VGG-AM : Towards a new Hybrid Medical Imaging Analysis based on VGG classification Model and deep DATA preparation

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abstract

During the pandemic, the classic method for diagnosing SARS-CoV-2, "Reverse transcription polymerase chain reaction" (RT-PCR), unfortunately showed its limits in terms of processing time and accuracy rate. As an alternative solution, the analysis of thoracic computed tomography (CT) images has shown this evidence in terms of reliability and accuracy rate. Nevertheless, the analysis of a large mass of images by radiologists represents a real challenge to overcome. In this sense, it should be mentioned that deep learning solutions for imaging, in particular, convolutional neural networks (CNN), have demonstrated numerous applications in radiology, particularly in image classification, object detection, semantic segmentation and instance segmentation. In this work, a benchmark study of deep learning (DL) approaches was carried out, for the automatic detection of COVID-19 on thoracic computed tomography (CT) images by performing experiments on advanced deep networks, at namely: XCEPTION, VGG, RESNET, and INCEPTION. Then, a new advanced deep architecture, "VGG-advanced-Model", was proposed by bringing improvements on the architecture having led to the best "VGG" results. A combination of different preliminary data preparation and preprocessing techniques was also performed. The results demonstrate the effectiveness and efficiency of our method, with 100% precision, 99.52% accuracy and 99% recall.

OBJECTIVES

In this study, deep learning (DL) methodologies were investigated to automatically detect confirmed COVID-19 cases from a database of CT images compiled by our research team.

Materials and methods

During this work, the tests and experiments were carried out in a high-performance computing center (HPC) under the National Center for Scientific and Technical Research of Morocco "CNRST". This calculation platform is made up of nodes interconnected by a 100 Gbps network (OPA) with the aim of ensuring performance optimization during parallel calculations.

The dataset was fed by 6200 computed tomography images obtained at the Cheikh Khalifa International Hospital in Casablanca, Morocco.

To enhance the size of our dataset before the training phase, four techniques were mainly used: 1) adding blurring, 2) adding a random amount of Gaussian noise, 3) random horizontal flipping, and 4) changing brightness and contrast. To add Gaussian noise to our images, we used the formula that: (ImNoise)n = (ImOriginal)n + (noise)n , (noise)n is a continuous random variable which follows the Gaussian law (or normal law), assuming that it is centered and therefore having the density:

$$P(x) = \frac{1}{\sigma\sqrt{2\pi}} e\left(\frac{-x^2}{2\sigma^2}\right) \qquad (1)$$

To change the contrast of our images we simply replaced the value of our pixels by (255-α), α ε ℕ, and depending on the values of a, we change the brightening of our images.

After applying the data augmentation methods, the resulting dataset contained 3100 confirmed COVID-19 cases and 3100 non-COVID-19 cases.

To improve the performance of our approach and ensure a better understanding of the decisions and predictions made by the different models, the "Grad-Cam" visualization technique was adopted. This approach introduced by Selvaraju et al. [is a gradient-weighted class activation mapping technique that provides an explainable view of deep learning models. The goal here is to understand the decision-making of our algorithms during the classification phase.

To demonstrate the efficacy of our various models, experiments conducted in this section are described by exposing the various approaches and performance evaluation metrics and then discussing the results achieved by the various models on our dataset. Our technique for detecting COVID-19 from CT images was implemented in two stages. First, we preprocessed the images to prepare our data so that our neural network could identify confirmed COVID-19 cases and non-COVID-19 cases. Subsequently, we applied the learning transfer method. to train and construct our different models using the weights formed by these models on ImageNet (You et al., 2018).

To evaluate our models, we considered the different performance evaluation metrics. For each model, we counted the number of cases predicted as true positives (TP), true negatives (TN), false positives (FP), and false negatives (FN) (see Table 1). Then, we calculate the following metrics.

