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TLS MEASUREMENT AUTOMATION – CASE STUDY SITEPLANNER

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Abstract

Surveys using LiDAR technology have become very popular over the past several years due to their high accuracy, speed of acquisition and completeness of space capture. Due to the progressive ease of use, these measurements are increasingly being carried out by less skilled field workers. On the other hand, however, more and more knowledge and 'know-how' is emerging in the processing stages of the data collected in the field. If both parts of this process are properly organised and supported by technology, satisfactory results can be obtained at the level of efficiency gains in both field work and automatic LiDAR data processing. This analysis presents the results of the work on the SITEPLANNER application developed by 3Deling.

Keywords: Terrestrial Laser Scanning, LiDAR, measurement automation, TLS registration, point cloud

AUTOMATYZACJA POMIARÓW TLS – STUDIUM PRZYPADKU SITEPLANNER

Abstrakt

Pomiary przy pomocy technologii LiDAR w ostatnich kilkunastu latach stały się bardzo popularne ze względu na wysoką dokładność, szybkość pozyskiwania oraz kompletność przechwytywania przestrzeni. Ze względu na postępującą łatwość obsługi, coraz częściej pomiary te są wykonywane przez mniej wykwalifikowanych pracowników terenowych. Z drugiej strony coraz większa wiedza i „know-how" pojawia się na etapach przetwarzania danych zebranych w terenie. Jeżeli obydwie części tego procesu będą odpowiednio zorganizowane oraz wspomagane przez technologię, można uzyskać satysfakcjonujące efekty na poziomie wzrostu efektywności zarówno prac terenowych, jak i automatycznego przetwarzania danych LiDAR. W niniejszej analizie przedstawiono efekty prac nad aplikacją SITEPLANNER opracowaną przez firmę 3Deling.

Słowa kluczowe: naziemne skanowanie laserowe, LiDAR, automatyzacja pomiarów, wyrównanie danych TLS, chmura punktów

1. INTRODUCTION

Laser scanning is one of the measurement technologies that has seen the most progress in recent years. This applies to both the airborne and ground-based parts. In the aerial part (ALS – Airborne Laser Scanning), solutions from the ceiling of aircraft and helicopters have descended to the level of drones. This has increased the availability of the resulting point clouds for clients/designers. The availability and popularity of point clouds is also due to their high level of applicability, examples of which can be found in publications: [1] geology, monitoring of mine objects: underground [2] or above ground [3], development of models from integrated data [4], transport [5] or in bathymetry of shallow reservoirs [6] or coastal zones [7]. The development of ground-based solutions followed two tracks. In the static scanner segment (TLS – Terrestrial Laser Scanning), there was an acceleration in the speed of point cloud acquisition and maximisation of coverage. Also technologically, the aim was to optimise the measurement sensors by exploiting the advantages of the first time-of-flight and phase scanners. As a result, today we achieve both high data acquisition speeds (up to 2 million in the case of Faro scanners), with long ranges (e.g. Riegl VZ-6000) and low noise. The second part of field solutions – mobile laser scanning (MLS), like aerial scanning – has changed scale. From exclusively large-scale solutions, i.e. on cars, to mobile kits that fit in a backpack or in the hand. This has resulted in a definite acceleration in the rate of LiDAR point cloud acquisition and greater accessibility. An even greater 'revolution' in accessibility has been brought about by low-cost survey sensors. In addition to the positive effects, these changes also bring with them some 'inconveniences' in the form of poorer registration accuracy, lower point cloud density, or poorer quality of additional attributes (RGB, Intensity) or their complete absence.

What is obvious to laser scanning professionals unfortunately escapes the customers/orders of LiDAR data or products in very many cases. Usually then quality loses out to price.

Usually, the best quality clouds are obtained from TLS measurements in their classic version, in which the operator of the device has the possibility to set the individual operating parameters. In this situation, the intensity is extracted and saved to a result file, the density can be set according to the parameters of the instrument (sometimes several predefined resolutions and sometimes full adjustment), and in addition RGB images can be taken. In terms of registration accuracy, one of two approaches can be chosen: target-based or cloud to cloud registration, presented in [8]. Each strategy has its advantages and disadvantages, and the decision to choose one must be made before the scanning starts. This is because each approach enforces a different location of the scanner stations. The cloud-to-cloud strategy usually performs final registration or fine registration using the ICP (Iterative Closest Point) algorithm [9], but for this to work properly, the scans must first be 'brought closer' to each other by performing pre-/coarse registration. For this, at software level, the operator is asked to indicate the same points on two adjacent scans. Based on the indicated coordinates, an on-the-fly transformation is performed, allowing an immediate evaluation of the effect achieved. If this is not satisfactory, a second pair is indicated, and so on. All the time, however, this requires manual intervention by the operator for each of the scans.

