DOCTORAL THESIS

-SUMMARY-

POSSIBILITIES FOR IMPROVING TOPOGRAPHIC MEASUREMENT METHODS IN MINING WORKS

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Introduction

In an era marked by exceptional technological progress, unmanned aerial vehicles (UAVs) have brought a profound transformation in the field of topographic measurements. The paper explores the impact and benefits of UAVs in this field, with an emphasis on their applications in mining, both underground and on the surface. Topographic measurements are essential in civil engineering, architecture, mining, and land management. The use of UAVs has become popular due to the considerable advantages in terms of efficiency, accuracy, and reduced costs. UAVs allow measurements to be made with accuracy and speed that surpass traditional methods, facilitating the collection of precise data in a shorter time.

A fundamental aspect of the paper is the analysis of the technological evolution of UAVs used in topographic measurements. Technological advances in recent decades have profoundly impacted how topographic measurements are performed. The development of advanced sensors, such as high-resolution cameras and LiDAR (Light Detection and Ranging) technology, has allowed UAVs to collect data with unprecedented precision and accuracy. These technologies enable the creation of highly precise digital terrain models, essential for infrastructure projects and natural resource management. LiDAR technology provides detailed distance measurement by measuring the return time of a laser pulse, generating 3D models of the terrain with impressive accuracy.

In the underground environment, difficult and dangerous conditions for operators include narrow spaces, high humidity, and lack of natural light. UAVs can easily access these spaces and collect precise data without endangering human life. On the surface, UAVs offer a fast and efficient method of collecting data over large areas, significantly reducing the time and costs compared to traditional measurement methods.

The practical applicability of UAVs in various fields is essential. In mining, UAVs are used for monitoring dumps and dams, managing the volumes of extracted material, and assessing the stability of slopes. These applications are important for preventing accidents and optimizing extraction processes. UAVs provide an efficient and safe method of data collection in difficult and dangerous environments. Additionally, UAVs allow real-time monitoring of mining activities and efficient resource management, contributing to reducing risks and improving safety in work environments.

In the mining industry and quarries, UAVs are used for monitoring the volumes of extracted material and assessing the stability of slopes. These operations are essential for preventing accidents and optimizing extraction processes. Through precise flights and the ability to collect real-time data, UAVs contribute to the efficient management of mineral resources and ensure workplace safety.

In civil construction, UAVs play a crucial role in infrastructure projects. They are used for detailed inspections of construction sites and measuring construction progress with high precision. The data obtained from these inspections are essential for project management, facilitating real-time decision-making and resource optimization. The use of UAVs significantly reduces the time and costs associated with manual measurements and field inspections, thus contributing to the efficiency and success of construction projects. By eliminating the need for manual measurements and physical inspections, UAVs allow rapid and detailed assessment of the condition of construction sites and progress.

The main purpose of using UAVs in topographic measurements is to ensure the acquisition of precise and detailed data in a fast and efficient manner. Both in underground and surface environments, they minimize risks to operators and operational costs. UAVs' ability to quickly cover extensive areas and perform precise measurements makes them indispensable for urban planning, infrastructure monitoring, and sustainable natural resource management.

The general objectives of UAV measurements in the topographic field are essential for technological progress and operational efficiency in various industries. UAVs bring significant advantages, contributing to the improvement of topographic data collection and analysis processes. They offer precise and detailed data, reduce time and costs, increase operator safety, and optimize the post-processing of data. Through these advantages, UAVs become essential tools in modern topographic measurements.

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CHAPTER 1
CURRENT STATE OF RESEARCH

Chapter 1 of this thesis provides a detailed analysis of the current state of research in the use of unmanned aerial vehicles (UAVs) in topographic measurements. This chapter explores the technological evolution of UAVs, their significant contributions in various applications, associated challenges, as well as pro and con opinions and the legal framework for the use of these systems in measurements.

1.1. Evolution of topographic measurements performed with UAV

The use of drones in topographic measurements has marked a significant shift in the paradigm of geospatial data collection. Initially, the technology was mainly used for military and reconnaissance purposes. However, the rapid evolution of equipment and software has opened new horizons in the fields of cartography and topography. In the 2000s, the first experiments with using drones for photogrammetry and aerial photography were documented in the specialized literature. Studies have demonstrated the potential of UAVs in creating high-resolution topographic maps, highlighting the drones' ability to collect precise and detailed data at lower costs and with flexibility in planning and executing measurement missions.

