Universitatea Tehnică de Construcții București
Facultatea de Geodezie

HABILITATION THESIS

Contributions to the Development of Systems for the Acquisition, Processing and Integration of Geodetic and Geospatial Data

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ABSTRACT

The habilitation thesis “Contributions to the Development of Systems for the Acquisition, Processing and Integration of Geodetic and Geospatial Data” summarizes the scientific, teaching and professional activity that I have carried out after obtaining the doctoral degree. The thesis presents the consolidation of my own research direction in geomatics, at the intersection of engineering geodesy, astronomo-geodesy, multisensor technologies and geospatial informatics. The work analyses the development of systems for the acquisition, processing and integration of geodetic and geospatial data, in which instrumentation, observation methodology, data verification, processing algorithms and software applications are treated as parts of the same technical workflow.

In this approach, data acquisition, measurement, instrument verification, observation synchronization, numerical processing and the integration of geospatial information are not independent stages. They form a unified technical process, aimed at controlled, reproducible results that can be used in research and engineering practice. I considered that the performance of a geodetic system should not be evaluated only through the accuracy of the instrument used, but through the coherence of the entire chain of work: observation design, monumentation of points, error control, data recording, processing and integration of the results into a verifiable geospatial framework.

The starting point of this research direction is my doctoral research on the use of digital imagery for acquiring data intended for geospatial information systems, with applications in landslide identification and monitoring. After obtaining the doctoral degree, this concern extended to precise geodetic measurements, validation of satellite products, astronomo-geodetic observations, design of multisensor platforms and development of software applications required for automating data acquisition and processing. The contributions presented in the thesis are organized into three main research directions.

The first research direction is oriented towards high-precision terrestrial geodetic measurements, used for monitoring natural hazards and infrastructure, validating satellite products and supporting astronomo-geodetic determinations. Within this research direction, I developed and applied methodologies that integrate GNSS observations, precise geometric levelling, total-station measurements, digital terrain models and InSAR products. These methods were used in applied research projects, among which the GEOSPACE project is an important milestone.

Within the GEOSPACE project, as leader of Partner P1, I coordinated the design and implementation of a geodetic monitoring network in Bucharest. The network included two control points and eighteen monitoring points. For the new points, I designed a monumentation system dedicated to multi-epoch monitoring, based on forced centering elements and on the use of a fixed-height rod. This solution reduced the influence of errors associated with repeated GNSS antenna-height determination and enabled the comparison of observation series carried out in successive campaigns. GNSS observations were complemented by precise geometric levelling, and the results were used for displacement analysis and for the validation of InSAR products.

The second research direction concerns the development of platforms and instruments dedicated to the astronomo-geodetic determination of the deflection of the vertical. This research direction marks the transition from adapting commercial instruments to designing dedicated observation systems. Within the AGEO project, in which I coordinated the activity of Partner P1, the instrumental and software foundations of the mobile platform were defined. I pursued the integration of the high-precision total station, the camera, the optical components, the time

receiver and the field computer into a system capable of supporting controlled astronomo-geodetic observations.

At this stage, I paid particular attention to the control of instrumental errors of the Topcon MS05AX total station. I analysed the determination of instrumental errors, the activation and deactivation of automatic corrections and the behaviour of the biaxial compensator. These verifications were necessary because astronomo-geodetic observations use azimuthal directions and zenith distances for which collimation errors, the error of the secondary axis, the index error and the residual inclination of the vertical axis may directly influence the final result. I treated instrument calibration and verification as part of the observation methodology, not as a separate preparatory operation.

Also within the AGEO platform, I evaluated the optical components, mounts and diagonal eyepiece, because the technical objective was the transition from visual astronomical observation to electro-optical observation. I verified the compatibility between the total station, the CCD camera, the optical micro-components and the mounting solutions. This stage was necessary in order to control image stability, mounting geometry and the transfer of mechanical or optical errors into the acquisition and processing stages.

The mobile platform was also tested as a unified system. I followed the simultaneous operation of the geodetic instrument, the optical system, the camera, the time receiver, the field computer and the acquisition application. The tests examined the connections, the stability of the assembly, the automatic guidance of the instrument, image quality and continuity of acquisition. This functional validation confirmed that observational performance does not depend on a single component, but on the integration of mechanics, optics, electronics, temporal synchronization and acquisition software.

