carried out using system input in the form of ship speed data at the port and changes in ship position in previous studies. The ship's AIS real data is obtained from the marinetrack.com website, namely Nordic Bahari ship data. This approach is carried out with the assumption that a port is a ship stationary in the middle of the sea waiting for another ship to carry out a transhipment. The validation data is a ship berthed at the port of Sorong, Papua on April 16, 2016 at 11.00 West Indonesia Time (WIT) until April 16, 2016 at 11.15 WIT. The second validation data is AIS data on the Eagle Seville and Lurongyuanyu 105 ships in Batam Waters on 02 May 2016 at 11.30 WIB until 02 May 2016 at 11.45 WIB.

Validation for the occurrence of illegal fishing is carried out using system input in the form of ship speed data in the Singapore Strait, fishing vessel 1 on August 21, 2017 at 02.40 WIB until August 21, 2017 at 05.15 WIB. The second validation data is AIS data from fishing vessel 2 on 21 September 2017 at 06.43 WIB until 21 September 2017 at 10.45 WIB. The ship's AIS real data was obtained from NASDEC-ITS, as many as hundreds of data, and already sorted when there was indication of illegal fishing. This approach is taken because the ship has a motion pattern that is exactly the same as the cantrang, which is to make a circular motion. The validation data is real AIS data from vessels caught in illegal Transhipment and illegal fishing.

3. Results and discussion
Several tests were carried out for AIS data on fishing vessels sailing in the Singapore Strait area. The ship's starting position is at a1 and the end point - stops at a20. The ship makes the movement through the closed trajectory, and returns through the starting position on a1 until it stops at a20. It is assumed that data is missing for areas a4 to a9, as well as at a12 to a1. The series data, are as follows (Latitude - L, Longitude - B, Heading - Ψ, Speed - U) in unit of (°, °, °, knot) that are: a1 = (103.78357; 1.18565; 266;
0.6), \(a_2 = (103.78050; 1.18559; 267; 0.6)\), \(a_3 = (103.77229; 1.18592; 275; 0.6)\), \(a_4 = (103.76632; 1.18667; 277; 0.6)\), \(a_9 = (103.74566; 1.18925; 141; 0.6)\), \(a_{10} = (103.75596; 1.18288; 110; 0.6)\), \(a_{11} = (103.75857; 1.18214; 91; 0.6)\), \(a_{12} = (103.76138; 1.18225; 83; 0.6)\), \(a_{17} = (103.78396; 1.18568; 70; 0.6)\), \(a_{18} = (103.78951; 1.18568; 78; 0.6)\), \(a_{19} = (103.79813; 1.18921; 82; 0)\).

The illustration of the presence of missing data is shown in Figure 5 (a) below. The presence of missing data in Figure 5, assuming it is replaced by 4 data. The predictive trajectory pattern is shown in Figure 5.b.

The results of the ship trajectory prediction are shown by the position, heading and speed of the ship as follows, \(a_5 = (103.7646; 1.1868; 277.53; 0.6)\), \(a_6 = (103.7655; 1.1869; 277.72; 0.6)\), \(a_7 = (103.7664; 1.1868; 278.25; 0.6)\), \(a_8 = (103.7669; 1.1868; 279.07; 0.6)\), \(a_{13} = (103.7603; 1.18568; 77.86; 0.6)\), \(a_{14} = (103.7611; 1.1823; 73.40; 0.6)\), \(a_{15} = (103.7618; 1.1824; 74.70; 0.6)\), \(a_{16} = (103.7629; 1.1824; 75.9; 0.6)\). Figure 5 (c) shows the real trajectory pattern based on AIS data.

Several tests were carried out on: 30 illegal fishing data and 30 illegal transhipment which be generation patterns. The accuracy was very high, that is 90.3% of IUU transhipment and 89.9% of illegal fishing identification.

4. Conclusions

This study presents the design of system integration with predictor has successfully identified the motion patterns of vessels that do not perform and perform IUU transhipment and fishing, even with the loss of AIS data. The system integration for identification is divided into 2 subsystems, namely, ANN selection for sorting two vessels, and ANN decision as the final identification whether the vessels practice IUU fishing or transhipment. The predictors for the prediction of missing AIS data are divided into 2 subsystems, namely, the RNN predictor for predict the missing AIS longitude, latitude, and heading data of illegal fishing and transhipment vessels, and speed predictors for predict the missing AIS speed data of illegal fishing and transhipment vessels.

This study also demonstrated the ability of Recurrent Neural Networks (RNN) to effectively predict the missing of AIS data and the ability of Artificial Neural Networks (ANN) to effectively identify the motion patterns of vessels. The pattern of in a normal trajectory or in do not perform and in IUU transhipment and fishing.

Acknowledgement

Thank you to Ministry of Education and Culture for funding of this research, and also to Directorate of Research and Community Services ITS.

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