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ORIGINAL

The Digital Transformation: Challenges in Topographer Education

La transformación digital: los retos en la formación del topógrafo

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ABSTRACT

From its origins, topography has been a cornerstone in the design and materialization of civil engineering projects, forming the basis for accurate planning and construction. Globalization and technological evolution have minimized historical limitations in topographic surveys, enabling more extensive work with less personnel and in less time. Currently, this progress is driven by digital transformation, such as Artificial Intelligence (AI), which is revolutionizing the discipline by potentially influencing nearly most of topographers' main tasks in the next decade, according to a recent report by the Royal Institution of Chartered Surveyors (RICS). This presents the challenge of training professionals capable of mastering these new technologies and generating high-quality geoinformation for construction projects. This essay explores how digital transformation is modifying the field of topography and geomatics, analyzing the benefits and risks that emerge for professionals and the training of future topographers, in a context where the importance of topography is undeniable, but its evolution requires a deeper and more current examination.

Keywords: Civil Engineering Works; Digital Transformation; Geomatics; Professional Training; Revolution 4.0.

RESUMEN

Desde sus orígenes, la topografía ha sido una piedra angular en el diseño y la materialización de proyectos de obras civiles, siendo la base para una correcta planificación y construcción. La globalización y la evolución tecnológica han minimizado las limitaciones históricas en los levantamientos topográficos, permitiendo trabajos más extensos con menos personal y en menor tiempo. Actualmente, este avance se ve impulsado por la transformación digital como la Inteligencia Artificial (IA), que está revolucionando la disciplina al influir potencialmente en casi la mayoría de las tareas principales de los topógrafos en la próxima década, según un informe reciente de la Royal Institution of Chartered Surveyors (RICS). Esto plantea el desafío de formar profesionales capaces de dominar estas nuevas tecnologías y generar geoinformación de alta calidad para proyectos constructivos. El presente ensayo explora cómo la transformación digital está modificando el campo de la topografía y la geomática, analizando los beneficios y riesgos que emergen para los profesionales y la formación de futuros topógrafos, en un contexto donde la importancia de la topografía es innegable, pero su evolución requiere una mirada más profunda y actual.

Palabras clave: Formación Profesional; Geomática; Obras Civiles; Revolución 4.0; Topografía.

INTRODUCTION

Topography, described as a science, technique, art, or discipline, allows the measurement of the Earth's surface and its natural or anthropic characteristics to represent them in scale plans. It is considered one of the oldest and most important arts, essential for the demarcation of boundaries and the quantification of surfaces since ancient times.[1] Today, its applications are vast, ranging from the orientation and dimensioning of land to the surveying of baselines for civil engineering projects and their layout in the field.[2] Various branches of engineering and architecture draw on topography to obtain accurate information about the position, dimensions, and shape of the terrain, which is the starting point for any study or project.[3,4]

Although topography has always been fundamental, the changes brought about by the emergence of new technologies have driven its evolution toward paths full of opportunities.[5] Instruments such as high-precision theodolites, electronic distance meters, laser collimators, and remote sensing using drones and satellite images have greatly facilitated topographic work. However, understanding how these instruments and new techniques work requires a solid knowledge of the theoretical fundamentals to ensure their correct application and prevent professionals from becoming mere button pushers who do not understand the reasons behind the results.[3,6]

Digital transformation requires a thorough review of the training of surveying professionals, a challenge that is already evident in the UK construction industry, where a shortage of skills in this field is restricting its growth.[7] To overcome this, surveying education must prioritize a strong practical component and the use of up-to-date instruments and software. This is part of educational innovation, which involves transforming teaching methods, incorporating technologies, and improving teaching practices.[8] The goal is to train professionals with the necessary skills to quickly integrate into the labor market, while maintaining a solid theoretical foundation.

In this context of rapid technological evolution, Artificial Intelligence (AI) and its application in the geospatial field is emerging as an unprecedented transformative factor.[9,10,11] AI not only optimizes existing tools, but also redefines the role of the surveyor and the way civil engineering projects are conceived and executed. This essay will delve into how AI is dramatically changing the field of surveying and geomatics, its benefits, and the challenges it presents for professionals and academic training.

