Development of Solution for Safety and Optimal Weather Routing of a Ship

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Abstract : *When a ship sails on sea, it may be influenced by the environmental disturbance such as wind, wave, sea surface temperature, etc. These affect on the ship's speed, fuel consumption, safety and operating performance. It is necessary to find the optimal weather route of a ship to avoid adverse weather conditions which can put the crews in serious danger or cause structural damage to the vessel, machinery, and equipment. This study introduced how to apply A* algorithm based on sea trial test data for determining the optimal ship routes. The path cost function was modelled as a function of minimum arrival time or minimum energy depending on the time of various environment conditions. The specially modelled path-cost function and the safety constraints were applied to the A* algorithm in order to find the optimal path of the ship. The comparison of ship performances estimated by real sea trial's path and estimated optimal route during the voyage of the ship was investigated. The result of this study can be used to create a schedule to ensure safe operation of the ship with short passage time or minimum energy. In addition, the result of this study can be integrated into an on-board decision supporting expert system and displayed in Electronic Chart Display and Information System (ECDIS) to provide all the useful information to ship master.*

Keywords : *A* algorithm, Optimal Route, Ship Safety, Sea Trial Test, Path-Cost*

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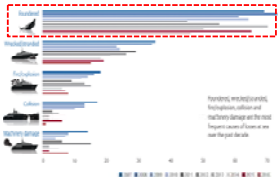
Introduction

Background

- When the ship sails on the sea, it will be influenced by environmental disturbance such as wind, wave, current, ice,…
  - These affects on the ship's speed and fuel consumption, safety and operating performance.
- The optimal weather routing of a ship
  - is the process of determining the best route of oceangoing under different ship characteristic and weather circumstances.

Rena losing container in rough weather in 5th October, 2011


<Causes of total shipping losses from 2007 to 2016>

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Previous works

- Hagiwara, 1989
  - Modified isochrones method
- Padhy et al. 2008; Takashima et al., 2009
  - Dijkstra's algorithm
- Wei et al., 2012
  - A new forward three-dimensional dynamic programming (3DDP)
- Lin et al., 2013
  - Three-dimensional modified isochrones (3DMI)
- Nguyen et al., 2016
  - Study on the optimal weather routing of a ship considering parametric rolling, slamming and deck wetness, PRADS.
- Yoon et al., 2017
  - Optimal Weather Routing considering Seakeeping Performance based on the model test, TransNav.

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OWRSU

Optimal Weather Routing Setting Unit (OWRSU)

- a sub-module in the navigation supporting expert system of Voyage Helper program.

Concept of a navigation supporting expert system

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OWRSU

❖ Structure of OWRSU

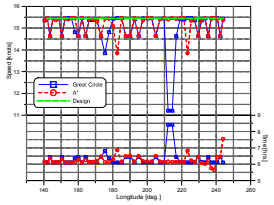
- Dynamic environment condition
  - ➢ The data set of weather forecasts is updated every 12 hours and is obtained from SAS.

Result

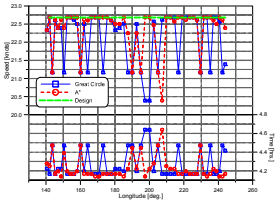
❖ Case 1: Constant power

Comparison minimize arrival time of two ships

Ship Type	Algorithm	ETA [hours]	Time saving ratio[%]
KCS	GC	211.4	-
	A*	214	1.23
KVLCC2	GC	315.9	-
	A*	310.5	1.71



<Speed and voyage time at each node in case of KVLCC2>



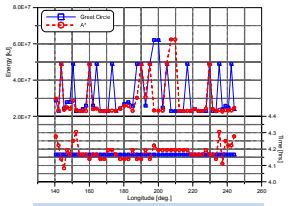
<Speed and voyage time at each node in case of KCS>

Result

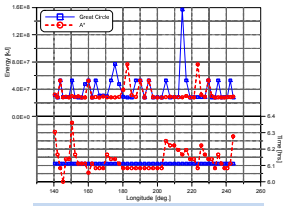
❖ Case 2: Constant speed

Estimated energy consumption of two ships

Ship type	Algorithm	ETA [hours]	Energy [kJ]	Energy saving ratio[%]
KCS	GC	208.3	1957000000	-
	A*	209.2	1661000000	15.13
KVLCC2	GC	305.5	1615000000	-
	A*	306.7	1433000000	11.27



