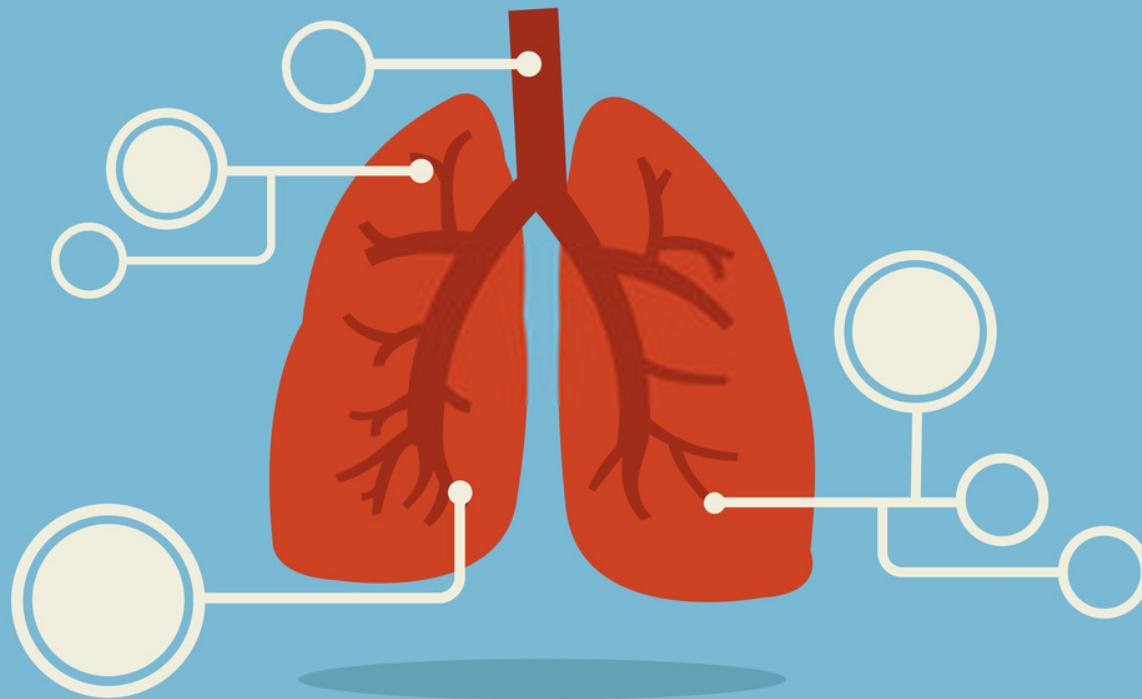
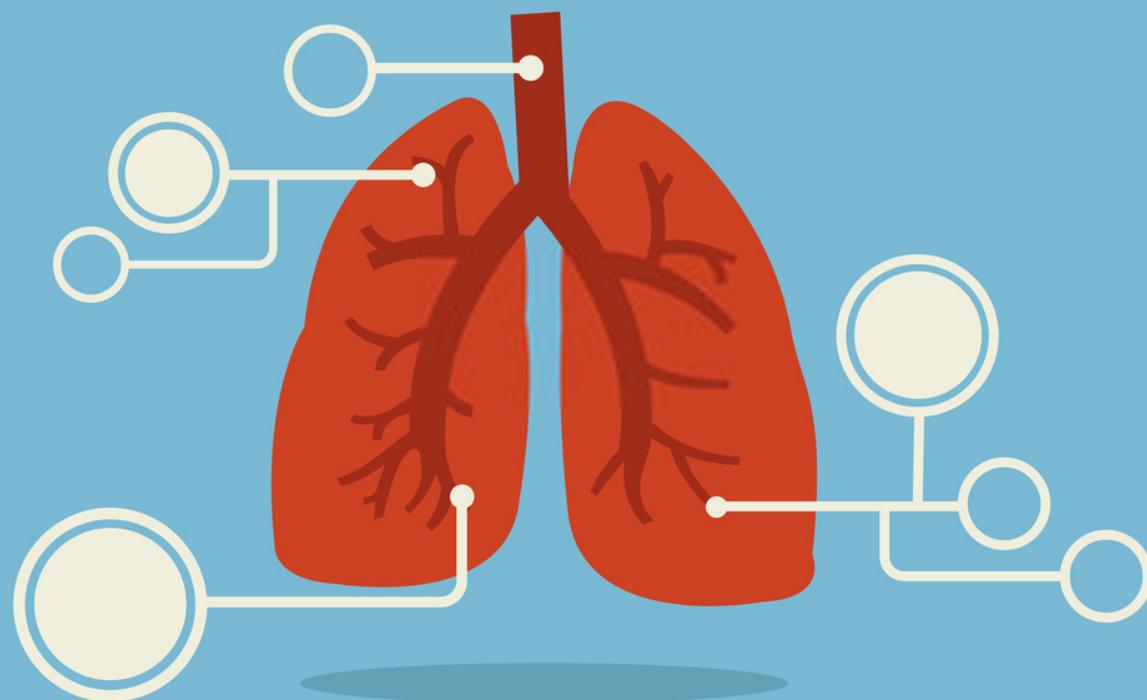


