Scientific Area	Synchrotron Light Applications		
Project Title	Deep learning for 3D Synchrotron X-ray tomography data		
Recruiting Institution	Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME)		
PhD awarding Institution	The Cyprus Institute (CyI)	**PhD Duration**	36 Months
Supervisor/Institution	Dr. Mihalis Nicolaou / CyI		
Co-Supervisor/Institution	Dr.-Ing. Gianluca Iori / SESAME – BEATS Dr. Charalambos Chrysostomou / CyI - CASTORC		
Secondment(s)	Computation-based Science and Technology Research Center (CASTORC), Cyprus		

Project Description

The PhD project will integrate the strengths brought on by recent advances in **Machine and Deep Learning** (ML and DL), Computer Vision and Imaging, leveraging **novel datasets** that will be collected at the **BEATS beamline of SESAME** (Synchrotron-light for Experimental Science and Applications in the Middle East), located in Allan, Jordan. It combines opportunities for contribution both in terms of developing **novel deep learning architectures**, as well as creating a framework for data collection and analysis in the context of 3D data in general, and **Synchrotron CT scans**, creating impact across a diverse array of applications ranging from materials science to biology and medicine. In particular, the beamline hosts the first synchrotron full-field X-Ray Computed Tomography (CT) experiment of the region, which will become operational in 2022. A vast database of 3D microscopic images will be generated and collected, enabling the study of the internal composition and morphology of materials to scientists from fields including materials science, biology, medicine, and cultural heritage.

Due to the large volume and resolution of the resulting datasets, the application of suitable deep learning methods that exhibit scalability is necessary. In fact, Deep Learning has been successfully applied to CT datasets for the segmentation of anatomical structures, pathological features, fossils, rocks, and multiphase or composite engineering materials. At the same time, opportunities are presented for the development of tailored deep learning methods that capture data structure and their high-order interactions (e.g., via tensor-based methods, non-Euclidean deep learning etc.), and can thus enable predictive analysis of local material properties, as well as transfer-learning methodologies that can exploit prior knowledge from existing models to extend and adapt them, even with limited data. One avenue includes designing predictive or generative ML models that can derive and map local material properties from synchrotron CT scans based on Finite Element (FE) simulations (that can be developed from 3D CT data). This approach can then be used to generate 3D FE models of different samples and materials.

The project is divided into three overarching tasks that are **outlined** below, and can be **adapted** to fit the candidate background and interests:

(i) **CT data collection** at the BEATS beamline for X-Ray tomography of SESAME. Identification of key examples from materials engineering, geology, or biomechanics. Development of routines for collection and registration of multi-scale datasets. Development of phantoms for density and materials properties calibration. Investigate the possibility of creating a **deep learning challenge** using this dataset at a workshop in a high-impact conference.

(ii) **FE simulations** of mechanical tests from synchrotron CT images. The data required for this task will be acquired within Task 1. An automated pipeline for the generation of finite element models derived from synchrotron CT scans will be implemented. The candidate will become familiar with applications of DL and ML for automatic 3D image segmentation during FE model generation

(iii) **Deep Learning for 3D CT data**. This task will include developing DL approaches for the 3D synchrotron data, that are suitable to the properties of the data outlined above. This includes designing novel deep learning architectures for automatic mapping of local material properties derived from synchrotron CT scans, also exploring generative models, tensor-based networks, and non-Euclidean (graph or manifold-based) learning. Efficient adaption and extension of existing DL models to materials from different domains with common microstructural and mechanical features will also be investigated.

Project Objectives

The PhD candidate will work closely with the beamline staff, implementing automated image analysis routines and exploring the application of ML and DL to different steps of the CT data processing and FE model generation pipelines. In particular, the candidate's work will i) produce and advance tools for the generation of finite element models of the mechanical performance of materials from 3D CT datasets and ii) develop deep learning methods for the extraction of mechanical and microstructural properties of materials from synchrotron CT images.

Required Candidate Qualifications

- M.Sc. in one of the following relevant fields: Applied Mathematics, Computer Science and Engineering, Physics.
- Proficiency in a programming language such as Python, Julia, Matlab, C++, etc.
- Experience in Signal and Image Processing and/or Deep Learning and Artificial Intelligence
- Good academic records in relevant fields.
- Good communication and writing skills; ability to work as part of an interdisciplinary team.
- Proficiency in oral and written English.

Desirable skills:

- Experience with numerical simulations.
- Experience with Deep Learning frameworks, preferably PyTorch or TensorFlow/Keras.
- Previous experience with synchrotron radiation facilities, 3D data, or CT/X-ray scans.