# 3D Visualization and Interaction for Studying Respiratory Infections by Exploiting 2D CNN-Derived Attention Maps and Lung Models

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Abstract: Nowadays, research activities in the fields of precision health and biomedical image analysis are developing rapidly. In this context, research work on the analysis of respiratory infections is still extensively investigated. Few open source systems with the goal of visualizing and manipulating lungs with infections in 3D space are currently proposed. Such systems could become an important tool in the training of new radiologists. In the present work, we propose an approach that allows the user to visualize and interact with respiratory infections in 3D space by exploiting 2D CNN-derived attention maps. The source code will be made publicly available at https://github.com/Adn-an/3D-Visualization-and-Interaction-for-Studying-Respiratory-Infections-by-Exploiting-2D-Attention-Maps.

## 1 INTRODUCTION AND MOTIVATION

Nowadays, research activities in the fields of precision health and biomedical image analysis are rapidly evolving. Especially since the COVID-19 pandemic, many researchers have focused their attention on analyzing chest and respiratory related pathologies. In particular, chest X-ray images have been extensively used in this area due to their low intrusivity and high availability (Hammoudi et al., 2021) (Slika et al., 2024a).

In the literature, few systems which have the goal of visualizing and manipulating lungs with infections in 3D space are currently proposed. Some approaches for visualizing lung infections in 3D exploit the use of a fully self-contained holographic computer (Hololens) which is a specialized Augmented Reality (AR) equipment (e.g. (Liu et al., 2024)) or traditional infection reconstruction methods with static views (strategy of marching cubes) which are based on CT scans (e.g. (Hameed et al., 2024)).

In our case, we presently propose an open-source, cost-effective (headsetless) and lightweight approach that allows the user to visualize and dynamically interact with respiratory infections in 3D space from a conventional laptop having a camera and using an Augmented Reality marker.

Specifically, our AR-based visualization approach particularly exploits CNN-based 2D features; namely, attention maps from chest X-rays (queries) in order to automatically generate semi-realistic lung representations with associated infections. Our main contribution is the proposal of a real-time 3D visualization approach which facilitates the study of lung characteristics such as anatomical and infected regions through virtual interactions.

Indeed, medical education faces huge difficulties to form students, practitioners, and future radiologists to the interpretation of chest X-rays (Sait and Tombs, 2021). Through automated and interactive visualization systems of organs using laptops equipped with cameras and augmented reality technologies (Abu Halimah et al., 2024; Tene et al., 2024; Jones et al., 2023; Lastrucci et al., 2024), it is thus possible to allow a large number of learners to discover characteristics of the human body (location of organs, shapes of organs, location of recurring infections) and to improve the understanding of complex anatomical concepts.

Additionally, we provide a solution that can integrate various levels of visualization of the loaded lung models. Furthermore, we propose an approach allow-

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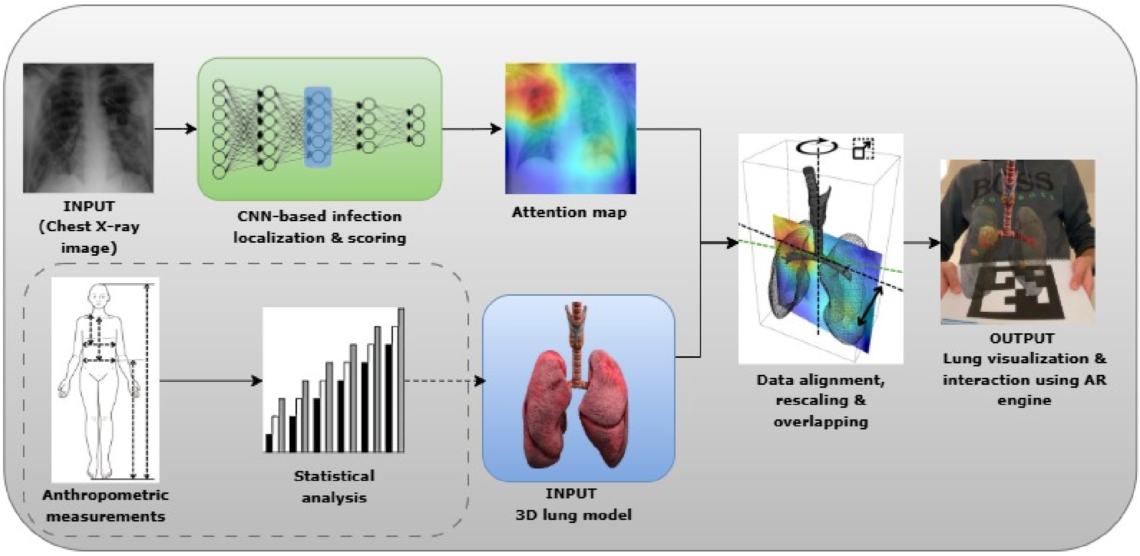