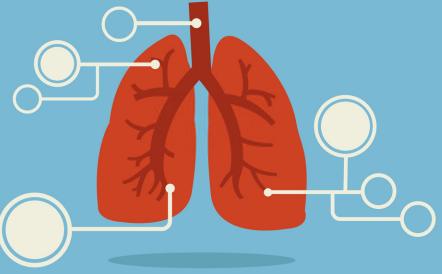
End-to-End Lung Cancer Diagnosis on Computed Tomography Scans using 3D CNNs and Explainable AI



A project sponsored by *Persistent* and undertaken by –
Dhaval G, Chaitanya R, Anushka V and Sumedh P.

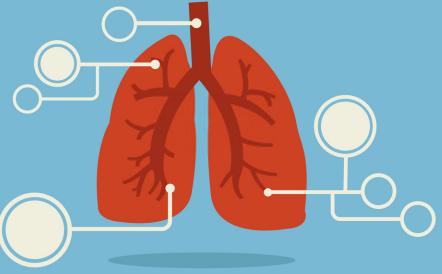
Introduction





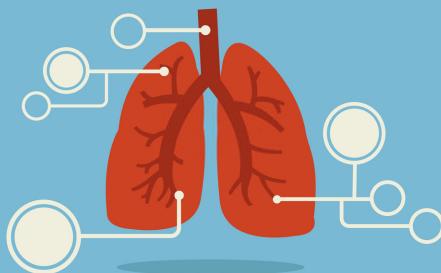
Introduction

- Lung cancer is one of the most prevalent of all cancers in India, and millions of people are diagnosed with lung diseases.
- There is a dearth of trained radiologists that can always, accurately diagnose the likelihood of the disease.
- We aim to create a deep learning tool that can aid in the diagnosis process of radiologists by detecting nodules and predicting their malignancy by making use of 3D CNNs.



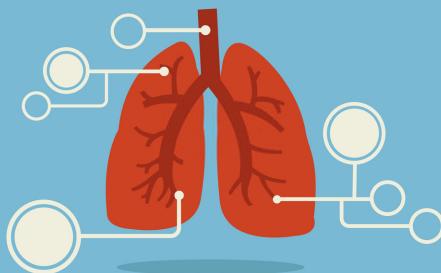
Abstract

- Lung cancer is one of the most common malignant neoplasms all over the world. It accounts for more cancer deaths than any other cancer. It is increasingly being recognized in hospitals all across the globe. With the increasing prevalence of smoking, Lung cancer has reached epidemic proportions, we propose a 3D-CNN-based model that uses a patient's Computed Tomography scans to detect nodules and check for malignancy.
- We intend to add an explainable aspect to the result since the central problem of such models is that they are regarded as black-box models and they lack an explicit declarative knowledge representation. This calls for systems enabling to make decisions transparent, understandable and explainable.



Motivation

- Deep Learning / AI tools have seen great advancements in the past few years, but very select ones have been of practical help to the field of medical science.
- In the diagnosis of lung disease, assessing the pattern, location, and regional distribution of involvement is the domain of radiology.
- Trained radiologists cannot always accurately diagnose the likelihood of the disease.
- Any of the current attempts at automating the process have not been intuitive enough for actual use by radiologists in clinics.



Literature Survey

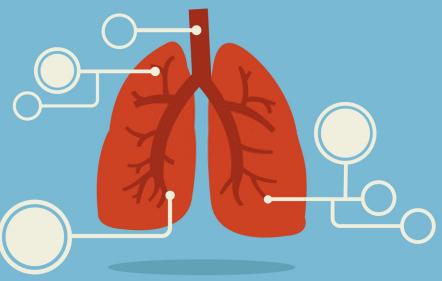
- LETTERS

<https://doi.org/10.1038/s41591-019-0447-x>

nature
medicine

End-to-end lung cancer screening with three-dimensional deep learning on low-dose chest computed tomography

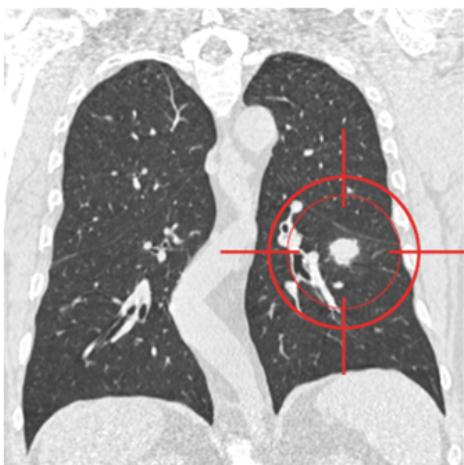
- Lung Cancer Screening With Low-Dose Computed Tomography in the United States-2010 to 2015
- Observer variability for Lung-RADS categorisation of lung cancer screening CTs: impact on patient management



