Co.R.S.A

Covid **R**adiographic imaging **S**ystem based on **A**I

Le basi dell'Intelligenza Artificiale

Deep Learning applicato al medical imaging

Dissemination event, 10 marzo 2023, Pinerolo

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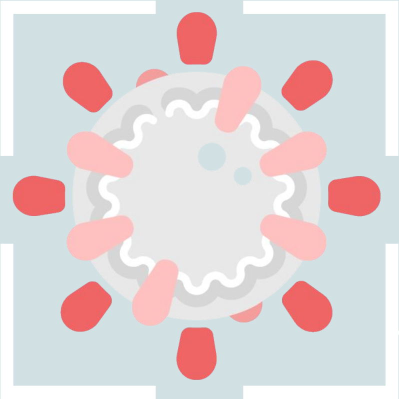
Bando INFRA-P2 - Potenziamento di laboratori di prova ed infrastrutture di ricerca già esistenti nella disponibilità di organismi di ricerca pubblici e progetti di ricerca e sviluppo finalizzati al contrasto della pandemia Covid-19

Table of Contents



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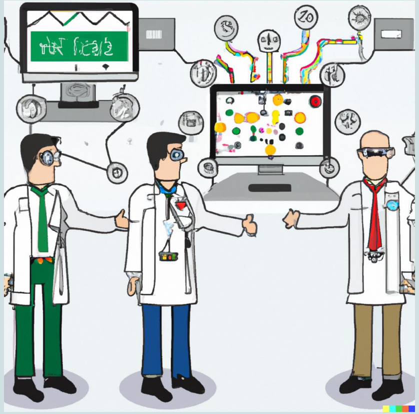
01

AI primer

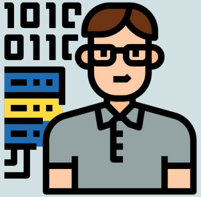
Introduction to Deep Learning in medical imaging



Actors in the play

Methods&tools

Challenges



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Feature Engineering

Challenge

Data samples

- Problem understanding and method mapping
- Tool/model selection based on target features
- Development and validation

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Learning based approach

Challenge

- Problem understanding and method mapping
- Dataset
- Model selection & training
- Development and validation

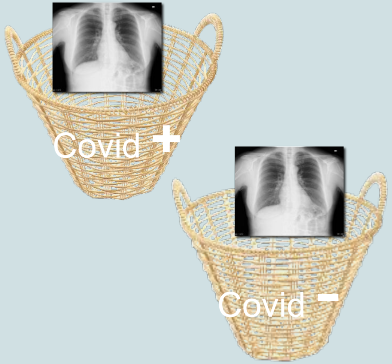
Data

Magic and Threats

- Deep learning is
  - Powerful and **general method**
  - Maps **knowledge** on complex model **through data**
  - Can **tackle ill-posed problem** (missing data, noise, high dimensionality, etc.)

The Co.R.S.A. Challenge

- Challenge: can we detect Covid-19 from simple CXR imaging?
- Supervised learning approach



Large labeled image dataset

Deep Learning:
Convolutional layers + neural classifier

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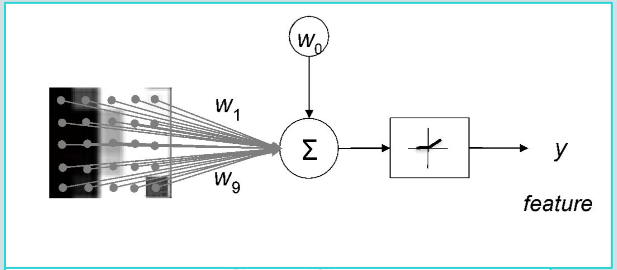
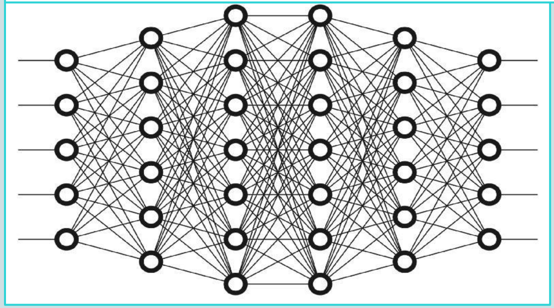
Deep Learning for dummies (supervised)

