TEAM MEMBERS: Huan Li, Fabio Pecora, and Abayomi Shosilva

Title: Implementation of convolutional neural network approach for COVID-19 disease detection

Author: Emrah Irmak

Abstract:

This paper examines the research that employs convolutional neural networks (CNN)s to identify COVID19 using chest X ray images. This research presents a distinct contribution as it marks the use of CNN with the most extensive clinical dataset, to the author's knowledge, for classifying COVID-19 chest X rays. The study examines two different CNN architectures, and each of the CNNs has a specific classification function. The first CNN can detect the presence of COVID-19, checking if the chest X-ray of a patient contains COVID-19 or not. The second CNN classifies multiple X-rays into three different categories: COVID-19, normal, and pneumonia. In order to show the effectiveness of the architectures, very big datasets have been used for testing, and the experimental results were promising. The first model reached an accuracy of 98.92% and the second model of 98.27%. As previously mentioned, the dataset is very extensive, containing 1,524 COVID-19 images, 1,527 pneumonia images, and 1,524 normal X-ray images. The hyperparameters have been optimized automatically using Grid Search, enhancing performances by removing the need for manual adjustment. Additionally, the models are fully automated, requiring no manual extraction of diseased areas, which advances the efficiency of COVID-19 detection from medical images.

Introduction:

COVID-19 was first identified in Wuhan, Province of China, in December 2019, and its diagnosis put a hold on everybody's life all over the world. The high contagion and mortality rates made COVID-19 a significant threat, many deaths occurred when this disease turned into pneumonia, and it was not easy to control. Infected people could be contagious even before developing symptoms, causing COVID-19 to be highly unpredictable, and making it a big challenge to control the spread of the virus. The whole world started looking for a solution, and the first idea was to develop a vaccine, but developing any vaccine could have taken at least 12 months, and fast actions needed to be taken. A lot of people kept on getting infected, and by July 10th, 2020, the total number of confirmed COVID-19 cases worldwide reached 12,294,117; and 4,976,653 of them were active cases. As of the same date, deaths kept increasing, reaching a number of 555,531. Even the diagnosis wasn't efficient at that time. The typical diagnosis was based on swabs from the nose and throat, but the major disadvantages of this type of diagnosis were both the time consuming, and the fact that it was susceptible to sampling errors, making it inefficient. One way to increase the diagnostic capabilities of physicians and reduce the time spent for accurate diagnosis is using computer-assisted automatic detection and diagnosis systems. These systems can help experts make better, quicker, and more accurate decisions. Automatic detection of COVID-19 disease from medical images is a critical component of the new generation of computer-assisted diagnostic (CAD) technologies and has emerged as an important area in recent years. It can be very worth using X-rays as imaging methods for detection, classification, and analysis of diseases caused by viruses, and this study tries to use these images for an early diagnosis of COVID-19 diseases. Many studies tried to detect COVID-19 using CNN. One example is the researchers' group Ozturk et al, that achieved 98.08% accuracy for binary classification and 87.02% for multiclassification, but they used a small dataset (127 COVID-19 X-rays, 500 normal X-rays, and 500 pneumonia X-Rays). Another example is Loey et al. That employed a GAN-based deep transfer learning model and collected 307 X-ray images per class (COVID-19, normal, and pneumonia). Another great study achieved a 96% accuracy using 1,296 COVID-19 CT images from six hospitals using a fully automatic CNN framework. Togacar et al obtained a 99.27% overall accuracy rate for the COVID-19(+), normal, and pneumonia multiclassification. They achieved it using 295 COVID-19, 65 normal, and 458 pneumonia X-ray images. The result was great, but the number of images they used was still not enough. Studies with smaller datasets may achieve impressive accuracy rates, but the model performance could be limited. There can be overfitting when the model learns specific patterns in the training data that may not generalize well to new data. By using larger and more diverse dataset the model is exposed to more variation in the data, helping generalization and ensuring that the model performs well in the real world. For this reason, the aim of this study is to use 1,524 COVID-19 images, 1,527 pneumonia images, and 1,524 normal X-ray images to present two fully automatic deep CNN models, with hyperparameters automatically determined by Grid Search for COVID-19 detection and virus classification.

Technical Approach and Models:

The paper introduces two novel CNN architectures tailored for specific classification tasks-:

- **Task 1: Binary Classification (COVID-19 positive vs. negative)**
  The model proposed for binary classification consists of 12 layers, which include convolutional, ReLU (Rectified Linear Unit), and max-pooling layers, followed by a fully connected layer and a Softmax classifier. This architecture begins with an input image size of 227x227 pixels and uses a sequence of convolutional operations to extract features from the images. The first convolutional layer utilizes 96 filters of size 7x7, followed by ReLU activation to introduce non-linearity. The subsequent layers are designed to extract more complex features, ultimately leading to a fully connected layer that feeds into a Softmax function to make the final classification decision. The model’s hyperparameters, such as learning rate, batch size, and regularization terms, are optimized using Grid Search, which systematically tests various combinations to find the best configuration.

