MARIN

BETTER SHIPS, BLUE OCEANS

Intelligence for automated manoeuvres; docking of a feeder vessel

Bas J. de Kruif

Previous - ISAM waypoints tracking

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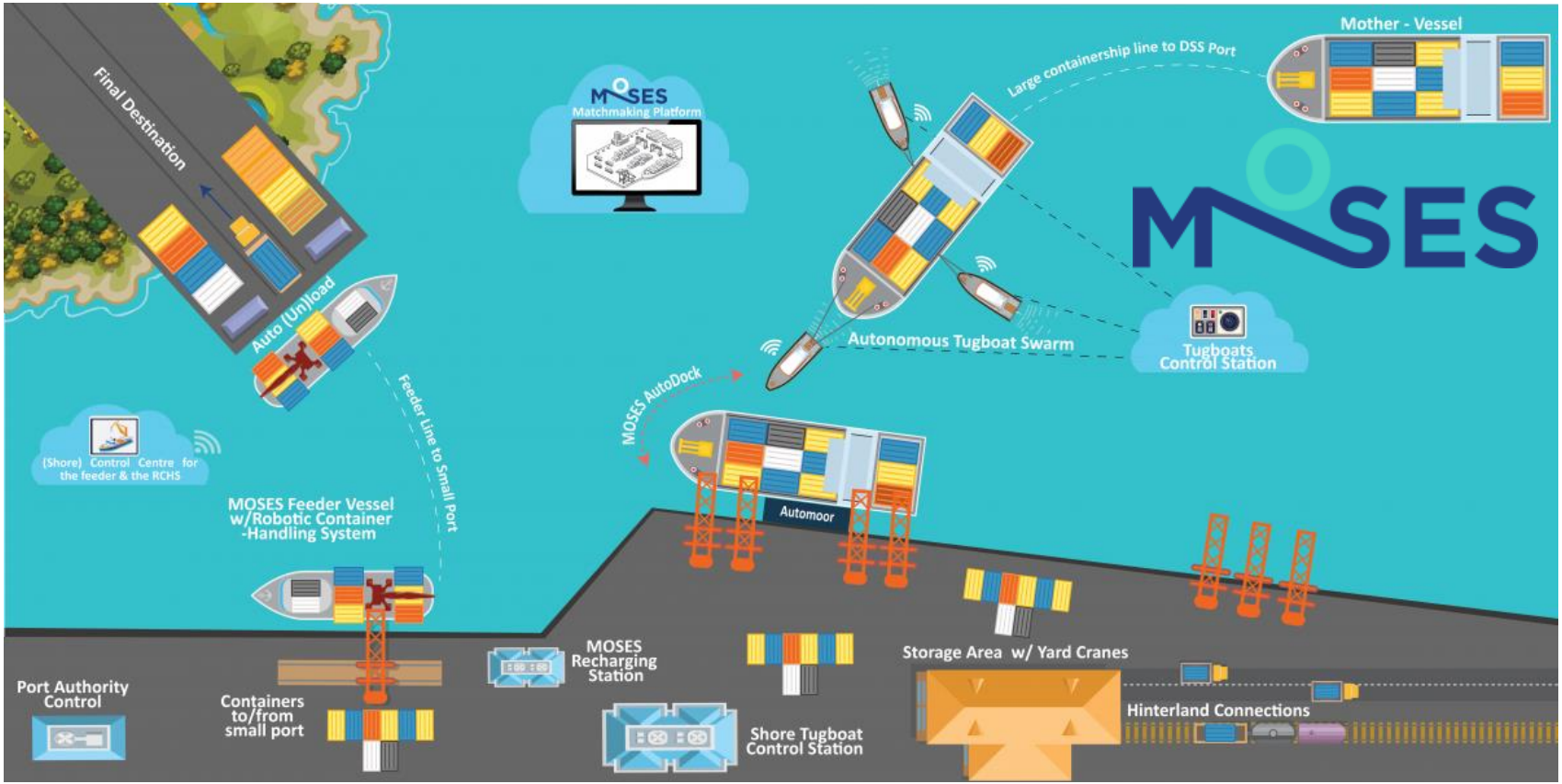
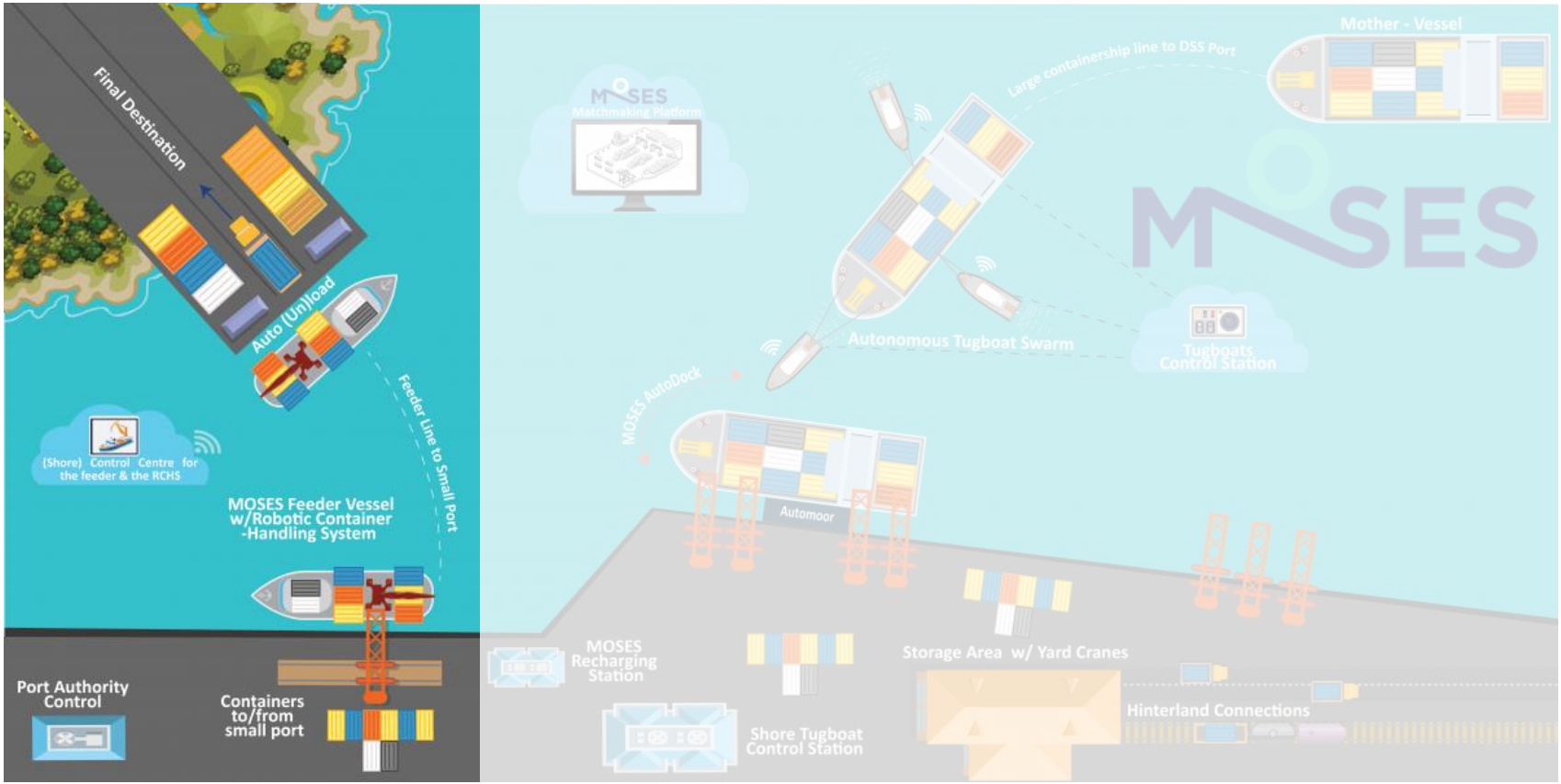
Introduction - EU Moses project



