SARC developments on early ship design support in PIAS

Bremen, March 2025

Funded by the European Union

Background

SEUS task 2.4

T2.4 Integration for early design stages (SARC)

Parametric early design & variant management, in order to facilitate the quick evaluation of present and future propulsion/power systems. Developed for the selected type of vessels and extrapolated to other types.

Proposed in Turku

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And now the elaboration

- Quick configuration of internal layout (spaces and compartments).
- Propulsion and machinery.
- Running OpenFoam CFD from PIAS.
- Global hull shape modifications.

Quick configuration of internal layout (spaces and compartments)

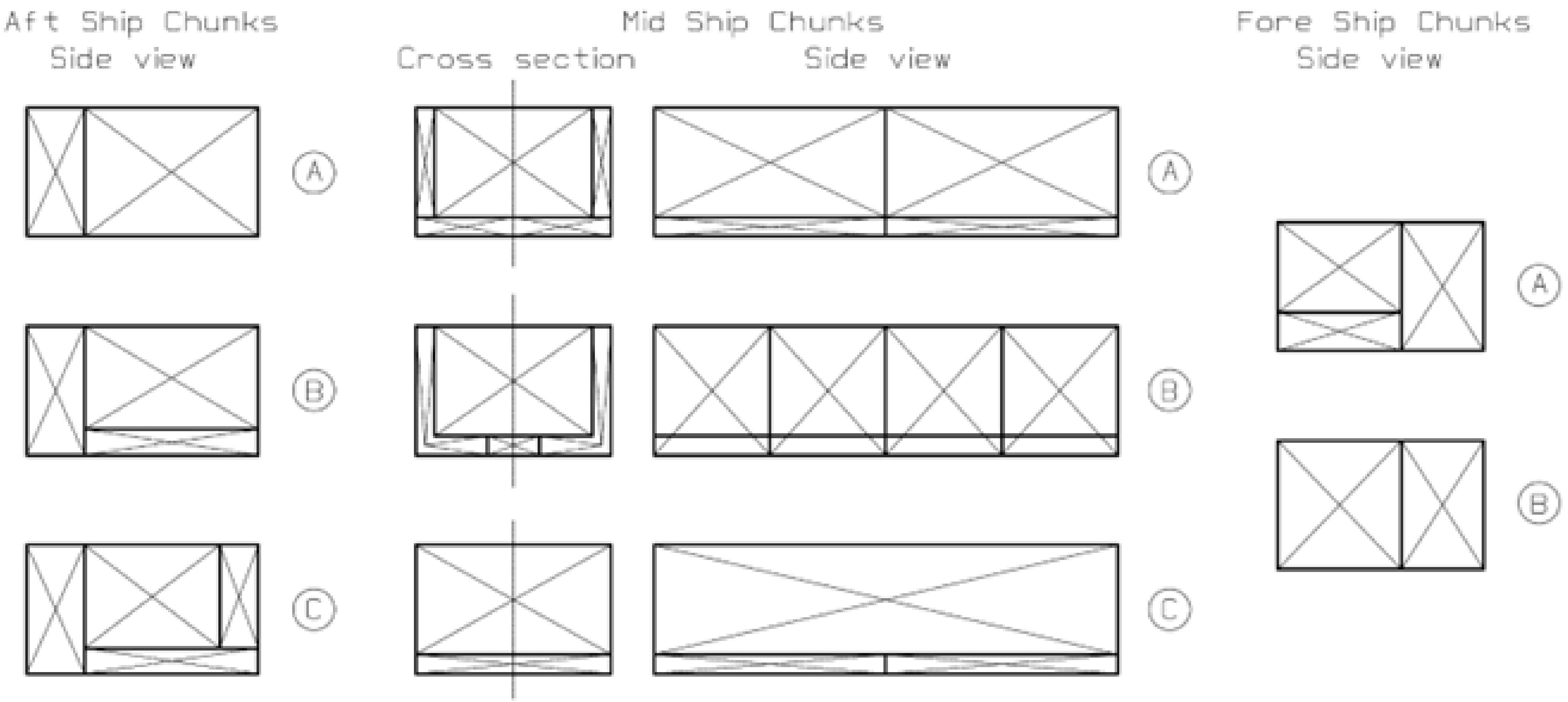
Constituents

- PIAS' Layout module, www.sarc.nl/images/manuals/pias/htmlEN/layout.html
- A library of chuncks.
- A function to assemble chunks.
- Tuning to requirements.