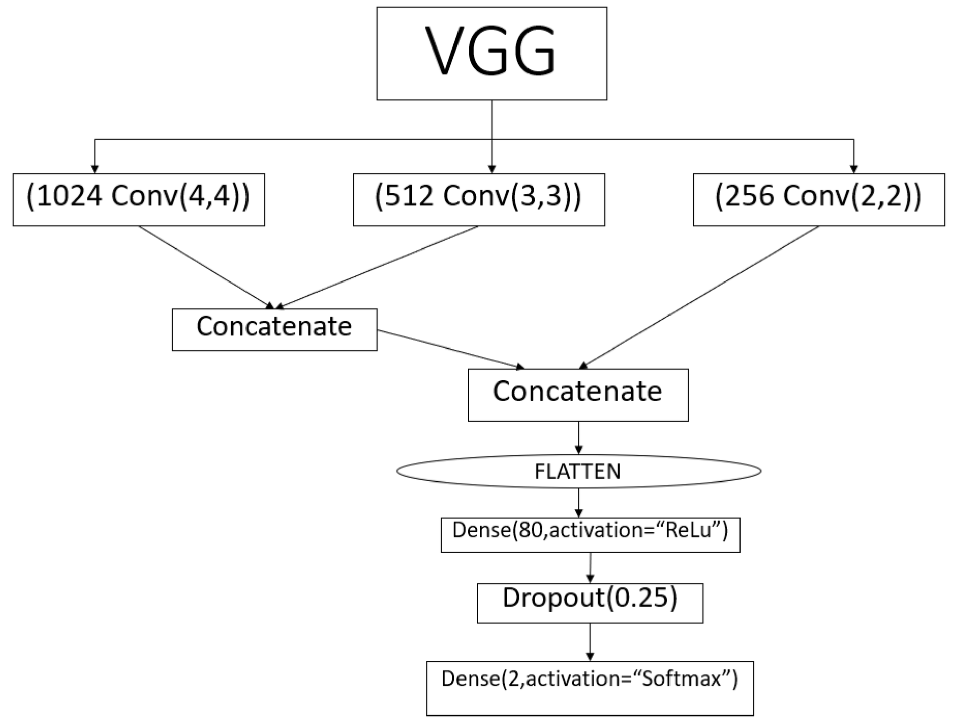
RESULTS

First, the following architectures: XCEPTION, VGG, RESNET, and INCEPTION, were programmed and tested. The scientific community often uses these architectures to process, analyze, and classify this type of data [27]. Subsequently, the improvement of the two best architectures in terms of performance was performed and summarized in Table.

Model	Input Shape	Acc	Prec	Recall	F1-score
Xception	(224,224,3)	0.9694	0.96	0.98	0.97
VGG19	(224,224,3)	0.9935	0.99	0.99	0.99
VGG16	(224,224,3)	0.9935	0.99	0.99	0.99
Resnet101	(224,224,3)	0.9694	0.99	0.99	0.97
Resnet50	(224,224,3)	0.9758	0.96	0.96	0.98
Inception	(224,224,3)	0.9885	0.99	0.99	0.99

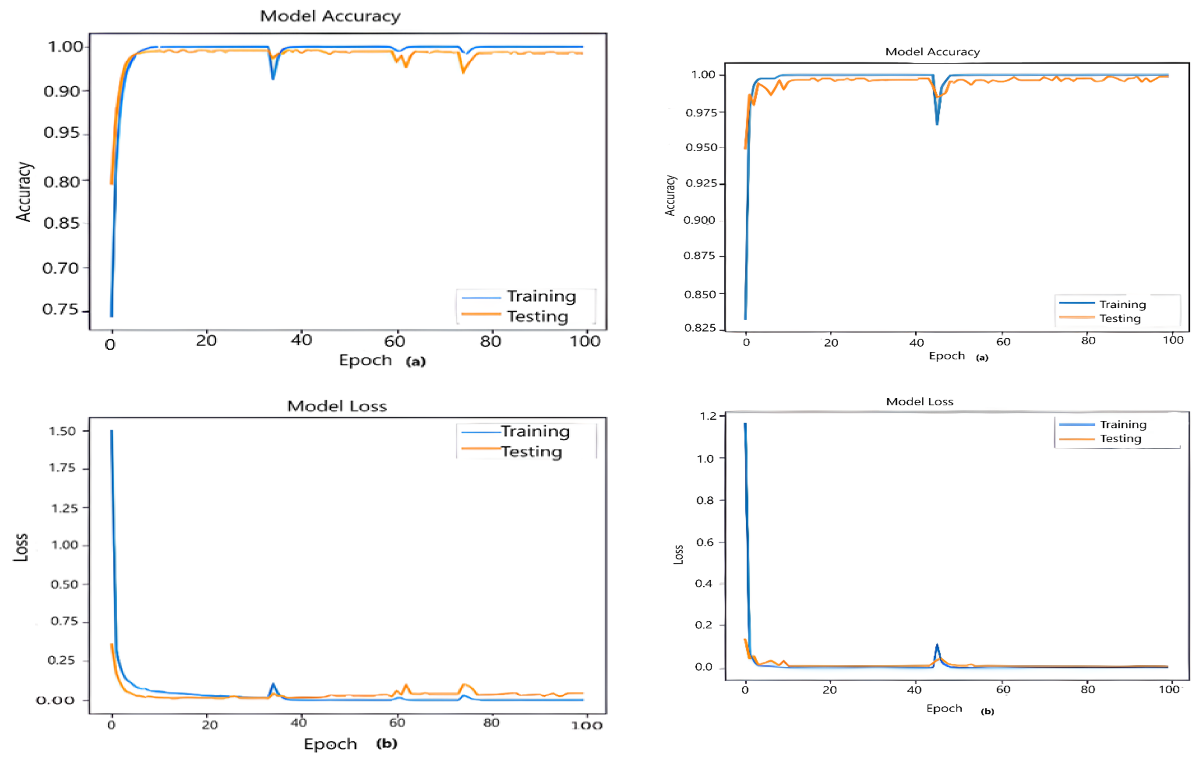
All of the defined models performed well in terms of learning and classification. The best performances were obtained with the VGG16 and VGG19 models. To produce more efficient outcomes, we contributed to enhancing the findings by improving the two best architectures found during our comparative study.