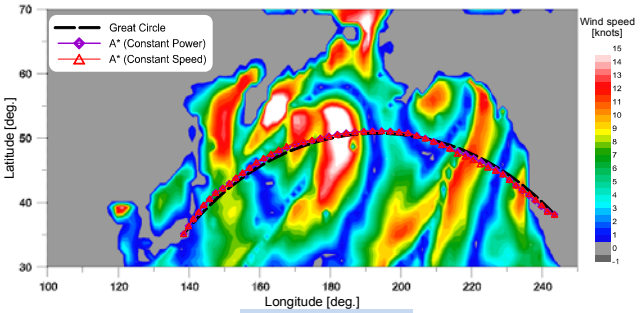
<Estimated energy consumption and voyage time at each node in case of KCS>



<Estimated energy consumption and voyage time at each node in case of KVLCC2>

Result

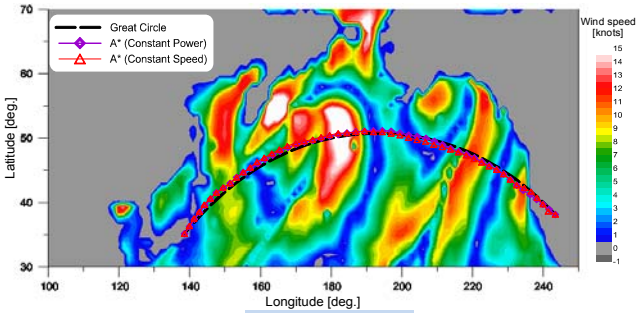
❖ Scenario 1



<Optimal routing in case of KVLCC2>

Result

❖ Scenario 2

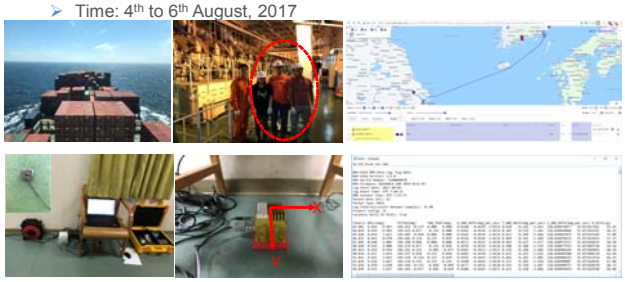


<Optimal routing in case of KCS>

Result

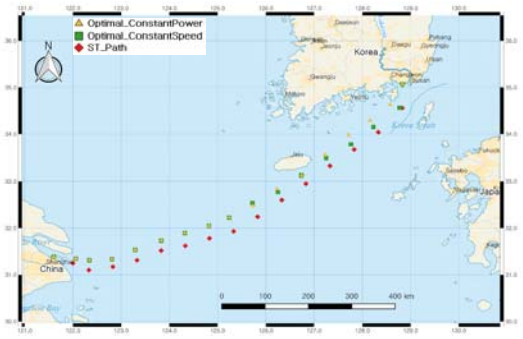
❖ Sea trial

- was conducted to verify VoyageHelper program
  - ➢ Hyundai Brave belongs to Hyundai Merchant Marine (HMM).
  - ➢ Time: 4th to 6th August, 2017



Result

❖ Scenario 3



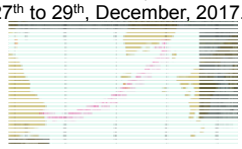
Commercial contribution

❖ Integration's result

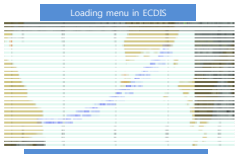
(ECDIS: Electronic Chart Display and Information System)

- was done by MECys Maritime Electronics Company and Changwon National University in 27th to 29th, December, 2017.

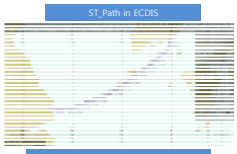
Loading menu in ECDIS



ST_Path in ECDIS



Optimal route (Constant power) in ECDIS



Optimal route (Constant speed) in ECDIS

Conclusion

❖ The concluding remarks are as follows:

- An optimization method with avoiding hazard situations has been proposed by using the A* algorithm to a ship master.
- The validation of the capability of the A* algorithm was investigated using real weather conditions and sea trial's data.
- It is clear that A* algorithm is efficient to find the optimal route based on minimum arrival time, minimum energy and safe operation of a ship.
- This algorithm can provide quick results when looking for the optimum route.
- This study will can be used for commercially contribute to the development of the ship navigation system.