Chunks

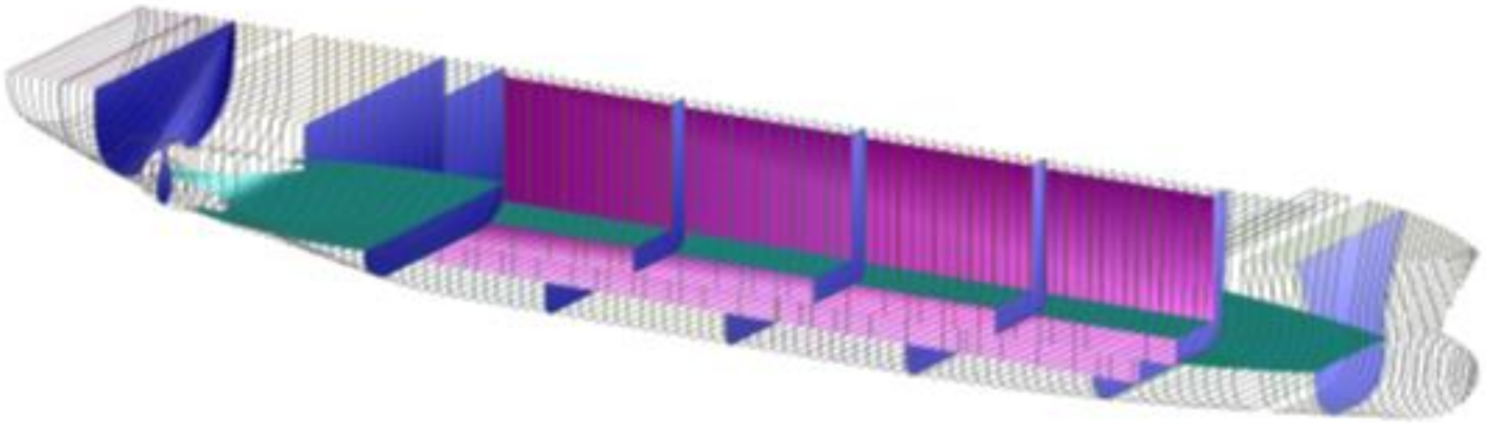
- 'Chunks' is an optional method to be used instead of, or in combination with PIAS' conventional Layout module.
- A chunk is a 'boxed' portion of the subdivision of a ship. It is scalable and determines the (rough) layout a portion of the ship.
- There is a library of chunks to choose from. From this, a user can choose multiple chunks. With this, and a given hull, the subdivision of the vessel will be easily generated.