Introduction - EU Moses project



Introduction

Aim:

- autonomously sail from quay to quay

Why:

- investigate the difficulties to better assist industry

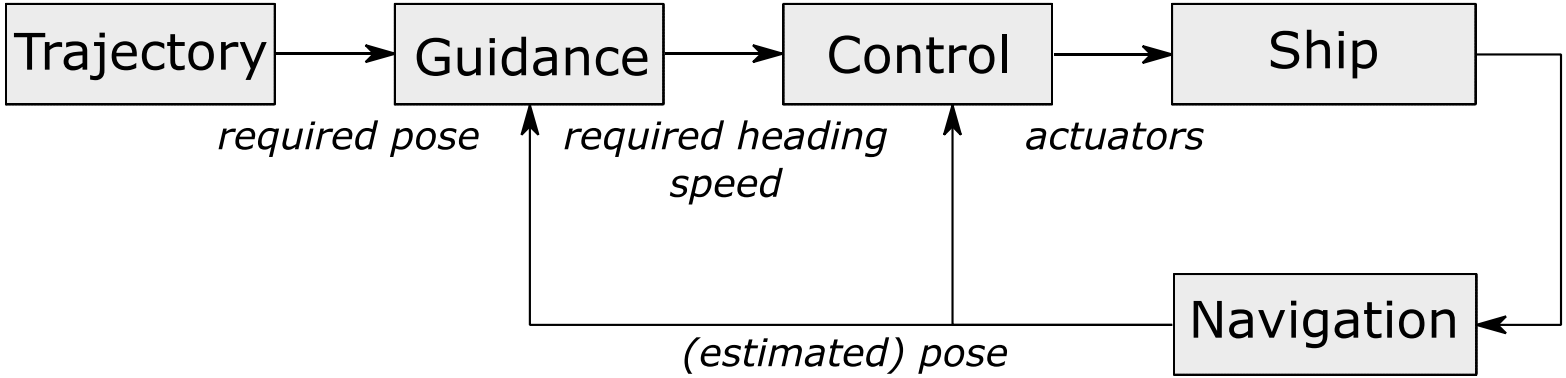
Approach:

