The Wireless Remote Survey Method

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Abstract— In 2014 the Remote Survey method was presented. This method implements the Image Assisted Total Stations' (IATS) and the Image Assisted Scanning Total Stations' (IASTS) capabilities to transmit the target's image from the field to a remote device. These stations are connected via a USB cable to a laptop and then via the internet to a remote device. So, it is possible to remotely operate them. In this paper the wireless evolution of the Remote Survey method and the results of its implementation in a variety of experiments are presented. Initially, in laboratory environment such as the tests for evaluating the precision achieved during the horizontal directions and vertical angles measurements, in accordance with the standard ISO 17123-3. Furthermore, in realistic surveying conditions, such as the deformation monitoring of an existing geodetic network and the astrogeodetic measurements. Then, useful conclusions are presented and the pros and cons of the Wireless Remote Survey method are aggregated. Finally, a comparison between this method and the Robotic monitoring methods is attempted. The implementation of the suggested method will significantly reduce the surveyor's presence in the field in a variety of projects, amongst them in the Landslide and Natural Hazard Monitoring.

Keywords— Geodesy; Wireless Remote Survey method; Deformation constructions monitoring; Astrogeodetic measurements; Image Assisted Total Station (IATS); Image Assisted Scanning Total Stations (IASTS); Landslide and Natural Hazard Monitoring.

INTRODUCTION

The demand for specialized geodetic works is constantly increasing, such as for landslide and natural hazard monitoring, mapping large buildings, skyscrapers and dams. Many different techniques of 3D geodetic and photogrammetric measurements have been developed to perform them. A typical example is a prototype combination of a total station with a digital camera and the description of the calibration of this system [1]. Another example is the placement of a video camera on a total station to capture building details. In this way, the interconnection between Topography and Photogrammetry was also achieved [2].

Remarkable work was carried out in the scientific field of astrogeodetic observations. These efforts aim at exploiting either the images of a CCD camera attached to the total station [3] or the capabilities that arise from connecting a GNSS receiver with a total station [4-6].

The evolution of technology made possible the production of the IATSs or IASTSs [7]. These stations, have the typical structure of the total stations, such as an electronic theodolite, an EDM and a microprocessor [8], while they incorporate the user-friendly Windows CE and a high-resolution CCD camera on their telescope.

A step forward is the Wired Remote Survey method, which makes it possible to remotely and reliably operate an IATS (from this point and on this term also includes the IASTS) and perform remote observations with the help of two PCs wired to the internet and a combination of nil cost software [9]. This means that the observers are able to aim, measure, scan, supervise the field work and communicate with their partners remotely through the screen of a PC. Based on this method, a methodology for the calculation of the time delay between the UTC time when the remote observer performs the measurement and the respective UTC time when the measurement is executed in the IATS, is introduced [10].

The development of technology permitted the evolution of the Wired Remote Survey method and the presentation of the Wireless Remote Survey method, which facilitates the execution of measurements by connecting an IATS directly to the internet via Wi-Fi. In this way, there is no more need of a wired connection between the IATS and a laptop or PC, to connect the instrument to the internet.
In order to investigate the usability of the Wireless Remote Survey method a hypothesis is set in question in this paper. In detail, it is assumed that the horizontal directions and vertical angles measurements executed with the method meet the nominal accuracy given for the IATS, in accordance with the standard ISO 17123-3. After proving this hypothesis is true, the implementation of the specific method in realistic surveying conditions, such as the deformation monitoring of an existing geodetic network and the astrogeodetic measurements are attempted and the results of these experiments are analyzed.

MATERIALS AND METHODS

The basic concept of the Wireless Remote Survey method is that an IATS has all the features that permit a surveyor to perform geodetic observations by distance. The integrated high-resolution CCD camera serves to transmit the image of the target field of view to the station's display and from there to any remote device. Also, the instrument has a built-in Wi-Fi network card which enables the connection to the internet. In addition, an auxiliary device is necessary, usually a PC or laptop. The device located at the remote location is called the "User Device".

