

DEEP LEARNING FRAMEWORK FOR DENTAL DISEASE IDENTIFICATION IN X-RAY IMAGES

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Abstract - This Dental X-ray images play a crucial role in diagnosing oral diseases. This study proposes a deep learning-based approach for the simultaneous detection of periodontitis and dental caries from dental X-ray images. Initially, individual teeth are detected and cropped from periodical X-ray images using the object detection model YOLOv7. The cropped images are then enhanced using Contrast-Limited Adaptive Histogram Equalization to improve local contrast and Bilateral Filtering to reduce noise while maintaining edge details. For disease classification, a deep learning architecture based on EfficientNet-B0 with fully connected layers is used to identify the presence of periodontitis and dental caries simultaneously. The proposed method demonstrates effective performance in detecting both diseases and provides a reliable tool to support dentists in accurate and efficient dental diagnosis.

Keywords — Periodontitis, Dental caries, Dental X-ray, Deep learning, YOLOv7, Convolutional Neural Network.

I. INTRODUCTION

With the rapid development of artificial intelligence (AI) and the availability of large medical datasets, AI has become an important tool in medical imaging and dental diagnosis. Deep learning techniques, especially convolutional neural networks (CNNs), can automatically learn complex patterns from dental radiographs and help detect oral diseases efficiently. Among oral diseases, Periodontitis and Dental Caries are the most common and can significantly affect oral health and overall well-being. Early detection of these diseases is essential for effective treatment. Traditionally, dentists rely on clinical examination and radiographic analysis, which can be time-consuming. Recent research has applied deep learning models to dental X-ray images for disease detection. Many studies use Convolutional Neural Network and other machine learning techniques to identify dental conditions. However, most existing approaches focus on detecting only one disease at a time.

Therefore, this work proposes a deep learning-based approach that can simultaneously detect periodontitis and dental caries from dental X-ray images, improving diagnostic efficiency and assisting dentists in clinical decision-making.

II. REVIEW OF THE LITERATURE

Ivane Delos Santos Chen et al. (2023) – It was proposed a deep learning framework for the simultaneous detection of Periodontitis and Dental Caries from dental X-ray images using YOLOv7 for tooth detection and EfficientNet-B0 for classification.

Lukas Kunt et al. (2023) - developed a deep learning system using Convolutional Neural Network to automatically detect dental caries from bitewing radiographs, achieving diagnostic results comparable to dentists.

Rasool Esmaeilifard et al. (2024) proposed a CNN-based method to detect and classify dental caries from Cone Beam Computed Tomography images for improved dental diagnosis.

Arman Haghanifar et al. (2020) introduced PaXNet, a deep learning model combining transfer learning and capsule networks to detect dental caries in panoramic X-ray images.

Geunseok Lee et al. (2018) applied Google Net InceptionV3 to identify dental caries from periapical radiographs, showing that CNN models can support automated dental diagnosis.

Jae-Hong Lee et al. (2021) proposed a CNN-based system for detecting early dental caries in bitewing radiographs and demonstrated improved diagnostic accuracy with AI assistance.

S. Kim et al. (2022) used U-Net architecture to segment teeth and detect dental caries automatically from panoramic radiographs.

Hyeong-Seop Kim et al. (2022) developed a sequential deep learning system combining Faster R-CNN, U-Net, and VGG16 for dental disease detection.

Debesh Jha et al. (2020) introduced Double U-Net, which improves medical image segmentation performance and has been applied to dental image analysis.

Farooq Ahmad et al. (2023) conducted a systematic review of deep learning applications in dental radiology and reported that CNN-based models are widely used for disease detection and segmentation in dental imaging.

III. DATASET

A dataset of periapical dental X-ray images was collected from a dental clinic in Hualien, Taiwan. In these images, Periodontitis is identified by alveolar bone loss around the tooth, while Dental Caries appears as radiolucent areas in the enamel or dentin. The dataset includes both anterior and posterior teeth, as well as teeth with root canal treatment and dental restorations. All images were annotated by an experienced dentist. Each single-tooth image was labeled into four categories: normal tooth, periodontitis, dental caries, or both diseases.

Individual tooth images were extracted from periapical X-rays using YOLOv7 and resized for model training. To improve model performance, data augmentation techniques such as horizontal flip, vertical flip, and image rotation were applied. The dataset was divided into training, validation, and testing sets, and 10-fold cross-validation was used to evaluate the deep learning model.

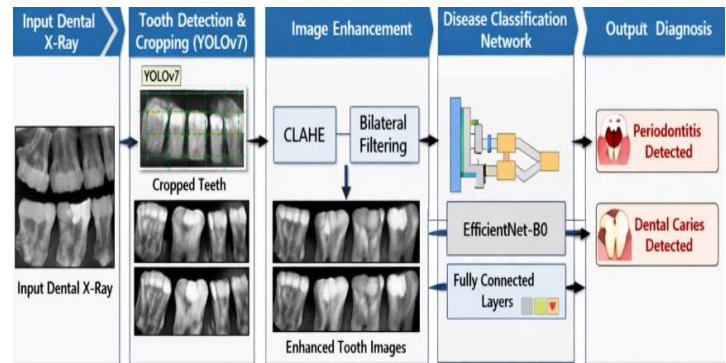
	Dataset	Normal	Periodontitis	Dental Caries
Original	Training and Validation	700	1000	400
	Testing	100	50	50
Augmentation	Training and Validation	3300	1000	1600
	Testing	300	150	150
Total	Training	3200	1600	1600
	Validation	800	400	400
	Testing	400	200	200

IV. HARDWARE AND SOFTWARE

The hardware platform consists of a 12th Gen Intel Core i5-12400 CPU, an NVIDIA GeForce RTX 3070 GPU, and 32 GB DDR4 DRAM with 3200 MHz. On the software side, the platform includes Python version 3.7.16, Tensor flow version 2.9.1, and PyTorch version 1.7.1. These specifications are employed to facilitate the implementation and evaluation of the proposed methods in our study.

