CFD Based Optimisation of a River Ferry

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Part I

Introduction

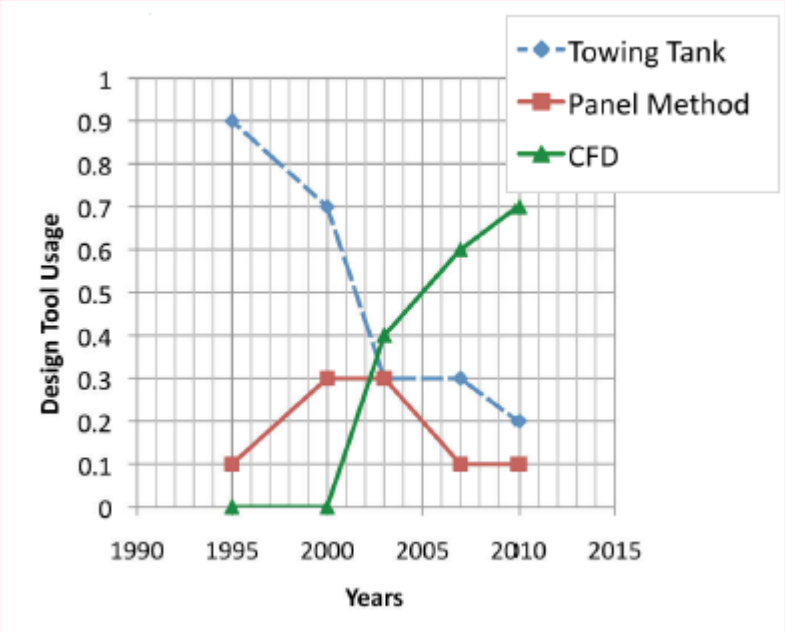
Introduction

This work deals with development of an optimisation framework which can be implemented in an general ship design office. The developed framework is used to optimise an River ferry hull for improving its wave making characteristics. Work was developed at **NAVYK Design & Engineering, Galati** and **Dunarea de Jos University of Galati**

CFD in Ship Design Optimisation

- In recent years, CFD has been decisive factor in development of new efficient hull forms.

CFD usage for america's cup[a]



[a]CAPONNETTO M, Solutions for Marine Applications, CD-adapco Marine Webinar, 22nd January 2009

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- It is possible to analyse a large number of design variation using CFD codes in less time which is an arduous task in EFD.
- Can be used to optimise sea-keeping, manoeuvring & propulsion characteristics

Motivation

Key motivations for this work:

- Developments of design with superior performance.

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	Potential	**CFD**		
No of Licence/CPU	1 licence 1 core	1 licence 32 core	10 licence 320 core	20 licence 640 core
Study Duration	24 hours	208 days	20 days	10 days

courtesy : Hydrocean

Motivation

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- Developments of design with superior performance.
- Better understanding of the design task.
- To obtain optimum design in practical time.
- Reduction of design cost for optimisation

Objectives

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- Formulation of practical optimisation method

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- Formulation of practical optimisation method
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  - Incorporate open source tools
- Optimisation of hull form of a River Cruise Ferry
  - To obtain minimum wave making resistance

Practical Difficulties

General difficulties in Optimisation using CFD are:

- Parametric Modelling of hull

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- Interfacing of softwares

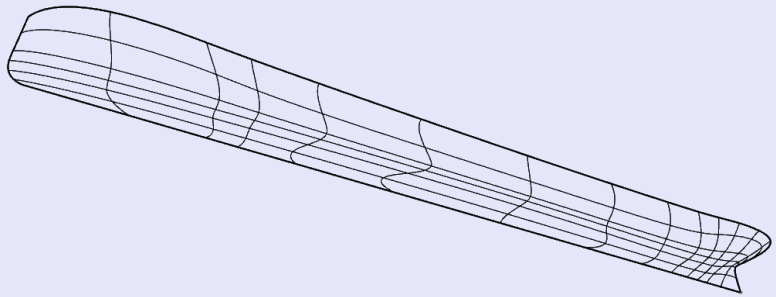
Part II

Tools Used

Tools Used - Geometric Modelling

Requirements:

- Parametric representation



Tools Used - Geometric Modelling

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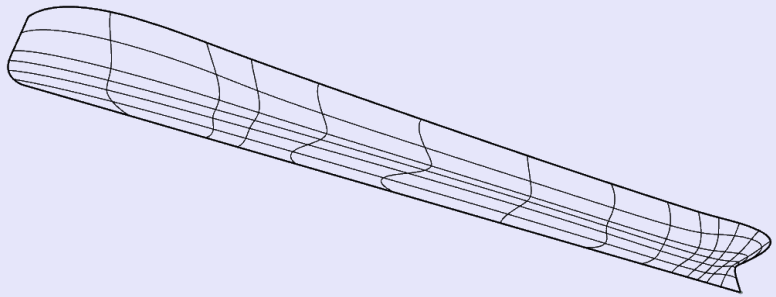
- Possibility of automation



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Requirements:

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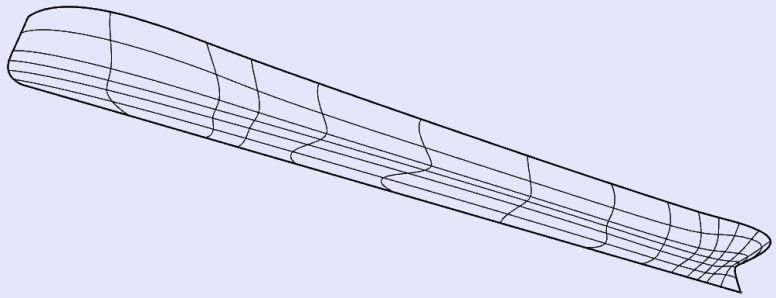
- Robust and Widely used



