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Application of Deep Learning Model in Detection of Dental Periapical Lesions

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***Abstract*—The lightweight deep learning model developed in this study shows promising results in the early detection of dental periapical lesions. By implementing the Retinex algorithm, the problems associated with inconsistent lighting and contrast in radiographic images are effectively resolved. The application of this algorithm successfully addresses the issues related to uneven illumination and varying levels of contrast in radiographs. Additionally, the incorporation of the U-Net segmentation technique significantly improves the precision of lesion detection. These findings highlight the potential of this model to assist dental practitioners in achieving more accurate and efficient diagnoses, ultimately leading to better patient outcomes.**

***Index Terms*— periapical lesions, deep learning, segmentation, Retinex, image enhancement.**

I. INTRODUCTION

Accurate and timely detection of periapical lesions is a game-changer in the field of dentistry! This is an exciting development that can revolutionize patient care and improve outcomes. Periapical lesions, as depicted in Figure 1. They are oral diseases caused by layers of bacteria or other microbes that tend to appear in the periapical area of an infected tooth. Identifying these lesions promptly and accurately is crucial for providing effective treatment and ensuring the overall well-being of patients.

Figure 1. Periapical lesion

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Neglecting to address a periapical lesion can result in serious consequences, such as tooth loss, which significantly impacts one's quality of life [1]. Dental diagnosis and the assessment of treatment success rely on imaging and radiological tests [2]. However, dental imaging encounters various challenges when it comes to detecting lesions [3]. In order to tackle these obstacles, the utilization of Retinex-based image enhancement is implemented to optimize the contrast and brightness, resulting in a more distinct and intricate depiction of dental radiographs [4], [5], [6]. This research presents an innovative method that combines Retinex-based image enhancement techniques with a lightweight deep learning (LCNN) model and the U-Net based segmentation technique. By utilizing a lightweight architecture, computational efficiency is maintained without compromising accuracy [7], while U-Net excels in segmentation tasks [8]. The incorporation of the U-Net algorithm in the segmentation of the periapical region proves to be a valuable approach that enhances the efficiency of dental image analysis. This contribution ultimately leads to improved clinical decision-making. However, it is crucial to highlight that the outcomes generated by this model should not be seen as a replacement for the expert judgment of a trained professional [9], [10]. Additionally, it is crucial to recognize that in the European Union and many other nations, there are legal provisions that govern the use of algorithms in medical settings [11]. These regulations are in place to protect the fundamental rights and welfare of patients, which could impact the adoption of this technology.

II. Related Work

Researchers have extensively studied different radiographic techniques and scoring systems to improve the precision and dependability of diagnosing apical periodontitis. Şeker et al. [12] conducted a comparison of high-definition ultrasound (US), cone-beam computed tomography (CBCT), and periapical radiography to determine their effectiveness. Patel et al. [13], [14] conducted thorough analyses on the detection and monitoring of apical lesions. Bornstein et al. [15] compared radiographic images of periapical lesions using restricted CBCT to examine anatomical changes. Sakhdari et al. [16] investigated the efficacy of CBCT in detecting periapical bone lesions. Saidi et al. [17] conducted a long-term review study comparing CBCT with periapical radiography for endodontically treated teeth. Estrela et al. [18] compared CBCT, panoramic radiography, and periapical radiography for identifying apical periodontitis. Additionally, other technologies such as digital radiography and computer-aided diagnosis (CAD) have also been utilized. Numerous researchers have made valuable contributions to the advancement of research in this field. Dutra et al. [19], Low et al. [20], Kazemipoor et al. [21], Sebring et al. [22], Molander et al. [23], Wülk et al. [24], Meusburger et al. [25], Tibúrcio-Machado et al. [26], Freire et al. [27], Li et al. [28], Foros et al. [29], and Cotti and Schirru [30] have all played a significant role in pushing the boundaries of knowledge in this area. Additionally, Latke and Narwade [31] have identified the problems in endodontic procedure and proposed an advanced AI-based method to refine the dental procedures like root canal.

III. Proposed System

In the present investigation, the input dataset was collected from practicing endodotists, which comprised of 500+ periapical radiographic images. Before feeding to the present model, the raw images were enhanced using Retinex based image enhancer and high dynamic range (HDR) algorithm. Data augmentation technique was used to enrich the diversity and robustness of the images. Enhanced and augmented images constituted ideal training and testing set in 80:20 proportions for training the lightweight CNN model to detect and classify periapical lesions.

The U-Net model was employed to achieve a high level of correctness in generating intricate masks, effectively capturing the complex outlines and margins of the board areas. The diagram illustrating the comprehensive structure of the system can be found in Figure 2 below;

IV. Results and Discussion

An impressive enhancement in the peak signal-to-noise ratio (PSNR) was observed when comparing the baseline images without Retinex and HDR techniques to the improved ones, as shown in Table 1 below.

