The following literature review provides insight into the existing works involving the medical imaging and machine learning, dose-related noise in CT and how these have been combined. It begins by providing context in lung functional analysis with both deterministic and data-driven methods. The description, simulation, and removal of noise in X-Ray and Computed Tomography are then discussed. Gaps in this literature are then stated, and the relevant end-to-end architectures are reviewed.

Automatic Lung Functional Analysis is a well-established area of study. With the recent explosion of applied machine learning research, the area has seen significant progress. [3] is an excellent example of this. It analyses a few hundred papers published in 2021, that used machine learning to diagnose COVID-19. The paper [3] focusses on investigating the clinical relevance of the reviewed research papers, finding that none of them were clinically applicable for various reasons. It also provides common pitfalls and recommendations going forward specifically in the realm of automatic lung functional analysis. This is particularly relevant, in terms of how the model designed in this thesis will be developed and assessed. The number of papers reviewed in [3] demonstrates how current the study area is, and thus how important it is to critically investigate the metrics and methods used.

Generally, the approaches to this type of problem can be categorized into 1) deterministic and 2) data-driven methods. The term “deterministic” is used to refer to direct, computational methods such as those in classical computer vision, where a given input image will always provide the same output, while “data-driven” refers to models involving machine-learning-type models built from training data.

Earlier models, such as those described in [4] and [5] provide examples of deterministic methods for lung segmentation and analysis. While [5] is more focused on the segmentation step, [4] demonstrates the effectiveness on the end goal – the task-based accuracy for the classification of lung nodules. Without any machine learning techniques, and a very limited dataset (only 38 scans), the method was quite successful, failing on only 4.9% of the test set. [5] describes the development of an automatic method for the segmentation of 3-Dimensional CT reconstructions. It introduces optimal (dynamic) thresholding and used dynamic programming to identify anterior and posterior junction lines. The paper provides a useful in-depth statistical analysis of the results that will be very useful when informing the assessment of the results of this thesis. Both [4] and [5] were relatively successful, without the use of a data-driven approach. Deterministic methods can thus contribute significantly to the end-to-end system developed here.

Modern papers are increasingly focused on the development of data-driven, machine learning models. [2] compares the use of pre-trained deep-learning image models with training from scratch for several medical imaging modalities and datasets. The results showed that the pre-trained models usually outperformed those built from scratch, particularly when the training dataset decreased in size. Deep and shallow fine-tuning was also compared, and overall, the paper shows just how useful pre-trained models can be when combined and trained with task-specific data. [6] is an example of a 3D network architecture used for lung nodule detection, similar to the popular U-net architecture [9]. [6] also discusses and compares other popular machine learning architectures and tools (including the pre-trained models mentioned in [2] used for lung functional analysis. The 3D type of architecture in [6], being popular and current, will be relevantly applied in this study. Furthermore, [6] provides a valuable, robust statistical argument to base our assessment from.

The dose vs image quality tradeoff is another significant aspect of study in Computed Tomography and Medical Imaging research. As described in [7] and [8], higher doses are linked to higher image quality, but also more risk to the patient, while low doses are better for the patient, but result in much more noise. The ALARA principle (As Low As Reasonably Achievable) describes the goal of gaining as much information as possible with as low radiation dose as possible. [7] details the sources and effects of image quality issues in low dose Computed Tomography as well as the effect of CT exposure on humans. Understanding the physical aspects of this relationship is necessary for the accurate simulation of low dose imaging in this thesis. [8] provides an alternative perspective, providing a more practical description of how CT scanner dose settings (included in the CT DICOM file headers) affect patients medically and the effective dose patients experience as a result. The nuances of CTDI, Effective Dose and Radiation Energy transfer is described, clarifying the concept of “low dose”. Furthermore, [8] details several metrics that are used to describe CT image quality, including Contrast-to-Noise Ratio (CNR) which is not mentioned in [7]. The description and effects of this tradeoff thus justifies the need to improve the modelling of low dose CT images.