1.2. Significant contributions in the conduct of topographic measurements performed with UAV

Several personalities and researchers have become reference figures in the development and promotion of drone use in topographic measurements. Among them are Dr. Michael S. Gebre, Dr. Stuart Blundell, and Dr. Jonathan Li, who have significantly contributed to advancing this field. Their studies and research have highlighted the advantages of using UAVs, including efficiency, accuracy, and safety in data collection. Technological advances such as the development of advanced sensors and LiDAR (Light Detection and Ranging) technology have allowed UAVs to collect data with unprecedented precision and accuracy, facilitating the creation of highly precise digital terrain models.

1.3. Benefits and challenges of UAV measurements to date

The use of UAVs brings numerous benefits in topographic measurements:

- **Efficiency and speed:** UAVs allow measurements to be performed in a significantly shorter time compared to traditional methods.

- **Precision and accuracy:** The development of advanced sensors, such as high-resolution cameras and LiDAR technology, has enabled UAVs to collect extremely precise data.
- **Safety:** UAVs can access dangerous or hard-to-reach areas for human operators, such as underground environments and rugged terrains, reducing risks for field personnel.
- **Versatility:** UAVs can be used in various applications, including monitoring dumps and dams, assessing slope stability, and monitoring construction progress.

Despite these advantages, the use of UAVs also presents challenges such as the influence of weather conditions on flights and data accuracy, strict regulations regarding UAV use, and cybersecurity issues related to data protection and preventing unauthorized access.

1.4. Pro and con opinions in the field

This section presents various pro and con opinions regarding the use of UAVs in topographic measurements. Pro opinions highlight the significant advantages of UAVs, such as operational efficiency, cost reduction, and increased safety. On the other hand, con opinions emphasize challenges and limitations, such as dependence on weather conditions, the need for strict regulations, and cybersecurity risks. Discussions focus on balancing benefits and challenges to maximize the efficient use of UAVs in measurements.

1.5. Legal framework for the use of UAV systems in measurements

The use of UAVs is strictly regulated in many countries, and compliance with these regulations is essential to ensure safe and legal operation. In Romania, the use of drones in terrestrial measurements is regulated by the Romanian Civil Aeronautical Authority (AACR) and other relevant authorities. Individuals or legal entities wishing to use UAVs for commercial purposes must obtain specific licenses and authorizations. Regulations include restrictions on maximum flight altitude and distance from airports and other restricted areas. It is essential to respect privacy and property rights and ensure the security of collected data.

1.6. Use of drones for underground measurements

The use of drones in underground measurements represents a significant evolution in the field of topography. These drones are adapted to operate in underground environments and are equipped with special sensors and equipment to collect precise data. The first tests regarding the use of drones in underground measurements took place in mines and caves worldwide. In Romania, the use of drones in underground measurements is continually evolving, with increased interest in the mining industry. Mining companies and research institutions are exploring the potential of using drones for mapping and monitoring mines and underground galleries.

1.7. Necessary steps in data acquisition and processing using UAV systems

Performing topographic measurements with UAVs involves several essential steps, from flight planning and data collection in the field to post-processing and interpretation.

1.7.1. Flight plan realization

Flight planning is crucial to ensure complete and detailed coverage of the area of interest. This process includes determining the flight route, setting the UAV's altitude and speed, and selecting the appropriate sensor equipment. The use of flight planning software, such as Agisoft Metashape and Pix4D, allows the creation of precise and efficient flight plans.

1.7.2. Data post-processing

After completing the flights, the collected data is transferred for processing. Data processing includes aerial triangulation, image alignment, and generating digital terrain models (DTM) and high-resolution orthophotos. The use of ground control points (GCP) is essential to correlate and adjust data, ensuring its accuracy. Advanced software such as Agisoft Metashape and Pix4D is used for data post-processing, providing precise and reliable results.

1.7.3. Data processing method from the point cloud and interpretation by making the situation plan

The point cloud generated by the 3D reconstruction of points from aligned images forms the basis for the 3D model of the studied surface. The processing process includes using optimization algorithms, such as the least squares method, to adjust projection and rotation parameters. These data are used to create situation plans and detailed topographic maps.