Test the model

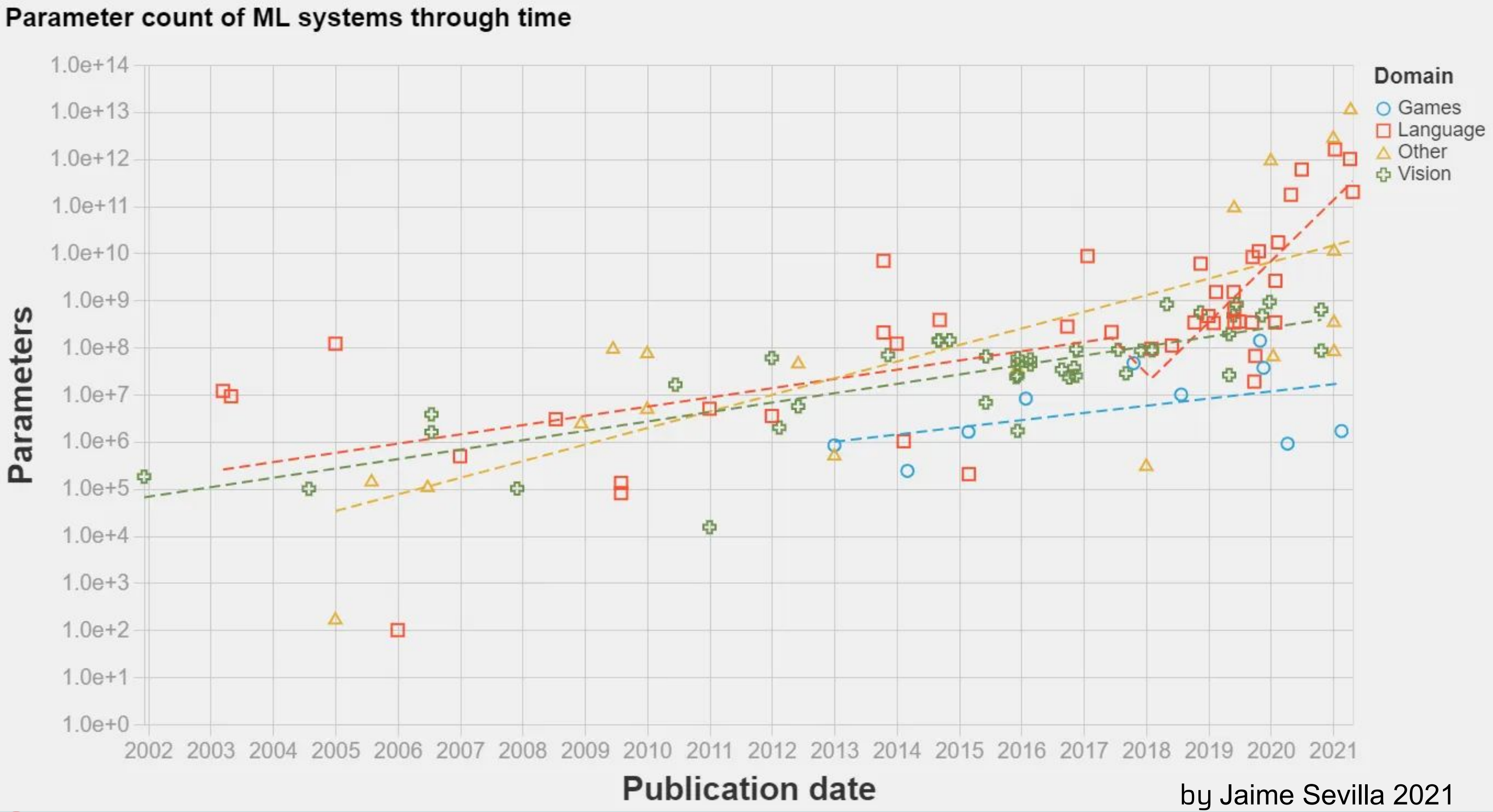
Data & labels





Target output
&
Loss function

Improve the model



by Jaime Sevilla 2021

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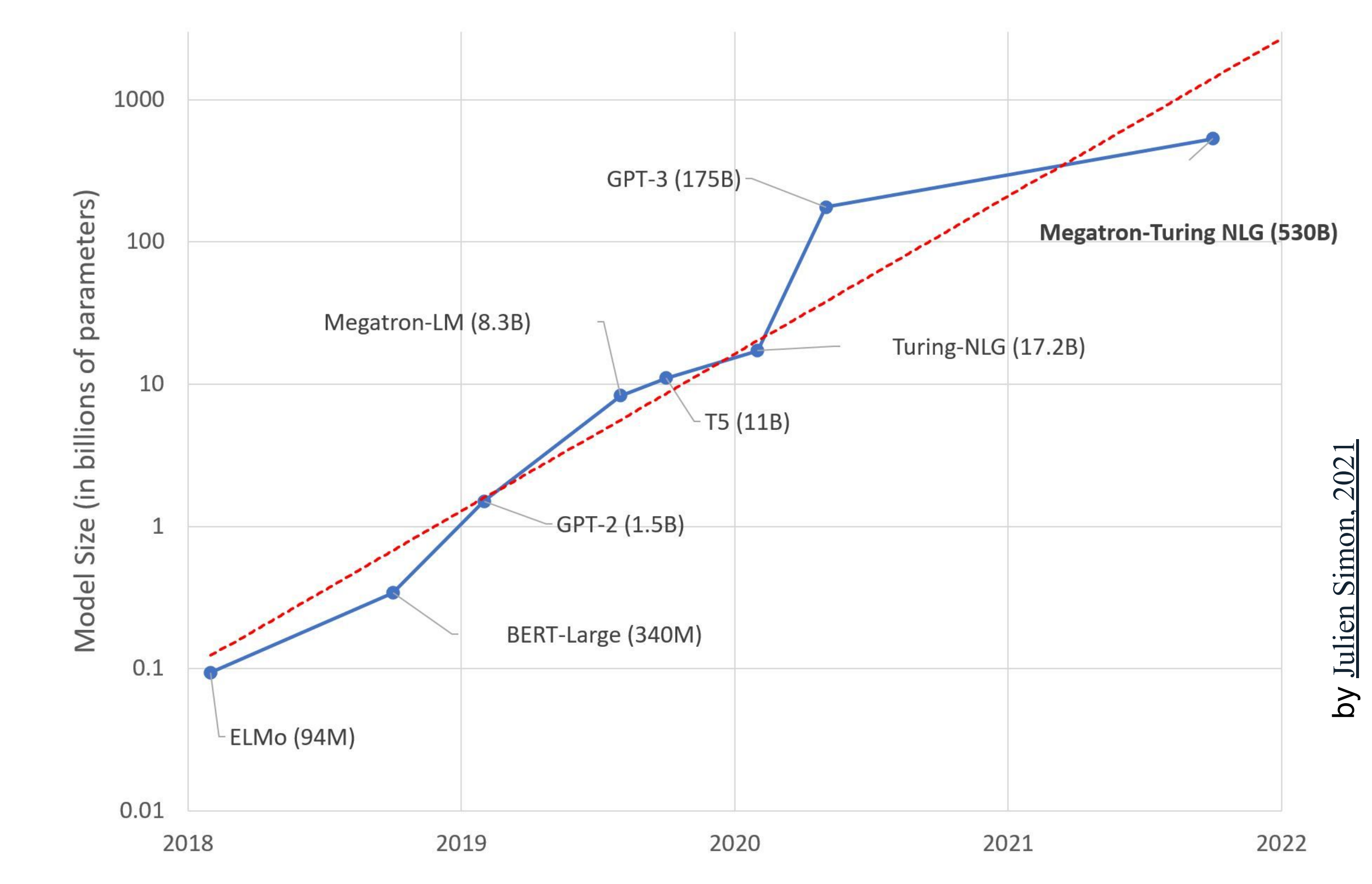
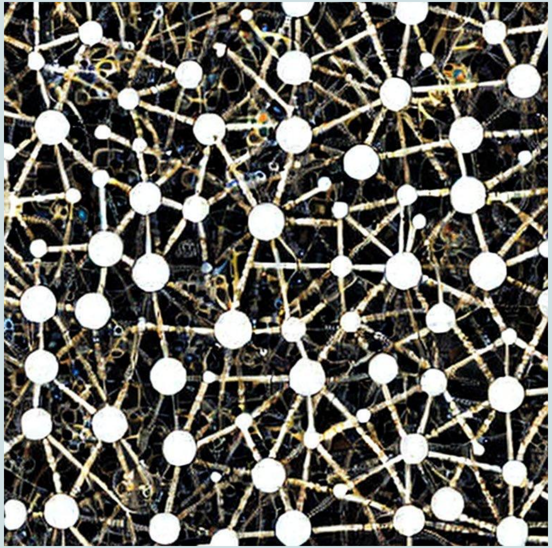


by Julien Simon, 2021

What it is

- IS **powerful**: allows one to train huge models (billions of parameters)
- IS **general**: can extract knowledge directly from examples
- IS getting momentum in **medical imaging** (unsupervised learning, generative models, multimodal)



and what it is not

- is NOT **intelligent**: dataset shall be balanced, learn by examples (with random sampling)
- is NOT guaranteed to be explainable (**trust**)
- is NOT guaranteed to generalize well (**robust**): biases and collateral learning can limit the learning, new data can cause catastrophic forgetting

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A receipt

- Spend as much time as needed to define/understand the challenge
- Data collection
    - consider all possible correlated/potentially useful information
    - beware biases (age, gender, acquisition method, etc.)
- Importance of preprocessing/quality of data (especially on small dataset)
- Discuss and **refine obtained metrics**
- Inspect (try to understand, to constrain) extracted features
- Exploit learning complexity to unveil unexpected phenomena **challenging prior assumptions**
- Public dataset & GDPR and ethical issues

