Robust Positioning –
Provision of Safe Navigation at Sea

Next Generation Forum
Köln, 26.-27. Oktober 2016

Daniel Arias Medina
Department of Nautical Systems
Institute of Communication and Navigation
Agenda

• Motivation

• Our Work

• Case Study

• Summary and Outlook

source: www.waterways-forward.eu
Motivation: Importance of Nautical Systems

• Maritime transport is the **backbone** of international trade and the global economy:
  • ~80% global trade by volume is made by sea
  • Around 400 Mio. passengers move through European ports each year

Nautical Transport Systems are **essential** for the economic development, competitiveness and prosperity

Transport volume increases year by year... and results into

• increasing traffic densities
• larger vessels

Source: www.hamburg.com
Motivation: Problem Statement

There is a large amount of marine accidents!

- Enormous material losses, severe ecological damage

Grounding on reef of the *Rena* container ship in 2011

Crashed against the Danish Great Bridge of the *Karen Danielsen* ship in 2005

Navigational accidents are induced by:

- Invalid or inaccurate nautical information
- Misinterpretation of navigation data
- Incomplete situation awareness
- ...
Our Work

Provision of **safe** navigational data to minimize the risks of accidents, to avoid the loss of life and goods and to protect the environment.

- **What is our solution?**
  
  Sensor fusion to estimate accurate and reliable position, velocity, orientation of the vessel

- **Satellite navigation (GPS, Galileo,...)**

- **Inertial navigation (IMUs)**

- **Others:**
  - Maps
  - Speed log
  - etc...
Case Study: Mitigation of Errors for a Challenging Scenario

- Test scenario in the Moselle River in Koblenz (one of the busiest waterways in Germany)
- Vessel *MS Bingen* performed 8–shaped trajectory passing under the bridges
- The bridges block and reflect the satellite signals → multipath effects
Case Study: Performance of Standard Techniques

❌ Standard positioning techniques completely fail nearby the bridges (errors of more than 50 meters!)
❌ Under low visibility conditions, vessels could easily collide against another vessel or against the pillars of the bridges
❌ Autonomous navigation cannot be provided (accuracy requirements not fulfilled!)

![Image of bridges and vessels with performance data]
Case Study: KF – MCDM, our Solution

- Use of Kalman Filter (KF) for the sensor fusion and estimation of the position
- Different methods (RAIM, GM, LMS) with complementary characteristics

**Context** can be exploited to choose the best estimator at every moment → **Multi Criteria Decision Making (MCDM)** problem
Case Study: Performance of the Proposed Technique

**KF — MCDM*** is a filter technique designed to detect and reject „bad” satellite signals

- ✓ Max error is reduced more than 40 m compared to classical positioning!
- ✓ Fusion of GPS, IMU and map information

<table>
<thead>
<tr>
<th>Method</th>
<th>Mean HPE [m]</th>
<th>RMS HPE [m]</th>
<th>Max HPE [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS</td>
<td>2.9</td>
<td>4.5</td>
<td>50.7</td>
</tr>
<tr>
<td>KF-MCDM</td>
<td>2.5</td>
<td>2.9</td>
<td>10.4</td>
</tr>
</tbody>
</table>

Summary and Outlook

The maritime community still faces several challenges related to positioning and safe navigation but...

*Sensor fusion & outlier detection* algorithms are a big part of the solution

Nonetheless, there is still a long way to go...

- Integration of additional on-board sensors: RADAR, anemometer, etc.
- Integrity concept for multi-sensor systems:
  - Error bounds in integrated navigation system
- Extension to MMM: Multi-antenna, Multi-constellation, Multi-frequency
- Fusion of phase measurements (precise positioning)
Thanks for your Attention

More information:
daniel.ariasmedina@dlr.de