Advances in Nonlinear Variational Inequalities
ISSN: 1092-910X
Vol 28 No. 2s (2025)

Early Prediction of Alzheimer Disease and Multiclass Classifier System

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Article History:

Received: *11-09-2024*

Revised: *29-10-2024*

Accepted: *06-11-2024*

Abstract:

Alzheimer disease (AD) is a neurological disorder damaging the memory systems of the brain that gets worse as time passes and significantly affects neuropsychological function.These days, the field of medical imaging is significantly evolving due to advancements in deep learning (DL). Large datasets can be effectively employed using DL, such as the Alzheimer Disease dataset, which has several classifications. In this project, 6400 MRI images that have been reduced to 256 × 256 pixels and are separated into four unique categories are used to create a RBF kernel based SVM model for multistage classification and detection of Alzheimer's MRI pre-processed dataset. The dataset with 4 classes was used for this detection and was used for the purpose of training and testing our SVM model, giving the detection accuracy 86% and classification accuracy 78%. The resulting model implements the automated AD detection and staging using MRIs of brain, providing the valuable tool for clinicians in diagnosing and monitoring the development of Alzheimer disease.

Keywords: Alzheimer Disease, Deep Learning, SVM, MRI, Deep Learning.

1. Introduction

Today, Alzheimer disease has become one of the most common dementias. This disease is degenerative and begins with loss of memory and eventually leads to low interaction with the surrounded environment and even being unable to make conversation with others. The brain parts that are utilized in thinking, remembering, and learning, i.e., in cognition and to store memory, are the ones that are mostly targeted by Alzheimerdisease, which might lead someone to not even carry out their daily activities. For now, Alzheimer disease has come to be dangerous, and number of people get affected by it; even in 2020, United State produced over 5.8 million AD cases[1].AD is far less likely to affect younger people and more likely to affect older adults. In every 5 years the number of people beyond age 65 is having AD gets double. We can expect this number to be tripled to 14 million by the end of 2060. Greater the age, higher will be the chance of getting affected by AD, and commonly, individuals that are beyond the age of 60 may get captured by it.For detection of AD there are various tests like cerebrospinal fluid test, but they are quite time consuming luxurious and require specialized know-how that won't be readily to be had in all healthcare settings. This situation now not exceptional diminishes the quality of existence for sufferers however also places a extensive emotional and financial burden on caregivers and healthcare structures[2].

This project uses SVM classifier which is a supervised machine learning model and used to classify unstructured data like images, audio, etc. The SVM approach tries to find an ideal line or a hyperplane in the data space for effectively classification data classes by maximizing the distance between each class. This research utilizes SVM along with Radial Basis Function (RBF) kernel, to detect dementia through brain MRI images. The RBF kernel's ability to manage smaller details and high-dimensional nature of medical imaging data, making it ideal for this application. This project uses a dataset which contains MRI images of all stages of dementia, from non-demented to moderately demented cases. The preprocessing of MRI images includes standardizing image dimensions, noise reduction, and feature enhancement which ensures consistency and also enhance model performance. Along with that we also implemented techniques like intensity normalization, skull stripping, and spatial realignment which make images to prepare for analysis. Then it is divided into train set and test set, where SVM model is applied on train set which further will tested on testing set. We assessed the model's accuracy, recall, and F1 score using cross-validation to make sure the findings were reliable and broadly applicable[3]. The ultimate aim of this research is to build an approach that will accurately classify all the phases of AD so it can be detected early.

Our test's findings show that an RBF kernel-equipped Support Vector Machine (SVM) version can identify multiple stages of dementia from MRI images with an abnormally high degree of accuracy. This research demonstrates the effectiveness of SVM in conjunction with RBF as a strong and trustworthy technique for early dementia assessment; this is crucial for prompt intervention and better patient outcomes. Our method takes advantage of the RBF kernel's ability by effectively handling the data, which is complex and non-linear in nature, followed by capturing the minute changes in mental structure linked to dementia progression, which are critical for accurate diagnoses. Additionally, we identify potential avenues for future development of the suggested approach, such as adding more imaging modalities or expanding the dataset to encompass a wider range of dementia cases. These enhancements should also increase generalizability and accuracy of the model, leading it to become a more useful weapon in the fight against dementia [4]. Our artwork no longer only highlights the abilities of SVM with RBF within the context of dementia detection however additionally opens new avenues for research and improvement in medical imaging and tool studying.

