



# Determination of the Severity and Percentage of COVID-19 Infection through a Hierarchical Deep Learning System

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## Introduction

- The coronavirus disease 2019 was first detected in the city of Wuhan, Hubei province
- Mainly symptoms:



Detection



Main method - reverse transcription polymerase chain reaction (RT-PCR)

Detection  
and Severity



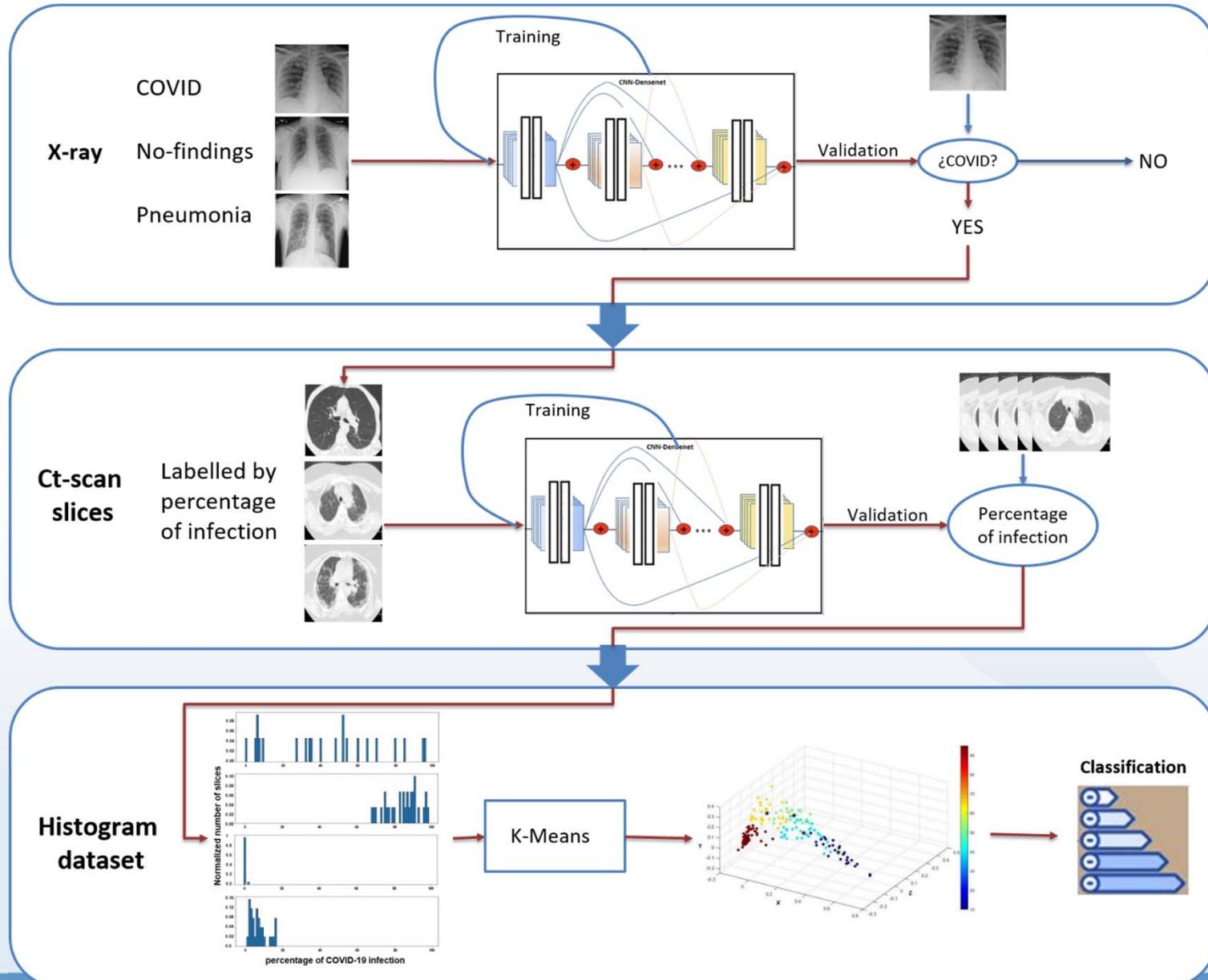
- Medical imaging (X-ray and CT) in conjunction with Deep Learning (DL)

