Hybridization of atomic and electrostatic accelerometers for satellite control and gravity field recovery

A. Knabe\textsuperscript{1}, H. Wu\textsuperscript{1}, M. Schilling\textsuperscript{2,1}, J. Müller\textsuperscript{1,2}

\textsuperscript{1}Institute of Geodesy, Leibniz University Hannover, Germany
\textsuperscript{2}DLR-Institute for Satellite Geodesy and Inertial Sensing, c/o Leibniz University Hannover, Germany

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Motivation

- Addition of laser ranging interferometer (LRI)
- Accelerometer: no improvement

Concept of our simulation study: combination of cold atom interferometry (CAI) & electrostatic accelerometer (EA)

- long-term stability
- high short-term stability
- drift in low frequencies
- calibration needed
The closed-loop simulation includes five modules:

1. Data input
2. Synthesis of noise-free signals
3. Different kinds of noise
4. Gravity field recovery
5. Model evaluation
LRI/KBR noise

Noise of LRI ranging acceleration (Abrykosov et al., 2019):

\[ ASD_{LRI} = A \cdot (2\pi f)^2 \cdot \sqrt{\left(\frac{10^{-2}}{f}\right)^2} + 1 \text{ m/Hz} \]

\[ V0: A = 1.0 \times 10^{-8} \]
\[ V1: A = 2.0 \times 10^{-9} \]
\[ V2: A = 2.0 \times 10^{-7} \]

Approximation to (Abich et al., 2019):

\[ ASD_{LRI} = 2 \times 10^{-9} \cdot f^{-0.003} \cdot \left(\frac{3 \times 10^{-7}}{f}\right)^3 \text{ m/Hz} \]
Hybrid accelerometer noise

Combination of

- \( ASD_{CAI}(f) = 10^{-9} \text{ m/s}^2/\sqrt{\text{Hz}} \) (Abrykosov et al., 2019)

- \( ASD_{EA}(f) = 10^{-11} \sqrt{\left(\frac{10^{-3}}{f}\right)^4 / \left(\frac{10^{-5}}{f}\right)^4 + 1} + 1 + \left(\frac{f}{10^{-1}}\right)^4 \) m/s\(^2/\sqrt{\text{Hz}} \) (Darras and Pail, 2017)
Comparison of the models

ACC (case 1): accelerometer noise according to slide 5
AOD: Atmospheric and Ocean De-aliasing model, RL6

Eigen-6c4: Static gravity field model
LRI: laser ranging acceleration noise according to slide 4
Impact on Drag-free System

- Requirement on drag compensation

\[ ASD(f) = \frac{1}{2} \frac{ASD_{acc}(f)}{s_{known}} \] (Gruber et al., 2014)

- \( s_{known} \): scale factor knowledge
- \( ASD_{acc} \): noise of the accelerometer measurement

- Assumption for scale factor knowledge
  - Electrostatic accelerometer 0.2%
  - Hybrid accelerometer 0.001%

- Impact studied for different orbit configurations and drag-free system parameters, see slides 8, 9 and 10
Impact on Drag-free System

- $h=303\text{km}$
- drag compensation in along track direction
- control system parameters of the GOCE mission
Impact on Drag-free System

- $h=361\,\text{km}$
- drag compensation in along track direction
- control system parameters improved
Impact on Drag-free System

- $h=361\text{km}$
- no drag compensation
Summary

• CAI concept can improve gravity field solutions (Trimeche et al., 2019)

• Using CAI measurements for the calibration of the EA
  • better knowledge of the scale factor
  • large impact on drag free requirement

• Next steps
  • Refine CAI noise behavior depending on architecture of the sensor
  • Investigate impact of further parameters: orbit configurations, perturbation sources, …
References