Introducing New Technology in the cadastral surveying

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Abstract

GNSS measurements and digital photogrammetric procedures have long been introduced into the cadastral surveying process. However, the latest visual positioning technology which provides integrated solutions by combining various sensors together such as a modern GNSS receiver, IMU and a camera may open new ways in this field. It becomes now possible with the use of integrated technology to capture several images of the site on the go, every half second, create a 3d model from the georeferenced point cloud while still being in the field, and obtain coordinates of the various points of the model either right there in the field or later in the office. The principle is identical to that of digital photogrammetry and it allows the capturing of a large number of point details, even those that cannot be accessed by a GNSS receiver. At the same time, the integration of a modern GNSS receiver that can map points with either tilted or leveled pole enables the measurement of other points, too, those with obstructed view to the sky, more efficiently and easily.

This technology may have an immediate applicability in speeding up the systematic cadastral surveying, where a lot of measurements with a total station are needed. It is anticipated that a significant flexibility and time-saving may be introduced in the field cadastral surveying.

This paper attempts to test this new technology in two case studies, one in Romania and one in Greece, where parallel systematic cadastral surveying is currently taking place for the establishment of modern land administration systems in both countries. For the case studies the GS18 I of Leica will be used. The studies will assess (a) the flexibility of the method when used in the various terrain types such as rural or peri-urban areas, the required time for field work or the need for revisiting the place for additional measurements, (b) the productivity and efficiency of the technical tool in capturing large numbers of point coordinates of high accuracy within a short time, (c) the advantage of no need for using other time-consuming equipment and for long data processing time in the office to catch all needed detail points over its cost, (d) the required need for staff training, as well as the required staff numbers during the field work, (e) the potential for doing real-time field controls in the collection of the boundary points, etc. These case studies aim to present the advantages and disadvantages of using new GNSS receivers in systematic cadastral works.

Keywords: GNSS receiver, total stations, systematic cadastral surveying.

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1. Introduction

In Romania, since 2010 began the systematic registration of properties through government funding of ATUs involved in the program. Under the conditions imposed, the accuracy of determining the corners of the property was required to be ± 10 centimeters. In these circumstances, two instruments were mainly used in the field measurements: the total station and the GNSS receivers. GNSS receivers have the ability to determine with ROMPOS technology, which ensures the required accuracy. GNSS receivers have the advantage of instantly determining the position in optimal conditions. Thus, in urban areas it was impossible to determine the corners of buildings due to the poor geometry of the satellites. Also, in areas with abundant vegetation it could not be measured under the trees.

Subsequent use of UAV devices, which ensure the size of a pixel of 2-3 centimeters in the field, has the same problems with the corners of the house due to the eaves and with the areas covered by vegetation under which the details cannot be observed.

The advent of the Leica GS18i receiver made it possible to determine these elements of detail in a shorter time than the total station and with less staff.

To demonstrate the efficiency and performance of the receiver, we conducted a case study in Romania, UAT Schitu, in Giurgiu County, where fieldwork on the systematic cadastre was completed. The data had been taken with the total Leica TS06 plus station (traverse), with Leica GS08 plus dual frequency GNSS receivers, combined with the vectorization on the orthophotoplan made in flight with a UAV, resolution 2-3 cm.

For an intra urban area in the Schitu ATU, measurements were performed using the Leica GS18i receiver, and the results (point coordinates) were compared to determine the differences in position and whether they meet the accuracy required by law.

2. Presentation of the data collection method

2.1 The technology used in performing the systematic cadastre.

In the systematic cadastre work, as mentioned above, data taken with the total Leica TS06 plus station and with Leica GS08plus dual frequency GNSS receivers were used.

2.1.1 Leica TS06 plus total station, by the traversing method, performing direction and distance measurements in the field. These measurements were calculated with applications developed for this purpose to determine the detail points of the real estates (land and construction).