Chest radiography (X-ray): fast acquisition time and low cost

Computed tomography (CT): higher average acquisition time and cost



## Structure of the proposed task





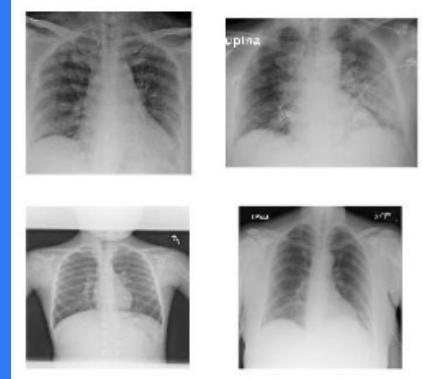
## Material: Dataset

Dataset 1 → X-ray images

COVID-19: 125

Pneumonia: 500

No – findings: 500

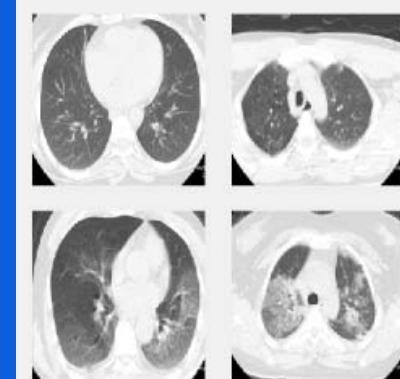


Dataset 2 → CT scans images

Labeled as a function of their  
infection with COVID-19

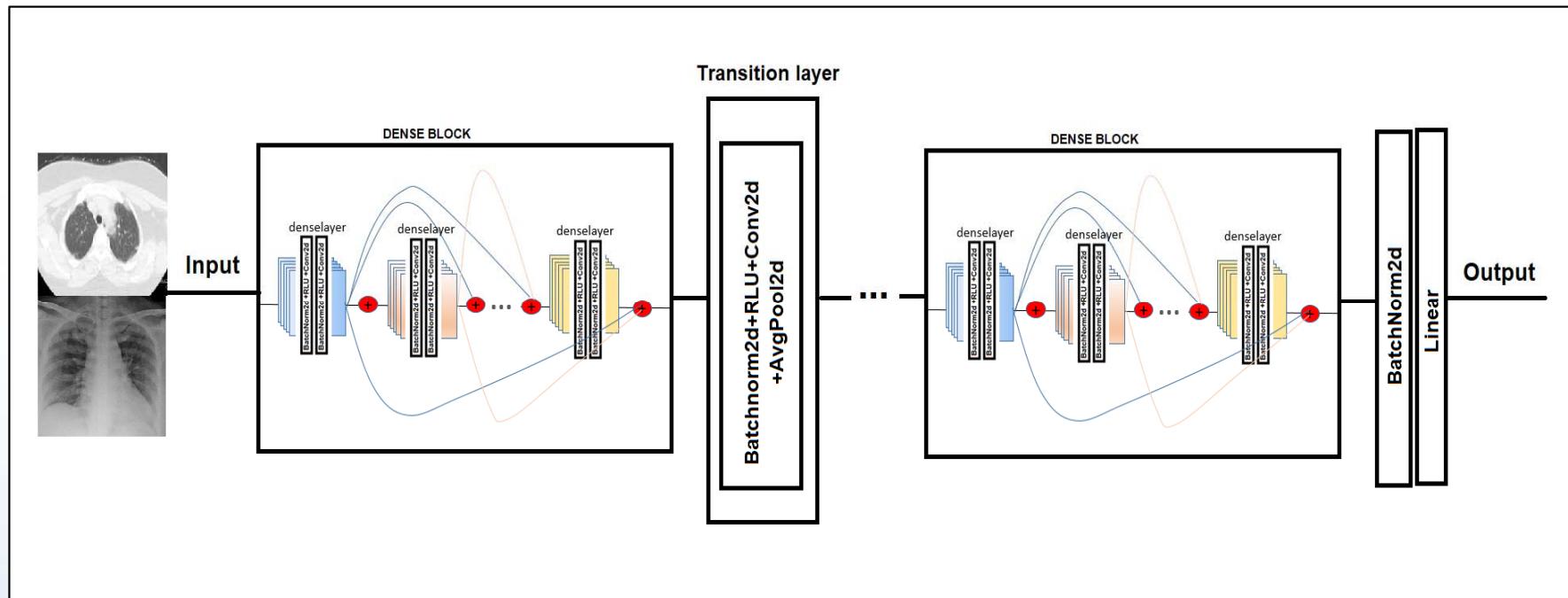
0% to 100% of infection

Slices labeled: 3987





## Densenet





# RESULTS

- Cross Validation (5-fold)

## Stage1 and Stage 2

- Down-sampled images 224x224
- Active data augmentation techniques:
  - Random crop
  - Random rotation
- Densenet-161
  - Batch size: 20
  - Number of epoch: 50
  - Schedule learning rate:  $1 \times 10^3$  to  $1 \times 10^6$
  - Optimizer : RMSprop with momentum equal to 0.9

## Stage3

- K-means and PCA



## Stage1

Confusion Matrix fold 1			
