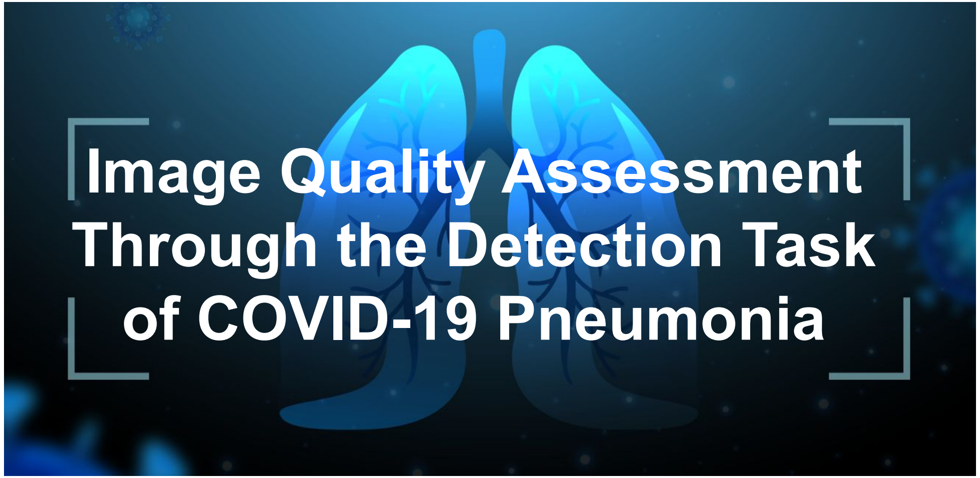

Image Quality Assessment Through the Detection Task of COVID-19 Pneumonia

Houda Jebbari[1], Meriem Outtas[1], Lucie Lévêque[2] and Lu Zhang[1]

[1] IETR - INSA Rennes, [2] LS2N - Nantes Université

OUTLINE

01 **Introduction**

02 **Task-based approach**

03 **Evaluation of medical image quality in the COVID-19 pneumonia detection task**

1- Choice of database
2- Selection of a classifier
3- Denoinsing methods

04 **Comparison of the results**

1- Comparison of the model performances on the original and post-processed database
2- Interpretation of the results

05 **Conclusion**

INTRODUCTION

- Emergence of COVID-19 in late 2019.
- Computed tomography (CT): to diagnose the severity of patients' infection.
- In CT images, X-ray radiation is used, but radiation dose level affects image quality.
- Now, low dose is the standard as it reduces the risk of X-ray exposure.
- WHO recommendation: minimise radiation dose, which can affect human health, while maintaining diagnostic image quality.
- Can we improve diagnostic image quality? By reducing noise in low-dose CTs?

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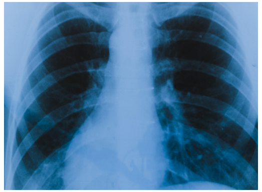
Diagnostic Quality : Task-Based approa

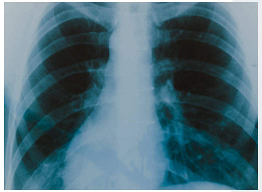
VQEG

Image quality is assessed in the context of a specific task: detection or localisation.



Imaging system 1

Imaging system 2



Imaging system 3

Medical experts

Human Observer (HO) performs a diagnostic task for the different medical imaging systems.

Computation of a quantitative value that characterizes the radiologist's task performance for a given imaging system. Figure Of Merit (FOM).

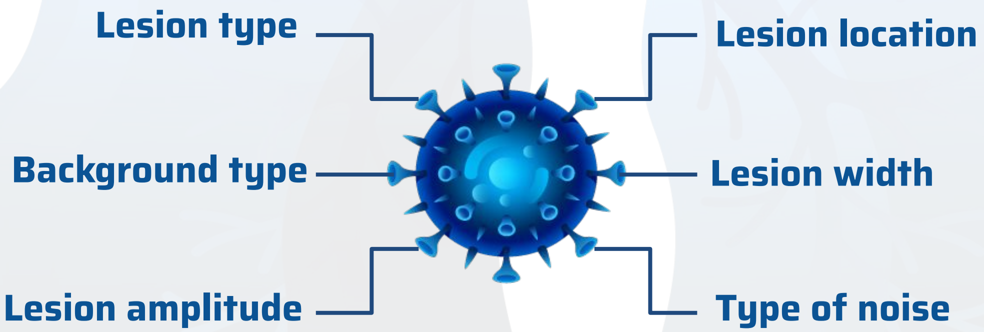
- FOMs comparison.