1.7.4. Conclusions

This chapter provides a comprehensive overview of the current state of research in the use of UAVs in topographic measurements. Technological advances and significant contributions from researchers have demonstrated the considerable advantages of UAVs in terms of efficiency, precision, and safety in topographic data collection. Despite challenges and limitations, the use of UAVs continues to evolve, opening new horizons in the field of topography and offering innovative solutions for various applications. Strict regulations and compliance with legal frameworks are essential to ensure the safe and legal operation of UAVs, contributing to the continuous advancement of this field.

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CHAPTER 2
USE OF UAV SYSTEMS

Chapter 2 of the thesis explores the use of UAV (unmanned aerial vehicle) systems in monitoring dumps and dams, as well as in monitoring the behavior of constructions over time and creating support plans for land use monitoring. This is an area where UAVs have brought significant innovations, offering more efficient and precise solutions compared to traditional methods..

2.1. Monitoring of dumps and dams used in mineral resource exploitation

2.1.1. Introduction

Monitoring dumps and dams is essential for infrastructure safety and environmental protection. Dumps are deposits of waste and mineral residues resulting from ore extraction and processing, while dams are major hydraulic structures used for water resource management, hydropower production, and flood protection. The integration of UAVs has revolutionized how these structures are monitored.

2.1.2. Description of the fieldwork method

The fieldwork method with UAVs involves several critical stages. Initially, a detailed flight plan is created, which includes determining the UAV's route, setting ground control points (GCP), and ensuring that all equipment is properly calibrated. Detailed planning is essential to ensure the accuracy of the collected data.

UAV flights are conducted at variable altitudes, depending on the monitoring objectives and terrain characteristics. For example, in the case of dumps, UAVs are used to collect detailed topographic data, which is later used to create digital terrain models and assess the structure's stability. In the case of dams, UAVs monitor both the structure's integrity and water levels and any possible leaks.

2.1.3. Description of the post-processing method

Post-processing the data collected by UAVs involves using advanced photogrammetry and 3D modeling software. The data is processed to generate digital terrain models, topographic maps, and high-resolution orthophotos. These final products are essential for detailed analysis and informed decision-making in dump and dam management.

An important aspect of post-processing is the calibration and adjustment of data to eliminate errors and ensure the accuracy of the results. The use of GCPs is crucial in this regard, as they allow the correlation of UAV data with existing geospatial reference systems.

2.1.4. Methods of error comparison obtained

Comparing the errors obtained from UAV measurements with those from traditional methods is essential for validating and improving UAV technologies. In this regard, various statistical methods and optimization algorithms are used to evaluate data accuracy and reliability. The root mean square error (RMSE) and adjustment through the least squares method are just two of the methods used to evaluate and minimize errors.

2.1.5. Calculation of the dam volume

One of the main objectives of using UAVs in dam monitoring is the precise calculation of their volume. This involves collecting detailed topographic data and using 3D modeling algorithms to determine the structure's volume. This information is essential for resource management and planning maintenance and repair works.

2.1.6. Results obtained

The results obtained from using UAVs in monitoring dumps and dams are remarkable. UAVs have demonstrated an excellent capacity to collect precise and detailed data, reduce the time and costs associated with traditional measurements, and improve operator safety. In addition, the digital models and topographic maps generated by UAVs are essential for the analysis and efficient management of these structures.

2.2. Integration of UAVs in monitoring the behavior of constructions over time and creating support plans for land use monitoring

2.2.1. Introduction

The integration of UAVs in monitoring the behavior of constructions over time and land use represents another important application of this technology. UAVs offer an efficient and precise solution for collecting data necessary for assessing the state of constructions and planning land use.

2.2.2. Advantages of using UAVs in monitoring the behavior of constructions over time and land use

Using UAVs in monitoring constructions and land use brings numerous advantages, including:

- **Efficiency and speed:** UAVs allow measurements to be performed in a short time and with reduced effort compared to traditional methods.

- **Precision and accuracy:** UAVs are equipped with advanced sensors that allow the collection of extremely precise and detailed data.
- **Safety:** UAVs can access dangerous or hard-to-reach areas for human operators, reducing risks associated with traditional inspections.
- **Versatility:** UAVs can be used in various applications, including structural inspections, assessing land stability, and monitoring construction progress.
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2.2.3. Description of the fieldwork method

The fieldwork method for monitoring constructions and land use with UAVs involves detailed flight planning, similar to the method described earlier. UAVs are equipped with high-resolution cameras and LiDAR sensors to collect detailed data on the state of structures and land.

