Thesis Title:

Artificial Intelligence and Medical Imaging: Toward Accurate and Automated 3D Reconstruction of Vascular Structures

Thesis Topic:

2D medical imaging plays a crucial role in managing vascular pathologies requiring urgent interventions. However, the growing integration of 3D imaging before and after procedures enhances diagnostic analysis when combined with artificial intelligence (AI) algorithms exploiting multimodal data. One of the main objectives of this thesis is to transition from 2D images to 3D segmentation of vascular trees, thereby improving the detection and analysis of vascular diseases. U-Net 2D and 3D models with attention layers are key references in segmentation. This research will focus on these models, combined with recent diffusion models, to generate more effective training datasets.

A first application involves the detection and classification of the Circle of Willis, a critical structure in the cerebral arterial tree, visualized through 7T TOF-MRI. This enables fine segmentation of essential vessels, where occlusions can have major clinical consequences. Morphological variations in the Circle of Willis (bifurcations, angles, diameters) are known risk indicators for vascular diseases. By analyzing these variations across cohorts, the study aims to identify new risk factors and improve image registration between 2D and 3D modalities. The analysis of key points extracted from segmentation will help enhance dedicated AI methods.

Finally, the integration of Physics-Informed Neural Networks (PINNs) ensures reconstructions that comply with physical laws, reducing the need for expert-labeled data. PINNs, combined with physical models such as phase fields, will be studied to optimize the reconstruction of 3D vascular trees from 2D images, ensuring more reliable and clinically usable results.

Thesis Supervisors:

Thierry Urruty – thierry.urruty@univ-poitiers.fr – XLIM Laboratory, University of Poitiers
Pascal Bourdon – pascal.bourdon@univ-poitiers.fr – XLIM Laboratory, University of Poitiers