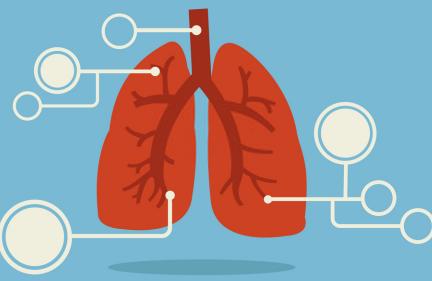
The Dataset

Grand Challenge All Challenges

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LUNG NODULE ANALYSIS
2016



The Dataset

- Source of the data: Lung Nodule Analysis 2016 (LUNA 2016) challenge (<https://luna16.grand-challenge.org>)
- 10 sets, each containing ~89 CT Scans
- Figure 2 shows the annotation for the data: the (x, y, z) coordinates of the centre of a nodule and its diameter are provided.



Figure 1: 3D CT Scan visualized as a stack of 2D grayscale images

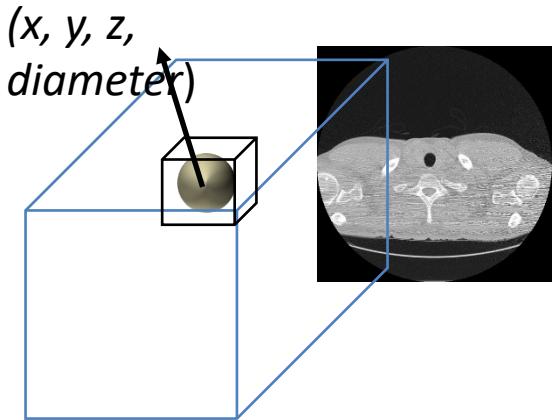
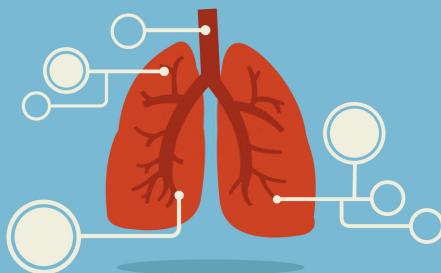
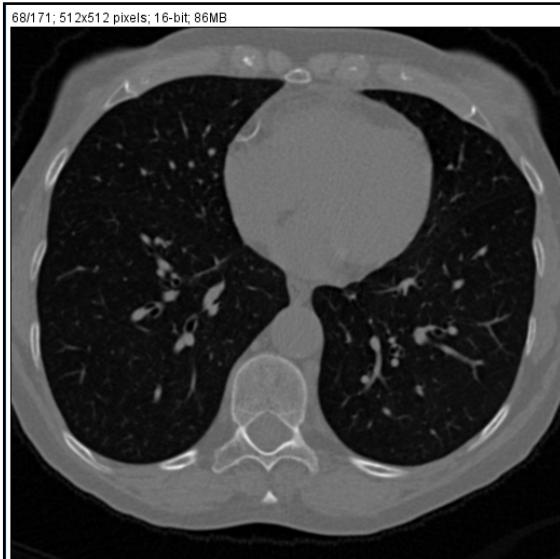