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02

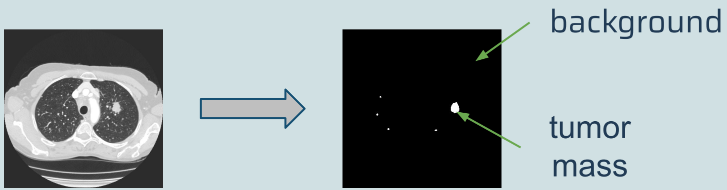
Lung nodules segmentation

Deep learning for lung nodules segmentation in CT scans

DeepHealth UC4: A successful collaboration

UniToChest

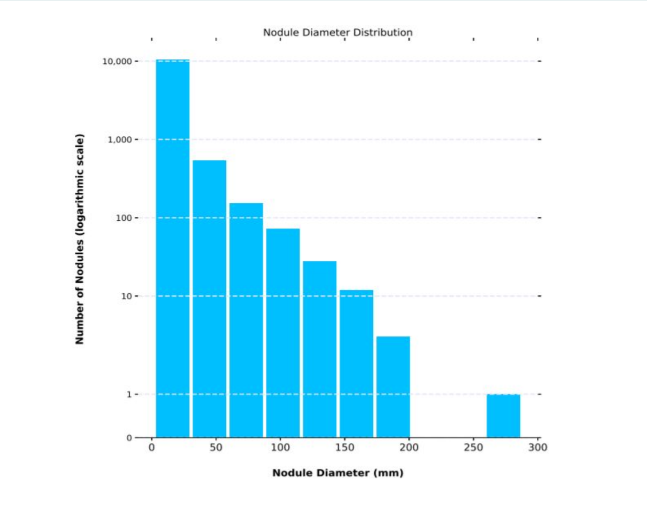
https://zenodo.org/record/5797912#.Y_yoztLMJhE



UniToChest

Attribute	Category	Number of nodules
Nodule diameter	$< 03mm$	96
	$< 10mm$	4321
	$< 30mm$	6031
	$> 30mm$	847
Splits	*Training*	9823
	Validation	483
	Test	990
Total		11295

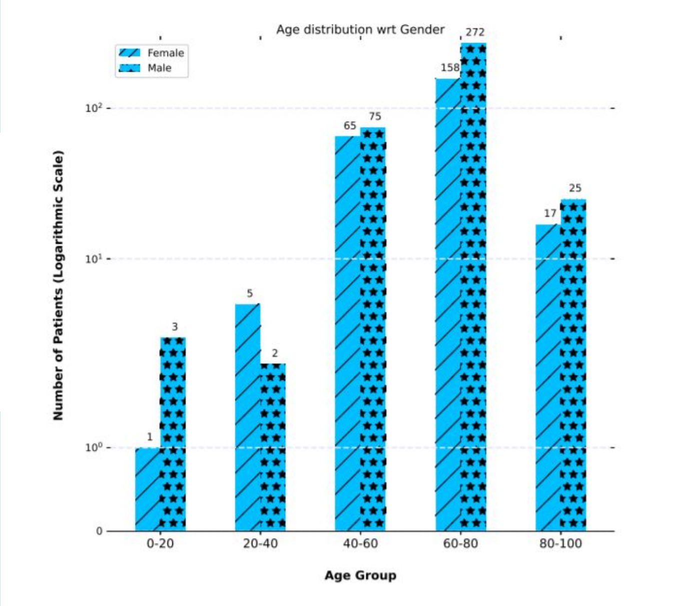
UnitoChest nodules distribution



UniToChest

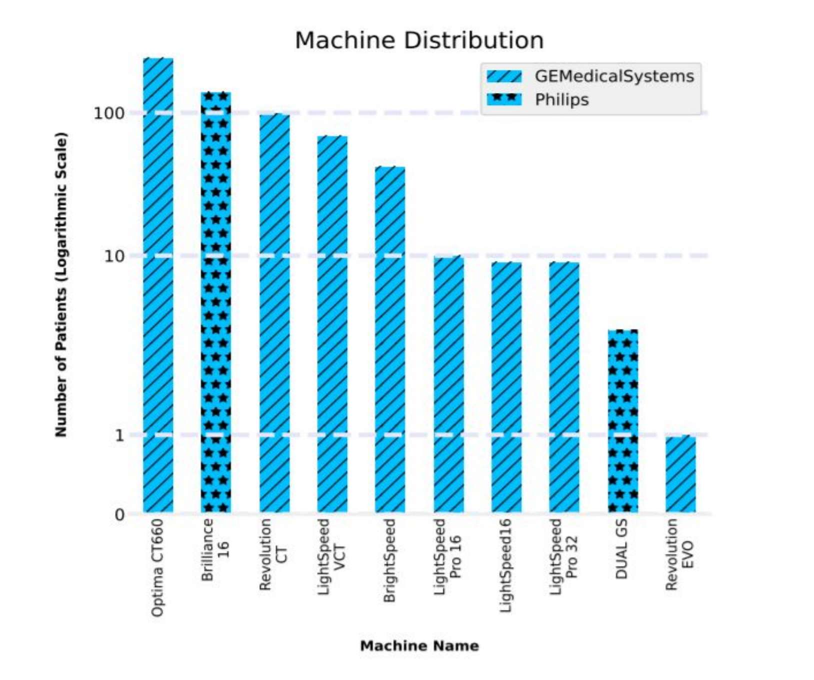
Splits	Number of Patients	Male	Female	Average Age
Training	498	303	195	66
Validation	62	39	23	68
Test	63	35	28	65
Total				623

UnitoChest dataset population



UniToChest

Robustness to the biases of CT acquisition machines



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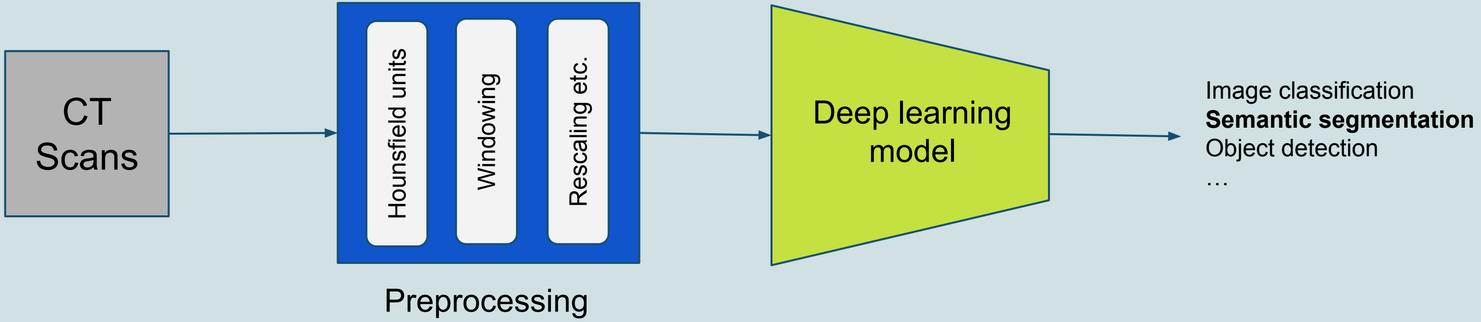
Pipeline