2.1.2 Leica GS08plus GNSS systems, dual frequency receiver, using real-time positioning services (**RTK**) provided by the Romanian **ROMPOS** Positioning System (consisting of a number of 74 permanent national stations). These services involve the transmission via the Internet of information which, in the literature, is called differential corrections. With the help of access to differential corrections, positioning accuracies of ± 3-5 cm in real time are obtained, in optimal conditions. To access the corrections, users must log in with the rover's username and password, using the NTRIP client software corresponding to the field GNSS receivers. Real-time positioning services provide access to two types of products:

- Nearest products type (Single - Base RTK)**.** These involve the use of differential corrections from a single reference station. An example of such a product is Nearest_2.3, which means that differential corrections are to be accessed from the reference station in RTCM 2.3 format.
- Network RTK type products (network products). These involve calculating corrections based on observations from the nearest reference stations around the user. It is recommended to use them if you are far away from any reference station or if the nearest reference station is malfunctioning. ROMPOS offers access to 4 types of network products: MAX, iMAX, FKP and VRS. An example of a network product is RO_MAX_3.1, which means that a MAC-type product is to be used, in RTCM 3.1 format, with data from the GPS and GLONASS satellite constellations. Products with 3G or MSM extension contain Galileo corrections.

2.1.3 Coordinate transformations is made through an application called TransDatRo version 4.0 provided free of charge by the National Agency for Cadastre and Real Estate Advertising

According to the legal provisions in force, in Romania three reference and coordinate systems are used:

• ETRS89, for the expression of ellipsoidal and Cartesian geocentric geodetic coordinates

• Stereographic 1970, for the expression of plane Cartesian coordinates

• Black Sea 1975, as a reference system for normal altitudes (having as reference surface the quasi-geoid) [1]

For any measurement performed using GNSS technology, the default coordinates obtained are in the WGS84 reference system and coordinates. By connecting to the ROMPOS reference stations, in case of real-time measurements, or by constraining on the ROMPOS stations, in case of post-processing the RINEX files, the resulting coordinates for the new points will be in the ETRS89 system. Given that for cadastral works the coordinates of the real estates must be expressed in the Stereographic System 1970, ANCPI together with CNC have developed and made available to users free of charge a standard solution for transforming coordinates, from ETRS89 to Stereo70 and vice versa, which includes a model of data distortion in order to maintain the integrity and topology of spatial data in national and European reference systems and coordinates. This solution was materialized by creating the **TransDatRo** coordinate transformation software, which has reached version 4.04 and can be downloaded for free from the website www.cngcft.ro, in the "Download" section

2.2 **Leica GS18i presentation**

When using a GNSS sensor to be able to measure points, the GNSS sensor must receive signals from the satellite. The position of a point can only be measured when the GNSS sensor has access to the open sky and the tip of the measuring staff is physically placed on the detail to be measured. If this is not possible, surveyors may use alternative methods such as [2]:

- distances measured with roulette, COGO function and sketch;
- additional accessories, in combination with the GNSS sensor, e.g. controller with integrated dystomat or a 4.5 meter measuring staff. This measurement method can take a long time and can also compromise accuracy.
- alternative sensors such as total stations.

GS18 I is a versatile **GNSS RTK** sensor. It can be used to measure points with a measuring staff **held upright or tilted**, thanks to the integrated **IMU** sensor. In addition, it can be used to measure inaccessible points, with topographic accuracy, **by capturing and measuring from images**.

