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HABILITATION THESIS
– ABSTRACT –

Deep learning and advanced conventional techniques for medical image based severe pathology detection and modeling, as well as for other computer vision and data mining solutions

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Computer vision and artificial intelligence represent two important coordinates of modern computer science approaches, significantly involved in the most technological developments. The conventional, advanced texture analysis methods, as well as the deep learning techniques, were widely involved in the automatic and computer aided diagnosis, based on medical images and data, as well as in many other areas of life.

The current habilitation thesis, entitled "Deep learning and advanced conventional techniques for medical image based severe pathology detection and modeling, as well as for other computer vision and data mining solutions" presents original approaches of these methods, mainly targeting the detection of tumours and of other severe affections in a non-invasive manner. Other significant problems, such as client segmentation and attribute dependency mining in the domain or car insurance, or data mining for performing predictions in the domain of collaborative robotics, are approached as well. Tumours represent severe affections nowadays, significantly affecting health in many situations. The traditional method for tumour diagnosis is the biopsy, which is invasive and dangerous, as it could lead to infections and to the spread of the tumour through the human body. However, many medical image-based investigation methods exist, representing a safer alternative. Ultrasonography is an investigation technique which is unexpensive, non-invasive, non-irradiating and repeatable, suitable for patient disease monitoring. Computed-Tomography (CT) and Magnetic Resonance Imaging (MRI) are also appropriate, being able to highlight the tumoral structures. In this context, it has been demonstrated that the involvement of advanced computer vision methods leads to an important improvement regarding the disease detection performance.

In the first part of the thesis, which refers to the scientific, professional and academic achievements of the author, after illustrating the state of the art of the approached domains and the corresponding limitations, the author presents first the employment of conventional techniques, targeting the automatic diagnosis and grading of some severe affections, such as liver cancer or cirrhosis. Considering these objectives, the author elaborated the imagistic textural model, approached in supervised, respectively unsupervised manner, consisting of the relevant textural features that best differentiate between the targeted affections, also of the specific values associated to the relevant textural features. In parallel, the author defined and experimented, in an original manner, the Generalized Cooccurrence Matrices (GCM) of superior order [2]. Thereafter, the development and employment of the deep learning methods is illustrated, involving specific techniques, such as Stacked Denoising Autoencoders (SAE), respectively Convolutional Neural Networks (CNN) and transformers. Both classical and original architectures were approached, also their combinations at classifier and decision level, respectively their fusion with the conventional techniques, for performing both recognition and segmentation within ultrasound and CT images. The case of multi-modal medical image recognition was approached as well. Last generation CNNs, enhanced with attention mechanisms and Atrous Spatial Pyramid Pooling (ASPP) modules, along with an appropriately tuned Segment Anything Model (SAM), were employed, tackling the possibility of automatic diagnosis, based on MRI images, considering multiple classes of malignant brain tumors. The application of other specific, respectively original methodologies and techniques, from the domains of computer vision and artificial intelligence, is further illustrated, in the context of practical applications such as: robotic

assisted surgery for advanced Hepatocellular Carcinoma (HCC) reduction, CoviD19 detection within CT images, the automatic segmentation of the gingival sulcus and periodontal epithelial junction from ultrasound images, liver tumor segmentation within ultrasound and CT images, face expression recognition, a data-mining approach for dentistry, specific data analysis techniques employed in the domain of collaborative robots, data mining techniques in the domain of car insurance. Based on the described methods, it can be concluded that deep learning techniques have generally led to superior performances, as compared to the conventional techniques, with some exceptions, however, especially in the case of applying advanced texture analysis methods. Thus, complex conventional methods, involving higher-order GCM matrices, have led to performances comparable to those of lower complexity CNN networks.