2. Objectives

This paper aims to develop an early-stage prediction model for Alzheimer disease using machine learning techniques. It aims to enhance predictive accuracy by integrating various non-invasive features like social behaviour, demographic data, neurological tests, clinical cardiovascular indices, and brain atrophy ratios. The research takes data from ADNI and employs MRI scans to differentiate between normal controls, MCI and pre-MCI [5]. The research paper utilizes a CNN-based approach for the early detection and multi-stage classification of Alzheimer disease using MRI images. The approach involves preprocessing images. The research uses AI in advancing early AD diagnosis and enhancing patient care [6]. The research paper uses extensive datasets to enhance the predictive accuracy and treatment planning from electronic health records and clinical systems. By using SVM the paper underscores the importance of early detection in providing timely treatment, and details the benefits of the proposed method over conventional techniques, emphasizing faster data processing and improved pattern recognition for better treatment plans across different age groups [7]. A fully automated CADsystem designed to enhance the early diagnosis of AD using SPECT images. By using advanced feature selection and SVM classification, the system reduces the subjectivity and errors that often occur with traditional visual assessment methods. This method achieves the accuracy rate of over 90%, by focusing on the most discriminant features such as standard deviation and correlation of brain image slices [8]. MRI pictures and a CNN model to identify Alzheimer early. The model uses a dataset of 7,635 photos from the ADNI and obtains a high accuracy rate of 99%. Using deep learning, a fully automated CAD model is created to boost the accuracy of early AD disease diagnosis by enhancing MRI brain pictures and integrating sophisticated feature extraction techniques with a CNN model to correctly identify patients [9]. The study emphasizes the value of exact early diagnosis to facilitate preventive measures and minimize irreversible brain damage. It traces the progression of AD diagnostic methods, from traditional observations to advanced computational techniques that leverage DL to handle large biomedical datasets, particularly MRI scans. The study underscores the potential of DL to significantly enhance early diagnosis and treatment outcomes for AD patients, reflecting advancements in neuroimaging and machine learning technologies [10]. Multiple kernel learning (MKL) by approximating Gaussian kernels using random Fourier features, which enables the problem to be solved in the primal space, thereby reducing computational complexity. This technique effectively merges diverse data sources, such as MRI and CSF biomarkers, improving classification performance while maintaining computational efficiency. The ADNI dataset's results demonstrate that the proposed method outperforms traditional single-feature and other MKL approaches, offering a promising solution for early AD detection [11]. Multistage classifier approach utilizing machine learning technique to enhance AD prediction and retrieval from MRI scans. The proposed methodology integrates Naïve Bayes, SVM, and KNN classifiers. This approach leverages the strengths of each classifier while mitigating their individual limitation, leading to improved accuracy in early AD detection compared to single classifier systems. The approach shows promising results on the ADNI database, highlighting the capability of combined ML methods for early detection of AD [12]. The methodology integrates MRI, PET, cerebrospinal fluid (CSF), and genetic data, utilizing linear discriminant analysis (LDA) to compute scores indicative of AD progression for each modality.Experiments conducted using the ADNI dataset demonstrated improved performance compared to methods utilizing raw features, with the proposed approach achieving accuracies of 66.7% for three-way classification and 57.3% for four-way classification. The research emphasizes the significance of maintaining