Figure 2: Diagrammatic representation of a nodule

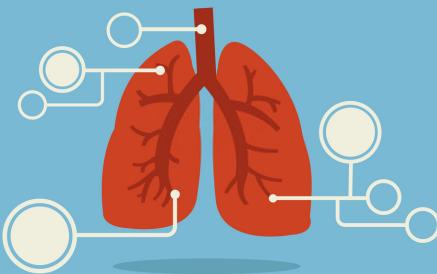


Data – Source and Nature



1	seriesuid	coordX	coordY	coordZ	class
438	1.3.6.1.4.1.14519.5.2.1.6279.6001.100225287222365663678666836860	104.0839	-211.756	-227.018	1
1011	1.3.6.1.4.1.14519.5.2.1.6279.6001.100225287222365663678666836860	-128.982	-175.177	-298.51	1
2055	1.3.6.1.4.1.14519.5.2.1.6279.6001.100398138793540579077826395208	69.97438	-141.067	876.7773	1
3635	1.3.6.1.4.1.14519.5.2.1.6279.6001.100621383016233746780170740405	1.79	166.34	-408.88	1
3709	1.3.6.1.4.1.14519.5.2.1.6279.6001.100621383016233746780170740405	1.859783	172.2215	-405.366	1
3750	1.3.6.1.4.1.14519.5.2.1.6279.6001.100621383016233746780170740405	95.92724	143.0743	-425	1
3844	1.3.6.1.4.1.14519.5.2.1.6279.6001.100621383016233746780170740405	89.32	190.84	-516.82	1
3868	1.3.6.1.4.1.14519.5.2.1.6279.6001.100621383016233746780170740405	90.79489	148.8605	-426.786	1
3872	1.3.6.1.4.1.14519.5.2.1.6279.6001.100621383016233746780170740405	88.69091	150.3106	-434	1
3903	1.3.6.1.4.1.14519.5.2.1.6279.6001.100621383016233746780170740405	-23.8516	192.9823	-391.434	1
4036	1.3.6.1.4.1.14519.5.2.1.6279.6001.100621383016233746780170740405	88.69091	156.4336	-428	1
4050	1.3.6.1.4.1.14519.5.2.1.6279.6001.100621383016233746780170740405	8.8	174.74	-401.87	1

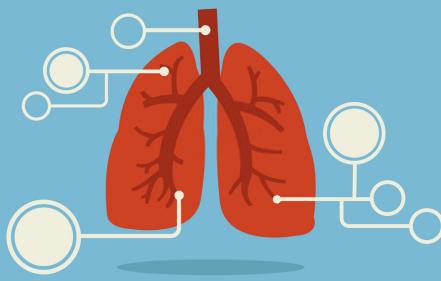
candidates_V2.csv



Data – Source and Nature

9 attributes: extracted from XML file

- Malignancy (range: 1~5)
 - sphericity (range: 1~5)
 - margin (range: 1~5)
 - spiculation (range: 1~5)
 - texture (range: 1~5)
 - calcification (range: 1~6)
 - internal structure (range: 1~4)
 - lobulation (range: 1~5)
 - subtlety (range: 1~5)
- Seven academic centers and eight medical imaging companies collaborated to create this data set.
 - Each subject includes images from a clinical thoracic CT scan and annotations performed by four experienced thoracic radiologists.



