Inference System of Collision Risk Index based on Ship Near-Collision Data via Multilayer Perceptron

13th November 2019

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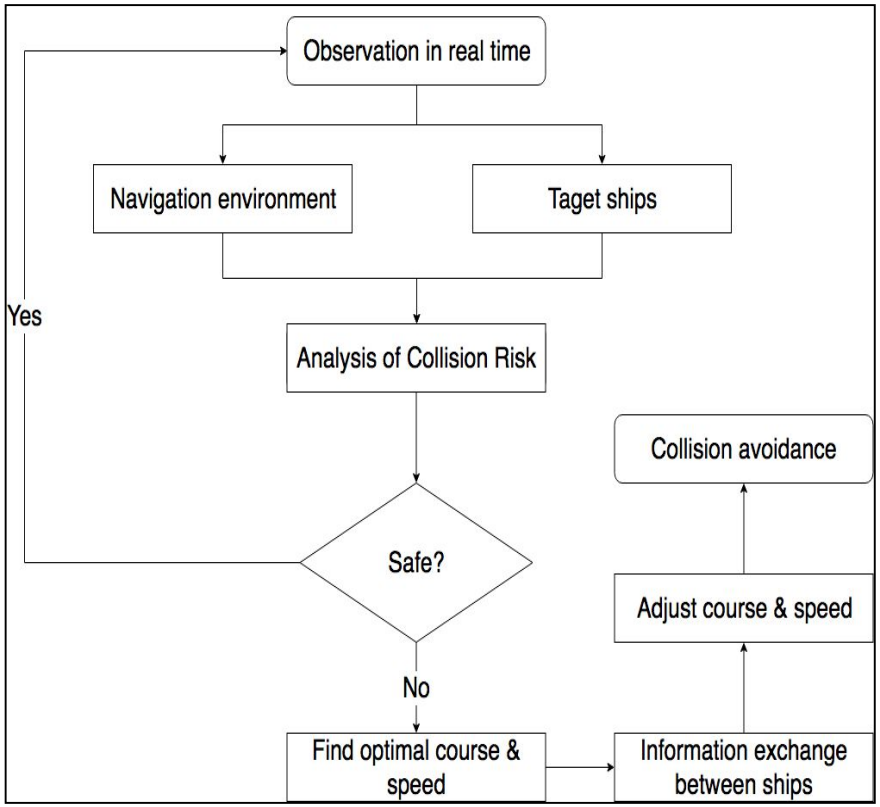
Outline

1. Background and Purpose

Background

According to statistic investigation Korean Maritime Safety Tribunal (KMST), *approximately 80% of collision accidents at sea have reported in result of human errors.*

Procedure for collision avoidance



i. Detects target ship or obstacles, and assess the collision risk

ii. Establish a navigation plan on the basis of the calculated collision risk and environmental factors

iii. execute a control command to perform the planned navigation based on the collision risk

1. Background and Purpose

Review of COLREGs

- ***Risk of Collision in the COLREGs***

(a) Every vessel shall use ***all available means appropriate*** *to the prevailing circumstances and conditions to determine if risk of collision exists. If there as any doubt such risk shall be deemed to exist.*

(b) Proper use shall be made of ***radar equipment*** *if fitted and operational, including long-range scanning to* ***obtain early warning of risk of collision*** *and* ***radar plotting or equivalent systematic observations of detected objects.***

Based on DCPA & TCPA

Fuzzy Inference system (FIS)

- ***Hasegawa K et al. (1989)*** *connected DCPA and TCPA to the collision risk via interviews of navigator.*
- ***Lee and Rhee (2001)*** *used dimensionless DCPA and TCPA with ship length and velocity.*
- ***Kim et al. (2001)*** *added VCD(Variance of Compass Degree) into input parameter proposed by Lee and Rhee.*
- ***Ahn et al. (2012)*** *suggested the FIS considering ship's characteristic in virtual navigation situation on simulator without interviews of navigator.*
- ***Namgung et al. (2019)*** *proposed the FIS by using near-collision data via ANFIS (Adaptive Neuro Fuzzy Inference System).*

