UDK 528.04

HIGH-PRECISION GEOSPATIAL MONITORING USING THE LEICA MS60 MULTISTATION

Igor Trevogo
Lviv Polytechnic National University
Andrei Gorb Leica Geosystems, **Alexander Meleshko** Navigation Geodetic Center (Kharkiv)

Keywords: multistation, monitoring, high-precision geospatial monitoring (HPGM)

Introduction

To save lives and property - this slogan is quite suitable to describe the purpose of high-precision geospatial monitoring (HPGM). Science, aerospace, automotive production, shipbuilding, industrial machinery, civil and industrial development, construction of energy, transport or tunnel facilities – it would be easier to list those economic branches, which have no place for HPGM.

The importance of HPGM will rise, especially in the modern conditions of inevitable and continuous urbanization, since the role of cities grows higher for the economy development of a society.

As a result of a continuous urbanization, we have a disproportional saturation of major urban centers by the infrastructural objects, such as: pipelines, transport and energy facilities; landscapes, even those of huge size, turn into inhabited areas with dense housing. The cities are seizing the mountains, tunnels are penetrating through the rocks, multi-level road junctions are becoming more and more incredible.

Indeed, a mankind has created such environment, in which there is a strict necessity for regular assessment of any potential collisions. Assessment should be carried out in order to provide enough time for detection and prevention of possible threats for a civilization.

Statement of the problem

Being aware of the HPGM importance, the specialized professionals must realize clearly all possible methods to solve the monitoring tasks. Having a wide variety of devices on the global market, there is a problem to choose a proper set of hardware and software for an efficient and cost-effective monitoring, even though the method of solving HPGM task has been defined.

The purpose

Currently, the most commonly used HPGM methods are: GNSS-observations, coordinate measuring systems, laser-optical methods, holographic methods and photogrammetric techniques [2]. This article is focused on laser-optical methods. According to results of the actual monitoring projects a technically perfect and economically viable option has been proposed.

The exposition of research results

Overview of the modern methods

Without going into details of lasers, we shall consider the range of those modern coordinate measuring systems, whose operation is based on the use of laser-optical methods such as: trackers, laser scanners, robotic total stations and multistations (see table 1).

Laser trackers

Laser trackers (see Fig. 1) - are the most expensive devices, they are indispensable to solve monitoring tasks of large objects with extremely high precision, such as: metrological provision, tools calibration, space and aircraft construction, power units checking and precision objects centering [3].

Laser scanners

Laser scanners (see Fig. 2) determine the 3D-coordinates with extraordinary speed - one million points per second with a determined step. In addition to the coordinates obtained with geodetic accuracy, each point carries information about the real color and light intensity.

Thereby, the cloud of 3D-points is formed as a result of laser scanner work. Therefore, the best way to use such data is to capture spatial information of complex and large surfaces.

Table 1

Device	Tracker	3D-Scanner	Totalstation	Multistation
Product model	Leica AT401	Leica P40	Leica TS16	Leica MS60
The accuracy of angular measurements	15 µm + 6 мкм	8”	1”	1”
The accuracy of distance measurements	~10 µm	1,2 mm + 10 ppm	1,5 mm + 1,5 ppm (reflector)	1,5 mm + 1,5 ppm (reflector)
Measurements range	horizontal: +/- 360° vertical: +/- 145° working dist.: 320 m	horizontal: +/- 360° vertical: +/- 270° working dist.: 270 m	horizontal: +/- 360° vertical: +/- 270° working dist.: 1 km	horizontal: +/- 360° vertical: +/- 270° working dist.: 2 km
Working conditions	altitude from -700 to 5500m, humidity 95% (non-condensing) operating temperature: 0 ° .. + 40 ° C IP54	altitude from -700 to 5500m, humidity 95% (non-condensing) operating temperature: -20 ° .. + 40 ° C IP54	altitude from -700 to 5500m, humidity 95% (non-con-densing)operating temperature: -20 ° .. + 40 ° C IP55	altitude from -700 to 5500m, humidity 95% (non-con-densing) operating temperature: -20 ° .. + 40 ° C IP65
Price (USD)	~150,000 USD	~75,000 USD	~25,000 USD	~45,000 USD

For the purposes of monitoring, the laser scanners are used within the large infrastructural projects (e.g. dams and tunnels technical supervision); also, at harsh industrial environment (e.g. quality control during the operation with large industrial complexes, the analysis of the ship parts at any time of its building etc).

