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THE USE OF GEOGRAPHIC INFORMATION SYSTEMS (GIS) IN THE TEACHING OF MILITARY TOPOGRAPHY

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Abstract: *The introduction of digital technology in the process of creating topographic maps significantly changes the way spatial phenomena are used and presented. Geographic Information Systems (GIS) represent a modern tool that enables access to analysis, and interpretation of spatial data in digital form. In the context of military education, particularly in the teaching of Military Topography, GIS provides faster, more precise, and more detailed terrain visualization, which is essential for planning and conducting military operations. The paper compares the use of GIS technology with traditional methods of orientation and terrain analysis. It presents modern informational devices for geolocation and orientation in the field, used in the realization of thematic teaching content and special forms of teaching in the subject of Military Topography at the Military Academy. The impact of these devices on the quality and efficiency of military training was explored, and the use of these devices during extreme weather conditions was analyzed. Recommendations for further research and improvement of the teaching process in this subject are also given.*

Keywords: *GIS, Topographic map, Military topography.*

1. INTRODUCTION

Military Topography is a specialized scientific discipline that focuses on understanding the tactical properties of terrain, methods for land assessment, and the geographic, topographic, and tactical orientation necessary for combat operations. This field often involves conducting field measurements to support military operations and creating operational schemes, both in analog and digital formats.

The primary goal of Military Topography is to ensure that military personnel can effectively collect, interpret, and use terrain data for the efficient deployment of equipment and weapon systems. Topographic maps serve as a key resource for this purpose, and the ability to read and interpret these maps is crucial for decision-making in military contexts.

Modern military education incorporates technological innovations in all aspects of teaching. The integration of Geographic Information Systems (GIS) has brought new techniques and tools into the military topography curriculum, enhancing the ability to analyze and visualize terrain data. By using GIS, cadets can more easily answer spatial questions and visualize their findings in real-time, improving their overall understanding of the subject matter [1].

2. TEACHING MILITARY TOPOGRAPHY

Military Topography is an essential part of military education, ensuring that future officers are well-prepared for field operations.

At the Military Academy in Belgrade, the subject is taught through a combination of lectures and practical exercises. Cadets learn to use traditional orienteering methods and modern geolocation tools to effectively assess terrain and plan military operations.

During classes, cadets learn to read and use topographic maps, understand scale, recognize topographical signs, and interpret relief representation with isohypses. This knowledge helps accurately determine the position of friendly and enemy units, identify natural obstacles, and

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tactically utilize the terrain.

In addition to classroom sessions, practical exercises form a significant part of the training. These exercises are conducted in summer and winter at the Serbian Armed Forces' training centers.

Cadets learn to orient themselves in unfamiliar terrains using hand compasses, which is crucial during low visibility conditions, such as night operations or operations in dense fog or vegetation.

Figure 1. Orientation using a topographic map and compass

Military Topography education also involves modern technologies like satellite and aerial photogrammetry imagery, digital maps, Global Navigation Satellite Systems (GNSS), and GIS. These tools are increasingly vital in modern military planning and operations. Cadets learn how to use these tools to collect, analyze, and interpret geographic data.

Overall, these components of military topography training equip cadets to conduct operations under various conditions effectively. Soldiers well-versed in topography can quickly adapt to changing terrain conditions, contributing significantly to the success of any military mission.

3. TECHNOLOGICAL PROGRESS IN MILITARY TOPOGRAPHY

The integration of GIS and GNSS into military education represents a significant advancement in terrain analysis and visualization. These tools provide faster, more accurate assessments of terrain, aiding military personnel in planning and executing operations.

3.1. The Serbian Army GIS software

The Serbian Army GIS software (SA GIS) is an application specifically designed to support operational planning through geospatial analysis and battlefield visualization. SA GIS primarily facilitates the creation of tools that analyze military aspects of terrain and their subsequent effects on realizing planned operations.

Using this software offers both 2D and 3D terrain visualization, which significantly aids spatial analysis in planning and decision-making processes prior to the exercise conduction. With the use of certain tools, distances are easily calculated, land slopes determined, sightlines between points checked, fire zones displayed, and more.

SA GIS provides a comprehensive toolset, allowing users to establish the project, define the coordinate system, map workspace, and visual display. It also offers a broad range of terrain processing tools. The interface of this software and some of its capabilities are shown in Figures 2, 3 and 4.

