BIOENGINEERING AND MEDICAL-SURGICAL SCIENCES

PNRR Ammin/Medics - HAi3D – 3D Hyperaccuracy based on artificial intelligence

Funded By	MEDICS Srl [P.iva/CF:11621780011] Politecnico di TORINO [P.iva/CF:00518460019]

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Context of the research activity	The goal of the project is to design and produce a set of artificial neural networks (ANNs) trained to segment CT or MRI medical images. Each ANN will specialize in a specific organ, organ part, or organ vasculature (e.g., an ANN for the localization and segmentation of the liver + tumor lesion, for the localization and segmentation of the kidney + lesion, etc.). The outcome produced by each ANNs will be integrated to manufacture customized HA3D® digital twins of the patients. Once artificial intelligence algorithms with accuracy comparable to that of human radiology professionals (defined by real-world validation studies in phase 2) are obtained, the AI-based algorithms will be implemented in a software platform for generating patient-specific 3D models in real-time online, allowing surgeons to autonomously obtain patient-specific HA3D® models. The web-based AI application will include the possibility of having quality control and editing tools directly on the platform. Progetto finanziato nell'ambito del PNRR - PNRR M4C2, Investimento 1.5 - Avviso n. 3277 del 30/12/2021 - ECS00000036 Nord Ovest Digitale E Sostenibile (NODES) - CUP E13B22000020001

	Activity: Design and development of specialized ANNs for organ and lesion segmentation. The focus will be on developing a deep learning platform based on ANNs. For the main specialties of thoracoabdominal oncological surgery (i.e., lung, kidney, liver, pancreas, bone), Medics will leverage approximately 1000 patients already available in its database. Specifically, validated segmentations of real clinical cases for different specialties will be immediately used for the preliminary training of an ANN for abdominal organ segmentation (liver, kidney, colon, pancreas), which will be further trained with new annotated images (i.e., images with segmentation instructions required for network learning) from incoming or transferred new clinical cases.

Objectives	Objective 1: Mechanisms for improving U-NET networks will be considered, referring to the most common state-of-the-art implementations of convolutional networks (including, but not limited to, improved, dense, and dilated U-NET architectures for network performance). The goal will be to balance the pursuit of higher accuracy in capturing complex 3D shapes and the computational cost of training. Some of these implementations have proven highly effective in easy segmentation tasks such as liver, kidneys, lungs, prostate (most of the abdominal structures subject to medical reconstructions). Various initialization methods will be tested to ensure unbiased weight optimization. Augmenting the training dataset will involve both histogram operations and volume-controlled deformations, as well as generating synthetic lesions in healthy patients to cover as many shape and consistency variations as possible. All these activities will be performed with annotated liver images initially before extending the training to other organs and specialties. Objective 2: To develop a pipeline for enhancing blood vessel images based on noise diffusion filtering, sigmoid gray scale mapping, vesselness metrics, or similar techniques. This objective will involve studying the best convolutional network for predicting vascular structures integrated with computer vision methods. Synthetic data resembling vessel images will be generated to increase the training dataset, potentially influencing speed performance and computational memory footprint in the initial phase of network training.

Skills and competencies for the development of the activity	- Strong background in computer science, machine learning, and deep learning. - Proficiency in programming languages such as Python, MATLAB, or C++. - Sound knowledge of medical imaging modalities (e.g., CT, MRI) and image processing techniques. - Familiarity with popular deep learning frameworks like TensorFlow or PyTorch. - Ability to preprocess and analyze medical image data using relevant libraries and tools. - Understanding of convolutional neural networks (CNNs) and other neural network architectures. - Experience in developing and fine-tuning deep learning models for image segmentation and analysis. - Proficient in evaluating model performance using appropriate metrics and validation techniques. - Knowledge of medical imaging terminology and clinical workflows. - Strong problem-solving skills and ability to propose innovative solutions for image analysis challenges. - Effective communication skills to collaborate with multidisciplinary teams and present research findings. - Familiarity with ethics and regulatory aspects related to medical imaging and AI research.