Unlocking DP Performances thanks to generalised nonlinear robust control

Kerkeni S. & Penin B., MTS Dynamic Positioning Conference 2022, Houston, TX, 11 -12th October 2022

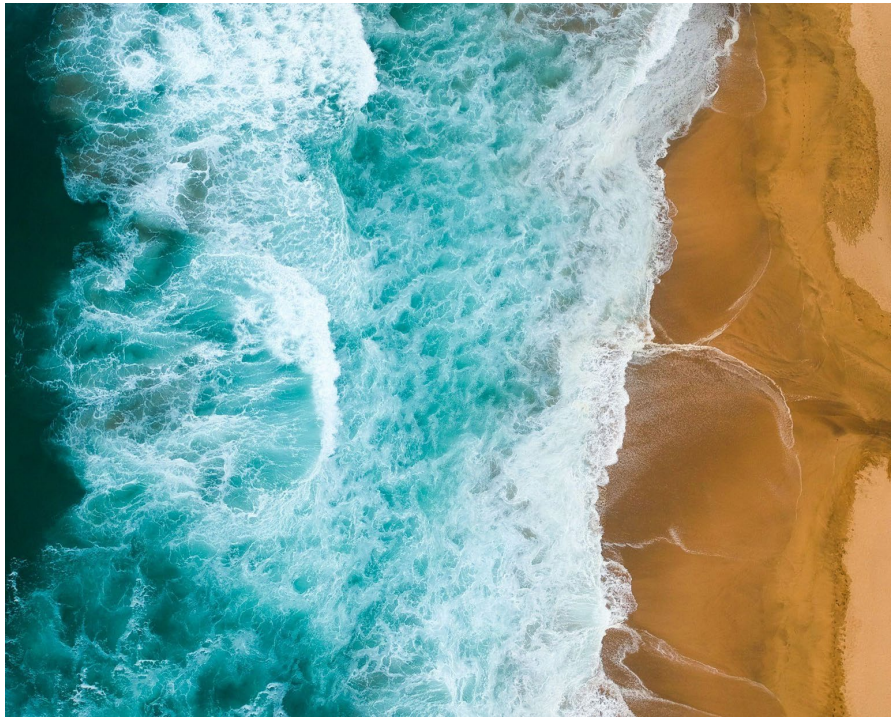
Property of D-ICE Engineering

D - I C E
ENGINEERING

Context

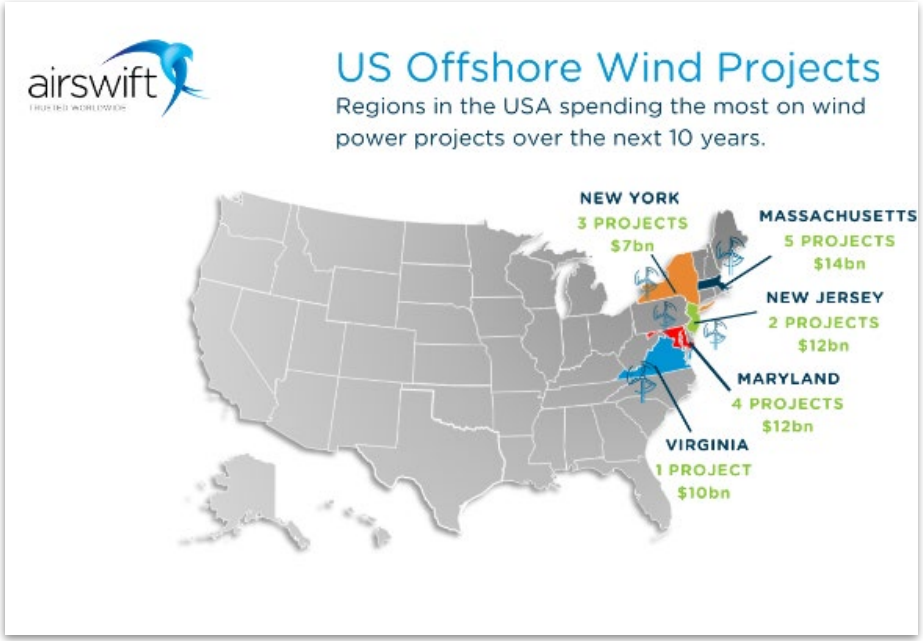
- **Blue Economy** is booming (Market added value estimated to **+3,000 G$** in 2030 [1] e.g.
  - Increase of human activities at sea (e.g. offshore wind energy)
  - Increase of maritime traffic (240-1209% by 2050 [2])

- IMO & UN progressive rules & regulations implementation towards 2050 **carbon neutrality**
  - New ship designs (e.g. foils)
  - New fuels (H_2, NH_3)
  - New propulsion systems (e.g. wind propulsion)