- split whole operation
- solve tasks
- stitch together
- simulate

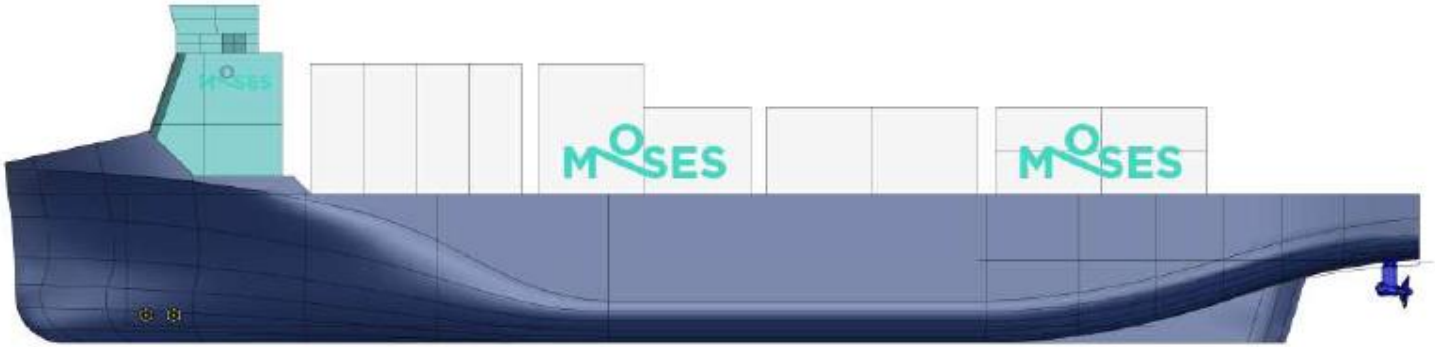
Split operation

Split operation

Guidance - Navigation - Control framework



Ship model

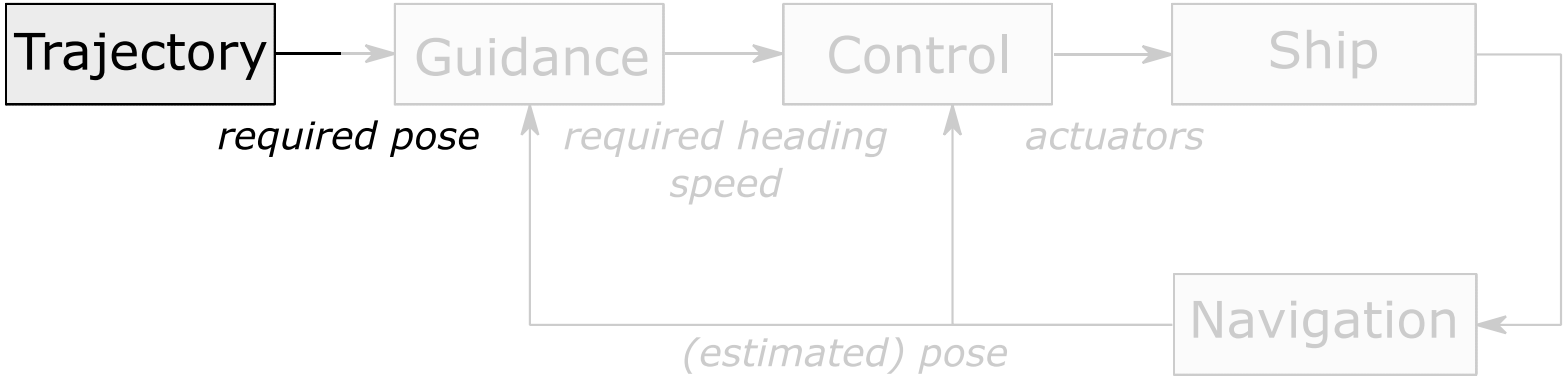


Lpp	71.0 m
B	13.0 m
t	4.5 m
∇	2.8 10^3 m^3
m	2.9 10^6 kg

- two azimuthing pods
- two bow thrusters
- course unstable ship

manoeuvring model from CFD calculations
→ available in xSimulation

Approaching - GNC



Approaching - trajectory

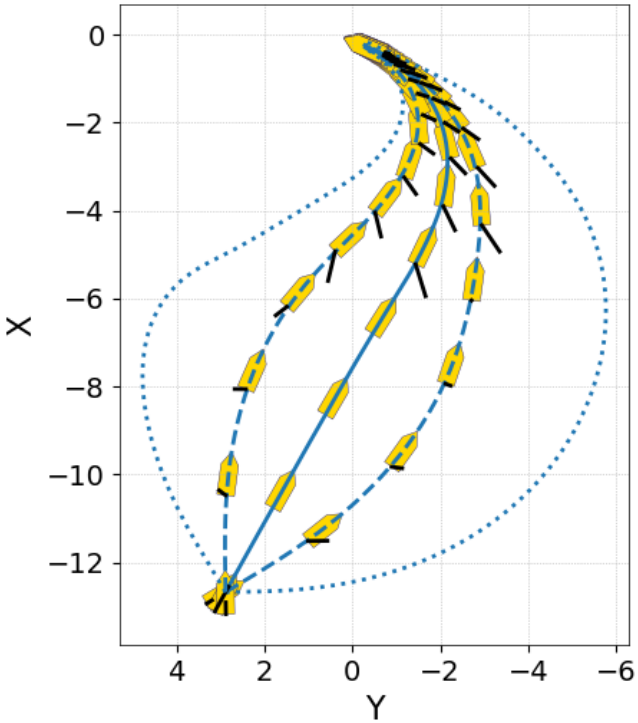
Solve as Optimal Control Problem:

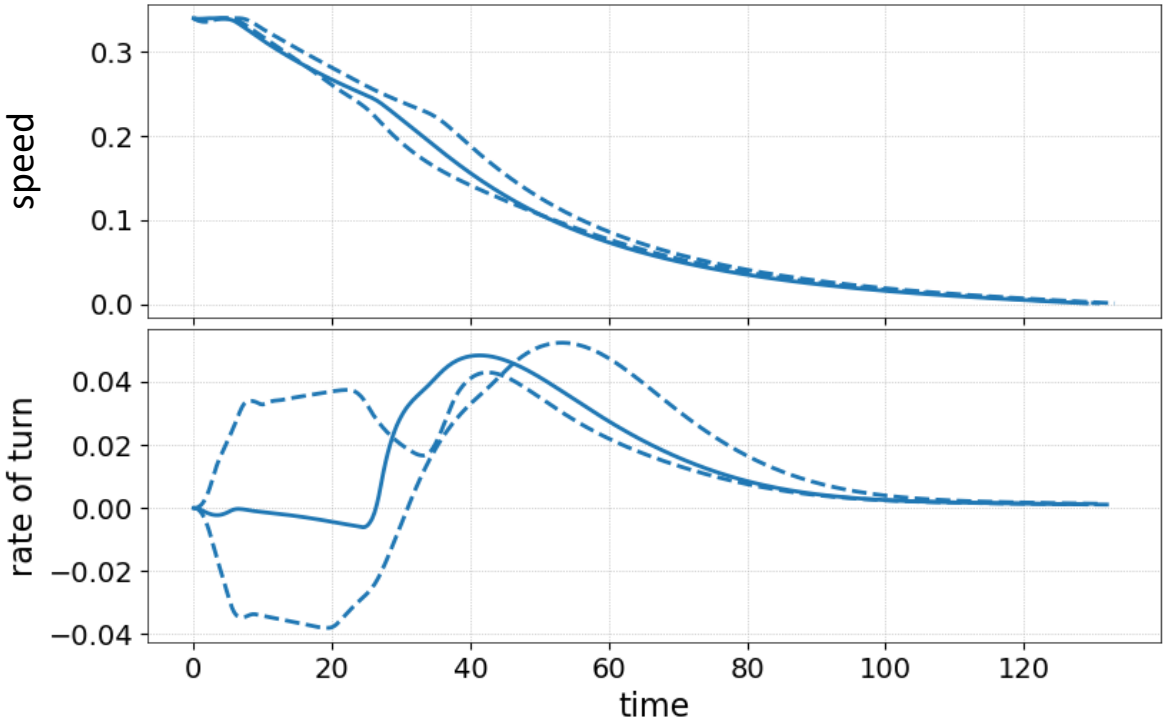
- optimisation with ship dynamics as constraints
- constrain initial pose, actuator usage
- minimise time (and energy) usage

