PhD project 2024-2025 (one-page proposal)

Robust lung segmentation and registration to assess local ventilation from computerized tomography images of patients with acute respiratory distress syndrome

Laboratory: CREATIS, CNRS UMR 5220 – INSERM U1294 – Université Claude Bernard Lyon 1, INSA Lyon

Research team: MYRIAD (Modeling & analysis for medical imaging and diagnosis)

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✕ **EDISS fellowship 2024** ☐ **Other funding**

Project description including a short introduction, aim/objectives and methods/approach to be used

Patients with acute respiratory distress syndrome (ARDS) require artificial ventilation to survive while the cause of the disease is treated, but inappropriate settings of the ventilator can increase mortality, and clinicians lack tools to assess the response of the patient's lungs to artificial ventilation. Lung aeration maps and biomarkers useful to clinicians, such as alveolar recruitment and hyperinflation, can be extracted from pairs (e.g., inspiratory-expiratory) of 3D thoracic computed tomography (CT) images, provided that accurate lung segmentation and registration methods are available. However, conventional algorithms fail due to the lack of contrast typical of ARDS and are slow. We have recently shown that deep learning methods can successfully and rapidly perform these tasks [1-3].

The main aim of this project is to develop and validate a clinically usable methodology for assessing local changes in lung parenchymal aeration between CT scans acquired under different ventilatory conditions and, subsequently, to provide clinicians with a reliable and effective tool for assessing the response of the patient's lungs to artificial ventilation, using CT-derived metrics. This tool should be used in multi-center clinical trials devised to propose and validate CT-driven ventilation strategies that enable personalized treatment aimed to minimize ventilation-induced lung injury and, ultimately, reduce mortality. To this end, the PhD student will strive to improve the robustness of our deep-learning models and guarantee their high performance, regardless of CT scan acquisition conditions.

Investigations will involve optimizing the model architecture (with innovative regularization based on spectral shape analysis) and learning strategy (with domain adaptation), as well as diversification of the database. The models will be trained and evaluated on annotated CT scans of ARDS patients from an ongoing study at our hospital. However, high-density ARDS lesions strongly blur the contrasts between the lungs and other tissues, making accurate lung delineation a challenge even for human experts. Consequently, the reliability of annotations is limited. The amount of annotated data is also low, compared to the typical requirements of deep-learning algorithms. To overcome these limitations, a new method will be developed to generate numerous ultra-realistic CT-scan pairs with ground-truth lung shape and deformations. These hybrid images will combine thorax morphologies and lung masks from easy-to-segment images of patients without ARDS, on the one hand, and lung lesions, heterogeneous deformations and density changes learned from patients with ARDS, on the other. The sum of these innovative developments will contribute to increasing the validity of segmentation and registration algorithms, with the aim of offering a robust solution adapted to the clinical environment and the pursuit of clinical trials.

References

[1] Penarrubia L., "Quantification de l'aération pulmonaire sur des images CT de patients atteints du syndrome de détresse respiratoire aiguë", PhD thesis 2022LYO10164, EDISS, Univ. Lyon 1, Dec. 2022.

[2] Penarrubia L., *et al.*, "Precision of CT-derived alveolar recruitment assessed by human observers and a machine learning algorithm in moderate and severe ARDS", *ICMx*, 2023, **11**, 8. DOI: 10.1186/s40635-023-00495-6.

[3] Shekarnabi M., "CT Registration-Derived Lung Function Imaging", PhD thesis, EDISCE, Univ. Grenoble Alpes, 2023.

Skills required: Image processing, applied mathematics, programming (python), deep learning (PyTorch)

Application procedure: **send a detailed CV to the PhD supervisor**