System Architecture

Nodules

Nodule 1

Nodule 2

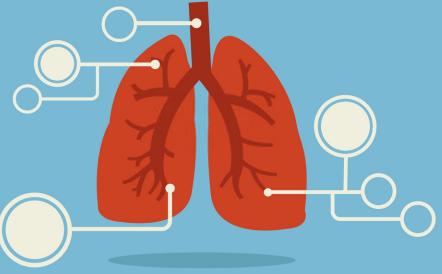
Nodule 3

Nodule 4

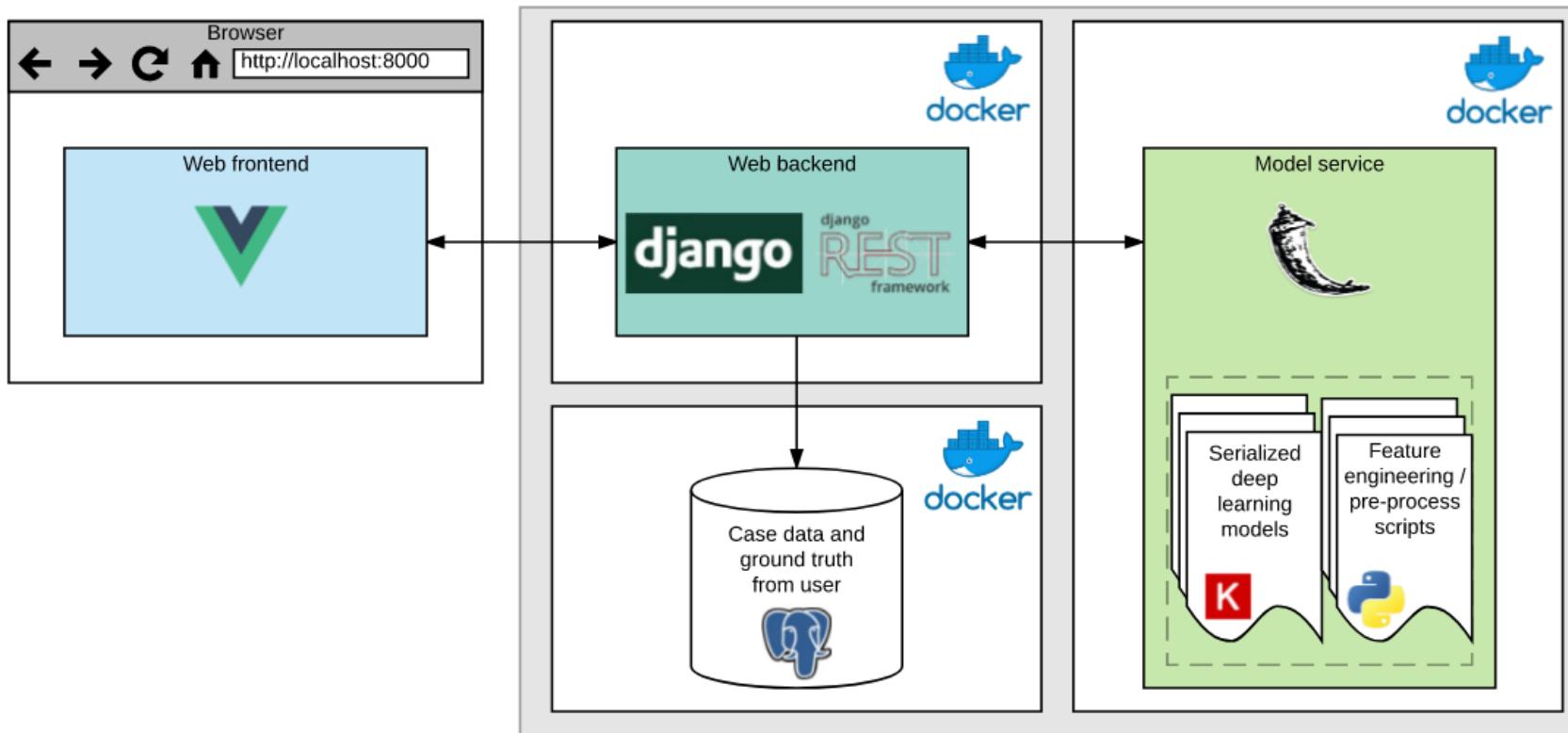


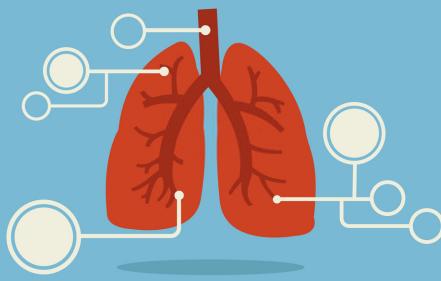
The nodule is benign because spiculation is marked and margin is poorly sharp and size is medium (< 5.9 mm)

Parameter	Value
malignancy	
sphericity	
margin	
spiculation	
texture	
calcification	
internal structure	
lobulation	
subtlety	



System Architecture





Patient Case Management Module

← → C ⌂ <http://localhost:8000/>

Open image > Detect and select > Annotate and segment > Report and Export

Open image

root

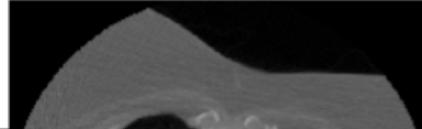
- └ test cases, no nodules
 - └ test_case_0001
 - └ test_case_0002
 - └ test_case_0003
- └ test cases, benign
 - └ test_case_0004
 - └ test_case_0005
 - └ test_case_0006
- └ test cases, cancerous
 - └ test_case_0007
 - └ test_case_0008
 - └ test_case_0009
 - └ test_case_0010
 - └ test_case_0011

test_case_0009

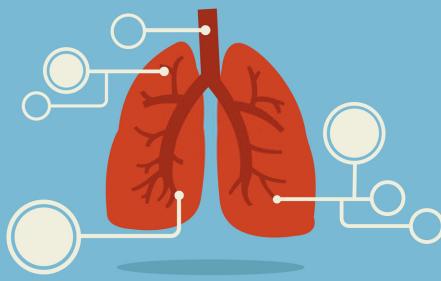
Metadata

Field	Value
Date	2017-02-15
Age	51
Sex	M
KVp	120
mA	93

Preview



Connected to DICOM server: test-image-server



Nodule Detection Module

← → C ⌂ <http://localhost:8000/>

Open image > Detect and select > Annotate and segment > Report and Export test_case_0009

Detect and select

Candidate 1 (p=0.94)

```
lidc_max_sensitiv: 0.98
convnet_vgg: 0.94
convnet_vgg_lidc: 0.90
```

Centroid (predicted):
Slice: 66/128
X: 54
Y: 78

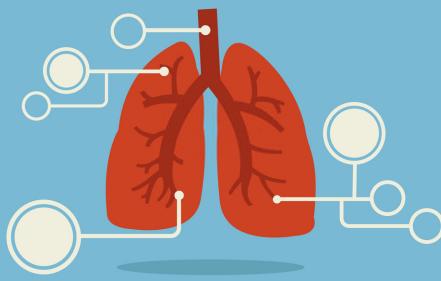
Dismiss Mark concerning

Candidate 2 (p=0.64)
Candidate 3 (p=0.41)
Candidate 4 (p=0.39)
Candidate 5 (p=0.22)
Candidate 6 (p=0.13)
Candidate 7 (p=0.08)

