Feature based Classification of X-Ray Images using Artificial Intelligence

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Abstract~ Artificial intelligence (AI) is a rapidly growing field of work and research. Its applications are numerous in a medical context and allow in particular to detect and distinguish anomalies or diseases in patients. In this paper, we show how to distinguish different cases of lung diseases (Covid, Pneumonia, Lung Opacity) from X Ray images of lungs. We first use different tools to extract features from these images and then we put forward image classification models by training first basic Machine Learning techniques, then more advanced classification techniques using Deep Learning and neural network models. We then compare the results on three different test sets in order to highlight the techniques that best distinguish between these different diseases and better classify those images.

Keywords- **Artificial intelligence (AI), Machine learning, Deep learning, Covid, Keras, TensorFlow**

I. INTRODUCTION

According to the Internet Data Center (IDC), worldwide data volume will exceed 181ZB by 2025. More than 70 percent of the information is transmitted through the use of pictures and videos. To get the useful information from it computer vision comes up. Computer Vision has quickly gained popularity in the field of image classification. Classification is the systematic grouping and categorization of items based on their characterization. Image classification was created to bridge the gap between computer vision and Human vision by teaching computers with data.[1] In this paper, we look at how machine learning and deep learning may be used to categorize images. Traditional image categorization methods are a subfield of artificial intelligence (AI), which is known as machine learning in technical terms. A feature extraction engine collects important characteristics like edges, textures, and other attributes, whereas a classification engine categorizes the data based on the extracted features. The main disadvantage of machine learning is that it can only extract particular qualities from photographs and cannot derive distinguishing features from the training data. This issue is resolved by using deep learning.[1] Deep Learning (DL) is a sort of machine learning that has its own mathematical approach of learning. A deep learning algorithm is described that breaks down data in a consistent manner, similar to how humans make decisions. Deep learning does this by layering many algorithms into a layered structure known as an artificial neural system (ANN). The architecture of an ANN is modeled after the organic neural network of the human brain. They are thus more effective than typical machine learning models.[2]

In this work, keras and tensorflow in Python are used to implement machine learning and deep learning algorithms. Covid, Lung opacity, Pneumonia, and normal are all detected using 16000 distinct X-ray pictures. Distinct CNN architectures on CPU systems are studied in this work, using combinations of different classifiers and activation functions, including softmax, sigmoid classifiers, and reLu activation functions and Adam and SGD optimizers.

In the first section, we discussed some medical background on the various diseases and how they affect the lungs. In the second section we discussed feature extraction and noise filtering methods and at the end we discussed the machine learning and deep learning part and their results.

II. MATERIAL AND METHODS

A. MATERIAL

a. Medical indication

Thorax x-ray is a check-up for lung diseases. The thorax (chest) with the organs (heart, diaphragm) in it specially the lung and alveoles are imaged.

X-ray radiation is high energy and can pass through the human body. Depending on the composition of the organs will the radiation attenuate. The denser a tissue is, the stronger is the attenuation and the tissue will appear brighter on the x-ray image. Bone has high density and absorbs the radiation strongly so that bone appears white in the image. Air has very low density and does not absorb the radiation so that air appears black in the image.

Healthy lungs should be dark because of the air. The branches of the lung are a bit visible in an x-ray. An x-ray of a healthy lung shows the organ sharply demarcated from other organs and bones. The outlines of the lungs (black in the image) are clearly visible, as are those of the heart and diaphragm (both white). [3]

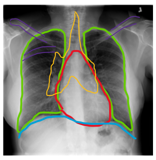

Figure 1: *x-ray image of normal lung. green=lung, red=heart, diaphragm=blue, trachea and branches=yellow, bone=purple*

Pneumonia is a lung infection that causes inflammation of lung tissue and alveoles in one or both lungs. In x-ray the lung appears brighter (white) because of the collection of water and pus which are denser than water and attenuate more radiation and appear brighter in the image. White spots in the lung identify infection. [4]

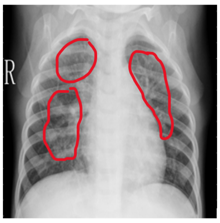

Figure 2: *x-ray image of lung with pneumonia diseases red=indication for pneumonia*

Covid is a disease that can affect the lungs in severe cases and cause pneumonia. The alveoles are damaged in diffusion due to thickening and locating of immune cells. Characteristics are like pneumonia accumulations of fluid and tissue in alveoles. Primarily affect lower areas of the lung. [5]

