DISEASE PROGNOSIS USING ML AND DL TECHNIQUES: A REVIEW

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Abstract

Patients suffering from chronic diseases need lifelong treatment. This study aims to find recent trends of Machine Learning and Deep Learning techniques and their performance for the disease prognosis. The importance of Image processing in medical images is also analyzed here. The results of this study demonstrated that disease prognosis using ML and DL techniques has experienced dramatic rise in recent years.

Keywords: Image Processing, Machine Learning, Deep Learning, Disease Prognosis, XAI, Explain ability, Interpretability, Cancer, Chronic Diseases, Transfer Learning, Medical Images

I INTRODUCTION

To reduce death rate from chronic diseases, early disease detection, preventive treatments and proper follow ups are required. This can be achieved with the help of ML and DL algorithms with a greater accuracy. ML algorithms can be used for analysis, prediction, classification, grading of disease stages etc. In medical field, the predictive power of ML algorithms is greatly employed for decision making purposes. These algorithms also help in the diagnosis of diseases.

Medical data could come in various forms, of which, image data in the form of X-rays, CT scans, MRI etc. gives more information about diseases. Image analysis is very crucial in healthcare industry. Using Image processing algorithms, one can analyze images and extract useful information from it. Such algorithms are helpful in diagnosing tumors and cancers efficiently.

The whole paper is structured as follows: Section II summarizes the concepts of Image Processing, Machine Learning, Deep Learning, Transfer Learning and Interpretability, Section III briefs the review of literatures, Section IV contains Discussion and Section V concludes the paper.

II BACKGROUND STUDY

In this section, the basics of Image processing is examined first. Then, the Machine Learning and Deep learning approaches and its widely used algorithms are discussed. Finally, the concept of Transfer Learning and Interpretability is explained.

A. Image Processing

Image processing is a method to perform operations on an image to get an enhanced image or to extract useful information from it [1]. In medical field, imaging such as X-rays, CT scan, MRI, PET scan and ultrasound scan of organs or tissues give vital information about our body. These images can be processed and fed into different computer aided diagnosis systems to analyse, evaluate and make certain decisions. The images should undergo some pre-processing steps before feeding it to the model for training. It could be from simple tasks such as resizing, reorienting, scaling etc. to complex tasks such as filtering, segmentation etc.

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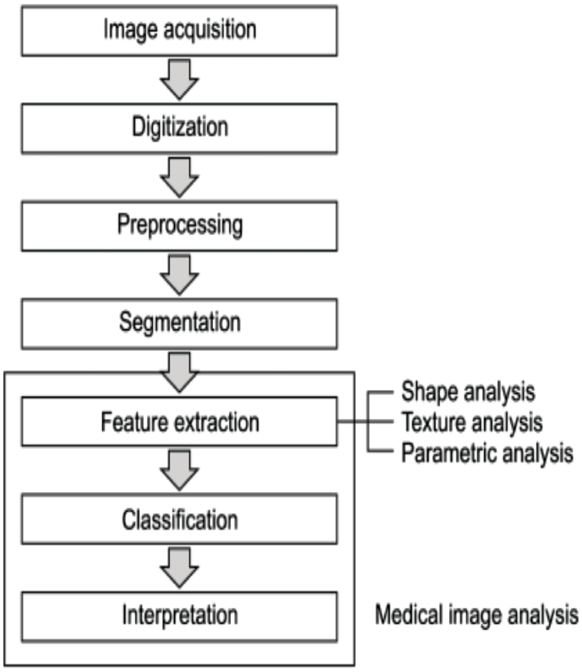

Fig. 1. Steps in Medical Image Processing

Fig. 1 [2] shows different steps in medical image processing.

B. Machine Learning

Machine Learning (ML) is a branch of Artificial Intelligence (AI) which uses data and algorithms to imitate the way human learns by gradually improving its accuracy [3].