One of the key advantages of a cloud-to-cloud solution is that there is no need to set up/assemble targets (chessboards or spheres). This saves a great deal of time, which can be spent on subsequent or redundant scans. By scanning elongated objects, it is possible to quickly move 'forward' using spheres, which in some terrain cases is not possible in a cloud-to-cloud solution. In contrast, by abandoning target-based registration, scans must be taken with appropriate overlaps between adjacent scans, making 'moving forward' usually slower. For an experienced team, with a scan time of about 3–5 min per survey station, the time required for targets deployment is usually less than the scan time, resulting in one pair (scan and targets deployment taking a total of about 5–9 min). For a novice survey team, the time required to deploy targets is 1.5 to 2.5 times the scan time, which translates into a total time of around 12–18 minutes per pair.

To reduce the time needed for scanning in the field, in addition to lowering the scanning parameters (e.g. lower density, lower quality – if adjustable, no images for RGB), one can opt for scanning without targets or automating the production process. This means giving up the placement of signalised targets that can easily be retrieved by the registration software.

In most cases, this automation is intended to 'facilitate' the registration of individual scanning stations. Hardware and software manufacturers offer various solutions in this respect. In most cases, additional information is used to determine the initial location of a scanning station or its position relative to the previous one (coarse registration). For example:

- Riegl VZ scanners in the 'i' versions use information from the IMU (Inertial Measurement Unit) to approximate the offset between successive scans, and it is also possible to retrieve the scanner position from a single- or dual-frequency GNSS receiver, if one is fitted to the scanner,

– Faro Focus may have had an additional accessory, the Scan Localizer, which, by scanning in continuous mode, created a live view of the rooms,
– The Leica RTC uses cameras mounted on the corners of the scanner to track the movement of the scanner (VIS).

All of the above solutions are aimed at facilitating proper registration, in other words, actually reducing fine registration time. An additional possibility to speed up the postptocessing time is to perform some of the tasks while measuring in the field. Following this approach, the Riegl VZ series scanners are equipped with a separate processor for coarse registration during fieldwork. This requires such an additional function to be enabled, the scans to be performed with the appropriate overlaps so that the clouds in the cloud-to-cloud approach have something to fall back on, and the scans must be performed 'sequentially', i.e. the next one must have a 'part in common' with the previous one. If there is no spatial continuity in the measurement, coarse registration directly in the scanner will be stopped and can be completed in the desktop software (RiScanPro) after manually moving the scan to the appropriate location. Similar solutions can be seen in the Faro – Focus and Scene, Leica – RTC and Cyclone FIELD 360 and Z+F – IMAGER + LaserControl Scout pairs.

The above pairs are compatible with each other and definitely improve work comfort and efficiency. If, on the other hand, an operator uses scanners from other manufacturers for measurements, or uses different scanners within the same project, he or she will unfortunately not be able to take full advantage of the benefits of the above solutions.

For the above reasons, as well as the desire for greater integration of field work with the computational process, the Siteplanner software developed by 3Deling was created.

2. SITEPLANNER SOLUTION

Work on this solution was initiated in 2018 as part of the project "Development of software to optimise the process of creating project documentation based on data obtained as a result of terrestrial laser scanning, with particular emphasis on simplifying access and interpretation possibilities of point clouds", as part of Activity 1.1: R&D projects of enterprises of the Operational Programme Intelligent Development 2014–2020, co-financed by the European Regional Development Fund – grant number POIR.01.01.01-00-1283/17-00 founded by The National Centre for Research and Development. The finished solution has been in place as an internal project support application at 3Deling since 2020, so it is not a concept or theoretical consideration, but an actual tool for everyday work and increasing the efficiency of the projects carried out.

