Vehicle-based vector gravimetry using a navigation-grade inertial measurement unit

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Introduction
The starting point of this thesis are recent developments in the field of airborne gravimetry which is a cost-effective and time-efficient method to determine local and regional gravity field structures with spatial resolutions of up to 2 km. Today, it is the major method to collect extensive gravity field data in regions with sparse local gravity information (i.e. Antarctica (Fig. 1), Himalaya) and in coastal areas, where terrestrial and marine observation techniques normally have to be combined. Three main disadvantages of the standard airborne gravimetry concept are the high costs for the stabilized single-axis gravimeter and its limitation to scalar gravimetry, the low level of automation as well as the vulnerability towards dynamic motion. In the dissertation of D. Becker[1] (2016) a navigation-grade SIMU (strapdown inertial measurement unit) successfully replaced the standard airborne gravimeter, compensating the disadvantages of the old system without conceding a loss of accuracy. Based on this step towards airborne “strapdown” gravimetry, the thesis is dedicated to implement vehicle-based vector gravimetry at the 1 mGal/1 arcsec accuracy level with a spatial resolution <500 m using a navigation-grade SIMU. By conducting surveys on ground more frequent updates by different types of sensors are available, which allows estimating systematic SIMU sensor errors more reliable and thus improves the overall data quality. Due to the lower speed on ground also the resolution of the gravity information will increase. Since those surveys do not rely on airplanes, their realization becomes cheaper and more flexible, but a survey’s extent is limited to smaller areas and depending on the region’s infrastructure at the same time.

The gravity field information collected with the vehicle-based vector gravimetry system can be used to improve and/or independently validate local, regional and global gravity field models as well as airborne gravity data.
**Instrumentation and concept**

In this thesis the instrumentation is limited to a navigation-grade SIMU, GNSS (global navigation satellite system) equipment, a relative gravimeter and a digital zenith camera.

Before a survey starts, the survey track has to be defined in the region of interest, in combination with some stopover points. When driving along the track, the SIMU and the GNSS equipment will be fixed to the car and measure throughout the whole ride. At each stopover point, the car halts for a certain amount of time. After having finished the track, the relative gravimeter and the digital zenith camera have to be deployed at the stopover points to provide important update information for the SIMU in the Kalman Filter\[^2\] (Fig. 2).

**Method**

The key point for achieving the 1 mGal/1 arcsec accuracy level is optimal sensor fusion and data filtering. An extended Kalman Filter in combination with the Rauch-Tung-Striebel\[^2\] smoother is used to fuse all sensors’ data optimally, to separate kinematic accelerations from gravity and to estimate sensor errors.

![Kalman Filter loops](image)

**Results**

The aim of this thesis is to reveal the benefit of vehicle-based strapdown gravimetry to gravity field modelling as well as validation of gravimetric data. Having in mind, that a navigation-grade SIMU is used, the 1 mGal accuracy level (see airborne gravimetry) is achievable for the scalar part. A more sophisticated goal is the 1 arcsec accuracy level for the determination of vertical deflections, which is equal to just 5 mGal in the horizontal gravity components, but is subject to an adverse error propagation.

**References**

