POLITECNICO DI MILANO

# PhD in BIOINGEGNERIA / BIOENGINEERING - 38th cycle

## PNRR_352 Research Field: EVOLVING CANCER DIAGNOSIS AND CARE THROUGH THE USE OF DIGITAL TWINS¿ AND ARTIFICIAL INTELLIGENCE: FOCUS ON THE ABDOMINAL SURGERY.

| Monthly net income of PhDscholarship (max 36 months) |
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| **€ 1250.0**<br>In case of a change of the welfare rates during the three-year period, the amount could be modified. |

| Context of the research activity | |
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| **Motivation and objectives of the research in this field** | With advances in cutting-edge technologies for patient profiling, digital twins in particular have emerged as the basis for the development of an all-new class of simulation platforms tailored for diagnosis and treatment. However, digital twins, incorporating descriptive mathematical models and structured patient data, are relatively new in oncology. Especially, descriptive models not only may help in leveraging the available incomplete knowledge of the patient, but they are also important to generate additional information. Nonetheless, two main issues are still detrimental to the clinical translation of digital twins in oncology:<br>1) assessment of model parameters, which is fundamental for accurate simulation of tumor growth and the interplays with the micro-environment, including the response to the drug therapy, requires complex multi-omics patient data, collected via expensive and invasive experimental techniques;<br>2) processing very large datasets of multi-modal images to capture full anatomical and physiological details of the patient, being relevant for computer simulation of the surgical intervention (e.g. hepatectomy), requires extensive manual activities and demands high-level radiological expertise.<br><br>Starting from this context, the work aims at addressing the latter subject by leveraging the growing experiences of the |

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| | proposing team in image segmentation and surface reconstruction using artificial intelligence techniques, especially based on deep learning. The proposal has the following scientific and technological objectives:<br>- advancing encoder-decoder neural networks to perform accurate segmentation of organs of the digestive system in the abdomen and tumor lesions in both contrast-enhanced computed tomography (CT) and magnetic resonance (MR) images, reducing the uncertainty of and dependability on manual segmentation (currently semi-automatic detection of lesions, especially of small size, is imprecise and requires a lot of manual effort for verification);<br>- predicting liver and pancreas tumor staging by automatic analysis of images and reconstructed shapes with the use of explainable classification networks (currently for tumor staging intensive morphological analysis, performed by radiological/oncological experts, is mandatory);<br>- tailoring an accurate digital twin of the abdominal region of the patient using the reconstructed shapes to speed up and automate the planning stage in digestive surgery, with the ultimate goal of supporting the clinical activity (currently virtual surgical planning, simulating resections, is limited by the uncertainty in the 3D shape reconstruction). |
| **Methods and techniques that will be developed and used to carry out the research** | The work will focus on new AI approaches for multi-label image segmentation and shape reconstruction based on deep neural network. Acknowledging the current state-of-the-art architectures (e.g. encoder-decoder networks and multi-task Unet variants), the work will start by revising the competitive approaches, with focus on abdominal soft structures, and the obtained results across the literature to highlight advantages and shortcomings. Based on prior knowledge and open-source SW libraries and implementation facilities (Jupiter, Python, Tensorflow, PyTorch), the work will design and develop innovative solutions to address the complexity of segmentation of |

pathological organs in the abdominal region. Pancreas, liver, spleen, pancreatic veins and arteries, cave vein, renal veins and hepatic vessels will be the main structures of interest, including the potential tumor lesions, to be detected in arterial/venous phase CT. The network will be endowed with the ability to recognize clinically relevant features of detected lesions (e.g. geometry and staging). In order to address the topic of result interpretability, the work will investigate new self-explainable neural architecture embedding intrinsic clinical knowledge about the task. Interpretation provided by the model will inform the operator about the clinical quality of the achieved results.

The work will be developed in cooperation with AIMS Academy Foundation and ASST Grande Ospedale Metropolitano Niguarda (Milan, Italy).
The work might harness computational facilities available at Politecnico di Milano.