Several stages can be distinguished in each TLS project, as shown in Figure 1, below.

The main functionality of SITEPLANNER is located in the field work, i.e. stage A (Fig. 1), although its impact also translates significantly into stage B.

In classical surveying, the location of individual survey points was plotted on a field sketch to facilitate orientation and the assignment of individual coordinates to the relevant vector objects. Within the scope of TLS, a field sketch is maintained to locate reference points for georeferencing the entire project, for locating control points and scanner positions. For small projects of the order of 10 or 20 scans, and where the field survey and registration are carried out by the same person, the creation of the field sketch can be omitted. If, on the other hand, the shape of the scanned object, the degree of density of the infrastructure on it, is large then a sketch is indispensable. The same applies if one person or team is responsible for the field work and someone else for registration. Then the person submitting the project

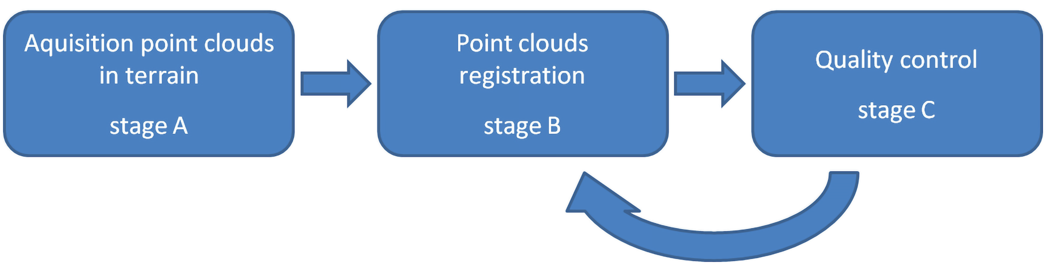

Fig. 1. General TLS project registration workflow
Ryc. 1. Ogólny schemat wykonania złożenia projektu TLS

relies solely on the field sketch to properly position and connect the individual scanner stations. Nowadays, it is not necessary to keep a field sketch in paper form.

With this in mind, and in order to provide information to the operator performing the registration, the SITEPLANNER mobile application was developed to support data acquisition in the field. Its main purpose is not that much to indicate the location of individual scans, as in the case of a field sketch, but to indicate connections between scans. Determining the visibility or its lack thereof between successive point clouds allows the entire project to be schematised as a network.

The base for manual insertion of the scanner position can be any raster file – an orthophotomap if the scans are taken outside, a base in the form of a scan of an archived floor plan or a photo of the evacuation scheme taken by phone – if the measurements are taken inside the building. As with any sketch, when adding successive scans, the distance between them is not important, only the proportions in the distances, to make it easier to orientate oneself in the prepared scheme.

The above settings then make it easier to work at registration level. The moment the LiDAR data is acquired by the scanner is the ideal time to complete the field data with the information provided by the operator, who is waiting for the scan anyway. This provides a complete and complementary set of survey data immediately in the field.

