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ASPECTS RELATING TO THE POSITIONING BY THE SEMI-KINEMATIC METHOD (STOP AND GO) OF DETAIL CHARACTERISTIC POINTS, NECESSARY FOR THE DESIGN OF COMMUNICATION WAYS

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Abstract

The case study was carried out with the help of satellite technologies for the spatial positioning of the various characteristic points of detail in the town of Suiug, Bihor county, and has as its objective the spatial positioning of the points of detail with the GPS system, through the post-processing kinematic method (pseudokinematics) Stop and Go, for the realization of the topographic plans in digital format, and respectively, of the digital models of the land, necessary for the rehabilitation and expansion of the roads in the locality. Trimble R3 receivers were used as base, and Trimble R4 as rover. When recording data from the field, we worked with the Trimble Digital Fieldbook and Trimble Access programs, and the processing with the Trimble Total Control (TTC) program. The coordinates of the base and initialization points of the rover were determined with the Trimble R4 receiver, with information acquired from the Oradea GNSS station, within the ROMPOS system. Mapsys 10.0 and Surfer programs were used to obtain the plan and land model in digital format.

Key words: *characteristic points of detail, Stop and go method, digital terrain model.*

INTRODUCTION

Modern Global Navigation Satellite System (GNSS) technologies provide highly accurate spatial positioning for topographic features, with the selection of a specific method being influenced by both logistical considerations and terrain conditions (Crainic, 2024). GNSS-based satellite positioning systems enable the automation and efficiency of data acquisition across diverse geographic areas, ensuring precise planimetric coordinates vital for applications such as cartography, navigation, transport infrastructure, and emergency response services (Mohanty & Gao, 2024; Kunisada & Premachandra, 2022).

In standard Stop & Go workflows, a static receiver is installed at a known geodetic control point, while a mobile receiver initiates the positioning process, which is influenced by both the equipment's technical capabilities and the field environment. The initialization consists of resolving the ambiguities linked to the carrier phase measurements, which involves determining the integer number of wavelengths of the received signal (Adam et al., 2006).

Technological advances have made it possible to perform this process "on-the-fly" (OTF), allowing real-time initialization while moving, thereby eliminating downtime. Once initialized, the mobile receiver (rover) sequentially occupies each target point, maintaining uninterrupted contact with satellites throughout movement. As a result, the rover must follow clear-signal paths within the work area to avoid satellite signal loss, which would otherwise require reinitialization (Adam et al., 2004; Hofmann-Wellenhof et al., 1997).

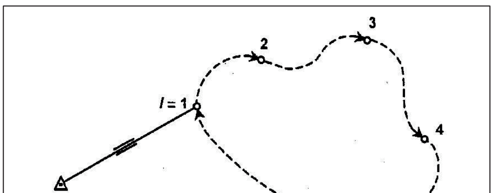

Figure 1. Stop & Go measurement scheme (from Adam et al., 2004)

For short distances between points along the predefined route, the operator typically moves on foot, carrying the mobile receiver mounted on a fixed-length support known as a bipod. This setup allows for quick stationing with high accuracy and operational efficiency. When the target points are situated farther apart or at significant distances from the base station, the rover can be transported by vehicle, if satellite signal continuity is maintained and the connection to at least five satellites is ensured. This condition also applies to pedestrian movement over open terrain. Although not mandatory for on-the-fly (OTF) initialization, maintaining such signal stability can significantly reduce the required data acquisition time and help avoid signal disturbances (Hofmann-Wellenhof et al., 1997).

At the base station - positioned at a known reference coordinate - the fixed receiver and antenna are mounted on a tripod via a dedicated base featuring an optical centering mechanism. The mobile receiver and its antenna are secured on the bipod, approximately 2 meters in height, equipped with a spherical leveling device to ensure precise vertical and horizontal alignment. Because the antenna height remains constant throughout the process, it only needs to be entered once in the measurement project.

Initial setup involves placing the fixed receiver on the tripod and the bipod-mounted rover at the initial known point, followed by configuring the working parameters in the control unit (U.C.), which interfaces directly with both the receiver and the antenna. If satellite signal is lost, the operator must either return to a previously recorded point (if the system allows reinitialization from that location) or repeat the initialization process entirely (Adam et al., 2004).