Fig. 1 Laser tracker Leica AT401

Total stations

Total stations (see Fig. 3) are able to determine the 3D-coordinates with millimeter accuracy, so they are successfully used for the purposes of monitoring. Modern electronic total stations are ‘robotic’, i.e. they are equipped with a piezo motors for precise aiming to the target.

Fig. 2 Laser scanner Leica P40

Leica TS16 total station has some usable features (*let alone those, listed in table 1*). They are: a) high speed distance measurement and minimal laser dot size (8mm x 20mm at 50m), as compared to devices of other manufacturers. b) *ATR-technology* – automatic aiming to the circular reflector without any auxiliary devices provides quick and accurate pointing to the center of reflector. c) *PowerSearch* function – remote search and automatic aiming at 360° prism in a single click. Total stations in this series are used primarily for the point monitoring purposes (e.g. analysis of strains that precede to the structural gaps inside the constructions, such as: dams, bridges, tunnels.). Also, total stations are used to monitor changes in the thickness of rocks, in order to predict natural dangerous processes (landslides, avalanches etc).

Fig. 3 Total station Leica TS16

Typical monitoring schedule with total station is as follows: standard circular reflectors fixed at critical points (e.g. bridge bearings or points of maximum flexibility) that give response to the slightest movement of the object; total station is installed firmly in a stable zone and controls each observation point; data collected and processed round-the-clock; special software generates diagrams to represent the displacement as a function of time. Since the data collected has three-coordinate values, there is a possibility to control movements of points in 3D-space. Some monitoring systems are able to inform human or activate the alarm when the movement amplitude reaches a certain threshold.

Fig. 4 Mountainous area monitoring using total station

An example of such monitoring system in Mauls settlement (Austria) shown at the photograph (see Fig. 4). An austrian company *Trigonos ZT GmbH* has installed a robotic total station Leica TS15 to control the mountainous surface near the village with a population of 2,000 people [5].

Another one example of monitoring system based on total station in Hong Kong subway (see Fig. 5). The *MTR* company has installed six robotic total stations Leica TM30 which observe 234 circular reflectors fixed inside the subway tunnels [6].

Fig. 5 Tunnel monitoring using total station

These examples prove that total stations - are reliable and relatively inexpensive devices. They are suitable to detect point movements with millimeter precision within the 1 km range.

Mostly, total stations are used to monitor certain key points fixed at observed objects. The downside of this monitoring method is revealed in a complex case, where there is need to observe a large number of points. The cost of one qualitative round reflector is approximately 1 thousand USD, respectively, in order to capture data of large complex surfaces, the cost for accessories would reach a significant sum.

Multistations

Multistations (see Fig. 6) — are modern engineering devices that combine the functionality of robotic total station, laser scanner and photogrammetric station. Also it is possible to supplement the multistation with the GNSS receiver. Multistations are specifically designed for rigid conditions industrial environment. Leica MS60 operates in a wide temperature range, its body is protected from wind, rain, sand and dust.

Accuracy of data measurements remains the same despite the bright sunlight or complete darkness.

Fig. 6 Multistation Leica MS60

Multistation Leica MS60 is able to form 3D point cloud including true colour, intensity and signal-to-noise data with 1000 Hz frequency (1 thousand points per second at distance less than 300 m). This is enough to form 3D-point clouds of a certain surface for further analysis.