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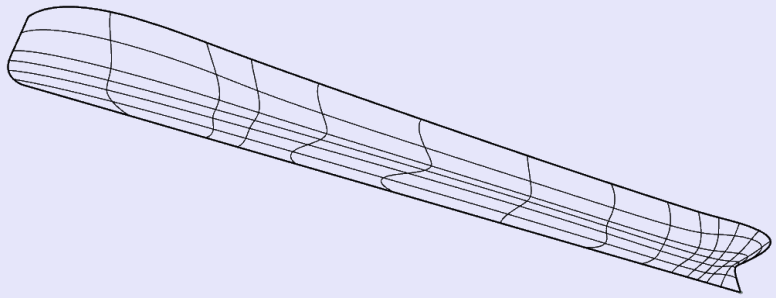

Rhino®

- Common in Industry
- Highly customisable, Python and .NET support
- Very less licensing cost
- NURBS representation

Tools Used - CFD Tool

Requirements in optimisation chain:

- Accurate & fast

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- Reliable & automatic

Tools Used - CFD Tool

Requirements in optimisation chain:

- Accurate & fast
- Reliable & automatic
- Able to communicate with other components in chain

SHIPFLOW-XPAN

Why???

SHIPFLOW-XPAN

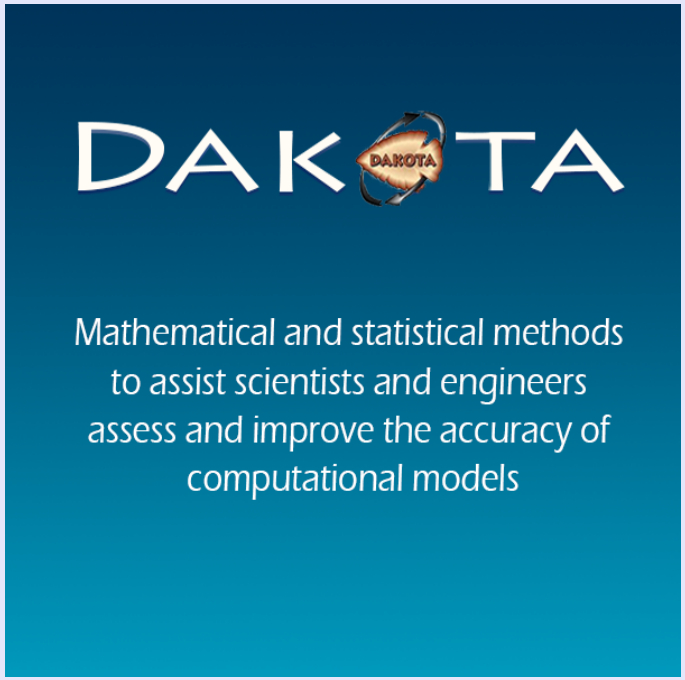
Why???

- Validated free surface potential flow solver
- Fast and Robust
- Integrated automatic meshing
- Console based and works with text files

Tools Used - Optimiser

Dakota

- Open Source / GNU Lesser General Public license
- Many Methods in One Tool: Sensitivity analysis, optimisation and uncertainty
- Flexible Interface to simulation codes: one interface; many methods



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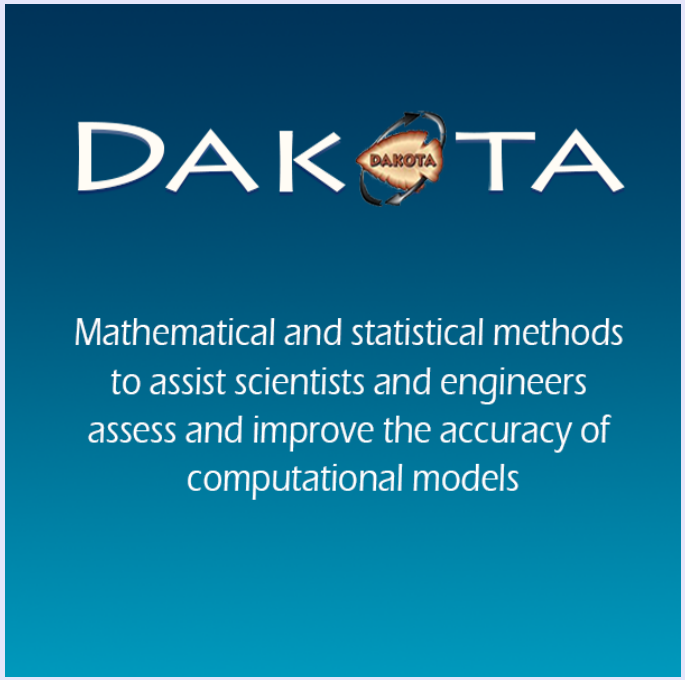
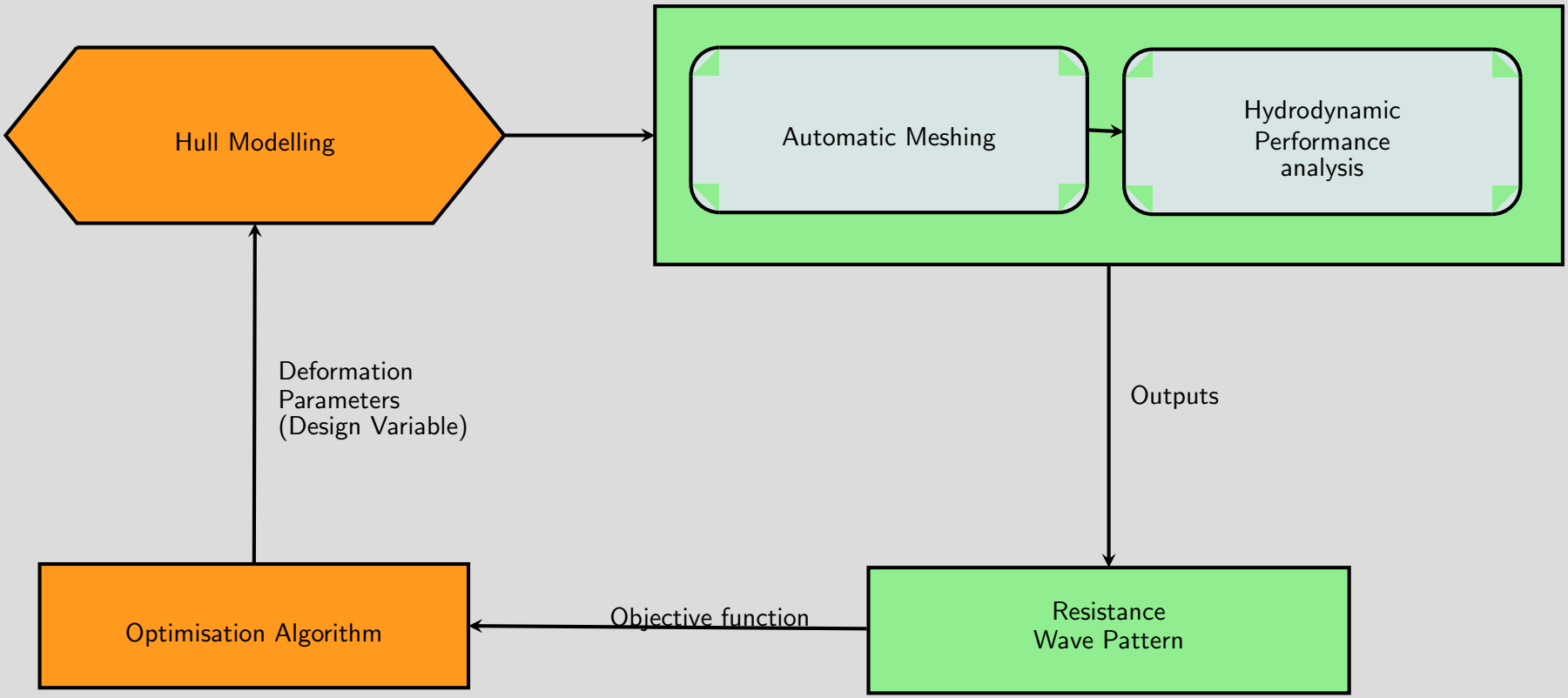
- Many Methods in One Tool: Sensitivity analysis, optimisation and uncertainty
- Flexible Interface to simulation codes: one interface; many methods
- Familiarity with mathematics, statistics and computer science required