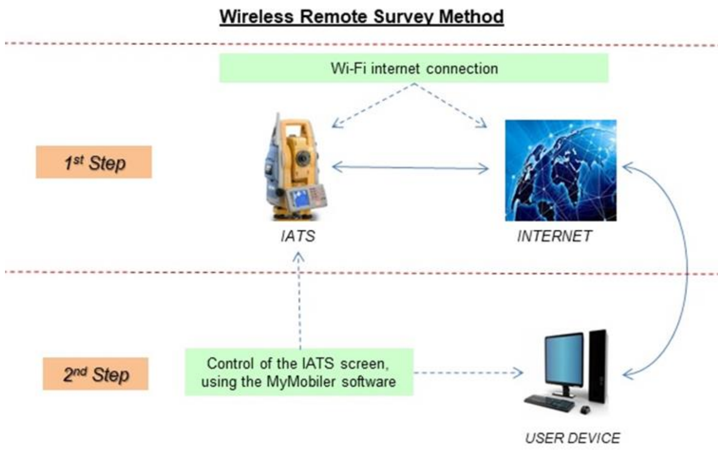

Figure 1. The Wireless Remote Survey Method.

This method has two steps, as in Figure 1. The first step is to establish the connection of the station and the "User Device" directly to the internet using Wi-Fi technology. Thus, the observer can gain control of the station with the "User Device" [11]. Once the Wi-Fi communication with the internet is restored, the issue of synchronizing the internal clock of the station with UTC world time is raised. The synchronization is done automatically since the "ActiveSync" software synchronizes every external device connected to the "Server Device". It is worth noting that on PCs using the Windows 8 and newer versions of this operating system, the software "ActiveSync" is no longer used because it is replaced by the "Windows Mobile Center", which is also activated automatically. Similarly, with the station's Wi-Fi connection to the internet the synchronization is also done automatically. Nevertheless, in the Wireless Remote Survey method the installation of the free software "SP TimeSync 2.3" [12] on the station was chosen, because it provides the user with the option to select the world time server and it gives the option to select the time interval for the repetition of the synchronization, for example every 10sec.

The second step is to manage the station screen from the "User Device" screen. This is achieved by installing the "MyMobiler" software [13] on the IATS and on the "User Device". This software manages, via the "User Device" screen, the screen of each connected mobile device and therefore the station's screen. It should be noted that the station has an automatic movement mechanism, which is operated using electrical or electromagnetic energy, while the movements of its telescope can be controlled from its screen by means of special software provided by the manufacturer. Thus, real-time transmission of the image from the station's screen to the "User Device" screen is implemented and at the same time the overall operation of the station is made possible by using the keyboard and mouse of the "User Device".

As far as it concerns the sources of uncertainty of the Wireless Remote Survey method, they include the following integral components of the method's system:

- The IATS;
- The screen of the "User Device";
- The observer;
- The target;
- The observer;
- The environmental conditions.

The impact of the IATS (as being a sophisticated total station), of the observer, of the target, and of the conditions have been already examined in details in the international bibliography. Moreover, the component "User Device" screen affects the uncertainty of the Wireless Remote Survey method only if it renders the transmitted target's image with fewer pixels per dimension than the original one displayed on the IATSs screen, in which case there is a degradation of the image quality [14].

Table 1. Optimal combinations of "monitor size" / "monitor analysis" for use in the Wireless Remote Survey method [14]

PC / Laptop Monitor Size (in inches)	Monitor Analysis (in pixels)	Size of each Pixel (in inches)	Number of pixels of the transferred image to the "User Device"
10.1	1920 x 1200	0.0045 × 0.0045	628 × 471
12.3	2736 × 1824	0.0043 × 0.0043	658 × 493
13.3	1920 × 1080	0.0060 × 0.0060	464 × 348
14	1920 × 1080	0.0064 × 0.0064	441 × 330
15.6	1920 × 1080	0.0071× 0.0071	395 × 297
16.1	1920 × 1080	0.0073 × 0.0073	383 × 287
17.3	1920 × 1080	0.0079 × 0.0079	357 × 267
19	1920 × 1080	0.0086 × 0.0086	352 × 243

In Table 1 optimal combinations of monitor/analysis for use in the Wireless Remote Survey method are presented for future use, without degrading the quality of the transmitted image, provided that the combination of the aforementioned software is used [14].