As the rover moves from point to point, data collection is optimized by briefly pausing (typically 1-2 minutes) at each new station to ensure accurate data recording, depending on the length of the data collection epochs (Păunescu et al., 2006; Neuner, 2000). Consequently, only those positions where the mobile receiver was properly stationed and data were actively recorded are retained in the final dataset (Adam et al., 2004).

For enhanced efficiency in Post-Processed Kinematic (PPK) surveying, a single fixed receiver may be used to simultaneously support multiple mobile rovers, provided that the appropriate logistics are available.

In single-base PPK configurations, each newly determined point relies on a single position vector. When using two fixed receivers as reference bases, positioning is achieved using two independent vectors for increased redundancy and accuracy (Adam et al., 2004).

Optimal conditions for implementing PPK satellite positioning depend on several factors, including:

- the availability of geodetic or GNSS network points within the survey area, with at least two single-frequency GNSS receivers (Zuliani, 2022);
- or one dual-frequency and one single-frequency receiver, along with access to data from a permanent GNSS station.

Under these conditions, several working approaches can be adopted:

- positioning known reference points along the survey route;
- returning to the initialization point to close a measurement loop;
- finalizing at another known point;
- or static positioning at the last station with subsequent post-processing.

Alternatively, when starting from the final surveyed point, software equipped with advanced algorithms can compute the positions of intermediate points where satellite signals were captured (Basso et al., 2021). This flexibility ensures that brief signal interruptions do not invalidate all previous recordings, if the processing model accounts for such gaps.

The method is particularly effective for detailed positioning tasks within a 5-6 km radius from the base station. On smaller areas, it offers a cost-efficient alternative. Recent studies highlight that for short GNSS baselines, PPK performance surpasses that of RTK, although over longer distances, a slight reduction in accuracy is noted. To meet accuracy standards, recording durations should exceed one hour, and the baseline distance must fall within the manufacturer's recommended range (Jemai et al., 2023).

PPK offers several advantages:

- data recording is faster since a continuous base-rover link is not needed, allowing for extended operational distances;
- fewer base stations are required compared to total station surveys;
- it provides high positional accuracy;
- and it can operate with minimal equipment - sometimes even a single dual-frequency receiver - if access to permanent

GNSS stations is available within 30-50 km (Zavate, 2008; Adam et al., 2004).

Despite the requirement of maintaining visibility to at least five satellites between consecutive points (Adam et al., 2004), the horizontal accuracy typically ranges from 1-3 cm, and vertical accuracy between 1-10 cm (Pirti, 2021). The method has proven efficient and reliable in cadastral surveys within both urban and rural contexts (Tang et al., 2017; Sicoe et al., 2023), as well as in environmental assessments and real-time or post-processed GNSS applications (Bodog et al., 2024; Jaskowski et al., 2022).

Moreover, research demonstrates that PPK solutions anchored by high-precision ground control points yield more accurate results than those derived from low-precision observations, particularly in drone-based photogrammetric workflows. Thus, the number, spatial arrangement of control points, and baseline length to the GNSS station are critical factors for achieving optimal results (Tamimi & Toth, 2023).

In the civil engineering sector (Costinaș et al., 2024), the success of infrastructure projects relies heavily on accurate site plans derived from GNSS data, alongside effective logistical planning (Costinaș et al., 2024; Sabău, 2010; Coşarcă, 2003). For the planning and construction of roads in rural or urban settings and for improving forest accessibility, detailed coordinate inventories and cartographic materials - both analog and digital - are indispensable (Călina & Călina, 2022; Călina et al., 2020; Coşarcă, 2003). The geometric layout of transportation routes must follow the terrain configuration and the precise spatial coordinates of topographic elements to accurately reflect the real-world situation (Belc, 1999).

Thus, field surveys must capture the transverse and longitudinal profile elements in the national reference system to support the development of execution projects.

MATERIALS AND METHODS

The case study was carried out in the village of Șuiug, part of Abram Commune, Bihor County, Romania (Figure 2). The main goal of the research was to evaluate the applicability and efficiency of GNSS technology - specifically the Stop & Go method using Post-Processed Kinematic (PPK) positioning - for determining the spatial coordinates of topographic detail necessary in the planning and rehabilitation of rural transport infrastructure.

