Automatic Lung Nodule Detection in Thoracic CT Scans Using Dilated Slice-Wise Convolutions

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Abstract

- With the advent of machine learning, exponential increase in the number of exams in the form of "big data", and a vast improvement in computational powers, new CADe/x devices hold a strong potential to improve clinical care.
- Careful and rigorous training and validation on large population-based datasets are necessary to ensure the safety and effectiveness of CADe/x systems.
- A novel data-driven CADe system [1] is developed for lung nodule detection. The proposed method replicates the process used by radiologists when reading CT scans, where they scroll through the CT scan in a slice-by-slice fashion to locate nodules.

Introduction

Design of CADe systems to automatically detect lung nodules has proven to be challenging for two important reasons:

- Pulmonary nodules exhibit a large degree of variation in terms of size shape, anatomical context, and density
- Nominal anatomy mimics such as blood vessels, airways, etc. can resemble nodules

We propose a two-stage framework in which each stage tries to primarily target one of the challenges above:

- The first stage sensitively detects a wide range of pulmonary nodule variations
- The second stage precisely discriminates between true nodules and falsely detected nodules in the first stage

Our proposed method is inspired by the radiologists' reading process; similar to how clinicians locate nodules and make decision based on intensity patterns observed in a stack of slices, our proposed method extract 3-D visual characteristics of objects through connecting the visual features extracted from consecutive slices within volumes of interest.

Materials and Methods

- We used 888 CT scans from the publicly available Lung Image Database Consortium (LIDC) [2] for training and evaluation
- A total of 1,186 ground truth nodules are available across these scans based on radiologists' markings

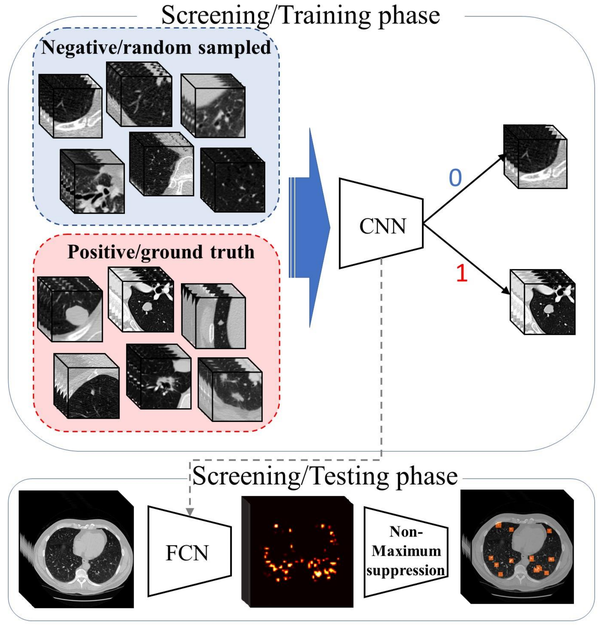

Figure 1. Top: Overview of training and testing of the network. **Bottom:** Schematic of hierarchical dilated 1-D convolutions that operate across slices to encode 3-D information in a volume of interest.

Results and Discussion

- We evaluated our proposed algorithm by performing 10-fold cross validation over the entire dataset of 888 scans
- The networks parameters were trained using data available in 9 folds and evaluated in the remaining fold
- The process was iterated 10 times in a round robin fashion to obtain the performance over the entire data set

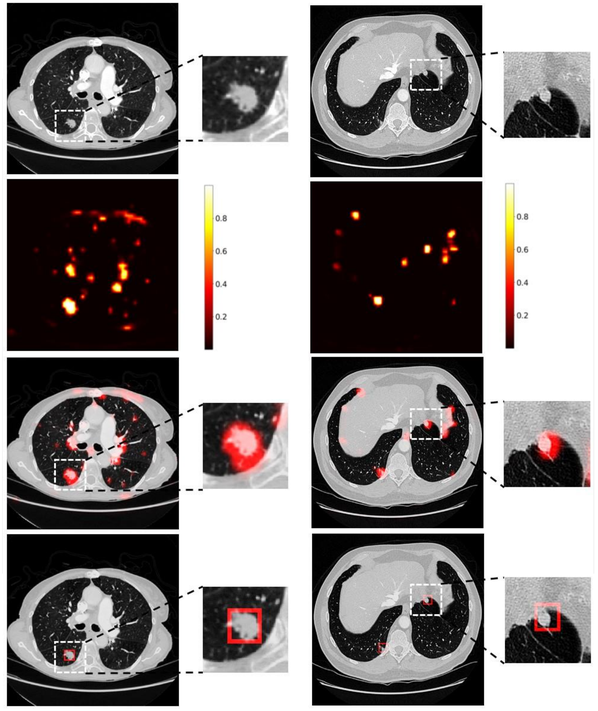

Figure 2. Illustration of the result of the proposed network. First row shows the central slices of CT exams containing a nodule; nodules in each scan are centered inside abounding box. Second row illustrates the corresponding color-coded score maps. Third row shows the original CT exams overlaid with the heatmaps from the second row. Last row shows the candidate locations remaining after removal of low confidence locations.

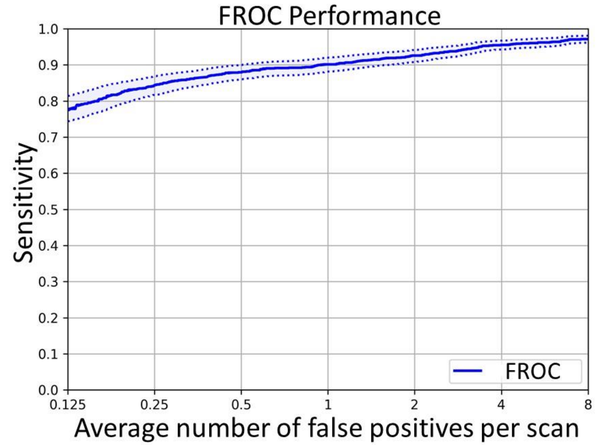

Figure 3. Free-response receiver operating characteristic (FROC) curve of CNN performance.

Conclusion

Lung nodules present as 3-D structures in CT, thereby requiring AI/ML classifiers that can fully capture the 3-D context of the volumetric data. The training of 3-D CNNs, which have a larger number of free parameters compared to 2-D CNNs, is hampered by the shortage of available training samples and the heavily imbalanced nature of data in medical imaging. In this study, we propose an alternative approach to multi-view 2-D or 3-D CNNs by a combination of 2-D and 1-D convolutions in a slice-wise manner to produce an efficient 3-D implementation that mimics how clinicians review CT data.

References

[1] Farhangi, M. Mehdi, et al. (In press) "Automatic Lung Nodule Detection in Thoracic CT Scans Using Dilated Slice-Wise Convolutions." Medical physics

[2] Armato III, Samuel G., et al. "The lung image database consortium (LIDC) and image database resource initiative (IDRI): a completed reference database of lung nodules on CT scans." Medical physics 38.2 (2011): 915-931.