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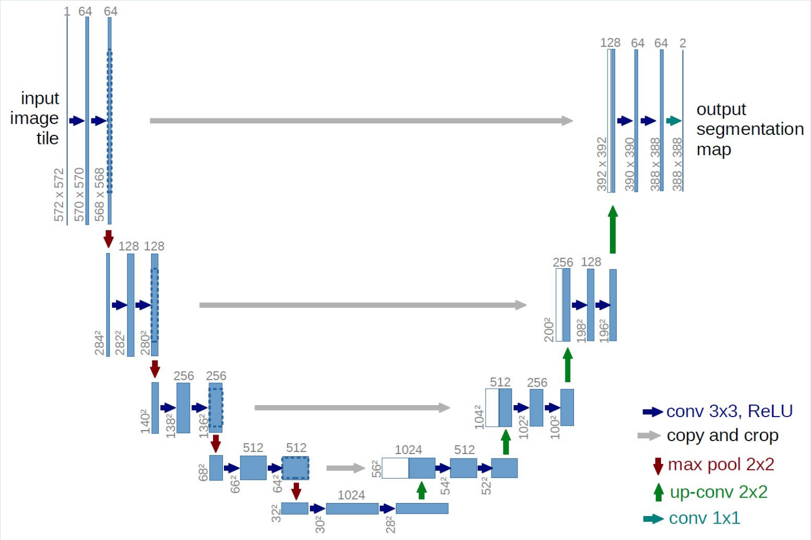
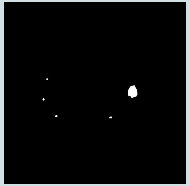
AI Model

Model presented in 2015 (pdf) for biomedical image segmentation (UNet-2D).





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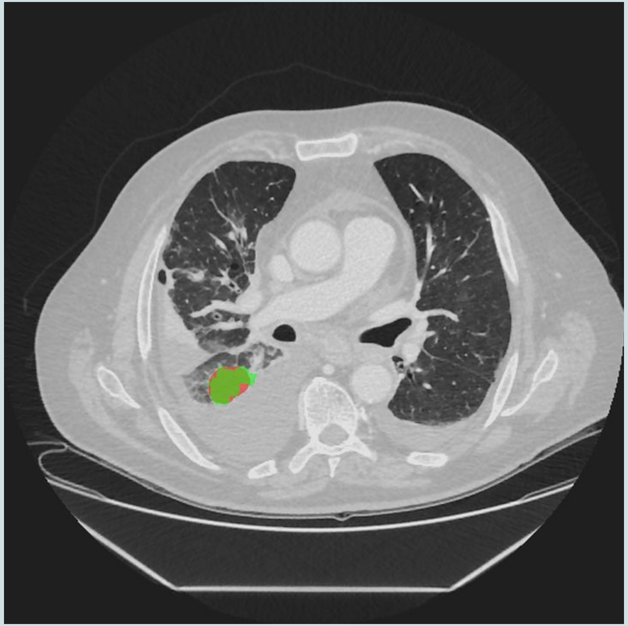
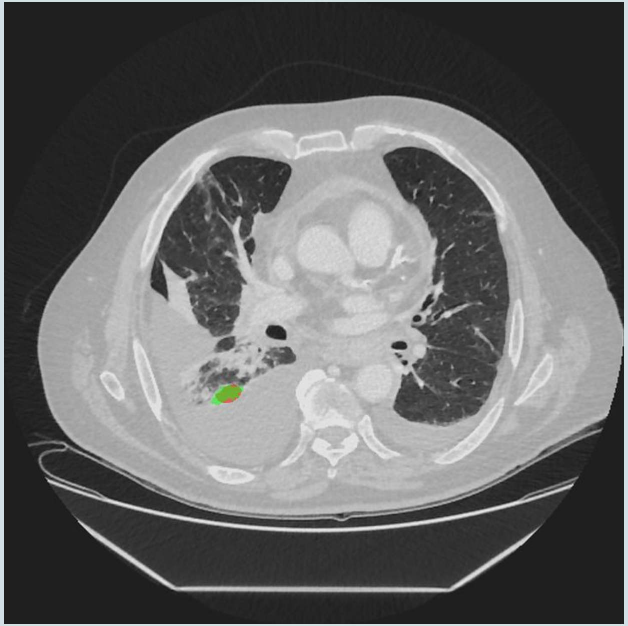
Results

Ground truth

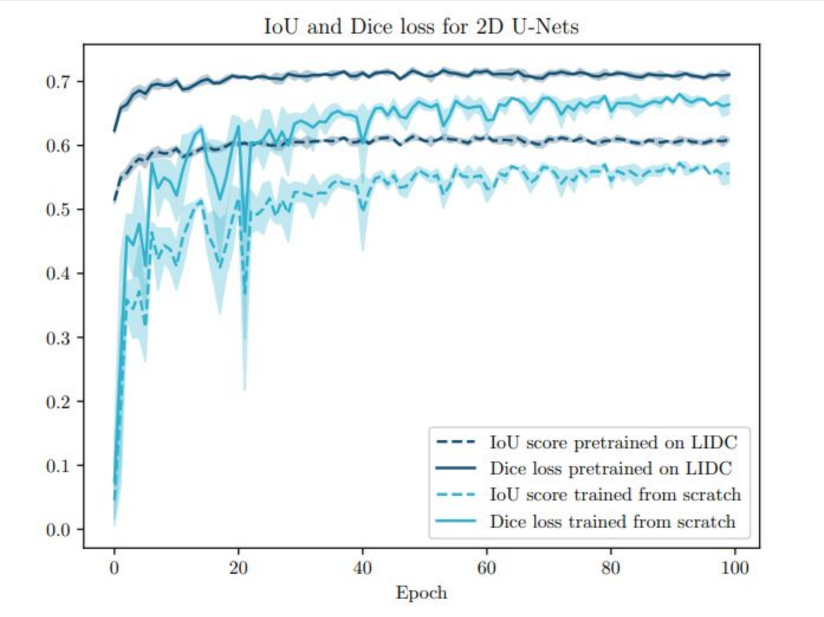
Prediction

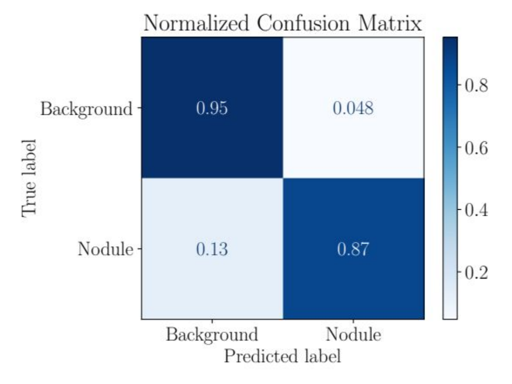




Results

	Trained	Input size	Dice Score	IoU
UNet-2D	from scratch	512x512	0.70	0.59
UNet-2D	pretrained on LIDC	512x512	0.73	0.62