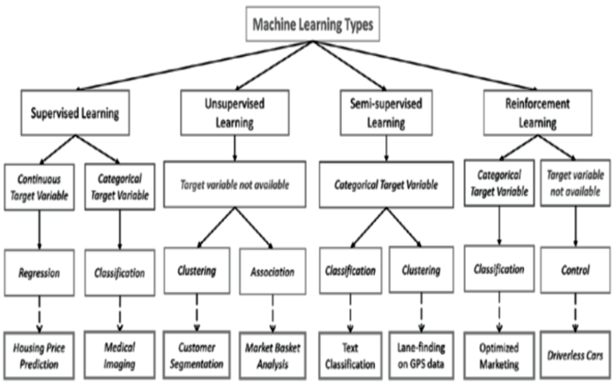

Fig. 2. Types of Machine Learning Algorithms

Based on the input data given, labelled or unlabeled, ML algorithms make a classification or prediction. Error functions help to assess the ML model for its accuracy and the algorithm continues to optimize until a threshold accuracy is met [3].

In general, ML can be categorized as supervised, unsupervised and semi-supervised algorithms. The Fig. 2 [4] shows the types of Machine Learning algorithms and its sub-categories.

1) Supervised ML Algorithms: In supervised learning, the machine is trained with labelled data. Here, an output is determined by a set of input variables. Fig. 3 [5] shows

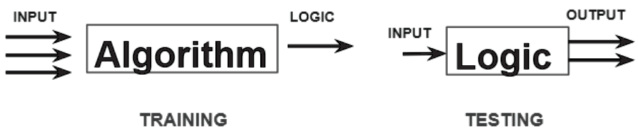

Fig. 3. Supervised ML Algorithms

The algorithm analyses training examples and try to produce correct outcomes for the new set of data given. Supervised algorithms are mainly used for regression and classification problems. Fig. 4 [5] shows the categories of

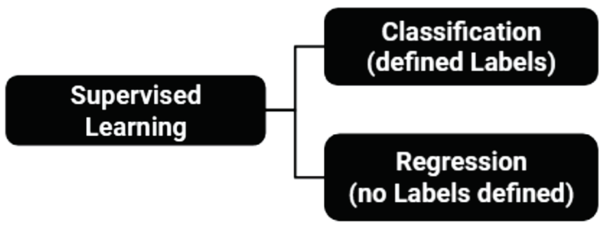

Fig. 4. Supervised ML Categories

Some of the important supervised algorithms are discussed below:

a) Logistic Regression (LR): LR is a supervised classification algorithm. For a given set of features, X, the target variable, y, can take only discrete values [6]. It predicts the probability of a target variable.

b) Support Vector Machine (SVM): SVM tries to find out a hyperplane in the N-dimensional space which classifies the datapoints distinctly. Hyperplanes are the decision boundaries that can segregate multidimensional spaces into classes. This helps to put new data points into correct category. 2 types of SVM are linear and non-linear SVM. SVMs are primarily used in classification problems and can be used for regression problems as well [7]. Fig. 5 [7] depicts a two-class SVM classifier.

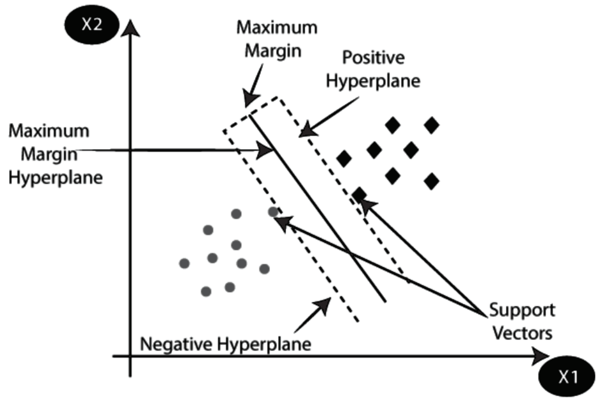

Fig. 5. Support Vector Machine

c) Naive Bayes (NB): NB algorithm is based on Bayes theorem. In NB, it is assumed that each feature is independent of other features in the same class. This simple and effective algorithm is used to solve classification problems.

d) K-Nearest Neighbour (KNN): KNN uses feature similarity for classifying a new datapoint [8]. It would be assigned to the class with nearest neighbors. Number of nearest neighbors is represented by 'K'. KNN is mostly used for classification problems, but can be used for regression problems as well.

e) Decision Tree (DT): DT is a tree structured classifier. nThe features of a dataset are represented by the internal nodes of the DT, decision rules by its branches and outcome of the problem by the leaf nodes [9]. Fig. 6 [9] shows the schematic diagram of a decision tree.

