Parameterization and Approximation of Sampled Surfaces

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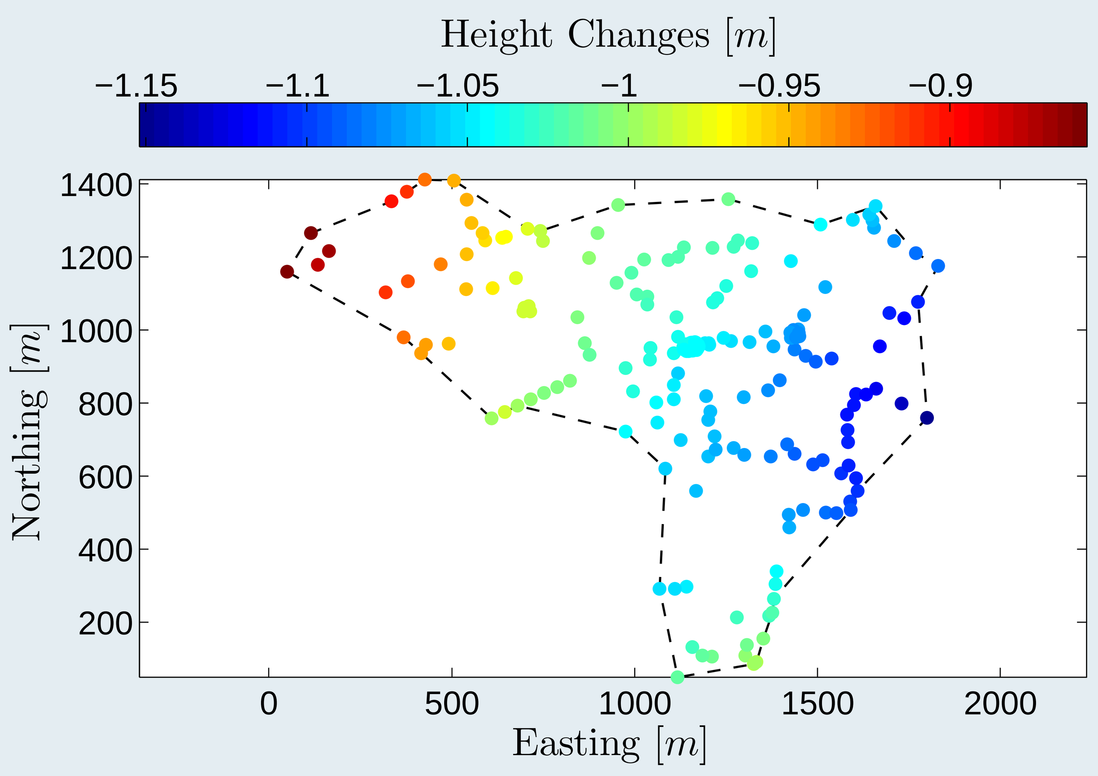
Motivation

The analysis of deformations develops from pointwise considerations to an analysis of surfaces and their estimated parameters due to the technical progress, e.g. of laser scanners. Long known methods as high precision leveling benefit as well from these innovations, e.g. for monitoring subsidence.

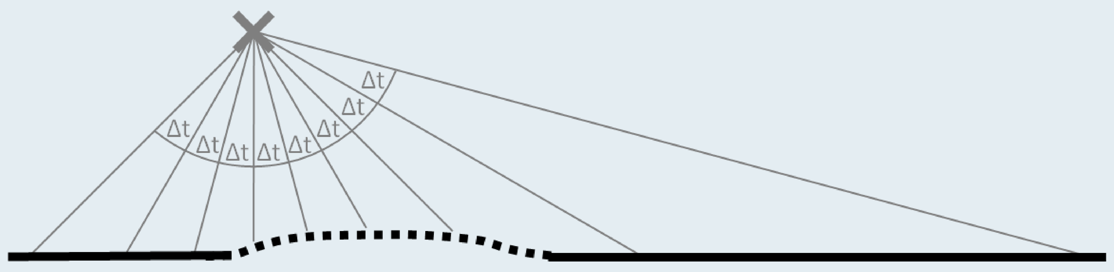
Independent from the amount of observations from the sampled surface, the observations should be analyzed regarding their spatial distribution. This spatial distribution might impact the (deformation) analysis, i.e. the surface parameterization and approximation, significantly. This is investigated in several studies with focus on levelings and laser scans:

Leveling



- how many points are necessary?
- where to add / save points?

