MSc project proposal 2024

Title of the MSc project:	**Improving the robustness of deep-learning models in lung segmentation and registration: generating CT image pairs at different inflation levels with dense lung lesions for data augmentation**
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Keywords:	simulation, segmentation, registration, deep learning, lungs

UMR 5220

U1206

Scientific field and context: The heterogeneous aeration of diseased lung parenchyma can be assessed using computed tomography (CT). This assessment is crucial for identifying the patient's phenotype in cases of severe lung function impairment, such as acute respiratory distress syndrome (ARDS), to personalize artificial ventilation settings. To do so, lung tissues must be delineated and aligned in scans acquired at different inflation levels. These image processing tasks, segmentation and registration, are hampered by dense lung lesions that blur the contrasts between parenchyma and neighboring tissues (Fig. 1). Our team has implemented deep learning models capable of achieving these tasks in a matter of minutes [1], with uncertainties close to inter-expert variability and a success rate of 85% [2]. Our approach consists in exploiting the complementarity and redundancy of information carried by scans representing the same lungs at different inflation levels. The models were trained on annotated data from two local hospitals, acquired as part of a clinical study protocol, which involves CT scans at up to four different inflation levels. To increase the success rate and accuracy, it is necessary to expand and diversify the training database beyond the scans that can be collected in clinics.

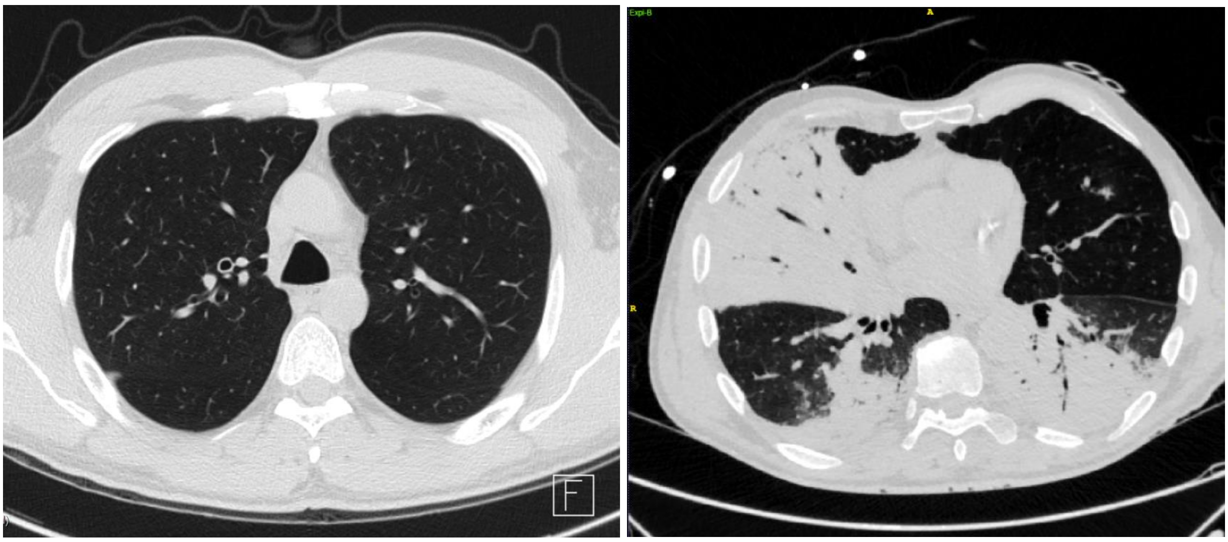

Figure 1. Comparison between lungs with normal contrast (left) and with ARDS (right).

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Objectives of the project: The main objective is to improve the accuracy and robustness of our models. To this end, the candidate will have to develop a method capable of generating highly realistic pairs of synthetic CT scans with different morphologies and lesions, as well as with heterogeneous density changes between simulated inflation levels. Improvements to model architecture and training strategy may also be considered, depending on the candidate's skills.

Scientific challenges: The main challenge of artificial intelligence approaches applied to medical images is the scarcity of annotated data and the huge volume represented by each image, which considerably limit the diversity of training data compared to other application fields. To overcome the limitation of available annotated data from ARDS patients, and increase the diversity of lung morphologies, we plan to use CT scans from patients with normal lungs and incorporate two aspects learned from ARDS patients: 1) lesions of varying extent, density, and location, as well as 2) heterogeneous aeration patterns (fig. 2). The former is expected to be achieved prior to this MSc project. The latter will need to address several challenges, such as avoiding unrealistic variations of mass in different lung regions and aeration compartments.