The Stop & Go technique is particularly suitable when rapid, yet highly accurate point positioning is required, with minimal time spent at each location. This method relies on post-processing of satellite data, hence the term Post-Processed Kinematic (PPK) (Chiţea et al., 2009; Neuner, 2000).

Accurate positioning is ensured by employing at least two GNSS receivers: one serves as the fixed base station, while the other(s), referred to as rovers, operate as mobile units to measure the detail points.

Methodological Approach

The study employed a combination of the following research methods:

- *Bibliographic review:* analysis of specialized literature, standards, and previously completed contracts involving similar GNSS-based topographic work.
- *Field observation*: including route inspection and on-site evaluation of positioning conditions.
- *Experimental work:* application of GNSS positioning methods under real terrain conditions.
- *Comparison and analysis:* assessment of technical performance and outcome reliability.

Figure 2 presents the geographical location of the study area.

GNSS equipment and data collection

The experiment involved the spatial positioning of detailed topographic points using GNSS technology and the Post-Processed Kinematic (PPK) method, conducted along three separate routes, tailored to field conditions. To carry out the measurements, two Trimble R3 GNSS receivers paired with A3 antennas and one Trimble R4 dual-frequency receiver were employed. One Trimble R3 unit, equipped with an A3 antenna, was mounted on a tripod to serve as a base station, while the second R3 receiver, installed on a 2.04-meter bipod, was used as a rover for positioning characteristic detail points along the routes.

Figure 2. Location of the case study: Șuiug village, Abram commune, Bihor County (https://ro.wikipedia.org/wiki/Suiug,_Bihor)

In addition, satellite recordings from the permanent GNSS station in Oradea were accessed via the ROMPOS service to enhance positioning accuracy through the RTK method. The Trimble R4 receiver, also mounted on a 2.00-meter bipod, was used as a rover for data acquisition on Routes 1 and 2.

Field data were collected using Trimble Digital Fieldbook (for the R3 receiver) and Trimble Access (for the R4 receiver), both licensed programs provided with the equipment. A critical step during the fieldwork involved defining specific layers for recording each positioned point and assigning corresponding attribute codes. These codes were applied during stationing with the rover and are essential for the organized import of final coordinates into mapping software. This structured approach ensures efficient graphical representation and accurate generation of digital plans.

Data processing and graphical reporting

The graphic representation of the final coordinates of the characteristic detail points, referenced to the national coordinate systems STEREO-1970 and MN-1975, as well as the generation of the detailed digital plan, was performed using the Mapsys 10.0 software (Marton, 2007). The experiment followed a structured sequence of steps, including field data collection, data transfer, validation and processing, computation of ellipsoidal coordinates, transformation into the national reference system, and the preparation of the final coordinate inventory. These stages, along with the graphical reporting process and detailed plan generation, are summarized in the schematic diagram shown in Figure 3.

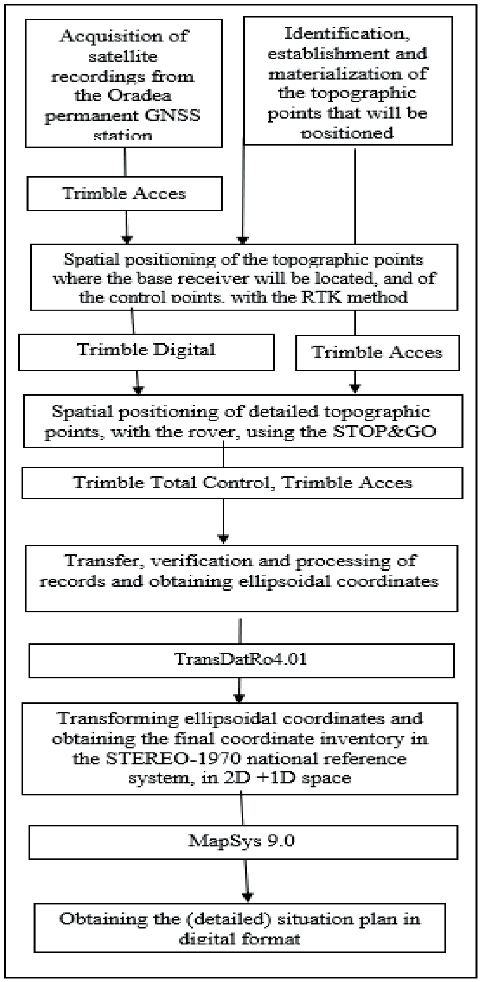

Figure 3. Summary presentation of the stages of carrying out the case study

The case study was further evaluated by comparing the technical implementation and results with similar projects conducted under both comparable and varying field conditions. Based on this comparative analysis, several insightful conclusions were drawn.

