Intelligence for automated manoeuvres; docking of a feeder vessel

Bas J. de Kruif
Previous - ISAM waypoints tracking
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

- Approaching
- Docking
- Undocking
- Transit
- Transit
- Transit
Ship model

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

manoeuvring model from CFD calculations → available in xSimulation

<table>
<thead>
<tr>
<th>Lpp</th>
<th>71.0 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>13.0 m</td>
</tr>
<tr>
<td>t</td>
<td>4.5 m</td>
</tr>
<tr>
<td>∇</td>
<td>2.8 (10^3) m(^3)</td>
</tr>
<tr>
<td>m</td>
<td>2.9 (10^6) kg</td>
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</tbody>
</table>
Approaching - GNC

Trajectory → Guidance → Control → Ship

- *required pose*
- *required heading speed*
- *actuators*
- *(estimated) pose*

Navigation
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:
Approximating - Bézier approximation

Approximate with curve:
- fast calculation
- only for non-challenging situations
Approaching - Bézier approximation

Approximate with curve:

- fast calculation
- only for non-challenging situations
Approaching - guidance

Convert earth-fixed trajectory
→ to ship-fixed heading/speed

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

Convert earth-fixed trajectory
→ to ship-fixed heading/speed

- Constant bearing
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Approaching - GNC

- Trajectory
  - required pose

- Guidance
  - required heading speed

- Control
  - actuators
  - (estimated) pose

- Ship

- Navigation
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

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

Bech’s reverse spiral test

![Diagram of Bech's reverse spiral test](image_url)
Approaching - control

- Cascade control - outer loop
  - calculates required rate-of-turn to control course
• 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
• logic to execute an operation
• connected to mission planning
• prone to explosion of states
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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