# 극지 운항 선박을 위한 항로 계획 방법 연구

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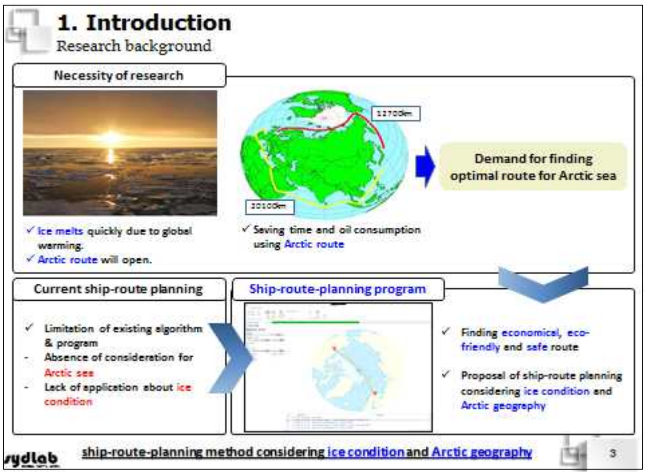
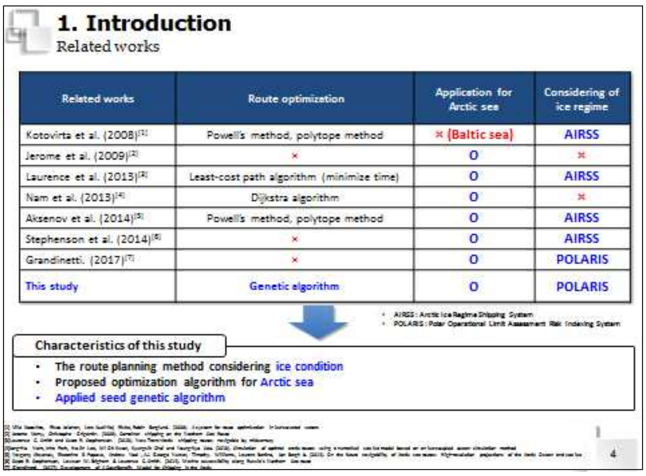
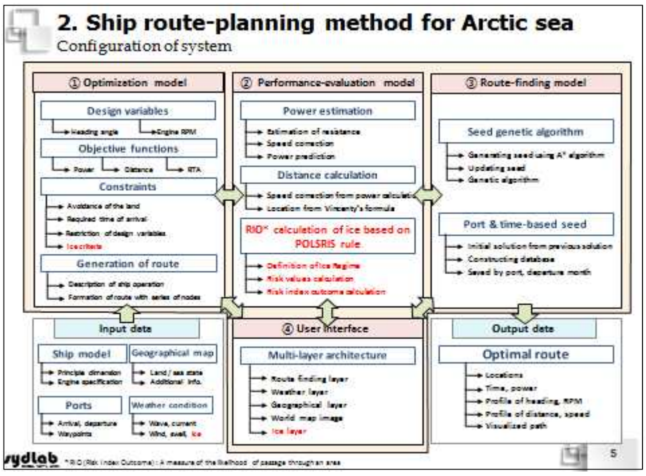
**요 약** : 지속되는 지구 온난화 현상으로 인해 해빙 속도가 가속화되면서, 북극 항로 활용의 필요성이 증가하고 있다. 본 연구에서는 북극해의 지형과 해빙 상태를 모두 고려한 최적 북극 항로 계획 방법을 제안하였다. 먼저, 연료 소모량을 최소화하는 항로를 탐색하기 위해 북극 항로 계획을 각종 지표를 전산화한 최적화 문제로 정식화하였다. 또한, 해빙을 고려하기 위해 POLARIS 규정을 고려한 선박의 운항 제약 조건을 추가하였다. 제안된 방법을 이용해 최적 북극 항로를 탐색한 결과, 안전하고 경제적인 항로를 도출할 수 있음을 확인하였다.

