Optimization of Lilla Edet Land Slide GPS Monitoring Network

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Abstract

Since the year 2000, some periodic investigations have been performed in the Lilla Edet region to monitor and possibly determine the landslide of the area with the GPS measurements. The responsible consultant has conducted this project by setting up some stable stations for GPS receivers in the risky areas of Lilla Edet and measured the baselines among the stations according to their observation plan. Here, we optimize the existing surveying network and determine the optimal configuration of the observation plan based on different criteria. The current sensitivity of the network for detecting the displacements is around 6 mm for each station. However, by increasing the sensitivity and according to the precision and reliability objective functions and/or their combinations we acquired an optimal observation plan with fewer independent baselines and higher sensitivity. The optimized network with the bi-objective model of reliability and precision is sensitive enough to detect the displacements up to 3 mm with 8% less measurements, meaning 8% of saving time, cost and energy in the project.

Study Area

In order to implement the methodology of network optimal design and deformation monitoring network design in the case of a real application, Lilla Edet municipality was chosen. This region is well known for its landslides and subductions. Due to many residential areas within this municipality, the study about landslide is of high interest for the community.

Lilla Edet Municipality is located in Västra Götaland County, Sweden. Our study area surrounded the central village from east to west of Göta Älv, a main river on the west coast of the country.

A surveying network has been established around the area such as shown in Fig. (1). Based on the size of the area and purpose of surveying, GPS measurements were chosen to create a geodetic network for this region. The existing network, which was made by a consultant for the municipality, has 35 stations. 6 stations are assumed as fixed points around the village, and the rest are set up inside the area. The purpose of the network is to monitor the landslide deformations within the area. The consultant had measured the points in 8 epochs in different time intervals since 2000. During these years, a fixed structure of the observation plan has been followed to monitor the movements.