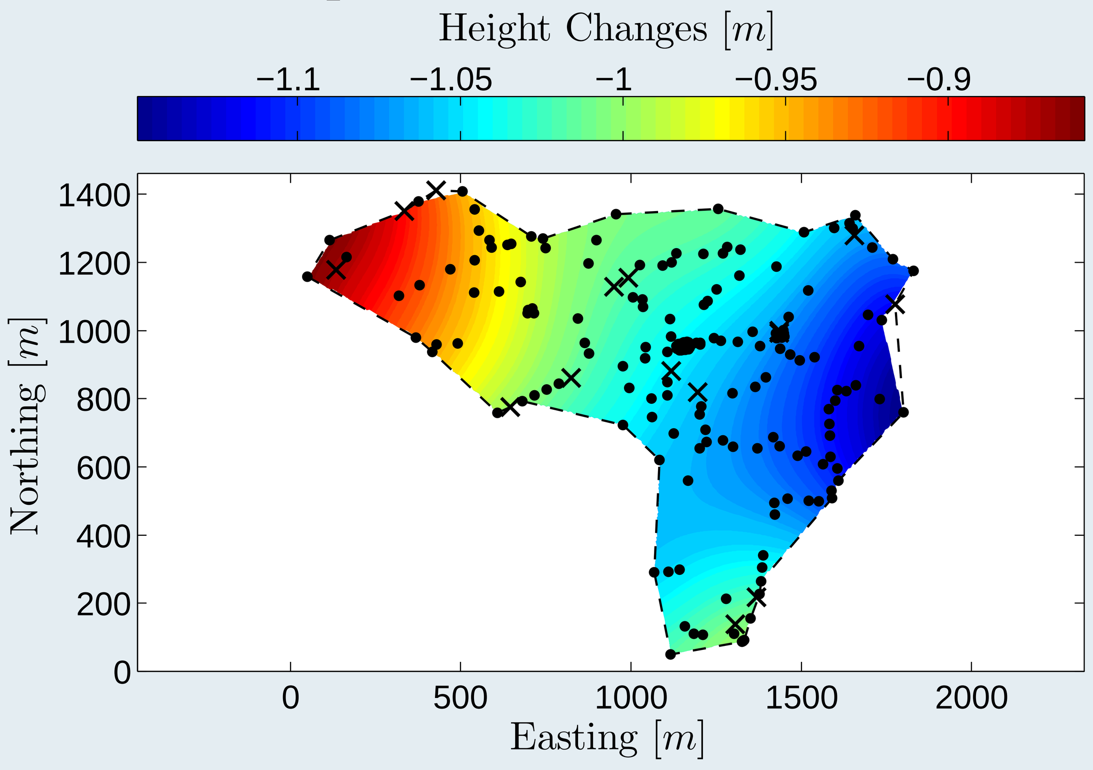
Laser Scanning



- how does the spatial distribution impact the approximation of deformed surfaces?
- how to optimize the point cloud for improved / unbiased approximation results?