The results obtained in AGEO were continued through the development of the PASSO platform within the ASTRES project, in which I participated as a member of the research team. The initial experimental evaluation of the system with the AVT Guppy Pro F046B CCD camera revealed limitations related to the mass of the assembly, IEEE1394 connectivity, cable rigidity and delays introduced by the Windows operating system. The analysis of these limitations led to the adoption of CMOS sensors, reduction of component mass, migration to Ubuntu and development of dedicated software applications.

This experience was later used in the VERA and ASTROZEN projects. Within the VERA project, which I coordinated, I pursued the mechanical and functional optimization of the total-station-based platform. Several design variants of the mount were designed, manufactured and experimentally evaluated, using CAD design and additive manufacturing. The result was a platform validated in laboratory conditions and field campaigns. Within the ASTROZEN project, a distinct zenith instrument was developed, based on a refracting telescope, high-precision inclination sensors and a portable mechanical structure mounted on a geodetic tribrach. The sensitive constructive details are discussed in the thesis only at methodological and conceptual level, considering the intellectual protection stage of the solution.

The third research direction is devoted to software development, observation automation and the integration of results into geospatial workflows. The software component was developed in parallel with the instrumentation. The first application was created within the AGEO project and later extended for the PASSO and VERA platforms. It controls image acquisition, temporal synchronization, the virtual reticle, camera parameters, the apparent trajectory of stars and the organization of observation files. The processing module ensures star identification, application of astronomical reductions, construction of mathematical models and determination of the components of the deflection of the vertical. For ASTROZEN, a distinct application was developed, adapted to its own instrumental architecture. The software ecosystem was developed using C, MATLAB and Python.

The results presented are supported by participation in competitively funded research projects, publications in specialized journals and proceedings of international conferences, as well as by the elaboration of books and university materials. An important result of this activity is the development of functional prototypes, experimentally validated and usable in real applications. The VERA and ASTROZEN platforms demonstrate the maturation of this research direction, through the transition from component testing to the development of integrated systems for observation, processing and validation.

Teaching activity was correlated with research activity. I integrated the results obtained into laboratory applications, diploma projects, dissertations, software projects and teaching materials. Undergraduate and master's students were involved in the design and monumentation of geodetic networks, the execution of observation campaigns, software development and verification of results. This approach supported the formation of applied skills and created the premises for interdisciplinary teams capable of working with real data, geodetic instruments, algorithms and reproducible processing workflows.

The second part of the thesis presents the research directions proposed for the post-habilitation stage. They are formulated in continuity with the results obtained so far. Within the first research direction, the emphasis is placed on the innovation of astronomo-geodetic techniques through numerical computation, the automation of observation acquisition and the development of integrated systems for astronomo-geodetic observations. The second research direction aims to integrate data from GNSS, InSAR, TLS, photogrammetry, LiDAR and satellite observations into models for analysis, validation and forecasting, for monitoring natural hazards, terrain dynamics and critical infrastructure. Within this research direction, GeoAI methods will be used for the analysis, classification, interpretation and correlation of complex geospatial datasets. The third research direction aims to develop integrated geospatial platforms for monitoring, analysis and technical decision support.

The academic strategy associated with these three research directions aims to consolidate a research platform in geodetic engineering. I intend to systematically integrate Python programming, geospatial automation and artificial intelligence methods into the training of future geodetic engineers. I will pursue the development of interdisciplinary teams capable of participating in national and international research projects. Future activity will be oriented towards verifiable results: software applications, processing methods, scientific articles, submitted projects, institutional collaborations and technology transfer.

Overall, the thesis presents the maturation of my own research direction, built on the development of systems for the acquisition, processing and integration of geodetic and geospatial data. I followed the entire technical chain: instrumentation design, observations, error control, numerical processing, data integration and interpretation of results. The main contribution consists in the unified treatment of methodological, instrumental and software components. Through the results obtained and through the research directions proposed for the post-habilitation stage, the thesis supports the continuation of applied research in geomatics, astronomo-geodesy, geospatial monitoring and automated data processing.