DEVELOPMENT

History and Evolution of Surveying into the Age of AI

Surveying, understood as the detailed description of the Earth's surface, has accompanied the history of humanity, providing the graphic representation of landforms and details on scale plans.[12,13] It is estimated that the ancient Egyptians carried out the first topographic work more than 3,000 years ago, using geometry to divide plots of land and restore boundaries destroyed by the flooding of the Nile, using "knotted ropes".[14,15,16]

Throughout history, surveying has been crucial in major construction projects around the world, from railways and the Hoover Dam in the United States to the construction of the Panama Canal (figure 1) and viaducts in Europe. The evolution of topographic instruments has been constant, from the Gnomon (560 BC) and the Dioptra, which allowed the measurement of angles, and Vitruvius' descriptions of distance-measuring carts using turn counters, to the invention of the first theodolite in 1720 by Jonathan Sisson.[6]

Figure 1. Symbolic representation of the surveying work carried out on the Panama Canal. Scene with plaster figures in the Canal Museum.

The 20th and 21st centuries witnessed rapid evolution, driven by rising land costs and technological

progress. Photogrammetry, computers, robotic total stations, 3D lasers, and the Global Positioning System (GPS) were incorporated into surveying work, allowing for more accurate and efficient surveys of large areas. These advances laid the foundations for what we now know as Modern Surveying, characterized by the use of robotic total stations, high-precision GPS, and digital scanners that generate three-dimensional point clouds.[3,17] Drone technology, in particular, has emerged as a versatile and multidisciplinary tool for geospatial data acquisition, revolutionizing photogrammetry and remote sensing (figures 1 and 2).

Currently, this evolution is transitioning into the era of Artificial Intelligence. AI is not just a new tool; it is a paradigm that enhances existing technologies. For example, Machine Learning and Deep Learning algorithms allow the vast point clouds generated by laser scanners and drones to be automatically processed and classified, identifying objects, surfaces, and anomalies with a speed and accuracy that cannot be achieved manually.[18,19] AI facilitates the integration and analysis of geospatial data from multiple sensors (satellites, drones, IoT sensors), creating predictive models and digital twins of infrastructure.[20] This qualitative leap transforms topography from a discipline of "data collection" to one of "intelligent analysis and proactive management of geoinformation," driving strategic decision-making at every stage of a project.

Figure 2. GPS equipment with RTK differential GNSS technique

Figure 3. Application of remotely piloted aircraft (drones) to produce aerial orthophotographs and digital elevation models (DEM)

Impact of AI on the professional field of Surveying and Geomatics

The integration of Artificial Intelligence is profoundly changing the field of surveying and geomatics. This impact is evident in several key areas:

- *Automation and efficiency:* AI automates repetitive and high-volume tasks, such as point cloud

classification, terrain feature detection, and 3D model generation. This not only significantly reduces time and cost, but also minimizes human error.[21] Professionals can devote more time to critical data analysis and complex decision-making, rather than manual collection and processing.

- *Data accuracy and quality:* AI algorithms improve the quality and reliability of geospatial data, enabling the detection of inconsistencies and the optimization of models (Zambrano)[11]. This results in more robust information for the design and execution of civil works, reducing risks and costs associated with inaccuracies.
- *New services and applications:* AI opens the door to innovative services. For example, intelligent real-time infrastructure monitoring through the analysis of data from sensors and drones, predictive maintenance of civil works, or the simulation of complex construction scenarios to optimize resources and safety.[22] The ability to generate and analyze "digital twins" of projects enables comprehensive management from the planning phase through to operation.
- *Integration of data sources:* AI facilitates the fusion of heterogeneous information from different platforms (satellite images, data obtained using Light Detection and Ranging <LiDAR> technology, aerial photographs, terrestrial sensors) into a single analysis environment. This provides a holistic and multidimensional view of the terrain and projects.[23]

Benefits and risks for professionals and training

The surveying industry is experiencing an impact from digital services that is as profound and transformative as any other profession. Unlike previous technological revolutions, where the tangible nature of buildings offered some protection, surveying will no longer have that insulation. The convergence of technologies such as the Internet of Things, building management systems, and Building Information Modeling (BIM) will expose surveyors to rapid and uninterrupted change.[24]

The incorporation of AI into surveying brings both substantial benefits and significant challenges for professionals and educational processes:

Benefits

- Increased productivity and new opportunities: AI allows more work to be done in less time, increasing the productivity of surveyors. This does not necessarily imply a reduction in staff, but rather a reorientation toward higher value-added roles, such as geospatial data analysts, algorithm developers, or AI project managers.[25]
- Reduced risks in the field: The implementation of new technologies such as drones and autonomous vehicles in the automation of surveying optimizes operations, relieving staff of arduous, repetitive, and tedious tasks.[26] This results in a crucial reduction in human exposure to risky or inaccessible geographical environments.
- Improved work quality: AI can identify patterns and anomalies in large data sets that would go unnoticed by the human eye, increasing the accuracy and quality of surveying deliverables.[27]
- Boosting innovation: The application of AI encourages research and development of new methodologies and tools, keeping surveying at the forefront of technology.[28]