- **Task 2: Multiclass Classification (COVID-19, normal, pneumonia)**
  For the multiclass classification task, a deeper architecture with 14 layers is developed. This model also begins with a 227x227 pixel input size and incorporates three convolutional layers, each followed by ReLU activation and max-pooling. The first layer uses filters of size 11x11, while subsequent layers use smaller filters to capture finer details in the X-ray images. The fully connected layer at the end of the network outputs a three-dimensional feature vector, which is classified using a Softmax function into one of the three classes: COVID-19, normal, or pneumonia.

The study's use of Grid Search for hyperparameter tuning is a notable contribution, as it automates the selection process, thus saving time and computational resources. By exploring a predefined parameter space, the model identifies the optimal settings that maximize accuracy. The research highlights the importance of hyperparameter optimization in enhancing the performance of deep learning models, particularly in medical image classification.

Experiments and Results:

The experimental setup involved training the CNN models on a comprehensive dataset collected from multiple sources, including the COVID-19 Image Data Collection, ChestX-ray8, and the COVID-19 Radiography Database. The dataset used in this study is one of the most extensive collections of COVID-19 chest X-ray images to date, with a total of 4,575 images categorized into 1,524 COVID-19 cases, 1,527 pneumonia cases, and 1,524 normal cases.

The data was split into training (60%), validation (20%), and testing (20%) sets to ensure the models' robustness and generalizability. Each model was trained using a stochastic gradient descent with momentum (SGDM) optimizer, which helps accelerate convergence by considering the previous gradients. The training process involved multiple iterations, where the models were evaluated on the validation set to prevent overfitting.

- **Task 1 Results (Binary Classification)**
  The binary classification model achieved an impressive accuracy of 98.92%, with a sensitivity and specificity of 98.72%. The model also demonstrated a high AUC score of 0.9957, indicating excellent discriminative ability. The confusion matrix revealed that the model had a low false-positive rate, making it reliable for clinical use where false positives can lead to unnecessary anxiety and further testing.

- **Task 2 Results (Multiclass Classification)**
  In the multiclass classification task, the model attained an accuracy of 98.27%, with an AUC score of 0.9979. The sensitivity for detecting COVID-19 cases was 98.09%, while the specificity was 99.13%. These metrics highlight the model's capability to distinguish between COVID-19, pneumonia, and normal chest X-rays, thus proving useful for differential diagnosis in clinical settings.

The study compares the performance of its proposed models with other state-of-the-art methods, such as those by Ozturk et al. and Loey et al., demonstrating superior accuracy, particularly in multiclass classification tasks. The models' ability to achieve near-perfect accuracy with a larger dataset indicates their potential for real-world deployment.

Conclusion:

After reviewing the research paper, we learned the importance of High-Quality and large dataset, as the study's reliance on a large, diverse dataset of 4,575 images—currently one of the most extensive COVID-19 datasets in medical imaging—demonstrates the value of high-quality, substantial data in enhancing model performance and generalizability, also the performance of deep learning models improves with access to large and diverse data. We learned also that CNNs are highly effective for medical image classification. We realized that the use of Grid Search for automatic hyperparameter optimization is a significant step in ensuring that the deep learning models perform at their best. We also noticed that the study's use a variety of performance metrics to evaluate the model, because it offers a clear picture of the model's effectiveness and its potential for real-world applications in healthcare.

Future ideas:

- While the study already utilized a large dataset, future research could benefit from an even broader range of medical images, one example could be incorporating varying disease severities. This would improve the robustness and generalizability of the model.
- In the future we would also focus on optimizing these models to run on devices with limited resources, like mobile phones or resource-limited environments, for real-time COVID-19 detection and diagnosis.
- Also, deep learning models like CNNs are very powerful, but they are often hard to understand and lack transparency which can make it difficult for doctors to trust their decisions, and could be a barrier to clinic adoption. In future studies we could explore techniques for improving the interpretability of these models.
- Lastly, the success of the proposed CNN models for COVID-19 detection and pneumonia classification might suggest to us that similar approaches could be applied to other diseases, such as tuberculosis or lung cancer, so it could be worth expanding the model to cover a broader range of diseases.

References:

1. Ozturk, T., Talo, M., Yildirim, E. A., Baloglu, U. B., Yildirim, O., & Rajendra Acharya, U. (2020). Automated detection of COVID-19 cases using deep neural networks with X-ray images. *Computers in Biology and Medicine*, 121, 103792.
2. Apostolopoulos, I. D., & Mpesiana, T. A. (2020). Covid-19: Automatic detection from X-ray images utilizing transfer learning with convolutional neural networks. *Physics and Engineering Sciences in Medicine*, 43(2), 635-640.
3. Hemdan, E. E. D., Shouman, M. A., & Karar, M. E. (2020). Covidx-net: A framework of deep learning classifiers to diagnose covid-19 in X-ray images. *arXiv preprint arXiv:2003.11055*.
4. Lin, L., et al. (2020). Using artificial intelligence to detect COVID-19 and community-acquired pneumonia based on pulmonary CT. *Radiology*, 296, E65-E71.