V. PROPOSED METHODOLOGY

The training process for the proposed method to detect periodontitis and dental caries simultaneously. The single-tooth X-ray images are detected by the YOLOv7 algorithm and cropped from periapical X-ray images. After performing resizing and augmentation, the single-tooth X-ray images are enhanced by contrast-limited adaptive histogram equalization (CLAHE) and bilateral filtering (BF). The enhanced images are further resized as the inputs for the deep-learning CNN, which is trained using transfer learning to determine whether the single-tooth X-ray image belongs to normal tooth, periodontitis, dental caries, or both diseases of periodontitis and dental caries.



A. Data Collection

Dental X-ray images are collected from publicly available datasets or clinical dental image repositories.

B. Tooth Detection

Individual teeth are detected and extracted from periapical X-ray images using the YOLOv7 object detection model.

C. Image Preprocessing

To improve image quality and enhance features, the following preprocessing techniques are applied:

- Contrast-Limited Adaptive Histogram Equalization (CLAHE)
- Bilateral filtering for noise reduction
- Image resizing and normalization

D. Disease Classification

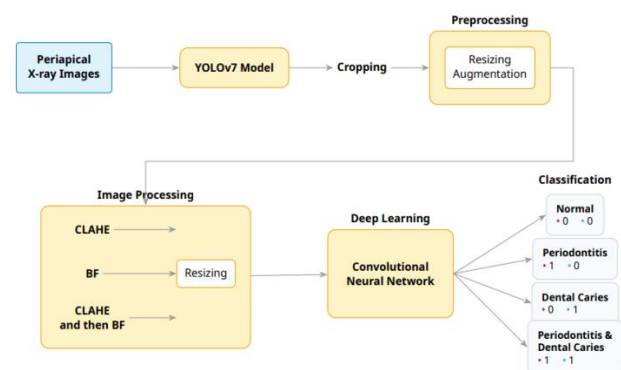
The preprocessed tooth images are fed into a CNN-based classification model using EfficientNet-B0 with transfer learning. The network outputs two labels:

- Presence of periodontitis
- Presence of dental caries

The final classification categories include:

- Healthy tooth
- Periodontitis
- Dental caries
- Both diseases

VI. FLOW DIAGRAM



VII. EXPERIMENTAL RESULTS

The proposed system is evaluated using dental X-ray datasets. The model performance is measured using several evaluation metrics:

- Accuracy
- Precision
- Recall

The results demonstrate that the deep learning model effectively detects both periodontitis and dental caries simultaneously, outperforming several baseline CNN architectures. Three CNN models Xception, MobileNetV2, and EfficientNet-B0 were compared using 10-fold cross-validation. All models used pre-trained weights from Keras through transfer learning. Among the models, EfficientNet-B0 achieved the best overall performance in detecting both Periodontitis and Dental Caries, outperforming the other CNN architectures in classification results.

model	Disease	Accuracy (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	ROC AUC (%)	PR AUC (%)	
0	Xception	Periodontitis	89.76	89.26	90.59	86.40	92.54	94.58	93.34
1	Dental_caries		88.13	86.98	83.50	91.21	93.49	90.44	NaN
2	MobileNetV2	Periodontitis	91.42	91.21	91.60	87.73	94.01	96.86	95.89
3	Dental_caries		89.03	88.25	85.32	91.87	96.31	94.76	NaN
4	EfficientNet-B0	Periodontitis	95.44	93.28	96.88	95.24	95.59	98.67	98.38
5	Dental_caries		94.94	94.15	93.30	96.08	98.31	97.55	NaN

Method/Citation	CNN Network	Accuracy (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	ROC AUC (%)	PR AUC (%)
0 [16]	GoogLeNet InceptionV3	82.00	81.00	83.00	82.7	81.40	84.50	84.50
1 Proposed method	EfficientNet-B0	94.94	94.15	95.47	93.3	96.08	98.31	98.31

8. CONCLUSION

The proposed system presents an effective deep learning-based framework for automatic detection of dental diseases from periapical X-ray images. In this workflow, the YOLOv7 model is first used to detect and crop individual teeth from the input X-ray images, ensuring that only the relevant dental regions are analyzed.

After cropping, preprocessing techniques such as resizing and augmentation are applied to standardize the images and increase dataset diversity. Image enhancement methods including Contrast Limited Adaptive Histogram Equalization and Bilateral Filtering are then used to

improve image contrast and reduce noise while preserving important edge details.

The enhanced images are subsequently fed into a Convolutional Neural Network (CNN) for disease classification. The model is capable of identifying four conditions:

- Normal teeth
- Periodontitis
- Dental caries
- Combined periodontitis and dental caries

Experimental results demonstrate that the integration of object detection, image enhancement, and deep learning classification improves diagnostic performance and supports accurate automated dental disease detection.

Overall, this approach can assist dentists in early diagnosis, improved clinical decision-making, and efficient screening of dental conditions, thereby contributing to better oral healthcare management. In future work, the system can be extended with larger datasets, advanced CNN architectures, and clinical deployment through web-based diagnostic platforms.

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