→ time-dependent trajectory results

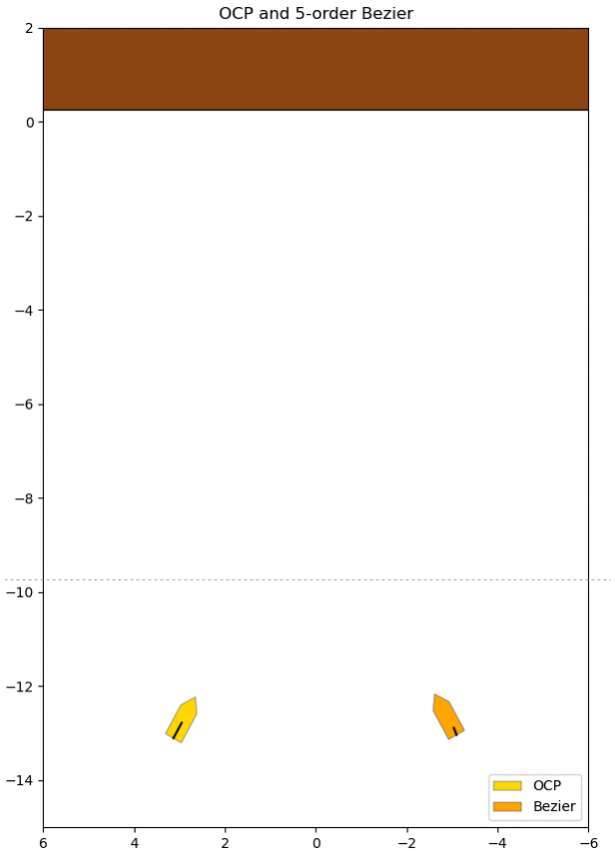
Approaching - trajectory

Solve as Optimal Control Problem:



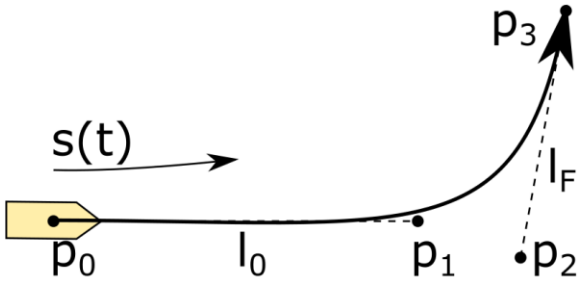


Approaching - Bézier approximation



Approximate with curve:

- fast calculation
- only for non-challenging situations



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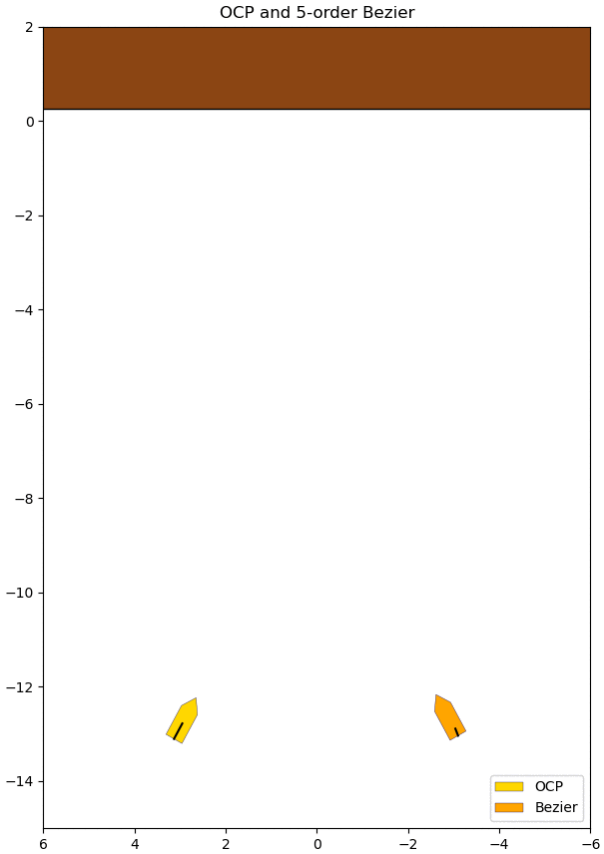

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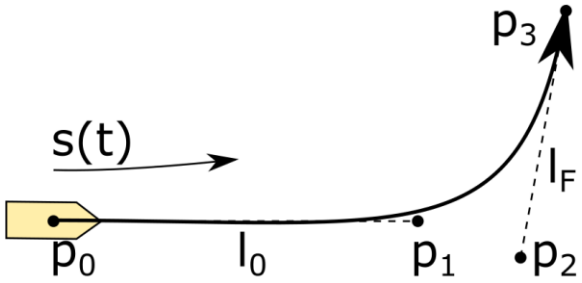
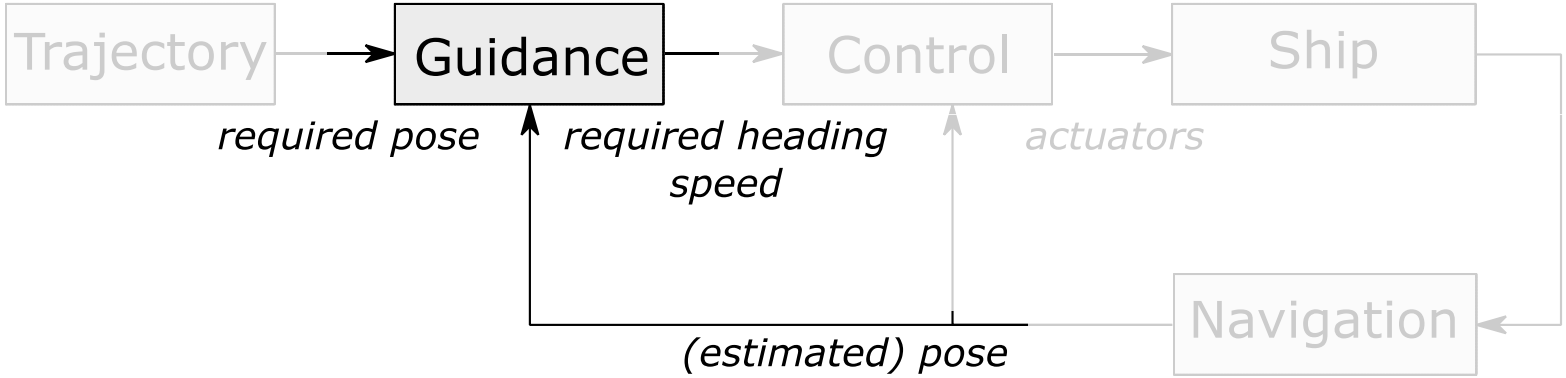