Risks and Challenges

- *Need for constant updating:* Professionals must acquire new skills in areas such as programming (Python, R), data analysis, machine learning, and geospatial database management. Skill obsolescence is a real risk if there is no commitment to continuous learning.
- *Skills gap:* The rapid advancement of AI can create a gap between professionals who master these new tools and those who do not.
- *Technological investment:* Implementing AI solutions requires significant investment in specialized software, high-performance hardware, and cloud storage capacity.
- *Loss of intuition without fundamentals:* As mentioned above, there is a latent risk of turning surveyors into button pushers if the theoretical fundamentals and critical interpretation of AI-generated results are not reinforced. An understanding of surveying principles is essential for validating and contextualizing AI information.
- *Ethical and privacy issues:* The handling of massive volumes of geospatial data, including land and property information, raises ethical and privacy challenges that must be addressed with appropriate regulatory frameworks.

The challenges facing surveying professionals and their training

In a globalized and highly competitive world, engineering and construction professionals, including surveyors, require skills and competencies aligned with current technological developments. For Alcántara[3], surveying is

fundamental in the training of engineers and architects, not only because of the technical skills it confers, but also because of its educational influence.

The future of the surveyor lies in the ability to adapt to these technological changes. As established by Cabel by Jiménez et al.[17], one of the main challenges is to implement a new paradigm based on computer theories and an interdisciplinary approach in traditional surveying curricula. The ideal educational profile should integrate Measurement Sciences and Land Management under the broad umbrella of Geographic Information Management, now deeply influenced by AI.

In 2013, Dr. Israel Quintanilla already pointed out that "everything is moving very fast because, just as remote sensing is evolving, so is photogrammetry with laser scanning, and that is what it means to be the surveyor of the future: adapting to new technologies in the conditions of the environment in which we find ourselves".[29] Today, that adaptation extends crucially to Artificial Intelligence.

AI applications require powerful and efficient computer equipment to meet the new demands of students. However, a common problem in schools and homes is a lack of resources or insufficient funding, resulting in obsolete equipment or, quite simply, the absence of any devices, creating a significant barrier to learning.[8]

CONCLUSIONS

Surveying continues to play an essential role in the design and construction of civil engineering projects, serving as the fundamental starting point and facilitating subsequent processes through accurate surveys and stakeouts. Global population growth and the resulting demand for infrastructure have intensified the need for frequent, high-quality surveying work, requiring professionals capable of generating reliable inputs for designers.

Globalization and the emergence of new technologies, especially Artificial Intelligence, have dramatically accelerated the way surveying work is carried out. Today, the combination of remotely piloted aircraft (drones) and other advanced georeferencing techniques, powered by AI algorithms, allows tasks to be performed more quickly, efficiently, and with fewer personnel. AI not only optimizes data acquisition, but also transforms the capacity for analysis and the generation of valuable information, enabling more informed and strategic decision-making.

It is imperative that educational processes adapt to this new reality. Higher education institutions must implement teaching with a high practical component, without neglecting a solid theoretical foundation, and must have up-to-date tools and programs that integrate AI. Training programs must be developed that allow professionals to quickly enter the workforce, keeping pace with the technological growth of instruments and software, but always based on the principles of the discipline. The surveyor of the future must be an expert in the application of AI for surveying work, a geospatial data analyst, and a strategist in the implementation of solutions that optimize the life cycle of civil works.

Surveying training programs must evolve to:

- *Strengthen theoretical foundations*: Ensure that professionals understand the underlying principles of surveying and geomatics, which is vital for interpreting and validating the complex results produced by digital transformation.
- *Integrate programming and data analysis skills*: Train students in relevant programming languages and the use of tools for massive geospatial data analysis.
- *Teach applied machine learning and deep learning:* Provide specific knowledge on how to apply AI algorithms for classification, segmentation, prediction, and modeling in geospatial environments.
- *Promote the use of AI platforms and tools:* Familiarize future surveyors with specialized software, cloud computing platforms for geoprocessing, and advanced visualization tools.
- *Encourage critical thinking and problem solving:* Develop students' ability to tackle complex challenges where AI is a tool, not the ultimate solution.

This approach will ensure that surveying professionals are not only competent in the use of current technologies, but also agents of change, capable of innovating and leading the implementation of AI-based solutions to meet the demands of 21st-century civil engineering.

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