MINISTRY OF EDUCATION AND RESEARCH

TECHNICAL UNIVERSITY
OF CLUJ-NAPOCA, ROMANIA

Fundamental field: Engineering Sciences
Specialisation: Electronics, Telecommunications, and Information Technologies

HABILITATION THESIS
– ABSTRACT –

Applied Signal Processing: Contributions to Robotics, Environmental Monitoring, Filter Design, and Natural Language Processing

Assoc.Prof.Eng. Lăcrimioara-Romana GRAMA, PhD
Faculty of Electronics, Telecommunications and Information Technology
Technical University of Cluj-Napoca

– Cluj-Napoca –
2025

str. Memorandumului nr. 28, 400114 Cluj-Napoca, România
tel. +40-264-401200, fax +40-264-592055, secretariat tel. +40-264-202209, fax +40-264-202280
www.utcluj.ro

Thesis Table of Contents

The habilitation thesis entitled *Applied Signal Processing: Contributions to Robotics, Environmental Monitoring, Filter Design, and Natural Language Processing*, submitted by **Lăcrimioara-Romana GRAMA**, proposes a coherent research program at the intersection of robot audition, embedded signal processing, and human–robot interaction, with sustained emphasis on assistive and healthcare contexts. The central objective is the design and validation of signal processing solutions that enable service robots to perceive, interpret, and respond to auditory information in realistic environments, while meeting constraints of latency, energy efficiency, and robustness. Complementary contributions in environmental monitoring, filter design and phase approximation, as well as natural language processing, extend this program, confirming the role of applied signal processing both as a scientific discipline and as a driver of societal impact. Methodological rigor, reproducibility, and practical relevance guide the thesis throughout, with results validated through public datasets, transparent evaluation protocols, and embedded-ready implementations.

The thesis is organized into two parts. **Part I** provides a retrospective synthesis of achievements obtained after the doctoral stage and outlines the candidate's evolution as educator, researcher, and academic leader. **Part II** defines a forward-looking agenda for the next decade, demonstrating strategic vision and alignment with European and national research priorities.

The first part comprises four chapters. The chapter on **academic achievements** highlights constant contributions to teaching and curriculum development, the coordination of courses and laboratory activities, and the integration of research results into the educational process. Teaching experience spans over two decades, covering courses in digital signal processing, adaptive filtering, and data modeling and analysis for decision support, delivered either in Romanian or in English. Curricular innovation has been supported by online resources, project-based learning, and digital assessment. More than 30 bachelor's and 15 master's theses have been supervised, many of them awarded, with some results published jointly with students. Doctoral mentorship has led to relevant contributions in robotics, audio processing, and natural language processing.

The chapter on **professional achievements** emphasizes involvement in institutional leadership and academic governance, including the role of Vice-Dean of the Faculty of Electronics, Telecommunications and Information Technology, coordination of admissions and scholarship processes, and participation in the EUt+ European academic alliance. Responsibilities also included coordinating national research grants in areas such as phase approximation, robotics, environmental monitoring, and multimodal perception. These projects systematically involved master's and doctoral students, fostering their integration into research and early dissemination of results. The chapter further reviews contributions to the academic community through workshops organization, editorial and peer-review activities for international journals, as well as participation in international leadership (Harvard) and entrepreneurship (Babson College) programs.

Scientific Achievements form the core of the thesis and synthesize original research across four thematic directions: robotics and intelligent platforms, environmental monitoring and intruder detection, filter design and phase approximation, and natural language processing for Romanian.

In **robotics and intelligent platforms**, the research focused on audio perception for service robots, with an emphasis on context-aware interactions. Work centered on the TIAGo service robot (PAL Robotics) and the OMNI-Z platform, developed within a Romanian national research consortium. A key outcome is the *TIAGo Audio Dataset*, released in two phases and

comprising 3300 isolated events across 110 classes. Independently funded and aligned with national research objectives, the datasets were built with consistent acquisition protocols, real-world scenarios, and embedded-friendly formats. Their public release ensured experimental reproducibility, supported systematic benchmarking of classifiers, and facilitated the integration of embedded modules into robotic platforms.

