최적 항로 평가 시스템의 개발 및 적용에 대한 소개

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An Introduction for Optimum Route Assessment System

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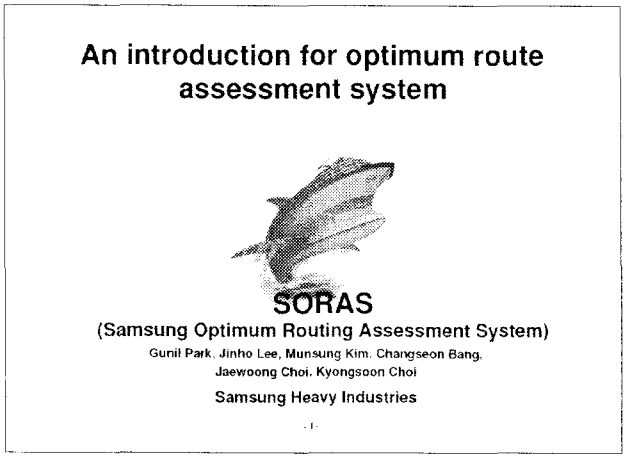
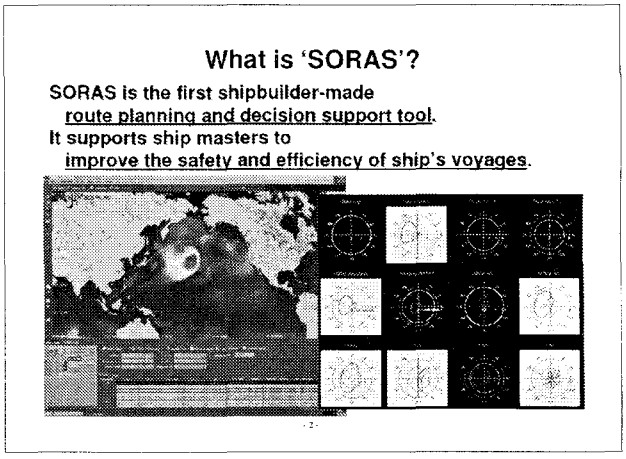
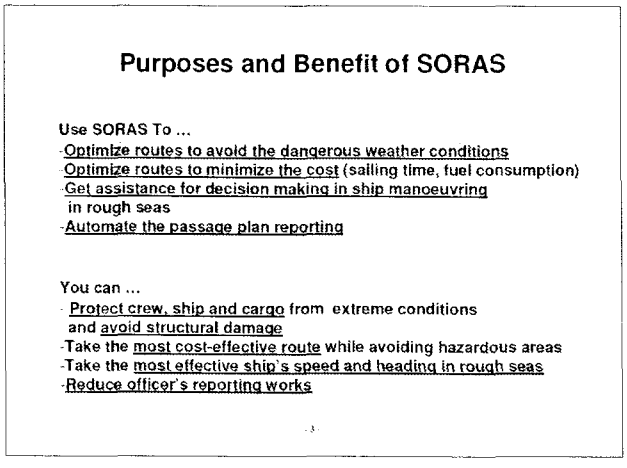
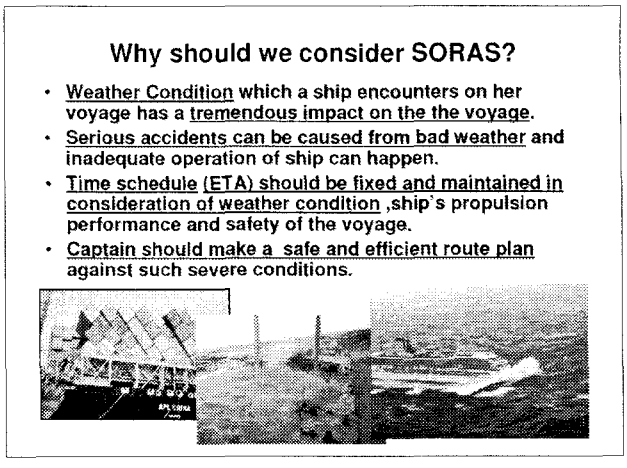
Abstract : 고유가 시대에 정보시스템의 발달과 더불어 안전하고 경제적인 항해계획의 수립을 지원하는 시스템에 대한 요구가 증대되고 있다. 이에 저자들이 개발한 최적항로평가시스템에 대하여 그 개발 내용 및 적용 사례를 소개한다. 기상예보데이터를 이용하여 소요시간 및 연료소모량 관점에서 최적화된 항해 계획을 생성하며, Parametric roll을 포함한 각종 내항성능 지표를 정량적으로 평가하여, 항해자로 하여금 항해의 안전성 및 경제성 관점에서 최적화된 항해 계획을 수립하도록 지원하는 시스템을 개발하였다. 개발된 시스템의 유효성은 실 항해중 적용한 사례 및 시뮬레이션 결과를 통해서 검증하였다.