True labels	Predicted labels		
	Covid-19	No_findings	Pneumonia
Covid-19	26	0	2
No_findings	0	91	6
Pneumonia	1	25	74

Confusion Matrix fold 2			
True labels	Predicted labels		
	Covid-19	No_findings	Pneumonia
Covid-19	21	2	5
No_findings	0	86	4
Pneumonia	0	15	92

Confusion Matrix fold 3			
True labels	Predicted labels		
	Covid-19	No_findings	Pneumonia
Covid-19	23	0	8
No_findings	0	89	13
Pneumonia	0	9	83

Confusion Matrix fold 4			
True labels	Predicted labels		
	Covid-19	No_findings	Pneumonia
Covid-19	16	2	0
No_findings	0	102	6
Pneumonia	0	22	77

Confusion Matrix fold 5			
True labels	Predicted labels		
	Covid-19	No_findings	Pneumonia
Covid-19	17	0	3
No_findings	0	96	7
Pneumonia	0	17	85

Summary Confusion Matrix			
True labels	Predicted labels		
	Covid-19	No_findings	Pneumonia
Covid-19	103	4	18
No_findings	0	464	36
Pneumonia	1	88	411



## Stage1

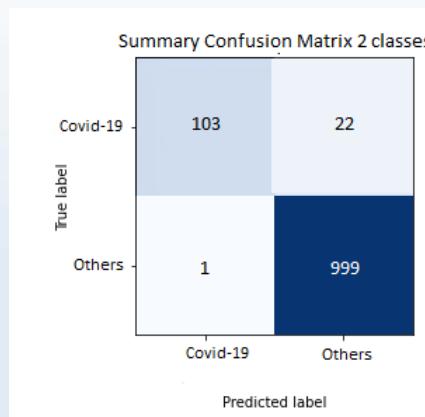
Table of results in detection  
Covid-19 vs Pneumonia and  
Non-findings

'Three classes'