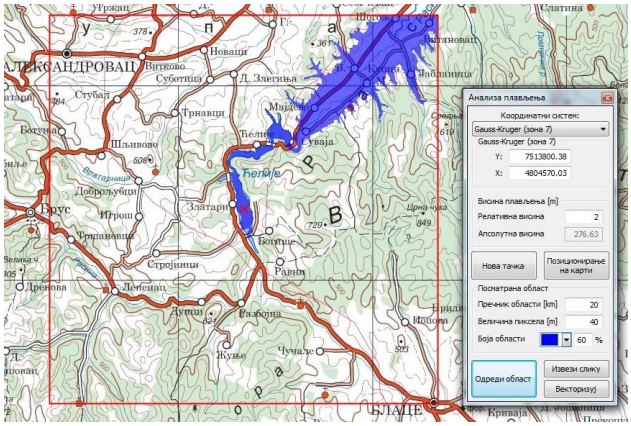

Figure 2. Analyzing flooding areas using SA GIS

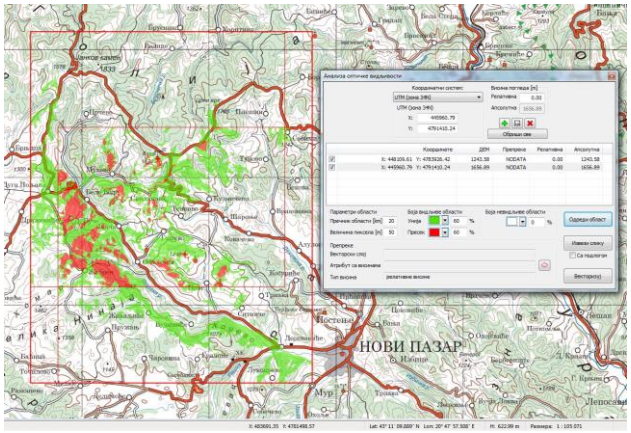

Figure 3. Analyzing optical visibility using SA GIS

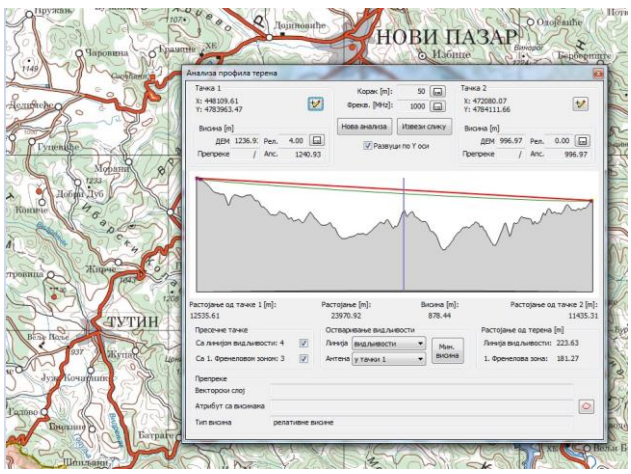

Figure 4. Analyzing terrain profiles using SA GIS

SA GIS is used in the GIS cabinet at the Military Academy. This cabinet houses suitable desktop computers networked into a secure system. All spatial data for analysis and processing is sourced from a server-based database.

Figure 5. GIS cabinet [2]

3.2. Mobile GIS devices

Mobile GIS technology combines hardware, software, and information tools. It provides cartographic modeling, integrated representation of geographic and attribute data, as well as collection, storage, and analysis of geospatial information in the field [3]. Due to the technological advancements in handheld devices for GIS, they are both robust and easily portable. This versatility allows for their use in various conditions and terrains, making them ideal for military topographical training.

Figure 6. Mobile GIS devices

Tablets

In terms of mobile hardware, there are two tablets in active use, each boasting similar high-end characteristics. The first is the Dell Latitude 7230 Rugged Extreme Tablet. This piece of technology was specifically acquired for field reambulation of Topographic Maps at the Military Geographical Institute - "General Stevan Bošković". The second is a Trimble T100 tablet, which was purchased by the Military Academy to enhance the teachings of Military Topography.

The tablets are equipped with GIS software that allows users to visualize and analyze data immediately in the field. This possibility is of great importance for the decision-maker, because it enables a faster response to changes and optimization of resources.