[1] *OECD, 2016*
[2] *Nature, 2019*

The Offshore Wind Driver



source : airswift, 19 August 2022

Room for efficient operations

Control system should enable efficient transitions

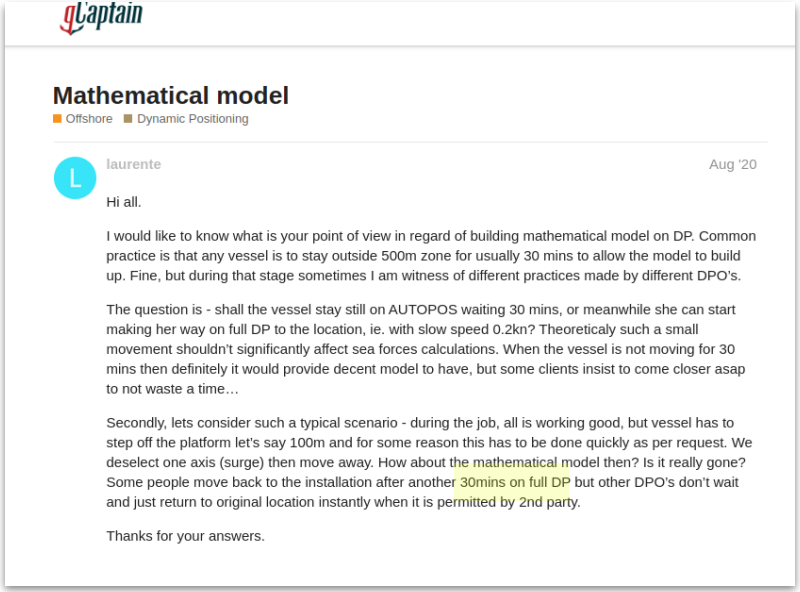
- From transit phase to wind turbine arrival
- Movement between wind turbines
- Coordination of gangway and vessel: ideal position for gangway connection
- Enable efficient, faster and safer
- Waiting

source : Dynamic Positioning Systems for the Offshore Wind Service Industry, Ivar Ihle, MTS Dynamic Positioning Conference 2018

Position of the Problem - Operators point of view

The DP software contains static data on the vessel parameters, but it is also an adaptive feature. The analogy is that of steering a vessel by hand. Although skilled at steering, a helmsman will take five minutes or so to get the feel of the vessel after taking the wheel. The DP system does the same: the control takes up to 30 minutes to adapt fully to the vessel configuration and the present environment. Subsequently, the system adapts to changes in the vessel or environment, just as helmsmen will adapt their steering to changing sea states. It is normal to allow 30 minutes as a model-building period, or settling time, to reduce oscillations in position and/or heading. In recent years some system manufacturers have shortened the modelling period to 10–20 minutes. In safety-critical operations 30 minutes is still recognised as a standard settling period.

Captain David Bray FNI, DP Operator's Handbook - 3rd edition, 2020



gCaptain

Mathematical model

Offshore Dynamic Positioning

L laurente Aug '20

Hi all.

I would like to know what is your point of view in regard of building mathematical model on DP. Common practice is that any vessel is to stay outside 500m zone for usually 30 mins to allow the model to build up. Fine, but during that stage sometimes I am witness of different practices made by different DPO's.

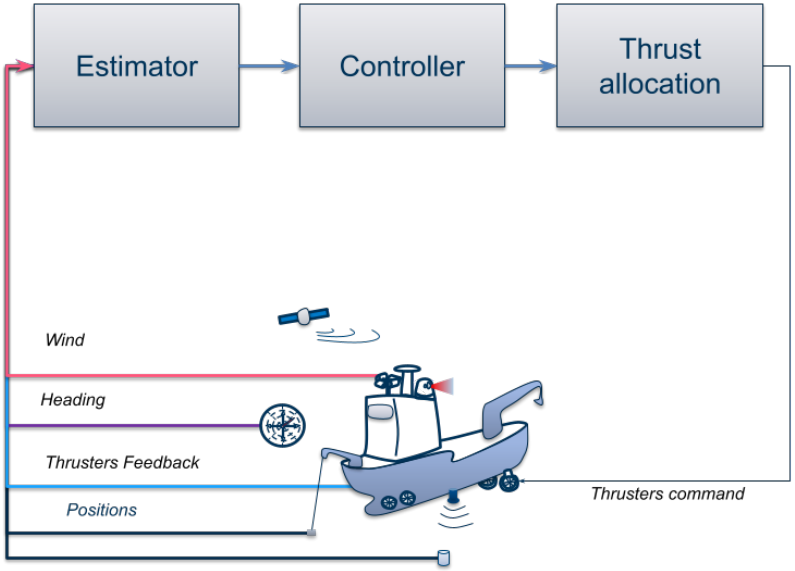
The question is - shall the vessel stay still on AUTOPOS waiting 30 mins, or meanwhile she can start making her way on full DP to the location, ie. with slow speed 0.2kn? Theoreticaly such a small movement shouldn't significantly affect sea forces calculations. When the vessel is not moving for 30 mins then definitely it would provide decent model to have, but some clients insist to come closer asap to not waste a time…

Secondly, lets consider such a typical scenario - during the job, all is working good, but vessel has to step off the platform let's say 100m and for some reason this has to be done quickly as per request. We deselect one axis (surge) then move away. How about the mathematical model then? Is it really gone? Some people move back to the installation after another 30mins on full DP but other DPO's don't wait and just return to original location instantly when it is permitted by 2nd party.