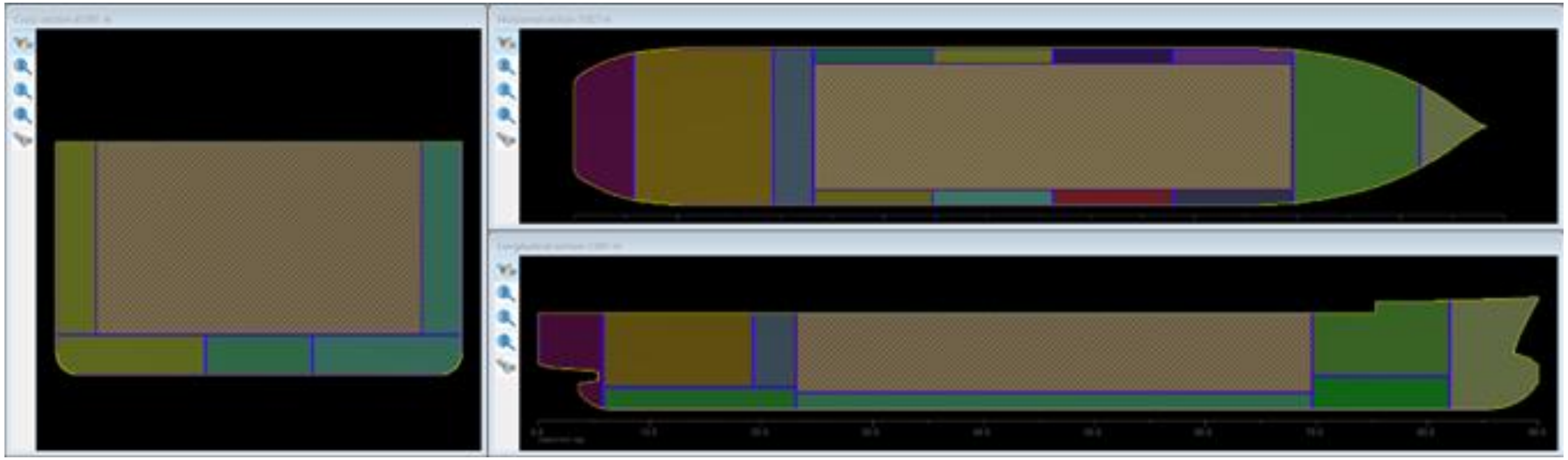
A library of chunks



Extending over full L, B and H. Lateron Boolean *and*ed with the hull form.

An assembly of chunks





Combination of Chunks (Aft C - Mid B - Fore A)

Tuning to requirements

- Requirements on volumes, areas or distances.
- Mininimum, maximum or ‘range’.
- Available in PIAS under the name ‘constraint management’, although ‘matching to requirement’ could be an alternative term.
- White paper: www.sarc.nl/resources/uploads/2022/08/Constraint-Management-paper.pdf.
- Manual:www.sarc.nl/images/manuals/pias/htmlEN/layout.html#layout_constraint_management.

Status

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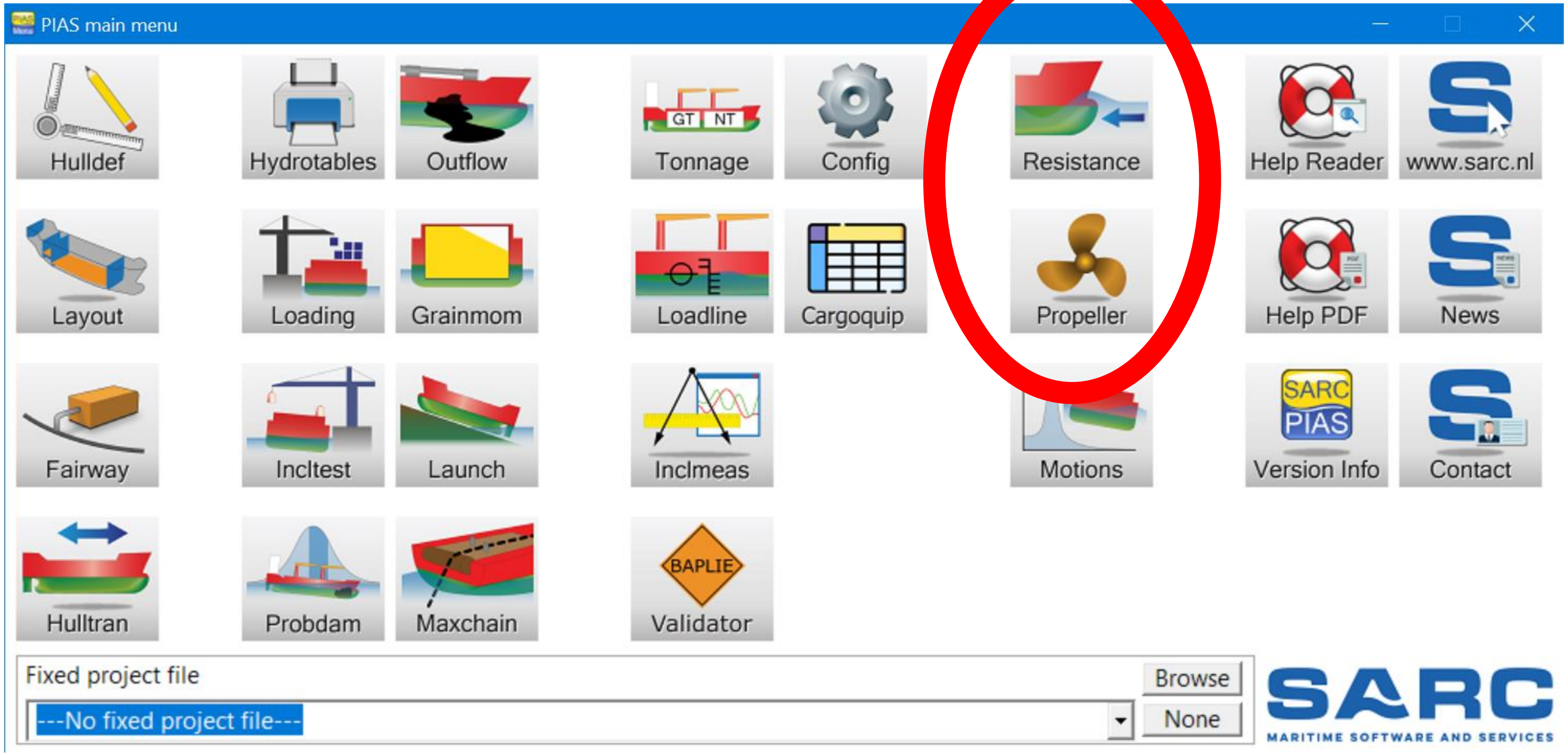
- Design specification of the software is finished.
- Constraint management is available. Yet,perhaps to be refined towards new insights in combination with chunks.