Fold-1	Precision	Recall	F1-score	Images	Fold-2	Precision	Recall	F1-score	Images
COVID-19	96	93	95	28	COVID-19	100	75	86	28
No-findings	78	94	85	97	No-findings	83	96	89	90
Pneumonia	90	74	81	100	Pneumonia	91	86	88	107
Accuracy			85	225	Accuracy			88	225
Fold-3	Precision	Recall	F1-score	Images	Fold-4	Precision	Recall	F1-score	Images
COVID-19	100	74	85	31	COVID-19	100	89	94	18
No-findings	91	87	89	102	No-findings	81	94	87	108
Pneumonia	80	90	85	92	Pneumonia	93	78	85	99
Accuracy			87	225	Accuracy			87	225
Fold-5	Precision	Recall	F1-score	Images	Summary	Precision	Recall	F1-score	Images
COVID-19	100	85	92	20	COVID-19	99	83	90	125
No-findings	85	93	89	103	No-findings	84	93	88	500
Pneumonia	89	83	86	102	Pneumonia	87	82	85	500
Accuracy			88	225	Accuracy			87	1125

Results in detection Covid-19 vs Others

'two classes'



Summary 2-classe	Precision	Recall	F1-score	Images
COVID-19	99	82	88	125
Others	98	100	99	1000
Accuracy			98	1125
MCC			89	1125
BACC			91	1125



## Stage2

Performance metrics:

- PC
- MAE
- RMSE

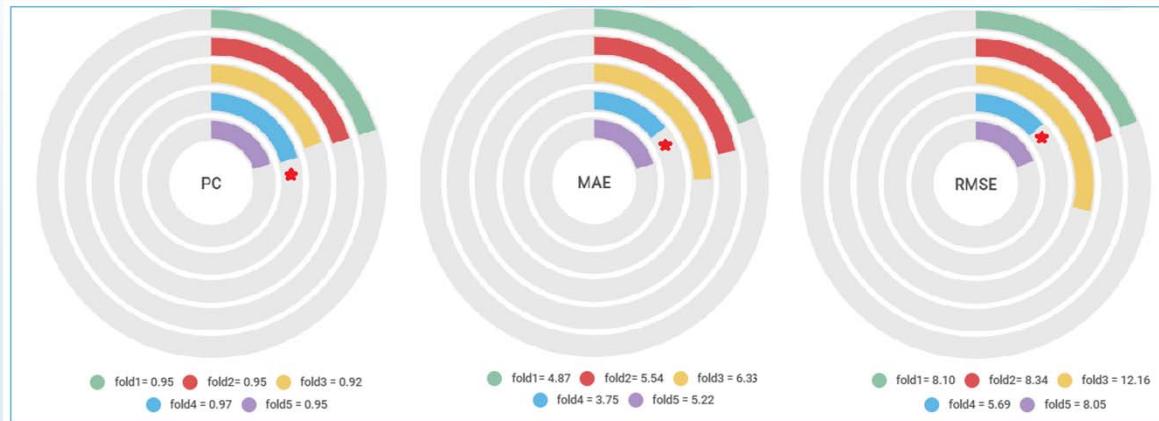
$$MAE = \frac{1}{n} \sum_{i=1}^N |y_i - \hat{y}_i|$$

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^N (y_i - \hat{y}_i)^2}$$

$$PC = \frac{\sum_{i=1}^N (y_i - \bar{y}_i)(\hat{y}_i - \bar{\hat{y}}_i)}{\sqrt{\sum_{i=1}^N (Y_i - \bar{Y}_i)^2} \sqrt{\sum_{i=1}^N (\hat{y}_i - \bar{\hat{y}}_i)^2}}$$

Results in the detection of the percentage of Covid-19 infection in each slice of the CT-scans