Thanks for your answers.

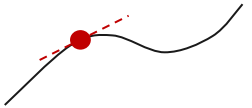
GCaptain Forum, August 2020

Position of the Problem - DP Architecture point of view



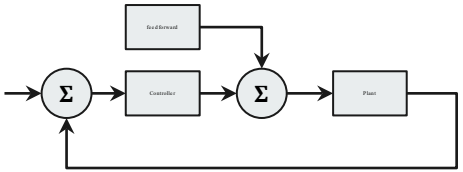
Estimator

State-of-the-art ; Extended Kalman Filter



Controller

Feedforward PID controller



Thrust Allocation

Optimisation problem

State-of-the art ; Quadratic Problems

Real Challenges.
True Solutions.

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Theoretical Considerations
Application Case
Generalised nonlinear control

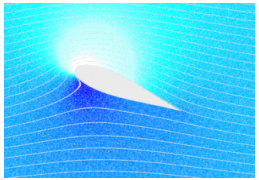
High-Fidelity Physics Based DP

A Millenium Problem…

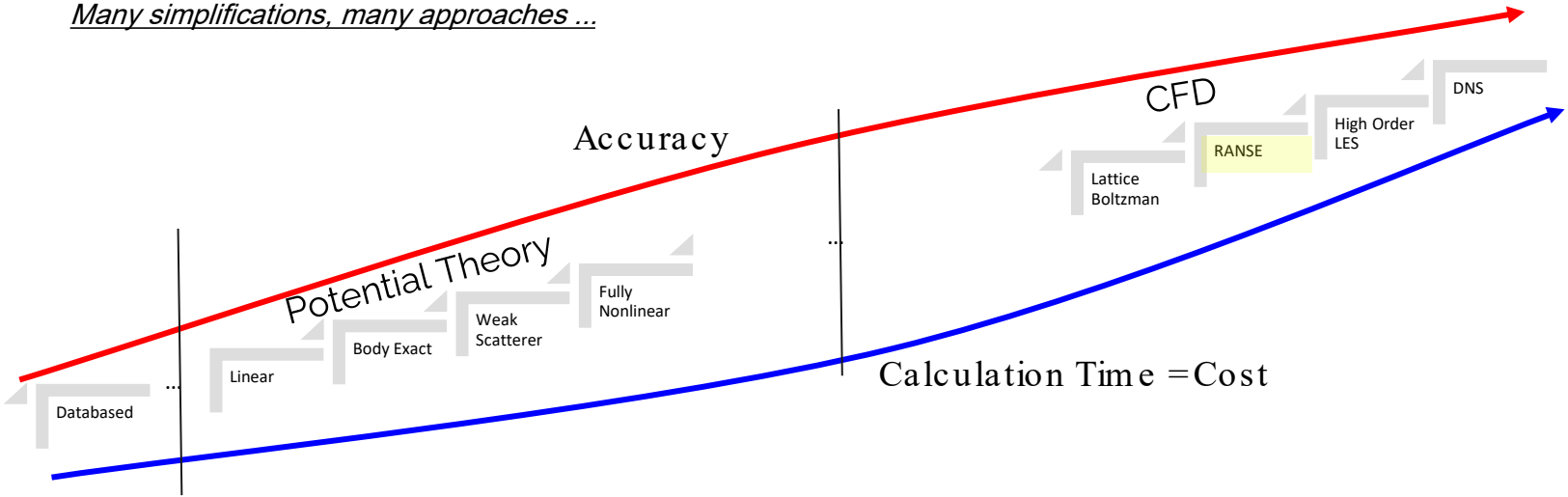
Navier-Stokes Equation

$$\nabla \cdot \vec{V} = 0$$

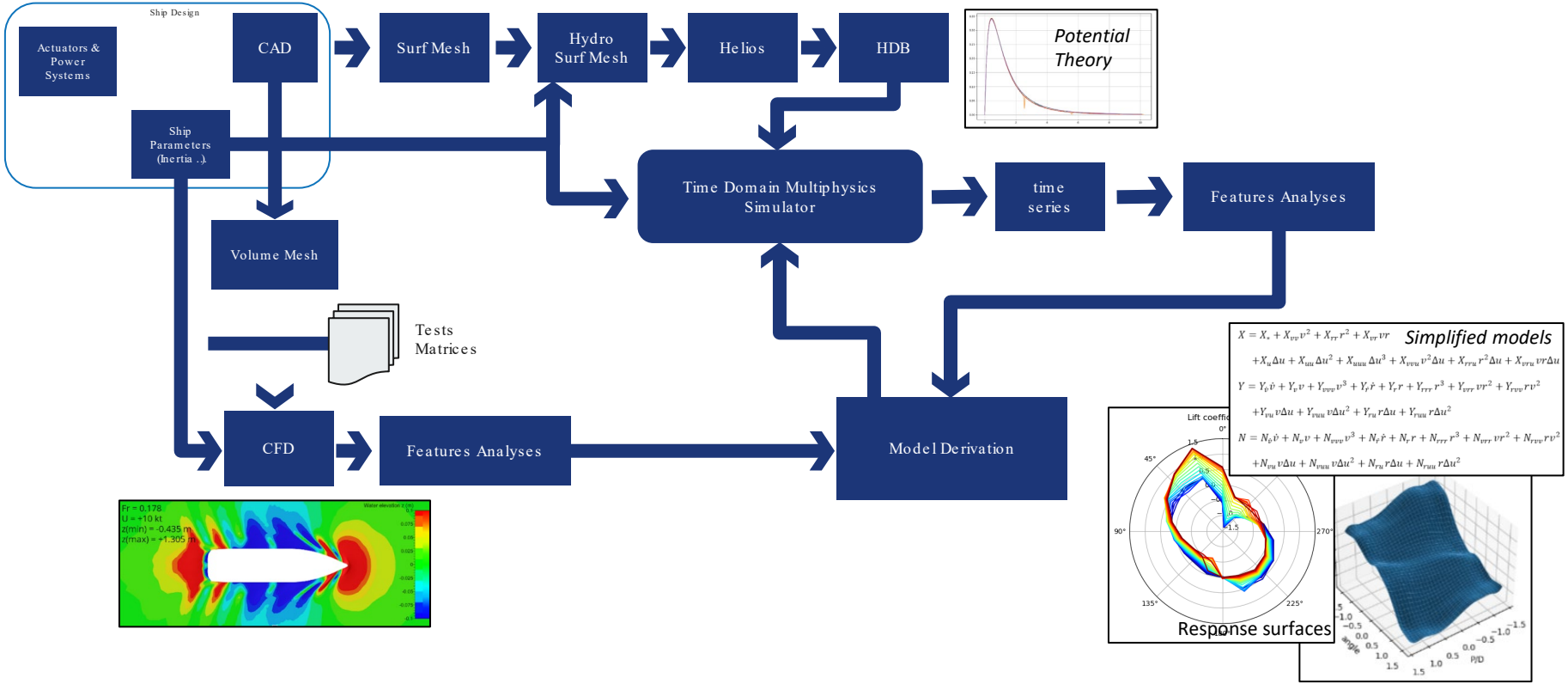