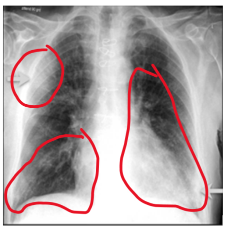

Figure 3: *x-ray image of lung with covid diseases. red=indication for covid*

Lung opacity defines areas that attenuates the x-ray and therefore appears less transparent than the surrounding area. Are areas in x-ray that are brighter (white) than they should be. Differences between lung and tissue are not clear as for a normal lung, there is less sharpness. [6]

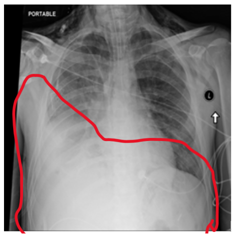

Figure 4: *x-ray image of lung with covid diseases. red=indication for lung opacity*

b. Data set

To carry out our experiments, we need data. In our case, we use different datasets consisting of X-ray images of lungs. In total we have 4 different datasets:

- A training set with 16930 Xray images. These images are annotated (Normal, Covid , Lung Opacity , Pneumonia). We have 8153 normal images, 2892 images of patients with Covid, 4809 images of patients with Lung opacity and 1076 images of patients with Pneumonia.

- 3 sets of test data: a test data comprising images without noise (4235 images), a noise_test data comprising 4235 images including noisy images (images modified by translation, rotation, zoom, etc.) and a mtec_test data comprising only 12 Xray images.

This data is essential for the future as it allows the training and evaluation of Machine & Deep Learning models.

B. METHODS

a. Feature extraction

When working with images using fairly standard Machine Learning models, Feature extraction is the first important step because it allows us to obtain information from these images in the form of a list of numbers that constitute the main input to our models. This reduces the amount of information that will be interpreted by the model. Of course, there are many types of features. In our case, we have decided to extract 5 main features from our images, namely:

- Root Mean Square of the pixels

- Standard deviation of the image

- Entropy of the image: Entropy here is a statistical measure of randomness which is used to characterize the texture of the image. In image classification, a texture might have a certain entropy as certain patterns repeat themselves in approximately certain ways. In this context, a high entropy could mean that the level of disorder rises in the image. In general entropy is defined by the formula:

$$H(X) = -\sum_{i=1}^{n} P(x_i) log_b P(x_i)$$

- Skewness: Skewness measures the lack of symmetry in an image. This is mostly related to the normal distribution. If the curve of the distribution is shifted to the left or to the right, it is said to be skewed. Skewness is defined by the formula:

$$\text{skewness} = \frac{\sum_{i=1}^{N}(x_i - \bar{x})^3}{(N-1)s^3}$$

where:

- $\bar{x}$ is the mean of the distribution
- σ is the standard deviation
- N is the number of observations of the sample

- Kurtosis: It measures the sharpness of the peak in a normal distribution. Also, Kurtosis is heavily related to the notion of outliers in data since a distribution with high kurtosis tends to have heavy tails. The formula of Kurtosis is similar to the skewness one except it is raised to fourth power in the numerator and denominator.

We compute those features on all our train images using some Python libraries that already provide the formula. Later on, we see that using only those 5 features lead to unconvincing results. Therefore, searching in-depth about new features or new ways to extract features lead us to what is called Local Binary Patterns.

Local Binary patterns are features often used in computer vision to recognize textures or to detect objects in numerical images. It allows a local representation of textures and patterns recognition. This representation is constructed by comparing each pixel with its surrounding neighborhood of pixels in a circle shape.

Local binary patterns use mostly two parameters: The radius of the pattern surrounding the central pixel and the number of points to consider. This means that changing the parameters can lead to different visualization as we can see below:

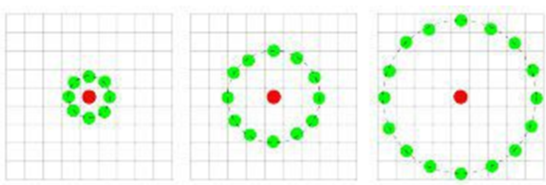

Figure 5: Three neighborhood examples with varying *p* and *r* used to construct Local Binary Patterns.

Also, these visualizations can be combined which give us more features to work with in our image classification. We implement the Local Binary pattern in our workflow and use two different local binary patterns: the first one takes 24 points and a radius of 8, the second one takes 16 points and a radius of 4. We then concatenate the results of both visualizations into one long vector that is used later as an entry to our machine learning models.

b. Noise filtering

Images are mostly degraded by noises. Noise can occur and be obtained during image capture, transmission, etc. like Gaussian, Poisson, Blurred, Speckle and salt-and-pepper noise. An important task in image processing for further processing is to remove the noise. Noise is a random variation of image Intensity and visible as a part of grains in the image.