The Leica MS60 multistation comes with the revolutionary *Leica Captivate* software, turning complex data into the most realistic and workable 3D-models. With easy-to-use apps and familiar touch technology, all forms of measured and design data can be viewed in all dimensions.

Fig. 7 Field controller CS35

Using a field controller CS35 (see Fig. 7) surveyor is able to join and review the measurement results and project data directly in the field with a simple swipe. Leica MS60 multistation can work as a part of multicomponent automatic monitoring system, which integrates GNSS-receivers, geotechnical sensors, total station and other IT-infrastructure communication units managed by the monitoring software *Leica GeoMoS*.

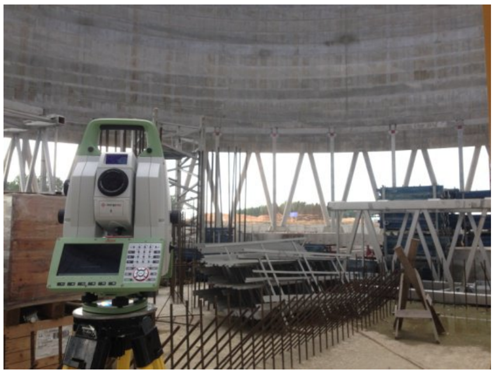

Fig. 8 Cooling tower monitoring using multistation

An example of operating multistation shown at the photograph (see Fig. 8).

Fig. 9 Power plant cooling tower

The *Navigation and geodesic center*, LLC (Kharkiv, Ukraine) used multistation Leica MS60 in order to control the construction process of cooling tower power plant (see Fig. 9).

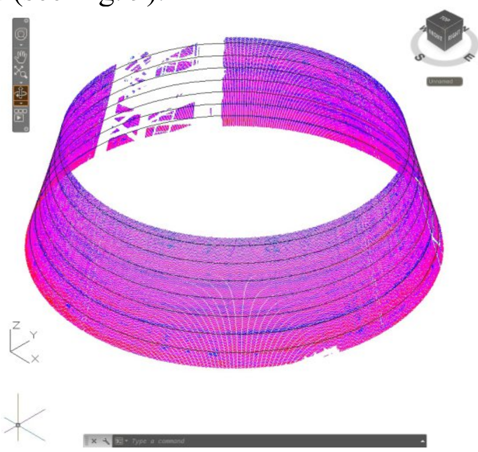

Fig. 10 Operation with the 3D-point cloud

The engineers of *Navigation and geodesic center* successfully scanned the cooling tower from the inside, than processed the cloud of 3D-points (see Fig. 10) and transferred results to the customer.

Fig. 11 Multistation of WestLAND Company

The popularity of multistations has been growing during the las three years. An example shown at the photograph (see Fig. 11) is an operating multistation, which belongs to the *WestLAND Group* (California).

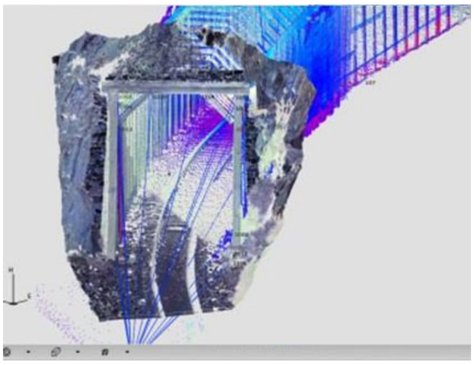

Fig. 12 Tunnel monitoring using multistation

This company successfully uses multistation in order to decide the HPGM tasks where needed, also, to carry out surveying works for the reconstruction of railway tunnels, and to execute laser scanning if there is a need to create clouds 3D-points (Fig. 12). [7]

Conclusion

We live in a dynamic world. Right now buildings and dams are sinking, bridges are deforming and vibrating, rocky stratas are shifting, and glaciers are melting. This world is constantly changing because of human impact (e.g. vibration, mining and construction), and because of natural processes (e.g. erosion and climate change).