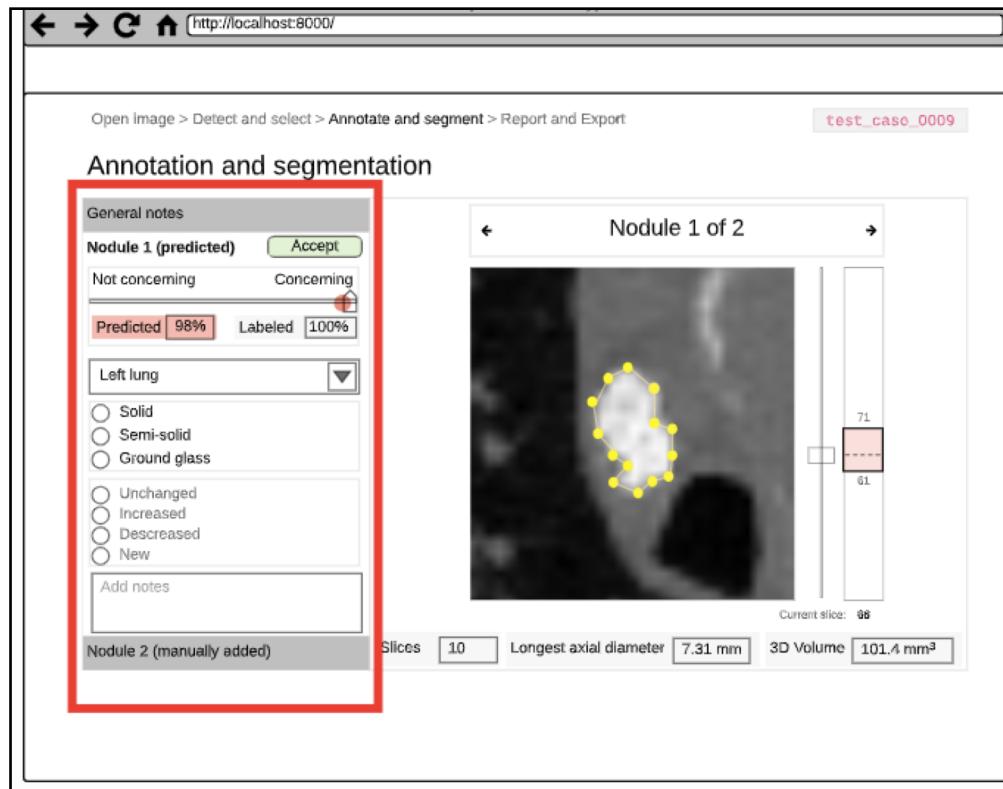
Mark other site not predicted

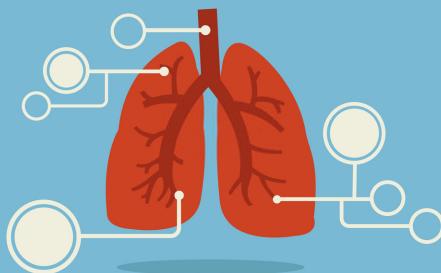
7 candidates found T G

A grayscale CT scan slice of a lung. A small red '+' sign is placed on the image, indicating the location of a detected nodule. The image shows the internal structure of the lung with various airways and tissue densities.



Annotation and Segmentation Module



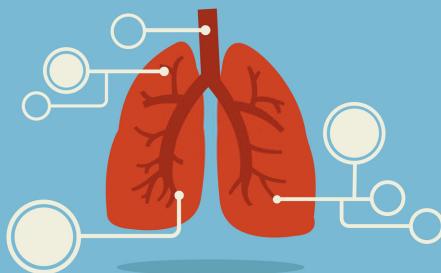


Report Generation Module

← → C ⌂ <http://localhost:8000/>

Open image > Detect and select > Annotate and segment > Report and Export test_case_0009

