Leveraging Machine Learning Algorithms for Medical Image Classification Introduction

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ABSTRACT

The use of machine learning to medical image classification has seen significant development and implementation in the last several years. Computers can learn to identify patterns, make predictions, and use data to inform their judgements; this capability is known as machine learning, a branch of Artificial intelligence (AI). Classifying images according to their contents allows us to do things like identify the type of sickness, organ, or tissue depicted. Medical picture classification and interpretation using machine learning algorithms has greatly improved the speed and accuracy of diagnosis and treatment. Machine learning algorithms can aid radiologists and doctors in diagnosing patients using medical pictures from X-rays, positron emission tomography (PET), computed tomography (CT), magnetic resonance imaging (MRI), and other scans.

This work is aimed at discussing the use of various machine learning methods for image classification in medical data

INTRODUCTION

Machine Learning Methods for Medical Image Classification

For the purpose of medical picture classification, many machine learning algorithms are employed. Several factors, including the problem's characteristics, the dataset's size, the features' complexity, and the available computer resources, dictate the approach to be used.

The various methods include:

1. **Support Vector Machines (SVMs)**

Support vector machines (SVMs) are a type of supervised machine learning technique that seeks to identify the hyperplane that most effectively divides the data into distinct groups. To maximize the margin between the two classes, the hyperplane is chosen in a certain way. One use of support vector machines is the classification of brain scans for the purpose of cancer diagnosis (Kim et al., 2022). Another approach that has been developed for medical picture classification is a combination of SVMs and Artificial Neural Networks (ANNs) (An et al., 2021). Support vector machines (SVMs) have shown good generalizability when faced with difficult photo classification tasks involving only high-dimensional histograms. According to Mathhur et al. in 2021, support vector machines (SVMs) outperform competing techniques.

2. **Naïve Bayes Classifier**

The naïve Bayes classifier, known for its simplicity and effectiveness, is a probabilistic classifier that applies Bayes' theorem with strong assumptions of independence between features. This algorithm is highly regarded in the field of medical image classification. In a recent study by Nayak and Kengeri (2023), a hybrid approach combining the Naïve Bayes classifier with other machine learning techniques was developed specifically for medical image categorization. This hybrid method, which includes the use of a median filter, has shown to be particularly effective in removing scalp and skull noise from MRI brain images. The performance of this hybrid classifier was rigorously tested using a large dataset of MRI images to distinguish between normal and abnormal scans.

Despite its widespread application in medical image categorization, the Naïve Bayes classifier faces some challenges. It operates under the presumption that the features it analyzes are completely independent, which is not always the case in real-world scenarios. This assumption can sometimes compromise the accuracy of the classification. Nevertheless, due to its straightforward approach and proven efficiency, the Naïve Bayes classifier remains a popular choice in the domain of medical image analysis, as demonstrated in the study by Nayak and Kengeri.

3. Convoluted Neural Network (CNN)

Convolutional neural networks (CNNs) are a type of deep learning technique used for picture recognition. They employ convolution to compress images into smaller formats while preserving important details. Classification of medical pictures, including brain MRIs, mammograms, and chest X-rays, has been accomplished with the use of CNNs. Conditions such as breast cancer, Alzheimer's disease, and lung cancer have also made use of CNNs for detection and diagnosis. Sarvamangala and Kulkarni (2022) conducted a thorough review of CNN frameworks that have won awards and how they are used in medical image understanding for tasks such as detection, segmentation, localization, and classification.

4. Generative Adversarial Network (GAN)

In Generative Adversarial Networks (GANs), two neural networks, namely the generator and the discriminator, engage in a form of competition that enhances their predictive accuracy. This model operates within the realm of unsupervised deep learning. Research by Makhlouf et al. (2023) highlights the application of GANs in tasks such as classification and segmentation, contributing significantly to the identification and diagnosis of various medical conditions. Additionally, a novel approach known as Weakly-Supervised Generative Adversarial Networks (WSGAN) has been introduced for medical image classification, as described by Mao et al. (2021). This method, WSGAN, effectively increases the training set size by generating mask images from a limited collection of real, unlabeled images.