Part III

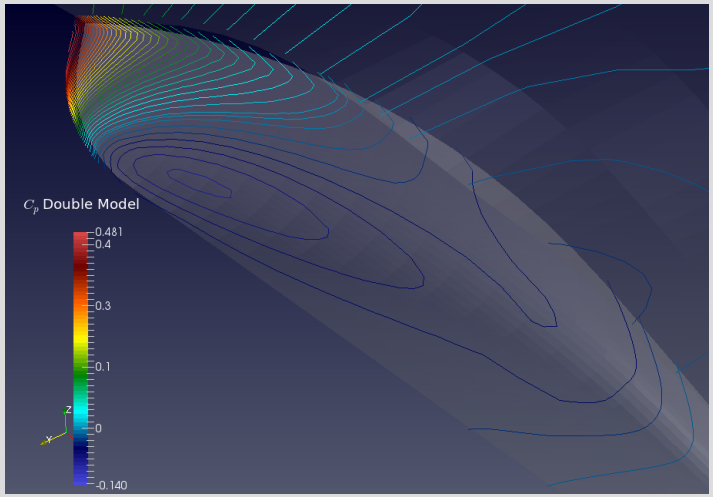
Methodology

Overview


Hull Modelling
Automatic Meshing
Hydrodynamic Performance analysis
Deformation Parameters (Design Variable)
Outputs
Optimisation Algorithm
Objective function
Resistance Wave Pattern

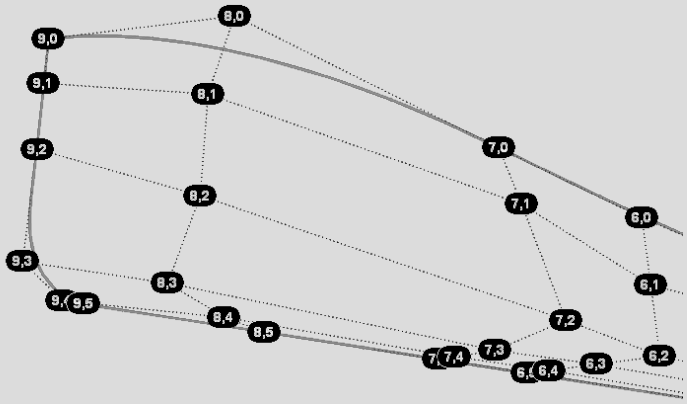
Selection of Design Variables

- Identify sources of wave generation
  - ⋆ *c_p distribution on hull*
  - ⋆ *If c_p is high results local wave crest plus a trailing wave system*



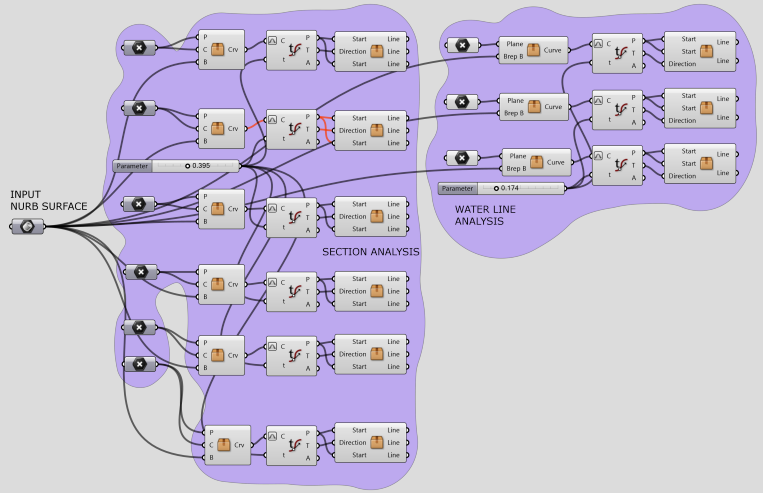
Selection of Design Variables

- Identify sources of wave generation
- Perturbation of control points of NURBS surface
  - ⋆ *Translation of control point along co-ordinate axis*