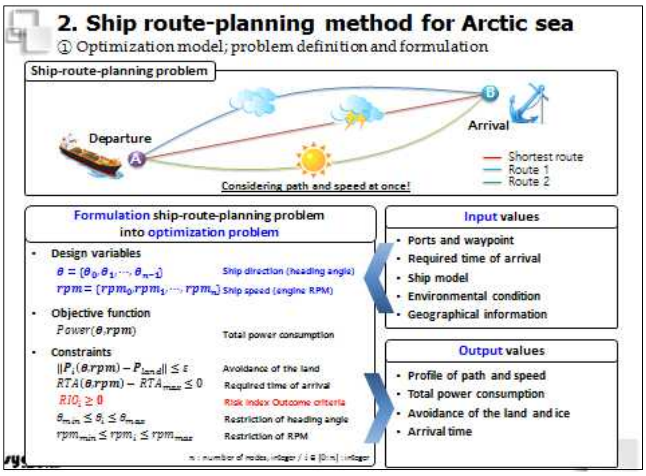
**핵심용어** : 항로 계획, 북극해, POLARIS




| Related works | Route optimization | Application for Arctic sea | Considering of ice regime |
|---|---|---|---|
| Kotovirta et al. (2008)[1] | Powell's method, polytope method | × (Baltic sea) | AIRSS |
| Jerome et al. (2009)[2] | × | O | × |
| Laurence et al. (2013)[3] | Least-cost path algorithm (minimize time) | O | AIRSS |
| Nam et al. (2013)[4] | Dijkstra algorithm | O | × |
| Aksenov et al. (2014)[5] | Powell's method, polytope method | O | AIRSS |
| Stephenson et al. (2014)[6] | × | O | AIRSS |
| Grandinetti. (2017)[7] | × | O | POLARIS |
| This study | Genetic algorithm | O | POLARIS |

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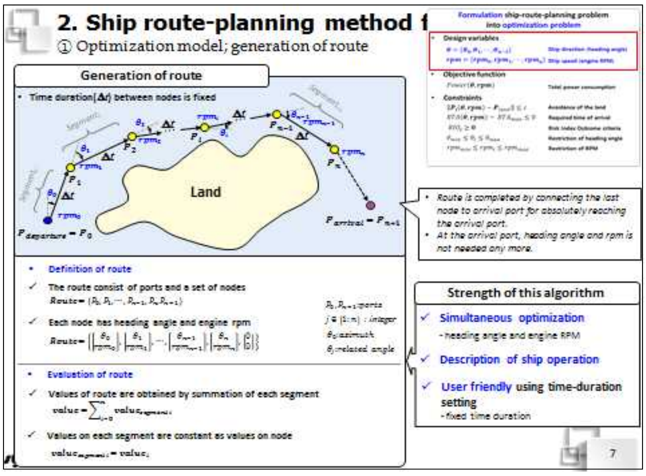
2. Ship route-planning method f
① Optimization model; generation of route
Generation of route
Time duration(Δt) between nodes is fixed
Land
Definition of route
The route consist of ports and a set of nodes
Each node has heading angle and engine rpm
Evaluation of route
Values of route are obtained by summation of each segment
Values on each segment are constant as values on node
Formulation ship-route-planning problem into optimization problem
Design variables
Objective function
Constraints
Route is completed by connecting the last node to arrival port for absolutely reaching the arrival port.
At the arrival port, heading angle and rpm is not needed any more.