RESULTS

3.1. Implementation of the Standard ISO 17123-3 Full Test

This test took place in order to investigate the reliability of the targeting via the "User Device" screen with the Wireless Remote Survey method [14]. For the implementation of the ISO 17123-3 full test procedure in the control of horizontal direction measurements, five targets were placed in a NTUA laboratory, at equal distribution [15]. This distribution is shown in Figure 2.

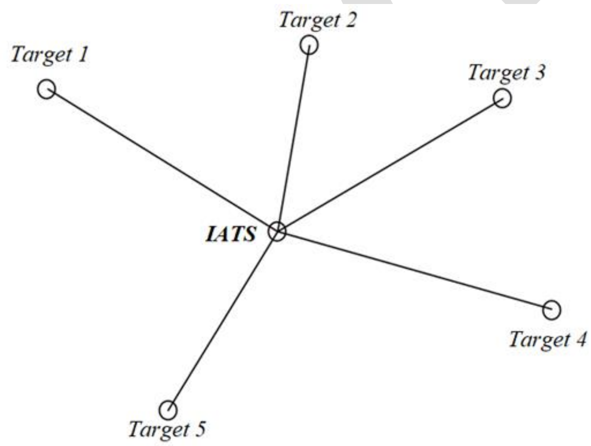

Figure 2. Test configuration for measurement of horizontal directions.

The targets were aimed at both face positions of the telescope, in four periods and in three series of measurements. Similarly, for the vertical angles, a vertical rod was placed and measurements were made by aiming at specific points on the rod, as in Figure 3, in four measurement series at both face positions of the telescope.

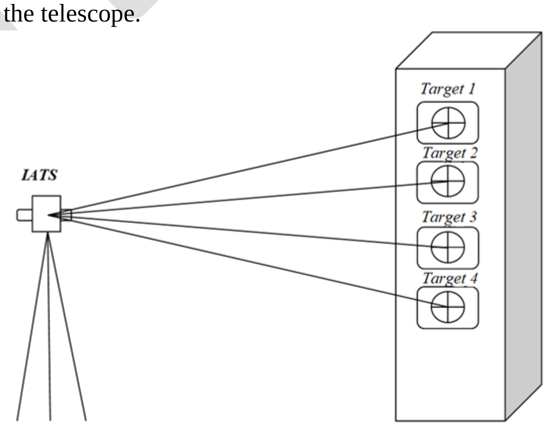

Figure 3. Test configuration for measurement of vertical angles.

The tested IATS was a Topcon IS-203. This instrument has a built-in Wi-Fi network card which facilitates the wireless connection. Also, it has a nominal accuracy of ±3" (±9.3^{cc}) in direction measurements and ±2mm ±2ppm in distance measurements [16].

In accordance with the standard if the equation (1) is valid for horizontal directions and vertical angles (Hz and V), by following the chi-square (χ^2) distribution for confidence level 95%, the measurements meet the IATS nominal accuracy.

$$s \le \sigma \cdot \sqrt{\frac{\chi^2_{1-\alpha}(\nu)}{\nu}} \tag{1}$$

where ν is the freedom degree of the ISO procedure.

σ is the nominal accuracy, $\pm 9.3^{cc}$ given for the IS-203.

s is the experimental standard deviation

$\chi^2_{0.95}(32) = 46.19$

The calculated experimental standard deviation of a horizontal direction, was:

$s = s_{ISO\text{-}THEO\text{-}HZ} = \pm 6.6^{cc}$

The equation (1) is valid because:

$$6.6^{cc} \le 9.3^{cc} \cdot \sqrt{\frac{46.19}{32}} \Rightarrow 6.6^{cc} \le 9.3^{cc} \cdot 1.2 \Rightarrow 9.3^{cc} \le 11.16^{cc}$$

So, the remote targeting of a horizontal direction with the Wireless Remote Survey method meets the required specification.