Propulsion and machinery

Propulsion and machinery

PIAS now:



Now under development

- Resistance.
- Mechanical and/or electrical propulsion.
- Gear boxes.
- Wind propulsion.
- All interfaced by means of:
  - Logical connections (e.g. equality of RPM of (direct drive) engine and propellor).
  - Equality of power (e.g. KW out shaft line = kW in propellor),
- Constructs a set of equations, with unknows that can be solved.

Specifics

- Stationary (= constant ship speed).
- # equations = # unknowns, yet the program will assist in this.
- Most common empirical toolset (on resistance, propulsion) pre-programmed, but others importable through a data set.
- Combustion engine characteristics also to be provided in tabular form (incl. SFOC).
- Resistance importable from CFD (as data set).
- Without ship motion, yet with drift and induced resistance (wind assist).

Example: CODAE

- Combined Diesel And Electric.
- Compare Toyota Prius, where the different components were connected by a planetary gear.
- For a ship we could conceive a similar arrangement, with a combustion engine and E-motor jointly, through a planetary gear, driving a propellor (with fixed dimensions and shape).
- With the question which speed will be obtained by an input of 190 KW (at 400 RPM) by the combustion engine and 127 KW of the E-Motor (ignoring wake and thrust deduction).

Set of equations

No.	Equation	Content
1	n3 = f(n1,n2)	The RPM ratio of the gear (depending on the number of teeth)
2	2*pi*n1.M1 + 2*pi*n2.M2 = 2*pi*n3.M3	Equality of powers[10] around the gear
3	M3 = f(n3)	By e.g. Kq from standard propellor series
4	F3 = f(n3)	By e.g. Kt from standard propellor series
5	M1. 2*pi*n1 = 190	190 KW from the combustion engine
6	M2. 2*pi*n2 = 127	127 KW from the E-motor
7	F3 = f(V)	Ship resistance, e.g. by Holtrop & Mennen or CFD
8	n1 = 400/60	Fixed angular velocity (1/sec) of combustion engine

With eight unknowns (n1..n3, M1..M3, V, F3) these eight (non-linear) equations will provide the steady-state solution. And hence solve V (and as side effect the other seven parameters).

Versatile (1)

With a small variation --- given speed instead of available power --- this system can be applied to compute required engine power to achieve a ship design speed.