Strength of this algorithm
Simultaneous optimization
- heading angle and engine RPM
Description of ship operation
User friendly using time-duration setting
- fixed time duration
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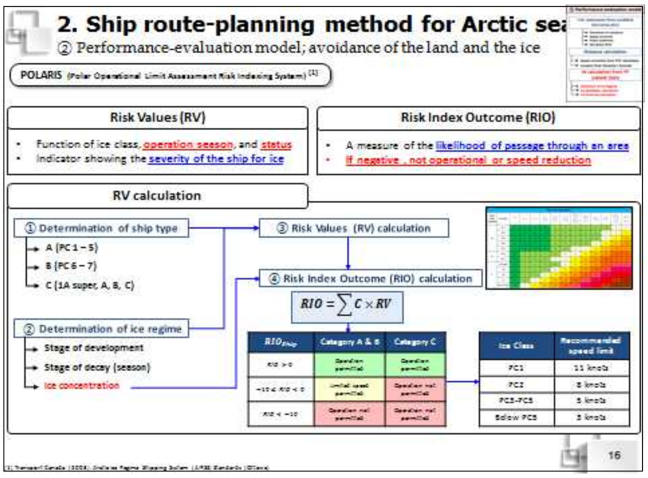
2. Ship route-planning method for Arctic sea
② Performance-evaluation model; avoidance of the land and the ice
POLARIS (Polar Operational Limit Assessment Risk Indexing System) [1]
Risk Values (RV)
Function of ice class, operation season, and status
Indicator showing the severity of the ship for ice
Risk Index Outcome (RIO)
A measure of the likelihood of passage through an area
If negative, not operational or speed reduction
RV calculation
① Determination of ship type
A (PC 1 – 5)
B (PC 6 – 7)
C (1A super, A, B, C)
② Determination of ice regime
Stage of development
Stage of decay (season)
Ice concentration
③ Risk Values (RV) calculation
④ Risk Index Outcome (RIO) calculation
RIO = ∑ C × RV
Category A & B
Category C
Ice Class
Recommended speed limit
PC1
11 knots
PC2
8 knots
PC3-PC5
5 knots
Below PC5
3 knots
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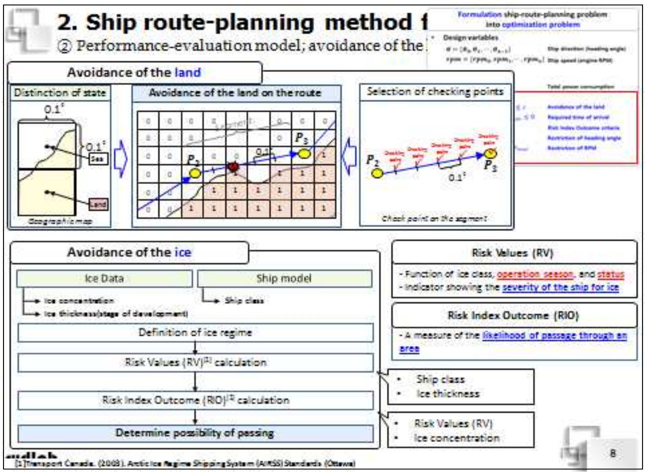
2. Ship route-planning method f
② Performance-evaluation model; avoidance of the
Avoidance of the land
Distinction of state
Avoidance of the land on the route
Selection of checking points
Geographic map
Check point on the segment
Avoidance of the ice
Ice Data
Ship model
Ice concentration
Ice thickness(stage of development)
Ship class
Definition of ice regime
Risk Values (RV)[1] calculation
Risk Index Outcome (RIO)[1] calculation
Determine possibility of passing
Risk Values (RV)
- Function of ice class, operation season, and status
- Indicator showing the severity of the ship for ice
Risk Index Outcome (RIO)
- A measure of the likelihood of passage through an area
Ship class
Ice thickness
Risk Values (RV)
Ice concentration
[1] Transport Canada. (2003). Arctic Ice Regime Shipping System (AIRSS) Standards (Ottawa)
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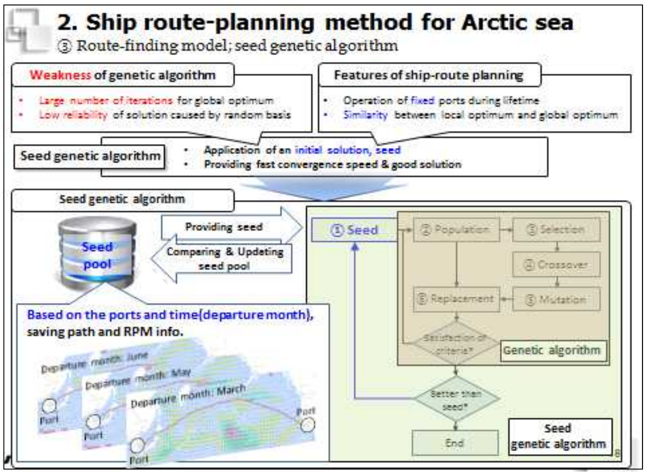
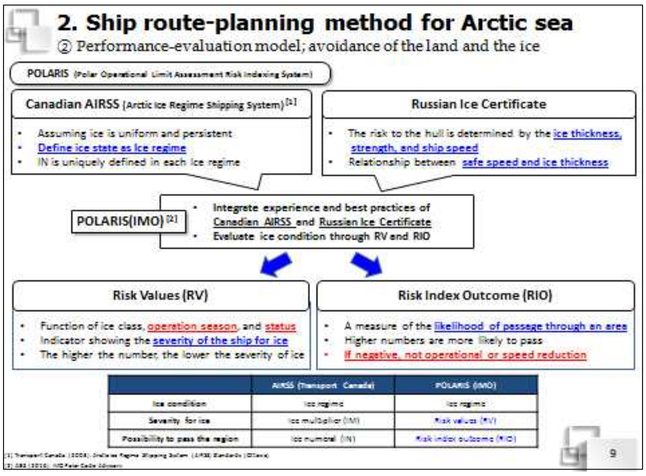

2. Ship route-planning method for Arctic sea
③ Route-finding model; seed genetic algorithm
Weakness of genetic algorithm
Large number of iterations for global optimum
Low reliability of solution caused by random basis
Features of ship-route planning
Operation of fixed ports during lifetime
Similarity between local optimum and global optimum
Seed genetic algorithm
Application of an initial solution, seed
Providing fast convergence speed & good solution
Seed genetic algorithm
Seed pool
Providing seed
Comparing & Updating seed pool
Based on the ports and time(departure month), saving path and RPM info.