Furthermore, the calculated experimental standard deviation of a vertical angle was:

$s = s_{ISO\text{-}THEO\text{-}V} = \pm 4.8^{cc}$

The equation (1) is valid because:

$$4.8^{cc} \le 9.3^{cc} \cdot \sqrt{\frac{46.19}{32}} \Rightarrow 4.8^{cc} \le 9.3^{cc} \cdot 1.2 \Rightarrow 4.8^{cc} \le 11.16^{cc}$$

So, the remote targeting of a vertical angle with the Wireless Remote Survey method meets the required specification.

The implementation of the ISO 17123-3 full test procedure proved that the initial hypothesis set in question for the Wireless Remote Survey method, is TRUE. So, the experimental conclusion that can be drawn is that the specific method has similar results as the classic geodetic measurements.

After proving the reliability of the Wireless Remote Survey method in laboratory environment, then geodetic applications in realistic surveying conditions took place, such as the deformation monitoring of a geodetic network and the astrogeodetic measurements. For these experiments as IATS a Topcon IS-203 was used, with the aforementioned technical characteristics.

3.2. Deformation monitoring of a geodetic network

This work was carried out in order to investigate the suitability of the Wireless Remote Survey method in performing geodetic network monitoring. The network was established in year 2000 at the Polytechnic Campus of Zografou and remeasured in year 2004 [17]. It consists of 5 points. The distances between the points vary approximately from 111m to 509m.

The horizontal and vertical angles and distances were measured at both telescope faces, for 4 sets of measurements between the network points. The point 1 (LAMP) was considered fixed for the network adjustment with the Least Squares Method. Then a total reliability control took place. The null hypothesis Ho was tested using the chi-square (χ^2) distribution for confidence level 95%. The solution revealed that the null hypothesis Ho was true, so the network adjustment result is acceptable. The absolute horizontal - vertical deformation vectors and ellipses of the network adjustment, as well the relative ones, are presented in Figures 4 to 7 [14].

Summarizing the next figures, the following absolute displacements are detected:

- of the point 2 (F), to the point 1 (LAMP), only in the vertical direction.
- of the points 3 (GE), 4 (XM) and 5 (FE), to the point 1 (LAMP), both in the vertical and horizontal direction.

Moreover, relative displacements between the network points are detected.

Concluding, this experiment proved that the specific method is acceptable for the deformation monitoring of a geodetic network and in general can be used also for landslide and natural hazard monitoring by implementing the above described procedures.

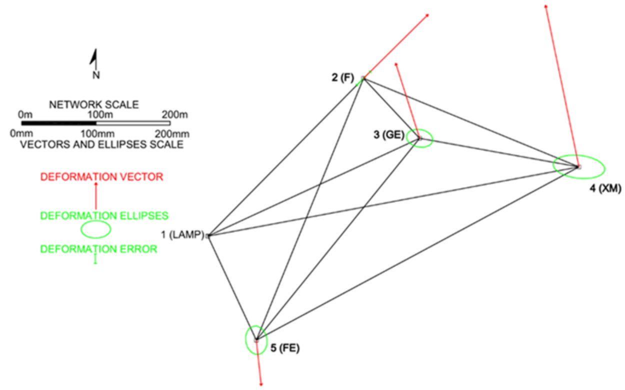

Figure 4. The absolute horizontal deformation vectors and ellipses [14]

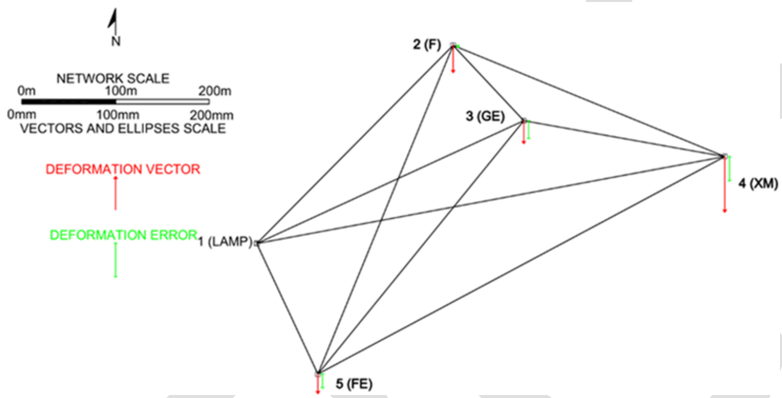

Figure 5. The absolute vertical deformation vectors and errors [14]