2.2.4. Description of the data processing method

Processing the data collected by UAVs for monitoring constructions and land use involves using specialized photogrammetry and 3D modeling software. The data is processed to generate digital models of structures and detailed topographic maps that are used for analyzing the state of constructions and planning land use.

2.2.5. Conclusions

Using UAVs in monitoring constructions and land use has demonstrated multiple advantages, including increased efficiency and precision of measurements, cost reduction, and improved operator safety. UAVs have become essential tools in modern infrastructure and land resource management, offering innovative solutions to challenges in these fields.

CHAPTER 3
CASE STUDY

Chapter 3 of this thesis presents detailed case studies demonstrating the use of UAVs for verifying and monitoring mining structures, especially at the exploitation pillar E36 and the subsidence cone. These studies highlight the advantages of using UAVs in complex and dangerous environments, offering efficient and precise solutions for data collection and analysis.

3.1. Checks at Exploitation Pillar E36

3.1.1. Introduction

Verifying exploitation pillars in salt mines plays a crucial role in detecting exfoliations, fissures, cracks, and plastic deformations caused by the pressures they are subjected to, aiming to prevent mining accidents and ensure the structural stability of the entire complex. To date, at Ocna Dej Salt Mine, these measurements have been carried out annually or once every two years. Using UAVs for performing these measurements is a novelty for both this salt mine and Romania.

3.1.2. Flight plan

The DJI Phantom 4 Pro Plus drone, modified for underground use, was used. The difficult underground conditions, such as strong air currents and lack of satellite signal, required careful maneuvering and the use of multiple batteries to perform the measurements. In 2020, the flight lasted approximately an hour and a half, while in 2024, the measurements were easier due to reduced air current intensity.

3.1.3. Data post-processing

Data post-processing involved using a large number of key points and tie points for image alignment due to low light conditions and chromatic aberration. The error minimization method through bundle adjustment was used to ensure the accuracy of the 3D model. The point cloud was generated through 3D reconstruction of points from aligned images, forming the basis for the 3D model of the studied surface.

3.1.4. Section realization and data verification

Horizontal sections were made at different levels, and their contours were used to analyze changes over time. The superimposition of the contours from 2020 and 2024 highlighted differences and deformations of the exploitation pillar. Additionally, the obtained contours were compared with data from the salt mine archive to verify the accuracy and stability of the pillar.

3.1.5. Data interpretation

Data interpretation involved analyzing the sections made and comparing them with data from the salt mine archive. Changes over time were identified by superimposing the contours from 2020 and 2024. The observed differences highlighted areas with potential risk and the need for interventions to ensure structural stability.

3.1.6. Results obtained

The results demonstrated the ability of UAVs to collect precise and detailed data in difficult conditions. Measurements performed with UAVs allowed continuous monitoring of the exploitation pillar's stability, reducing risks for operators and ensuring an accurate assessment of the structural state.

3.2. Checks at the Subsidence Cone

3.2.1. Introduction

The subsidence cone represents a critical area for monitoring deformations and ground movements. UAVs offer an efficient solution for collecting data necessary for evaluating these phenomena, ensuring detailed and precise monitoring.

3.2.2. Fieldwork

Fieldwork involved systematic flights over the subsidence cone, collecting detailed topographic data. The flexibility and maneuverability of UAVs allowed complete coverage of the area of interest and the collection of comprehensive data. The collected images and data were processed to generate digital terrain models and topographic maps.

3.2.3. Data post-processing

Data post-processing included image alignment, point cloud generation, and creating digital terrain models. The data was processed to obtain precise 3D models that were used to evaluate ground deformations and movements. The processing involved using specialized photogrammetry and 3D modeling software.

3.2.4. Results obtained

The results obtained demonstrated the efficiency of UAVs in monitoring the subsidence cone. The 3D models and topographic maps highlighted changes over time, allowing the identification of critical areas and the assessment of associated risks. UAVs provided a fast and precise method of monitoring ground deformations, contributing to efficient resource management and accident prevention.

3.2.5. Conclusions

Using UAVs for monitoring the subsidence cone demonstrated numerous advantages, including efficiency in data collection, high precision, and the ability to access difficult and dangerous areas. The generated 3D models and topographic maps were essential for detailed deformation evaluation and informed decision-making regarding land management.