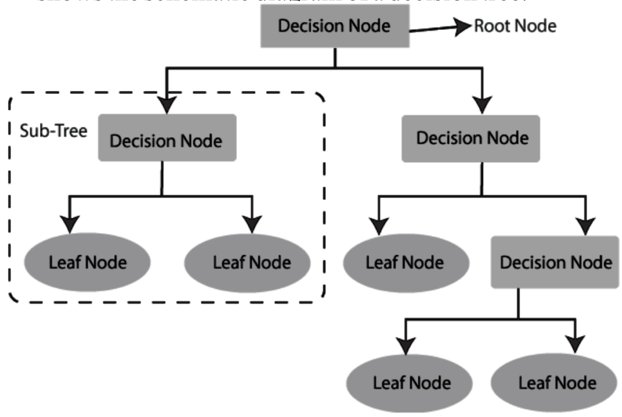

Fig. 6. Decision Tree

f) Random Forest (RF): RF is based on ensemble learning, i.e., it combines multiple classifiers for solving a problem thereby improving the performance of the model. A RF contains a number of decision trees and takes the average of the results from all the decision trees to improve the accuracy of prediction [10]. Fig. 7 [10]

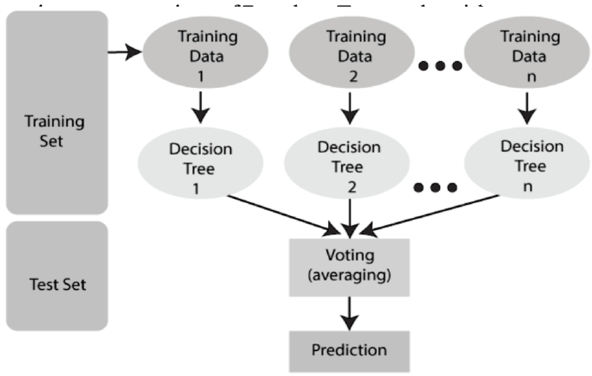

Fig. 7. Random Forest

2) Unsupervised ML Algorithms: In Unsupervised ML algorithms, machine groups data by considering similarities, differences or patterns among them and without any previous training. Fig. 8 [11] depicts the idea

of Unsupervised ML algorithms.

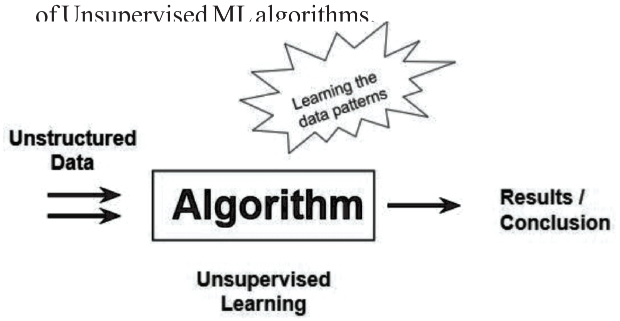

Fig. 8. Unsupervised ML Algorithms

Unsupervised algorithms perform clustering or grouping of inputs with similar interests. Clustering and association come under Unsupervised ML algorithms [11]. Fig. 9 [11] shows the categories of unsupervised ML algorithms.

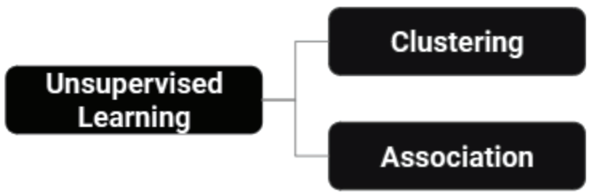

Fig. 9. Unsupervised ML Categories

Some of the important unsupervised algorithms are discussed below:

a) Hierarchical Clustering: It is an unsupervised algorithm in which the unlabelled data are grouped together based on their similarities. Here we develop a hierarchy of clusters in the form of a tree. This structure is known as dendogram [12]. Fig. 10 [12] shows an example of clustering and its corresponding dendogram.