RESULTS AND DISCUSSIONS

The processing of satellite recordings was performed using specialized computational models (Borko & Even-Tzur, 2021; Amiri-Simkooei et al., 2016). The data were processed differently depending on the type of receiver used. Specifically, the Trimble Access software was employed to process data recorded with the Trimble R4 receiver, as well as data obtained from the permanent GNSS station in Oradea using the RTK method, in order to determine the coordinates of the base and control points along the three routes. Additionally, Trimble Access was used to process recordings collected via the PPK method with the same receiver type.
Data recorded with Trimble R3 receivers were processed using Trimble Total Control (TTC) software. The ellipsoidal coordinates obtained from both programs were then converted into the national reference system using the TransDatRo4.01 software (Păunescu et al., 2010).
After completing these work stages, the final coordinates were inventoried by activating the corresponding layers within the mapping software.
The analysis of the plan with the reported details can be done in digital format, or after printing in analog format. In digital format, the details that need to be materialized on the plan will be activating all the layers that contain attributes, depending on the corresponding codes.
The graphical reporting of the measured detail points was conducted using orthophoto imagery for visual verification and planimetry purposes. The spatial distribution and positioning accuracy of the detailed points collected using the PPK method are illustrated in Figures 4, 5, and 6, which correspond to the three surveyed routes. These visual outputs demonstrate the precision and completeness of the data acquisition process across different sectors of the study area, facilitating the generation of the final site plan.

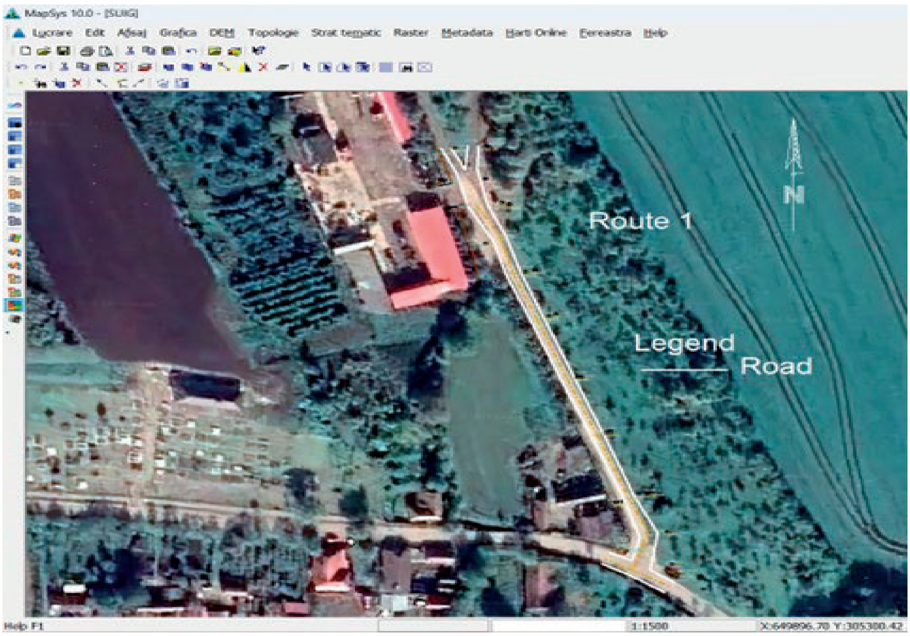

Figure 4. Reporting on the orthophoto plane of the routes on which the positioning of the detailed points carried out, using the PPK method (Route 1)