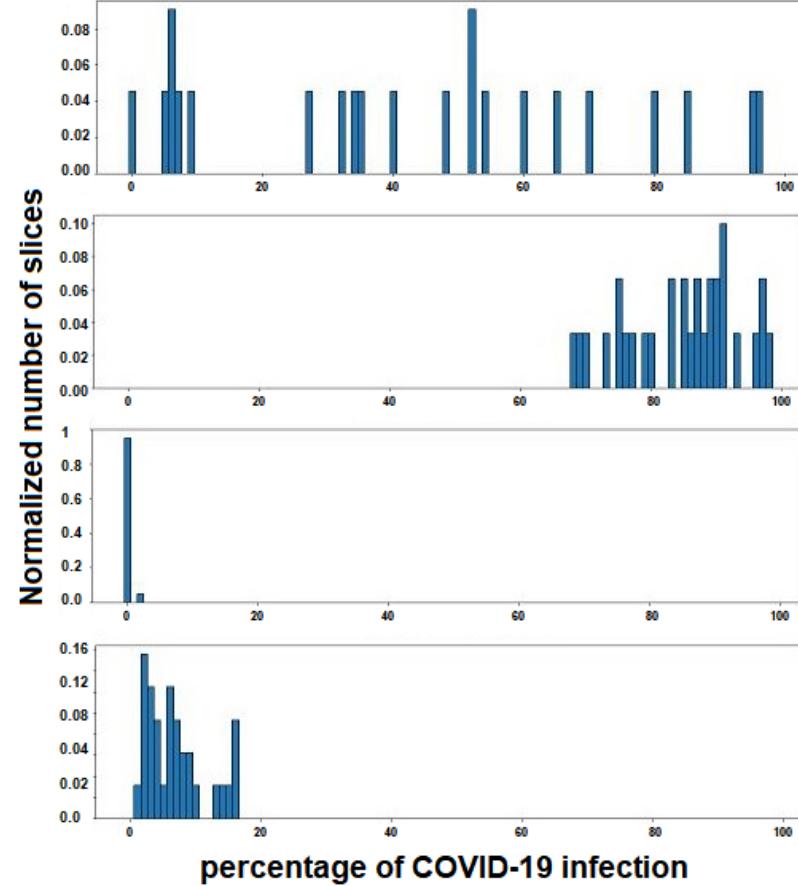
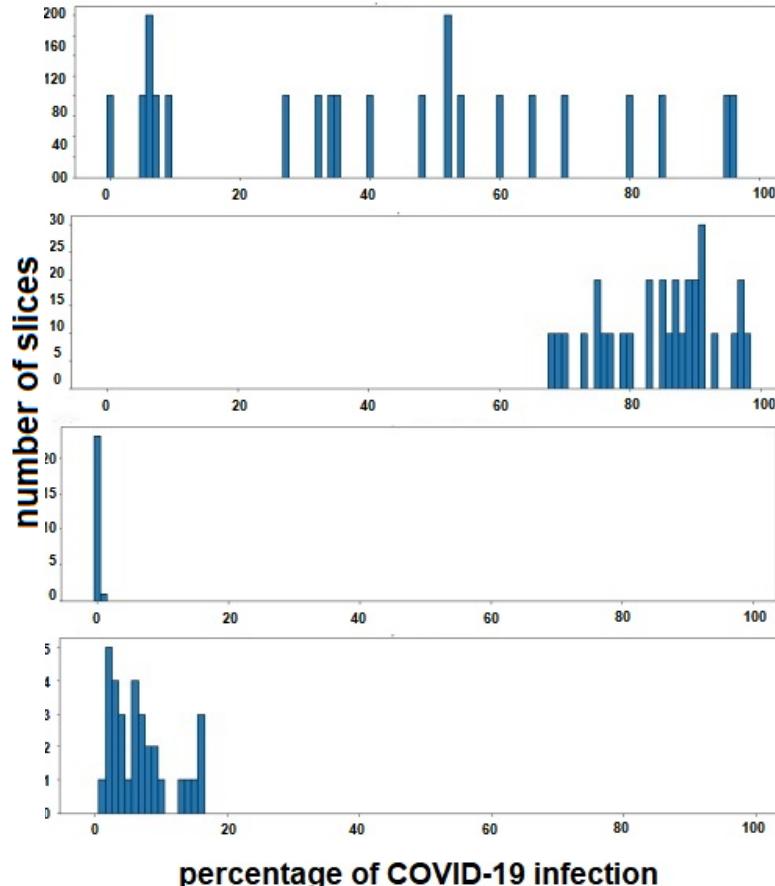
	RMSprop optimizer		
	PC	MAE	RMSE
K-fold-1	0.96	4.87	8.10
K-fold-2	0.95	5.54	8.34
K-fold-3	0.92	6.33	12.16
K-fold-4	0.97	3.75	5.69
K-fold-5	0.95	5.22	8.05
Summary	0.95	5.14	8.47





