POLITECNICO DI MILANO

PhD in BIOINGEGNERIA / BIOENGINEERING - 41st cycle

PARTENARIATO PNRR Research Field: MULTI-MODAL IMAGE ANALYSIS FOR PRE-PROCEDURAL PLANNING AND INTRA-PROCEDURAL GUIDANCE IN TRANSCATHETER CARDIAC INTERVENTIONS

Monthly net income of PhDscholarship (max 36 months)
1400.0 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	Background and Motivations: Transcatheter interventional procedures allow for the mini-invasive treatment of several cardiac pathologies, spanning from coronary artery obstruction to heart valve diseases. Their success depends on two key factors: - pre-operatively, the accurate anatomical and functional characterization of the target cardiac structures based on pre-procedural imaging, to select the most suitable implantable device or implant approach. Depending on the specific intervention, pre-procedural imaging can be, e.g., 3D transthoracic echocardiography (3DTTE), computed tomography (CT), or coronary CT angiography (CCTA). Each of these modalities has pros and cons, but none allows for a 3D, detailed and, when relevant, time-resolved information. - intra-operatively, the precise targeting of the implant site and of the optimal catheter pose to deploy the implantable device, under the guidance of real-time imaging such us X-ray fluoroscopy, 3D transesophageal echocardiography (3DTEE), or intravascular ultrasound (IVUS), depending on the procedure. 3DTEE is well-suited for visualizing intracardiac structures but can be non-trivial to analyze; each of these modalities has limitations such as radiation exposure, non-trivial interpretation of images, or lack of 3D information. On this basis, image fusion between different pre-procedural images, and between these and

	intraprocedural imaging, could improve and facilitate i) the understanding of the cardiac environment, ii) the identification of the target pose of catheters and implantable devices, iii) the intra-procedural implementation of the planned strategy. Despite this potential, the clinical implementation of these systems is hindered by the complexity of multimodal registration, differences in resolution and contrast, and the need for real-time processing. Research Objectives: This project aims to develop an innovative image fusion system based on artificial intelligence and deep learning techniques for real-time registration and fusion between intra-operative imaging. Specific objectives include: - Automatic segmentation: Develop deep learning algorithms for precise segmentation of relevant cardiac structures (heart valves, cardiac chambers, coronary arteries, access vessels) across different imaging modalities. - Multimodal registration: Implement hybrid registration techniques, based on neural networks and traditional algorithms, that allow accurate and robust alignment between ultrasound, CT, and fluoroscopic images. - Pro-operative planning: Develop computational tools to support decisions (e.g., size and number of the implantable devices) based on fused pre-operative images. - Intra-operative guidance: Create a system that augments intra-operative imaging by fusion with pre-operative one. - Clinical validation: Evaluate the accuracy and clinical utility of the system in collaboration with Artiness and partner clinical centers.
Methods and techniques that will be developed and used to carry out the research	Segmentation of medical imaging through manual or semi-automated (e.g., based on region growing and thresholding) methods to generate ground-truth segmentations Deep learning to perform automatic segmentation Computational modeling to quantify geometry and dynamics of the relevant anatomical structuresDeep

	learning to perform image-fusion
Educational objectives	Understanding of cardiac pathophysiology and transcatheter techniques Understanding of cardiac and cardiovascular imaging Proficiency in advanced coding Proficiency in image analysis and deep learning Capability to translate clinical needs into technological/technical requirements
Job opportunities	Medical imaging and image processing field (i.e., vendors of imaging technology) Implantable device industry (developing of software for procedural planning and intraprocedural guidance)
Composition of the research group	1 Full Professors 1 Associated Professors 0 Assistant Professors 10 PhD Students
Name of the research directors	Emiliano Votta, Alberto Redaelli

Contacts
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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents	--

Scholarship Increase for a period abroad	
Amount monthly	700.0 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
Educational activity: The students will be encouraged to attend courses at POLIMI or abroad, as well as 2-3 National or International Summer Schools. Teaching assistantship: There are various forms of financial aid for activities of support to the teaching practice. The PhD student is encouraged to take part in these activities, within the limits allowed by the regulations. Computer and desk availability: the student will be allowed to access the facilities of the DEIB.