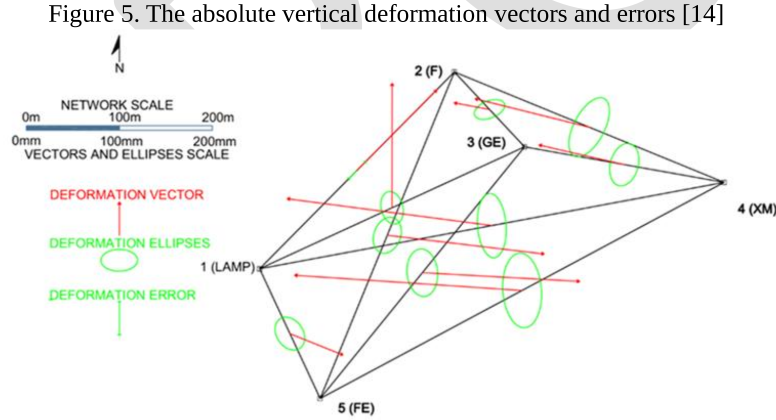

Figure 6. The relative horizontal deformation vectors and ellipses [14]

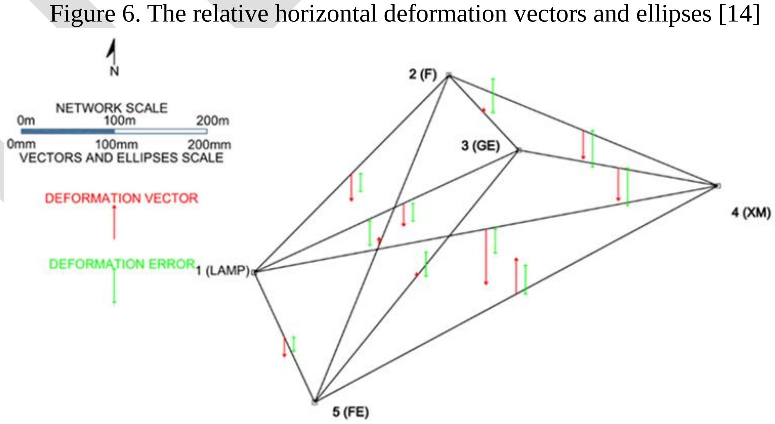

Figure 7. The relative vertical deformation vectors and ellipses [14]

3.3. Astrogeodetic determination of the Astronomical Azimuth

Astrogeodetic observations towards Polaris for the determination of the Astronomical Azimuth of a random direction, using the hour angle method, took place, also with the implementation of the Wireless Remote Survey method. The purpose of this experiment was to determine whether it is feasible or not to use the specific method for astrogeodetic observations.

Two series of measurements took place. The 1st series of measurements was performed via the IATS telescope in order to establish a reference direction and a reference Astronomical Azimuth. Then, the 2nd series of measurements was performed using the Wireless Remote Survey method, by aiming the Polaris via the “User Device” screen of the remote observer, as in Figure 8.

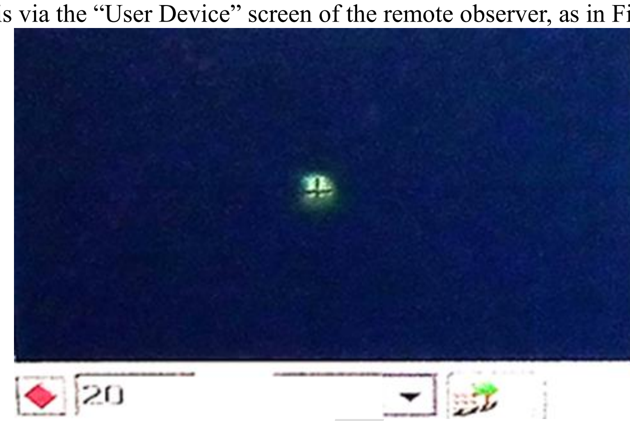

Figure 8. Aiming at the Polaris with Wireless Remote Survey method via the screen of the “User Device” [14]

The Astronomical Azimuth of a random direction, using the hour angle method via [14]:

the IATS telescope was $123.4717^{g} \pm 3.5^{cc}$;

the “User Device” screen was $123.4721^{g} \pm 3.9^{cc}$.