$$\rho \frac{D\vec{V}}{Dt} = -\nabla p + \rho \vec{g} + \mu \nabla^2 \vec{V}$$



Many simplifications, many approaches ...



Global Workflow



Application Case For Technip Energies

ALP Future Tug

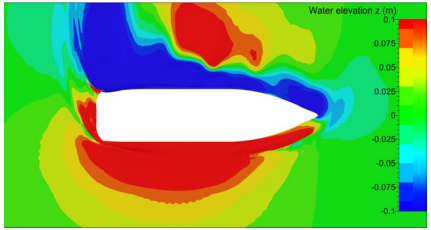
Courtesy Technip Energies

Coral South LNG

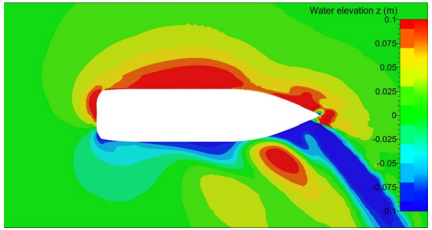
Courtesy Technip Energies

CFD Calculations

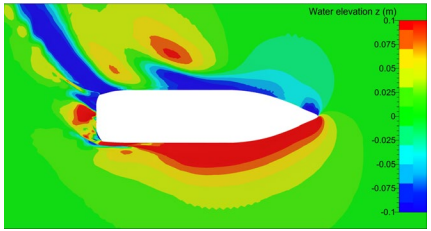
- Use of RANSE commercial CFD software (FINE™ / Marine)
- Investigation of more than 80 scenarios and complex trajectories
- Deep investigation of all computed variables to ensure proper post processing



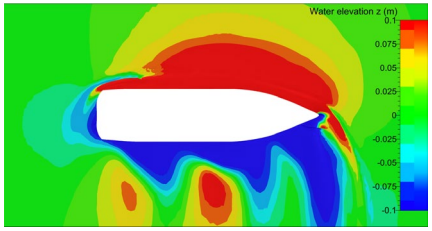
90° (starboard)



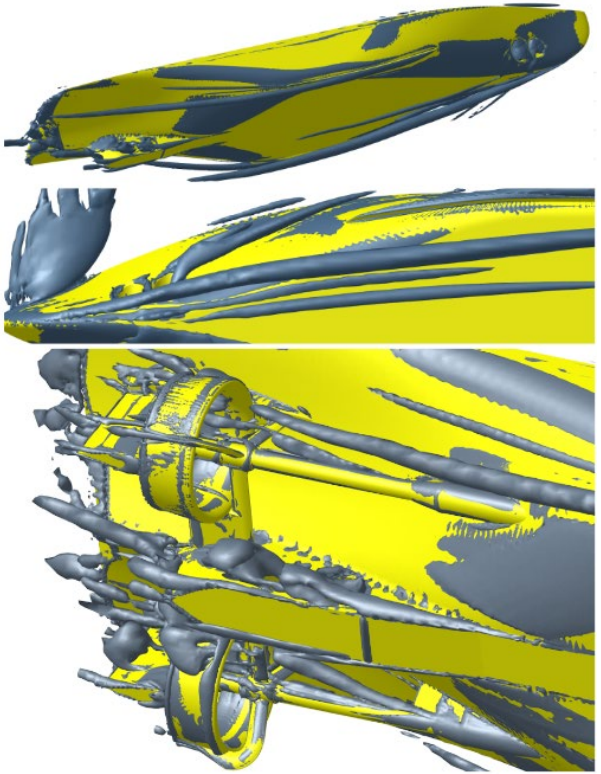
-135° (backward / starboard)