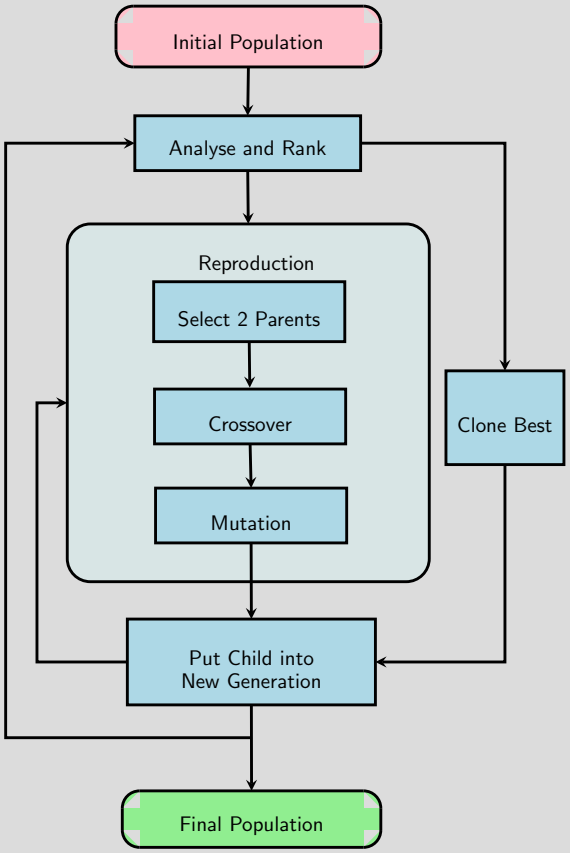
Selection of Design Variables

- Identify sources of wave generation
- Perturbation of control points of NURBS surface
- Limits of perturbation found using Grasshopper
  - ⋆ *Ensures no double curvature is developed on modification*



Optimiser configuration

- Genetic algorithm used
- Input configuration
- Interfacing through python program developed by author



Coliny EA

Optimiser configuration

- Genetic algorithm used
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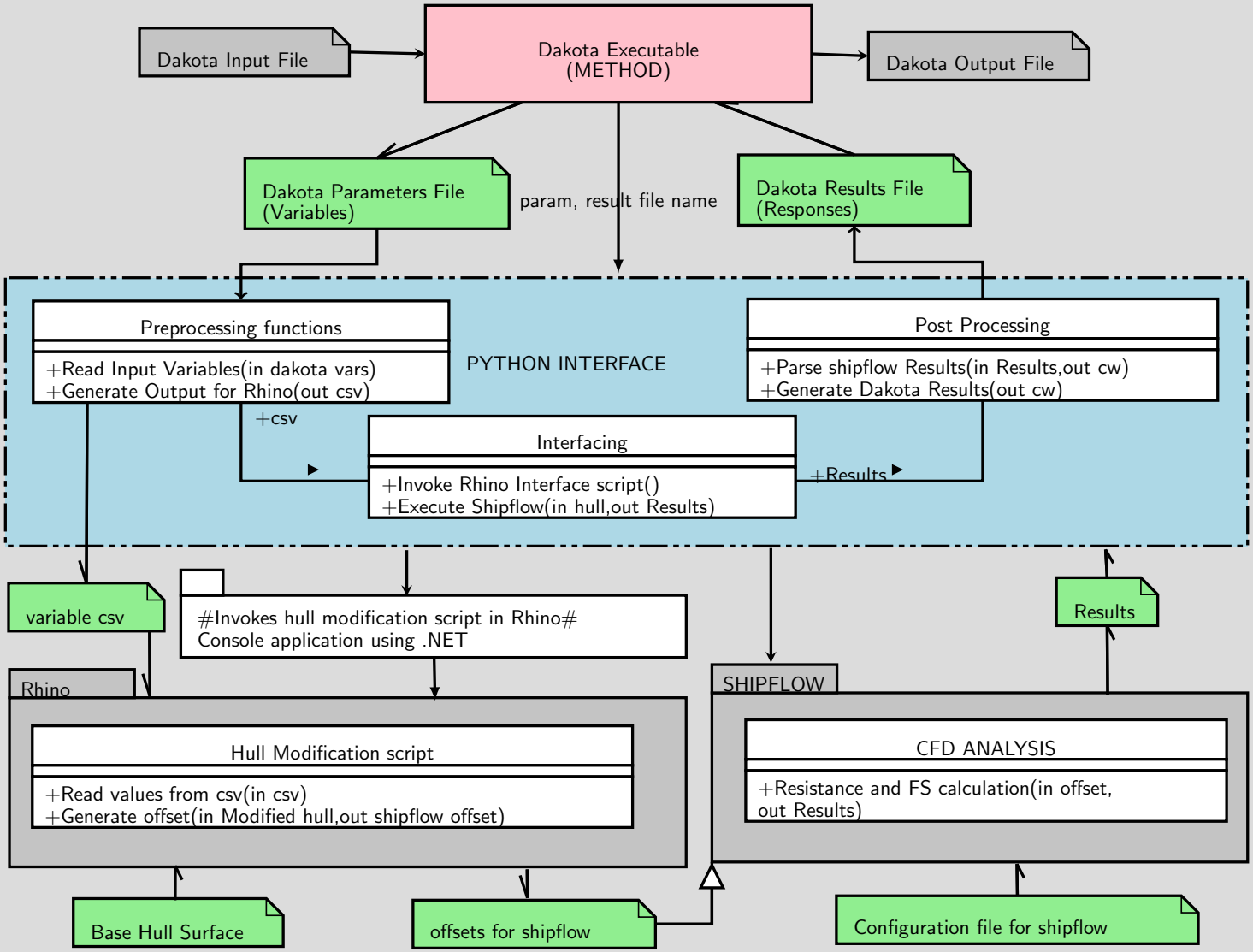
- Variable definition
- Genetic algorithm configuration
- File descriptors