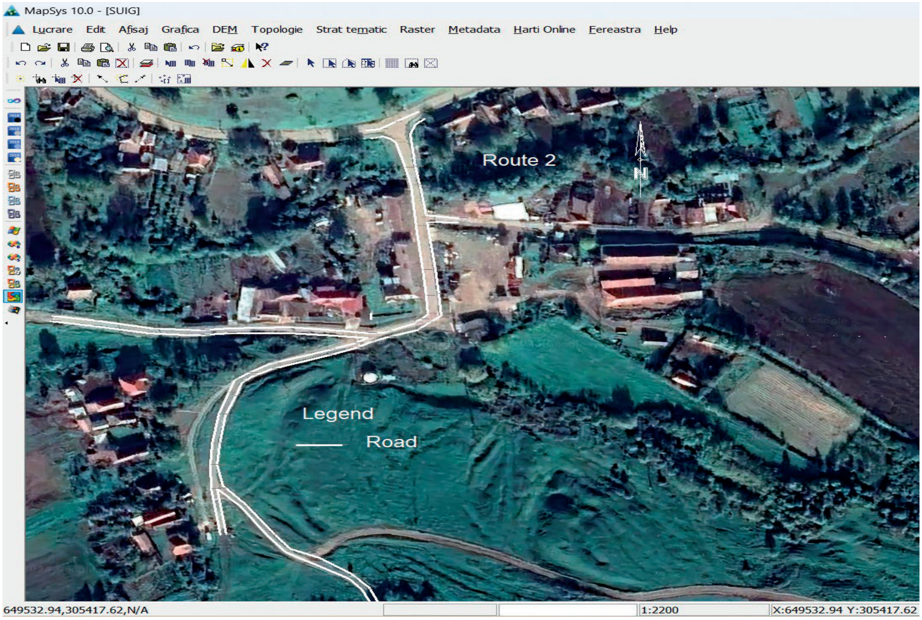

Figure 5. Reporting on the orthophoto plane of the routes on which the positioning of the detailed points were carried out, using the PPK method (Route 2)

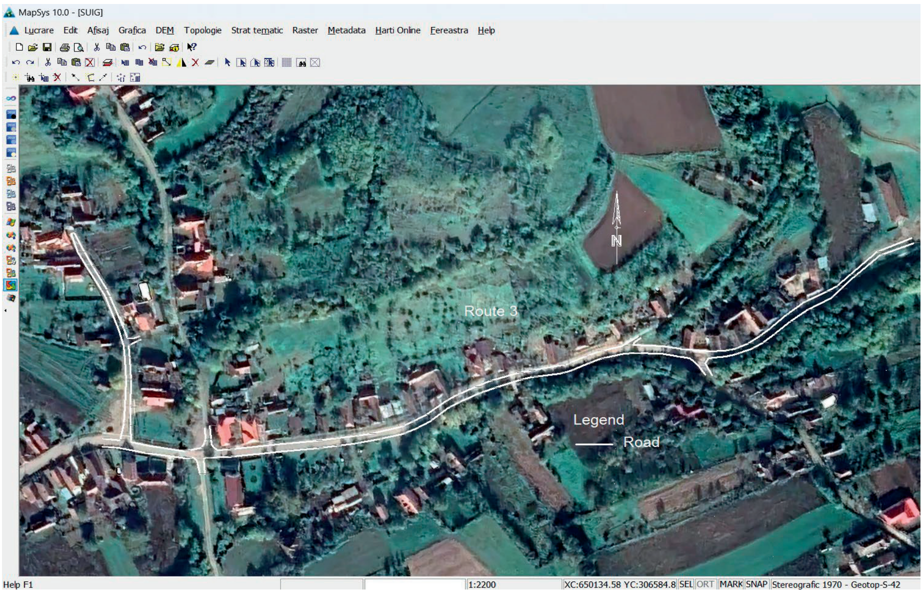

Figure 6. Reporting on the orthophoto plane of the routes on which the positioning of the detailed points were carried out, using the PPK method (Route 3)

The reporting of the final coordinates of the characteristic points was carried out with the found that a number of 1048 detail characteristic points, 292 lines, 680 symbols and 724 text attributes were graphically reported for the creation of the situation plan.

A representative extract from this inventory of coordinates is presented in Table 1. As a result, 1048 detail points were positioned on the three routes traveled.