a balance in feature counts across modalities and showcases the advantages of the binary ELM-driven tree decision approach over SVM-based methods [13]. The research highlights the adoption of structural MRI (sMRI) owing to its non-invasive characteristics, while also exploring prevalent classification methods such as SVM, Relevance Vector Machine (RVM), and regularized extreme learning machine (RELM). Utilizing the ADNI dataset, the research highlights the importance of feature extraction and dimensionality reduction using PCA to improve classification performance. The findings suggest that integrating PCA with algorithmic learning approaches can significantly improve the accuracy of AD diagnosis and categorization [14]. CNN model recognizes various phases of dementia, including Alzheimer disease, from MRI images. The Kaggle MRI dataset used in this research presented a significant challenge due to class imbalance, which was effectively addressed by applying the SMOTE. The model, evaluated on the Kaggle dataset, achieved remarkable outcomes with an accuracy of 95.23%. The model generates detailed probability maps of disease risk and offers intuitive visualizations, demonstrating superior performance compared to existing methods and proving to be a robust technique for timely and precise recognition of Alzheimer disease and dementia [15]. SVM system to recognize AD from MRI brain scan images. Utilizing Kaggle dataset with images resized to 128x128 pixels and augmented through horizontal flipping, the study concentrated on the binary classification of demented versus non-demented individuals. The SVM classifier was trained and evaluated using 15-fold cross-validation, achieving a remarkable accuracy of 99.06%. The research demonstrates that SVM-based models can substantially boost the accuracy of dementia diagnosis, providing a promising alternative to conventional clinical methods [16]. The research addresses the complications of early AD diagnosis using ML models, emphasizing the need for both accuracy and explainability. This system demonstrated high efficiency, attaining an F1 score of 98.9% for binary classification (normal controls versus Alzheimer disease) and 90.7% for multiclass classification. This study highlights the pivotal task of the clinical Dementia Rating tool in AD prediction and demonstrates the potential of interpretable ML models to provide key insights for early diagnosis and targeted interventions [17]. Using a dataset from OASIS that includes longitudinal MRI data of 150 subjects aged 60 to 96, the research implements algorithms such as Logistic Regression, SVM, Decision Tree, KNN, AdaBoost, and Random Forest to identify the most accurate predictor.Among the models tested, Random Forest obtained the peak accuracy at 86.8%, pursued by AdaBoost with an accuracy of 80.3%. These findings highlight the potential of ML in early AD detection and suggest that future research should focus son hybrid approaches to enhance prediction accuracy [18]. The use of model integrating several classifiers, including Gaussian Naïve Bayes, Decision Tree, Random Forest, XGBoost, Voting Classifier, and GradientBoost, trained on the OASIS dataset. The ensemble-based voting classifier demonstrated a high validation accuracy of 96%.The study highlights the critical role of early detection in managing Alzheimer's disease, noting that accurate, machine learning based predictions could significantly reduce AD-related mortality rates. It also covers data preprocessing methods, including feature selection and managing missing values, to enhance model performance and reliability [19]. Emphasizing the importance of early detection, the study employs cognitive factors like age, visit frequency, MMSE scores, and educational background to develop predictive models, specifically SVM and Decision Tree algorithms. The implementation of SVM and Decision Tree classifiers achieved prediction accuracies of 85% and 83%, respectively. The authors propose that combining MRI scans with psychological data in future research could further improve early-stage prediction accuracy [20].