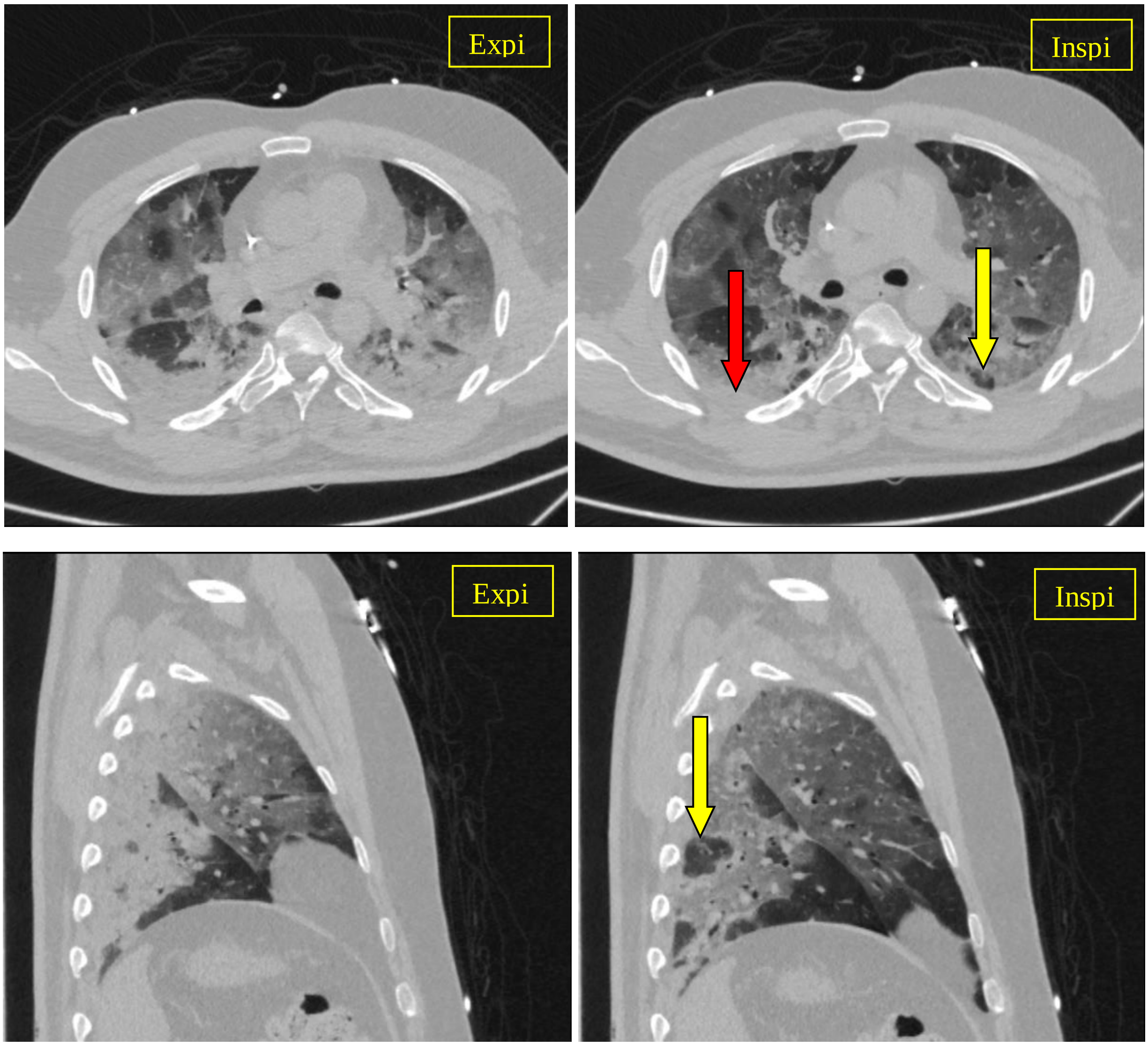

Figure 2. Example illustrating heterogeneous density changes in the lungs of an ARDS patient at lower (left) and higher (right) inflation levels: axial (top) and sagittal (bottom) views. While some non-aerated (light grey) regions become more or less re-aerated (darker) at higher inflation (yellow arrows), others remain non-aerated (red arrow).

Expected innovative contributions: The main contribution will be a tool capable of constructing an ARDS lung database of highly realistic image pairs with ground truth of both deformation and regional density variations. Such an augmented training database should significantly improve the robustness of our lung segmentation and registration tools, enabling better assessment of the lung function and better choice of ventilator settings.

Research program and proposed scientific approach: First, familiarize with the available ARDS data and implemented models. Second, propose a method to learn the ARDS lesion and aeration patterns thus retrieved. Third, identify publicly available databases of CT scans with segmented lungs. Then, propose a method for seamlessly incorporating lesions into normal lungs. Subsequently, for each synthetic scan thus generated, simulate heterogeneous inflation by modifying local volumes and densities. Finally, retrain the models and evaluate their robustness.

Expected candidate profile (prerequisite): image processing, machine learning, programming. Interest for biomedical field and biomechanical modeling for health sector.

Skills that will be developed during the project: deepening skills in image processing, strong experience in applied machine learning, integrating simulation tools for deep model training, collaborative/versionned programming. Ability to interact with the medical community.

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