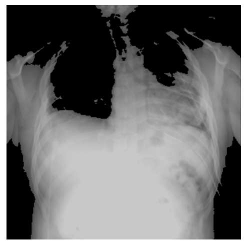

Figure 6: *example of a noisy x-ray image*

Noise removal algorithm is the process of removing or reducing the noise from the image by smoothing the entire image leaving areas near contrast boundaries. [7]

Most commonly used filters are Median filter, Mean filter and Gaussian filter.

The Median filter is an order-statistic filtering. Median filter is used for the removal of impulse noise (salt-and-pepper noise) because it runs through the signal cell by cell and replaces the value of each cell with the neighboring by a median of the intensity levels with its mathematical accuracy. [8]

The Mean filter is a smoothing filter which is used to reduce the amount of intensity variation between one pixel and the next. The idea is to replace the center value of the kernel with the average of all pixel values in the kernel. [9]

The Gaussian filter is used to remove speckle noise. In this filter, the average value of the surrounding pixel or neighboring pixels replaces the noisy pixel present in the image which is based on Gaussian distribution. [8]

c. Machine Learning

Machine learning is a subset of artificial intelligence. Machine learning allows systems to learn and evolve on their own without being explicitly programmed. Machine learning is largely concerned with developing programs that enable a model to be trained and learned from data.

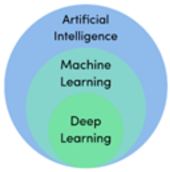

Figure 7: *Artificial Intelligence and Sub Groups*

Machine Learning can be performed both for regression problems and classification problems. Classification is predicting a label and regression is used to predict continuous quantity output. The dataset given has around16000 images with 4 types of data-Covid, Normal, Pneumonia and Lung Opacity images as shown in **Figure 7**.

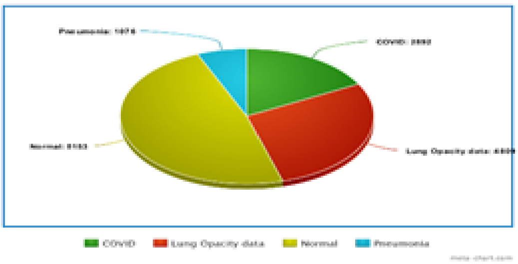

Figure 8: *Dataset and it's Distribution*

Machine Learning can be performed both for regression problems and classification problems. Classification is predicting a label and regression is used to predict continuous quantity output. The dataset given has around16000 images with 4 types of data-Covid, Normal, Pneumonia and Lung Opacity images. Machine Learning goes in different phases. Firstly, the data needs to be pre-processed before providing it to the model as input. In the Data pre-processing Phase, the images are taken and are read using OpenCV-python library. The read function provides the pixel information of the image in the form of an array. The obtained image Information is used to calculate different features. Root Mean Square, Standard deviation, kurtosis, Skewness and Entropy are the features calculated. Once the features of the image are calculated a dataframe is created using pandas to visualize data in a format. There are many classification models namely K-Nearest Neighbours, Logistic Regression, Random Forest and Support Vector Machines. The scikit learn package in python makes the programmers life a little easier. The existing package has all the functionality of the models, and the model is imported. The data is split into training and validation data. The model is fed with the training data to train it and then test the model using the validation data. The predictions can be done for test data. Once the predictions are done, we can get the confusion matrix and find the accuracy, Precision and various parameters. The more the accuracy, the better the model is on the data. The performance issues in machine learning is due to overfitting and underfitting of data. Overfitting occurs when the model performs well on training data and not on test data. Underfitting happens due to poor performance of the model on both training and test data. The overfitting can be limited by using a resampling technique to estimate model accuracy. The most common resampling method is K-fold cross-validation. It lets you train and test your model k times using different subsets of training data, as well as analyze the performance of a machine learning model with concealed data. The results of several models

Table 2: *Accuracy with Different Features*

Features	SVM	KNN
RMS	0.49	0.38
Kurtosis + Skewness	0.64	0.59
RMS + Std Dev + entropy + Kurtosis + Skewness	0.73	0.62

Since the results weren't very satisfying, we looked for other features that we can add or other means to extract features in a more efficient way. Our research led us to LocalBinaryPatterns. Local Binary Patterns are a local representation of texture and pattern recognition. This local representation is constructed by comparing each pixel with its surrounding neighborhood of pixels in a circle. Two parameters: the radius of the pattern surrounding the central pixel, along with the number of points to consider → Changing parameters leads to different computations.