Paper: https://link.springer.com/chapter/10.1007/978-3-031-06427-2_16

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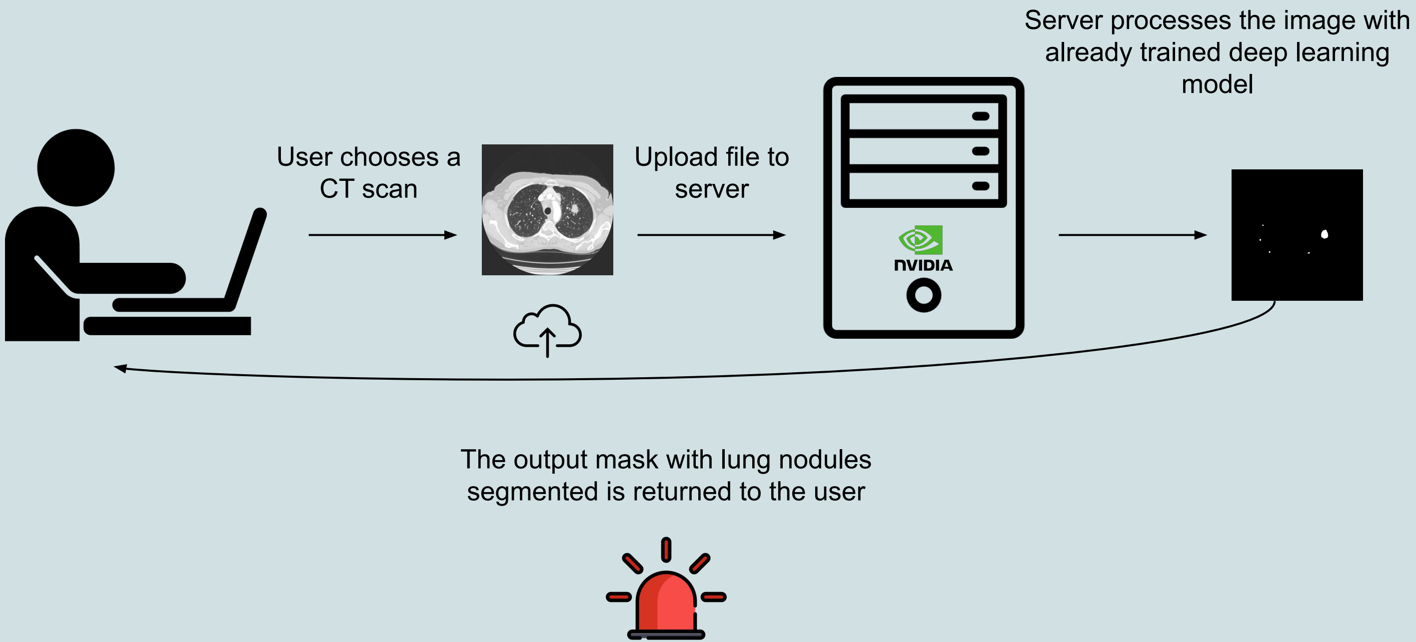
How AI can help radiologists?



03

COVID detection

The Co.R.S.A. challenge: dataset, trust, interpretability

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Imaging, AI and COVID-19

A step back in time …to ~Sept. 2020

- 28M+ cases worldwide
- RT-PCR as golden standard
- Chest X-Ray (CXR) less sensitive than CT, but easier to deploy
- CXR often used in practice for preliminary screening

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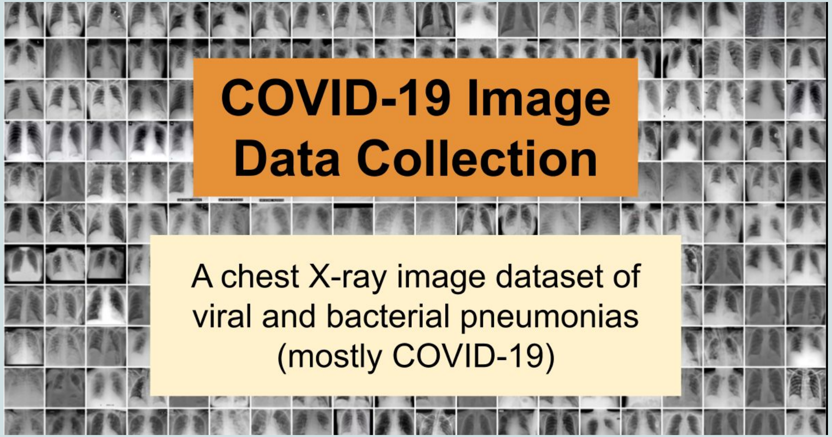
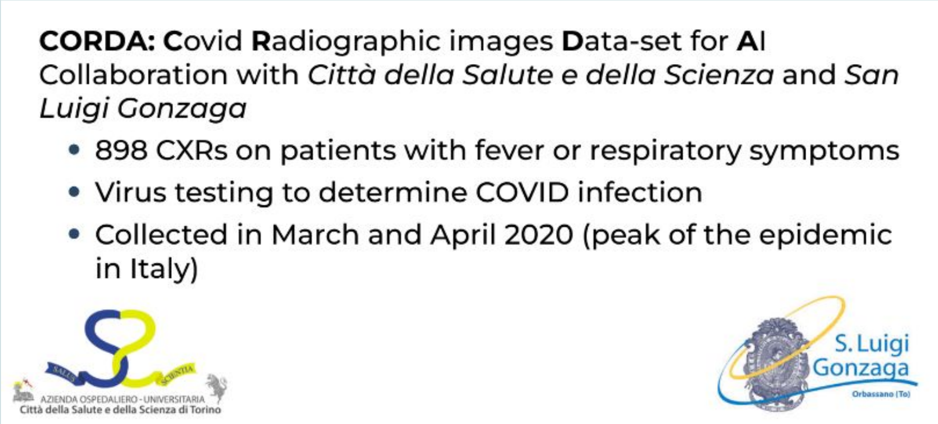
Early efforts to build datasets (< 2020)



Covid19-CXR: Around 100 images at the time (public); gathered from research articles and public sources - *Cohen et al.* https://github.com/ieee8023/covid-chestxray-dataset



CORDA (1st iteration): Largest dataset at the time ~900 CXRs; gathered directly from hospitals in Piedmont; however private at the time

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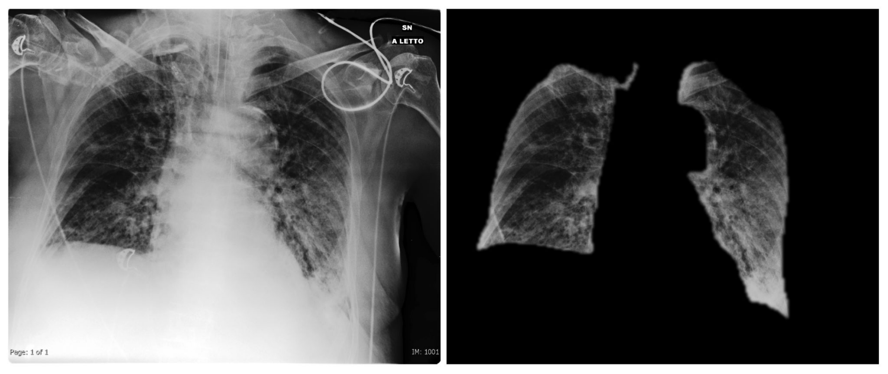
AI Pipeline

Preprocessing



Preprocessing ensures that all images are coherent with each other (e.g. histogram normalization). This helps the neural network to converge faster.