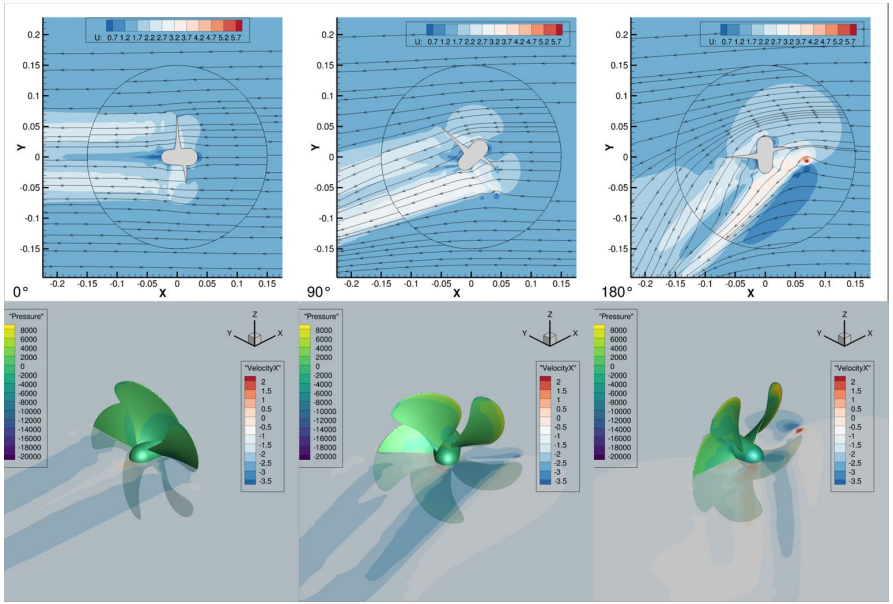
45° (forward / starboard)



°90 (port)



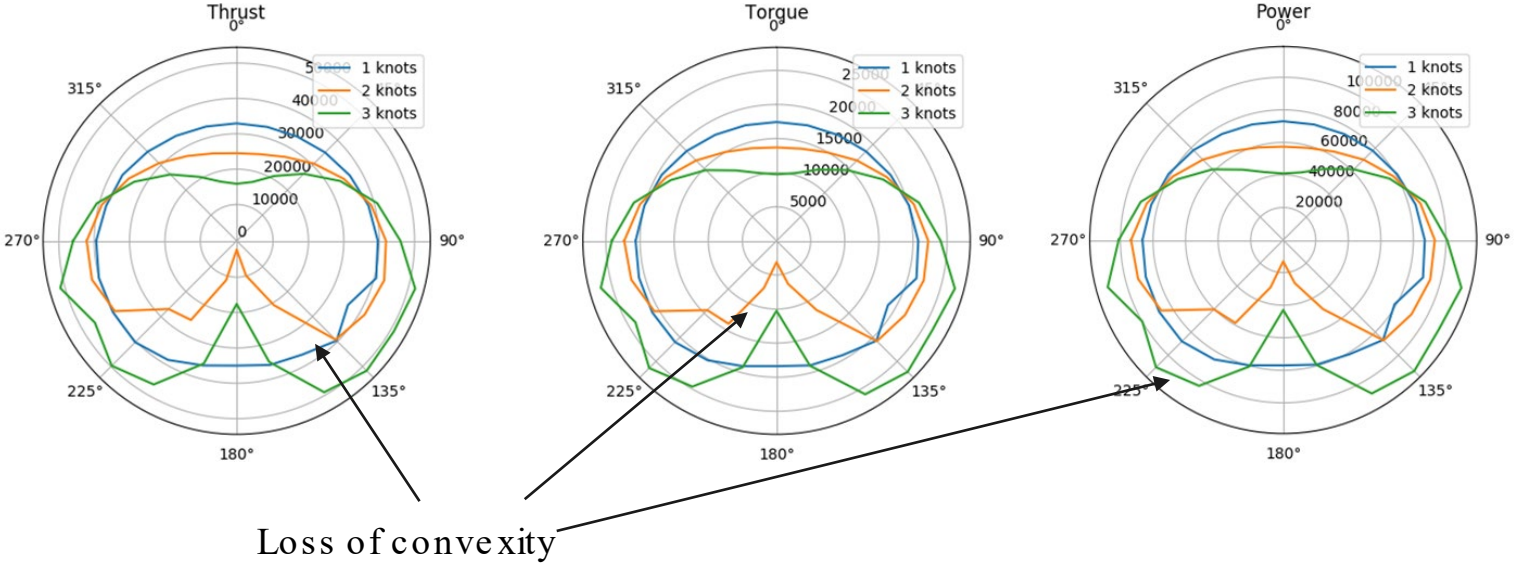
Focus on Propulsive Models



- Influence of Waves
- Influence of Current
- Influence of Control Parameters

Focus on Propulsive Models

Focus of the Influence of Current & Control parameters for a Duisburg-type Azimuth Propeller