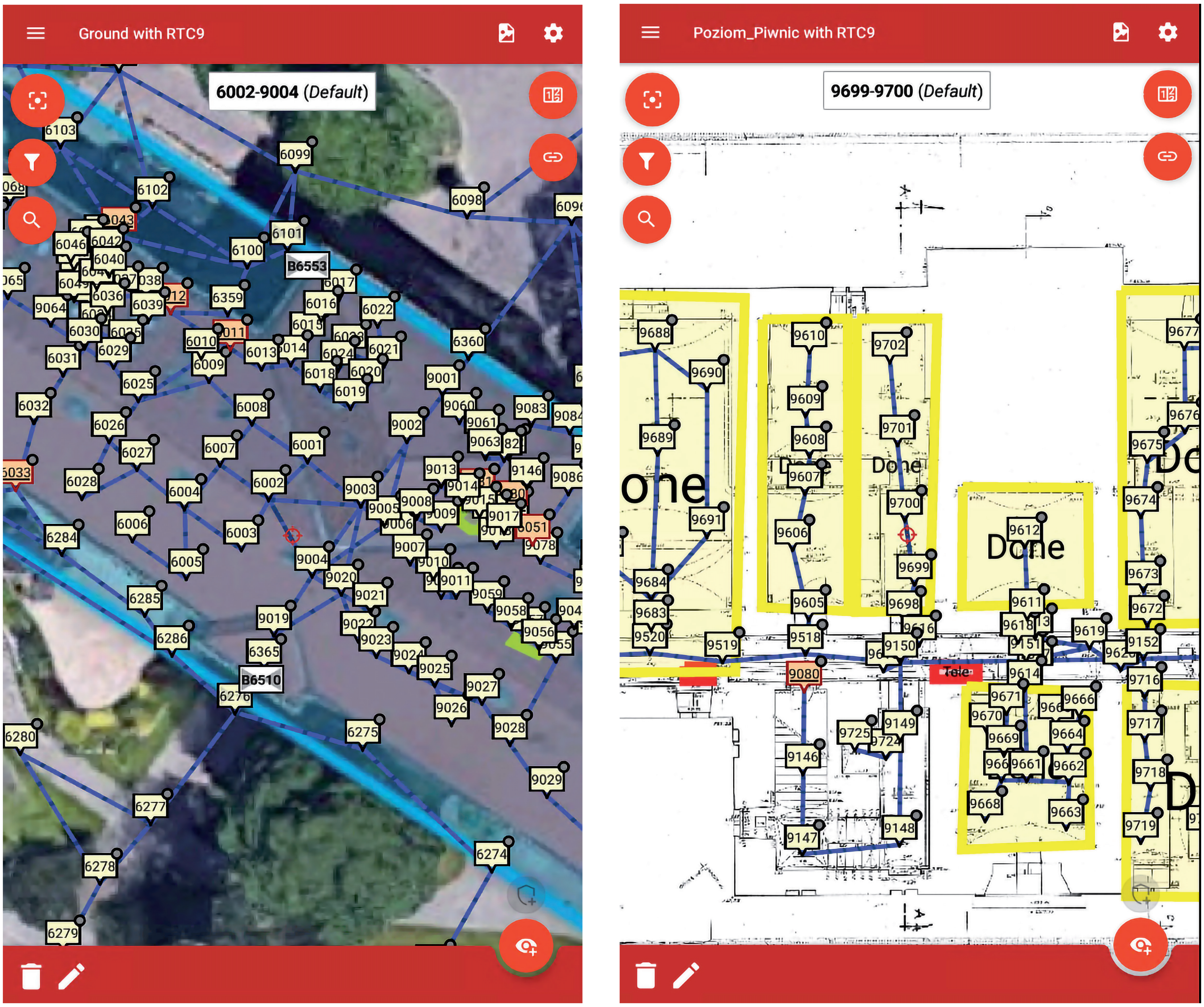

Fig. 2. Main working window of the SITEPLANNER application (left) and zoom – right
Ryc. 2. Główne okno robocze aplikacji SITEPLANNER po lewej i zbliżenie – po prawej

It is worth noting that SITEPLANNER, in addition to 'managing' the operator during the acquisition of the LiDAR point cloud by the scanner, also offers two possibilities for accelerating the execution of the TLS project. The first is the possibility of uploading data collected in the field to the server. This way, when arriving from the field to the office, we already have the point cloud imported, and in case these tasks are person-to-person, one can scan in the field while the other is already assembling the project at the same time. The second advantage is support for multiple users simultaneously. This means that more than one scanner can operate on a single site, and if their operators are logged into the same project in SITEPLANNER, newly added scanner positions will be visible to all users.

The continuous digital documentation of the measurements taken, in addition to data security issues, streamlines and facilitates the exchange of scanner operators in the field. There is no tedious stage of 'handing over' a project with the translation of what has been done and what remains to be done. This increases both the comfort of managing human resources of the project, as well as the smoothness of execution and reliability of the project.

3. METHODS

Due to the specificity of the issue presented, it is difficult to choose unambiguous, objective criteria that would allow a proper evaluation of the compared software. Therefore, parameters were selected which, in the opinion of the authors, were crucial for the functionality of this type of application. The registration execution time with and without the use of SITEPLANNER was used as one of the relevant parameters. The option without the use of SITELPANNER was performed in Trimble RealWorks (TRW).