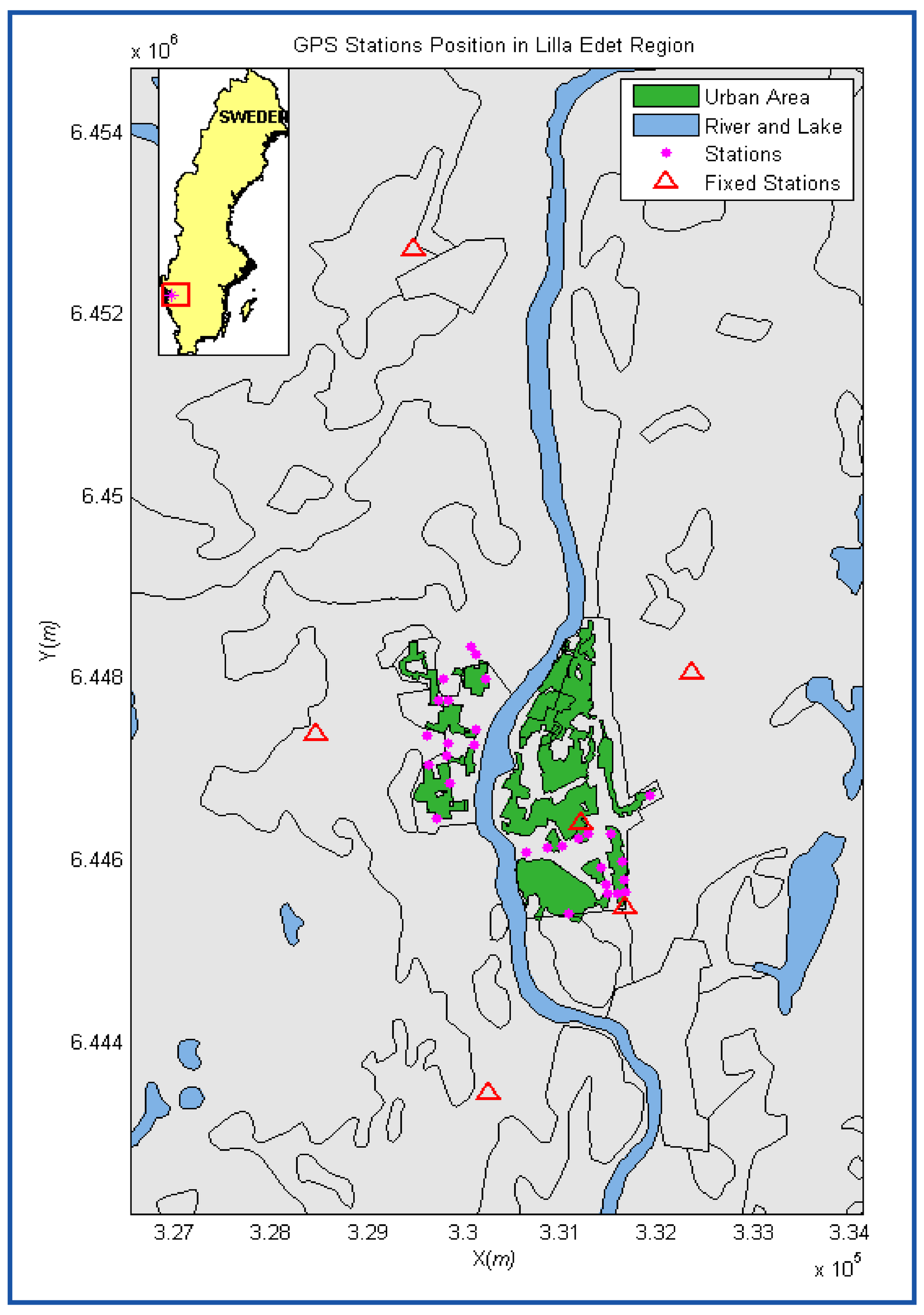

Figure 1. Study area and GPS Reference and observation stations

Methodology

Based on different optimization techniques, the current GPS network of the area is optimized in order to meet the network quality criteria. Precision and reliability are the two major criteria for acquiring the optimal network sensitive to detect a specific displacement. Single Objective Optimization Model (SOOM) and a Bi Objective Optimization Model (BOOM) are two techniques that we performed on the network.

SOOM:

Minimizing or maximizing any of the object functions for precision or reliability as:

$$\begin{cases} \|\mathbf{C}_x - \mathbf{C}_s\| = \min & \textit{precision} \\ \|\mathbf{r}\| = \max & \textit{reliability} \end{cases}$$

with variance-covariance matrix $\mathbf{C}_x$ and the criterion matrix $\mathbf{C}_s$ which can be obtained from our defined threshold for the ability of the network to detect the displacements. We can write:

$$\mathbf{d}^{\mathrm{T}}\mathbf{C}_s^{-1}\mathbf{d} > 2\chi^2_{1-\alpha} \quad (3)$$

where **d** is the displacement vector, and in this project we assumed it as 3 and 4 mm vs. the network's existing ability for detecting approximately 6 mm displacement of the object points at 95% confidence level (α).

r represents the reliability vector of the baseline observations, which we tried to maximize.

BOOM:

A combination of the above criteria gives us the ability to fulfill both criteria in our object function.

Results and Discussions

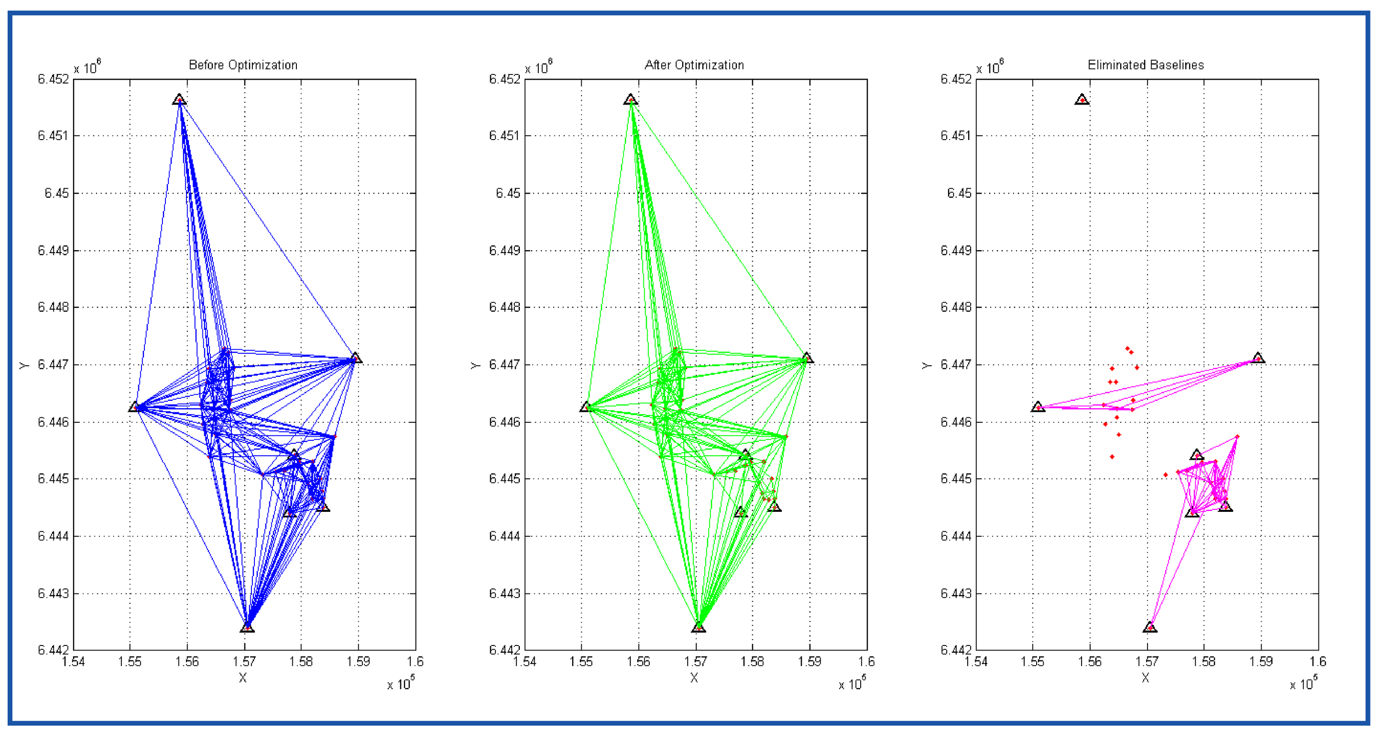

Figure 2. SOOM with precision constraints and sensitive to detect 3 mm displacement.

