UNET-based Multiclass Teeth Segmentation in Panoramic Dental Radiographs

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치과 파노라마 방사선 사진에서의 UNET 기반 다중 클래스 치아 분할

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Abstract

Recent advancements in deep learning have fostered significant improvements in medical image analysis, including dental radiograph segmentation. The model is designed to accurately segment 32 teeth by distinguishing between multiple classes corresponding to different teeth classes. Enhanced by custom training techniques and optimized architecture, we use custom UNET model which integrates advanced features that increase its sensitivity to subtle variations in dental imagery. Our experiments demonstrate the model's capability to handle complex segmentation scenarios, offering substantial improvements in accuracy, precision, and Dice scores over existing methods. These enhancements allow for more detailed and reliable dental assessments, potentially leading to better diagnostic outcomes and treatment planning.

Ⅰ. Introduction

Dental radiograph analysis is crucial in modern dentistry, significantly impacting diagnostic procedures, treatment planning, and patient care management. The accuracy of interpreting these images is vital, as any inaccuracies can directly affect clinical outcomes. Traditionally, dental segmentation is performed manually, requiring extensive expertise and time, and is prone to inconsistencies due to human error and fatigue.

This paper presents an enhanced UNET architecture, a convolutional neural network (CNN) specifically designed for high-detail image segmentation tasks. The UNET model excels in medical image segmentation by capturing intricate details and maintaining spatial hierarchies through its symmetrical downscaling and upscaling paths connected by skip connections. We have adapted the UNET architecture to tackle multiclass segmentation in high-resolution dental radiographs, aiming to provide a tool that segments 32 classes of teeth and improves the speed, accuracy of dental radiography analysis, thereby making the diagnostic process more streamlined and error resistant.

Ⅱ. Method

Our method employs a deep convolutional neural network, specifically an adaptation of the UNET model, which is highly regarded for its efficacy in medical image segmentation tasks. Notably, while UNET has predominantly been utilized for binary tooth segmentation or other multi-class segmentation scenarios, our implementation extends its capabilities to encompass the segmentation of 32 distinct tooth classes and background region separately, marking a significant advancement in dental image analysis.

The network architecture adopts symmetrical downscaling and upscaling paths with skip connections to preserve spatial hierarchies, as illustrated in Fig. 1. Operating on grayscale input images with a resolution of 1024x2048 pixels post-transformations, the model segments them into 33 classes, each representing a unique tooth class. During training, we employed a cross-entropy loss function optimized using the Adam optimization algorithm. Our dataset comprised annotated dental radiographs, which were partitioned into training and testing sets, with data augmentation techniques employed to bolster generalizability.

Ⅲ. Results

The model was trained on a dataset of 500 dental radiographs and tested on a separate set of 100 images obtained from a public dataset. We computed performance metrics such as accuracy, specificity and Dice scores to assess its effectiveness. The UNET model achieved notable results, including a high specificity of 0.99, a precision of 0.89, accuracy of 0.82, and a Dice score of 0.78. These outcomes illustrate the model's proficiency in accurately delineating individual teeth, even in scenarios involving teeth with complex shapes and close proximities. Table 1 compares the performance of the adapted UNET model against other prominent segmentation architectures like FCN and DeepLabv3+.

Table 1. Qualitative Comparison

Architecture	Precision	Specificity	Accuracy	Dice Score
FCN [1]	0.75	0.97	0.70	0.58
DeepLabv3+[3]	0.80	0.98	0.74	0.66
Adapted UNET [Ours]	0.89	0.99	0.82	0.78

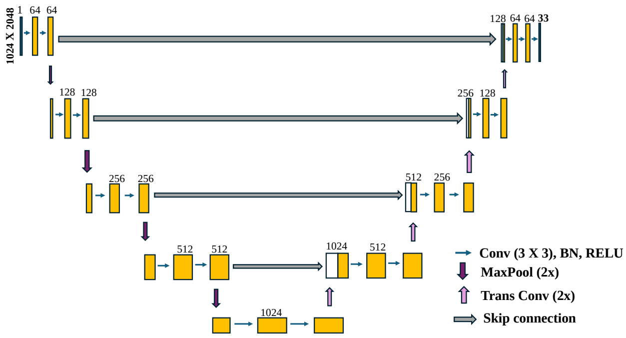

Fig. 1. Adapted UNET architecture

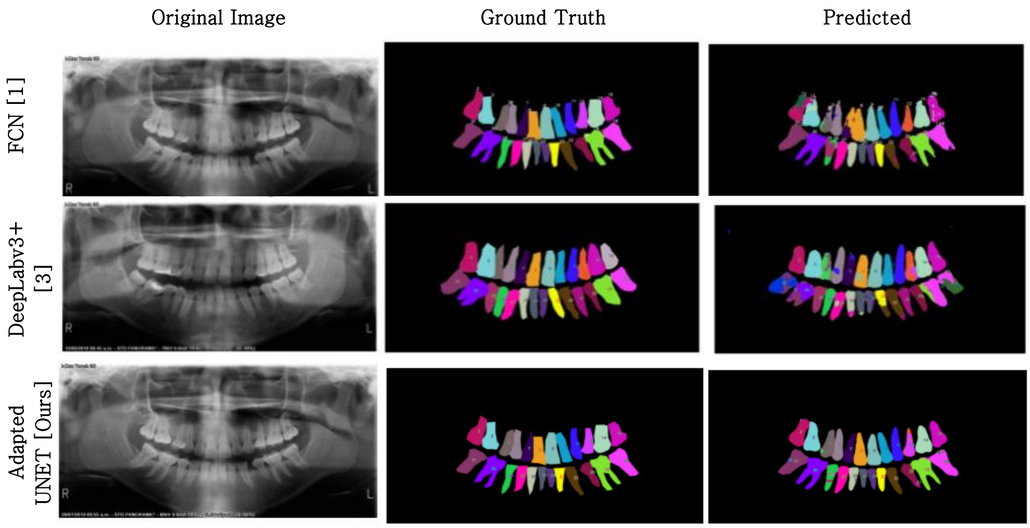

Fig. 2. Visual Comparison

The adapted model surpasses other architectures in handling detailed dental image multiclass segmentation tasks. Table 1 and Fig. 2 confirm its high specificity, precision, and accuracy, highlighting its potential for clinical dental radiography applications.

IV. Conclusion

The adapted UNET model excelled in multiclass segmentation of dental radiographs, surpassing traditional methods and advanced architectures in accuracy and efficiency. Its high specificity and accuracy demonstrate its capability in handling high-resolution images and segmenting multiple classes, highlighting its potential for clinical dental applications, particularly in diagnostics and treatment planning.

Future work will refine the model to enhance the metrics, aiming for integration into real-time diagnostic systems for improved speed and reliability. Additionally, we plan to extend its application to other medical imaging tasks, broadening its impact across healthcare.

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