Table 1. Extract from the inventory of coordinates of detailed topographic points, in the national reference system

No. point	X (m)	Y (m)	Z (m)	Cod
500	649930.48	305156.50	157.26	3
501	649930.28	305160.00	157.15	3
502	649930.01	305163.32	157.29	8
503	649929.43	305152.63	156.11	8
504	649929.54	305151.22	155.48	3
505	649929.26	305147.91	155.33	3
506	649928.90	305146.85	155.38	45
507	649927.87	305141.76	155.03	10
508	649927.56	305144.35	153.63	6
509	649918.64	305152.76	155.09	3
510	649919.77	305155.67	155.35	3
511	649919.82	305159.82	155.66	3
512	649915.73	305162.54	155.59	8
513	649914.09	305151.49	154.87	9
514	649912.69	305146.59	154.93	10
515	649913.22	305147.28	154.71	45
516	649913.85	305148.98	153.51	6
517	649910.60	305144.81	154.46	10
518	649904.83	305146.71	154.26	10
519	649903.43	305149.69	154.47	9
520	649903.26	305151.29	153.48	6
521	649903.89	305153.18	154.56	9
522	649904.25	305156.58	154.62	3
523	649904.54	305159.60	154.91	23
524	649904.81	305163.02	154.96	3
525	649905.59	305167.73	155.13	8
526	649904.77	305170.13	156.98	8
527	649891.29	305168.99	154.33	3
528	649890.41	305167.42	154.32	23
529	649888.97	305164.78	154.32	3
530	649887.70	305162.44	154.10	8
531	649886.41	305157.72	154.04	45
532	649886.61	305156.69	153.05	6
533	649871.86	305160.21	153.06	45
534	649872.27	305159.48	152.06	6
535	649869.78	305161.42	150.86	10

From the analysis of the data presented in Table 2, it was found that topographic detail points represent the largest share of elements included in the situation plan (38%), followed by text attributes (26%), symbols (25%), and lines (11%). These proportions are visually illustrated in Figure 7, offering a synthetic overview of the spatial features graphically reported using the MapSys 10.0 software.

Extracts from the situation plans, illustrating the reported topographic details, are presented in Figures 8, 9, and 10.

The results of comparative research indicate that the PPK-GPS method is clearly superior to classical topographic positioning methods, which have as their main objective the preparation of contour topographic maps, on very large surfaces. Consequently, it was found that by applying this method the estimated time of the works was reduced by approximately 70% (El Shouny et al., 2017).

Table 2. Synthetic evidence of the details that were graphically reported with the MapSys 10.0 program

Layer	Item name	Point	Line	Symbol	Attribute Text	Total
3	Building	0	0	0	0	**120**
4	Road	135	26	0	0	**161**
6	Groove	90	33	0	0	**123**
7	Zero altitude	6	0	0	0	**6**
8	Altitudes	114	0	0	0	**114**
9	Bridge < 5 m	94	49	0	0	**143**
10	Fence	86	48	0	0	**134**
11	Building	10	4	0	0	**14**
16	Concrete electric pole	29	0	0	0	**29**
17	Gate access	0	0	1	0	**1**
19	Retaining wall	2	1	6	0	**9**
21	Indication	0	0	1	0	**1**
23	Road axis lin	105	15	0	0	**120**
24	Bridge tube	4	1	0	0	**5**
26	Text attributes	0	0	12	47	**59**
27	Shrubby vegetation	0	0	1	0	**1**
28	Concrete fence	2	1	0	0	**3**
29	Trinity	0	0	1	0	**1**
32	Attribute Text for Zero altitude	0	0	6	7	**13**
33	Altitude text	0	0	1	659	**660**
34	Symbols	0	0	651	0	**651**
38	Alleys	56	11	0	0	**67**
39	Hydrant	4	0	0	0	**4**
45	Trench edge	149	79	0	0	**228**
50	Building w. elevation	6	6	0	0	**12**
56	Limit without altitude	36	18	0	0	**54**
78	Route text	0	0	0	11	**11**
Total		**1048**	**292**	**680**	**724**	**2744**

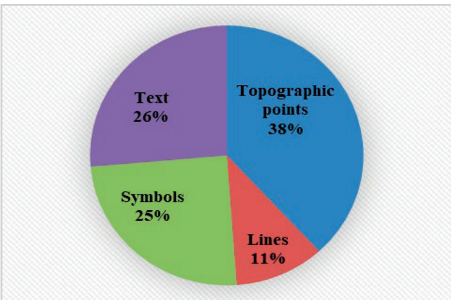

Figure 7. Graphical distribution of the elements included in the detail plan for the three surveyed routes

The application of RTK/PPK GNSS methods, for carrying out drone flights, which aim to map inaccessible forest areas, led to obtaining slight standard deviations in the plane of 0.026 m on the OX axis and 0.035 m on the OY axis, and on the OZ axis of 0.082 m. Consequently, RTK/PPK technology in combination with drones, constitutes a feasible and sufficiently precise solution for mapping areas covered with forest vegetation, and characterized by reduced accessibility (Tomaštík et al., 2019).