Principle of measurement with GS18i

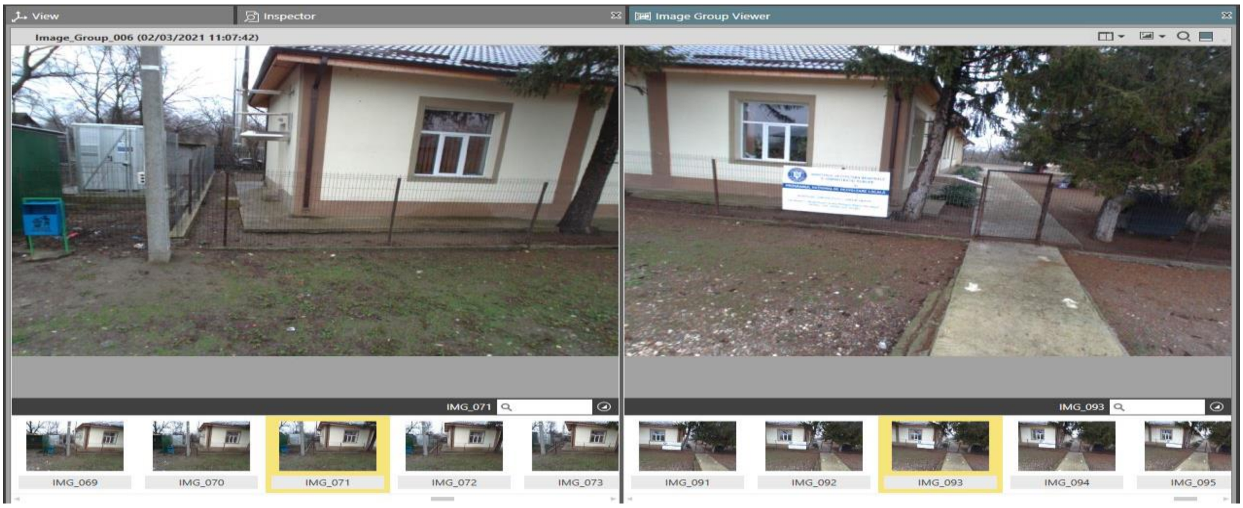


Figure 2.1 - Images captured with the GS18i receiver

Let's take the following image as an example: a user wants to measure certain points of interest. All you have to do is walk along the façade with the camera facing the object, while the GS18

I automatically captures images. GS18 I captures images at a speed of 2 per second ensuring optimal image overlay and geometry. Once the capture is stopped, the images will be processed automatically by the algorithms running on the application on the controller. Images can be used to measure points immediately after processing the captured images.