- *COLREGs : International Regulation for Preventing Collision at Sea*
- *DCPA : Distance of the Closest Point of Approach, TCPA : Time to the Closest Point of Approach*

1. Background and Purpose

Studies on the basis of FIS

- ***Son and Kim (2012)*** *designed an estimation algorithm of the collision risk among approaching multiple ship by using FIS.*
- ***C. Bukhari et al. (2013)*** *proposed an evaluation algorithm of the collision risk in order that VTSO (Vessel Traffic Service Operator) was able to analyze the collision risk among ships in advance.*
- ***Son and Kim (2018)*** *validate an autonomous collision avoidance system of MASS based on FIS on the sea trial test.*
- ***Namgung et al. (2018)*** *used the FIS as a point of time for creating and sending a navigation intention message from MASS to manned ship.*

Problems

- ***The existing FIS still have significant limitations***.

  - membership functions and rules were determined by virtual simulation result on based of interviews.

  - it did not reflect characteristics of original information before converting DCPA and TCPA.

1. Background and Purpose

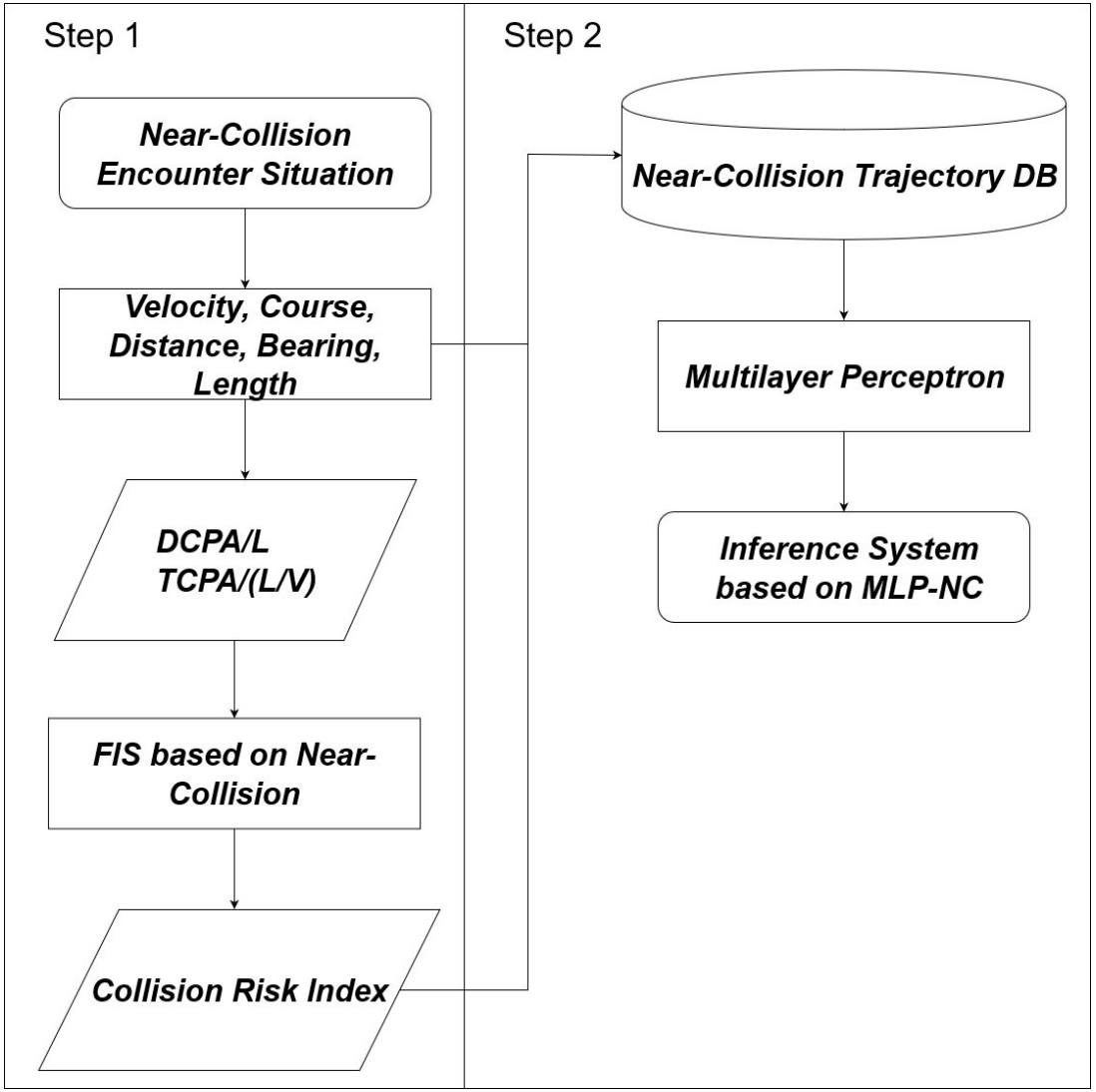
Procedure for development of inference system based on near-collision via MLP