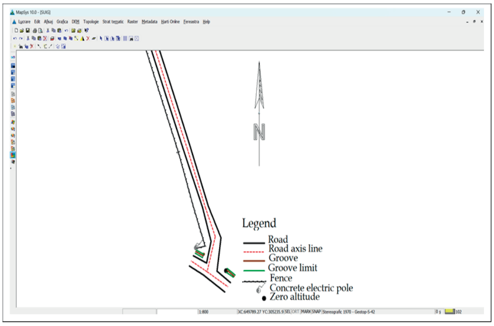

Figure 8. Extract from the detailed plan for route 1

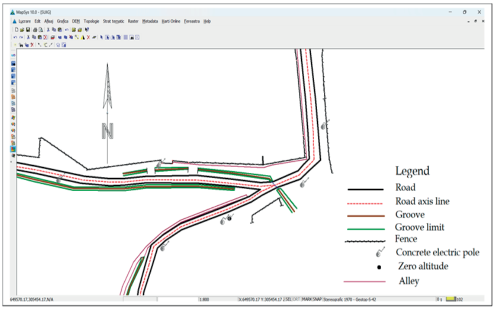

Figure 9. Extract from the detailed plan for route 2

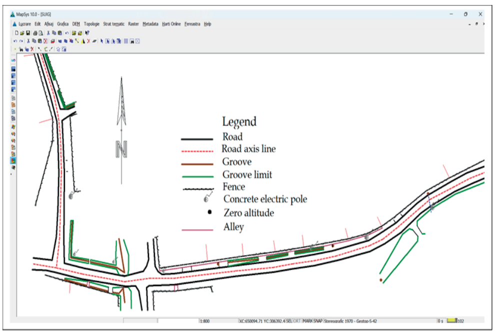

Figure 10. Extract from the detailed plan for route 3

CONCLUSIONS

The spatial positioning of the detailed characteristic points necessary for the design and rehabilitation of transport routes in rural areas can be achieved under optimal conditions with GNSS technology, through the Stop and Go method, if at least two GNSS receivers with single and dual frequency are available.

The optimal length of the routes on which positioning is performed with the PPK method, from the base to the end of the route, should not exceed 4-5 km.

Obtaining superior precision for the coordinates of the positioned points and substantially reducing working time is conditioned by the continuous recording of the signal by the base and rover receivers used, along the travel routes.

The use for base and control points of the coordinates of points in the geodetic network or those determined by the RTK method, with the use of recordings from permanent GNSS stations, through the ROMPOS system, ensures the PPK positioning method has extensive applicability.

The use of control points, with known coordinates, along the route and at the completion of the recordings, optimizes the positioning process within the PPK method, contributing to increasing the accuracy of determining the coordinates of new points.

To optimize the positioning process with the Stop and Go method, especially to reduce working time, multiple single-frequency GNSS receivers can be used as a rover, and the base will be located approximately in the middle of the route, depending on the field working conditions.

If two receivers are used as rovers on a single route, it is optimal for them to move from the base point towards the ends of the route, and the base is optimal for it to be located halfway along the route.

For two or more positioning routes with the PPK method, it is optimal to place the base at approximately equal distances from them, and to perform positioning with a rover for each route.

If the routes are located at large distances from each other, the base will be conveniently located in terms of distance and access to satellite recordings, for each separate route.

In the variant where multiple single-frequency GNSS receivers are available, for example four, the necessary base and control points can be positioned later using the traditional static method, and the recordings are post-processed. Also, the coordinates of the base and control points can be determined at the completion of the route positioning, by the RTK method, with a dual-frequency receiver, using the records from the nearest permanent GNSS station. They can also be determined with the total station, by a framed polygonometric survey, or by the free station method, if there are points from the support network in the work area.

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