Figure 1: Proposed approach for visualizing and interacting with 3D lung model. The section in dotted lines describes complementary possibilities to generate a lung model based on anthropometric patient data and population statistics.

ing to load textures with an organic appearance or to include on the surface of the visualized 3D objects asperities including different levels of granularity.

# 2 PROPOSED APPROACH

## 2.1 Visualization and Interaction of the Generated Lung Model

This approach involves exploiting a pre-trained CNN that aims to localize and quantify the severity of chest infections from frontal chest X-ray images (Slika et al., 2024b). Our approach operates in an original way in the sense that a pre-trained CNN is exploited in order to extract infection features from a 2D attention map (saliency map). In this way, the lung infection areas are potentially represented by automatically analyzing chest X-ray images (initial input). The lungs are represented by using a realistic 3D lung model which is the second input.

Then, the 3D lung model is aligned in order to get the lung frontally oriented. A rescaling step is performed in order to overlap the 2D attention map according to the bounding box of the realistic 3D lung model. The attention map is positioned at the center of the 3D lung model. We emphasize that the volume of the lung model can be adjusted according to the characteristics of people, see the section in dotted lines in Figure 1, which are provided by the metadata associated with the query chest X-ray (statistical information of the patient e.g., patient gender, size, height, weight (Sharma and Goodwin, 2006)).

We extract the areas of interest by using estimated infection severity, represented by high intensities in the attention map, and their positions. These extracted infection areas are then represented by spheres of which dimensions are weighted according to the severity of the infection, while ensuring that they fit into the lung model. The resulting 3D lung model is then loaded into an augmented reality visualizer as shown in Figure 1. The opacity of the lungs or associated infections is tuned by exploiting an alpha-blending approach (e.g. (Friederichs et al., 2021)).

## 2.2 Enhancement of the Generated Lung Model

One of the key components of the visualization method lies in the 3D model itself. The process of finding, modifying, and enhancing the model has required a rendering tool and a high-end graphics card. It also explores the benefits of baking details into a diffuse map. After finding a 3D lung model online, 3D art techniques are utilized to re-mesh and remodel such as polygon decimation and shape sculpting. Then the model is re-textured and re-rendered; and finally all the textures are correlated to one diffuse map. That's mostly aimed at enhancing the realism of the model, making it faster and easier for graphical handling.

To bake all these different maps into one, a computer graphics renderer is applied in order to produce a high-fidelity scene including the subsurface scattering, lighting, bump, displacement, reflections, and specular maps managed through one single KD map


Figure 2: Enhanced infection representations by varying model rendering and surface asperities.