Intended to withstand even the harshest conditions, these tablets are specifically designed for professional field use. Notable for their advanced performance capabilities, resilient housing, and extensive range of functionality, these tablets are armed with everything necessary for productive work in challenging field conditions. Their robustness is certified through resistance to falls, vibrations, dust, and extreme temperatures. Moreover, they are sealed against water and dust ingress, meeting the rigorous IP65 standard. Technologically, they are equipped with powerful processors that facilitate a broad spectrum of tasks, including advanced analytics and data processing. The tablets feature high-resolution screens with an anti-reflective coating, ensuring excellent visibility even under direct sunlight. The touch-sensitive screens can be used even with gloves, enhancing usability in various conditions. Their long-lasting batteries support hours of continuous work, and the Dell model even offers the option to replace the battery without the need to power down the device, thereby boosting productivity. Furthermore, they support a wide range of connectivity options, including Wi-Fi, Bluetooth, and 4G LTE, which ensures seamless connectivity with the database and other necessary devices. The specifications of these devices are given in Tables 1 and 2.

Table 1. Dell Latitude 7230 Rugged Extreme Tablet specifications [4]

Specification	Details
Processor	12th generation Intel Core i5-1240P
Memory (RAM)	16 GB LPDDR 2x
Storage	256 GB NVMe SSD
Operating system	Windows 11 Professional
Screen	12-inch FHD (1920 x 1080) anti-reflective, capacitive multi-touch
Graphics	Intel Iris Xe Graphics
GNSS	Integrated GNSS with support for GPS, QZSS, GLONASS, Galileo and BeiDou
Connection	Wi-Fi 6E, Bluetooth 5.2, optional 4G LTE and 5G
Ports	2 x USB 3.2 Gen 1 Type-A, 2 x Thunderbolt 4, HDMI, RJ-45, microSD
Battery	Double replacement battery, up to 25 hours of operation
Endurance	MIL-STD-810H, IP65
Dimensions	312 mm x 203 mm x 24 mm
Weight	1.35 kg

Both tablets were rigorously tested in harsh winter

conditions, at extremely low temperatures (below -20°C), where they proved to be exceptionally durable and functional. Additionally, they worked reliably and efficiently in hot summer conditions, even in environments with high humidity, intense sunlight, and heavy dust exposure.

Table 2. Trimble T100 tablet specifications [5]

Specification	Details
Processor	8th generation Intel Core i5
Memory (RAM)	16 GB LPDDR4
Storage	512 GB SSD
Operating system	Windows 10 Professional
Screen	10.1-inch WUXGA (1920 x 1200) capacitive multi-touch
Graphics	Intel HD Graphics 620
GNSS	Integrated GNSS with support for GPS, QZSS, GLONASS, Galileo and BeiDou
Connection	Wi-Fi 802.11, Bluetooth 5.1, 4G LTE
Ports	USB 3.0, microSD, SIM slot, audio jack
Battery	Lithium-ion, up to 10 hours of operation
Endurance	MIL-STD-810G, IP65
Dimensions	279 mm x 200 mm x 18.5 mm
Weight	1.65 kg

TruPulse R360 rangefinder

The TruPulse R360 is an advanced laser rangefinder designed for professionals who require the utmost precision and reliability in measuring distances and heights. This device is ideal for a wide range of applications, including surveying, engineering, forestry, environmental protection, and construction. The TruPulse combines high performance, ease of use, enabling users to perform measurements with high precision and efficiency.

Table 3. TruPulse R360 rangefinder specifications [6]

Specification	Details
Distance Accuracy to Typical / Weak Targets	± 0.2 m / ± 1 m
Inclination Accuracy	± 0.25° Typical
Max Range to Reflective / Nonreflective Targets	2000 m / 1000 m
Azimuth Accuracy	± 0.5°RMS; typical
Communication (COM Port / Bluetooth)	Windows and Android
Scope Magnification	7× / LCD
In-Scope Field of View	10 m on 91.5 m away
Environmental Rating	Waterproof IP56
Temperature Range	-20° to +60° C
Battery	Lithium-ion, up to 8 hours of continuous use
Dimensions	130 mm x 110 mm x 50 mm
Weight	385 g

The rangefinder has been tested in extreme weather conditions, where it provided extremely accurate measurements of non-reflective targets at a distance of up to 1000 meters. In addition to measuring distances, the TruPulse R360 can measure heights, slopes and horizontal distances, providing comprehensive data for a variety of applications. Equipped with Bluetooth technology, it offers easy data transfer to other devices and integration with GIS applications. It's designed to withstand tough off-road conditions, with a rugged construction that's dust and water-resistant, but it proved to be unreliable when measuring due to heavy precipitation (snow and rain) and in conditions of reduced visibility (fog and haze).