5. Transfer learning with CNN

Transfer learning (TL), particularly when used in conjunction with Convolutional Neural Networks (CNN), is a method that leverages knowledge gained from previous tasks to improve performance on a new, related task. This approach involves using pre-trained deep neural networks, such as ResNet or Inception, as feature extractors. In essence, these pre-trained networks have already learned a variety of features from a large and diverse dataset. When applied to a new task, especially where data may be limited, these networks do not start learning from scratch. Instead, they adjust their already learned features to the new dataset, which can significantly save time and computational resources. This aspect of transfer learning makes it particularly valuable in medical image analysis, where often, large annotated datasets are scarce. According to Kim et al. (2022), this ability to efficiently utilize pre-existing models and knowledge helps to overcome the challenges of data scarcity in the medical field, thereby enhancing the efficiency and effectiveness of image analysis processes.

Some research done that compares different machine learning methods for medical image classification

In their study, Ismael et al. (2020) employed various machine learning techniques to categorise images of blood cells. These methods included K* classifier, additive regression, bagging, input mapped classifier, and decision table. They set out to develop a method that could autonomously identify white blood cells (WBCs) in medical pictures. Neutrophil, basophil, eosinophil, monocyte, and lymphocyte are the five types of white blood cell pictures. Its other applications include picture enhancement, segmentation, and classification. K* algorithms, relative absolute error, mean absolute error, correlation coefficient, root relative squared error, and root-mean-square deviation are some of the metrics they use. When compared to other methods, K* classifier and decision tables both performed better when it came to WBC classification.

	K* classifier	Additive Regression	Bagging	Input Mapped Classifier	Decision Table
Correlation coefficient	1	0.9316	0.7974	0	0.9874
Mean absolute error	0	0.4578	0.8218	1.5733	0.06
Root mean squared error	0	0.5466	0.9526	1.6813	0.2236
Relative absolute error	0	38.15%	68.49%	100%	5%
Root relative squared error	0	38.65%	67.36%	100%	15.81%

Fig 1.1: Visual representation of Machine Learning Classifier Metrics

Optimal feature selection based medical picture classification was employed by Raj et al. (2020) for the classification of lung cancer, brain tumours, and Alzheimer's disease. This method comprises a convolutional neural network for feature selection and an opposition-based crow search algorithm for feature extraction. Their system attained a sensitivity level of 86.4 percent, a specificity level of 100 percent, and an accuracy of 95.22% when it came to classifying photos of lung cancer. An accuracy of 93.33%, sensitivity of 83.33%, and specificity of 100% were attained by the second best technique, which utilised a genetic algorithm for feature selection and a support vector machine for classification. Their method attained a sensitivity of 85.71%, a specificity of 100%, and an accuracy of 94.44% when it came to classifying photos of brain tumours. With a sensitivity of 83.33% and a specificity of 100%, the second best method—which utilised a support vector machine for classification and a particle swarm optimisation approach for feature selection—attained an accuracy of 92.59%. Their method attained a sensitivity level of 88.19%, a specificity level of 100%, and an accuracy of 96.30% for photos of Alzheimer's disease. An accuracy of 94.44%, sensitivity of 85.71%, and specificity of 100% were attained by the second best technique, which utilised a firefly algorithm for feature selection and a support vector machine for classification.

Additionally, Deep Convolutional Generative Adversarial Networks (DCGAN) is a class of GANs that primarily uses convolutional and convolutional-transpose layers in the neural networks, a semi-supervised learning approach for picture classification, was suggested by Tang and Hu (2020) for the purpose of classifying CT pathological images of the chest and brain. This approach makes use of a mix of convolutional and antagonistic neural networks. This first trains the network model using a limited set of labelled pathological images, and then uses the network's characteristics to identify the images. Their neural network outperformed more conventional image classification models and convolutional neural networks (CNNs) in terms of classification accuracy. Their counter neural network achieved about 10% higher classification accuracy with a minimal number of training data compared to other neural networks and conventional methodologies. This is worth noting.