For the safety and efficiency of voyage, the demand for decision support system in route planning has been increasing with the advance of information technology and the increase of oil price. According to the needs, the authors developed an optimum route assessment system. The system assists an navigator to make an optimum route plan with respect to sailing time and fuel consumption using weather forecast data. Also, the system provides the quantitative estimation for the various safety indexes including parametric roll and etc. Using these functions, a navigator is able to design the safe and efficient voyage plan. The effectiveness of system were verified by the operation during actual voyages and the simulation studies.









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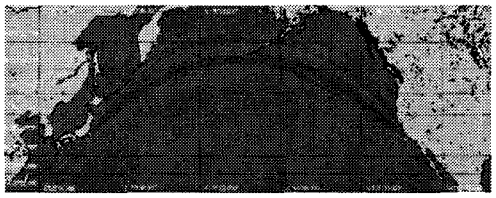
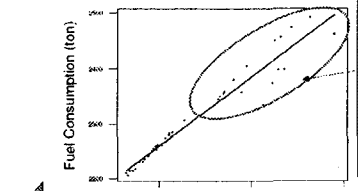
Minimum Time Path during December



36 Transpacific Routes From America to Japan
Each voyages started at every 12 hours from 1st Dec.

•For 4 voyages which had same route plan, and the only difference was departure time(0,+3d,+6d,+9d), Fuel consumptions of those were 111%,113%,116%,120% of the nominal fuel consumptions at calm sea.

The Relation of sailing time and fuel consumption on the Transpacific Route



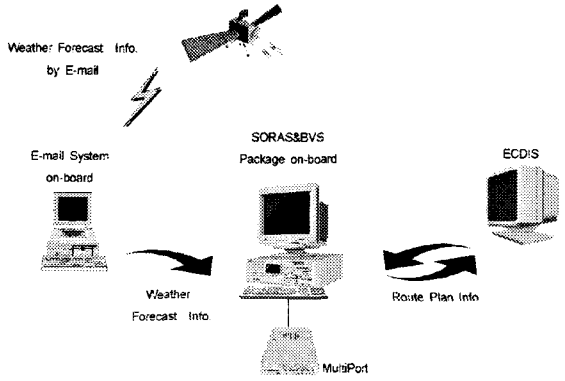
In bad weather condition, the scattering is bigger than the one in good weather condition. It means there are many different routes from usual route in bad weather condition.

Good Weather

Bad Weather

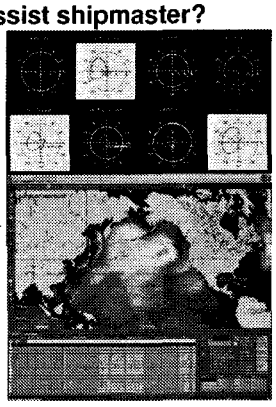
And the range of sailing time is 178 ~189hr. So, the influence of weather on voyage are quite so big. Also it is difficult to make a route plan and predict the sailing time without long term weather forecasting information.

System Architecture



How can SORAS assist shipmaster?

- By evaluating seakeeping performance to avoid and to survive rough sea condition
- Ship master can estimate the safety and performance of his route plan quantitatively.
- He can optimize his route plan using not only his skill and know-how but also the optimization function of SORAS.

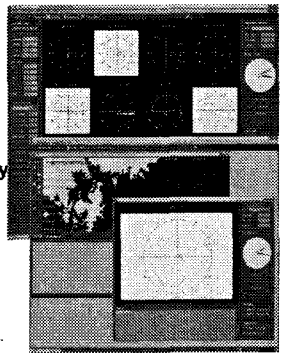


Major Functions of SORAS

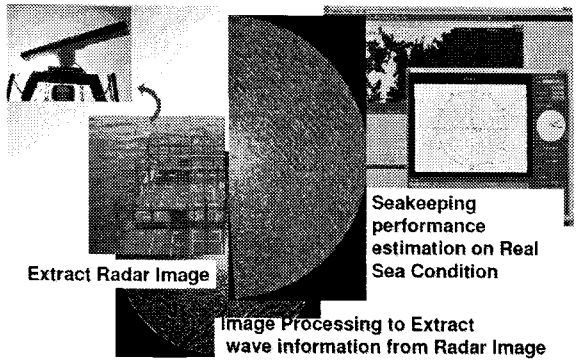
- Route planning (optimizing)
- Evaluation of seakeeping performance (prediction and realtime decision support)
- Managing of the voyage history
- Automatic reporting for the route and database management.