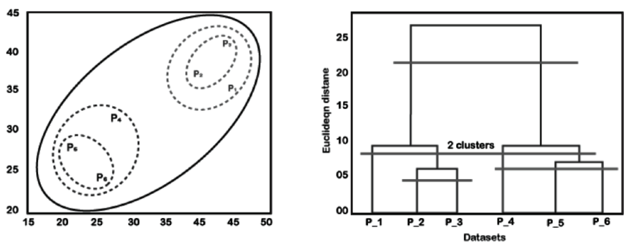

Fig. 10.a) Clustering and b) Dendogram in Hierachichal Clustering

b) K-Means Clustering: In this clustering algorithm, the centroids are iteratively computed until we are left with an optimum centroid. 'K' in K-Means represents the number of clusters, which is a predefined value [13].

3) Semisupervised ML Algorithms: Semi-supervised algorithms lie between supervised and unsupervised approaches. It works with small amount of labelled data and large amount of unlabelled data during training process. Here, unsupervised techniques can be used to predict labels and these labels are fed to supervised techniques. Such algorithms can be used in image data sets where all images are not labelled [11]. Fig. 11 [14] gives an overview of semisupervised ML algorithms.

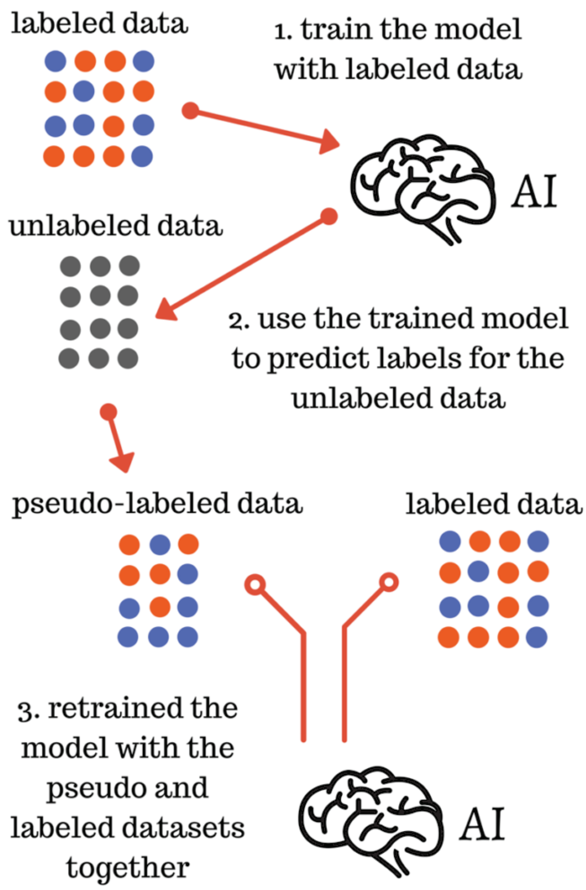

Fig. 11. Semisupervised ML Algorithm

4) Reinforcement Learning: Reinforcement learning is another ML model. Instead of training the model with sample data, it learns from consequences. Such consequences or outcomes are used to build the recommendation for the problem [11]. The model gradually improves its performance with the help of Reward feedback. The idea of reinforcement learning is illustrated in the Fig. 12 [11]

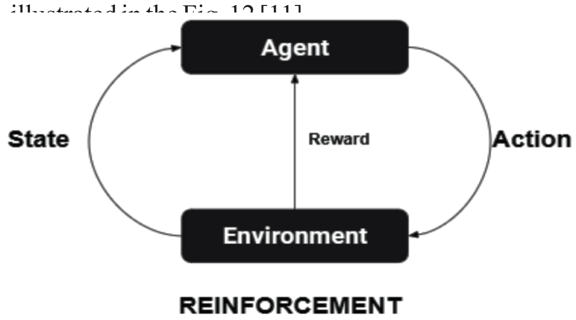

Fig. 12. Reinforcement Learning

Real world use cases of ML include Speech Recognition, Fraud detection, Customer service, Voice Assistance, Computer Vision, Recommendation system, Spam classification etc.

C. Deep Learning

Deep learning (DL) is a subfield of ML [3]. It is inspired by the structure of human brains. The model learns to classify directly from data such as text, sound, image etc.

