Universitatea Tehnică de Construcții București
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HABILITATION THESIS

MODELING OF THE GEOID AND QUASIGEOID, GNSS TECHNOLOGIES, AND APPLIED GEODETIC ASTRONOMY

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Abstract

This habilitation thesis summarizes an academic, scientific and professional path developed around modern geodesy, precise measurements and the integration of data obtained from different observation systems. The central idea of the thesis is the connection between reference surfaces, coordinate systems and the way in which geodetic, satellite and astro-geodetic observations can be transformed into reliable results for research, education and engineering practice. I have approached my postdoctoral activity as a continuation of my initial scientific training, but also as a gradual maturation of the topics that define my current research profile. The thesis therefore does not present isolated achievements, but a coherent line of work in which theory, field observation, numerical processing, validation and practical use are treated as parts of the same process.

The thesis is organized around three main research directions. The first direction is devoted to geoid and quasigeoid modelling, with emphasis on the development and modernization of altimetric reference surfaces. This direction starts from the fact that modern height systems require a well-determined reference surface, consistent with current geodetic reference frames and validated by independent data. The work discussed in this part concerns gravimetric, geometric and combined approaches, the use of global, regional and local models, the integration of GNSS/levelling observations and the assessment of the quality of the obtained solutions. I consider this direction to be the scientific core of the thesis, because it connects my doctoral research with my later work and with the broader need to modernize national geodetic infrastructure.

The second research direction concerns advanced applications of GNSS technologies in the realization, validation and exploitation of geodetic works and results. GNSS is no longer only a positioning technique; it is now a complex environment made of satellite constellations, permanent networks, precise products, real-time services, post-processing strategies and integrated monitoring applications. In this direction, I focus on the role of GNSS observations in geodetic networks, deformation monitoring, the validation of satellite products and the connection between horizontal and vertical reference systems. This topic allows me to make use of the practical and institutional experience accumulated in field campaigns, repeated measurements, reference networks and engineering applications where precision is not only a technical parameter, but also a condition for the correct interpretation of the observed phenomena.

The third research direction is applied geodetic astronomy, from observations and astro-levelling networks to advanced processing and statistical validation. I have treated this topic as a distinct direction because astro-geodetic observations have regained importance during the last decade. They provide independent information on the deflection of the vertical and may be used to verify, validate and improve existing geoid and quasigeoid models, especially when combined with GNSS/levelling and gravimetric information. In this part of the thesis, the emphasis is not limited to observation techniques. I also discuss the processing of astro-geodetic measurements, network adjustment, statistical testing, residual analysis, quality control and the automation of computational workflows.

The three directions should not be interpreted as separate and unrelated areas. They form a coherent research architecture. Geoid and quasigeoid modelling requires GNSS/levelling data, gravity information and, in specific cases, astro-geodetic observations. GNSS applications require stable reference frames, transformation models and reliable vertical reference surfaces. Geodetic astronomy becomes more relevant when its results are integrated into geoid validation,

quality control and the construction of local or regional models. For this reason, the thesis proposes not three parallel tracks, but an integrated programme in which each direction supports the others and the final results become more robust through methodological convergence.

A transversal component of my work is programming and the automation of geodetic processing. My early exposure to scientific computing, specialized geodetic software and the development of my own processing routines shaped the way I understand research in geodesy. Data processing is not a mechanical stage placed after observation; it is an essential part of the scientific result. The quality of a geodetic product depends on the observations, but also on data organization, traceability, the statistical criteria used and the possibility of reproducing the computations. For this reason, one of my future objectives is to develop and consolidate software tools for quasigeoid modelling, GNSS/levelling validation, astro-geodetic processing and the generation of reproducible technical reports.

The general scientific objective of the thesis is to formulate a coherent research programme in geodesy, focused on the integration of classical and modern observations for the production of robust geodetic results. This objective can be expressed through several concrete goals: improving methodologies for altimetric reference surface determination, extending the use of GNSS for validation and monitoring, bringing astro-geodetic observations back into applied research, and developing software instruments that make processing more transparent, faster and easier to verify. At the same time, the thesis shows that university research can respond to real needs of geodetic practice while preserving theoretical and methodological rigour.

From an educational point of view, the thesis supports the development of my academic career in direct connection with research. I intend to transfer the results and future directions into courses, seminars, laboratory work and research topics for undergraduate students, master students and doctoral candidates. Modern geodesy requires updated teaching applications: real data sets, complete processing workflows, code examples, comparisons between methods, sensitivity analyses and statistical validation exercises. I do not see teaching as the simple delivery of information, but as the formation of a technical way of thinking. Students should understand where observations come from, how they are processed, which assumptions are used and how much confidence can be assigned to a result.

The future perspectives of the thesis are organized on three levels. The first level concerns the consolidation of my own research, through methods and software tools developed for the three directions. The second level concerns the formation of a research group, by involving doctoral candidates and young researchers in concrete topics based on real data and clearly defined objectives. The third level concerns international visibility, through publications in high-quality journals and collaboration with groups working in physical geodesy, GNSS, remote sensing and geodetic astronomy. In the coming years, I intend to support these directions through research proposals, including national funding instruments dedicated to research, development and innovation.

This development cannot be separated from a working culture based on data, code and verification. I intend doctoral candidates and master students involved in future topics to work with real observation sets, to understand the limitations of each method and to contribute to reproducible applications. Through such topics, research becomes more than an individual activity; it becomes a training environment. Students can learn how a model is built, how a result is tested, how an error is identified and how a technical conclusion is written honestly. For me, this is one of the important meanings of habilitation: transforming accumulated experience into a working environment for others.

In the next stage, the future directions must be clear enough to generate doctoral topics, teaching applications and publishable results. In geoid and quasigeoid modelling, the objective is to develop computational workflows that allow the controlled testing of several alternatives: gravimetric solutions, geometric GNSS/levelling solutions, hybrid solutions, different interpolation strategies and independent validation scenarios. In GNSS, the objective is to consolidate observation and processing methodologies for specialized works, monitoring and satellite validation. In geodetic astronomy, the objective is to use observations of the deflection of the vertical within a modern framework in which measurement, adjustment, statistical testing and integration with geoid models are treated as parts of the same process.

Through this habilitation thesis I aim to show that the experience gained in academic work, research contracts and applied geodetic projects can be transformed into a mature programme for doctoral supervision. I believe I can offer doctoral students a working environment that combines field measurements, geodetic theory, numerical computation, programming, statistical interpretation and scientific writing. The proposed directions can generate current research topics with national relevance and international visibility: local and regional quasigeoid models, validation of satellite products through GNSS observations, astro-geodetic networks, adjustment algorithms, automated processing and software applications for the quality control of geodetic data.

In conclusion, the thesis proposes a view of geodesy as a discipline of precision and, at the same time, as a living field located at the intersection of infrastructure, satellites, terrestrial observations, software and education. The contributions presented here are not only past achievements; they are also starting points for the next stage of my academic career. I intend to continue research in geoid and quasigeoid modelling, to develop GNSS applications for specialized geodetic works and to strengthen the component of geodetic astronomy through modern processing and statistical validation. At the same time, I assume the development of a research and teaching environment in which rigour, clarity, collaboration and practical relevance remain essential criteria.