Voyage Safety Assessment

- Onboard and real-time seakeeping performance evaluation
  - ✓ Heave, pitch, roll, yaw Motion
  - ✓ Local acceleration
  - ✓ Slamming, green water, propeller racing probability
  - ✓ Wave bending moment
  - ✓ Parametric roll safety
  - ✓ Added resistance due to waves
- Evaluate on real weather conditions as well as forecasting data



Real Time Wave Measurement Using Marine X-band Radar



Extract Radar Image

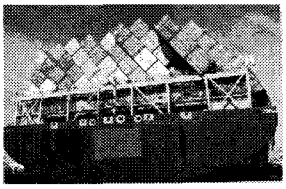
Seakeeping performance estimation on Real Sea Condition

Image Processing to Extract wave information from Radar Image

Parametric Roll

"Parametric Roll occurs when the following requirements are satisfied:
1. the natural period of roll is equal to approximately twice the wave encounter period
2. the wave length is on the order of the ship length (between 0.8 and 2 times LBP)
3. the wave height exceeds a critical level
4. the roll damping is low"

- Extremely High Roll Motion Caused by Parametric Resonance
- Happen in near Head and Following Seas
- May Cause Loss of Hundreds Containers



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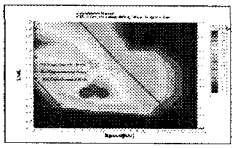
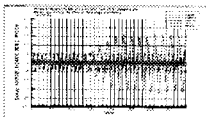
Assessment of Parametric Roll

Experiments in Samsung Ship Model Basin (SSMB)



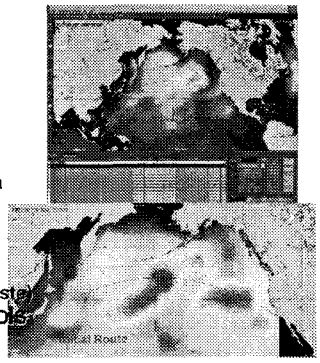


The simulation results have been verified by comparing with the model test.

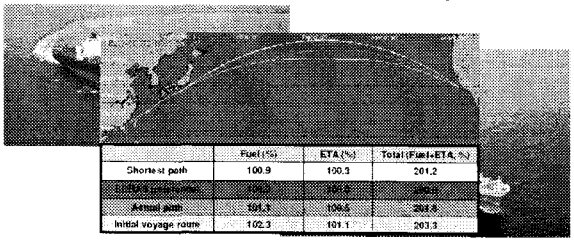
Evaluate the Parametric Roll possible region for various wave height, period, direction and ship speed on SORAS

Optimal Voyage Route Plan

- Optimized routing
- escaping risk and decreasing cost
- Ship motions prediction
- Route plan database management
- Detailed map data
- Weather forecasting data overlay
- Route comparison and display
- User-friendly route input and editing (copy and paste)
- Export route data for ECDIS (customized)



Application to container ship

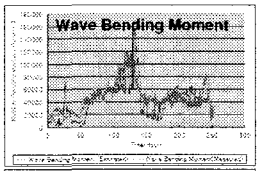


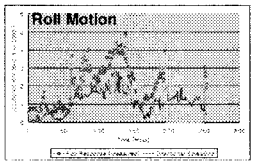
	Fuel (%)	ETA (%)	Total (Fuel+ETA, %)
Shortest path	100.9	100.3	201.2
[illegible]	[illegible]	[illegible]	[illegible]
Actual path	101.1	100.5	201.6
Initial voyage route	102.3	101.1	203.3

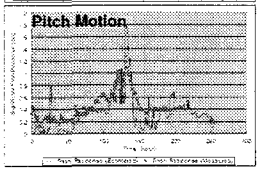
- Optimal route might be able to save 1.6% of cost for the voyage. We could save 10,000$ on the east bound of the transpacific route. When the fuel consumption is reduced by the amount of 2% , we can save 3% of the building costs for 20 years operation of a container ship. (For 6200 TEU, it amounts to 2.8 Million USD.)

