LABO - Axe et Equipe : Institut Pascal, team : CaVITI (TGI axis)

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Title of PhD subject: Towards a Frugal AI System for Computer-Aided Diagnosis of Pediatric Pulmonary Pathologies.

Summary :
This PhD project lies at the intersection of artificial intelligence, medical image analysis, and Green AI. It aims to develop a frugal AI-based system for automated diagnosis of pediatric pulmonary diseases from thoracic imaging.

Congenital malformations represent a major global public health concern and are responsible for over 240,000 neonatal deaths annually, according to the World Health Organization. Among these, congenital pulmonary malformations, such as congenital pulmonary airway malformations (CPAM) and pulmonary sequestration, pose significant diagnostic challenges due to their impact on respiratory function and their marked clinical and radiological heterogeneity. Diagnosis primarily relies on medical imaging, particularly radiography and computed tomography (CT), whose interpretation is especially complex in pediatric populations due to anatomical variability and the limited visibility of small lesions and vascular structures. These conditions may also be associated with complications, such as pleural effusion, further increasing the complexity of clinical assessment.

Addressing these challenges in pediatric pulmonary pathology requires innovative AI-driven solutions to assist clinicians in achieving accurate and timely diagnoses. Deep learning, in particular, has demonstrated significant potential for improving diagnostic accuracy and supporting clinical decision-making in this complex domain. However, existing approaches exhibit significant limitations that hinder their applicability to pediatric lung disorders, including poor generalization to pediatric datasets, limited consideration of the morphological localization of pathologies and their spatial relationship with the pulmonary vascular structure, and the high computational and energy costs associated with model training and inference. This thesis aims to address these limitations by proposing an accurate and frugal artificial intelligence system to assist in the diagnosis of pediatric pulmonary pathologies from thoracic imaging. The proposed system accounts for the morphological localization of the studied anomalies and their relationship with the pulmonary vascular structure, in order to improve diagnostic accuracy and assess disease severity.

More specifically, the objectives of this PhD are to:

- **Develop a deep learning-based approach for the identification and reconstruction of the pediatric pulmonary vascular network**, leveraging advanced segmentation methods, including interactive approaches, and integrating the solution into the 3D Slicer platform to enable real-time visualization and clinical validation. This work will build upon and extend prior methodologies developed by the CaVITI team, adapting them to the analysis of the pulmonary vascular network in a pediatric context.
- **Propose an artificial intelligence method for the detection, localization, and characterization of pediatric pulmonary pathologies**, particularly congenital pulmonary malformations and pleural effusion, from thoracic imaging (radiography and computed tomography). The approach will enable precise morphological localization of anomalies within the pulmonary lobes, as well as correlation with the pulmonary vascular network, in order to improve clinical assessment and support surgical planning.
- **Integrate frugal AI principles** to reduce model complexity, computational cost, and energy consumption while preserving high diagnostic performance, building upon resource-efficient methodologies previously proposed within the CaVITI team.
- **Validate the proposed approaches on real-world clinical data**, assessing their robustness, generalization capabilities, and clinical relevance.

This work will leverage real-world clinical data, including thoracic images (radiographs and computed tomography scans), collected in collaboration with hospital clinicians from the CaVITI team and supplemented by open-access databases such as PediCXR.

The thesis will be conducted within the laboratory facilities at the Puy-en-Velay site of IUT Clermont Auvergne.