AIMS Academy will provide datasets of CT images, already labeled on the following organ/structures of the digestive system:

1. Pancreas on arterial/venous phase: 1876 CTs
2. Pancreatic tumor on arterial/venous phase: 625 CTs
3. Wirsung duct on arterial/venous phase: 156 CTs
4. Duodenum on venous phase: 173 CTs
5. Lymph-nodes on venous phase: 130 CTs
6. Veins on venous phase: 1119 CTs
7. Systemic venous system on venous phase: 1119 CTs
8. Arteries on arterial phase: 268 CTs
9. Liver on venous phase: 215 CTs
10. Gallbladder on venous phase: 173 CTs
11. Hepatic vessels on venous phase: 304 CTs
12. Hepatic tumor on venous phase: 435 CTs
13. Intrahepatic arteries on arterial phase: 130 CTs
14. Kidney on arterial phase: 210 CTs
15. Left-kidney on venous phase: 43 CTs
16. Esophagus on venous phase: 43 CTs
17. Stomach on venous phase: 43 CTs

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| **Educational objectives** | The Ph.D. candidate will get in-depth the following main scientific topics:<br>1. Neural networks and deep learning<br>2. Biomedical image segmentation and diagnostic interpretation<br>3. 3D advanced digital planning in the field of abdominal oncological surgery (digital twin)<br>4. Development and integration of clinical support tools |
| **Job opportunities** | The Ph.D. might develop professional careers in the fields of:<br>1. Predictive analytics<br>2. Biomedical and clinical data analysis<br>3. SW tool development for biomedical applications<br>4. Artificial intelligence tools |
| **Composition of the research group** | 1 Full Professors<br>1 Associated Professors<br>1 Assistant Professors<br>4 PhD Students |
| **Name of the research directors** | Prof. Pietro Cerveri |

| **Contacts** |
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| pietro.cerveri@polimi.it<br>39.02.2399.3352<br>www.deib.polimi.it/eng/people/details/139286 |

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

| **Scholarship Increase for a period abroad** | |
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| **Amount monthly** | 625.0 € |
| **By number of months** | 6 |

| **National Operational Program for Research and Innovation** |
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| **Company where the candidate will attend the stage (name and brief description)** | Fondazione MIAS Academy; www.aimsacademy.org |
| **By number of months at the company** | 12 |
| **Institution or company where the candidate will spend the period abroad (name and brief description)** | University Hospital Essen; www.ikim.uk-essen.de/de/junior-research-group-ait-de |
| **By number of months abroad** | 6 |

**Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information**

**Attinenza alla tematiche, alle missioni/componenti prescelte del bando PNRR ex D.M. 352, art.6**

Among Key Enabling Technologies (KETs) prioritized by Europe in Horizon Program to support research and innovation this PhD proposal addresses both Life-science technologies and Artificial intelligence. The ambition is to design, develop and deploy innovative tools to support diagnostics and surgical planning in abdominal oncology, advancing deep learning techniques to automatically process and analyse CT and MRI images. In particular, with regard to the PNRR, this research project will develop algorithms for advanced image processing which the company can enhance into a broader spectrum that extends from research to technological development and engineering. As such the project will contribute to Mission 4, namely M4C2 - Dalla ricerca all'impresa. The project will also contribute to development of telemedicine protocols for the handling of medical images remotely acquired, thus partly addressing Mission 6, namely M6C1 - Reti di prossimità, strutture e telemedicina per l'assistenza sanitaria territoriale.

**Impresa, presso cui si svolgerà l'attività esterna**

Fondazione MIAS Academy
settore attività: formazione e ricerca in ambito medico
link alla pagina dell'azienda: www.aimsacademy.org
numero di mesi previsti: 12 mesi
descrizione sintetica attività: applicazione di reti neurali profonde encoder/decoder alla segmentazione in immagini TAC addominali con fase arteriosa e venosa di fegato e dotti biliari con particolare interesse nell?identificazione delle lesioni tumorali.

**Ente, università, azienda, centro di ricerca presso cui si svolgerà il periodo di studio e ricerca all'estero**

University Hospital Essen - Dr. Jan Egger
settore attività: Artificial Intelligence in Biomedical Science
link alla pagina dell'ente, università, azienda, centro di ricerca: www.ikim.uk-essen.de/de/junior-research-group-ait-de
numero di mesi previsti: 6
descrizione sintetica attività: AI-based methods for the analysis of medical images

A shared desk and a PC will be given to the student for the time needed to carry out research. A

limited budget will be available for travelling and purchases, too.