- The higher the FOM, the better the system.

Diagnostic Quality : Task-Based approach

Model observers (MO): mathematical models, can perform the same tasks as human observers (HO)?

MO needs information about:



- Research studies using a MO often use simulated images.
- Li *et al.*[1] concluded in a loss of task-relevant information after applying AI denoising methods on simulated images

Kaiyan Li, Weimin Zhou, Hua Li, and Mark A Anastasio, "Assessing the impact of deep neural network-based image denoising on binary signal detection tasks," IEEE TMI 2021.

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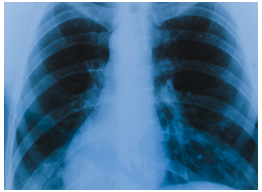
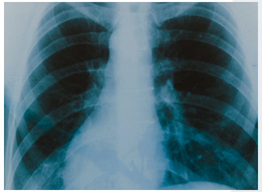
Diagnostic Quality : Task-Based approach

Use a classifier based on a supervised learning method for a detection task (binary classification).



Imaging system 1

Imaging system 2



Imaging system 3

AI: DL method

AI

MO

Model observer (MO) performs a classification task.

A present vs. absent signal (COVID-19) classification is performed

Better detection

↓

Best system

Best denoising Method

Adopted methodology

- **Choice** of a database resulting of **low dose CT scans** of **COVID 19** infected and non infected images.

- **Selection** of denoising method.

- Use of a **classifier** based on supervised-learning method.

- Evaluation of the detection task performed by the **classifier** on the original database and denoising methods.

1. COVID-19 databases

Dataset	Data type	Number of cases			Application			Source		CT vol.		Reliability	Metadata	
		COVID	CAP	Non-COVID	Classification	Segmentation	Reference	Multiple	Single	Available	Not available	Confirmed by	Available	Not available
SIRM [23]	Miscellaneous	60	NA	NA	✓		✓	-	-		✓	Radiologist		✓
MedSeg [24]	Segmented CT	49	NA	NA		✓		✓		✓		Radiologist		✓
Radiopaedia	Miscellaneous	9	NA	NA	✓		✓	✓		✓		Radiologist		✓
IMAIOS [25]	CT	38	NA	NA	✓		✓	-	-	✓		PCR test		✓
ChestXray [26] [27]	X-ray and CT	20	NA	NA	✓	✓		✓		✓		-	✓	
ZENODO [28] [29]	Segmented CT	20	NA	NA		✓		✓		✓		Radiologist		✓
MosMedData [30]	CT	856	NA	254	✓			✓		✓		Radiologist	✓	
COVID-CT-Dataset [31]	CT	216	NA	55	✓			✓			✓	Radiologist	✓	
SARS-COV-2 CTset [32]	CT	60	NA	60	✓			✓			✓	Radiologist	✓	
COVID-CTset [33]	CT	95	NA	282	✓				✓	✓		Radiologist	✓	
COVID-CT-MD [22]	CT	169	60	76	✓				✓	✓		Radiologist	✓	

Table 1: AVAILABLE COVID-19 CT SCAN DATABASES (NON-EXHAUSTIVE LIST INSPIRED FROM [22] AND COMPLETED).

[22] Parnian Afshar, Shahin Heidarian, Nastaran Enshaei, Farnoosh Naderkhani, Rafiee Moezedin Javad, Anastasia Oikonomou, Faranak

1. COVID-19 databases

- Should contain both COVID-19 and non-COVID-19 cases.
- Should contain chest CT scans.
- Should contain a wide variety of well-labeled data,
- should have been collected from single equipment and reconstruction algorithms.