CHAPTER 4
CONCLUSIONS AND ORIGINAL RESULTS

4.1. Conclusions of the doctoral thesis:

This doctoral thesis focused on using UAV equipment for topographic measurements both in underground and surface environments. The study demonstrated that using drones brings significant advantages in terms of efficiency, precision, and safety in topographic data collection. The main conclusions of this research are presented below.

Using UAVs for topographic measurements significantly reduced the time required for data collection compared to traditional methods. UAVs can quickly cover large areas and access hard-to-reach areas for human operators. In the underground environment, where access is often difficult and dangerous, UAVs demonstrated the ability to collect precise data without exposing operators to risks.

It is always important to distribute GCPs in the field in such a way as to cover the area of interest both inside and at its extremities and to be able to constrain the point cloud to minimize errors.

On the surface, drones provided high-resolution maps and 3D models essential for various engineering and scientific applications.

At the Runcu dam, measurements were performed with the drone in the drainage gallery to create cross-sections that would allow the design of its enlargement and the realization of the project through the drilling and blasting method.

When monitoring dumps, dams, and quarries in a specific area, special attention is needed to accurately determine the volume of embankment/excavation for timely verification of the total aggregates and minerals. These work procedures help both designers and builders to know the real state of the works and identify areas where intervention is needed in case of problems.

The study showed that drones equipped with high-resolution cameras can collect topographic data with very high precision. In the underground environment, where conditions are often difficult, drones managed to obtain precise data that allowed the creation of detailed digital models.

Checks helped understand the phenomena of cracking, dilation, and exfoliation of exploitation pillars, a phenomenon that needs to be considered and checked periodically because if they are not correctly positioned, due to cracks and mineral dislocations, entire mining systems can collapse, similar to the subsidence cone area at Ocna Dej Salt Mine above the Ferdinand Mine.

These checks help investigate areas that need intervention more easily and safely by creating 3D models of the point clouds.

A major advantage of using drones in the underground environment is reducing risks for human operators. Drones can navigate narrow and dangerous spaces, eliminating the need for operators to enter such areas. This has contributed to increased safety and reduced workplace accidents in the underground environment.

Implementing UAVs in topographic measurements has demonstrated a significant reduction in operational costs. Costs associated with traditional equipment and operator working time have been reduced, making the use of drones an economical solution for topographic measurement projects.

UAVs have proven to be extremely flexible and adaptable for different types of measurements and terrain conditions. In the underground environment, drones have been modified to operate without access to global positioning systems, using alternative technologies for navigation. On the surface, drones have been used in various applications, from monitoring construction progress to assessing natural resources.

The drones used in this research were modified from the software to be used in areas without mobile phone signal, internet access, or satellites. This led to a deeper understanding of the flight mechanism, which allows capturing relevant information using flight route planning programs.

Through collaborations with university professors, a LISP for the Autocad program was created to extract relevant information from the point cloud, which defines elements in the field and ultimately forms the basis for outlining situation plans.

Advanced data collection technologies implemented on drones facilitated a more efficient post-processing process. The collected data was easily integrated into specialized software programs for analysis and interpretation of results. This allowed a rapid and accurate evaluation of the collected information and improved the quality of the final results.

The thesis demonstrated that using UAVs can bring significant improvements in creating support plans for design, verification, and implementation.

4.2. Recommendations for the future:

It is recommended to continue integrating advanced technologies such as artificial intelligence and machine learning to further improve the precision and efficiency of UAVs in topographic data collection.

It is essential to develop strict safety protocols for their operation in both underground and surface environments to ensure the protection of operators and equipment.

Collaboration between cadastral engineers, technology developers, and regulatory authorities is encouraged to standardize the use of UAVs in topographic measurements and maximize the benefits of this technology.

Investments in the education and continuous training of UAV operators and cadastral specialists are essential to ensure the efficient and safe use of drones in various topographic applications..

4.3. Final conclusions:

The thesis demonstrates that using UAVs in topographic measurements, both underground and on the surface, represents an innovative and efficient solution for collecting precise data necessary in various fields. By improving precision, reducing costs, and increasing safety, drones have the potential to revolutionize how topographic measurements are performed, significantly contributing to technological progress and the development of modern infrastructure.

To perform certain works faster, better, and at a higher precision level, we need to intervene and turn to new technology, even more so in the future, with the intention of creating a data processing program based on artificial intelligence to reduce errors that may occur at various stages of the process..