Garmin Montana 700

The Garmin Montana 700 is an advanced GPS device designed for diverse outdoor activities, including hiking, camping, fieldwork, and navigation. With its large screen, rugged design, and advanced navigation features, the Montana 700 provides users with a dependable tool for precise navigation and orientation.

The Garmin Montana 700 is equipped with a 5-inch touch-sensitive screen, which enables a clear and transparent display of maps and navigation information, even in direct sunlight. The device is built to withstand challenging conditions, with certification for resistance to water, shock, vibration, dust, and moisture. It supports multiple GNSS (GPS, GLONASS, and Galileo) for precise navigation in demanding environments. It also includes ABC sensors (altimeter, barometer, and compass) for added accuracy. The device comes pre-loaded with TopoActive maps for Europe. Furthermore, it supports Wi-Fi, Bluetooth, and ANT+ to connect with other devices. It allows users to load digital surfaces from other devices and download satellite images through the Garmin Explore application. A detailed specification is given in Table 4.

Table 4. Specifications Garmin Montana 700 [7]

Specification	Details
Storage	16 GB of internal memory, microSD slot for expansion
Screen	5-inch WVGA (800 x 480) touchscreen, sunlight readable
GNSS	GPS, GLONASS, Galileo
Connection	Wi-Fi, Bluetooth, ANT+
Ports	USB, microSD slot
Sensors	Altimeter, barometer, compass

Endurance	MIL-STD-810G, IPX7
Temperature Range	-20° to +60° C
Battery	Rechargeable lithium-ion, up to 18 hours in GPS mode
Dimensions	183 mm x 87.6 mm x 32.7 mm
Weight	397 g

The Garmin Montana 700 is a premium GPS device intended for dedicated enthusiasts and professionals who require reliable and precise navigation in all conditions. Its robust design, large screen, and advanced navigation features make it an ideal choice for outdoor activities and fieldwork.

3.3. Integration of modern devices

Technological progress witnessed through the implementation of GIS software and the use of sophisticated mobile devices for orientation has significantly improved the capabilities of the Serbian Army. These tools enable precise planning, efficient execution of operations, and improved training, which are essential for the modern military. The integration of these modern technologies into military operations not only increases the efficiency and safety of military personnel but also contributes to better preparation for facing complex challenges in the field.

Using GNSS, locating the device itself is very simple and fast, but locating distant targets requires the interconnection of two devices. Figure 7 shows the integration of the rangefinder and the tablet using the ArcPad software, when determining the position of distant targets. The target is automatically positioned on the topographical surface, and all other measured parameters (coordinates, distance, azimuth and inclination) are displayed in an additional window. This integration eliminates the need for manual data entry, reduces the possibility of errors and speeds up the entire process.