① Seed
② Population
③ Selection
④ Crossover
⑤ Mutation
⑥ Replacement
Genetic algorithm
Better than seed?
End
Seed genetic algorithm
Departure month: June
Departure month: May
Departure month: March
Port


2. Ship route-planning method for Arctic sea
② Performance-evaluation model; avoidance of the land and the ice
POLARIS (Polar Operational Limit Assessment Risk Indexing System)
Canadian AIRSS (Arctic Ice Regime Shipping System) [1]
Assuming ice is uniform and persistent
Define ice state as ice regime
IN is uniquely defined in each ice regime
Russian Ice Certificate
The risk to the hull is determined by the ice thickness, strength, and ship speed
Relationship between safe speed and ice thickness
POLARIS(IMO) [2]
Integrate experience and best practices of Canadian AIRSS and Russian Ice Certificate
Evaluate ice condition through RV and RIO
Risk Values (RV)
Function of ice class, operation season, and status
Indicator showing the severity of the ship for ice
The higher the number, the lower the severity of ice
Risk Index Outcome (RIO)
A measure of the likelihood of passage through an area
Higher numbers are more likely to pass
If negative, not operational or speed reduction
AIRSS (Transport Canada)
POLARIS (IMO)
Ice condition
Ice regime
Ice regime
Severity for ice
Ice multiplier (IM)
Risk values (RV)
Possibility to pass the region
Ice numeral (IN)
Risk index outcome (RIO)
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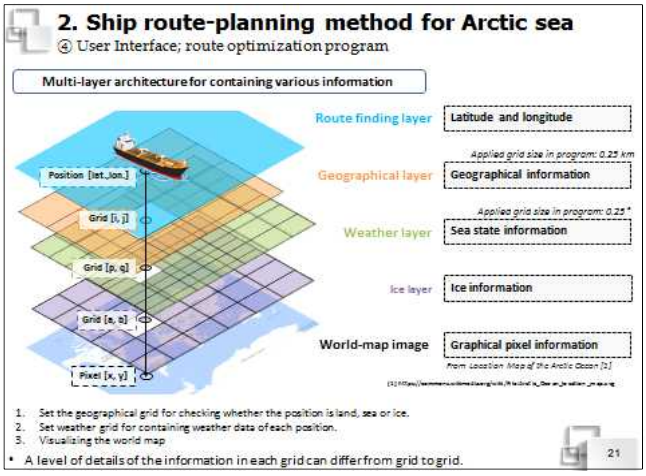
2. Ship route-planning method for Arctic sea
④ User Interface; route optimization program
Multi-layer architecture for containing various information
Route finding layer
Latitude and longitude
Applied grid size in program: 0.25 km
Geographical layer
Geographical information
Applied grid size in program: 0.25°
Weather layer
Sea state information
Ice layer
Ice information
World-map image
Graphical pixel information
Position [lat.,lon.]
Grid [i, j]
Grid [p, q]
Grid [a, b]
Pixel [x, y]
1. Set the geographical grid for checking whether the position is land, sea or ice.
2. Set weather grid for containing weather data of each position.
3. Visualizing the world map
A level of details of the information in each grid can differ from grid to grid.
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