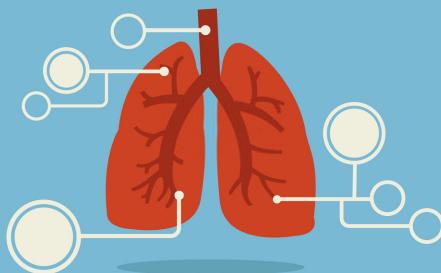
<p>Contents</p> <p>Overview RSNA Standard Template Technical parameters Clinical information Findings Exam parameters Lung nodules Lungs Right pleural space Left pleural space Heart Other findings Impression ACR Lung-RADS™ Findings Nodule 1 Nodule 2 Risk summary Export 3D Imagery SHP File STL Shapefiles</p>	<p>RSNA Standard Template Export</p> <p>Technical parameters kVp: 120 mA: 93 DLP: 18 µSv/mGy</p> <p>Clinical information Screening visit: Year 1 Lung cancer screening.</p> <p>Findings</p> <p>Exam parameters Diagnostic quality: Satisfactory Comments: None</p> <p>Lung nodules Present, detailed below: Left lung, 7.22 mm solid new, image #66 (centroid) ↗ Right lung, 2 mm semi-solid new, image #119 (centroid) ↗</p> <p>Lungs COPD: None Fibrosis: None Lymph nodes: None Other findings: None</p>
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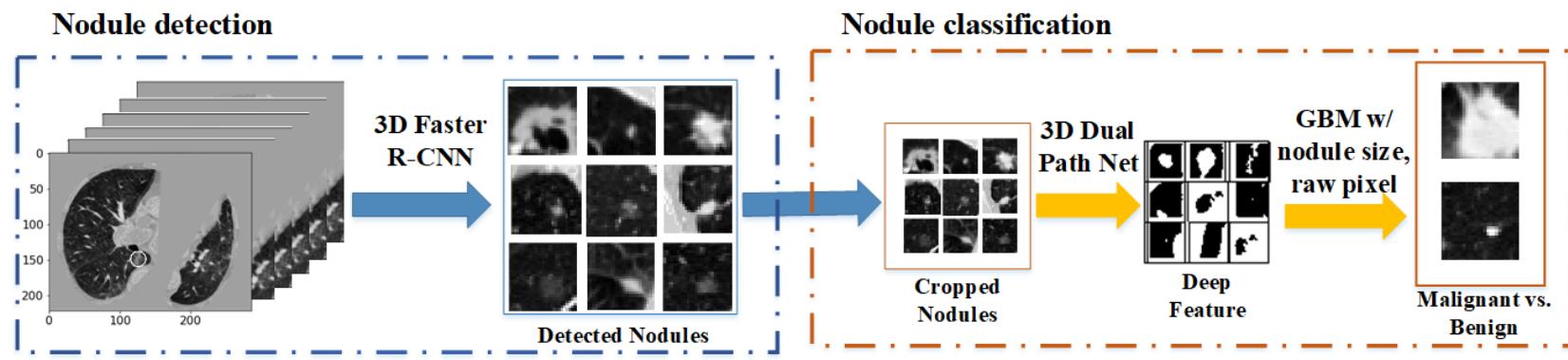
The Neural Network Model

Stage	Output	Weights
Pre-dual path	96×96×96, 24	$3 \times 3 \times 3, 24$
Dual path block 1	48×48×48, 48	$\left\{ \begin{array}{l} 1 \times 1 \times 1, 24 \\ 3 \times 3 \times 3, 24, (\text{stride } 2) \\ 1 \times 1 \times 1, 32 \end{array} \right\} \times 2$
Dual path block 2	24×24×24, 72	$\left\{ \begin{array}{l} 1 \times 1 \times 1, 48 \\ 3 \times 3 \times 3, 48, (\text{stride } 2) \\ 1 \times 1 \times 1, 56 \end{array} \right\} \times 2$
Dual path block 3	12×12×12, 96	$\left\{ \begin{array}{l} 1 \times 1 \times 1, 72 \\ 3 \times 3 \times 3, 72, (\text{stride } 2) \\ 1 \times 1 \times 1, 80 \end{array} \right\} \times 2$
Dual path block 4	6×6×6, 120	$\left\{ \begin{array}{l} 1 \times 1 \times 1, 96 \\ 3 \times 3 \times 3, 96, (\text{stride } 2) \\ 1 \times 1 \times 1, 104 \end{array} \right\} \times 2$
Deconv. 1	12×12×12, 216	$2 \times 2 \times 2, 216$
Dual path block 5	12×12×12, 152	$\left\{ \begin{array}{l} 1 \times 1 \times 1, 128 \\ 3 \times 3 \times 3, 128 \\ 1 \times 1 \times 1, 136 \end{array} \right\} \times 2$
Deconv. 2	24×24×24, 224	$2 \times 2 \times 2, 152$
Dual path block 6	24×24×24, 248	$\left\{ \begin{array}{l} 1 \times 1 \times 1, 224 \\ 3 \times 3 \times 3, 224 \\ 1 \times 1 \times 1, 232 \end{array} \right\} \times 2$
Output	24×24×24, 3×5	Dropout, p=0.5 $1 \times 1 \times 1, 64$ $1 \times 1 \times 1, 15$

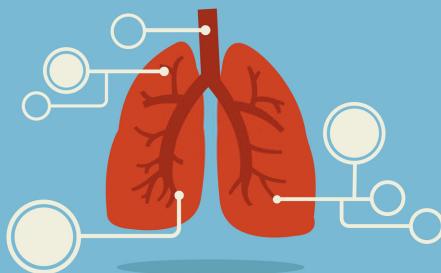
- The fully automated Lung cancer diagnosis system consists mainly of two parts: nodule detection and classification.
- This is the architecture for 3D Faster R-CNN for nodule detection.