<u>Preprocessing helps in removing noise in the data</u>

Data anonymization is also usually performed as first step

Other operations such as **lungs segmentation** can be used to partially remove polarizing features from the image (e.g. biases such as medical devices and text)

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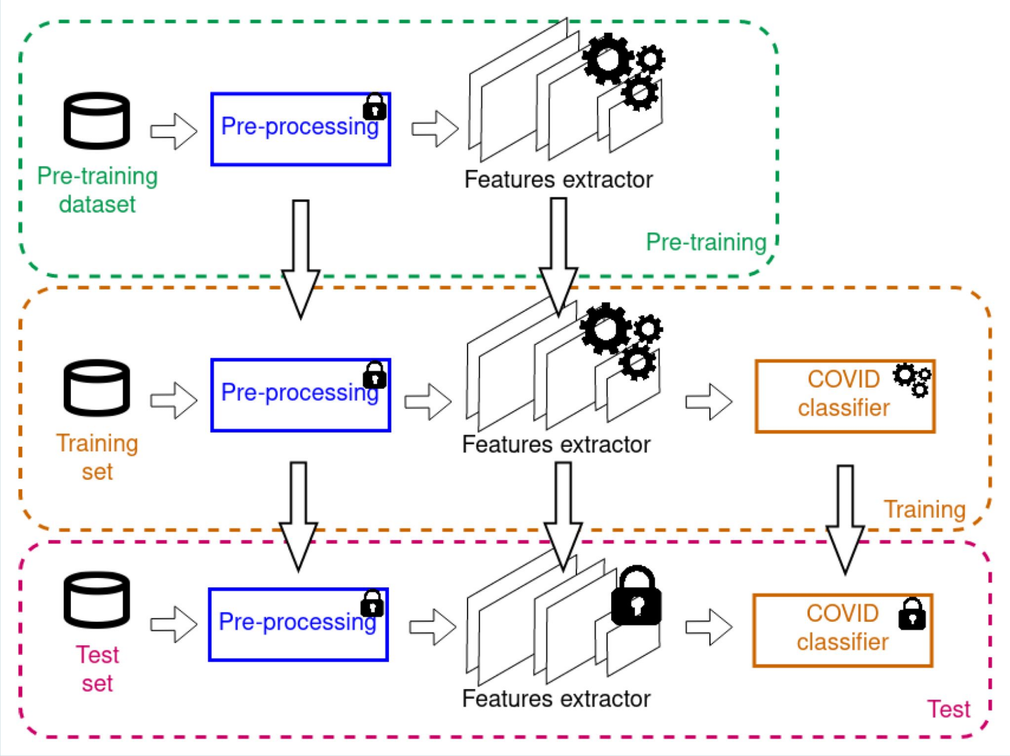
AI Pipeline



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The problem with small datasets - Biases

New data (>= 2020)

Mostly covid-19 positives

Previously available data (< 2020)

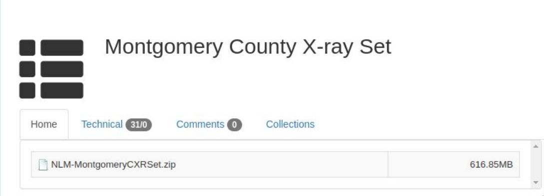

Brief Report

Two public chest X-ray datasets for computer-aided screening of pulmonary diseases

Stefan Jaeger[1], Sema Candemir[1], Sameer Antani[1], Yi-Xiáng J. Wáng[2], Pu-Xuan Lu[3], George Thoma[1]

[1] Lister Hill National Center for Biomedical Communications, National Library of Medicine, National Institutes of Health, Bethesda, MD 20894, USA; [2] Department of Imaging and Interventional Radiology, Prince of Wales Hospital, The Chinese University of Hong Kong, Shatin Hong Kong, SAR, China; [3] Department of Radiology, The Shenzhen No. 3 People's Hospital, Guangdong Medical College, Shenzhen 518020, China

All negatives



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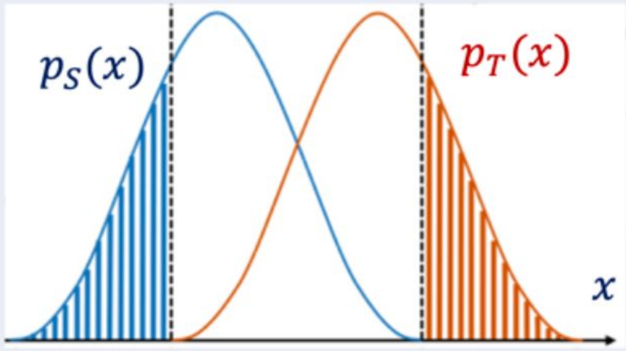
The problem with small datasets - Biases

New data (>= 2020)

Mo
pos

$$p_S(X) \neq p_T(X)$$



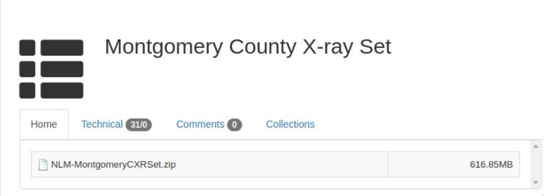
Previously available data (< 2020)


Brief Report

ray datasets for computer-aided screening of pulmonary diseases

ir[1], Sameer Antani[1], Yì-Xiáng J. Wáng[2], Pu-Xuan Lu[3], George Thoma[1]

Biomedical Communications, National Library of Medicine, National Institutes of Health, Bethesda, MD
maging and Interventional Radiology, Prince of Wales Hospital, The Chinese University of Hong Kong, Shatin
artment of Radiology, The Shenzhen No. 3 People's Hospital, Guangdong Medical College, Shenzhen


Montgomery County X-ray Set

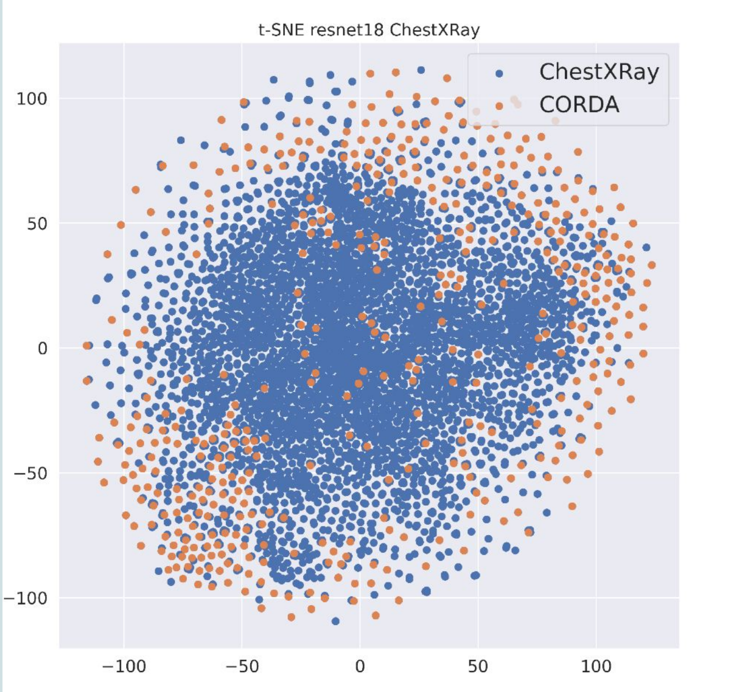
Home | Technical 31/0 | Comments 0 | Collections