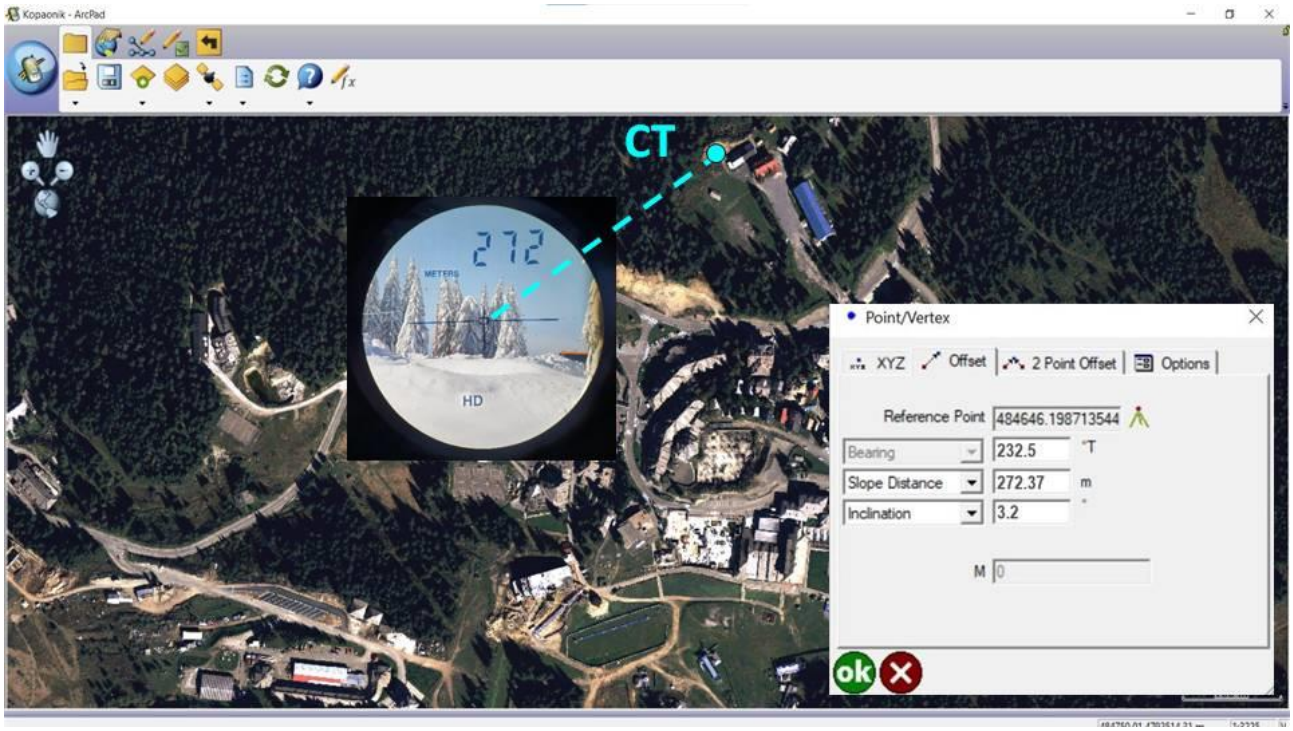

Figure 7. Locating a distant target by integrating mobile devices

4. COMPARISON OF TRADITIONAL AND MODERN METHODS

A significant challenge with traditional teaching methods in topography is promoting cadets' abstract thinking through three-dimensional visualization of two-dimensional topographical information. This visualization is crucial for learning how to make informed decisions in command. Without a solid grasp of basic topography concepts, conducting accurate spatial analysis becomes virtually impossible. Current GIS technologies can significantly enhance comprehension of these concepts and nurture abstract thinking. They do so by improving cadets' abilities to recognize, use, and analyze maps, and relate their content to real-world field examples.

By integrating modern GIS teaching methods, complex natural elements, spatial distribution of social phenomena, and abstract concepts can be presented in a dynamic, three-dimensional, intuitive manner. This approach enables efficient clarification of terrain information, improving the speed and accuracy of terrain element calculations. GIS technologies are already being used in topographic teaching, implementing interactive, autonomous, exploratory, and networked learning methods. These not only facilitate the acceptance of new information but also provide multisensory stimulation and combined visual-auditory perception. This results in cadets receiving more comprehensive and deeper information. A three-dimensional representation of the terrain, combined with various data of significance, besides enhancing teaching, facilitates on-the-spot

investigations at the battlefield rear, geographic evolution, development process, and distant space environment perception. Spatial analysis technology allows us to abstract battlefield environment problems into conceptual models, thereby solving specific terrain-related application problems [8].

While modern GIS technologies offer numerous advantages, traditional methods such as using printed maps and compasses remain vital. In cases where digital systems fail or are unavailable, military personnel must rely on these basic tools to continue their operations. Therefore, military education emphasizes a balance between traditional and modern methods.

The ability to navigate using traditional topographic methods ensures that soldiers are prepared for any situation, including those where technological tools are not available or reliable due to system failures or lack of satellite access.

Figure 8. Using traditional means combined with modern technologies in practical topography training

5. CONCLUSION AND RECOMMENDATIONS

Military topography teaching is a fundamental element of military education. It provides cadets with the necessary knowledge and skills to navigate the field effectively and plan military operations with precision. The combination of theoretical knowledge, practical training, and the use of modern technologies ensures that future officers are ready for the challenges that await them in their careers. Through this comprehensive training, soldiers develop the ability to think critically, plan accurately, and execute tasks efficiently, which are critical to success in military operations.

The integration of traditional orientation methods with modern technological tools equips cadets with the comprehensive knowledge and skills needed to face complex challenges in the field. During classes, cadets are trained on how to use these technologies. However, the importance of mastering basic methods of orientation is also emphasized, equipping them to navigate even in situations where technology is not available or reliable.

In order to improve the teaching process of Military Topography, it is necessary to continue monitoring technological achievements. The idea is to create a realistic virtual environment in which different scenarios and terrains can be simulated. Using this simulator, cadets can practice the necessary skills required for precise movement in unfamiliar or complex conditions without going into the field. These simulations could offer a realistic and effective alternative for skill development in Military Topography.

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