Deep learning algorithms draw conclusions like human beings by analyzing data using a multi layered structure of algorithms known as Neural Networks (NN) [15]. A NN make predictions fairly even with a single layer, but additional hidden layers help to optimize the predictions. A ty

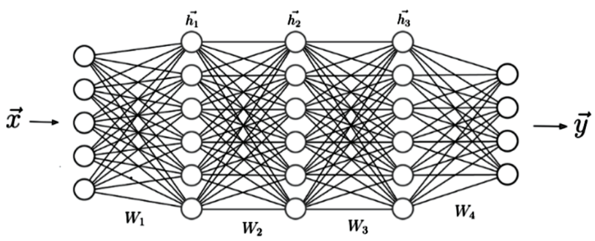

Fig. 13. A typical Neural Network

Neural Networks perform clustering, regression, classification etc. Major advantage of DL algorithms is that-feature extraction, a quite complex process, is automated

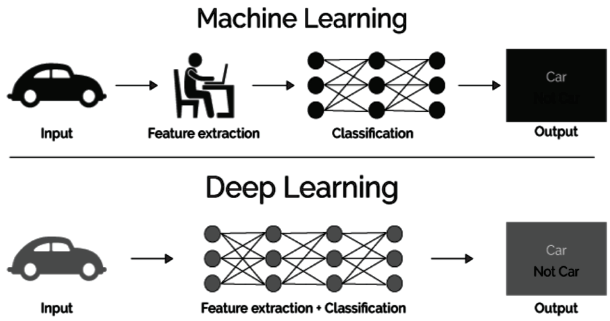

Fig. 14. ML and DL Learning

ML and DL differ in the way the algorithms learn. Learning in ML and DL is shown in fig. 14 [15]. More human interventions are required in ML algorithms than DL algorithms. DL algorithms are complex in nature. Some of the commonly used DL algorithms are:

1) Convolutional Neural Network (CNN): CNNs are primarily used in image classification tasks and computer vision. It can detect patterns and features in an image which enables object detection and recognition [16].

2) Recurrent Neural Network (RNN): RNNs support time series or sequential data and is widely used in speech recognition and natural language processing applications [16].

Long Short-Term Memory Network (LSTM), Generative Adversarial Network (GAN), Deep Belief Network (DBN), Radial Basis Function Network (RBFN), Restricted Boltzmann Machine (RBM), Self-Organizing Map (SOM), Autoencoders etc. are some of the other widely used deep learning algorithms. The importance of DL in language, audio and computer vision is getting a hike. Some of the Real-world use cases of deep learning algorithms are

Law enforcement, customer service, healthcare, financial services, etc. [16].

D. Transfer Learning

In Transfer Learning (TL), the model makes use of the knowledge gained from the previous task for a similar task, i.e., a model developed for a task is reused as the starting point for a model on a second task [17]. When there is no exact supervised data as required or when there is only a limited training data, then transfer learning is the best choice. In TL, the Neural network undergoes pretraining and fine tuning.

Standard deep learning architectures such as- ImageNet, ResNet, InceptionNet, NasNetMobile, GoogleNet- can be fine-tuned for medical tasks. Such architectures could then be used to perform lung CT segmentation, chest x-ray interpretation, brain tumor MRI segmentation, early detection of Alzheimer's disease, retina image classification, etc. Images captured using various medical devices comes in dissimilar forms [18] which can be best handled using TL techniques. Fig. 15 [18] shows the application of Transfer Learning in different medical domains.

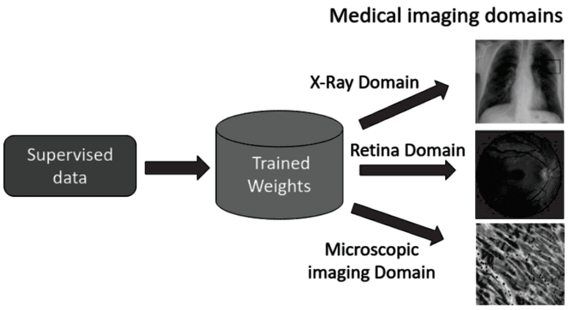

Fig. 15. Transfer learning in medical imaging

E. Interpretability

Interpretability is the degree to which a model can be understood in human terms [19]. ML and DL techniques follow black box approach. It rarely explains the prediction in human understandable form [20]. Addressing the problem of Blackbox approach of Neural Networks is a real challenge for the developers. Various types of interpretability methods and performance measures have been reviewed in the paper [20]. Interpretability of the model is important especially in medical field while taking crucial decisions in the case of life-threatening diseases. Interpretability ensures the trust, pr [illegible] l.