Approaching - GNC

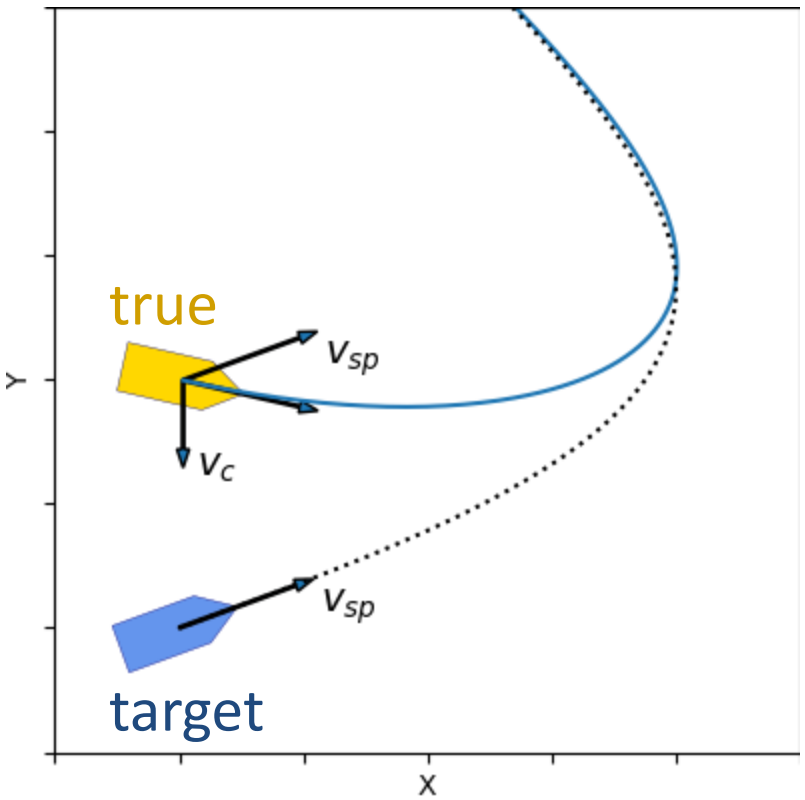


Approaching - guidance

Convert earth-fixed trajectory

→ to ship-fixed heading/speed

- Constant bearing
  - copies velocity vector of ‘target’
  - adds velocity vector to reach it



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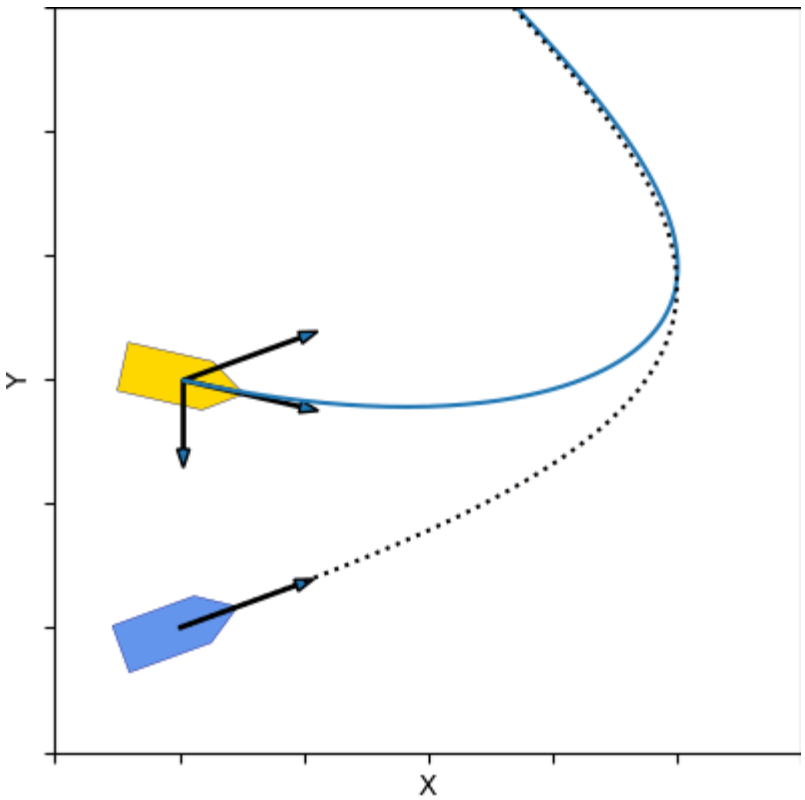
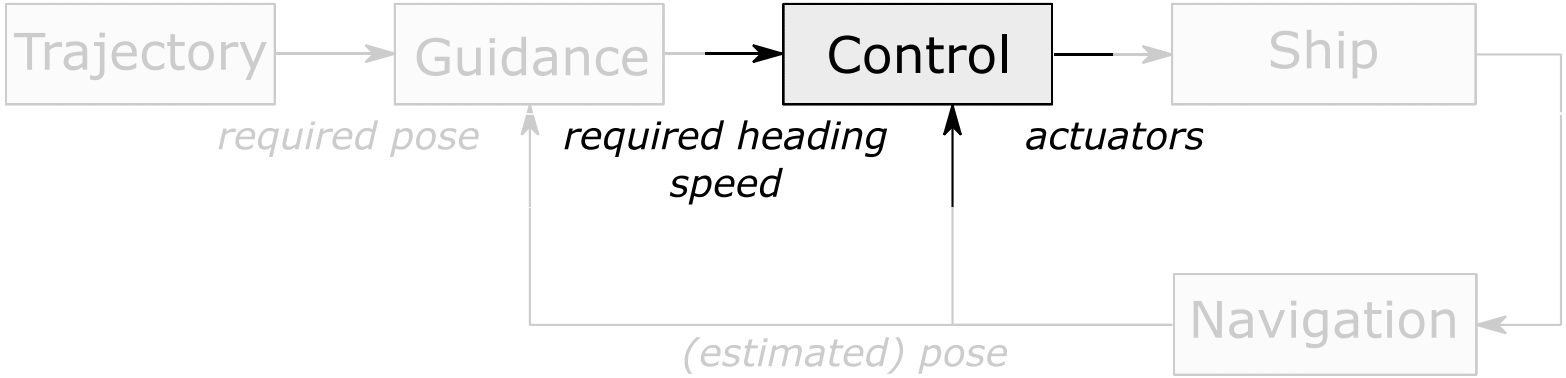
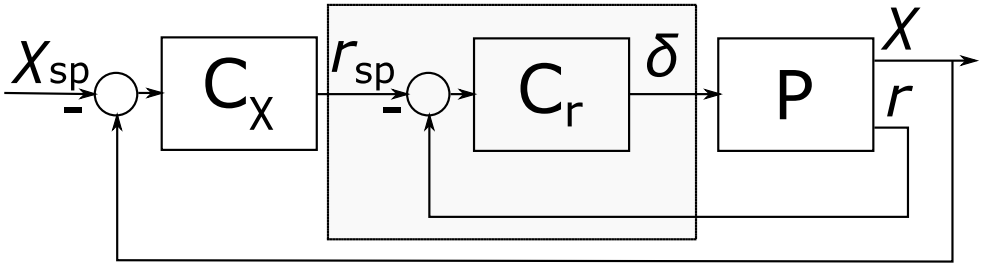