Step 1

- *CRI (Collision Risk Index) was obtained through the FIS-NC proposed by Namgung et al.(2019) by using DCPA and TCPA converted from near-collision data*

Step 2

- *Original information (i.e., velocity, course, distance, bearing, length) was used as input vectors, and CRI occurred at this time were used as target vectors*
- *Inference system of the CRI by learning based on MLP*



2. Related work

Application of ship safety domain (1/2)

- *The number of real collision accidents between ships was not enough in many sea area so that it was very difficult to verify a model for assessing the probability of the collision risk based on previous marine accidents.*
- *Therefore, near-collision, which was a situation in which there was the danger of collision between ships approaching each other, but with no collision eventually occurring.*

  - ***Wu, X. et al. (2016)*** *made use of near-collision data extracted from the ship domain(Fujji, J. and Tanake, K.) for analyzing of safe navigation criterion.*
  - ***Van Westrene, F. and J. Ellerbroek (2017)*** *collected near-collision data by examining violation of circular or elliptical ship's domains (Fujji, J. and Tanake, K.).*
  - ***Szlapczynski, R (2018)*** *constructed a ship domain for detection of the near-collision.*
  - ***Namgung et al. (2019)*** *decided near-collisions as criteria when ship domains(Fujji, J. and Tanake, K.) were overlapped.*

2. Related work

Application of ship safety domain (2/2)

- *In this study, near collision was determined by applying the ship domain(Fujji, J. and Tanake, K.) to encounter ships.*
- *Ship's trajectory data for designing of inference system were extracted until ship domain were overlapped.*