Despite being aware that project reliability, for example, which manifests itself in the certainty that documents (sketches of the layout of the individual stations, etc.) will not be lost, is equally important, it is difficult to give an effective measure of this. It is difficult to assess the solutions included in software, as in most cases manufacturers do not disclose details of their solutions, let alone code fragments. They rely on a 'black box' approach, where you throw in an input and get a result. In some software, you can 'work' the registration effect by reducing the overall error (TRW or RiScanPro), and in some you cannot – ReCap.

In terms of accuracy, it was decided to use the classic RMS known from the literature. In terms of efficiency, on the other hand, it was calculated as the ratio of the total time spent processing the project (import, processing, coarse registration, fine registration, QC and export) to the number of scanner stations processed.

4. RESULTS

Table 1 summarises selected functionalities of TLS software to support the data acquisition and registration stage. It was compiled on the basis of [10] and lacks were filled in with information from the manufacturer's websites. It is not easy to evaluate only the mobile applications supporting acquisition. They are generally very simple and therefore 'lightweight' and, on the other hand, provide key information used during the subsequent stages – registration and QC (Quality Control). At the same time, on their own, they can do little, being sometimes just a scanner interface on a smartphone/tablet or a 'connection' between the scanner and the target registration application.

The availability of information about the software and/or the cooperation of the manufacturer with the customer is also important. In most cases, the manufacturer, as a party with a vested interest in promoting and selling its solution, makes test versions, videos, functionality descriptions or case studies available in a free and open way. However, there are also companies that, despite their interest, do not make data available beyond a dry table of basic data.

A more measurable result is the comparison of projects submitted in the SITEPLANNER + PROCESSOR (S+P) pair and in TRW. This is a labour-intensive task because it requires the same project to be implemented in two software. The results are shown in Table 2.

What is noteworthy are the differences in the details of the execution of each project. The SITEPLANNER + PROCESSOR solution was designed for buildings, with a lot of infrastructure (pipes, HVAC systems, tanks), whereas Project 2 involved an urban, open area. So it is both a different density and data characteristics. In addition, Project 2 was done in PROCESSOR, but without the sketch run in SITEPLANNER, so the operator was

Table 1. Selected functionalities of the software for stages A and B, i.e. field acquisition and registration
Tabela 1. Wybrane funkcjonalności oprogramowań do obsługi etapów A i B, tj. pomiar w terenie i złożenie

	TRW	**Leica Field 360 + Cyclone 3DR**	**RiSCAN PRO**	**Z+F Laser Control Scout**	**SITEPLANNER + PROCESSOR**
Input formats	LAS, LAZ, DP, E57, PTS, PTX, RSP, ZFS, TXT, XYZ, DXF, DWG, FLS, TZF	3PI, AC, ASC, CSV, DP, E57, FLS, FWS, LAS, LAZ, NSD, PSL, PTS, PTX, RAW, RDBX, SDB, TXT, XYZ, YXZ, ZFS	3PF, CSV, DP, LAS (1.1-1.4), LAZ 1.2, E57, POD, DXF, DM, OBJ, PTS, PTX, RDBX, RQX, RXP, SDW	ZFS, ZFPRJ, ZFI, ZFC, SAT, PTX, ASC, TXT, PT, PTS, XYZ.ASC, PDF, PTG, E57, MPC, DP, ZFS,	LAS, POD, XYZ, PTS, PTX, ASC, XYZ, 3DL, E57
Export formats	LAS (1.2), LAS (1.4), LAZ, PTS, TXT, XYZ, DXF, DWG, DGN, POD, KMZ, OBJ, FBX, XML, ASC, E57, BSF, PDMSMAC, TDX	ASC, CSV, DXF, E57, GLB, IGES, IGS, IV, LAS, LAZ, LGS, MLI, MSD, MSH, NSD, OBJ, PLY, POLY, PTS, PTX, STEP, STL, STP, TXT, VRML, WRL, XML, XYZ, YXZ	CSV, LAS (1.1–1.4), LAZ 1.2, E57, POD, DXF, DM, OBJ, PTS, RQX, TIF, JPG, BMP	ZFS, ZFPRJ, ZFI, ZFC, SAT, PTX, ASC, TXT, PT, PTS, XYZ.ASC, PDF, PTG, E57, IV, VRML, WRL, JPG, PNG, BMP, JPW, GIF, TIFF, L, IDX, DXF, RCS, RCP, LAS, OSF, MPC	E57, PTX, XYZ, PTS, 3DL
Action required for coarse registration	indication of corresponding points	Data from (VIS) – Visual Inertial System	Data form IMU – MSA2	No information	Not required
Input data type	Any from the input list	Own	Any from the input list	Own	Any from the input list
is it possible to “work” on registration	Yes	Yes	Yes	No information	Yes
Registration c2c	Yes	Yes	Yes	Yes	Yes
Registration by targets	Yes	No/ depends on version	Yes	Yes	Yes
Support fot Polish CS	Yes	No	Yes	Yes	Yes
Is there a fine registration automatic	Yes	No information	Yes	No information	Yes
Geodetic report	Yes	Yes	Yes	No information	Yes
georeferencing	Yes	Yes	Yes	Yes	Yes