To complement these resources, a *modular software tool* was developed integrating the workflow into ROS (Robot Operating System)-compatible modules: (i) audio stream acquisition with semi-automatic segmentation, (ii) model generation for subsequent classification, and (iii) isolated-event recognition through a lightweight interface that classifies one signal at a time, with rapid repetition enabling session-level throughput. This tool serves both research by enabling rapid comparative evaluations and ablation experiments and education, by allowing hands-on experimentation with real data and models.

To further enable socially aware interaction, the thesis introduces the *first Romanian speech-emotion corpus* tailored for robotic applications, consisting of 2100 recordings labeled across three affective categories: happy, neutral, and sad. This resource supports affect-aware behaviors on constrained platforms, enabling robots to adapt their tone, provide empathetic responses, and react appropriately in situations of stress or distress.

In **environmental monitoring**, the research focused on low-power embedded acoustic sensors for intruder detection and eco-acoustic surveillance. The SASID project developed autonomous sensor nodes integrating sound acquisition, preprocessing, event detection, and wireless transmission. The averaged binary sparsogram, a compact and noise-robust time–frequency representation, was introduced for outdoor conditions. Prototypes validated in both laboratory and field scenarios demonstrated reliable detection of chainsaws, heavy cars, and gunshots, with applications in forest surveillance, biodiversity conservation, and climate-related monitoring.

In **filter design and phase approximation**, the research clarified the theoretical limits of discrete Hilbert transform–based phase recovery, showing its validity only under specific conditions rarely satisfied by real filters. Complementary methods, based on Kramers–Kronig relations and divide-and-conquer Hilbert approaches, improved numerical stability when only magnitude information was available. Circuit synthesis was advanced through a pipeline translating analog schematics or SPICE netlists into digital implementations, enabling modernization of legacy designs and reproducible prototyping. These contributions integrate symbolic modeling, algorithmic analysis, and practical implementation, reinforcing both theoretical understanding and engineering practice.

In **natural language processing**, the focus was on Romanian as a low-resource language. Contributions include corpora and embeddings (CBOW, Skip-gram), optimization-based summarization models, kernel-based scoring methods, and interpretable sparse polynomial classifiers. These tools supported applications in scientific and legal text summarization, synonym detection, and interpretable clinical decision-making. By combining statistical, symbolic, and machine learning approaches, the research promoted linguistic diversity in natural language processing and provided reusable resources for the Romanian research community.

The results are consolidated through peer-reviewed publications, reproducible datasets, and prototypes validated under real-world conditions. Beyond methodological rigor, they emphasize reproducibility, interdisciplinarity, and societal impact, addressing healthcare robotics, environmental protection, filter design automation, and low-resource language

technologies. Collectively, they demonstrate sustained scientific productivity, the anticipation of emerging research directions, and the ability to translate academic innovation into practical and socially relevant solutions.

The final chapter of Part I, **General Conclusions and Qualification Justification**, synthesis the results and substantiate the habilitation application.

Part II includes two chapters. The first outlines the **strategic plan** for the next 5–10 years in research, teaching, doctoral mentorship, and international collaborations. Priorities include artificial intelligence for assistive technologies, sustainable audio-based environmental monitoring with neuromorphic and edge computing architectures, analog-to-digital pipelines for filter design, and multilingual, interpretable natural language processing with a focus on low-resource languages. Educational plans emphasize project-based learning, open resources, and the integration of research into curricula. Doctoral mentorship will focus on reproducibility, responsible data governance, and interdisciplinary collaboration. Internationalization will be strengthened through co-supervision, joint projects, and shared infrastructures in European consortia.

The second chapter, **Final Conclusion**, reaffirms the candidate's commitment to academic excellence, institutional development, and societal relevance.

Overall, the habilitation thesis consolidates a research program centered on applied signal processing, expanded into assistive robotics, audio-based environmental monitoring, circuit-aware filter design, and natural language processing. Contributions include structured datasets, embedded-ready software tools, compact time–frequency representations, clarification of phase approximation theory, practical circuit-to-code tools, and interpretable natural language processing resources for Romanian. These results demonstrate scientific independence, leadership in research and mentorship, and alignment with institutional, national, and European priorities. They provide a solid foundation for sustainable academic development, institutional engagement, and societal impact.