Approaching - GNC

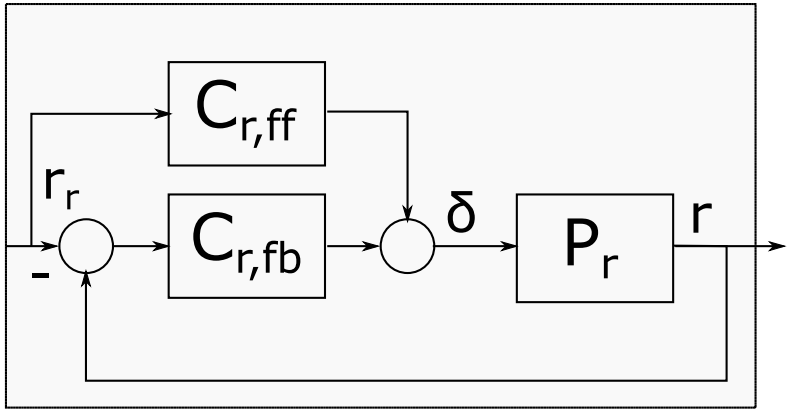


Approaching - control



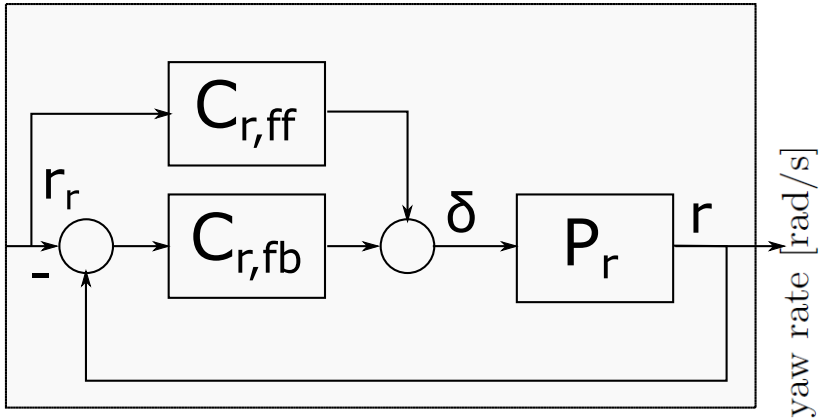
- Cascade control
  - inner loop: rate-of-turn
  - outer loop: course
- Stabilises unstable inner loop
- Counters fast disturbances in inner loop

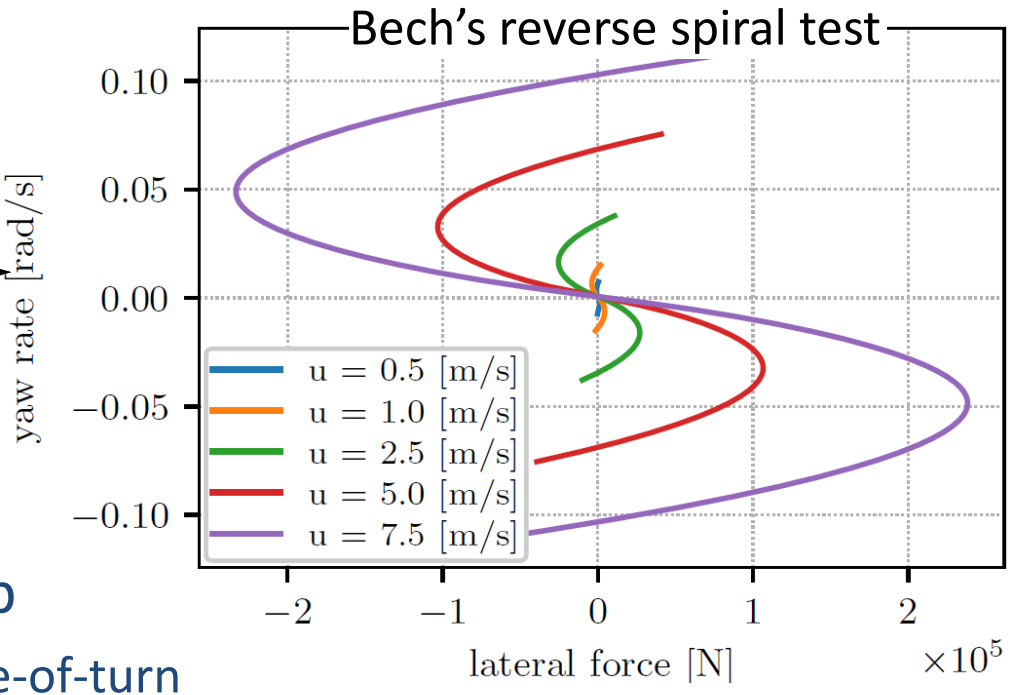
Approaching - control



- Cascade control - inner loop
  - controls rudder to obtain rate-of-turn
  - feedforward → control what you know
  - feedback → counter disturbances / instability