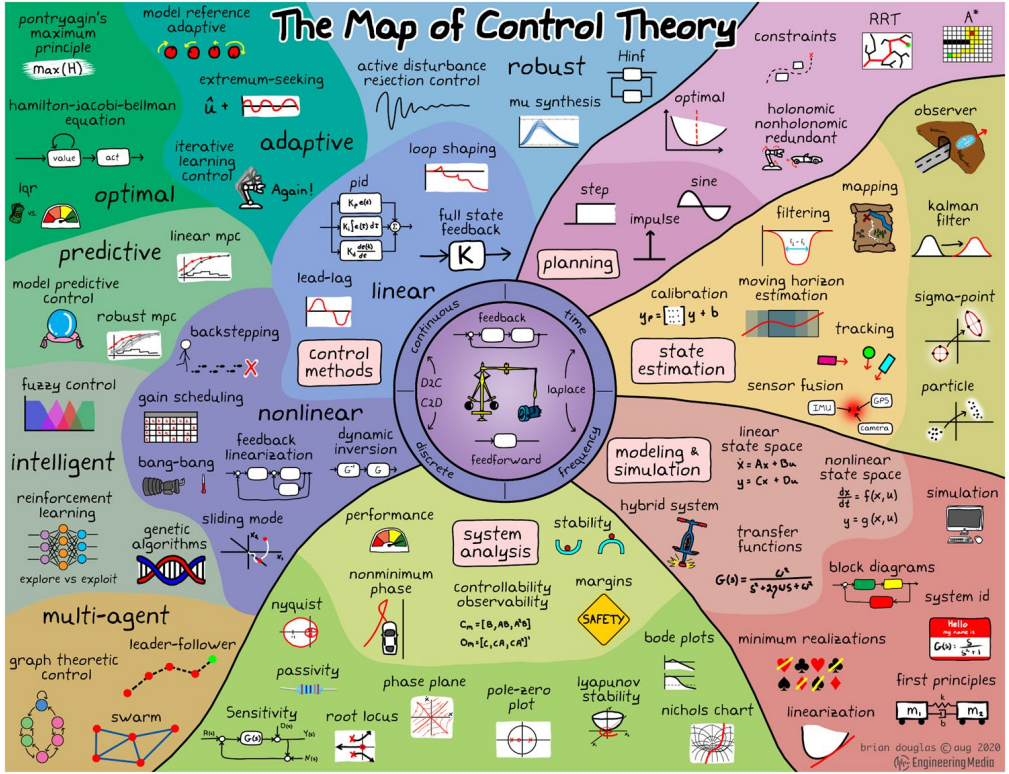
Real Challenges.
True Solutions.

2

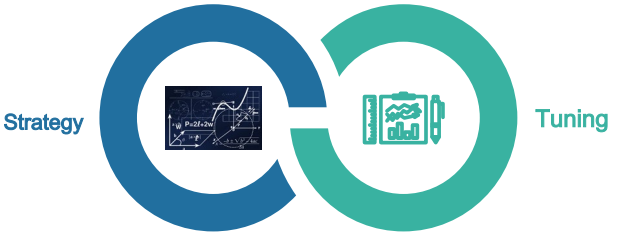
Introduction & Generalities
Application Case

Robust Nonlinear Control

Solvig Control problems in practice



Source : Brian Douglas, EngineeringMedia



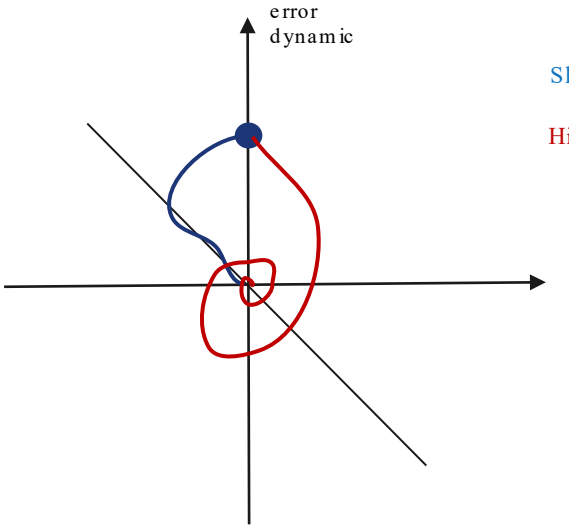
A combination of a strategy **and** a tuning

- The strategy must be adequate to the problem typology
- Tuning is often a difficult and potential long-process, requiring expertise and experience
- The most advanced strategy with a poor tuning may be much less performing than a regular strategy with a good tuning…
- Modern control strategies are often difficult to tune