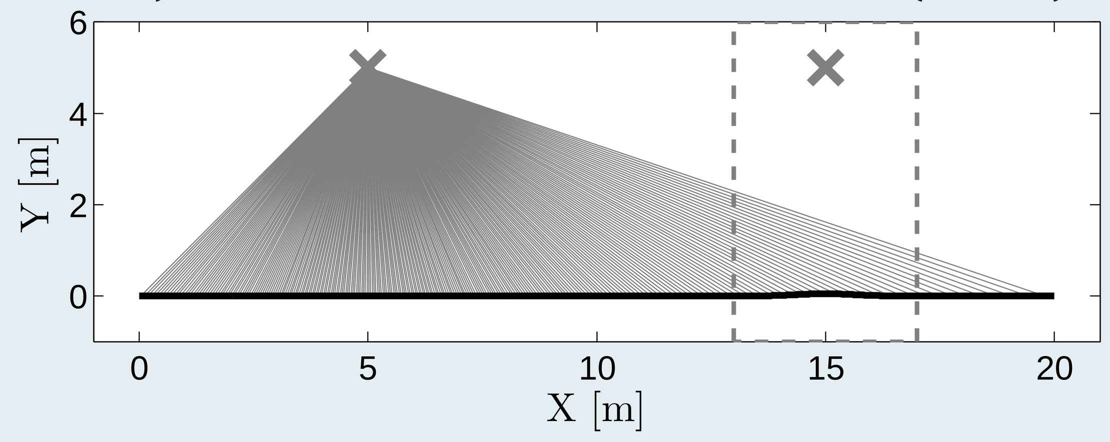
Leveling

- parameterizing measured height changes by model of bivariate polynomial
- estimating parameters by Gauss-Markov model
- defining polynomial order proportional to complexity of height changes, eliminating non-significant parameters, detecting outliers, quality control by global test
- acceptance of polynomial model due to 5 criterions considering a.o. number, magnitude and spatial distribution of outliers

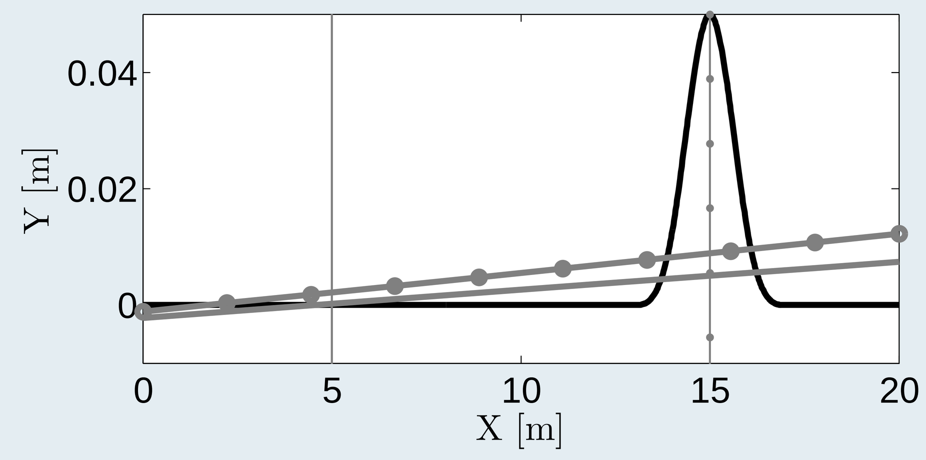


Laser Scanning

- parameterizing observations by geometric primitive (here: simulated 2D line)
- estimating parameters by strict evaluation of nonlinear Gauss-Helmert model
- analyzing impact of scanner station (crosses) on estimation of scanned line (black)

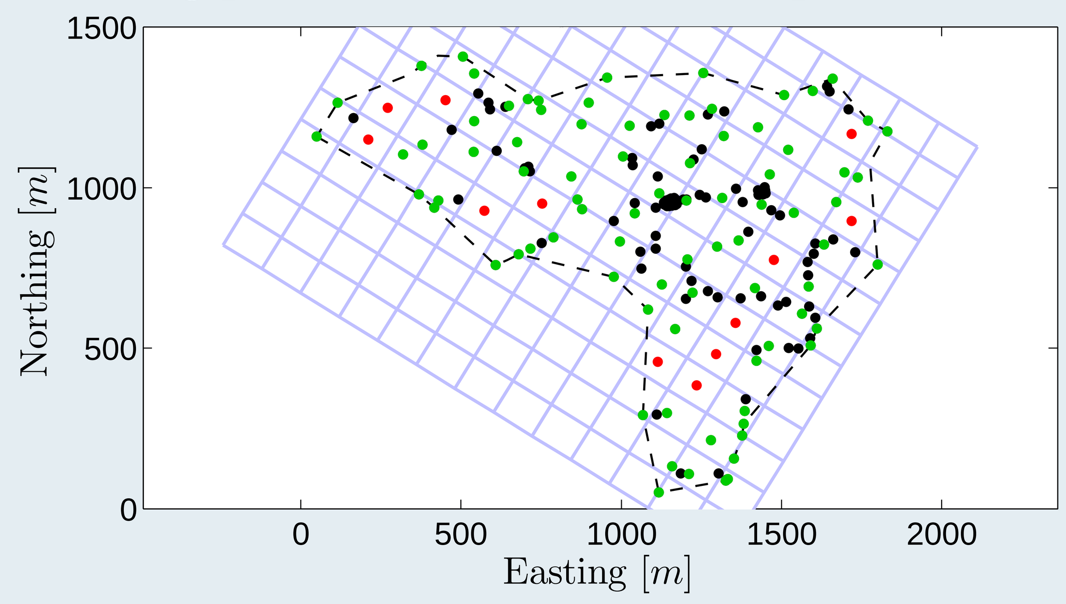


- parameters differ significantly between scans (station at $X = 5m$: lined, at $X = 15m$: dotted) if deformation (black) exists