3. Methods

The main objective of "Early Prediction of Alzheimer Disease and Multiclass Classifier System" is to use human body brain MRIs to forecast the presence and stage of Alzheimer's disease, thereby categorizing patients into four phases of the disease. Three key steps comprise our methodology: data preprocessing, model training, and model evaluation. This structure is standard for classification-based systems. To get ready for model training, MRI images are shrunk and labeled during the preprocessing stage. In the training stage, a Support Vector Classifier (SVM) with RBF kernel is used to build a predictive model. 20% of the dataset is used as testing, while the remaining 80% is used to train the SVM classifier and modify its hyperparameters. During the evaluation step, theperformance of the model is estimated using various performance metrics.

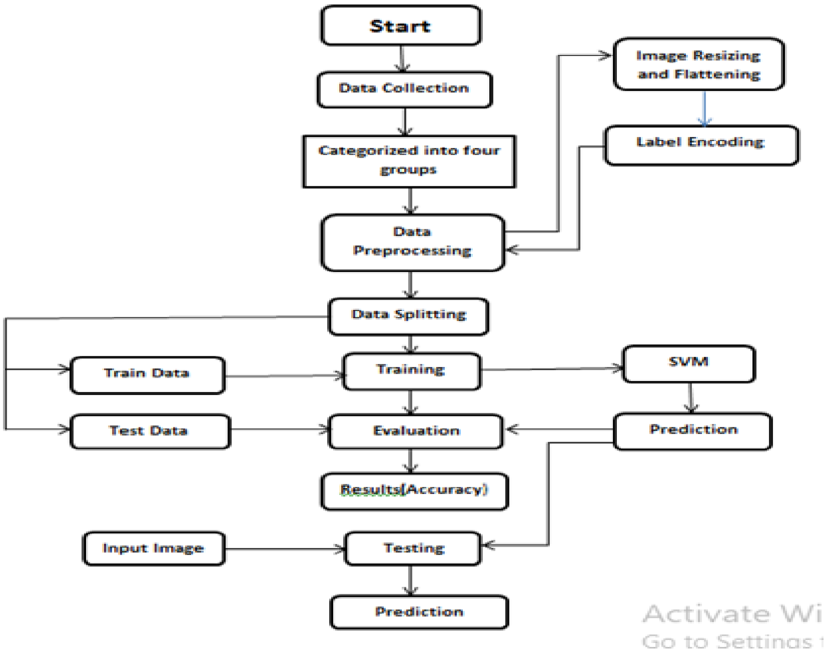

Figure 1. Architecture of Early Prediction of Alzheimer Disease and Multiclass Classifier System

A. Dataset:

MRI images from"Alzheimer disease" dataset from Kaggle were collected and categorized into four groups based on the severity of AD: cognitively normal, very mild, mild, and moderate demented. The photographs were saved in different files for each category, and they were taken from a predetermined dataset source.

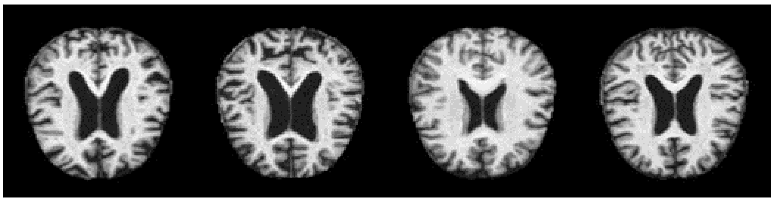

Figure 2. (a) Mild (b) moderate (c) normal (d) Very Mild

Class	No. of image samples
Mild Demented	896
Moderate Demented	64
Very Mild Demented	2240
Non-Demented	3200

Figure 3. Number of Images in Alzheimer disease Dataset

As part of the data pretreatment procedure, the images were structured correctly for machine learning techniques and shrunk to a standard size. Python Imaging Library (PIL) was used to resize each MRI image to 256 by 256 pixels. To produce a consistent data format for the model input, the scaled photos were then flattened into one-dimensional arrays.

Mathematically, the change is represented as:

Flattened Image=Resized Image$_{(256, 256)}$-->R$_{(256x256)}$

Very mild, mild, and moderate dementia were represented by the labels 1 for all stages of the condition and 0 for those who were not. The first detection duty is made easier with this binary classification configuration. The dataset split was performed with dividing the dataset into train set and test set using an 80-20 split ratio.

B. SVM Classifier:

The robustness of the Support Vector classifier (SVM) in high-dimensional domains led to its selection. The non-linear separation of data points was handled by an SVM with an RBF kernel.

$$K(X_1, X_2) = exp(-\frac{||X_1 - X_2||^2}{2\sigma^2})$$

Equation 1.Gaussian kernel function

$$\|x_i - x_j\|^2 = \sum_{k=1}^{d}(x_i^{(k)} - x_j^{(k)})^2$$

Equation 2.Euclidean Distance function

Where:

- feature vectors in the input space – (Xi , Xj)
- ‖ Xi – Xj‖ ^ 2 represents the Sq. Euclidean distance between Xi and Xjcomputed as above.
- d being the dimensionality of the feature vectors

To identify a hyperplane that maximizes the margin between distinct classes, use the SVM method. Given an SVM with a RBF kernel, the goal function is:

$$\min_{\mathbf{w},b,\xi}\left(\frac{1}{2}\|\mathbf{w}\|^2 + C\sum_{i=1}^{n}\xi_i\right)$$

Equation 3.SVM Objective function

Subject to:

$$y_i(\mathbf{w}\cdot\phi(\mathbf{x}_i) + b) \geq 1 - \xi_i, \quad \xi_i \geq 0, \quad i = 1, \ldots, n$$

Equation 4. Soft Margin SVM Constraintequation

SVMuse a decision function to identify the hyper plane that divides a dataset's classes the best. In terms of math, it is stated as:

$$f(\mathbf{x}) = \mathbf{w}\cdot\mathbf{x} + b$$

Equation 5.SVM Decision function

where b is the bias term, x is the feature vector of a data point, and w is the weight vector perpendicular to the hyper plane. A signed distance from the hyper plane is produced by the function (x), where the sign denotes the side of the hyper plane where the point is located. A point x is classified as belonging to class −1 if (x)<0 and to class +1 if $f(x)$>0. In order to create a more efficient classifier, the decision function tries to maximize the margin between the two classes.

