Ship Manoeuvrability and Its Control

- Thirty Years Research Review -

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Background and History of the Research

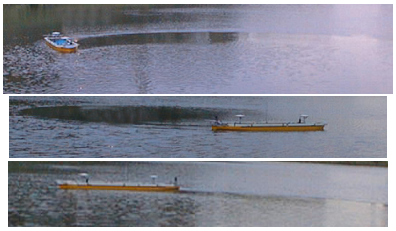
- Ship manoeuvring research in 1970s
- Autopilot for saving energy
- Necessity of the research of man-machine System
  - Developing a ship handling simulator, as one of the oldest ones in the world
- Developing standard mathematical model of ship manoeuvring

VLCCs

Ship Manoeuvring Model before 1970

- David and Schiff Model
  - Davidson, K.S.M., and L.I. Schiff, Turning and course keeping qualities, Trans. SNAME, Vol.54, 1946
- Abkowitz Model
  - Abkowitz, M.A., Lectures on Ship Hydrodynamics - Steering and Manoeuvrability, Hya Report no. Hy-5, 1964
- 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

Model Ship Experiments



Model Ship Experiments

Ship Manoeuvring Model in 1970s

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Ship Manoeuvring Model in 1980s

- Necessity to develop a model for new types of ships
  - MMG model (module type mathematical model considering hull, propeller, rudder and their interactions respectively)
- Still now several variation 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
  - Amerongen, J. van and A.J. Udink ten Cate, Model reference adaptive autopilots for ships, Automatica, Vol. 11., pp 441-449, 1975
- Self-tuning Control
  - Källström, C.G., K.J. Åström, N.E. Thorell, J. Eriksson and L. Sten, Adaptive autopilots for steering of large tankers, Report Department of Automatic Control, Lund Institute of Technology, Lund , Sweden, 1977
- Stochastic Model
  - Ohtsu, K., M. Horigome, G. Kitagawa, A new ships autopilot design through a stochastic model, Automatica, Vol 15, pp. 255-268, 1979
- Adaptive Control
  - Tiano, A., E. Volta, A.W. Brink and T.W. Verbruggen, Adaptive control of large ships in non-stationary conditions - a simulation study, Proceedings Symposium on Ship Steering Automatic Control, Genova, Italy, 1980
- etc

Cost Function of Fuel Consumption

- Koyama's criterion $J=\psi_2+\lambda\delta_2$
  - Koyama, T. On the optimum automatic steering system of ships at sea, J.S.N.A., Vol 122, Dec., 1967
- Norrbin, N.H., On the added resistance due to steering on a straight course, 13th ITTC,Berlin, Hamburg, 1972
- Clarke, D., Development of a cost function for autopilot optimization, Proceedings Symposium on Ship Steering Automatic Control, Genova, Italy, 1980
- Blanke, M. and J.C. Nortoft Thompson, Experiment with direct measurement of steering generated propulsion losses, 6th Ship Control Systems Symposium, Ottawa, Canada, 1981
- Hasegawa's criterion
  - K. Hasegawa : On a Performance Criterion of Autopilot Navigation, Journal of the Kansai Society of Naval Architects, Japan (J.KSNAJ) 178, pp.93-103, Sep., 1980
- etc

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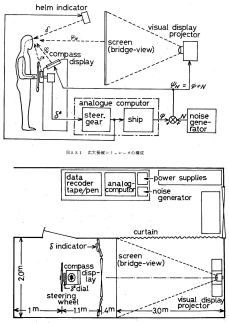
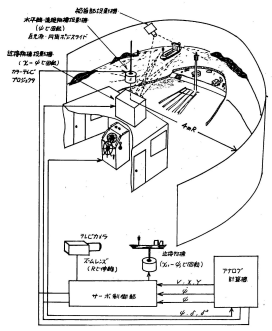
First Generation Ship Handling Simulator (1974)

- 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
  - T. Koyama, K. Kose and K. Hasegawa : A Study on the Instability Criterion of the Manual Steering of Ships (in Japanese), J. of the Society of Naval Architects of Japan (J.SNAJ) 142, pp.119-126, Dec., 1977

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



SR151 Ship Handling Simulator (1974)



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
  - A. Kouzuki and K. Hasegawa : Automatic Collision Avoidance System for Ships Using fuzzy Control (in Japanese), J.KSNAJ 205, pp.1-10, June 1987
  - K. Hasegawa : Fuzzy Modelling of the Behaviours and Decision-Making of Ship Navigators, Proc. of 3rd International Fuzzy Systems Association (IFSA)Congress, pp.663-666, Seattle, Aug. 1989
- Expert System for Multiple Ship Encounter
  - K. Hasegawa, A. Kouzuki, T. Muramatsu, H. Komine and Y. Watabe : Ship Auto-navigation Fuzzy Expert System (SAFES) (in Japanese), J.SNAJ 166, pp.445-452, Dec. 1989