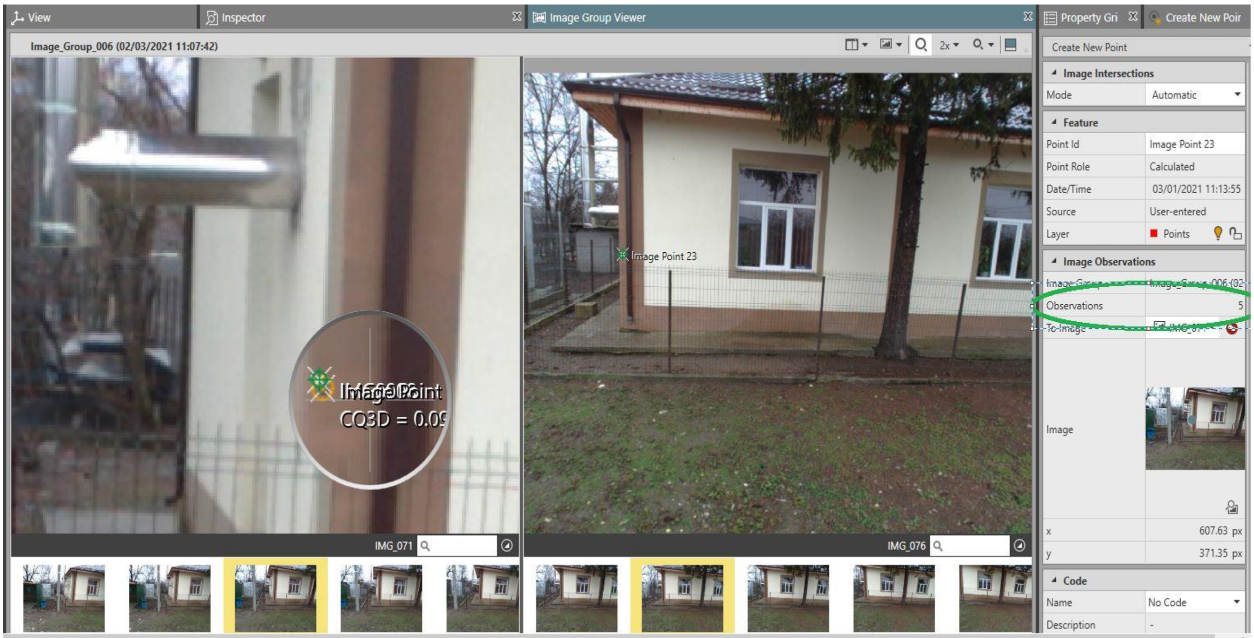


Figure 2.2 - Pointing on images

The application will automatically process, position and orient the captured images, thus ensuring quality control already in the field. The images can then be imported into the Leica Infinity software, where users can measure points in the office, on a larger screen. Simply choose a point in one image and the algorithm will automatically match the same point in the other images. With a single click, the 3D coordinates of the measured point will be calculated and stored. Points captured with GS18 I do not have to be manually selected in each image, as this is done by the algorithm. When the chosen point is identified in consecutive images, the 3D position of the point is constructed using the forward intersection. [3]

Visual positioning technology is based on the **correlation of information provided by GNSS positions, IMU and captured images**. It is also possible to create point clouds from the captured images.

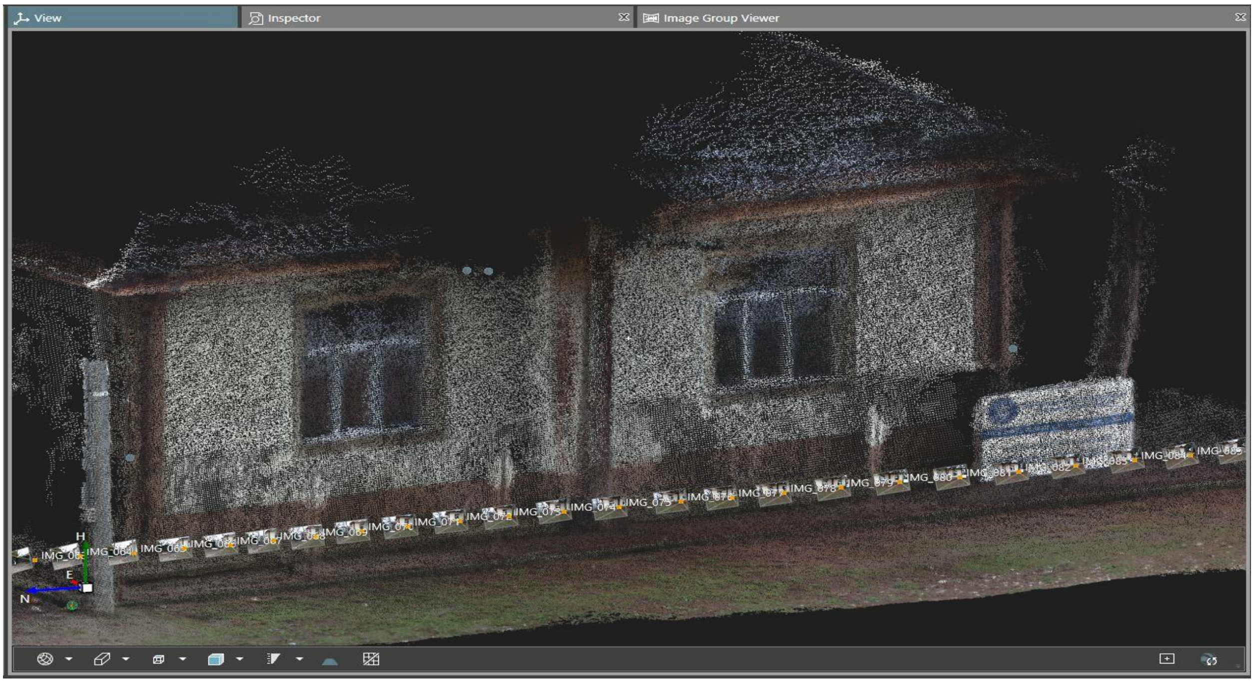


Figure 2.3 - Point cloud resulting from image processing

Differences obtained between the first phase of measurements and the measurements performed with the GS18i sensor (measurements with inclined measuring staff/points determined based on the groups of images taken in the field)

2.4 Point to point measurements

3. The result of the measurements

The tables below show the results of determining the position of each point determined with the total station in the systematic cadastre work and determined with the GS18i receiver.

