POLITECNICO DI MILANO

PhD in BIOINGEGNERIA / BIOENGINEERING - 39th cycle

PNRR 118 PA Research Field: DEVELOPMENT OF ADVANCED DIGITAL MODELLING FOR A MORE EFFECTIVE AND EFFICIENT APPROACH TO THE CLINICAL TREATMENT OF COMPLEX RARE PATHOLOGIES SUCH AS CONGENITAL HEART DISEASE

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	Congenital heart diseases (CHD) refer to a range of defects that affect the normal way the heart works since birth and are among the most common malformations diagnosed in newborns, with a prevalence of about 1% of live births worldwide. There are many types of CHD and they sometimes occur in combination, creating a very complex pathological condition that requires a difficult and expensive clinical management as well as leads to a problematic life for the patients. Indeed, clinical treatments are needed already in the first days after birth, followed by multiple open-chest surgical procedures or transcatheter endovascular interventions performed throughout the patient's life. In addition, the market of medical devices used in children for the treatment of rare diseases (therapeutic orphan devices) is characterized by a reduced return on investment due to very low production numbers. For this, very few devices exist specifically designed and produced by the companies to treat rare diseases such as CHD. Hence, together with the surgical complexity caused by CHD treatment, the paediatric cardiologists are often forced to an ‘off-label’ use of medical devices originally developed for adults and for a different pathology (e.g. an adult renal stent implanted in an aorta with coarctation of a baby). All the above factors make the management of the CHD patients a tough task for the public healthy system. Main objective of this project is the development of an

	advanced strategy, based on a combined digital-physical modelling approach, to help both clinicians and patients (or their families, in case of babies) in facing the respective difficulties with a better managing of the treatment event. The end result will be more efficient, effective and economical management of patients with congenital heart disease. Similar pipelines could be extended to other cardiovascular diseases.
Methods and techniques that will be developed and used to carry out the research	Based on patient clinical images, advanced digital twins (i.e. multiscale computational models) of the anatomical sites of interest will be created to exploit in the preoperative period. First, various virtual treatments (e.g. device implantation or surgical correction) will be simulated and comparatively evaluated (performing both computational structural and fluid-dynamics simulations) allowing the clinicians to better plan and perform the real intervention. Later, when the best option is selected, digital anatomy will also be used by the clinician to explain to patients (and their families) what the current disease is like, how the clinical treatment will be carried out and how the final condition will be improved. In order to enhance the usefulness of this image-based approach, starting from the digital twin of the patient-specific anatomical area affected by CHD, a suitable physical twin will be further created through advanced 3D printing techniques and soft materials mimicking the biological tissues. In this way, in addition to the previously developed virtual reality, an 'out-of-body' physical reality can be properly exploited and handled by both public health actors involved. Namely, the combined digital-physical approach will allow, from one side, the surgeon to simulate virtually and in a bench test a complex cardiovascular procedure before entering the surgical theatre, from the other side, will improve the communication of clinicians with patients and their families. The computational simulations will be validated by using the real post-treatment images and clinically collected data.
Educational objectives	• To learn the various modeling approaches for the

	cardiovascular system and how the different clinical treatment of complex cardiovascular diseases can be simulated. • To exploit the use of advanced computational models and make them suitable for health decision-making and for medical device assessment. • To apply 3D printing techniques for creating accurate physical models of patient anatomies to be used by clinicians for interventional planning • To collaborate with clinicians for developing multidisciplinary applied researches
Job opportunities	At the end of the PhD programme, thanks to the multidisciplinary experience and skills acquired, the student will be able to find various job opportunities: in biomedical companies for device design as an engineer expert in computational simulations, in hospitals as a bioengineer supporting clinicians, at the academic level as a post-doctoral fellow able to use both in vitro and in silico approaches.
Composition of the research group	1 Full Professors 1 Associated Professors 0 Assistant Professors 2 PhD Students
Name of the research directors	PROF. GIANCARLO PENNATI

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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

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

National Operational Program for Research and Innovation

Company where the candidate will attend the stage (name and brief description)	Fondazione Toscana Gabriele Monasterio per la Ricerca Medica e di Sanità Pubblica (FTGM)
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	Simbiotx Center Inria Saclay – Île-de-France
By number of months abroad	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
The PhD student will be involved in educational activities along with teaching assistantship. A shared desk and computer will be given to the student for the time needed to carry out the research.