Optimiser configuration

- Genetic algorithm used
- Input configuration
- Interfacing through python program developed by author

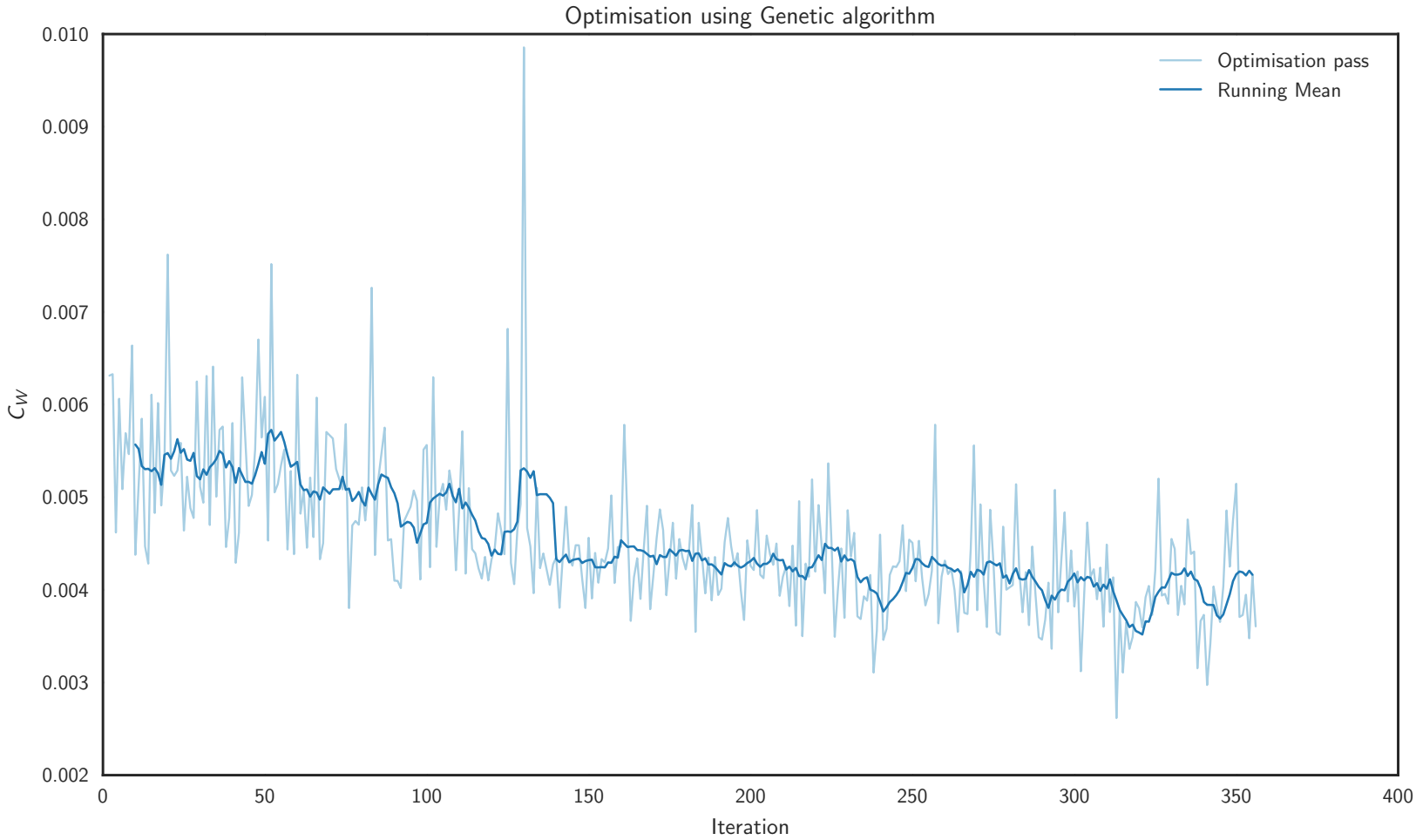
- Modification of hull
- Generation of offsets
- Execution of Shipflow
- Creation of results files for Dakota from output files generated by ShipFlow
- Capture of failure in case of failed calculation
- Coordination of above processes


Dakota Input File
Dakota Executable
(METHOD)
Dakota Output File
Dakota Parameters File
(Variables)
param, result file name
Dakota Results File
(Responses)
Preprocessing functions
+Read Input Variables(in dakota vars)
+Generate Output for Rhino(out csv)
PYTHON INTERFACE
Post Processing
+Parse shipflow Results(in Results,out cw)
+Generate Dakota Results(out cw)
+csv
Interfacing
+Invoke Rhino Interface script()
+Execute Shipflow(in hull,out Results)
+Results
variable csv
#Invokes hull modification script in Rhino#
Console application using .NET
Results
Rhino
SHIPFLOW
Hull Modification script
+Read values from csv(in csv)
+Generate offset(in Modified hull,out shipflow offset)
CFD ANALYSIS
+Resistance and FS calculation(in offset,
out Results)
Base Hull Surface
offsets for shipflow
Configuration file for shipflow

Part IV

Results

Iteration History

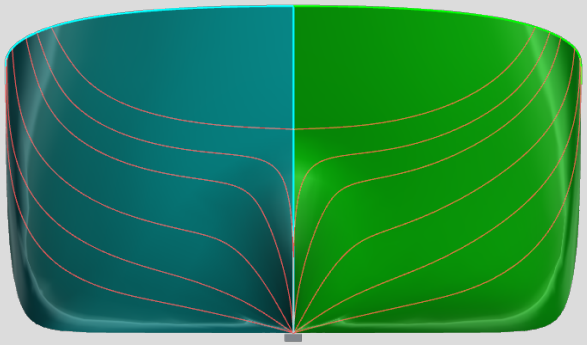


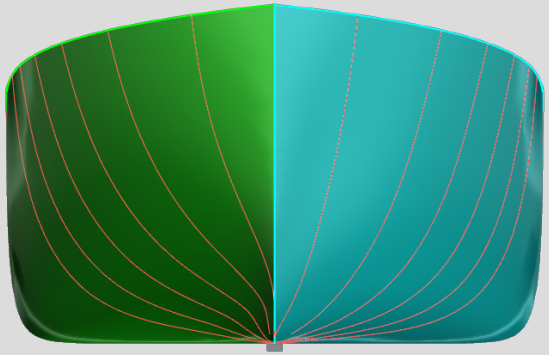
Comparison

	OD-1	Original	% Variation
∇	2.075e+02	2.139e+02	-2.976
S_{ref}	2.319e+02	2.351e+02	-1.367
C_W	3.175e-03	5.006e-03	-36.58
R_W	6.236e+03	9.969e+03	-37.44
R_T	1.053e+04	1.435e+04	-26.59