Automatic Collision Avoidance Experiment

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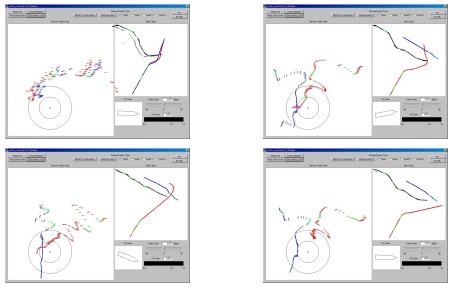

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Automatic Berthing Experiment

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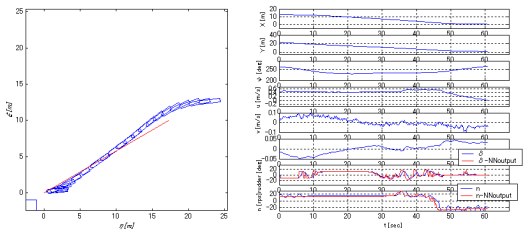

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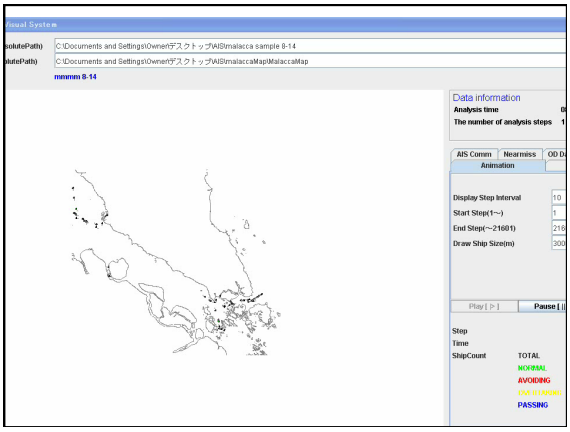

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Single-propeller Twin-Rudder Ship

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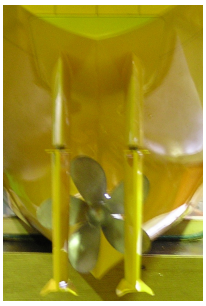
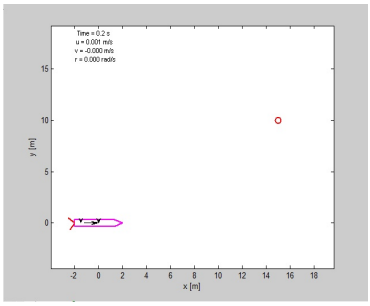


Automatic Navigation in Slow Speed by Single-propeller Twin-rudder Ship



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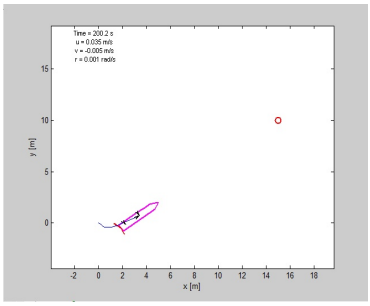

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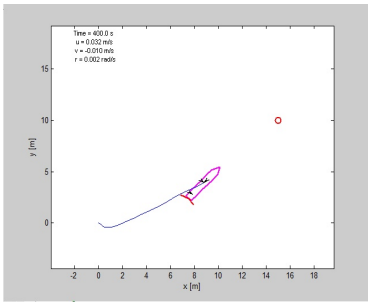

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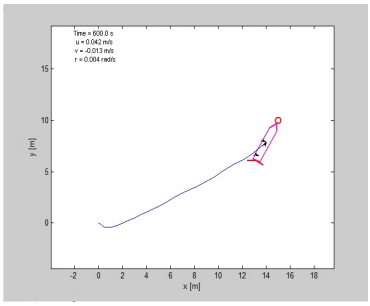

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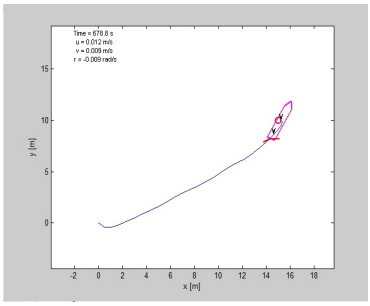

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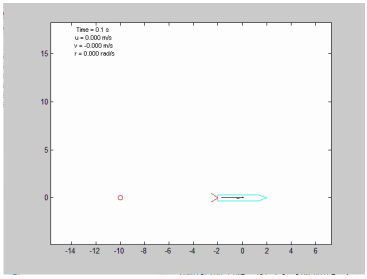

Concluding Remarks

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