The author's achievements related to scientific research activity, teaching activity, academic management and institutional activity are emphasized in a separate chapter, with references to the coordination and participation in scientific research projects, to the PhD, master and bachelor student coordination. Delia-Alxandrina Mitrea began her academic career in 2003, as a full-time doctoral student, at the Technical University of Cluj-Napoca, Faculty of Automatic Control and Computers, then progressing through the stages: junior lecturer (2004-2007), lecturer (2007-2012), senior lecturer (2012-2017), respectively associate professor (2017-present). She achieved the PhD title in Computer Science in 2011, in the field of medical image analysis and recognition. The author acted as a director, responsible and/or team leader in 3 national projects (achieved through national competition) of type Young PhD Students („Tineri Doctoranzi" – TD), during the PhD studies, entitled „Shape Recognition, 3D Reconstruction and Tracking of the Texture 3D Spatial Transforms with Applications in the Domains of Human-Computer Interaction and Autonomous Robots"; PCCDI (Complex Projects achieved in Consortia), entitled „High accuracy innovative approach for the robotic assisted intra-operatory treatment of hepatic tumors based on imagistic-molecular diagnosis (IMPROVE)" ; respectively Young Researchers (Tinere Echipe – TE), entitled "Automatic and computer aided diagnosis of abdominal tumors, through advanced machine learning, within various types of medical images (ACADTUM)", during the last decade. In the context of the projects coordinated during the last decade, young PhD researchers were involved. The author performed postdoctoral studies, during the years 2014-2015, this position being achieved through a competition carried at university level, referring to a project of type POSDRU (Operational Sectorial Program for Human Resource Development). In this context, the author managed her own project entitled "Developmen of advanced texture analysis methods for building imagistic models with applications in the study of the disease evolution phases within medical images, as well as in the recognition, tracking and understanding of some real-world scenarios". Delia-Alexandrina Mitrea was also involved in many other national and international projects as a team member or senior expert. During her scientific research activity, the author of the thesis has developed 89 scientific papers, published in ISI or BDI journals, respectively at prestigious international conferences, 48 of the total papers being indexed in ISI Web of Science, 7 of these papers being published in top ISI journals (Q1 or Q2), Delia-Alexandrina Mitrea being the first author for 3 ISI Q2 papers.

Based on the scientific research activity carried out, the author of the thesis obtained, in 2019, gold medal and diploma of honor at international scientific research, innovation and invention salons such as PROINVENT (Cluj-Napoca), INVENTICA (Iasi), and INFOINVENT (Chisinau); the Edmond Nicolau prize, awarded by the Romanian Society of Medical Informatics (SRIM), for the best technological solution in the field of medical informatics, in the context of the RoMedInf - Healthcare Digital Era conference, organized by the I. Hatieganu University of Medicine and Pharmacy in Cluj-Napoca, in September 2019. Delia-Alexandrina Mitrea was and still is a member of the scientific committee at 6 prestigious international conferences. As a guest editor, she contributed to the creation of a special issue of the *Sensors* journal (ISI, Q2), entitled "Deep Learning for Pathology Detection and Diagnosis in Medical Images", https://www.mdpi.com/journal/sensors/special_issues/dlvb. The author has an h-index of 8 in ISI Web of Science, an h-index of 11 in SCOPUS, respectively an h-index 13 in Google Academics (Google Scholar). The author was a committee member for a PhD thesis public defense, at I. Hatieagnu University of Medicine and Pharmacy in Cluj-Napoca, in 2019, being involved, as well, in committees for PhD student research reports or exam sustainment. Referring to the didactic activity, Delia-Alexandrina Mitrea taught and still teaches, as a part of Bachelor and Master programs, disciplines in the field of image processing and pattern recognition, of machine learning and data analytics, as well as of databases and software engineering. She has been, as well, a coordinator for more than 20 master theses, respectively for more than 50 bachelor theses, being an active member in bachelor and master thesis sustainment committees since 2018. At the institutional level, Delia-Alexandrina Mitrea contributed to the promotion of the Faculty of Automatics and Computers in high-schools, to the preparation of ARACIS files, respectively to the evaluation of academic activity (SIMAC) within UTCN.

In the second part of the thesis, which refers to plans of carrier development and evolution, a detailed view regarding the further development directions, targeting the scientific, didactic and academic management plans, is provided. Regarding the scientific research, the author further targets the field of computer assisted and automatic diagnosis of severe affections, like cancer or cirrhosis, with focus on identifying precursor phases, like chronic pancreatitis, fibrosis, hepatitis and advanced cirrhosis, also the incipient phases. This will give opportunity to approach the newest deep-learning architectures, such as CNNs, transformers and combinations among them, also adapted to the 3D case. The disease evolution will be also studied, through specific methods, such as Generative Adversarial Networks (GAN), or Graph Neural Networks (GNN). Another objective is to combine multiple medical image modalities, as well as multiple data types, such as image, text, clinical data, also genomic data and to develop appropriate fusion methods. Last but not least, methods such as domain adaptation and domain generalization, respectively semi-supervised learning (SSL), will be considered. The developed original methods are intended to be transferred to other application areas of interest, as well, such as the technical and industrial fields, recognition of human faces or facial expressions, recognition of gestures, the field of digital and generative art, scientific fields such as biology, geography or chemistry. These methods will enrich the bachelor and Master courses curricula, also the PhD theses of the students.