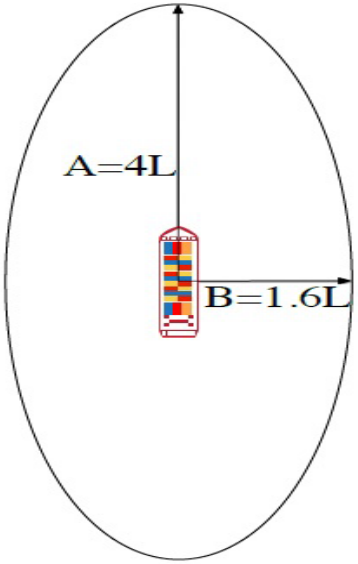


Figure. Ship domain

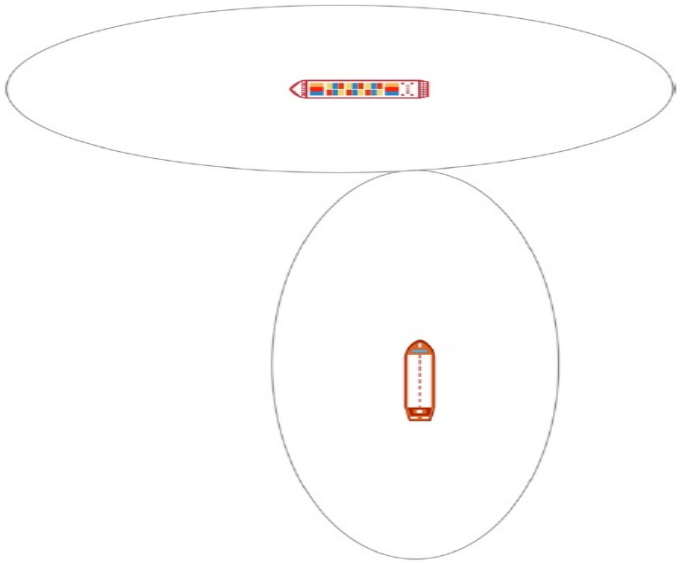


Figure. Near collision situation between ship's ellipse dimensions

** Length : ' L'*

2. Related work

FIS-NC

- *Membership function of DCPA/L, TCPA/(L/V), where 'L' is a length of ship and 'V' is a ships velocity.*
- *The CRI (Collision Risk Index) can be expressed from 0.0 to 1.0.*
- *Variables used Collision, Danger, Threat, and Attention.*
- *When the CRI exceed more than 0.33, give-way vessel must take an action for collision avoidance.*
- *In case of stand-on vessel, a point of time for collision avoidance is when the CRI is more than 0.66.*

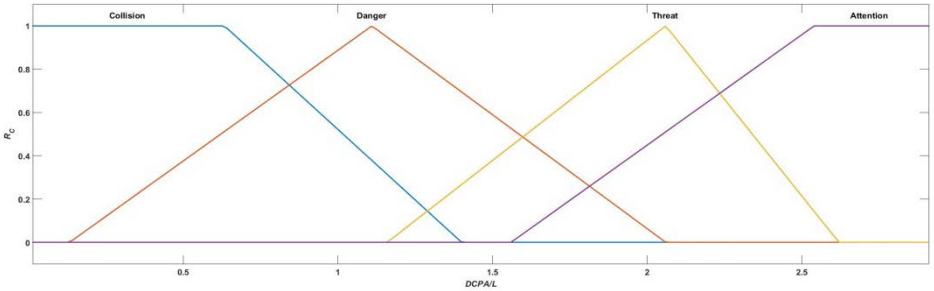


Figure. Membership function of DPCA/L

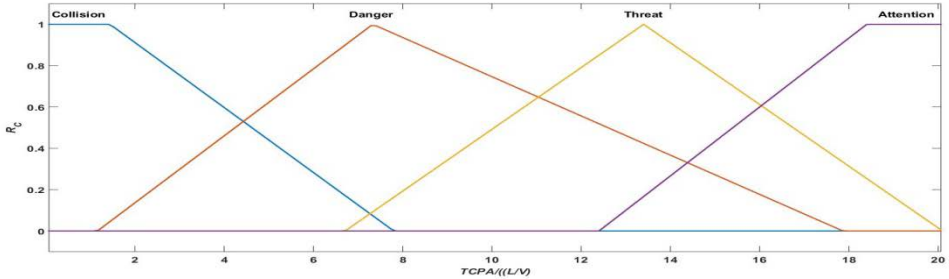


Figure. Membership function of TPCA/(L/V)

Table. FIS-NC table

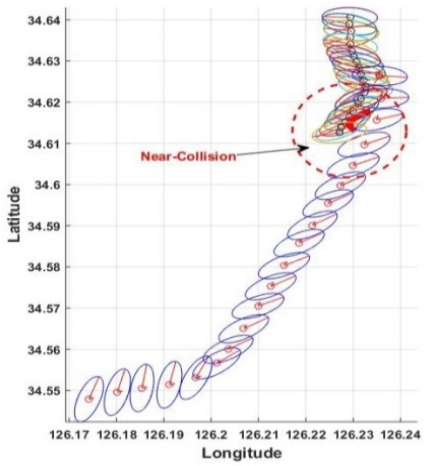
Division		DCPA/*L*			
		Collision	Danger	Threat	Attention
TCPA/(*L*/*V*)	Collision	0.994	0.773	0.477	0.021
	Danger	0.777	0.662	0.401	0.017
	Threat	0.395	0.423	0.335	0.015
	Attention	0.062	0.246	0.152	0.011