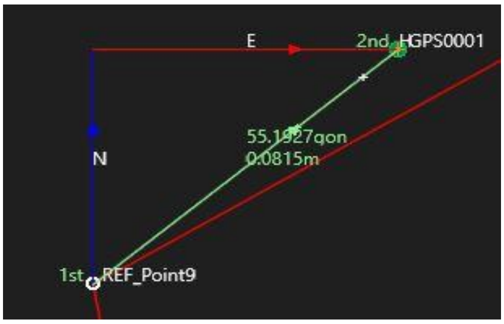
Input Settings

1st Point:	REF_Point9
2nd Point:	GPS0001

Input Coordinates

#	Point ID	Point Role	Easting [m]	Northing [m]	Height [m]	Tipe	Code	Code Description	Attributes
1	REF_Point9	Total station	568,175.6200	296,197.5890	-	Total station			fence
2	GPS0001	Fixed RTK	568,175.6822	296,197.6418	-	Gnss-tilt			fence

Results



Azimuth:	55.1927	gon
Zenith Angle:	100.0208	gon
Hz Dist.:	**0.0815**	**m**
Slope Distance:	0.0815	m
ΔHeight:	0.0000	m
ΔEasting:	**0.0622 m**	
ΔNorthing:	**0.0528 m**	

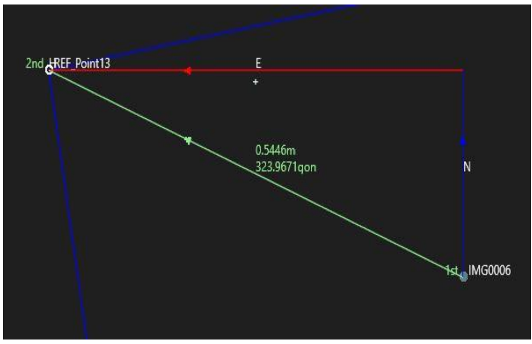
Input Settings

1st Point: REF_Point13
2nd Point: IMG0006

Input Coordinates

#	Point ID	Point Role	Easting [m]	Northing	Height [m]	Tipe	Code	Code Descriptio	Attributes
1	REF_Point13	Total station	568,181.2250	296,192.2770	-	Total station			constructions
2	IMG0006	Calculated	568,181.2516	296,192.2665	-	From image			constructions

Results



Azimuth:	123.9671	gon
Zenith Angle:	3.3458	gon
Hz Dist.:	**0.0286**	**m**
Slope Distance:	0.0286	m
ΔHeight:	0.0000	m
ΔEasting:	**0.0266 m**	
ΔNorthing:	**-0.0105 m**	

Input Settings

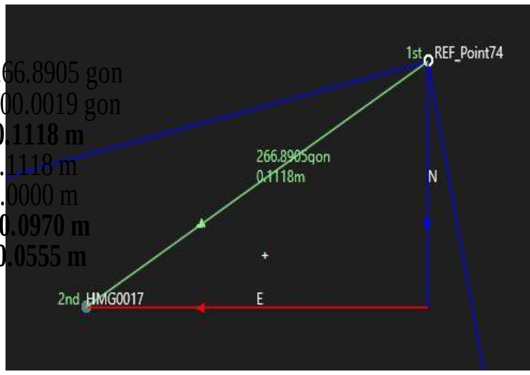
1st Point: REF_Point74
2nd Point: IMG0017

Input Coordinates

#	Point ID	Point Role	Easting [m]	Northing	Height [m]	Tipe	Code	Code Descriptio	Attributes

1	REF_Point74	Total station	568,224.9520	296,170.7200	-	Total station			constructions
2	IMG0017	Calculated	568,224.8550	296,170.6645	-	From image			constructions