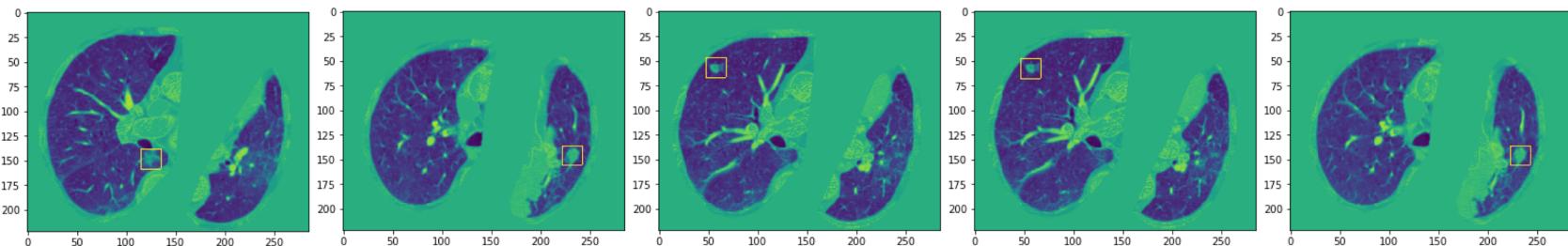
Pipelined Architecture



- As shown above, the nodule detection module and the classification module are pipelined making the entire diagnosis system completely streamlined.



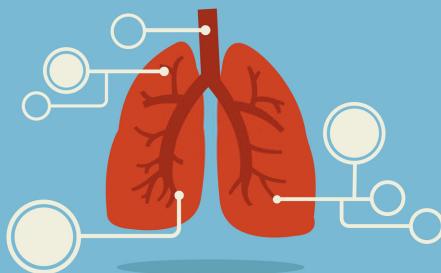
Results and Accuracy



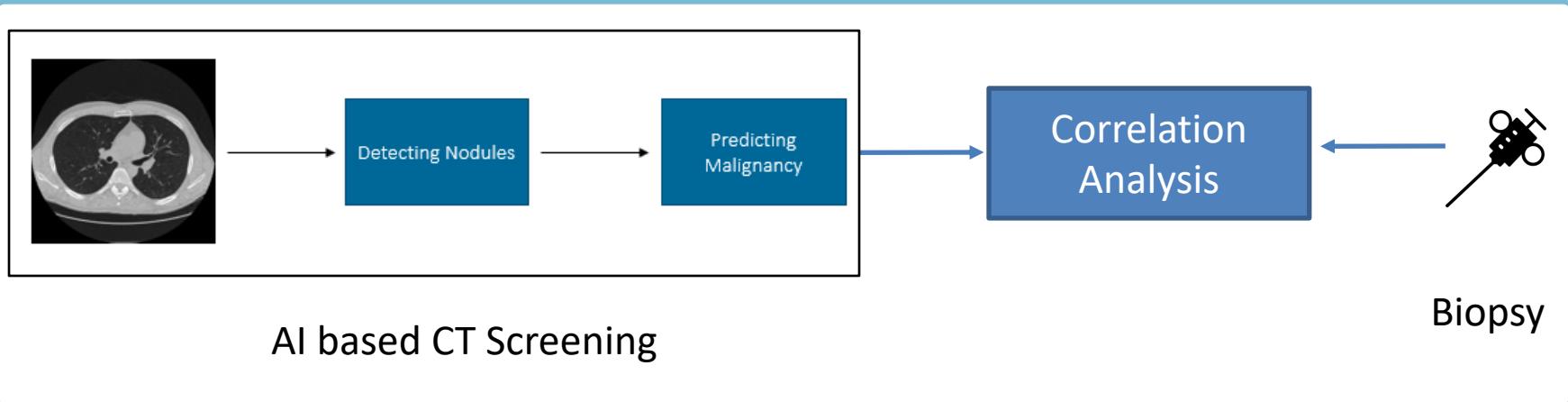
Accuracy

	Dr 1	Dr 2	Dr 3	Dr 4	Average
Doctors	93.44	93.69	91.82	86.03	91.25
Proposed Model	93.55	93.30	93.19	90.89	92.74

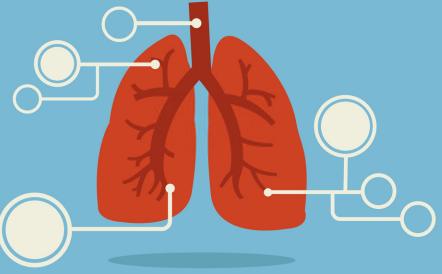
- We compared our predictions with those of 4 “simulated” experienced doctors on their individually confident nodules (with an individual score). Comparison results are given in the table above.



Correlation Analysis – The Future Scope



- Persistent plans to use our AI-based CT screening module alongwith biopsy reports obtained at the hospital to carry out correlation analysis for patients.
- This method will help in assessing the real world performance of our model.



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Thank You!