Versatile (2): extendable

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Including thrust deduction, wake fraction and the involvement of input voltage and current of the E-motor.

No.	Equation	Content
1	M1*2*pi*n1 = 190 = P1	190 KW from the combustion engine
2	M2*2*pi*n2 = 127 = P2	127 KW from the E-motor
3	n1 = 400/60	Fixed angular velocity (1/sec) of combustion engine
4	D = 4	Propeller diameter
5	ηe = 0.75	Efficiency of electrical motor
6	ηp = 0.9	Efficiency of planetary gear
7	Ui = 400	400 V 3 phase power grid on board of ship
8	I = f(Ui, P2)	Current expressed as a function of the voltage and power of the e-motor
9	M2 = f(Ui, I, ηe)	M2 expressed as a function of current
10	n2 = f(Ui, I, ηe, M2)	n2 expressed as a function of voltage, current, efficiency and M2
11	n3 = f(n1,n2)	The RPM ratio of the gear (depending on the number of teeth)
12	2*pi*n1*M1 + 2*pi*n2*M2 = 2*pi*n3*M3	Equality of powers around the gear
13	Q = f(M3, ηp, n3)	Propeller torque expressed as a function of M3, η, n3, Va
14	kq = f(Q, n3)	Torque coefficient expressed as a function of Q, n3 and Va
15	J = f(10*kq, kt)	Advance ratio expressed as a function of 10*kq , to determine from kt, 10*kq diagram
16	Va = f(J, n3, D)	Advance speed expressed as a function of J, n3 and D
17	ω = f(Cb)	Wake factor, determined with method Holtrop & Mennen
18	1-t = f(ω)	Thrust deduction, determined with method Holtrop & Mennen
19	T = f(kt, n3, D)	Thrust delivered by prop. Determined via kt-10kq diagram of the propeller
20	V = f(Va, ω, 1-t)	Vessel speed
21	Rt = f(V)	Total resistance of moving vessel, determined via Holtrop & Mennen

Ahhh..., and the user?

- Complex: on the contrary. It all boils down to conservation laws.
- Complicated: neither. With a well-designed user-interface the intricacies of the system of equations/unkowns can be hidden.

GUI overall design

Design variant(s)

Name
Hybrid propulsion with planetary gear

Connection of the components

Name	Type	Connected to
Hull	Hull	Propeller
Combustion engine	Chemical to rotary energy converter	Planetary gear
Electical motor	Electrical energy converter	Planetary gear
Planetary gear	Rotational energy transfer	Propeller
Propeller	Rotational to linear propulsor	Planetary gear, Hull

Characteristics of the components

Determination method:

Holtrop and Mennen

Parameter	Unit	Value	Source
Density	t/m3		
Length waterline	m		
Breadth	m		

Output of user defined case

Select	Name
Y	Speed determination for a given power
N	Delivered power for a given speed

Definition of variables

Name	Characteristics	Value	Link	Ratio
Combustion engine	Output power	190		
Electrical motor	Output power	127		
Combustion engine	Revolutions	400		
Electrical motor	Input voltage	400		
Hull	Speed			

One integrated UI, containing

- Design variants, which is simply a collection of varying properties of a single design.
- A set of components, with their properties. Componetns are things you can buy; an engine, a propellor, a gearbox, an E-motor.
- A box where the connections of components can be specified; which input connects to which output. Call it ‘the propulsion plant configuration’.
- Another box where fixed and variable parameters are specified. E.g. fixed power / computable speed, or fixed speed, comptable power. Or fixed speed & fixed engine power, computable wind-assisted power.

Further enhacements

This is all stationary. Additionally, support for ranges or sequences of stationary conditions is being co-designed:

- Optimizations. Automated (yet, limited to sensible optimization tasks).
- Scenarios / operational profiles.

Data flow

- This tool is partly founded on data as available in PIAS (hull shape, etcetera).
- The fruits of this tool (such as its results, the logs) remain in PIAS.
- In general, they will be used in design variations (e.g. hull shape modification / adapted engine room space to accomodate other propulsors).
- Through the PIAS – CADMATIC interface the related (shape) design changes will flow downstreams.