Comparison

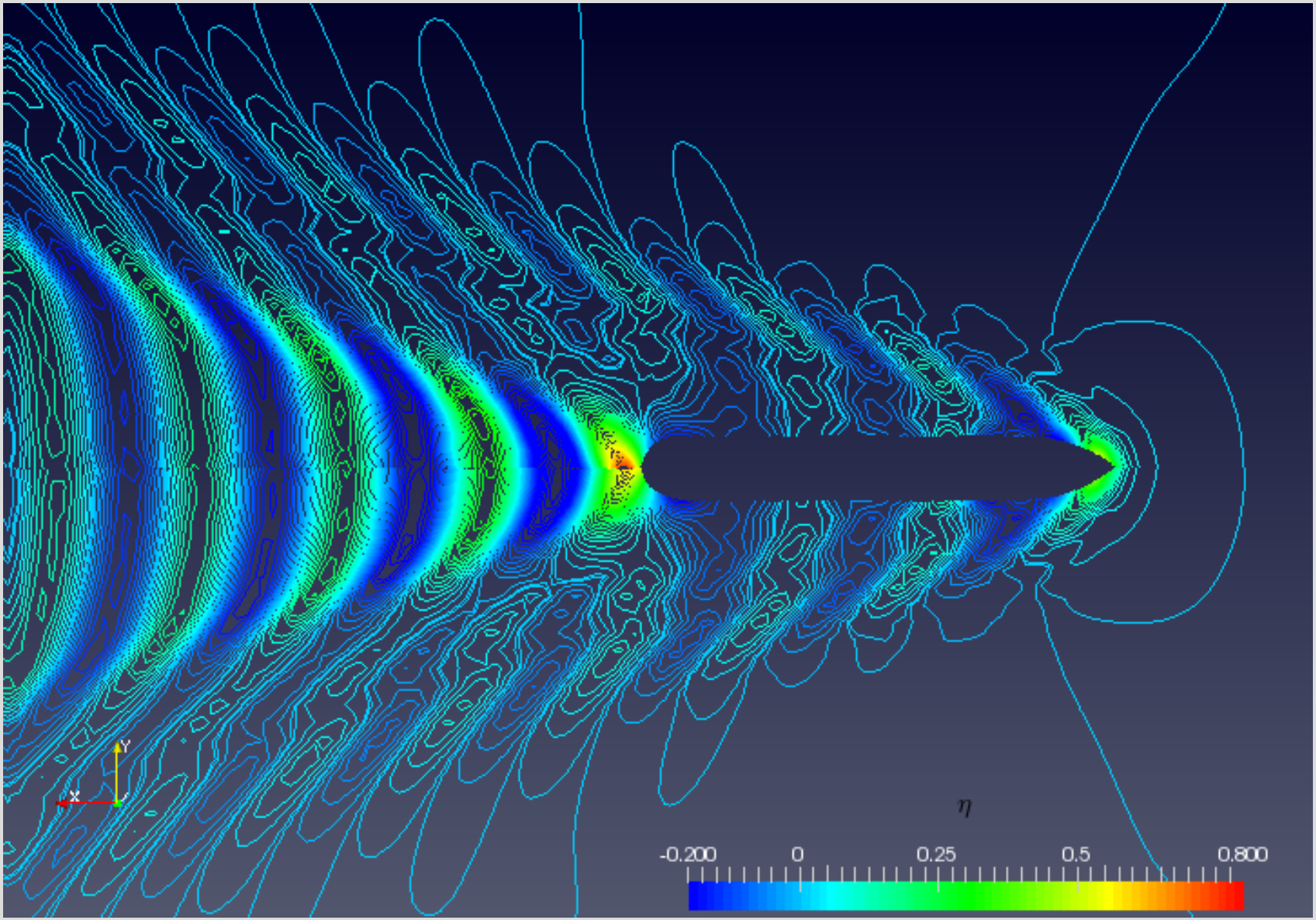
Hull



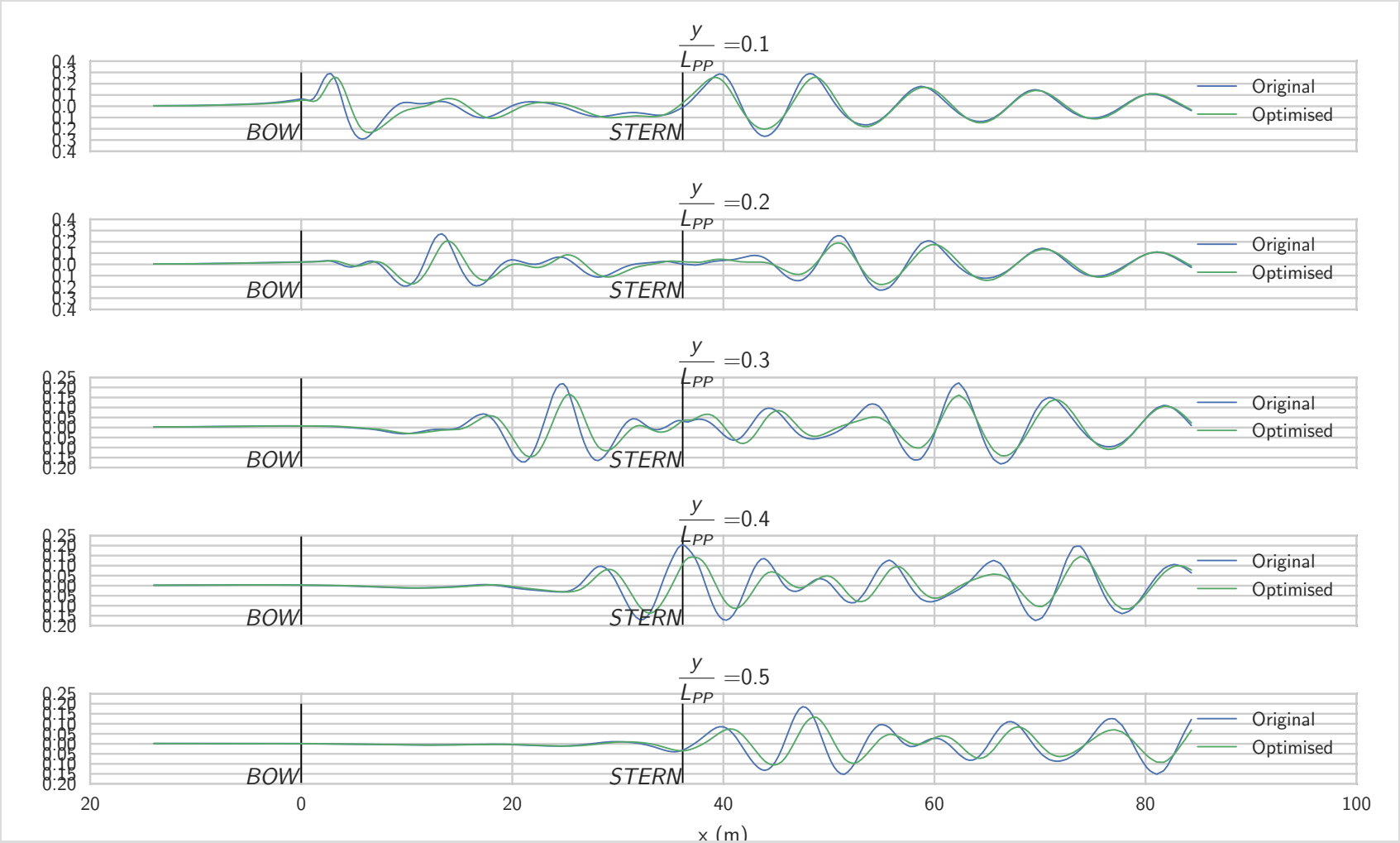


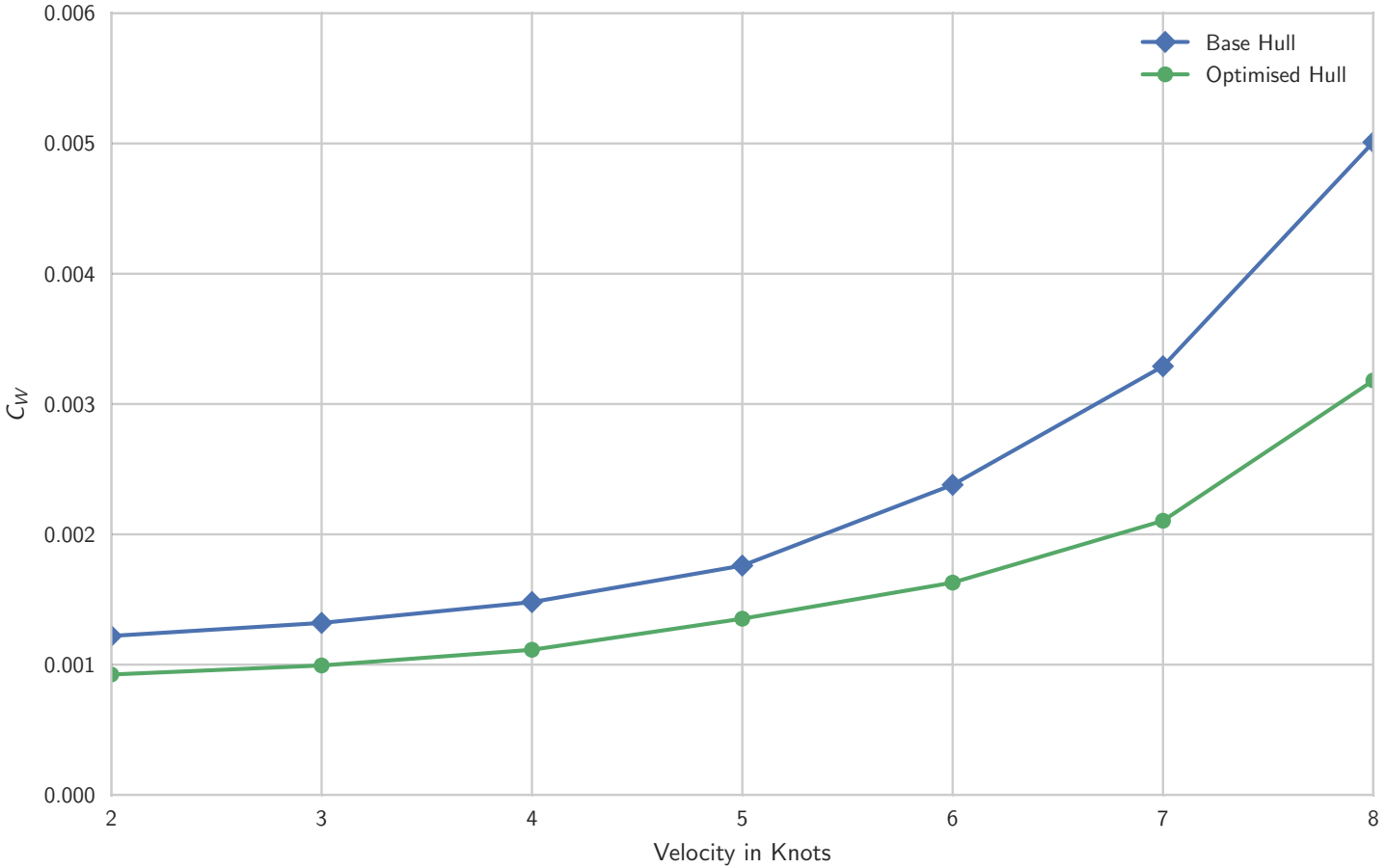
Green - Optimised
Blue - Original

Wave Pattern

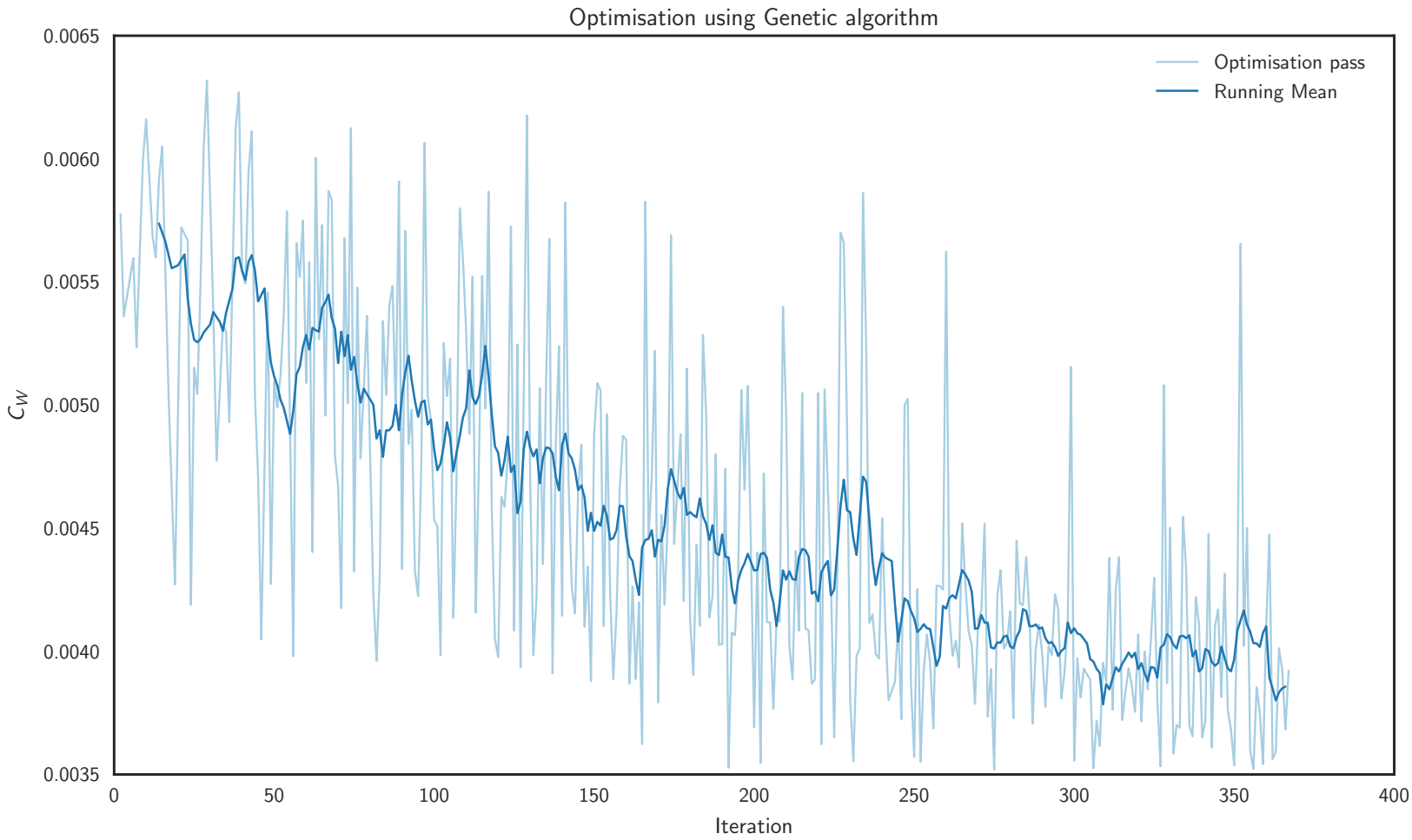


Far field wave cuts




0.006
0.005
0.004
0.003
0.002
0.001
0.000
C_W
2
3
4
5
6
7
8
Velocity in Knots
Base Hull
Optimised Hull

Iteration History



Comparison

	OD-1	Original	% Variation
∇	2.092e+02	2.139e+02	-2.187
S_{ref}	2.332e+02	2.351e+02	-0.812
C_W	3.673e-03	5.006e-03	-26.63
R_W	7.255e+03	9.969e+03	-27.22
R_T	1.158e+04	1.435e+04	-19.28

Conclusion

- Potential calculation with linearised BC are effective for the hull in the study.

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- Potential calculation with linearised BC are effective for the hull in the study.
- NURBS representation is very effective in quick geometry modification.
- About 37% reduction in wave resistance achieved. Validation using model testing is required

Recommendation

- Other flow solvers are required for complex hulls
  - ⋆ *Non-Linear method is recommended for flows with bulb.*
  - ⋆ *Viscous flow solvers for hull with strong turbulent flows*

Recommendation

- Other flow solvers are required for complex hulls
- Use of advanced algorithms
  - ⋆ *Surrogate models for reducing number of simulation in case of RANS solvers*

Recommendation

- Other flow solvers are required for complex hulls
- Use of advanced algorithms
- Extend for different problems
  - ⋆ *Manoeuvring* ⋆ *Seakeeping* ⋆ *Propeller* ⋆ ....

Recommendation

- Other flow solvers are required for complex hulls
- Use of advanced algorithms
- Extend for different problems
- Free of software costs
  - ⋆ *Use open source alternatives for Rhino and ShipFlow*
  - ⋆ *FreeCAD and OpenFOAM is a good choice*