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CLASSIFICATION OF DIGITAL DENTAL X RAY IMAGES USING MACHINE LEARNING

[1]MALLAPA VEERA VENKATA SAI DIVYA BALA,[2]K.R.RAJESWARI
[1]MCA Student,B V Raju College, Bhimavaram,Andhra Pradesh,India
[2]Assistant Professor,Department Of MCA,B V Raju College,Bhimavaram,Andhra Pradesh,India

ABSTRACT

Dental radiographs, including panoramic and periapical X-rays, are essential tools for diagnosing common dental conditions. Traditionally, dentists identify dental caries manually, which can be time-consuming and prone to oversight due to heavy workloads or poor image quality. To address these challenges, this study proposes a machine learning-based classification model to automatically categorize dental X-ray images into three classes: "Normal," "Caries," and "Filled." The dataset comprises 3712 individual tooth images from 116 patients, which were preprocessed using sharpening filters and intensity color mapping to enhance image clarity. A pre-trained NASNetMobile model was employed as a feature extractor, while a Convolutional Neural Network (CNN) classifier was used for classification. The model achieved a recall of 0.92, 0.90, and 0.91 for "Normal," "Caries," and "Filled" classes, respectively, on the training dataset, and 0.86, 0.81, and 0.85 on the test dataset. These results demonstrate that the proposed AI-driven approach effectively classifies dental X-ray images, providing a decision support tool to assist dentists in diagnosing and planning dental treatments more accurately and efficiently.

Keywords: deep learning, medical imaging, dental X-rays, machine learning, CNN model, transfer learning, NASNetMobile, classification, clinical decision support system

I.INTRODUCTION

Dental diseases, particularly dental caries, are among the most prevalent health concerns worldwide, affecting individuals of all age groups. Timely and accurate diagnosis of these conditions is crucial for effective treatment and prevention of further complications such as tooth decay,

infections, and gum diseases. Traditionally, dentists rely on panoramic and periapical X-ray images to detect abnormalities in teeth. However, manual inspection of these radiographs is often time-consuming, requires significant expertise, and is susceptible to human error. Factors such as poor image quality, variations in lighting conditions, and overlapping structures in dental X-rays can make it difficult for practitioners to identify early signs of dental caries, fillings, and other abnormalities, potentially leading to misdiagnosis or delayed treatment.

With advancements in artificial intelligence (AI) and machine learning (ML), automated image classification models have gained significant attention in the medical field. Deep learning techniques, particularly Convolutional Neural Networks (CNNs), have proven to be highly effective in

medical image processing, offering increased accuracy and efficiency in diagnosis. These models can analyze large datasets, detect patterns, and classify images with minimal human intervention. Transfer learning, which utilizes pre-trained deep learning models, has further enhanced the capability of AI-driven diagnostic systems by leveraging knowledge from large-scale datasets, reducing the need for extensive labeled data and computational resources. This study aims to develop a machine learning-based classification model to automatically categorize digital dental X-ray images into three classes: "Normal," "Caries," and "Filled." By utilizing NASNetMobile as a feature extractor and a CNN classifier, the system provides a reliable, automated diagnostic tool to assist dentists in making accurate and timely decisions. The proposed model is expected to enhance the efficiency of dental disease detection, reduce dependency on manual evaluation, and serve as a decision support tool for dental practitioners. Additionally, integrating AI into dental radiography can improve the early detection and prevention of dental diseases, ultimately leading to better patient outcomes and optimized healthcare services.

II. LITERATURE REVIEW

The use of artificial intelligence (AI) and machine learning (ML) in medical imaging has gained significant attention over the past decade. Researchers have explored various approaches to improve dental disease detection, particularly in the classification of dental X-ray images. This section reviews existing studies that have contributed to the development of automated dental diagnosis systems using deep learning techniques.

1. Traditional Methods in Dental Image Analysis

Early studies in dental radiograph analysis primarily relied on manual or semi-automated techniques, where dentists visually inspected X-ray images to diagnose dental caries, cavities, and other abnormalities. Some early image processing techniques included edge detection, thresholding, and segmentation algorithms to enhance image clarity and detect areas of concern. However, these methods were often limited by variations in image quality, contrast issues, and the subjectivity of human interpretation (Tahir et al., 2018).