Results



Azimuth: 266.8905 gon
Zenith Angle: 100.0019 gon
Hz Dist.: **0.1118 m**
Slope Distance: 0.1118 m
ΔHeight: 0.0000 m
ΔEasting: **-0.0970 m**
ΔNorthing: **-0.0555 m**

Input Settings

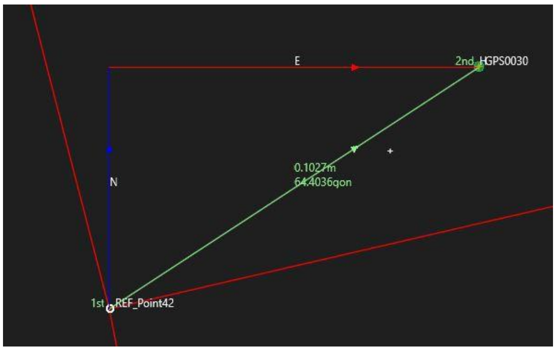
1st Point: REF_Point42
2nd Point: GPS0030

Input Coordinates

#	Point ID	Point Role	Easting [m]	Northing	Height [m]	Tipe	Code	Code Descriptio	Attributes
1	REF_Point42	Fixed RTK	568,181.445	296,166.910	-	Gnss			fence
2	GPS0030	Fixed RTK	568,181.532	296,166.964	-	Gnss-tilt			fence

Results

Azimuth:
Zenith Angle:
Hz Dist.:
Slope Distance:
ΔHeight:
ΔEasting:
ΔNorthing:



Input Settings

1st Point: REF_Point36
2nd Point: GPS0046

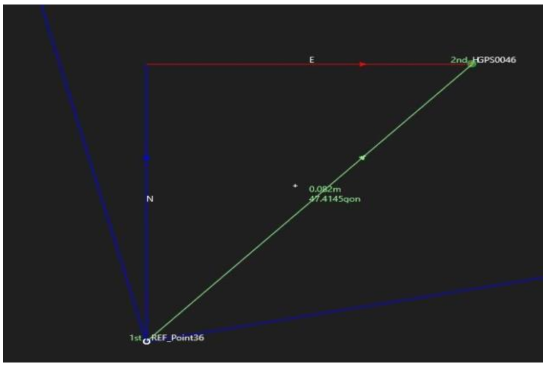
Input Coordinates

#	Point ID	Point Role	Easting [m]	Northing	Height [m]	Tipe	Code	Code Descriptio	Attributes
1	REF_Point36	Total station	568,211.4260	296,193.1000	-	Total station			constructions

2	GPS0046	Fixed RTK	568,211.481 6	296,193.160 3	-	Gnss-tilt			construction s

Results

Azimuth:	47.4145 gon
Zenith Angle:	100.0130 gon
Hz Dist.:	**0.0820 m**
Slope Distance:	0.0820 m
ΔHeight:	0.0000 m
ΔEasting:	**0.0556 m**
ΔNorthing:	**0.0603 m**



Total station coordinates		GS18i coordonate		Coordinate differences		
X (m)	Y (m)	X (m)	Y (m)	ΔX (cm)	ΔY (cm)	Total (cm)
568.175,6200	296.197,5890	568.175,6822	296.197,6418	-6,2200	-5,2800	8,1588
568.181,2250	296.192,2770	568.181,2516	296.192,2665	-2,6600	1,0500	2,8597
568.224,9520	296.170,7200	568.224,8550	296.170,6645	9,7000	5,5500	11,1755
568.181,4450	296.166,9100	568.181,5321	296.166,9645	-8,7100	-5,4500	10,2746
568.211,4260	296.193,1000	568.211,4816	296.193,1603	-5,5600	-6,0300	8,2021

The total difference is below the required tolerance of ± 10 centimeters.

