Fully Automatic Design Space Exploration by RANS Computations

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About me

- Naval Architect from TU Berlin
- PhD Thesis on Numerical Prediction of Ship Manoeuvring Performance in Waves
- Working at Friendship Systems since April 2019
- RANS code extensively used in R&D projects and for sophisticated applications

- Nevertheless, optimization projects in ship industry are often carried out using potential flow theory

- Drawbacks of RANS codes: More complicated setup, complicated grid design, increased computation time and more room for errors

- Goal is to undertake steps toward an easy to use and reliable setup
CAESES

- PIDO Platform for integration of various tools
- Parametric modelling of hull forms
- Connection of external tools using Software Connectors
- Powerful Optimisation algorithms (Dakota)
Parametric model

- Parametric model of a Ropax Ship developed in the scope of the Holiship project
- Twin-screw ship with skeg
- Total of 23 design variables
Software connectors

- Three chained connectors
  - Generate Grid
  - Preprocessing
  - Computation and basic postprocessing

- Execution of Jobs on HPC via Software Connector

- No manual interaction required after setup
- Computational Grid created with GridPro
- Topology separated from Geometry
- Translation of parts of the topology using command line tools provided by GridPro
- Internal surfaces required by GridPro can be generated in CAESES
- 800,000 cells, 6 minutes to generate, 6 grids in parallel
Neptuno

- In-House RANS code
  - Finite Volume
  - multi-block structured grid with non-matching interfaces
  - Standard $k\omega$ turbulence model by Wilcox
  - Two phase level set method
What do we do?

▪ Different means of design space exploration
  – Ensemble investigation
  – Sobol algorithm
  – Latin Hypercube Sampling

▪ Varied Parameters:
  – Length between perpendiculars ($L_{pp}$)
  – Length of parallel midship ($L_{MS}$)
  – Position of parallel midship ($x_{MS}$)

▪ No additional constraints
Results

- Total of 120 computations run in parallel

- Computations carried out at virtual model scale of $\lambda = 25$ and 21 kn ($F_n = 0.27$)

- Average computation time
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![Graph showing data points for different values of $x_{MS}$](image)
Results:

- Post processing script checks average $y+$ value on the hull and removes outliers

- Clear trends identified for parameter $x_{MS}$ and $L_{PP}$

- No trends identified for $L_{MS}$ - variation too small?
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Results:

\[ L_{PP} = 155 \text{ m}, \quad x_{MS} = 0.45, \quad L_{MS} = 1 \]

\[ L_{PP} = 155 \text{ m}, \quad x_{MS} = 0.3, \quad L_{MS} = 2 \]

Difference: 8%
Response Surface Model

- Reduce computational time for optimisation even more by using a RSM model
- Randomly select 16 out of 100 initial design variants
- Generate a response surface model
- Recompute other 84 designs for validation
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Response Surface Model
Response Surface Model
Validation of Response Surface Model
Conclusion and Future Work

- Robust and fully automatic design space exploration
- High-quality grids, automated quality checks (grid dependence study) can be included
- RSM model shows very good results
- Employ more sophisticated design space exploration methods to reduce number of designs
Thank you for your attention
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