About Robust Control

Position of the problem

- Dynamic changes of the process
- Variation of the control feedback
- Uncertainties
  - measurements
  - control variables
  - mathematical model



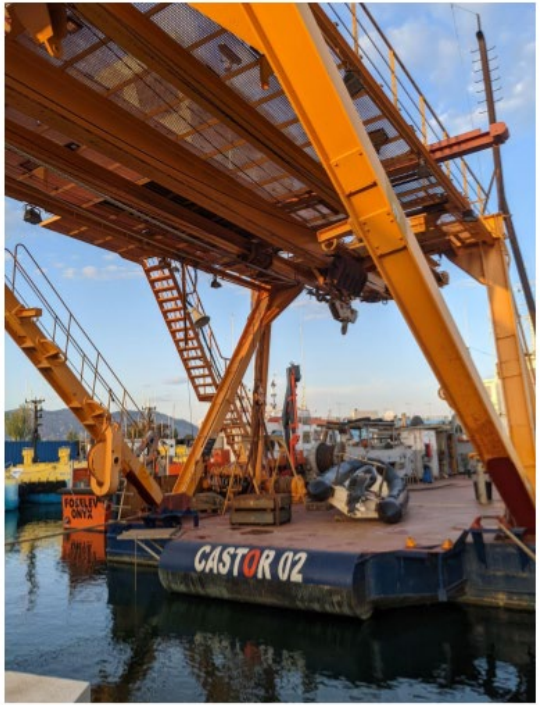
Sliding Mode

High-Order Supertwisting Sliding Mode

Application Case

- Refit of a old supply vessel
  - Castor02
    - Operated by FOSELEV Marine
    - La Seyne sur Mer (France)
    - Old DP System
      - Obsolete
      - No more maintenance

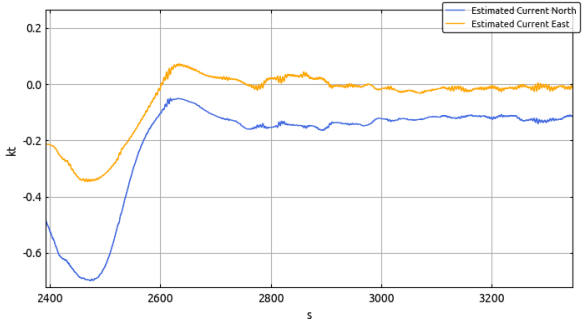
- Project constraints
  - Keep original system functioning
  - Lack of data (No data)
  - Tight timelines
  - Tight Budget

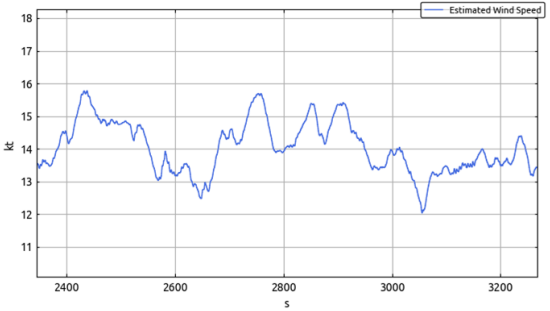


Application Case - Results

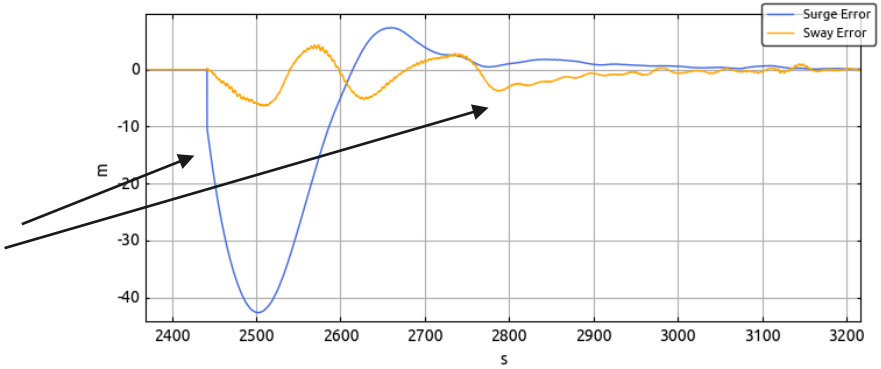
Example of Station keeping performances

- Direct Activation of Station Keeping Mode
- No standard procedure with joystick activation sequences