C. Algorithm:

Require: Image Dataset D with N images

1. Procedure AlzheimerDetection(D)

2: Preprocess(D) ← []

3: TrainingSet, TestingSet ← Split(D)

4: Model ← TrainSVM(TrainingSet)

5: ConfusionMatrix CM ← Initialize()

6: for i = 1 to |TestingSet| do

7: TestImage ← TestingSet[i]

8: TrueLabel ← Label(TestImage)

9: PredictedLabel ← Model.Predict(TestImage)

10: Update(CM, TrueLabel, PredictedLabel)

11: end for

12: Metrics ← Evaluate(CM)

13: PlotConfusionMatrix(CM)

14: return Metrics

15: end procedure

The algorithm "Alzheimer Detection" describes a systematic approach to detecting Alzheimer disease using an SVM model. First, the dataset D is preprocessed to ensure it's clean and suitable for training. The data is then divided into a training and a testing set. An SVM model is trained on the training set to categorize Alzheimerbased on features from medical data or images. A confusion matrix (CM) is initialized to evaluate model performance. For each image in the testing set, the model makes predictions, comparing the predicted label to the true label. These findings are added to the confusion matrix, which is then utilized to compute evaluation metrics such as recall, accuracy, and precision.Finally, the confusion matrix is plotted for a visual assessment, and the evaluation metrics are returned as the result. This process ensures the model's performance is analyzed and measured effectively.

To assess the effectiveness of our approach, various metrics are used. Recall represents the proportion of relevant instances among the obtained instances, while accuracy refers to the percentage of correctly predicted instances. Precision measures the proportion ofrelevant instances that were retrieved. The confusion matrix provides a detailed comparison of true and false positives and negatives. Meanwhile, the F1 score balances precision and recall, so that we can assess how well the model has performed.

4. Results

We created an RBF kernel-based SVM classifier to detect and predict the phases of AD based on MRI images. To guarantee consistency and computational efficiency, the dataset underwent preprocessing, and images were shrunk to 256 by 256 pixels. Data splitting was performed to separate the images.

For the detection system, our model achieved accuracy of 86%. The detected instances were subsequently categorized into various classes of AD by the classifier system, attaining an accuracy of 78%.

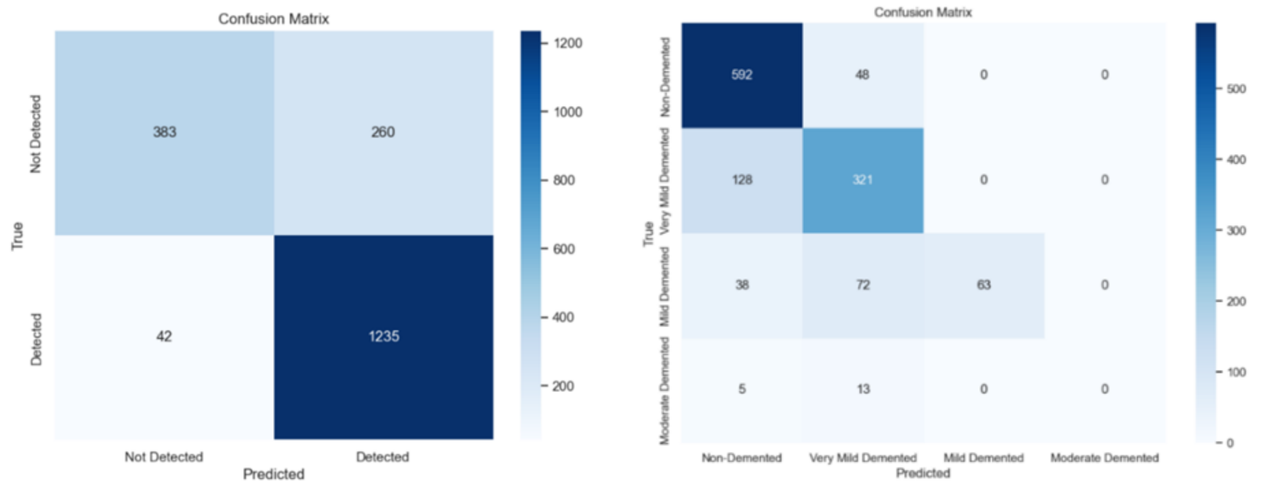

Figure 4. Confusion matrix for a) prediction model with 2 classes and b) classification model with 4 classes