NLM-MontgomeryCXRSet.zip	616.85MB

The problem with small datasets - Biases

The two datasets (e.g. *CORDA* vs *ChestXRay*) are very different, for two reasons:

- Covid19+ vs Covid19- **GOOD**
- Other reasons such as populations (i.e. children vs adults) **BAD**



<u>Deep Learning models are naive: they take the **simplest** solution to the problem</u>

The problem with small datasets

Despite many works initially claimed detection accuracy of >90%, the real accuracy (BA) is around 67% at max, and the sensitivity is low

Method	Baseline [20]		
Backbone	RN-18	RN-18	RN-18
Classifier	FC	FC	FC
Pretrain	-	RSNA	CXR
Train		CDSS	
Sensitivity	**0.56**	0.54	0.54
Specificity	0.58	**0.80**	0.58
BA	0.57	**0.67**	0.56
AUC	0.59	**0.72**	0.67

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Takeaway

Direct covid19 diagnosis from CXR is hard with limited data

- Differences in negative vs positive population have a major impact
- Together with the limited number of images, this prevents the model from learning any useful clinical features (e.g. lung pathologies, appearance, etc.)

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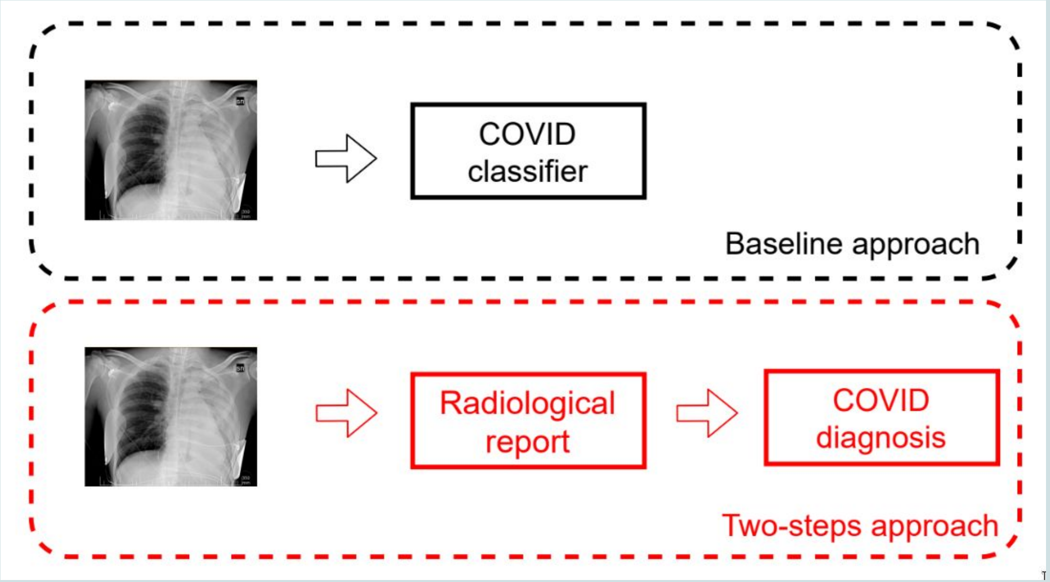
Mimicking the radiologist workflow

The direct approach fails to learn relevant features due to lack of sufficient data.

…but if we first explicitly focus on diagnosis objective radiological findings, we might obtain features also relevant for covid-19



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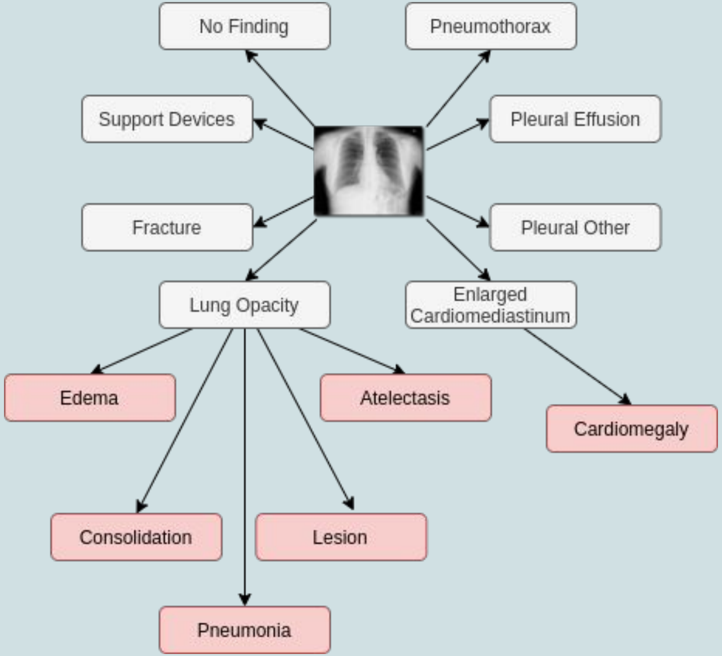
How to deal with limited data

Some large non-covid dataset exist, e.g. CheXpert, with more than 200k CXR images



CheXpert is well suited for learning objective radiological findings (e.g. opacity, consolidation, etc.).

The learned knowledge can then be transferred to the smaller covid datasets (*transfer learning*)

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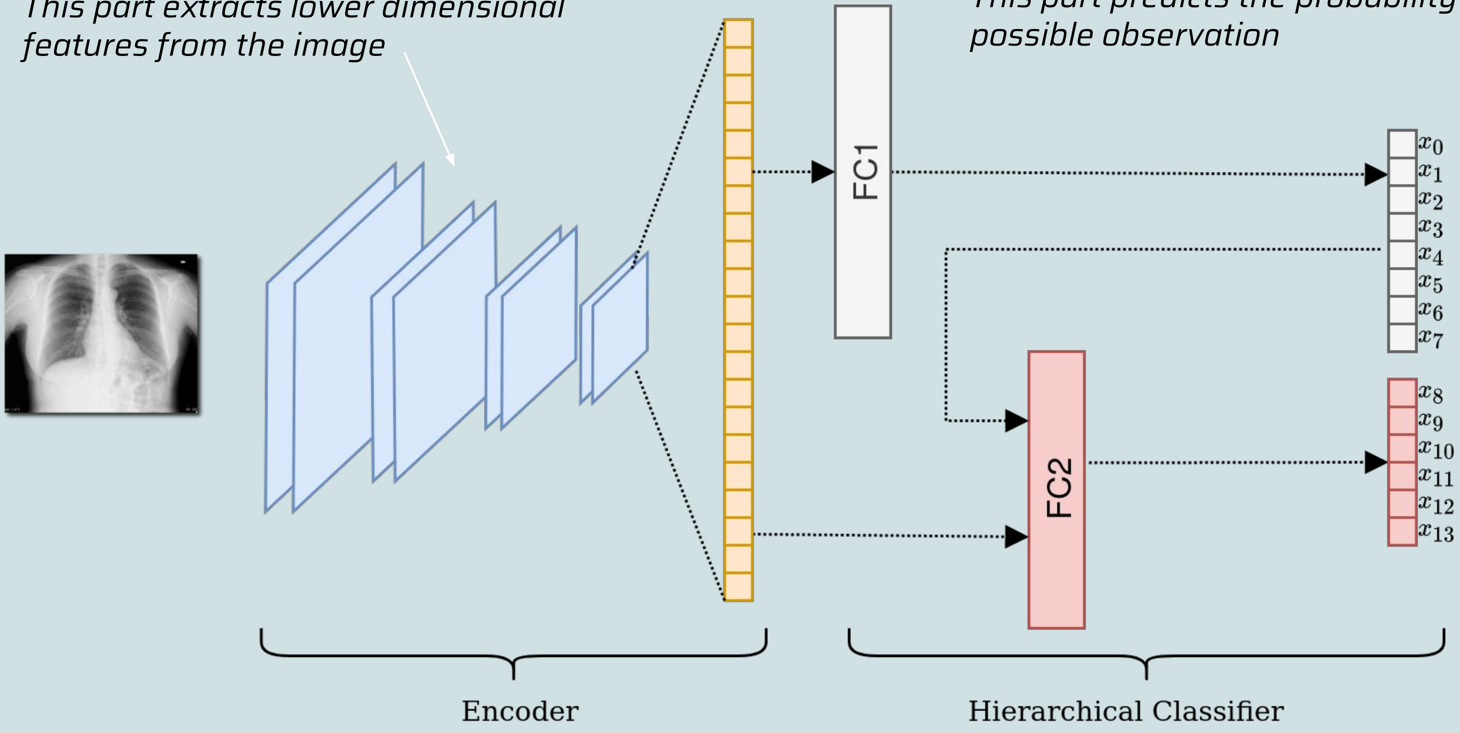
AI Radiological Report