1. COVID-19 databases

Dataset	Data type	Number of cases			Application			Source		CT vol.		Reliability	Metadata	
		COVID	CAP	Non-COVID	Classification	Segmentation	Reference	Multiple	Single	Available	Not available	Confirmed by	Available	Not available
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2. COVID-19 image classifier

Model	Tested on (datasets)	Performance
Detail-oriented capsule [34] networks (DECAPS)	COVID-CT	Accuracy: 87.6% - Precision: 84.3% Sensitivity: 91.5% - AUC: 96.1%
CovidNet3D-S, CovidNet3D-L [35]	MosMedData, COVID-CTset, and others	On MosMedData for CovidNet3D-L — CovidNet3D-S: Accuracy: 82.29% — 81.17% Precision: 79.5% — 78.82% Sensitivity: 98.82% — 99.22%
Based on U-Net [36]	Different sources from GitHub (2D)	Accuracy: 94.26% - Specificity: 93.47% Sensitivity: 92.19% - Precision: 94.86 %
COVID-FACT [37]	COVID-CT-MD	Accuracy: 90.8 % - Sensitivity: 94.55% Specificity: 86.04% - AUC: 98%
COVID-CT-CODE [33]	COVID-CT set	Accuracy: 98.49% Sensitivity: 94.96%
DL–based COVID-19 pneumonia classification (code not available)	COVID-CTset, MosMedData, and others	On COVID-CTset: Accuracy: 96.88%

Table 2: STUDIED COVID-19 CLASSIFIERS.

2. COVID-19 image classifier

- Should be able to classify 3D CT volumes as the chosen database contains cases with all the slices : patient-level classification instead of slice-level detection
- Should have a good accuracy and precision.
- Avoid data augmentation.

2. COVID-19 image classifier

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Table 2: STUDIED COVID-19 CLASSIFIERS.

Selected classifier : COVID FACT

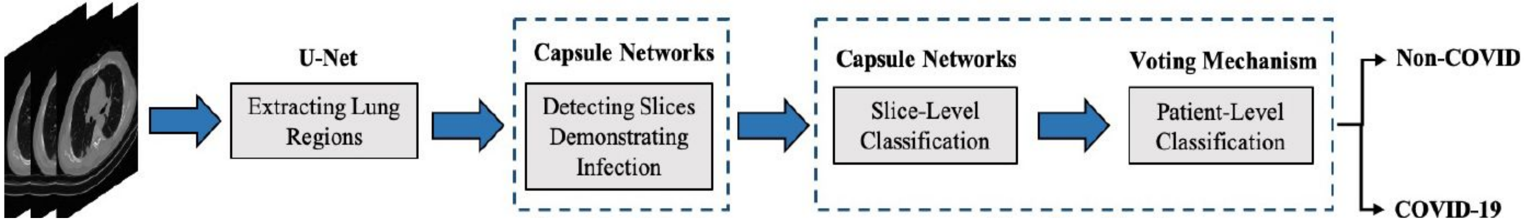

Figure 1: COVID-FACT architecture[1]

- Extracting lung regions using a training model base on U-NET region of interest
- Stage one: training on the annotated subset of data to detect slice demonstrating infection
- Stage two: classification of the infected slices into COVID-19 and non-COVID

[1] https://github.com/ShahinSHH/COVID-FACT, ‘A Fully-Automated Capsule Network-based Framework for identification of COVID-19 cases from Chest CT scans’

3. Denoising methods

- Anisotropic diffusion filter:

- Spatial filter.
- Improves details, especially low-contrast textures on images.
- Does not smooth the details of the images and stops diffusion at edges.

- Adaptive Total Variation (ATV):

- Spatial filter.
- Overcomes smoothing in image denoising.
- Avoids introducing artifacts by adding artificial structures, preservs details.

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Comparison of models performance

	Accuracy	Sensitivity	Specificity	Precision	AUC-ROC
Baseline model	**0.92**	**0.83**	0.944	0.801	**0.89**
Anisotropic model	0.9177	0.80	0.947	0.805	0.87
Adaptive Total Variation model	0.915	0.784	**0.95**	**0.809**	0.867

Table 3: CLASSIFICATION RESULTS FOR BASELINE (ORIGINAL IMAGES), ANISOTROPIC DIFFUSION, AND ATV DENOISED IMAGES.