4. The result of the evaluation of the study:
(a) the flexibility of the method when used in the various terrain types such as rural or peri-urban areas, the required time for field work or the need for revisiting the place for additional measurements
The method is suitable for use in rural areas, with low constructions (ground floor or ground floor plus one floor), because high constructions can become important obstacles for signals received from satellites. You can view the area to be determined on existing orthophotoplans or on Google Earth, which provides an image of the obstructions in each yard. Thus, in some yards the method can be used, in others not. Yards where there is abundant vegetation or tall buildings are not suitable for this method.
In extra urban areas it can usually be measured right on the point to be determined.
(b) the productivity and efficiency of the technical tool in capturing large numbers of point coordinates of high accuracy within a short time
The productivity of the method is clearly higher than the determinations with the total station. It is also useful in areas where trees cover an important part of buildings. The rate of determination may increase by at least 50% compared to total station determinations. Determinations with the inclined measuring staff make it possible to determine the corners of low-rise buildings in a very short time. Taking images and determining the coordinates of a point in the point cloud is fast and accurate, as the case study showed. The results are in line with the accuracy required for systematic cadastre.
(c) the advantage of no need for using other time-consuming equipment and for long data processing time in the office to catch all needed detail points over its cost

The positioning result can be obtained in two ways:
- Directly, on the field, by pointing and determining the position of a point after taking the images;
- Processing of the point cloud obtained from image processing.
Both methods give very good results. We chose the first option because it is not time consuming at the office and the result is very close and falls within the tolerances imposed by regulations.
(d) the required need for staff training, as well as the required staff numbers during the field work
Using this type of receiver is similar to using a regular receiver, with a few additional conditions that can be easily learned in a very short time (a few minutes, a maximum of one hour). In this way, an operator who frequently uses GNSS receivers in current work can become an operator on a GS18 I type GNSS receiver.
(e) the potential for doing real-time field controls in the collection of the boundary points, etc.
Property boundaries can be more easily and quickly determined using this tool, directly on the ground.
The number of staff is smaller, the time is shortened. In this way, the field costs for carrying out a systematic cadastral work are reduced by values between 30 and 50%, depending on the height regime of the buildings and the degree of vegetation cover.

5. Conclusions:

5.1 From a technical point of view.
Inaccessible points can be easily captured in images. Field work time is reduced, and measurement can be completed at the office, thus increasing productivity. There are several conditions that should be considered when using GS18 I for measurement from images: GS18 I must receive sufficient GNSS signals throughout the measurement. If the tracking of GNSS satellites is lost, the capture will stop automatically. If visual positioning is required, it should be avoided when using it in the dark or when the camera is facing the sun, as not enough details from the captured images are easily recognized to correlate them.
For optimal accuracy and performance, the object of interest must be captured from a distance between 2m and 10m. When images are captured from a distance of less than 2 m, images may be blurred due to the camera's fixed focus. On the other hand, when images are captured from a distance of more than 10 m, the accuracy decreases. When capturing images at a distance of less than 2 m or more than 10 m from the object, the user must take into account that the accuracy may be reduced. There is also a risk that measuring points using images may not be possible.
The image capture speed is optimized for normal travel speed.
5.2 From an economic point of view
From the above it is obvious that reducing the measurement time of each detail point and reducing field staff is important in reducing overhead costs.
Considering that the field works constitute only a part of the entire systematic cadastre work, the reduction of the overall expenses is about 7 - 10%, depending on the area where the works are carried out.
In the plain areas the reduction is lower and in the mountain areas the reduction is higher.

The GS18i receiver is an important step in the process of improving the determination of the position of points on the ground. Data collection can be made much easier in the event of obstructions in intra urban areas and in areas covered by vegetation. We recommend using the tool in systematic cadastral works to increase productivity and reduce costs.

Bibliography

[1] Testing Multi – GNSS Equipment (Systems, Simulators and the Production Pyramid – Ivan Petrovski, Bryan Townsed, Takuji Ebinuma
[2] Innovation: First AGPS - Now BGPS: Instantaneous Precise Positioning Anywhere - Ivan Petrovski, Harumasa Hojo, and Toshiaki Tsujii, GPS World, November 2008

[3] Multi-GNSS processing, positioning and applications - R. Odolinski,P. J. G. Teunissen &B. Zhang, Journal of Spatial Science, Volume 65, 2020 - Issue 1: Multi-GNSS processing, positioning and applications