Approaching - control





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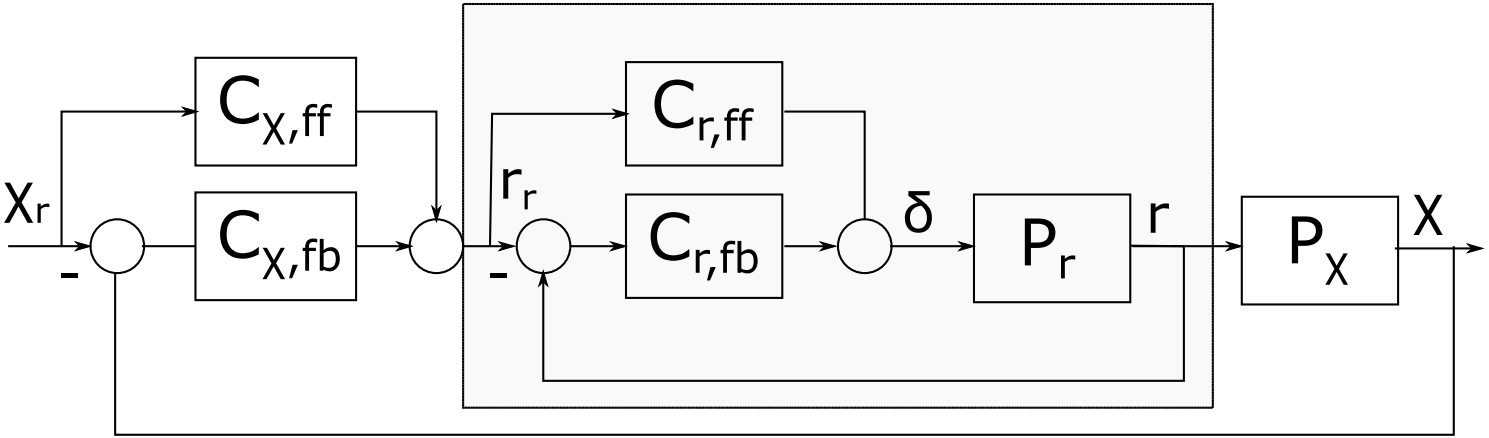
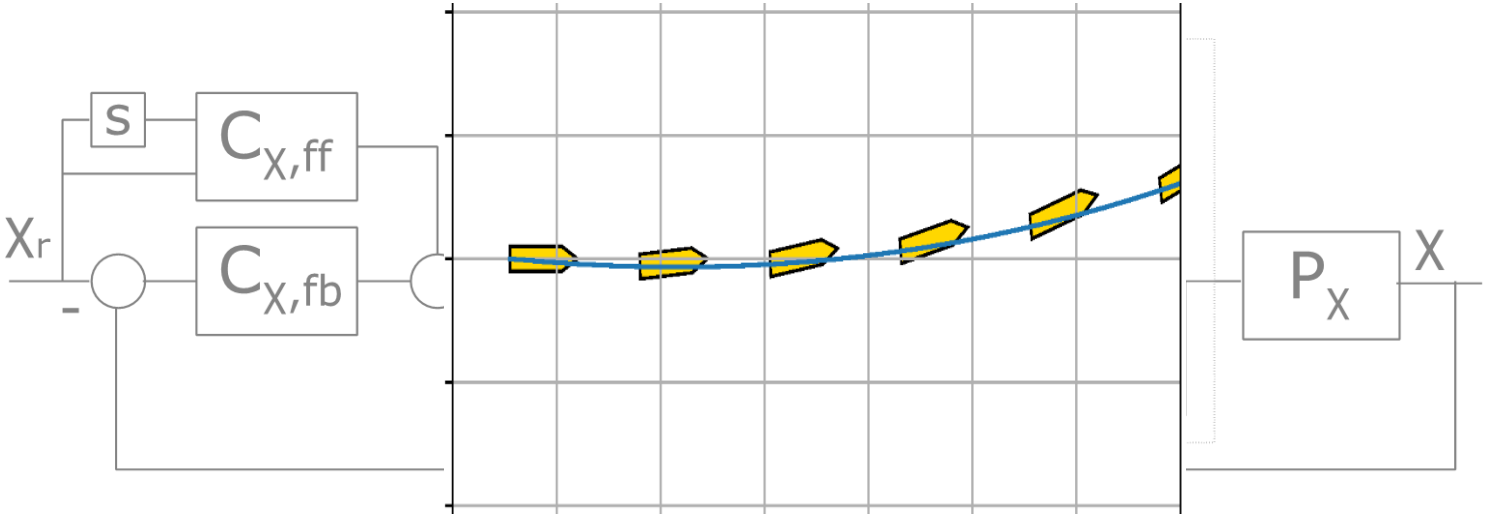
Approaching - control



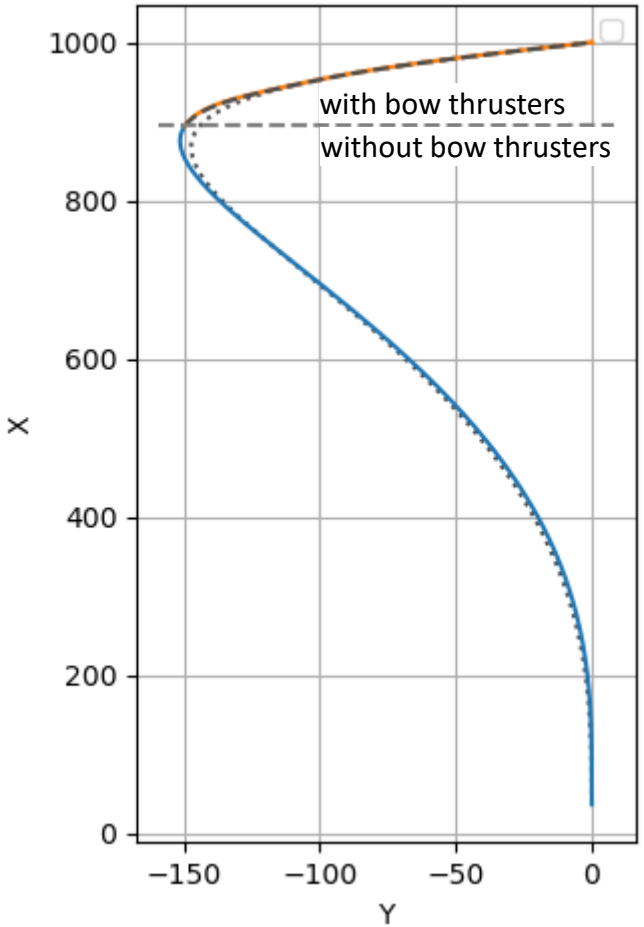
- Cascade control - outer loop
  - calculates required rate-of-turn to control course