- **AUC (Area Under Curve ROC)**.
- **Accuracy:** how many samples are correctly classified.
- **Sensitivity:** rate of positive samples correctly classified
- **Specificity:** rate of negative samples correctly classified
- **Precision:** how precise the model performs by examining the correct true positives from the predicted ones.

DISCUSSION

- Denoising methods enabled a slightly better classification for non-infected slices.
- ATV model reached best specificity and precision.
- Baseline model better classified infected slices: features of the infections were removed during filtering process.
- Some infected slices looked like non-infected slices, especially for low-contrast infections.
- Image denoising methods can reduce the visibility of structural details and low-contrast textures.

OUTLINE

CONCLUSION

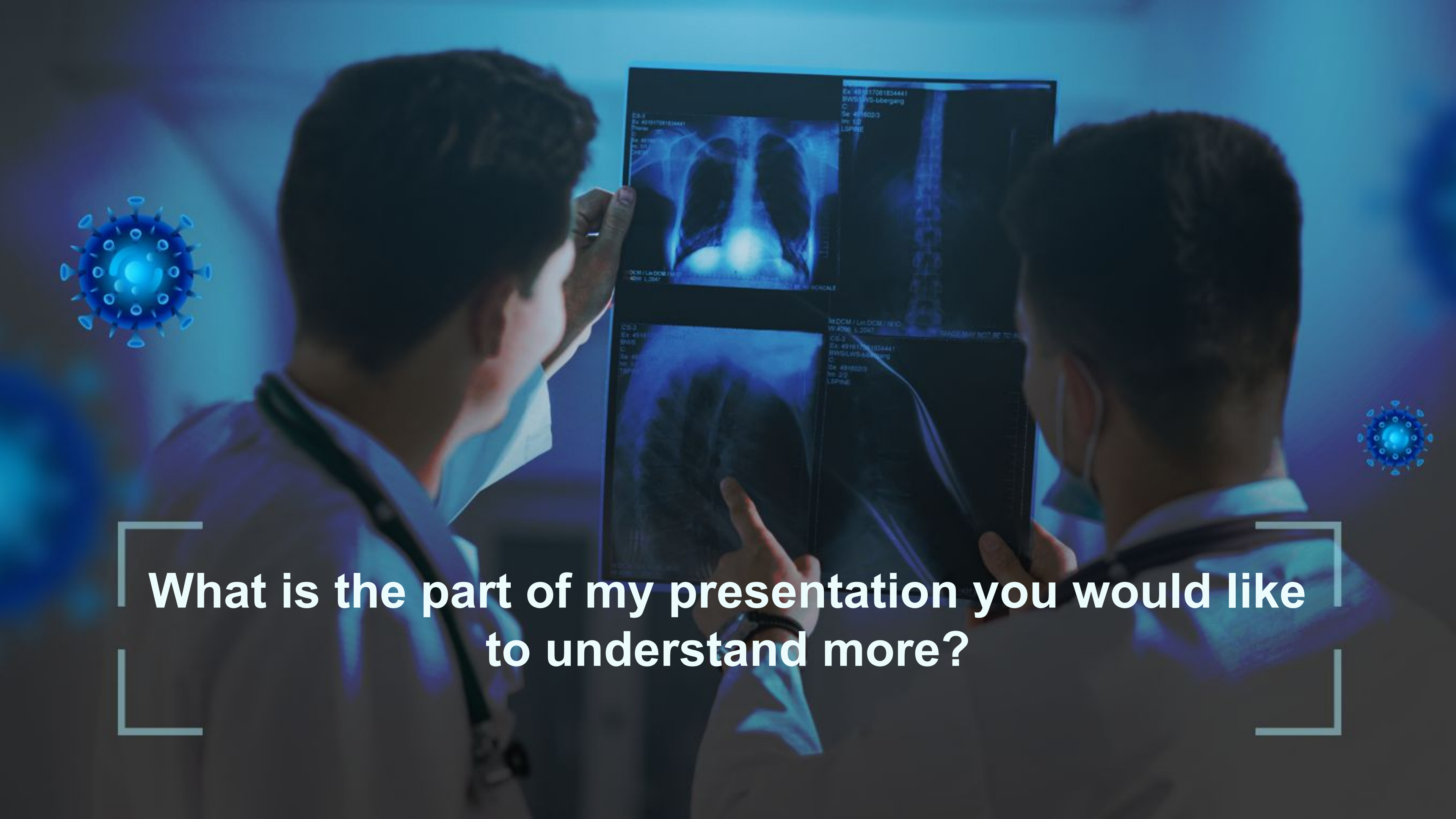
- Objective: study the impact of denoising methods in COVID-19 classification task.
- Only the first step of COVID-FACT classifier was successfully performed.
- Fine-tuning of the baseline model on denoised data may improve false negatives detection (which can lead to misinterpretation).
- Denoising of CT images can be better achieved with prior knowledge of noise in CT images and corresponding dose radiation.