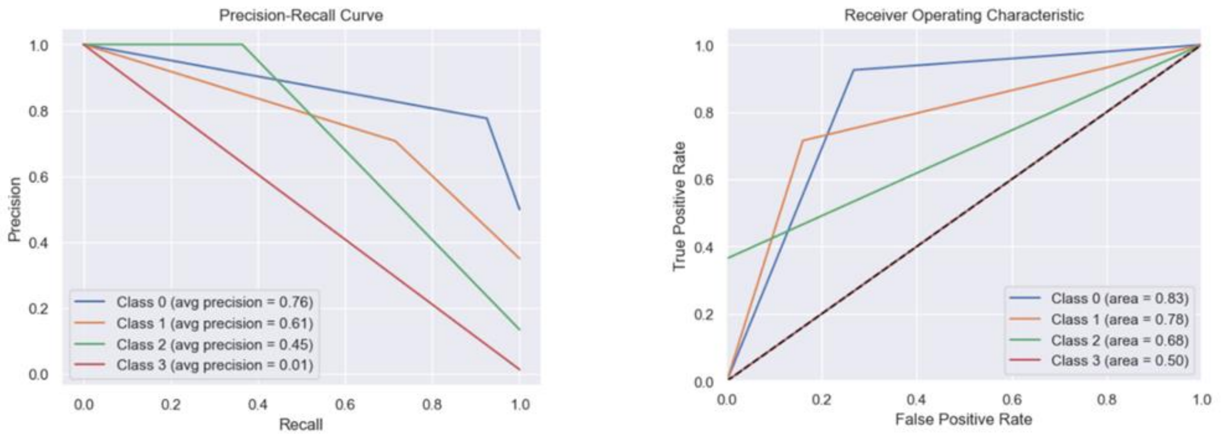

Figure 5. a) Precision-Recall Curve for classification model b) ROC Curve for classification model

Critical information regarding the efficiency of the model is provided by the ROC and Precision-Recall curves. The ROC curve swaps out the sensitivity rate and specificity rate at different points.

The model's high ability to differentiate cases of Alzheimer from cases of non-Alzheimer is demonstrated by its AUC of 0.86. On the other hand, the Precision-Recall curve shows the model's performance with imbalanced data by showcasing how well it maintains high precision while catching relevant positive cases (recall). These curves offer detailed evaluation of our model's diagnostic performance.

Sr No.	Features / Papers	Multistage Classification	Image Resizing	Multimodel Data Integration	Real Time Application	Early Detection Capability
1.	Our Paper	✓	✓	✓	×	✓
2.	Classification of Neurodegenerative Disease Stages using Ensemble Machine Learning Classifiers	✓	×	✓	×	✓
3.	A Modified Convolutional Neural Networks For MRI-Based Images For Detection and Stage Classification of Alzheimer Disease	✓	✓	×	×	✓
4.	Early Detection of the Alzheimer Disease Combining Feature Selection and Kernel Machines	✓	×	✓	✓	✓
5.	A CNN Model: Earlier Diagnosis and Classification of Alzheimer Disease using MRI	×	✓	×	×	✓
6.	Alzheimer's Diseases Detection by Using Deep Learning Algorithms: A Mini-Review	×	✓	✓	✓	×
7.	Multiple Kernel Learning in the Primal for Multimodel Alzheimer's Disease Classification	✓	✓	×	✓	×

Figure 6.Comparison of Early Prediction of Alzheimer Disease and Multiclass Classifier system with other papers

5. Conclusion

This study successfully adopted an MRI image-based method for identifying and categorizing Alzheimer's disease using an SVM classifier with an RBF kernel, achieving 86% accuracy for detection and 78% for classification. Image preprocessing, including resizing to 256x256 pixels, ensured consistency and efficiency. Future improvements include integrating the system into a comprehensive medical tool for clinical usethat operates under the guidance of a healthcare professional. In clinical contexts, this integration can offer invaluable help, assisting physicians in reaching better conclusions. Moreover, utilizing CNNs and other deep learning methods in the model could improve its quality and generalizability.

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