A COVID-19 PATIENT SEVERITY STRATIFICATION USING A 3D CONVOLUTIONAL STRATEGY ON CT-SCANS

J. RODRIGUEZ [1], D. ROMO [1], F. SIERRA [1], D. VALENZUELA [2], C. VALENZUELA [2], L. VASQUEZ [2]
P. CAMACHO [2], D. MANTILLA [2] and F. MARTINEZ [1]
1 Biomedical Imaging, Vision and Learning Laboratory (BivL^2ab), Universidad Industrial de Santander, Colombia
2 Clinica FOSCAL, Bucaramanga, Colombia

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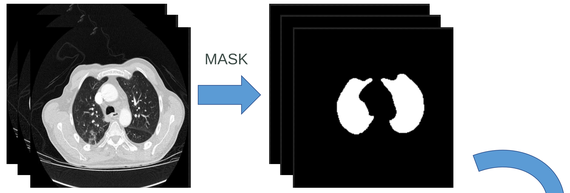
INTRODUCTION

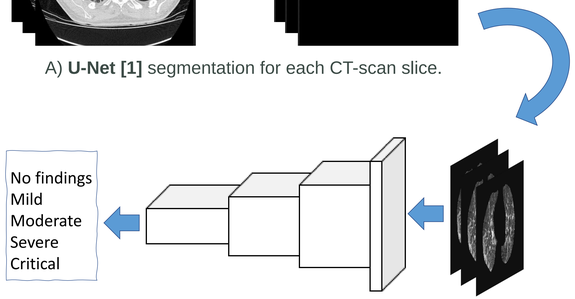
This work explores the use of volumetric convolutional architectures to stratify among **5 different COVID-19 levels**. These architectures learn a complete CT visual representation, without using explicit finding segmentations, retrieving also explainable attentions maps that could complement the diagnosis task.

METHOD

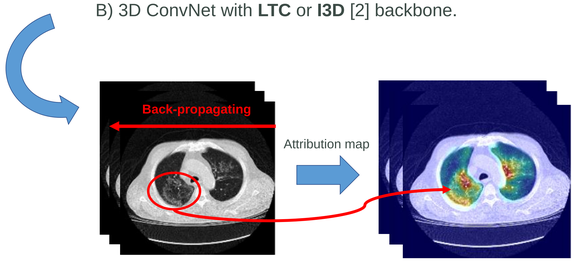
Two 3D convolutional architectures were previously trained to predict different COVID-19 severity levels. The general pipeline includes:



A) **U-Net [1]** segmentation for each CT-scan slice.



B) 3D ConvNet with **LTC** or **I3D** [2] backbone.



C) **Grad-CAM [3]** maps related to Covid-19 lung findings.

MATERIALS

The CT scans used was recorded and annotated by two FOSCAL's radiologists from March to August 2020. The severity analysis considers the extension of pathological findings in each lobe. The following tables describe all the data used:

Patients	Demographic information Genere/Age	Comorbidities distribution
COVID-19	109 males	46% hypertension
	(63 +- 15) years	28% no comorbidities
	66 females	15% cardiovascular
	(56 +- 22) years	11% cancer
Non COVID-19	70 males	59% no comorbidities
	(62 +- 16) years	28% cancer
	105 females	7% hypertension
	(57 +- 16) years	6% others

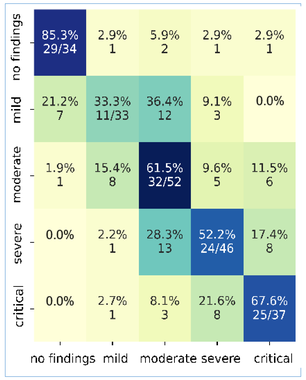
CT Score - Level	CT Global Score	Samples	CT Score and lung lobe involvement
0 – No findings	0	34	0: 0%
1 – Mild stage	1 – 6	33	1: <5%
2 – Moderate stage	7 – 12	52	2: 5-25%
3 – Severe stage	13 – 18	46	3: 26-50%
4 – Critical stage	19 - 25	37	4: 51-75%
			5: >75%

RESULTS

The results were divided into two experiments in order to evaluate the method in COVID-19 prediction and severity stratification. The results for each experiment are described below:

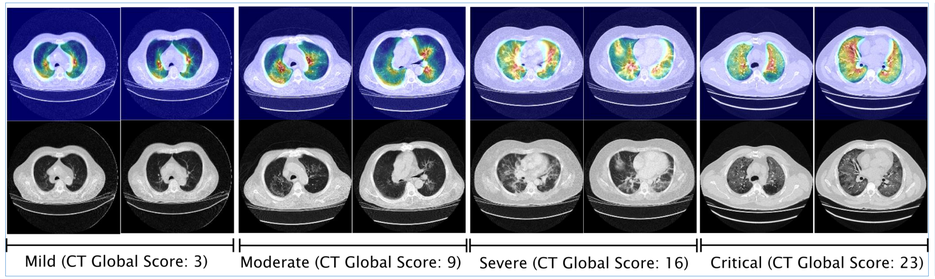
Weights	Scratch			Pre-trained		
Metrics	Precision	Recall	F1 score	Precision	Recall	F1 score
Model	LTC					
Non COVID-19	93%	94%	93%	**98%**	96%	97%
COVID-19	94%	93%	93%	96%	**98%**	97%
Model	I3D					
Non COVID-19	96%	95%	95%	96%	**100%**	**98%**
COVID-19	95%	96%	95%	**100%**	96%	**98%**

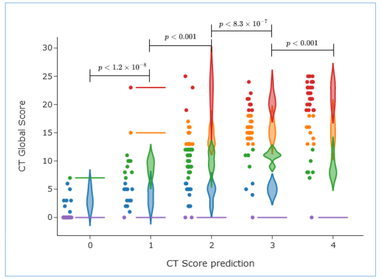
Results of the COVID-19 prediction task using the two convolutional architectures with pre-trained weights and from scratch.



Accumulated confusion matrix (cross-validation scheme) for the I3D Network in the severity stratification task. The main error rates occur in neighboring severity groups.

Illustration of the main correlations of Grad-CAM maps with radiological findings. In red color consolidations, green color ground glass opacities in mild stages, yellow and orange colors in more advanced stages. The figure on the right indicates the distribution of the predicted groups, which are significantly different.





CONCLUSIONS

- The proposed 3D CNN methodology was able to stratify the COVID-19 disease into severity groups.
- The I3D network obtained better stratification results compared to the LTC network.
- The predicted groups had patients with CT global score distribution that was increased accordingly to the severity.
- The 5 predicted severity categories were significantly different.
- The Grad-CAM attribution maps show a visual-spatial correlation with radiological findings in each severity group.

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CONTACT INFORMATION

Contact by email to famarcar@saber.uis.edu.co (Fabio Martínez Carrillo) and Jefferson.rodriguez2@saber.uis.edu.co (Jefferson Rodríguez)