## Stage3

Create a database of histograms



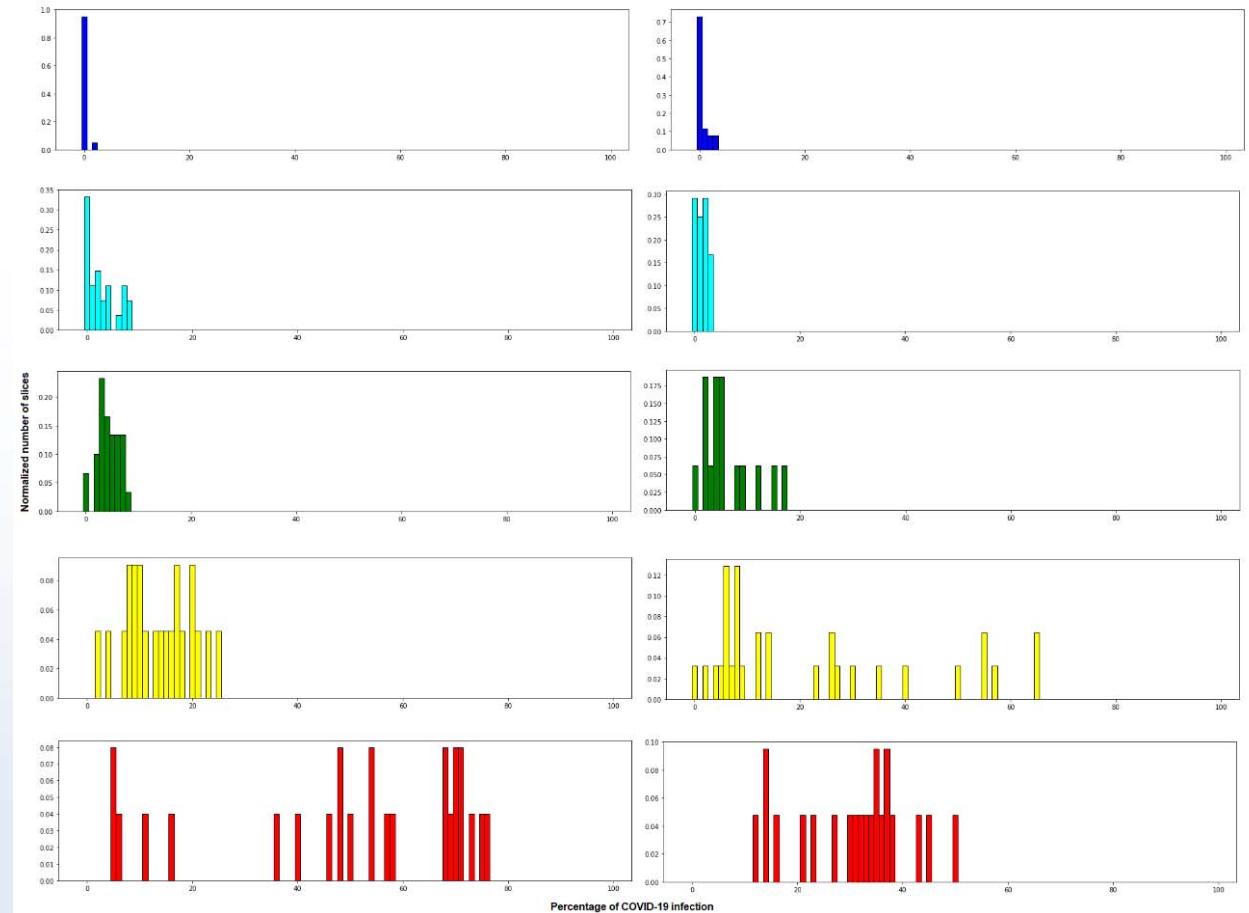
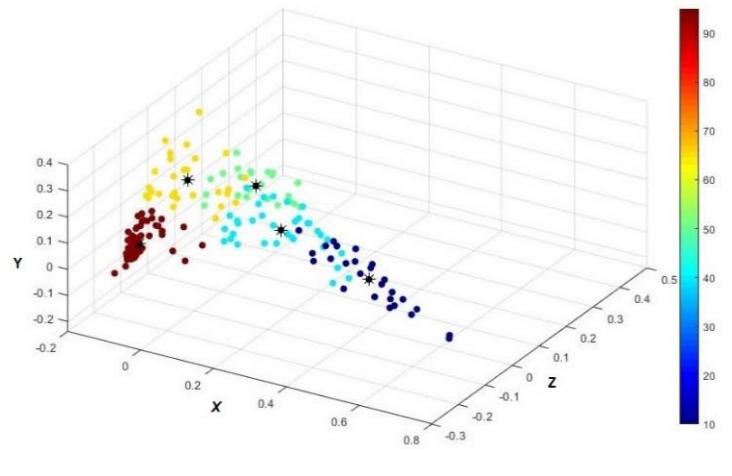