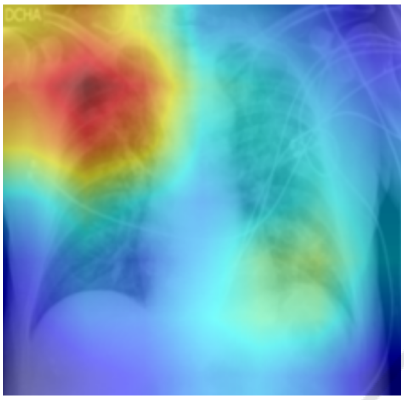
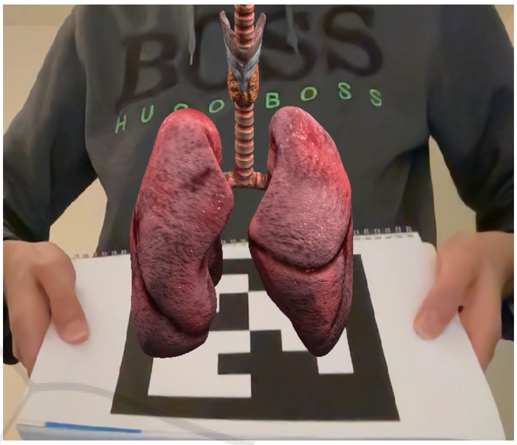
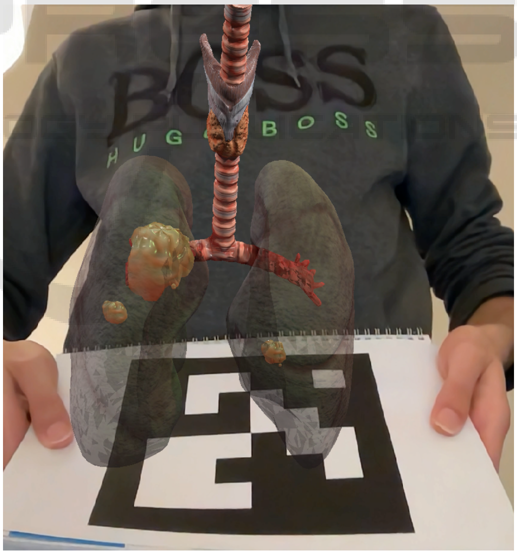


Figure 3: Attention map derived from the CNN architectures which is used for scoring infections (Slika et al., 2024b); e.g. potential lung infection areas (Misra, 2021).



(a) Opaque lung.



(b) Translucent lung with generated infection areas.

Figure 4: AR results of the lung model with and without transparency.

image, e.g. diffuse map (Yu et al., 2023).

An example of enhancements for our infection representation is illustrated in Figure 2. As can be seen, the infected areas can be represented by a sphere that is scaled according to the localized attention map intensities. For a realistic visualization, the appearance of the infections can also be enhanced by mapping textures over the generated spheres and/or by modifying the surface of the spheres with asperities.

# 3 EXPERIMENTAL RESULTS AND EVALUATION

The approach is based on a visualization model (Qing, 2022), which is capable of loading a 3D object and displaying it on an Augmented Reality engine (ArUco [1] (Garrido-Jurado et al., 2015)(Romero-Ramirez et al., 2018)) while exploiting computer vision functionalities (OpenCV [2]). In particular, a calibration chessboard is used to calibrate the model's parameters associated with the camera. Our approach uses a generic lung model available online (neshallAds, 2022).

[1]Aruco: Augmented Reality University Cordoba
[2]OpenCV: Open Computer Vision

Figure 3 displays the input chest X-ray image, accompanied by its attention map which highlights regions with potential anomalies (red and yellow regions of the heatmap). In Figure 4a, the initial 3D lung model is shown on top of the marker, which is generated from ArUco. Figure 4b shows the views resulting from the exploitation of the data observed through Figures 3 and 4a with the lungs shown with a transparency parameter.

The lung and its features can be visualized with varied representation levels in the sense that we can observe the lung without infections, only infections, or a mix of both the lungs and infections. The object rendering has been computed from an RTX 3080 graphics card. The interaction with loaded lung models operates in real time (approximately 25 frames per second).

# 4 CONCLUSIONS AND FUTURE WORKS

In this paper, we propose a concrete and effective tool to visualize a 3D lung model and control its opacity to inspect internal infections in the lung by automatically processing 2D attention maps extracted from a CNN pre-trained on frontal chest X-ray images. All features of this analysis tool work in real time, which shows its usefulness in facilitating chest X-ray studies and interpretations to physicians, practitioners, and future radiologists. Moreover, our approach can be generalized to visualize other organs.

In future work, we aim to better localize the lung infection in terms of depth by combining lateral with frontal images of the lung. This pair of images should give us more information about the shape, depth, and location of the infection in order to accurately diagnose the patient and improve patient care.

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