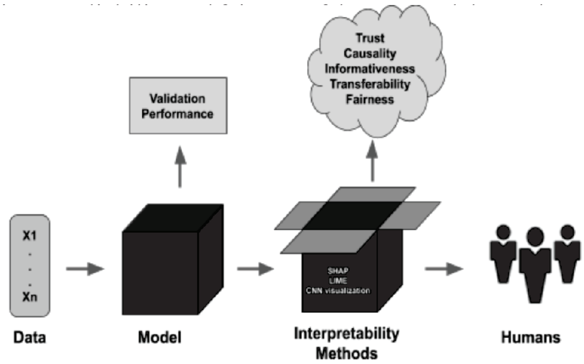

Fig. 16. Interpretability for ML models

Fig. 16 [21] shows the interpretability of ML models bridging the concrete objectives for the real world.

III LITERATURE REVIEW

A detailed study on disease diagnosis using ML and DL methods and the importance of IP on medical images has been carried out. The reviewed literatures are organized under 3 sub-sections- Image Processing, Machine Learning and Deep Learning.

A.Image Processing

Diverse medical images-Brain MRI, Breast MRI, Cardiac CTA- were segmented in [22] by employing a single CNN architecture. They proved that CNN could perform different segmentation tasks even though the model has not been trained specifically for individual tasks.

Segmentation task was carried out by [23] on Lung CT images of LIDC-IDRI dataset using U-net architecture. They required very few images for training and the model segmented the images accurately with a dice-coefficient index of 0.9502.

Image segmentation is an important step in image processing and a trend in research. Automatic Image segmentation techniques have been analysed, compared and explained along with their applications, merits and demerits by [24]. As a result, they found that CNN is very powerful for segmenting images automatically.

[25] proposed a VGG16 model to classify image into living and non-living categories which is further classified into several other sub-classes. They got an accuracy of 99.89%.

[26] have analysed the performance of four, pixel-wise lesion segmentation methods based on deep learning approaches on oral carcinoma images. They created an annotated dataset and the 4 architectures- U-Net, SegNet, U-Net+VGG16 Encoder, U-Net+ResNet50 Encoder- were trained and tested which provided promising segmentation results.

B. Machine Learning

A comparative study on different ML algorithms was performed for predicting thyroid disease and classify it into 3 classes- normal, hyperthyroidism and hypothyroidism by [27]. UCI dataset was employed for the experiment with 21 attributes and a label. Among the ML techniques used- Support Vector Machine, Multiple Linear Regression, Naive Bayes and Decision Trees- Decision trees had given a highest accuracy of 99.23%.

Performance of various supervised ML algorithms were analysed for disease prediction by [28]. It was found that SVM followed by Naïve Bayes were the most frequently used algorithms which also produced good accuracy. In their experiment, RF scored first followed by SVM.

[29] classified oral cancer into stages (0, 1, 2, 3, 4a, 4b, 4c) using ML techniques. They experimented with popular ML techniques such as SVM, KNN, LR, DT, RF, MLP and found that DT and RF were more effective in their classification task.

[30] reviewed the analysis of genomic data using ML techniques for the prediction of head and neck cancer (HNC). In their study they found that SVM was the most commonly used technique.

[31] reviewed 453 papers published in a period of 4 years which dealt with the applications of predictive ML models in diagnosing Chronic diseases. They concluded that, as every method has its own merits and demerits, none of the methods can be considered as a standard method in real time disease diagnosis. They also stated that LR, SVM and clustering are the most commonly used methods for chronic disease classification.

