**History, State-of-the-arts and Future Trend of Ship Maneuuvrability and Controllability - Thirty Years Research Review -**

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**Background and History of the Research**

- Ship manoeuvring research in 1970s
- Autopilot for saving energy
- Necessity of the research of man-machine System
  - Developing a ship handling simulator, as one of the oldest ones in the world
- Developing standard mathematical model of ship manoeuvring

**VLCCs**

**Ship Manoeuvring Model before 1970**

- David and Schiff Model
  - Davidson, K.S.M., and L. Schiff, Turning and course keeping qualities, Trans. SNAME, Vol.54, 1946
- Abkowitz Model
- Nomoto’s k-T Model
  - First order model
  - Second order model
  - Second order nonlinear model
- Necessity to develop a model for new types of ships

**Model Ship Experiments**
Ship Manoeuvring Model in 1970s

- David and Schiff Model
- Akkowitz Model
- Nomoto’s K-T Model
  - First order model
  - Second order model
  - Second order non-linear model
- Necessity to develop a model for new types of ships

Ship Manoeuvring Model in 1980s

- Necessity to develop a model for new types of ships
  - MMG model (module method mathematical model considering hull, propeller, rudder and their interactions respectively)
- Still many several variations of MMG model exists
- Some extended MMG models applicable for twin-propeller ship, for shallow water etc. exist

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Adaptive Autopilot

- Model Reference Adaptive Control
- Self-Exciting Control
- Stochastic Model
- Adaptive Control
- etc

Cost Function of Fuel Consumption

- Lovasik’s criterion (Ae 0.54)
- Norristol, N., On the added resistance due to steering on a straight course, 36th ITTC, Berlin, Hamburg, 1972
- Cawse, D., Development of a cost function for autopilot optimization, Proceedings, Symposium on Ship Steering Automatic Control, Genova, Italy, 1990
- Eberle, M. and J.C. Houghton Thompson, Experiment with direct measurement of steering generated propulsion losses, 6th Ship Control Systems Symposium, Offshore, Canada, 1981
- Harengrens’ criterion
- etc

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First Generation Ship Handling Simulator (1974)

- Feasibility study on instability criterion of human ability to control a VLCC (SR151, Japan)
  - Nomoto, K., Simulators from the naval architects point of view, Proceedings of MARSIM, Southampton, UK, 1978

SR151 Ship Handling Simulator (1974)

First Ship Handling Simulator in the world (Hiroshima University, 1970)

Full Mission Ship Handling Simulator

Background and History of the Research (contin'd)

- Developing intelligent ship control systems including
  - collision avoidance
  - berthing/deberthing control
- Developing a tool for safety assessment in congested waterways
- Developing standardisation of mathematical model of ship manoeuvring in low speed and/or in shallow water etc

Automatic Collision Avoidance

- Fuzzy Reasoning and Control
- Expert System for Multiple Ship Encounter
Automatic Collision Avoidance Experiment

Automatic Collision Avoidance Experiment

Background and History of the Research (contin'd)
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Automatic Berthing Experiment

Automatic Berthing Experiment

Background and History of the Research (contin'd)
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Background and History of the Research (contin'd)

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Single-propeller Twin-Rudder Ship

Automatic Navigation in Slow Speed by Single-propeller Twin-rudder Ship
Concluding Remarks

- Ship manoeuvrability and its prediction are long-time subject.
- It cannot be separated with human and autopilot behaviours and with environmental disturbances.
- New devices, new theories and new ideas to overcome these important issues are highly recommended to be searched by younger generation.
Invitation to Japan

Invitation to Osaka

Thank you for your attention.