MINISTRY OF EDUCATION AND RESEARCH

TECHNICAL UNIVERSITY
OF CLUJ-NAPOCA, ROMANIA

Fundamental Domain: Engineering
Specialization: Computer Science and Information Technology

HABILITATION THESIS

– SUMMARY –

Advanced Detection, Segmentation and Recognition Models for Static and Temporal Image Data

Assoc. Prof. Dr. Eng. Raluca Didona BREHAR
Faculty of Automation and Computer Science
Technical University of Cluj-Napoca

– Cluj-Napoca –
2026

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

An overview of my research and academic career trajectory, highlighting the evolution of my scientific interests and the goals guiding my work is presented in this thesis. I have presented the main achievements I had in the last years starting from 2015, after defending my PhD. My focus of research is in the field of machine learning, artificial intelligence, computer vision, image processing and data science, all these fields being combined in an interdisciplinary approach in both my research and my academic interests.

The habilitation thesis is structured in several parts and it starts with the description of the scientific and professional achievements. An overview of the most impactfull achievements is presented in Chapter 1 of the thesis. The main domains of research are (i) traffic scene perception and analysis and (ii) medical image processing.

For traffic scene analysis from image data my research is focused on developing models that consider infrared and color images and video sequences. In this context I have developed several methods for real time pedestrian detection and segmentation in infrared images and I have also constructed a model for identifying pedestrians in color and thermal images that are temporally aligned. Another path for original scientific contributions is related to temporal models for action recognition. I have developed approaches for pedestrian street cross action recognition in monocular infrared sequences. The proposed models use reccurent neural networks combined with various features such as: relevant keypoints for pose estimation, motion features, position of pedestrians with respect to the drivable area and their distace with respect to the ego-vehicle. A second research direction for temporal models brings contributions to risk assessment from RGB image sequences. I have developed models that evaluate the degree of risk in a sequence of RGB images. By analyzing temporal patterns and potential hazards, the models provides a framework for proactive risk management in traffic scenarios. A third direction of research targets models that estimate the driver's degree of attention during driving, utilizing visual cues to assess cognitive engagement and potential distractions. A forth direction of research comprises cyclist safety assessment and incorporates models that based on monocular depth estimation, object detection and image segmentation, assess the safety of cyclists in relation to vehicles.

In the field of medical image analysis I have developed methods and models for differentiating, within ultrasound images, between the Hepatocellular Carcinoma (HCC), respectively the cirrhotic parenchyma on which hepatocellular carcinoma had evolved. A second direction of research comprises the development of a two stage approach used for recognizing the kidney tumor grade in CT images by combining deep learning based segmentation models with local textural features. A third set of methods combines deep learning based retinal layer segmentation in OCT images with feature based image classification for finding fluids retinal areas and biomarker extraction from OCT images.

My research path was validated as the work was published in 3 journal papers, 47 conference papers. Some of these papers have as authors PhD students, master students and even batchelor students that I have mentored. At least ten papers have been written in colaboration with students based on the achivements of the license or master thesis and presented at student conference events or international conferences

I have been engaged in several professional activities that demonstrate the application and transfer of knowledge beyond the academic environment. I have participated in several research and development projects with industrial and academic partners. My research was shaped by the participation in the research team for 12 international research projects and 16 national research projects, out of which I was responsible for two of them. I am also grateful for being an active member of the research group Image Processing and Pattern Recognition Research Centre from the Computer Science Department of the Technical University of Cluj-Napoca. Being part of

this great research group is an exceptional experience that shapes my professional and academic career.

The second chapter of the thesis presents my academic achievements. I have actively contributed to teaching, mentoring and curriculum development in the field of computer science with focus on computer vision, machine learning, algorithms and programming. I have delivered courses, laboratories and seminars for disciplines like Data structures and algorithms, Object Oriented Programming, Pattern Recognition Systems, Image Processing, Machine Learning and Artificial Vision. I try to help students develop both technical and academic maturity. Over the past years I have supervised more than 100 bachelor theses, over 50 master theses and I was in the supervision committe of 5 PhD theses. I have also served as a study advisor for undergraduate students in their 1st and 3rd years.

The third chapter of the habilitation thesis describes the development objectives and future plans. It emphasises the research development plan that targets the application of computer vision techniques for real-world challenges. My interests are rooted in the field of medical image analysis, where I aim to develop and apply state-of-the-art deep learning methods to a wide range of imaging modalities and pathologies. A central focus of this research is to adapt and fine-tune advanced AI architectures to the specific challenges posed by different types of medical data (MRI, CT, Ultrasound, multi-spectral biological images), ensuring high accuracy, explainability, and clinical relevance in the context of 2D and 3D image analysis. I want to target large structures such as abdominal organs but also small and thin structures like vessels or neurons.

Object detection and scene understanding in adverse imaging conditions, particularly focused on infrared and low-light environments is also in the plan for future research. Building on the experience from the monocular thermal image detection project I coordinated, I aim to improve the resilience of detection systems by integrating data from multiple spectral domains and employing domain adaptation techniques for improved generalization. Temporal modeling in video data will augment the object detection and scene understanding in my future research topics. Interdisciplinary and collaborative projects will remain central to my strategy. Given my experience in industrial partnerships and large-scale consortiums, I plan to increase involvement in European projects and national research programs.

In parallel with the research activities, my academic development continues to be a priority. I intent to regularly update my courses and laboratory modules in response to the evolving research landscape. I will also continue to develop educational resources such as structured supervision guides, learning milestones, and feedback mechanisms to improve the quality and transparency of the student supervision process.

Professionally, I will continue to build expertise in managing and coordinating research projects. I will continue to encourage interdisciplinary collaboration and knowledge transfer. I believe research should not remain confined to academic outputs but must impact society, industry, and education.