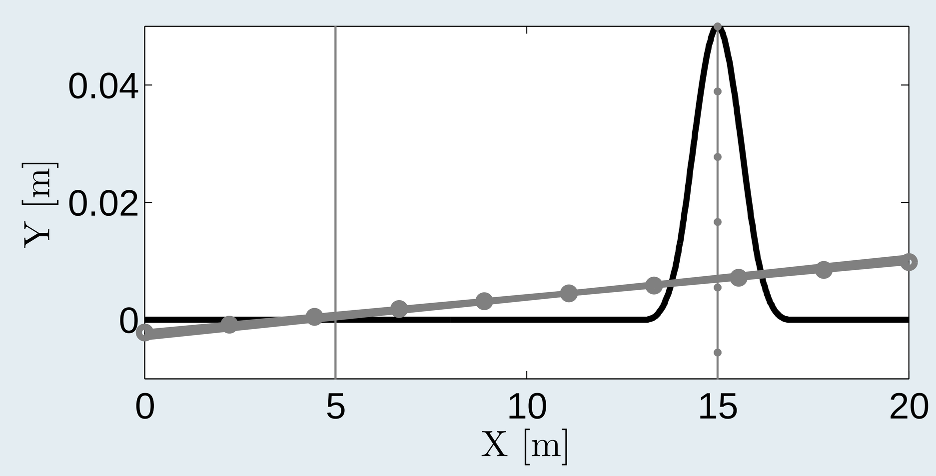


Optimization of Observation Network

- using sampling theorem for building regular grid $\propto$ to complexity of height changes
- using partial redundancies for validation
- optimization by labeling given points as retainable (green) and dispensable (black); defining positions for additional points (red)



- using partial redundancies for analyzing impact of deformation on approximation
- optimization by homogeneous reduction of point cloud to reduce impact of spatial point distribution
- afterwards, approximation not any more different between scans of scanner station at $X = 5m$ (lined) and $X = 15m$ (dotted)



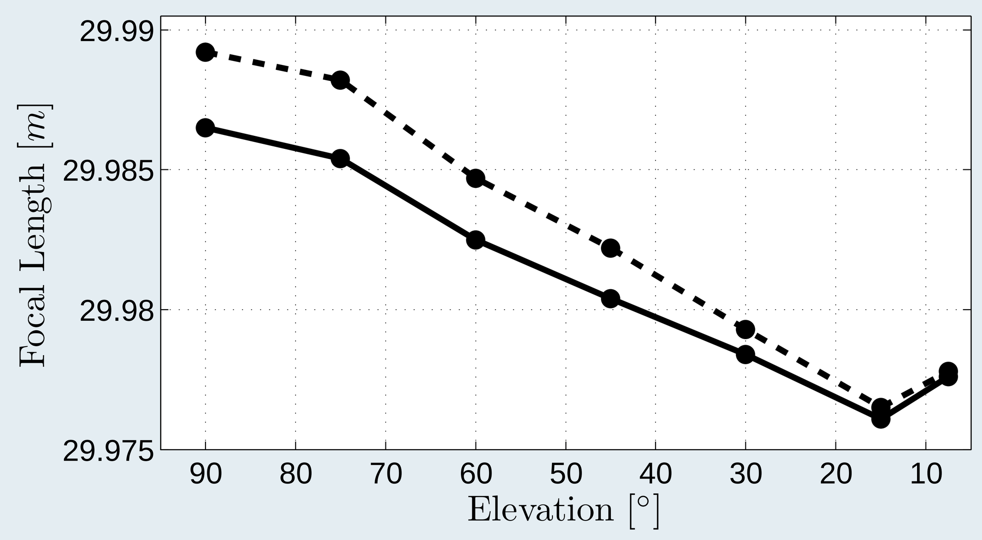
Outlook: Deformation Analysis of Radiotelescope