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## Stage3





## Conclusion

Research - Detection of patients with COVID-19 and the classification of these into different gravity degrees

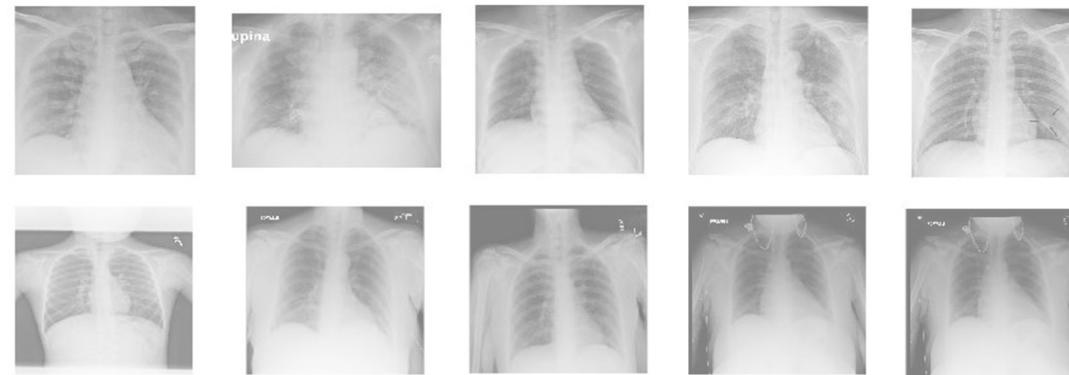
- It has been able to detect the presence of COVID-19 with a precision of 91%, a recall of 87%, an F1-score of 89% and an accuracy of 87% for three classes and 99%, a recall of 91%, an F1-score of 93% and an accuracy of 98% for two classes .
- It has been possible to determine COVID-19 infection in the slices of CT-scans with results in the evaluation metrics of 0.95 in PC, 5.14 in MAE and 8.47 in RMSE
- Finally, the patients has been classified in five degrees of gravity as a function of their histograms.

Note - Due to the limited number of COVID-19 images, more experiments are needed on a larger set of clearly labeled COVID-19 images for a more detailed estimation of the accuracy of the studies conducted in this paper.



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Thank you for the interest