[32] investigated different ML algorithms (Support Vector Machine (SVM), Naïve Bayes (NB), Decision Forest (DF), Boosted Decision Tree (BDT) and Permutation Feature Importance (PFI)) for classifying Oral Tongue Squamous Cell Carcinoma (OTSCC) patients to low and high-risk groups. The Ensemble ML method- Boosted Decision Tree- produced a greater accuracy among others.

Four ML algorithms- LR, DT, KNN, SVM- were populated to predict the outcome of the progressive disease, oral cancer by [33]. It is found that Decision Tree outperformed other ML algorithms in predicting the outcome of oral cancer.

C. Deep Learning

[34] employed Deep Recurrent Neural Networks for prostate cancer detection from Temporal Enhanced Ultrasound (TeUS). Among the RNN methods they experimented, LSTM produced greater accuracy.

[35] developed a model for brain tumor detection. The model was trained and tested using BRATS dataset. They segmented brain MRI images using seed growing method and the segmented slices are then input to Stacked Sparse Auto Encoder for feature extraction and thereafter the model predicted it as tumor or non-tumor images.

In [36], they made a review on cancer diagnosis using deep learning methods. They started with explaining the steps in the diagnosis of cancer. Then Artificial Neural Networks and Evaluation Metrics were briefed. Various types of cancer and algorithms used in the papers they reviewed were discussed then. They also provided links to github codes and various datasets.

[37] have performed automatic classification and detection of oral cancer. Initially, from multiple clinicians, they could combine bounding box annotations. They used two deep learning-based approaches- ResNet-101 for classification of oral lesions and Faster R-CNN for object identification.

[38] analysed the performance of 5 deep CNN and 4 ensemble models for skin cancer classification using HAM10000 dataset. ResNeXt101 architecture outperformed other models in multi class skin cancer classification with an accuracy of 93.20%.

In 2020, [39] compared and analysed different algorithms used for lung cancer nodule detection and false positive reduction. Among the state-of-the-art deep learning models they analysed, CNN was found to be more effective. They also presented details about the availability of lung CT scan datasets.

Analysis and classification of breast histopathological images into carcinoma and non-carcinoma classes were done by [40]. They employed ensemble of deep learning models to classify histopathological images automatically.

Diabetic Retinopathy was detected automatically by [41] from fundus images. They also localized lesions in retinal images by employing a Faster-RCNN based approach.

[42] employed 8 deep learning techniques- VGG16, InceptionResNetV2, ResNet50, DenseNet201, VGG19, MobileNetV2, NasNetMobile and ResNet15V2 - for the detection of Covid-19 symptoms. Among these, NasNetMobile architecture achieved greater accuracy. LIME method added explainability to the results.

[43] employed CNN by adding LSTM at the end of CNN architecture to classify Gastrointestinal tract into 10 different classes. They conducted 3 experiments with AlexNet, GoogleNet and ResNet50 architectures each with CNN+SVM and CNN+LSTM models. And they found that CNN+LSTM gave good classification performance whereas CNN+SVM didn't produce good results for unbalanced dataset.

Using style-based GAN network, [44] augmented and synthesized high quality images of skin lesion. Then a classification model was constructed using transfer learning model and the skin lesions were classified by Transfer-ResNet50.

In 2021, [45] classified oral MRI images into normal and abnormal images using deep learning algorithms. Through morphological operations, cancer regions are segmented then. These segmented images are then categorised into mild and severe classes. This CNN model works well with less oral images.

[46] proposed a new deep learning model with visual attention mechanism to increase the explainability of the

model. The Multiscale CNN constructed extracts the high-level features of the image and increased the robustness of the network's performance. Breast cancer classification and Lung nodule classification were experimented on this model which gained a greater classification accuracy.

IV. DISCUSSION

Latest papers on disease prediction and classification using ML and DL techniques have been reviewed and a few relevant papers have been classified and listed here. Table I. shows different Image Processing techniques carried out on medical images from different domains.