Stabilisation time in less than 10 minutes



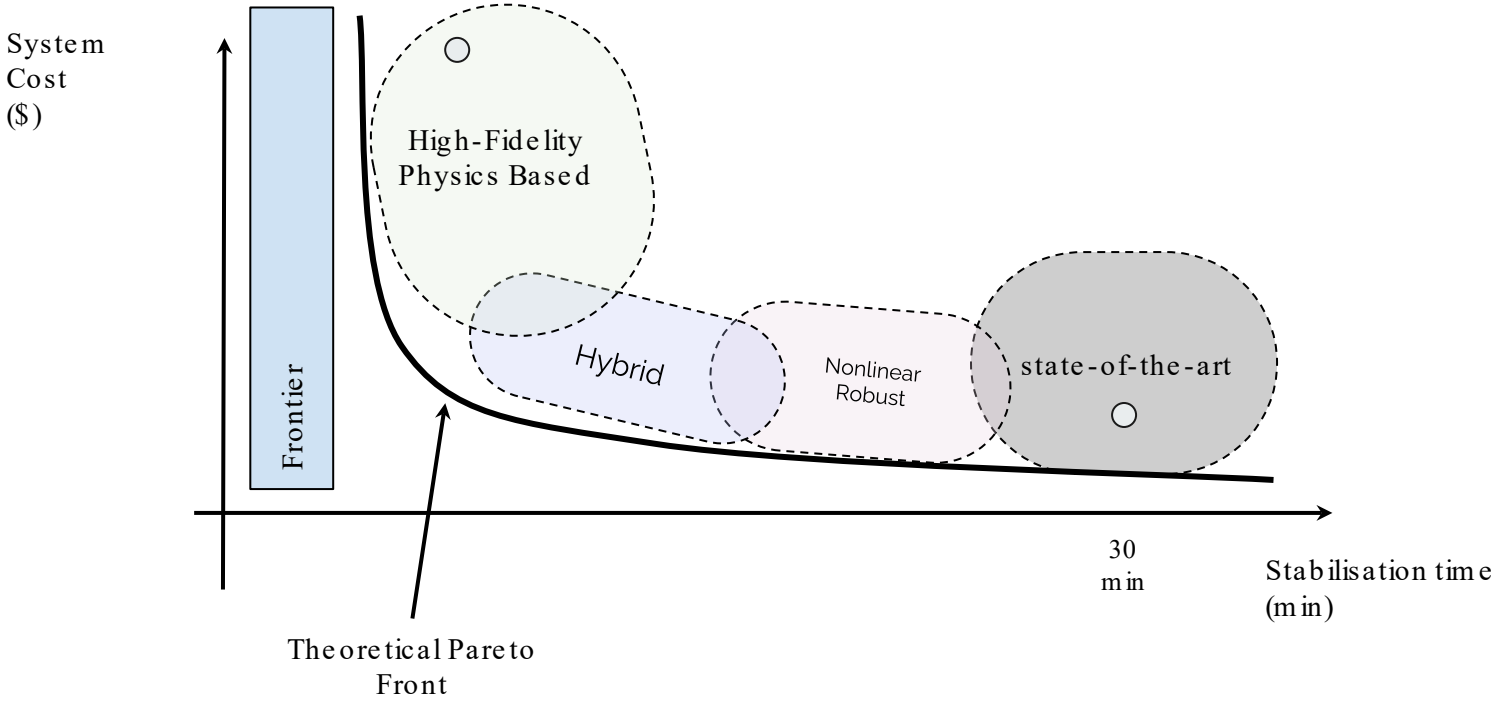
Real Challenges.
True Solutions.

3

Qualitative Considerations
Roadmap

Hybrid DP Control Approach

Qualitative Considerations



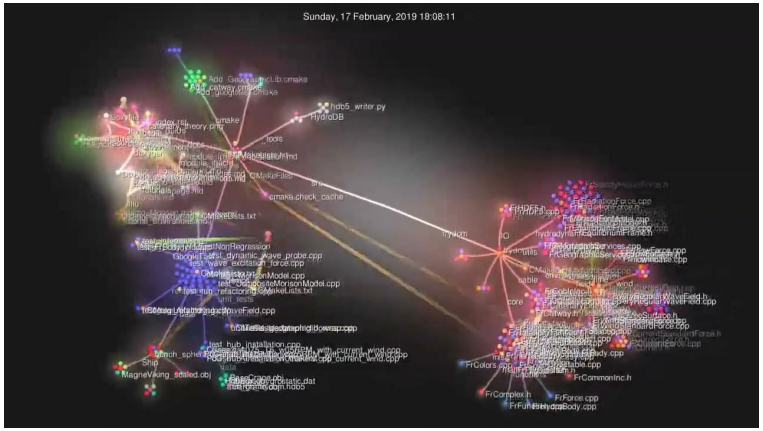
Generic Framework & Product Baseline

Main requirements

- Industrial-grade quality product
- Certification process

OCEANiCS, developed since 2017. Main features:

- Generic control framework, written in modern C++ (C++-20 standard), cross platform by the use of CMake compilation toolchain
  - Strong mathematical foundations
  - Proven real-time capabilities
- Generic HMI framework written with C++/ Qt
  - Automatic adaptation to the asset configuration
  - Elastic & Evolutive application
- System Design
  - COTS components
  - Generic PLC (brand agnostic)



Current Applications

- MED Autopilot Certified
- DP-0

Planned Evolutions

- DP-1 & DP-2 (2023)
- Integrated Bridge Navigation System (2024)

Conclusions & Outlooks

- New fields of applications are arising for dynamic positioning vessels.
- Importance to lower the stabilisation time
- Different strategies investigated, showing both advantages and disadvantages.
- New upcoming project led by TechnipEnergies with CEA, Ecole Centrale Nantes and D-ICE for a novel platform for O&M for FOWT wind farms

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