The results of this experiment confirmed that the Wireless Remote Survey method is applicable for common Astrogeodetic observations.

DISCUSSION

Useful remarks can be drawn from the analysis of the above results. First of all, the implementation of the ISO17123-3 full test procedure proved that the observations with the Wireless Remote Survey method meet the required specification and the nominal accuracy of the IATS.

Moreover, it is proved that specific geodetic works as a deformation monitoring of a geodetic network or Astrogeodetic observations towards Polaris for the determination of the Astronomical Azimuth of a random direction, can be performed with the specific method with acceptable results. Given that, it can be stated that the particular method is also applicable in the landslide and natural hazard monitoring.

In detail, a network of fixed points can be set in the area of interest and an IATS can be set in a place not affected by the evolution of the observed phenomenon. The only restrictions are the need for a fixed electric power supply for the instrument, a reliable Wi-Fi connection and a protective construction covering the instrument against severe weather conditions. Then, the scientist can observe the evolution of the phenomenon from his/her office in almost real time by having images and measurements of the field.

It is worthy to mention that during the above geodetic works some problems occurred. Firstly, interventions of other wireless networks caused instability in the internet connection of the IATS to the preferred network. Also, hardware problems occurred, like a battery loss. All of the aforementioned malfunctions couldn’t be prevented. So, the operator had to solve the problems in situ in order to restart the remote measurements.

Furthermore, four very important remarks should be mentioned. The first one is that a key element of the Wireless Remote Survey method is that only nil cost software is used, because the intention is to be widely used by any surveyor. The second one is that the IATS vendors have already presented for more than a decade the capability of the remote operation of their instruments focused on the image and scan capture but not oriented to the geodetic measurements [16]. So, the Survey Remote method is not competitive to the specific kind of software and procedures. The third one is that the Survey Remote method is not competitive to the Robotic monitoring methods. The one is developed in order to help the surveyor to remotely operate and continuously interact with the IATS. The others are based on the automated target detection and are used in facilitating the surveyor’s field works or in performing scheduled works automatically. So, the Wireless Remote Survey method is not opposing to the Robotic monitoring method nor can replace it. The final one is that the Wireless Remote Survey method is not proper for all surveying field works, especially for those which by statutory law requires the physical presence and responsible-in-charge supervision of an on the ground land survey, and the surveyor’s professional certification [9].

SUPPLEMENTARY MATERIALS

Not applicable.

AUTHOR CONTRIBUTIONS

All authors have read and agreed to the published version of the manuscript.

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This research received no external funding.

DATA AVAILABILITY STATEMENT

Not applicable.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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CONCLUSION

The main conclusion of this paper is that the remote control of an IATS is feasible, does not alter the nominal accuracy of stations in measuring horizontal directions and vertical angles and can be used to common geodetic works, such as monitoring geodetic networks, landslide and natural hazard and performing astronomical observations.

The implementation of the presented method in the context of this paper by the scientific community and the engineers in the geodetic works will finally determine the range of applications where it can be implemented. Also, it will be possible to extract the ″Lessons Identified - Lessons Learned″ in order to identify the weaknesses of the method and consequently to adapt the necessary improvements.

In addition to the above, the IATS vendors could improve the existing software in order to allow the IATS to be directly and automatically connected only to selectable Wi-Fi providers, because as mentioned above, there were problems to connect them to preferred networks.

Finally, it is estimated that the implementation of the Wireless Remote Survey method will achieve an economy of scale in the exploitation of human and financial resources, which is a demand today in all areas of human activity. Also, will undoubtedly support both of the scientific and surveying communities in their daily workload because it significantly reduces the surveyor's presence in the field.

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