Running OpenFoam CFD from PIAS

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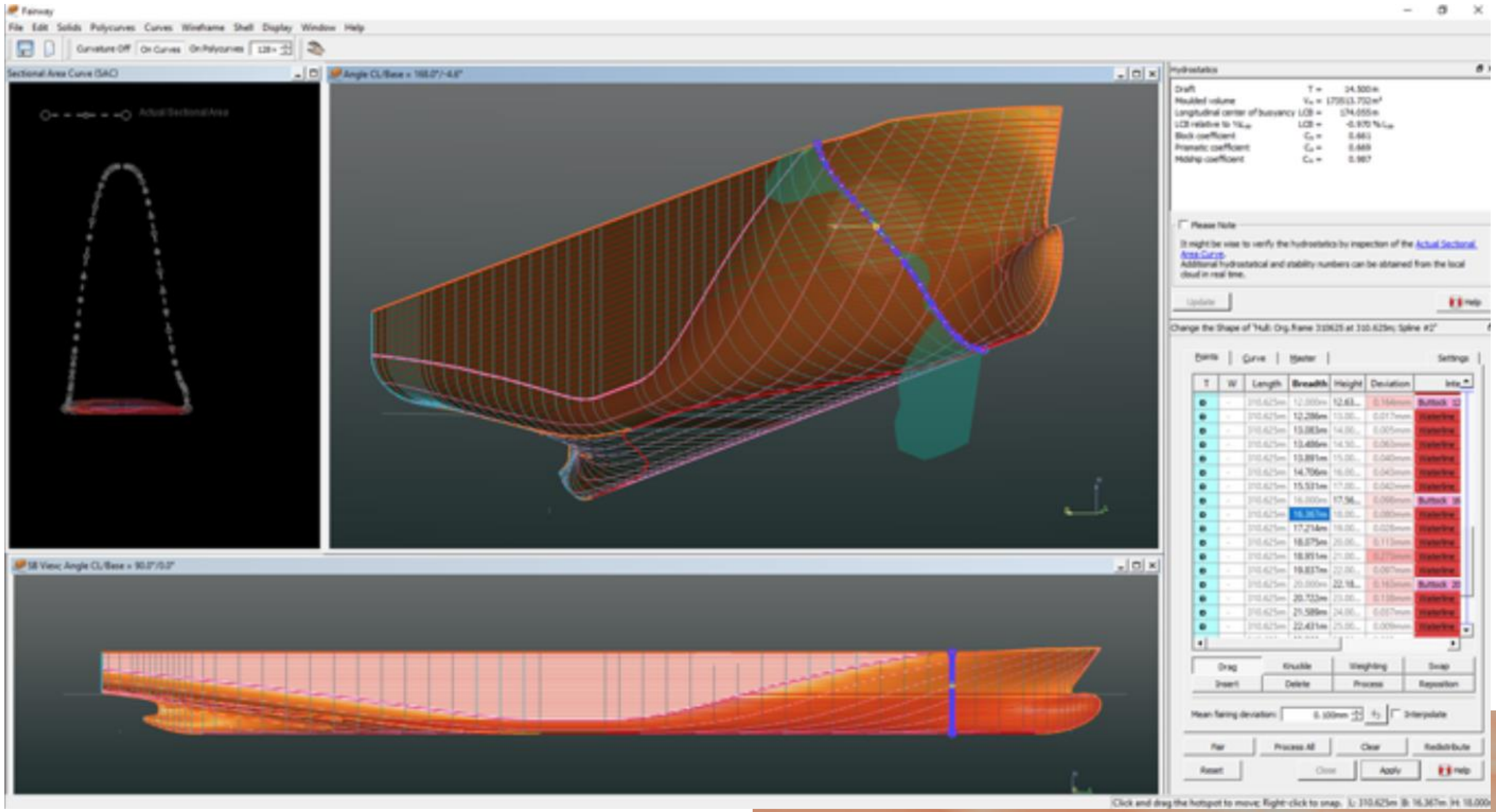