Construction companies and developers facing a growing problem – a problem of controlling the changes. These people are responsible for the structures they create and serve. To solve such problems, engineers must be able to measure the changes of points and surfaces with a high precision.

Because of financial reasons construction companies consider purchase of a laser scanner as unattainable investment. In this article we justified, that Leica MS60 multistation - is a proper case when the scanning tasks are somewhat required, but the company provided funds are only enough for the total station.

Multistation is the most productive geodetic device today, which is focused on the implementation of the most difficult and complex tasks.

References

1. Маліцький А. Аналіз наземних лазерних 3D-сканерів та сфера їх застосування / Маліцький А., Лозинський В. // Сучасні досягнення геодезичної науки та виробництва. – 2014. – Вип I(27) – С.21-26..
2. Пекарш А.И. Координатно-измерительные машины и комплексы / Пекарш А.И., Феоктистов С.И., Колыхалов Д.Г., Шпорт В.И. // Наука и технологии в промышленности. - No3. – 2011. – С.36-48.
3. Тревого І. Аналіз технологічних можливостей сучасних лазерних трекерів / Тревого І., Баландюк А., Григораш А. // Сучасні досягнення геодезичної науки та виробництва. – 2011. - Вип I(21) – С.131-136.
4. Тревого І. Аналіз технологічних можливостей сучасних лазерних сканерів / Тревого І., Баландюк А., Григораш А. // Сучасні досягнення геодезичної науки та виробництва. – 2010. - Вип I(19) – С.170-176.
5. Zeiner A. GNSS Monitoring for safety on the Brenner / The Global Magazine of Leica Geosystems. - Reporter 68. – 2013.

– С.26-29.
6. Leica Geosystems TruStory – "Monitoring System at Tsuen Wan West Station, MTR West Rail Line" / www.leica-geosystems.co.uk/common/shared/downloads/inc/downloader.asp?id=19034 – 2009.
7. Leica Geosystems TruStory – "The Leica MS50 MultiStation: the real deal pays out" /leica-geosystems.com/media/files/trustories/monitoring_traunstein_2010_tru_en.ashx – 2013.

High-precision geospatial monitoring using the Leica MS60 multistation

I. Trevogo, A. Gorb, O. Meleshko

Considered and analyzed modern noncontact coordinate-measuring machines, whose operation principle is based on the laser-optical methods, prodused by Swiss company *Leica Geosystems*, such as: trackers, 3D-laser scanners, total stations and multistations. Proved the priority of Leica MS60 multistations for high-precision geospatial monitoring in various fields of production of large and complex objects and structures, where high accuracy is required.

Застосування мультистанції Leica MS60 в цілях проведення високоточного геопросторового моніторингу

І. Тревого, А. Горб, О. Мелешко

Розглянуті та проаналізовані сучасні безконтактні координатно-вимірювальні системи швейцарської компанії Leica Geosystems, принцип дії яких базується на використанні лазерно–оптичних методів: трекери, лазерні сканери, тахеометри та мультистанції. Обґрунтовано пріоритетність застосування мультистанції Leica MS60 в цілях проведення високоточного геопросторового моніторингу у різних галузях виробництва великогабаритних та складних об’єктів і конструкцій, де необхідна висока точність вимірювання.

Применение мультистанции Leica MS60 в целях проведения высокоточного геопространственного мониторинга

И. Тревого, А. Горб, А. Мелешко

Рассмотрены и проанализированы современные бесконтактные координатно-измерительные системы швейцарской компании Leica Geosystems, принцип действия которых основан на использовании лазерно-оптических методов: трекеры, лазерные сканеры, тахеометры и мультистанции. Обоснована приоритет-ность применения мультистанции Leica MS60 в целях проведения высокоточного геопространственного мониторинга в различных отраслях производства крупногабаритных и сложных объектов и конструкций, где необходима высокая точность измерения.