REFERENCES

1. Marian Dacian-Paul - *Intocmirea planurilor topografi*ce - Editura Universitas, Petrosani 2019

2. Colomina, I., & Molina, P. - *Unmanned aerial systems for photogrammetry and remote sensing*: A review. ISPRS Journal of Photogrammetry and Remote Sensing (2014), 92, 79-97.

3. Costachel Aurel - *Cartografia cu baze de topografie* - Litografia Invatamantului, Bucuresti 1955

4. Dima Nicolae, Herbei Octavian, Veres Ioel - *Topografie generala si elemente de topografie miniera* - Editura Universitas, Petrosani 2005

5. Donisă Ion, Grigore Mihai, Tövissi Iosif – *Aerofotointerpretare geografică* – Editura Didactică și Pedagogică București, 1980

6. Ionescu P., Rădulescu M. – *Topografie generală și inginerească* - Editura Didactică și Pedagogică București, 1975

7. Balázs Csaba, Vereș Ioel, Fissgus Klaus Gerhart - *Realization of a situation plan using the drone (uav) as photogrammetric equipment* - Annals of the University of Petrosani, Mining Engineering, 21 (2020), pag. 231-251, Universitas publishing house, Petroșani 2020, ISSN 1454-9174

8. *https://github.com/agisoft-llc/metashape-scripts*

9. Sanna Marttila, Andrea Botero - *Bees, drones and other Things in public space: Strategizing in the city* - Strategic Design Research Journal, 9(2): 75-88 May-August 2016, 2016 Unisinos – doi: 10.4013/sdrj.2016.92.03

10. https://forums.autodesk.com/t5/visual-lisp-autolisp-and-general/select-3d-points-by-polylines/m-p/9493579/highlight/true#M399352, Prof. Univ. Giovanni Anzani, Prof. Univ. Universitatea de studii din Florența, Departamentul de Arhitectură

11. Stanescu E., Munteanu A., Seibulescu C. - *Constructia barajelor de pamant si anrocamente* - Editura Tehnica, Bucuresti 1969

12. Fissgus Klaus Gerhart – *Fotogrammetrie* - Editura Universitas, Petrosani, 2011

13. Marian Dacian Paul - *Urmarirea comportarii terenurilor si constructiilor afectate de exploatarea subterana* - Editura Universitas, Petrosani 2021

14. Gheorghe-Gavrilă Hognogi, Ana-Maria Pop, Alexandra-Camelia Marian-Potra, Tania Someșfălean - *The Role of UAS–GIS in Digital Era Governance. A Systematic Literature Review* – Sustainability 2021, 13, 11097. https://doi.org/10.3390/su131911097

15. Wenang Anurogo, Muhammad Zainuddin Lubis, Hanah Khoirunnisa, Daniel Sutopo Pamungkas Aditya Hanafi, Fajar Rizki, Ganda Surya, Arini Dewi Lestari Situmorang, Dirgan Timbang, Perdi Novanto Sihombing, Catur Agus Lukitasari, Novita Ayu Dewanti - *A Simple Aerial Photogrammetric Mapping System Overview and Image Acquisition Using Unmanned Aerial Vehicles (UAVs)* - Journal of applied geospatial information Vol 1 no 1 2017

16. Onica Ilie, Marian Dacian-Paul, Marina Ovidiu - *Monitorizarea si prognoza deformarii terenului de la suprafata Minelor Victoria si Cantacuzino: articol* - Editura Universitas, Petrosani 2021

17. Ersilia Oniga, Ana-Ioana Breabăn – *Aplicații utilizând nori de puncte laser scaner aeropurtate* - MatrixRom București, 2020

18. Ersilia Oniga – *Fotogrammetrie avansată* – MatrixRom București, 2019

19. Guțu Alexandru, Andrei Ovidiu – *Fotogrammetria terestră în cercetare și proiectare* – Editura Tehnică București, 1976

20. Toz G., Erdogan M. - *DEM (digital elevation model) production and accuracy modeling of dems from 1:35.000 scale aerial photographs* - The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B1. Beijing 2008

21. Vorovencii Iosif – *Fotogrammetrie* – MatrixRom București – 2010

22. Marian Dacian Paul - *Urmarirea topografica si analiza deformarii suprafetei terenului afectat de exploatarea subterana* - Editura Universitas, Petrosani 2012