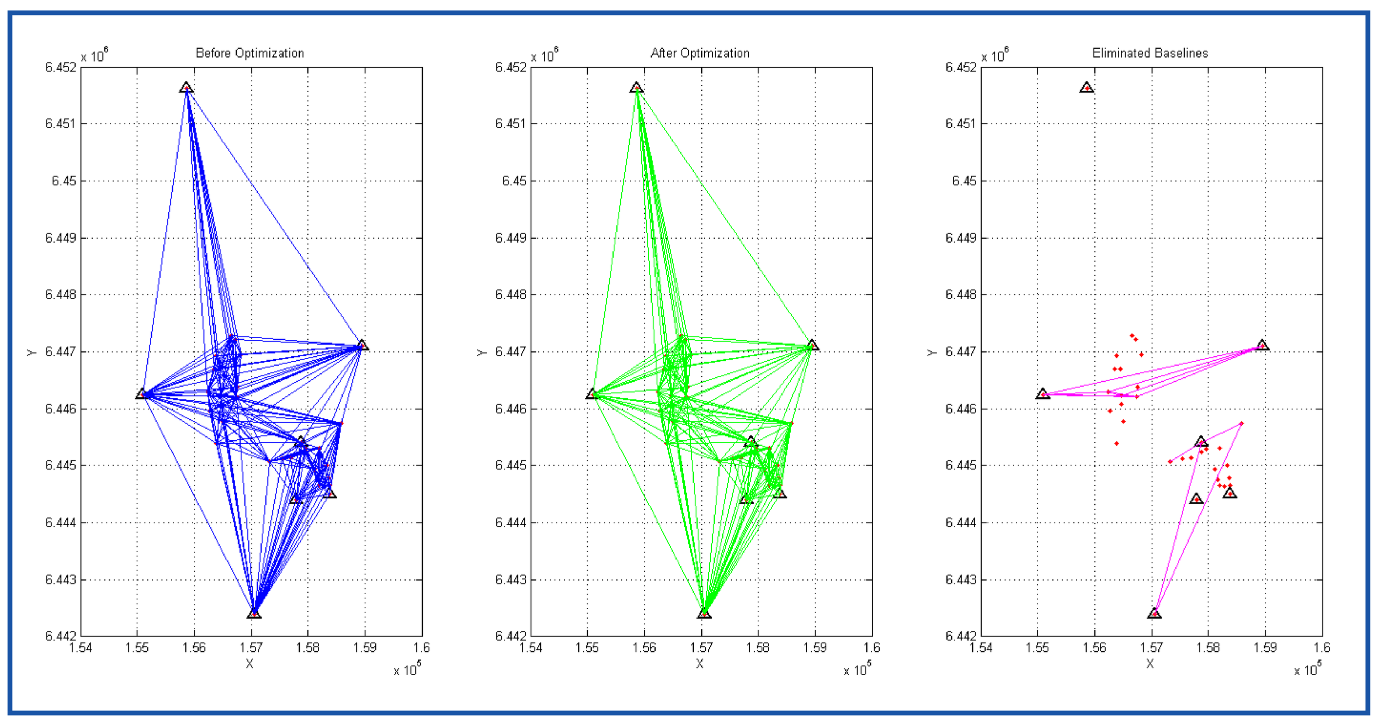

Figure 3. BOOM with precision and reliability constraints and sensitive to detect 3 mm displacement.

Table 1. Results of different optimization techniques performed on the GPS network.

	Before Optimization	After Optimization Sensitivity for detecting displacements			
		3 mm		*4 mm*	
		SOOM	BOOM	SOOM	BOOM
No. of necessary GPS baselines	245	176	226	148	190
Eliminated baselines in %		28%	8%	40%	22%

The GPS network of Lilla Edet region was optimized to obtain the optimal number of independent baselines. It is clear from Figs. 2 and 3 that we could remove unnecessary observations from the plan and come up with an even more sensitive network to displacement detection. Table 1. shows how much we could save our efforts and costs by optimizing the network. In the strict case, when we performed BOOM to obtain a sensitive network to 3 mm, we could eliminate 8% of current observations.

References

Amiri-Seemkooei, A., Asgari, J., Zangeneh-Nejad, F. & Zaminpardaz, S., 2012. Basic Concepts of Optimization and Design of Geodetic Networks. Journal of Surveying Engineering, 138(4), pp. 172-183.

Bagherbandi, M., Eshagh, M. & Sjöberg, L. E., 2009. Multi-Objective versus Single-Objective Models in Geodetic Network Optimization. Nordic Journal of Surveying and Real Estate Research, 6(1), pp. 7-20.

Kuang, S., 1996. Geodetic Network Analysis and Optimal design: Concepts and Applications. Chelsa, Michigan: Ann Arbor Press.

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