Approaching - control



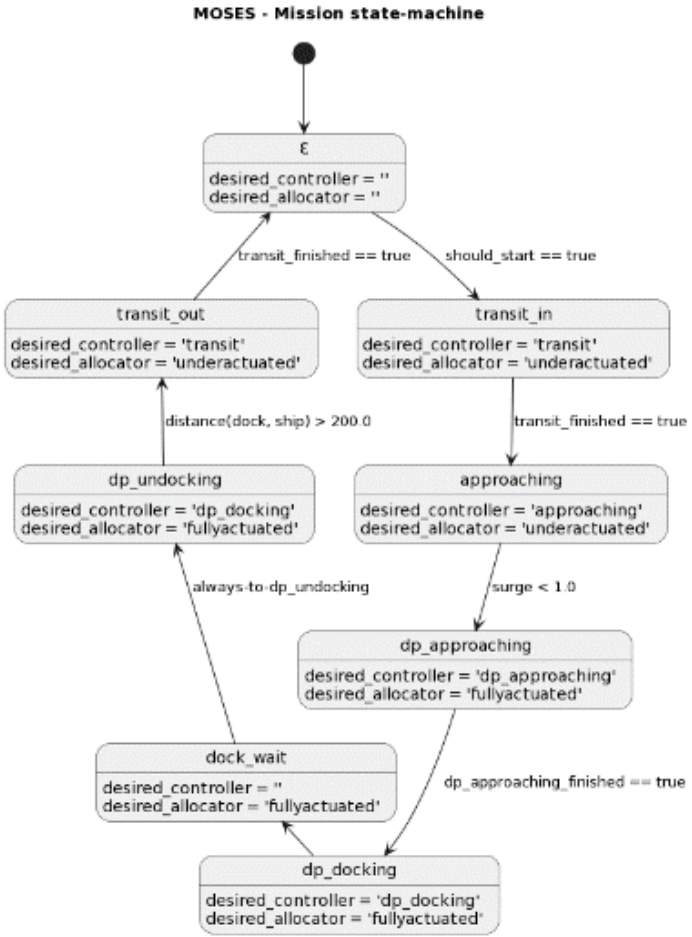
- Cascade control - outer loop
  - calculates required rate-of-turn to control course
  - surge speed needed to control course

Approaching - control



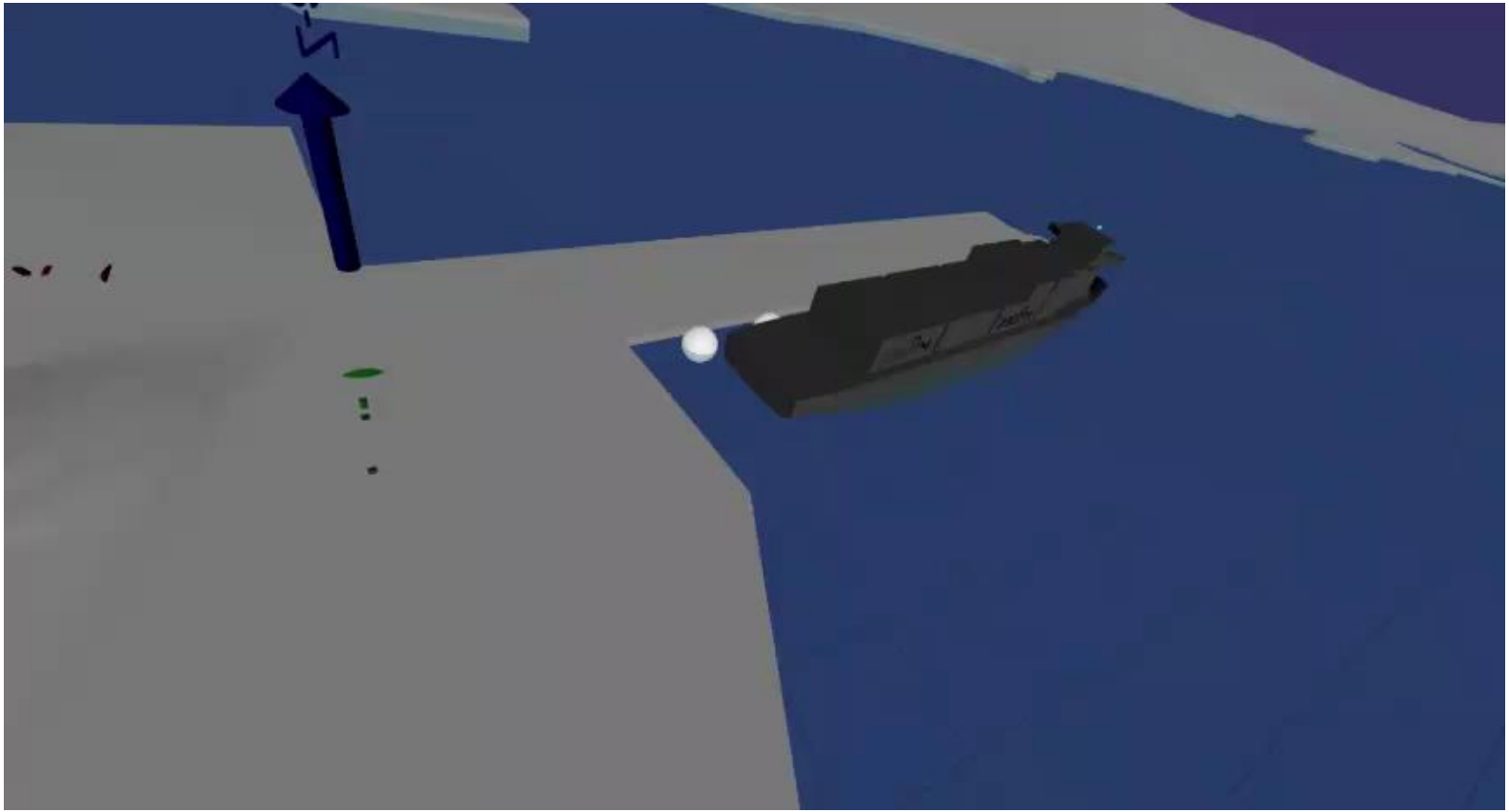
- dotted: trajectory required
- blue: measurement no bow thrusters
- orange: measurements with bow thrusters

Stitch together



- logic to execute an operation
- connected to mission planning
- prone to explosion of states

Simulate



Next steps

IAM research program 2023:

- talk to more captains to get better decomposition
- different approaches on mission execution
- improve control:
  - shallow water / quay effects / disturbances
  - wave disturbances
  - uncertainty

Next steps

- Extend use cases
  - Docking
  - Replenish operation
  - Launch and recovery
  - Platooning / swarming

Next steps

EU Moses project:

- simulation study on feasible conditions
- experiment in basin

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