To build our "VGG_Advanced Model" architecture, combinations of additional convolution layers were added to the output of the two VGG models. The output size has remained unchanged (i.e., 7×7) to precisely capture more feature maps. Our feature map was built on the map already provided by the VGG 19 and VGG 16 models (see Fig).



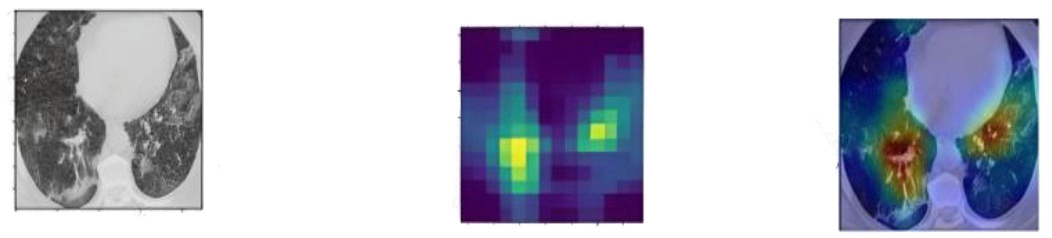
RESULTS

We had tried as previously explained to make some modifications to the VGG16 and VGG19 models in order to have a better performance and a higher prediction rate, our technique consisting in adding additional layers of feature extraction in order to capture mainly sensitive areas gave us as result an accuracy of 0.9952 and an F1-Score of 1. (see Fig. bellow)



we also performed a visual interpretation of the decisions made by our models to identify cases infected with COVID-19. To that end, we have provided Grad-CAM localization models [28] generated with the different architectures using test data from our database.

The objective of using this visualization technique is to interpret the decisions made by our models visually and to have some transparency in the decisions made to identify patients infected with COVID-19.



Conclusions

Deep Learning (DL) is an artificial intelligence technique that has proven itself, particularly in the analysis of medical imaging. In this article, We investigated DL methodologies to detect automatically confirmed COVID-19 cases from a dataset of CT images created by our team. Experiments using advanced deep networks such as XCEPTION, VGG, RESNET, and INCEPTION were used to undertake a benchmark analysis of (DL) methodologies. This study revealed the performance of the VGG 19 and VGG 16 architectures, in terms of accuracy, recall and precision. The next step of this work was to make improvements on both VGG 19 and VGG 16 architectures by developing a new improved architecture, which we called "VGG Advanced Model". For better performance, the data used, composed of 6200 CT images, underwent different pre-processing techniques based on ROI identification and data augmentation techniques, and in addition a custom input size was determined. The findings of our approach achieved an accuracy of 99.52%, a recall of 99%, and a precision of 100%. Results that go beyond all the approaches studied in this work.

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