** FIS-NC : Fuzzy Inference System based on Near Collision*

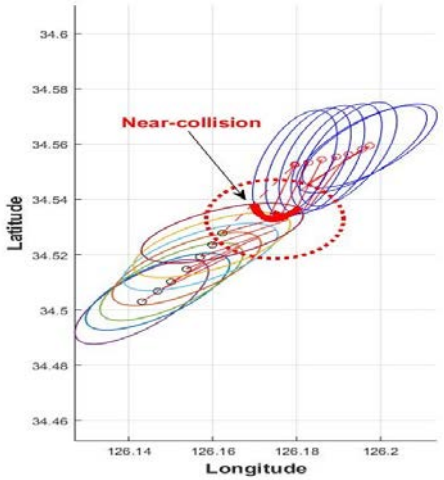
3. Inference System of Collision Risk

Ship's trajectory data based on near-collision

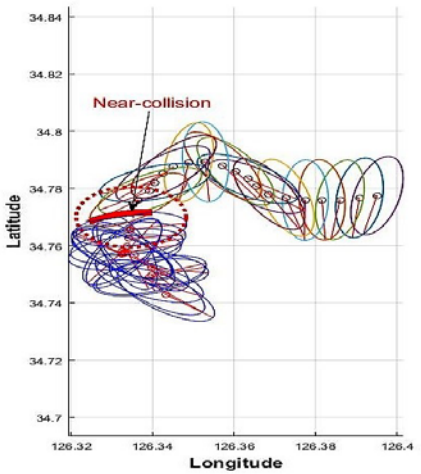
- *By applying the ship domain to both ships, ship trajectory was extracted when overlapped.*
- *Data was obtained from the beginning of the collision risk to the near collision.*
- *To collect trajectory data of near collision, we observed encounter ships navigating at Mokpo sea area during 24 hours with AIS (Automatic Identification System).*
- *83 ships out of total 137 ships had encounter situation, at this time, a total of near collision accidents occurred was 46.*
- *The total number of extracted trajectory data was 4264.*



[Crossing situation]



[Head-on situation]

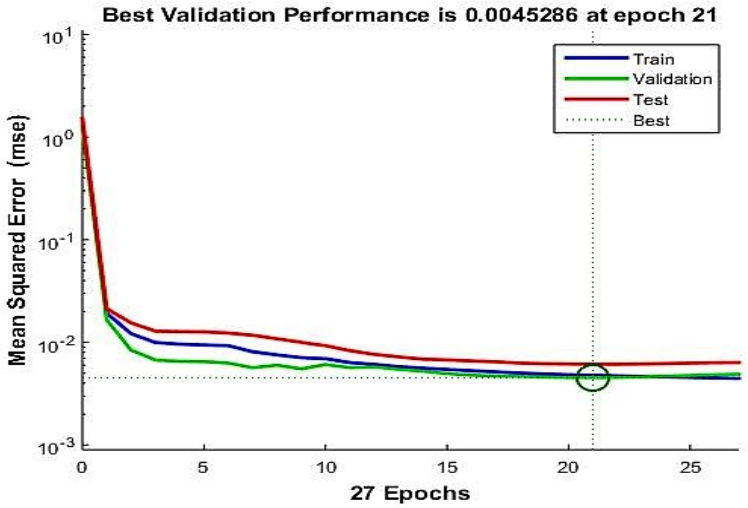


[Overtaking situation]

3. Inference System of Collision Risk

Learning result (1/2)

- *MLP is an information processing method derived from the learning data. It is composed of an input layer, one or more hidden layer(s) and an output layer.*
- *Out of the total number of 4264, input vector (own ship's velocity, target ship's velocity, own ship's course, target ship's course, bearing between own ship and target ship, distance between own ship and target ship) and output vector (CRI) extracted from when being near collision.*
- *70% of the total data was selected for training step, 15% for validation step, and 15% for test step.*