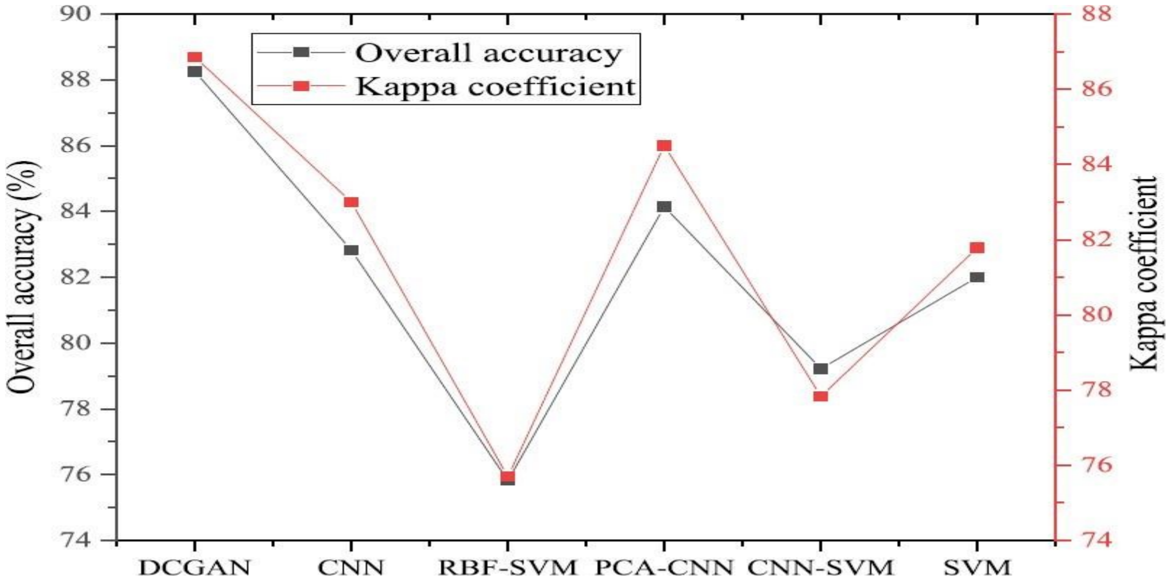

Figure 2: DCGAN in comparison with other machine learning methods

Alternative approach for future works

Machine learning and deep learning algorithms have shown tremendous growth in the medical field, especially in the area of medical image analysis. However future approaches for medical image classification requires first addressing the challenges and bias that occurs and can affect the machine learning algorithms. A major hurdle is the absence of annotated data. The quality and quantity of training data that is available determine how well machine learning algorithms work. Acquiring annotated data for medical picture classification is an expensive and time-consuming procedure. Transfer learning can be utilized to take advantage of pre-trained models and lessen the quantity of annotated data needed for training in order to get around this challenge (Kim et al., 2022). The security and privacy of data is still another issue that must be resolved. Sensitive information is contained in medical images, and there is a chance of data breaches and illegal access. In order to overcome this difficulty, machine learning techniques that safeguard privacy can be employed to make sure that the data is secure while still enabling the algorithms to learn from it. The interpretability of deep learning models presents another difficulty. Since deep learning models are frequently regarded as "black boxes," it might be challenging to analyze the findings and comprehend how the model came to a specific conclusion. Explainable AI (XAI) approaches can be utilized to overcome this difficulty by offering perceptions into the deep learning models' decision-making process (Solatidehkordi and Zualkernan, 2022). Also, there is need for collaboration with data scientist and medical practitioners to be able to address issues like dataset bias, label bias selection bias, etc.

CONCLUSION

The application of machine learning techniques has revolutionised medical picture categorization by enabling the precise and efficient analysis of intricate medical data. This medical picture classification has made use of many machine learning techniques such as SVM, naïve bayes classifier, CNN, GAN, and K* classifier (you didn't discuss K* classifier). Research into deep learning, transfer learning, and data augmentation techniques can significantly enhance the performance of machine learning models, regardless of the challenges. Data privacy and security, interpretability of deep learning models, and absence of annotated data are some of the obstacles to utilising machine learning for medical picture categorization. To overcome these obstacles and enhance the efficiency of machine learning algorithms in medical picture categorization, one might employ transfer learning, explainable AI, and privacy-preserving machine learning techniques. The development of robust frameworks for data interchange and the promotion of collaboration between medical practitioners and machine learning researchers bode well for the future of machine learning in medical image categorization.

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