Motivation

- the main reflector of the Effelsberg radiotelescope deforms during VLBI-measurements with varying elevation
- for reliable processing, this deformation has to be known regarding (1) focal length variations and (2) local surface deformations
- desired accuracy $\leq 1mm$

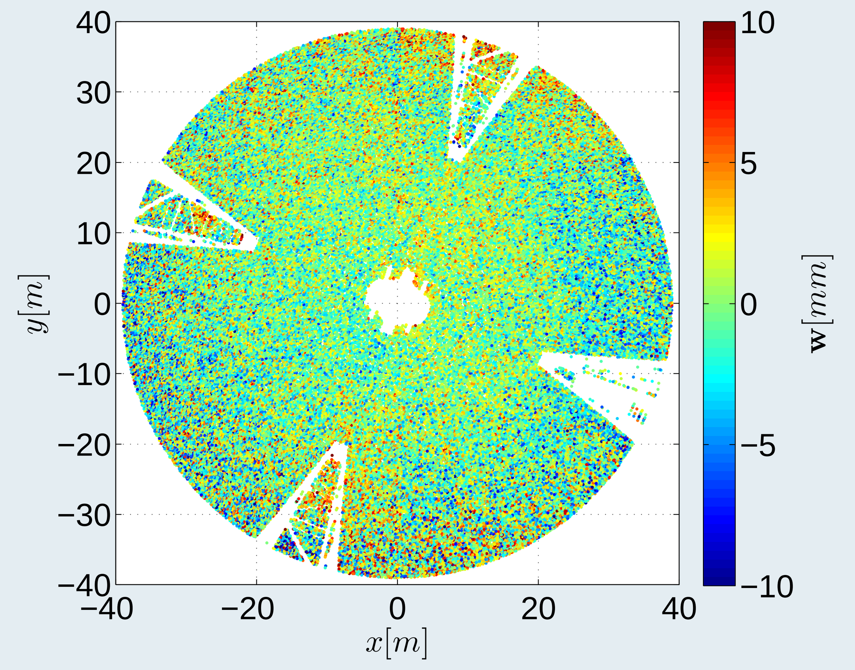
Deformation Analysis

- scanning the main reflector in 7 elevations by fixing a laser scanner to the subreflector
- by approximating a paraboloid, 7 focal lengths can be estimated
- the focal length decreases by more than $12mm$ due to gravitation
- parameters differ significantly between using complete point cloud (lined, ≈ 250 Mio points) and homogenized / reduced point cloud (dashed, ≈ 0.5 Mio points)



Outlook

- local deformations are revealed on surface of main reflector
- position and magnitude of local deformations varies between different elevations
- analyzing different impact of local deformations on parameter estimation
- finding best strategy for point cloud optimization: curvature-based, grid-based, ...
- investigating the impact of different laser scanner stations on approximation



Conclusion

Laser scanners, levelings and also many other sensors can be used to collect are-based measurements. The spatial point distribution of the derived measurements is not homogeneous in most times. However, this can be essential for a reliable analysis when parameterizing and approximating the sampled surfaces. Thus, several steps are recommendable when working with spatially given data:

- analyzing the spatial point distribution that is due to the measurement system
- optimizing the spatial point distribution similar to geodetic networks
- validating the benefit of the optimized point cloud

Performing these steps can increase the significance of estimated parameters in area-based (deformation) analysis or other surface approximation assignments.

- Holst, Ch., Eling, Ch., Kuhlmann, H. (2013): **Automatic optimization of height network configurations for detection of surface deformations**, J. Appl. Geodesy, 7(2), pp. 103-113
- Holst, Ch., Kuhlmann, H. (2014): **Impact of spatial point distributions at laser scanning on the approximation of deformed surfaces**, 17. Internationaler Ingenieurvermessungskurs, 14-17 Januar 2014, Zurich, Switzerland
- Holst, Ch., Zeimetz, Ph., Nothnagel, A., Schauerte, W., Kuhlmann, H. (2012): **Estimation of focal length variations of a 100-m radio telescope's main reflector by laser scanner measurements**, J. Surv. Eng., 138 (3) pp. 126-135

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