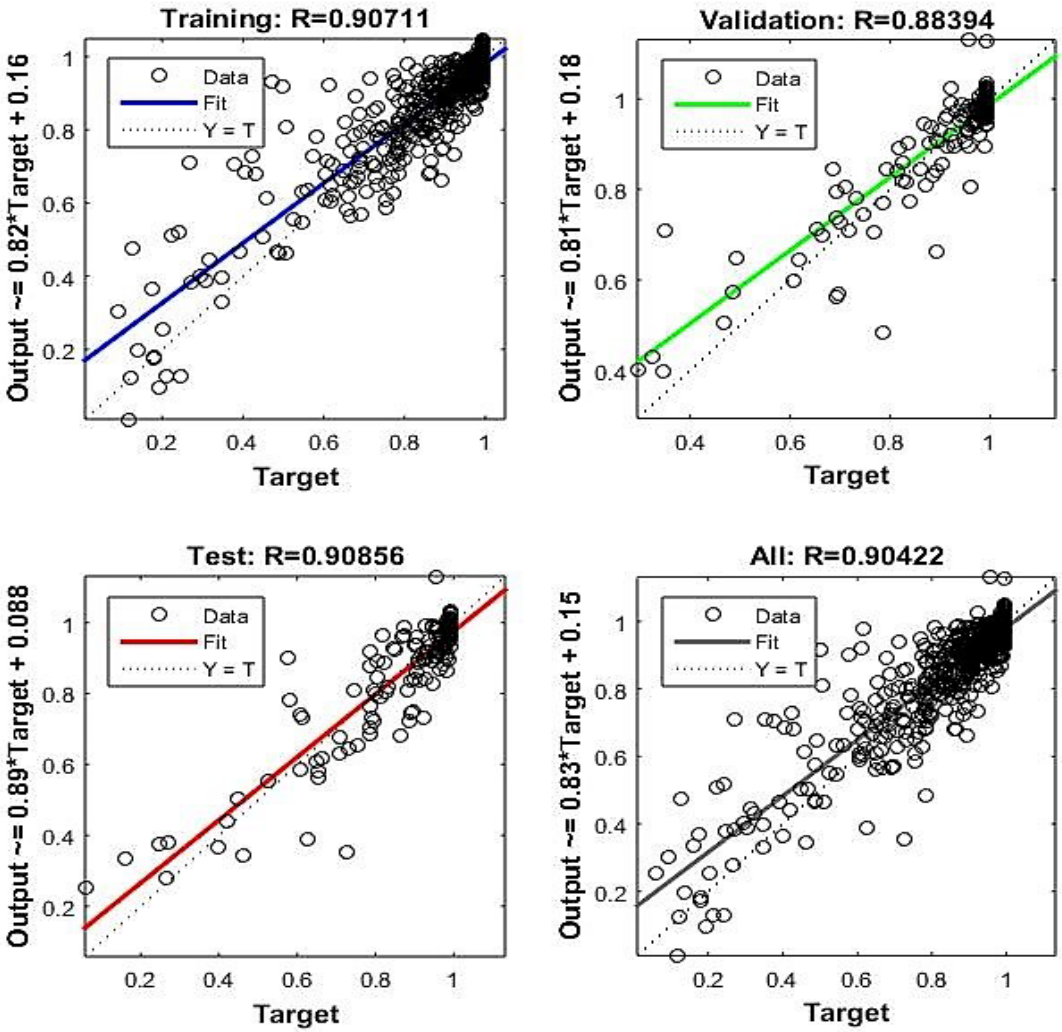
[Best validation performance in MLP]

- *It was worth mentioning that model training keeps going as long as the error of the network on the validation vector was reducing. In addition, the analysis stop point was equal to 27, i.e. 6 error repetitions after the epoch with the best validation performance (i.e., epoch 21).*