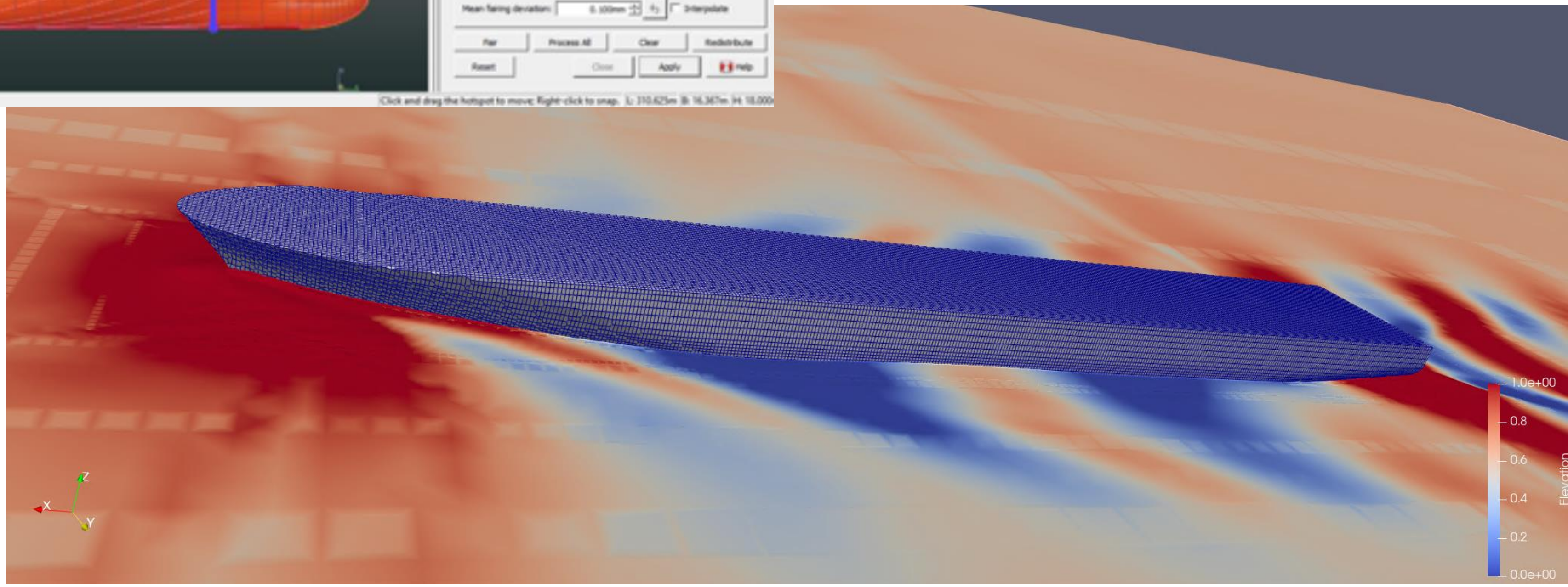

Global hull shape modifications

Global hull shape modification

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Variations of Shape in Industrial Geometric Models

Veelo, Bastiaan Niels

Doctoral thesis

Variations of Shape in Industrial Geometric Models

View/Open

Abstract

This thesis presents an approach to free-form surface manipulations, which conceptually improves an existing CAD system that constructs surfaces by smoothly interpolating a network of intersecting curves. There are no regularity requirements on the network, which already yields superior modelling capabilities compared to systems that are based on industry-standard NURBS surfaces.

Originally, the shape of such a surface can be modified only locally by manipulating a curve in the network. In this process there is an inherent danger that the curve is being pulled away from intersections that it has with other curves. When this happens, the network is invalidated as a surface representation, and many curves may have to be adjusted to restore network consistency and surface quality. This thesis contributes a method that solves these problems by propagating changes that are made in one curve to curves in its vicinity. How and to what extent curves react to changes is controlled by two parameters that can be varied along the curve that is being manipulated. Any curve may be constrained in one or more degrees of freedom. The integrity of the curve network is implicitly conserved, as well as the geometric continuity of the surface.