To improve results :

- Determine the noise model?
- Choose different denoising methods?

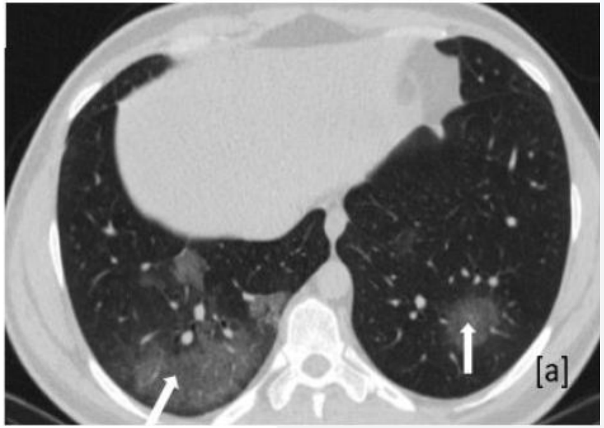
What's next?

- A new PhD thesis…
- Go backwards and take the reverse problem: simulate a radiation dose and try to define minimum dose that guarantees diagnostic quality.

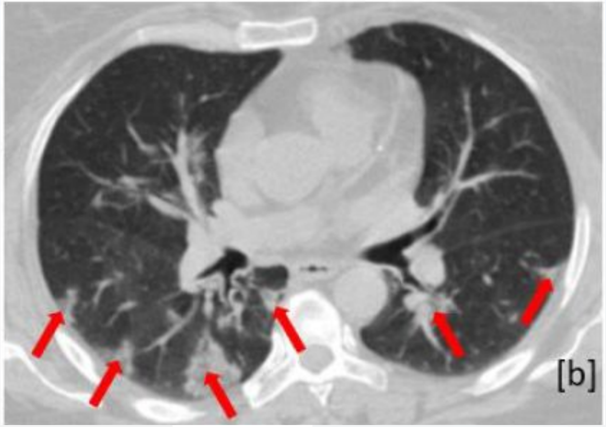

What is the part of my presentation you would like to understand more?

03 Evaluation of medical image quality in the COVID-19 pneumonia detection task

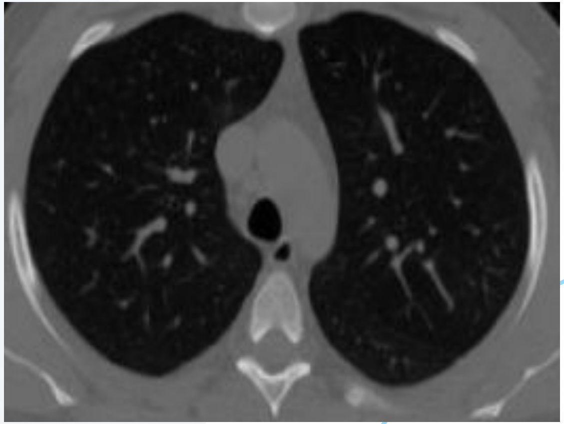
COVID-19 distinguishing features



bi-lateral GGOs distributed in posterior lung regions



scattered consolidation patterns with mainly peripheral distribution



Non-infected slice

GGO: Ground Glass Opacities