3. Inference System of Collision Risk

Learning result (2/2)

- *The following regression plots display the network outputs with respect to targets for training, validation, and test sets.*
- *For a perfect fit, the data should fall along a 45 degree line, where the network output are equal to the targets.*
- *The fit was reasonably good as average R values (correlation coefficient) of all datasets as 0.90.*

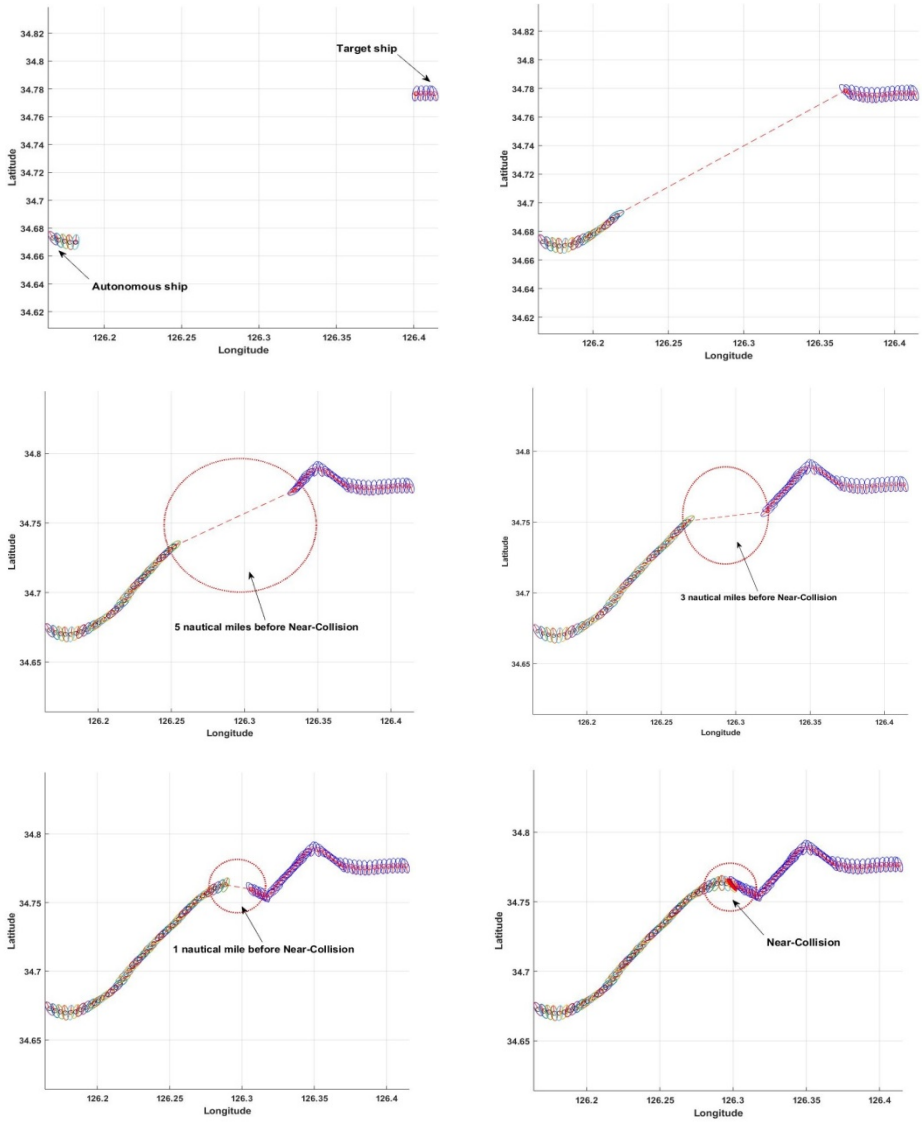


[Regression of training, validation, test, and all subset in M

4. Simulation Result

Results (1/2)