CS – Coordinates System, c2c – cloud to cloud

just ‘learning’ the area being developed. Project 1, on the other hand, had full information from SITEPLANNER about the shape of the network and, in principle, the operator did not need to go into it. This difference can be seen perfectly in the efficiency, i.e. the average time spent processing the scan. Without SITEPLANNER (Project 2), it takes 18 min per scan in the 3Deling solution, whereas with SITEPLANNER only 5.5 min. The folding efficiency in TRW is at a similar level of around 12–13 min with a slight indication of a building object. In terms of accuracy, it is both in Project 1 and Project 2 that S+P is twice as good.

Table 2. Comparison of selected parameters of projects register in TRW and SITEPLANNER + PROCESSOR
Tabela 2. Porównanie wybranych parametrów projektów złożonych w TRW i SITEPLANNER + PROCESSOR

	Project 1	Project 2
Number of scans	136	106
Object type	Public Building	Urban, open space
Total number of points	8 637 534 000	2 224 154 513
Avg. number of points per station	Over 63 mln	Almost 21 mln
Registration time – TRW [min] (registration + export)	1637 (900+737)	1370 (1024+346)
RMS – TRW	9.35 mm	17.02 mm
Efficiency min/scan – TRW	12 min	12 min 54 sec
Registration time – S+P [min] (registration + export)	750 (670+80)	1911 (1814+97)
RMS – S+P	3.81 mm	8.63 mm
Efficiency min/scan – S+P	5 min 30 sec	18 min

5. DISCUSSION

The results obtained for Project 1 (building) in both the Trimble RealWorks software and the 3Deling solution (SITEPLANNER + PROCESSOR) are in line with the values presented in publications from the various TLS application areas: Historical Building Information Modeling [11], Architecture, Engineering and Construction [12], TLS registration [13] or [14], wind power stations monitoring [15], updating the base map [16], or the certainty of TLS LiDAR data in the Scan-to-BIM methodology [17]. In the case of an urban, open space facility (Project 2), the values are lower, but also in line with the characteristics of the facility and examples from the literature of: trees TLS measurements [18], [19] or [20]and imaged based registration for urban scenes [21]. In terms of both total times and times per scan, the advantage of the presented solution can be seen on the object for which the application was created – the building. As a rule, the literature does not provide times for acquiring or processing point clouds, so it is difficult to relate the obtained results to the literature. The results obtained, in terms of time taken, strongly indicate the effectiveness of a comprehensive application of the SITEPLANNER + PROCESSOR solution.

6. CONCLUSIONS OR SUMMARY

The results achieved fully confirm the validity of the design assumptions and the effectiveness of the proposed solutions. While in the functional part, it is difficult to find support in "numbers", in the engineering aspects (accuracy, efficiency) the achievement of better effects than in the previous solutions was demonstrated. It is also worth pointing out the synergy effect, when the greatest effect appears when all elements of the designed process work properly. It is extremely important that to perform coarse registration in the 3Deling solution no additional data (IMU, VIS or GNSS) are required apart from the network sketch from SITEPLANNER. It is also worth emphasizing that the most time-consuming stage – automatic registration (coarse and fine), which takes 50–70% of preprocessing time, is performed without the presence of an operator.

In the scope of future research, it is planned to increase the number of projects carried out using SITEPLANNER + PROCESSOR, in order to increase the comparative sample, as well as diversify the projects due to the characteristics of the scanned object. Reference to other programs for submitting TLS data than Trimble RealWorks is also planned.

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