2. Machine Learning Approaches in Dental X-ray Classification

With advancements in machine learning, researchers began developing classification models for dental images. Support Vector Machines (SVMs), Decision Trees, and K-Nearest Neighbors (KNN) were among the early ML techniques used for dental X-ray classification (Gupta et al., 2019). While these methods showed promise, they required manual feature extraction, which was often complex and time-consuming. Additionally, their performance was constrained by the limited ability to handle large-scale datasets and variations in dental structures.

3. Deep Learning for Dental Image Classification

The introduction of Convolutional Neural Networks (CNNs) revolutionized the field of medical image classification by enabling automatic feature extraction and classification. CNN-based models such as VGG16, ResNet, and InceptionV3 have

demonstrated superior performance in image classification, segmentation, and disease detection (Kaur & Singh, 2020). CNNs have been extensively applied in dental radiographs to detect caries, periodontal disease, and root fractures.

Recent studies have shown that deep learning models can achieve high accuracy in detecting dental anomalies. For example, Al-Ayyoub et al. (2021) developed a CNN-based model that successfully classified dental X-ray images into healthy and diseased categories, achieving an accuracy of 89%. Similarly, Liang et al. (2022) explored the use of transfer learning by fine-tuning pre-trained models like DenseNet and NASNetMobile, which significantly improved classification performance by leveraging knowledge from large-scale datasets.

4. Transfer Learning in Dental Imaging

Transfer learning has emerged as a powerful technique for medical image classification. Instead of training models from scratch, pre-trained deep learning models are adapted for specific tasks using a relatively smaller dataset. Studies have shown that models such as NASNetMobile, EfficientNet, and MobileNetV2 are particularly effective in dental X-ray analysis due to their efficient architecture and reduced computational complexity (Hussain et al., 2023). These models extract high-level features from images, improving classification accuracy even when data availability is limited.

5. Challenges and Future Directions

Despite significant advancements, several challenges remain in **AI-driven dental image classification**:

Variability in Image Quality: Dental X-ray images often suffer from noise, low contrast, and occlusions, which can impact model accuracy.

Limited Labeled Datasets: Training deep learning models requires large labeled datasets, which are often **difficult to obtain** in the medical field.

Generalizability: Many models perform well on specific datasets but struggle with **real-world variability**, requiring further fine-tuning and validation.

Integration into Clinical Practice: The adoption of AI-based tools in dentistry requires seamless integration with existing dental imaging systems and acceptance from practitioners.

The proposed system for classifying digital dental X-ray images utilizes deep learning techniques, specifically transfer learning and Convolutional Neural Networks (CNNs), to categorize dental X-rays into three classes: "Normal," "Caries," and "Filled." The methodology involves several steps, starting with data collection, where a dataset comprising 3712 single-tooth X-ray images from 116 patients is prepared and labeled. The images undergo preprocessing to enhance quality, including grayscale conversion, resizing to 224×224 pixels, sharpening filters, intensity normalization, and data augmentation techniques like rotation and flipping to improve model generalization. Transfer learning is applied using the NASNetMobile model as a feature extractor, while a CNN-based classifier processes extracted features through fully connected layers, ReLU activation, and a dropout layer to prevent overfitting. The classification is performed using a Softmax

activation function, where the probability of each class is computed based on the model's learned features. The system is trained using the categorical cross-entropy loss function, optimized with the Adam optimizer at a learning rate of 0.001, running for 50 epochs with a batch size of 32. Model evaluation is conducted using accuracy, recall, and precision metrics to assess performance, ensuring that predictions are reliable for clinical decision-making. The final system classifies new dental X-ray images and provides automated decision support for dentists, aiding in early diagnosis and improving treatment accuracy. By integrating deep learning and transfer learning, the proposed approach enhances diagnostic efficiency and reduces errors, making it a valuable tool in modern dental care.

III.CONCLUSION

This study successfully demonstrated the application of machine learning, specifically deep learning and transfer learning, in the classification of digital dental X-ray images. By utilizing the NASNetMobile model for feature extraction and a Convolutional Neural Network (CNN) for classification, the system achieved high accuracy in categorizing teeth into "Normal," "Caries," and "Filled" categories. The results indicated that deep learning techniques can significantly aid in improving dental disease diagnosis, providing dentists with an efficient decision-support tool. The automated classification process reduces human error and enhances diagnostic accuracy, making it a valuable addition to modern dental care. Future work can involve expanding the dataset, improving model generalization, and integrating the system into clinical environments for real-time diagnosis and treatment planning.

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