Table 1: *Accuracy with LocalBinarypattern*

SVM	81.5
KNN	75.8
Extra Tree Classifier	77.6
Decision tree Classifier	64.87

d. Deep Learning

Neural Network: The neural network receives an input and sends it via a series of hidden layers. The hidden layer is made up of a succession of neurons, each of which is completely coupled to every other neuron in the preceding layer. Each layer performs an independent role. The final layer of the neural network is called "output layer" as shown in Figure 1.

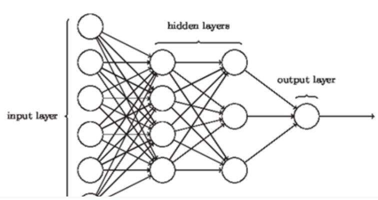

Figure 9: *Artificial Neural Network*

Convolutional Neural Network (CNN): CNN is a deep learning technique that assigns priority to various aspects/objects in a picture using learnable weights and biases, allowing them to be separated from one another. Compared to other classification techniques, CNN requires significantly less pre-processing. With adequate training, CNN can learn these filters/properties, but traditional techniques need hand-constructing filters.[10]

A CNN architecture is based on the visual cortex's organization and is similar to the human brain's neuronal connection network. The receptive field is a tiny area of the visual field where individual neurons respond to stimuli. A group of similar fields will encompass the full visual region if they overlap. [11]

Research Methodology: The flow chart for the recommended technique is shown in Figure 2. The blocks in the recommended flowchart are clearly identified and represent processing stages. Using this method, we compare separate CNN structures against different optimizers.

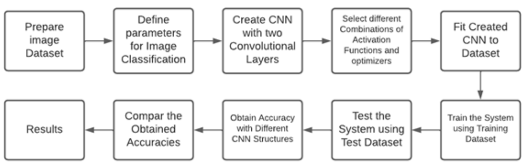

Figure 10: *Proposed Methodology [12]*

The input i.e., the dataset provided contains three folders with 16,000 pictures of chest X-rays images (without and with filter). The images are read using OPENCV- Python command and a data frame is created using pandas. The data is divided into Train, Test and Validation Data. Once the model is created, the data is sent into model and the data is fit. It happens in 3 steps. Model Creation, compile and then fit the data. The compile method has different parameters like optimizers, loss functions and the metrics. Varying these parameters affects your results. We used the most popular optimizers like Stochastic Gradient Descent and Adam. The loss function was Sparse Categorical Cross entropy and Categorical Cross entropy. The metrics we used are accuracy. Once the model is trained, we predicted the results of our test data and this process is repeated with different models.

Finally, we calculate the accuracy of multiple CNN structures, compare their accuracies for performance evaluation, and derive the CNN structure.

Experimental Setup: We utilize Python 3.9.2 on a CPU computer to run experiments on Windows 10 and build a CNN model with TensorFlow and Keras Libraries in this work. The CNN model used in the testing is depicted in Figure 3. The four main layers in this architecture are convolution, pooling, flattening, and completely connected layers.

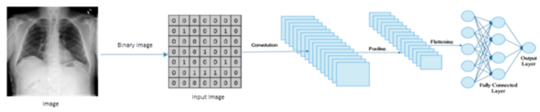

Figure 11: *Convolutional Neural Network Model*

To assess power, we used the ReLu (Rectified Linear Unit) activation functions in the hidden layers, SoftMax in the output layer. In this experiment, we use a mixture of different optimizers and loss functions to investigate which one delivers the greatest classification accuracy.

Results: The two classification accuracies provided by the CNN structures stated above (as shown in Table 1), which depict each CNN structure with accuracies.

Table 3: *Obtained Accuracy*

Number of Convolutional Layers	Loss Function	Optimizer	Accuracy
2	Categorical_CrossEntropy	SGD	86
2	Categorical_CrossEntropy	Adam	88

We compared the results of all the models and chose the one with highest accuracy to test our data.

III. CONCLUSION

The image data provided is preprocessed, noise filtered if there is any noise in the image and has been trained with different models in both machine learning and Deep Learning. Various parameters such as confusion matrix, accuracy, precision were calculated to find a model suitable for the image data provided. The results reveal that the images are accurately identified even for a portion of the test images, demonstrating the deep learning algorithm's reliability.

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