Reference Paper	Year	Problem	Methodology / Algorithm Used	Performance Measurement
[22]	2016	Medical Image Segmentation in multiple modalities	CNN	Segmented images from different modalities
[23]	2018	Lung CT image Segmentation	U-net Architecture	Dice-coefficient index- 0.9502
[24]	2019	Comparison of Image segmentation techniques	CNN	CNN is efficient
[25]	2020	Image Classification	VGG16	Accuracy- 99.89%
[26]	2020	Oral Squamous cell carcinoma lesion Segmentation	U-Net, SegNet, U-Net+VGG16 Encoder, U-Net+ResNet50 Encoder	All architectures were found effective

Table I. Image Processing Techniques Applied in Different Domains

Table II. shows different Machine Learning methods used and its performance measurements for solving different problems

Reference Paper	Year	Problem	Methodology / Algorithm Used	Performance Measurement
[27]	2017	Thyroid Disease prediction using ML algorithms	SVM, Multiple Linear Regression, Naïve Bayes, Decision Trees	DT outperformed other techniques with an Accuracy- 99.23%
[28]	2019	Performance Analysis of Supervised ML Algorithms	SVM, LR, NB, KNN, RF, DT	Frequently Used algorithms- SVM and NB Highest Accuracy- RF and SVM
[29]	2019	Classification of Stages of Oral cancer	SVM, KNN, LR, MLP, DT, RF	DT and RF outperformed others
[30]	2019	Genomic study of Head and Neck cancer	Majority used SVM	Accuracy varied from 56.7%- 99.4%
[31]	2020	ML Models in disease diagnosis	LR, SVM and Clustering	Most used methods for chronic disease classification
[32]	2020	Supervised ML for classification of locoregional oral cancer	SVM, NB, DF, PFI, BDT	Boosted Decision Tree outperformed others. Accuracy- 81%
[33]	2020	Oral cancer treatment outcome prediction	LR, DT, KNN, SVM	DT outperformed Accuracy- 70.59%

Table II. Machine Learning Methods Used in Different Problems

Table III. shows different Deep Learning techniques employed and its performance measurements for solving different problems.

Reference Paper	Year	Problem	Methodology / Algorithm Used	Performance Measurement
[34]	2017	Prostate Cancer Detection	Deep RNN	AUC- 96% Accuracy- 93%
[35]	2019	Brain Tumor Detection	Stacked Auto Encoder	Good performance on BRATS dataset
[36]	2019	Cancer diagnosis	Survey on deep learning models	CNN is effective
[37]	2020	Oral cancer detection and classification	Image Classification - ResNet101 Object Detection- Faster R-CNN	F1 score for image classification- 87.07% F1 score for object identification- 78.3%
[38]	2020	Multi-class skin cancer classification	5 CNN & 4 Ensemble models. ResNeXt101 outperformed other models	Accuracy- 93.20%

Reference Paper	Year	Problem	Methodology / Algorithm Used	Performance Measurement
[39]	2020	Lung cancer nodule classification from CT scan	Deep learning models	CNN is found effective
[40]	2020	Breast cancer classification based on histopathological images	Ensemble of Deep Learning models	Accuracy-95.29%
[41]	2020	Detection of Diabetic Retinopathy	Faster-RCNN	Accuracy-95%
[42]	2020	Detection of Covid-19 Symptoms	NasNetMobile, LIME	Accuracy-82.94%
[43]	2020	Classification of Gastrointestinal tract	LSTM	Accuracy-97.90%
[44]	2020	Classification of Skin lesion	GAN	Accuracy-95.2%
[45]	2021	Diagnose oral cancer from MRI images	CNN classification	Detection rate-99.3%
[46]	2021	Medical Image Classification	Visual Attention Mechanism-MCNN	Accuracy in Lung nodule classification-99.86% Breast cancer classification-99.89%

Table III. Deep Learning Methods Used in Different Problems

Among the problems reviewed, it is found that SVM, DT and ensemble techniques in Machine Learning are the widely used algorithms. These algorithms produced greater accuracy too. It is also observed that CNN architecture is the one which is used extensively and effectively among the available deep learning techniques.

V CONCLUSION

A review has been carried out on how Machine Learning and Deep Learning algorithms are helpful in diagnosing various diseases. The importance of Image Processing in medical images is also studied. Various problems have been reviewed and the problem description, methodology used and performance measurement has been summarized. By implementing ML and DL techniques in detecting and predicting deadly diseases at an early stage, we can prevent its spread or severity to a larger extent.

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