Validation of Seakeeping Prediction

The actual roll, pitch motion and wave bending moment at midship section were measured(pink line) and compared with the estimation(dark blue line) results of SORAS.
The estimated motion parameters are quite similar and verifies the performance of SORAS in real situations.







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Objectives of simulation study

- To understand **the variation of sailing time and fuel consumption** caused from the error of modeling **(related to the confidence Interval of estimation)**
- To understand **the variation of optimum route caused from the error of modeling (related to the spatial accuracy of optimum route)**

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Methodologies of simulation study

1. **For the variation of sailing time and fuel consumption**
   - Prepare a set of route plans (r#1,r#2, ... r#n)
   - *Select a route and estimate sailing time and fuel cons.*
   - Varying the resistance increase ratio : 0.93~1.07
   - Inspecting sailing time and fuel consumption
   - Check the correlation and make a regression model
2. **For the variation of optimum route caused from the error of modeling**
   - Prepare a set of departure times (t#1, t#2, ... t#m)
   - *For a given departure time*
   - Varying the resistance increase ratio between 0.95~1.05
   - *Generate minimum fuel consumption route plan*
   - Inspecting sailing distance
   - *Check Gage R&R and Test for equal variance*

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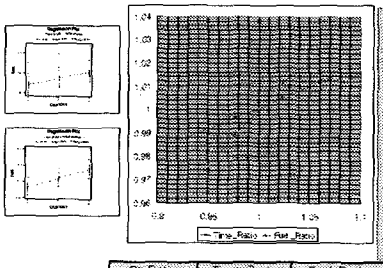
Variation of sailing time and fuel consumption

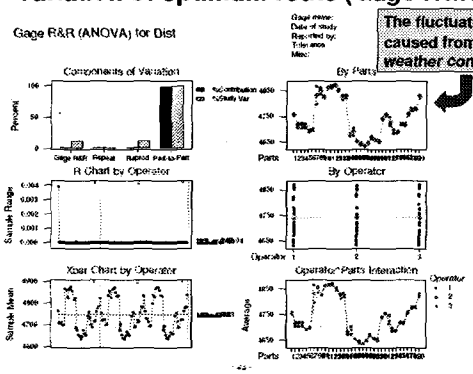


The increase ratio of sailing time and fuel consumption are proportional to the increase ratio of resistance.

If the confidence interval of resistance increase ratio can be found, then the confidence interval of sailing time and fuel consumption also can be found.

Rt_Ratio	Time_Ratio	Fuel_Ratio
0.930	0.928	0.966
0.977	0.997	0.989
1.000	1.000	1.000
1.023	1.005	1.011
1.070	1.014	1.033

Variation of optimum route (Gage R&R)



The fluctuation caused from weather condition

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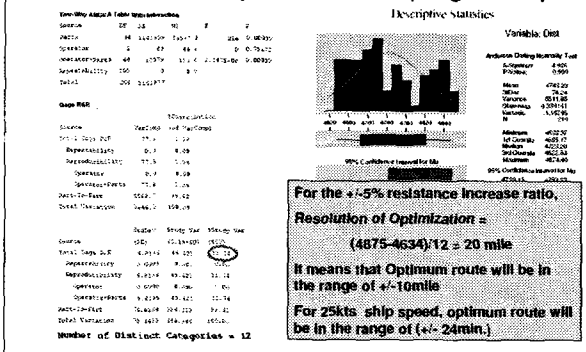
Variation of optimum route (Gage R&R)



For the +/-5% resistance increase ratio,

Resolution of Optimization =

(4875-4634)/12 = 20 mile

It means that Optimum route will be in the range of +/-10mile

For 25kts ship speed, optimum route will be in the range of (+/- 24min.)

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Conclusion of simulation study

- **The variance of sailing distance caused from modeling error is much less than the variance of sailing distance caused from weather condition.**
- **For the +/-5% resistance increase ratio, Optimum route will be in the range of +/-10mile. (For 25kts ship speed, optimum route will be in the range of +/- 24min.)**
- **The increase ratio of sailing time and fuel consumption are proportional to the increase ratio of resistance.**
- **Even if there were absolute errors in the estimation of sailing time and fuel consumption, the optimum route could be found with the acceptable resolution when the modeling error is in the acceptable range.**

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참고문헌

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