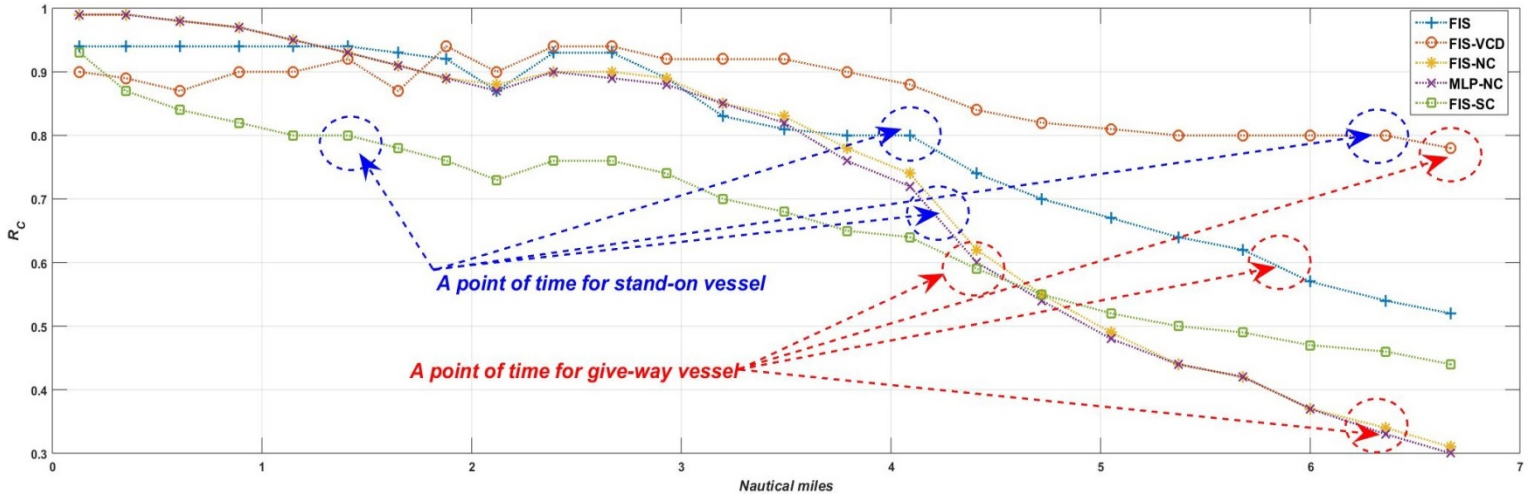
- *In order to demonstrate the performance of the inference system based on MLP, the existing system were used for comparison of the result values.*



[Near collision by encounter situation]

4. Simulation Result

Results (2/2)



[Comparison of the CRI by each inference system according to nautical miles]

- *The CRI calculated by inference systems except on FIS and FIS-VCD was continuously increases until a near collision situation.*
- *According to the "A guide to the collision avoidance rules (cockcroft, A. N.)", ship should take an action for collision avoidance within 2 to 3 nm of minimum distance.*
- *A give-way vessel using the FIS, FIS-VCD, FIS-SC, FIS-NC, and MLP-NC can obtain outer distance 2 to 3nm.*
- *In case of a stand-on vessel, FIS-SC did not obtain the requested distance.*

** FIS proposed by Lee and Rhee (2001), FIS-VCD proposed by Kim et al. (2001), FIS-SC proposed by Ahn et al. (2012), FIS-NC proposed by Namgung et al. (2019)*

5. Conclusion

- *To solve limitations of Fuzzy Inference System, Following procedure has been conducted.*

  (i) The CRI was obtained through the FIS-NC by utilizing ship near-collision data

  (ii) Original information and the CRI were designated as input vector and target vector

  (iii) inference system via MLP was developed by learning the input vector and the target vector

- *As a result of performance validation, MLP-NC expressed the various CRI for taking an action for collision avoidance according to NM.*
- *However, it did not reflect weather condition, ship size, congestion of navigation area, and so on.*
- *In further study, it is required to improve and validate the inference rule of the CRI taking consideration into drawbacks.*

Thank you for your attention!

Q&A