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Low-cost GNSS Receivers for Geodetic Monitoring Purposes

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Thesis Summary

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This article is an extended abstract of the doctoral dissertation entitled "Cost-effective GNSS receivers for geodetic monitoring" [1]. *For several years, geodetic Global Navigation Satellite System (GNSS) receivers have been argued as proper sensors to monitor natural hazards and engineering structures. Nevertheless, their use is questionable in areas where there is a risk of instrument damage considering their high costs. Therefore, low-cost GNSS receivers are considered as an alternative for such applications. Through various evaluation tests designed and conducted in the doctoral dissertation, substantial analyses for data and positioning quality, size of detected displacements, and application of low-cost GNSS receivers in geodetic monitoring were obtained. The developed Low-Cost GNSS Monitoring System (LGMS) represents a suitable solution for near real-time continuous geodetic monitoring with high accuracy and reduced costs. Furthermore, it can be applied in the geodetic monitoring of natural hazards like subsidences, sinking phenomena, and landslides, as well as, other engineering structures such as viaducts, bridges, dams, mining areas, and chimneys, provided it meets the accuracy standards.*

Povzetek: Predstavljena je doktorska disertacija z naslovom »Uporaba cenovno ugodnih sprejemnikov GNSS za geodetski monitoring«.

1 Introduction

Low-cost Global Navigation Satellite System (GNSS) receivers are considered an alternative to geodetic counterparts, particularly for projects and applications constrained by budget limitations. Low-cost GNSS receivers are highly desirable for geodetic monitoring of natural hazards and engineering structures, as they enable cost-effective monitoring at numerous points of interest while offering several advantages. These advantages include affordability, compact size, low energy consumption, ease of replacement in case of damage, and flexibility for configuration and data processing using open-source software and applications.

The main objective of the doctoral dissertation was to investigate the capabilities of using low-cost GNSS receivers for developing a Low-cost GNSS Monitoring System (LGMS) with high accuracy and decreased costs that can continuously monitor displacements in near-real-time.

2 Methods

a. Quality analysis of GNSS observation

A series of tests were conducted under various conditions, including open-sky and adverse scenarios, to assess the quality of GNSS observations acquired with low-cost GNSS receivers [2,3]. As a reference for comparison high-ended geodetic GNSS receivers were used. The results indicated that, in both open-sky and adverse scenarios, low-cost GNSS receivers provided lower data quality (worse results for carrier-to-noise ratio, multipath, phase noise, cycle slips, and others) compared to geodetic GNSS receivers [2,3]. However, the difference in cycle slips and phase noise was not very significant and it ensured first information for sufficient positioning quality even though the results from all tests were in favor of geodetic GNSS receivers [2].

b. Positioning performance evaluation

To perform a more comprehensive assessment of positioning quality for low-cost GNSS receivers, additional experimental tests were designed and performed. These tests encompassed a zero baseline test, a short baseline test, a comparison of coordinate precision, and 3D geodetic adjustment by using GNSS and Terrestrial Positioning System (TPS) observations [1,4].

The results from the zero baseline test confirmed that the low-cost GNSS receiver (ZED-F9P) has minor receiver noise (sub-millimeter error of estimated coordinates). In a short baseline test, the superiority of GNSS receivers was confirmed, while the precision of obtained horizontal and vertical positions was almost equal for geodetic and low-cost GNSS receivers in cases when long sessions (50h) were considered. However, geodetic GNSS receivers obtained higher positioning accuracy. The precision of obtained coordinates in short sessions (3h) was again in favor of geodetic GNSS receivers. The 3D geodetic adjustment of GNSS and TPS observations was shown to improve the positioning accuracy of low-cost GNSS receivers. Nevertheless, it was not an optimal solution for continuous geodetic GNSS monitoring applications with a high risk of instrument damage.

c. Displacement detection

To identify the size of detected displacements by low-cost GNSS receivers three evaluation tests were conducted [2,5,6]. The first was focused on analyzing the impact of using geodetic GNSS receivers as a base station [6]. In the second one, the impact of employing low-cost GNSS antennas with known calibrated parameters (Survey calibrated) was analyzed in static relative and Precise Point Positioning (PPP) methods [2]. In the third, the size of detected displacements in the Real-Time Kinematic (RTK) method was analyzed [5].

The findings revealed that 3D displacements of 10 mm are detectable in the static relative method by low-cost GNSS receivers (ZED-F9P receiver and ANN-MB antenna) with a high level of reliability [6]. The use of low-cost calibrated antennas (Survey calibrated) decreased the size of detected 3D displacements to 5 mm in 30-minute sessions [2]. However, the size of detected displacements increased to 20 mm in the PPP (8h sessions) [2] and RTK (15s sessions) [5].

d. Application of LGMS

The LGMS (Figure 1) was developed only from low-cost GNSS sensors (ZED-F9P receiver and Survey calibrated antenna), costing around 500 EUR per unit. Notably, the LGMS was capable of functioning in areas lacking an electricity network [7]. It underwent testing during a six-month monitoring period of the Laze landslide, where four LGMS were deployed. The system demonstrated consistent operation, continuously collecting GNSS observations that were post-processed to estimate displacements [5].

In three of the monitoring stations, no horizontal displacements were detected, but slow vertical movements were observed in those stations. By this, it was confirmed that LGMS can detect slow movements with sub-centimeter accuracy continuously and with reduced costs.

Figure 1. LGMS in Laze landslide.

3 Conclusion

The findings of the doctoral dissertation indicate that low-cost GNSS receivers currently do not provide observations of the same quality as geodetic GNSS receivers, but rather slightly inferior. Nonetheless, these GNSS sensors can still deliver positioning solutions with quality that is adequate for numerous surveying projects. Furthermore, low-cost GNSS receivers were shown as well-suited sensors for developing LGMSs. The system was successfully tested in the Laze landslide and represents a suitable solution for near-real-time continuous monitoring with high accuracy and decreased costs.

It is noteworthy that the LGMS can find application in monitoring natural hazards like subsidence, sinking phenomena, and landslides, as well as, various other engineering structures such as viaducts, bridges, dams, mining areas, chimneys, provided it meets the necessary accuracy standards.

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