This part extracts lower dimensional features from the image

This part predicts the probability of each possible observation



no finding: 1%
fracture: 2%
lung opacity: 80%
edema: 60%
consolidation: 70%
pneumonia: 70%
lesion: 60%
atelectasis: 65%
pleural effusion: 55%
pneumothorax: 35%
pleural other: 20%
enlarged cardiom.: 40%
cardiomegaly: 20%

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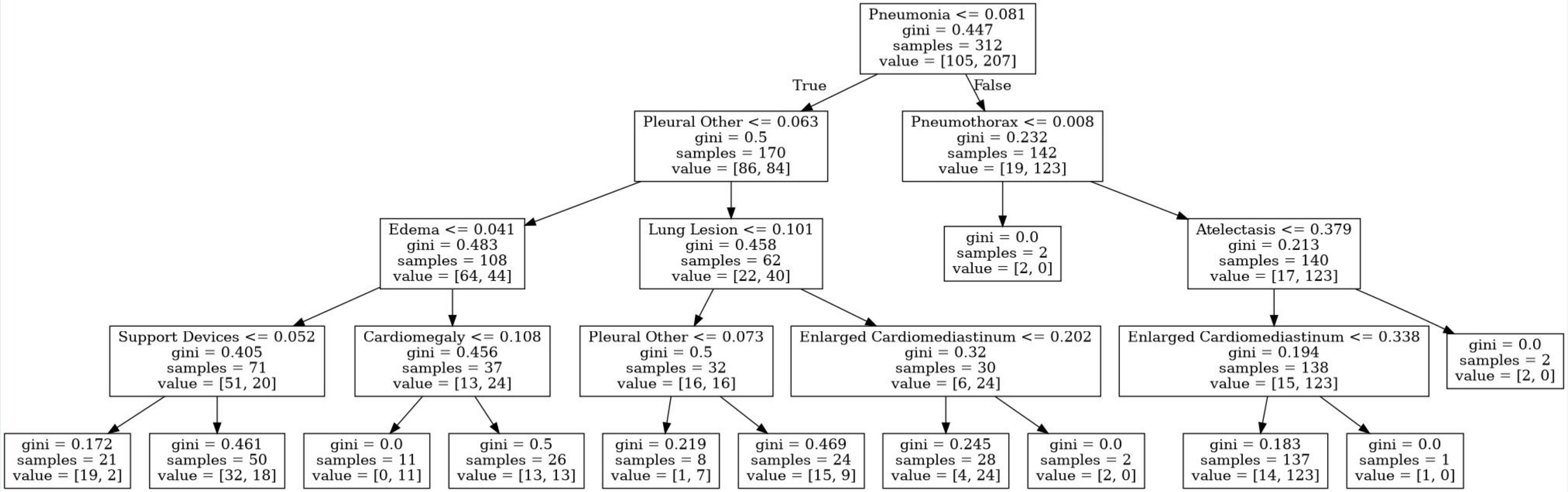
Covid-19 diagnosis from report

The AI radiological report can be used to predict the presence of Covid-19. For full explainability, a decision tree (a type AI model) can be employed



Covid-19 diagnosis from report

With this approach, we are able to improve the results significantly

- Previous accuracy 67%, sensitivity 56%
- Improved accuracy **75%** sensitivity **77%**

With slightly more sophisticated models we achieve:

- Accuracy 81% sensitivity 79%

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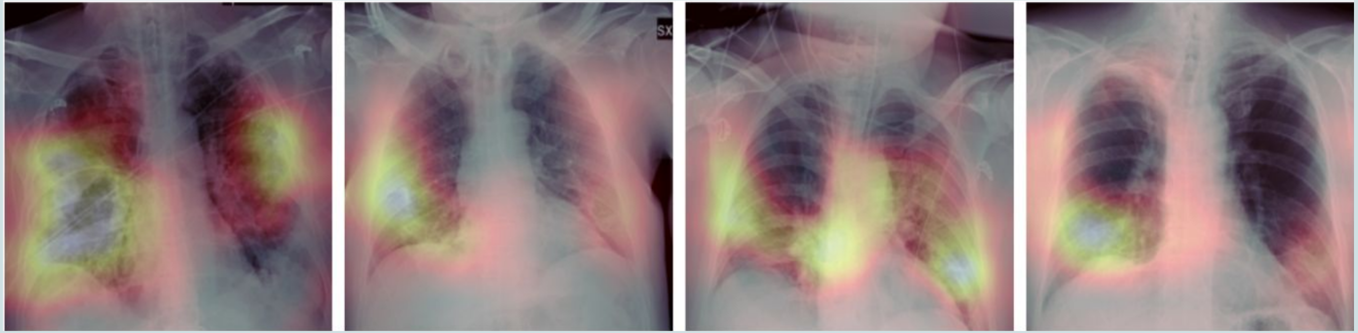
Interpreting AI predictions

- Other than the final covid diagnosis, with this approach we provide the **AI radiological report** which can explain the final decision (at least partially), and provide useful information to the clinician

- We can also visualize which region of the image influenced the most the decision process



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The CORDA data release

The CORDA dataset has since been publicly released, and is now available on Zenodo!
https://zenodo.org/record/7501816#.ZAeAv9LMJhE

The kept growing in size and now contains:

- 3000+ images (both CXRs and CTs)
- 4 participating hospitals (mauriziano, molinette, san luigi, monzino)

- **!! IMPORTANT: All images have been anonymized before sharing !!**

More information can be found on the CoRSA website: https://corsa.di.unito.it/

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Thanks

Do you have any questions?

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https://github.com/EIDOSLab

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