TABLE I. COMPARISON OF PSNR VALUE

Image	PSNR
Original vs. Retinex	27.89
Original vs. HDR	28.94

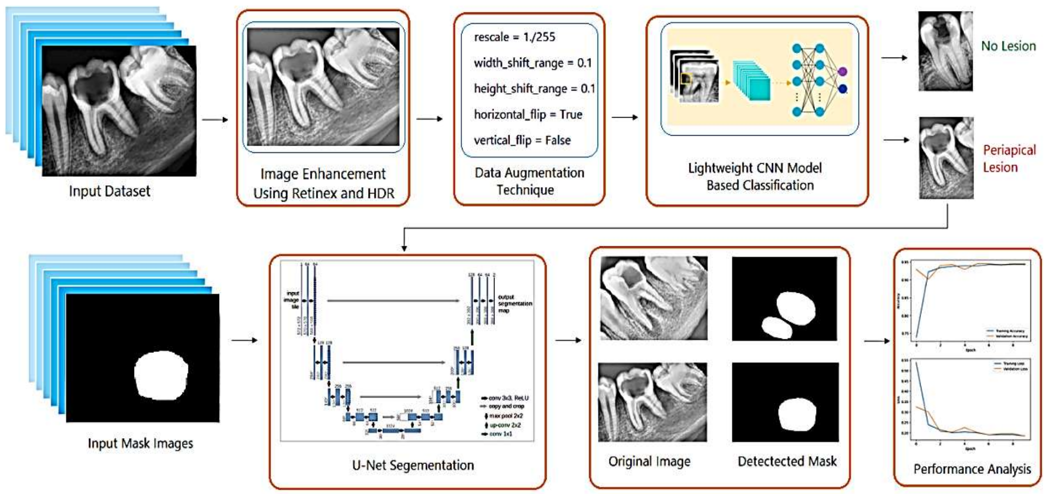

Figure 2. System Architecture

The comparison of the present model's performance with traditional CNN architectures is illustrated in Table 2 and in Figure 3 which shows an accuracy of 95.8% achieved using present model. Thus, the present model is observed to return accurate results, while reducing the computational efforts.

TABLE II. COMPARISON OF PERFORMANCE METRICS IF CNN VS. LCNN

Model	Accuracy	Precision	Recall	F1-Score
CNN	94.2	94.8	93.8	94.7
Lightweight CNN	95.8	96.1	95.2	95.5

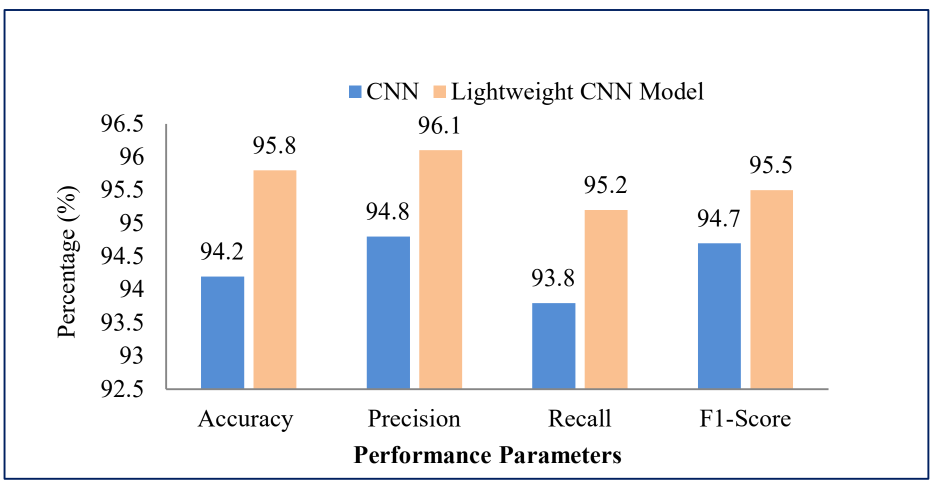

Figure 3.Performance Parameters Comparison Graph

Figure 4 and Figure 5 show the training and validation accuracy and loss for both the models. Figure 6 below depicts the confusion matrix for the present model; The depiction of the disparity in accuracy and loss when utilizing the U-Net segmentation model for both training and testing data is presented in Figure 7 below; In Figure 8-(a), the original input image that underwent enhancement using Retinex and HDR is displayed. Figure 8-(b) showcases the provided mask, which depicts physically marked areas of attention inside the input image. Lastly, Figure 8-(c) exhibits the expected covering produced by the segmentation model, emphasizing the targeted area.

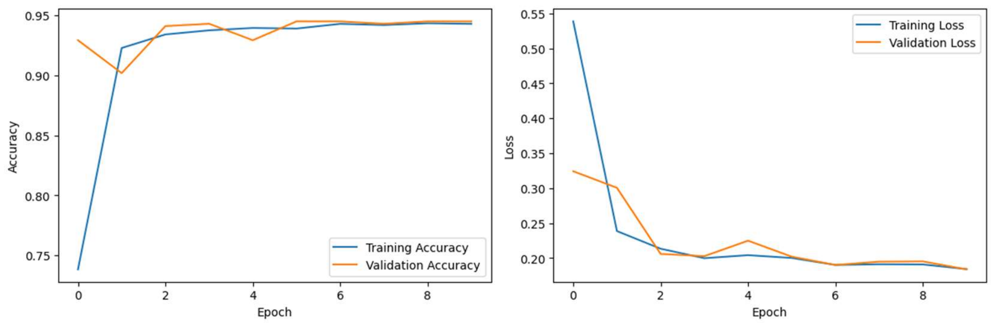

Figure 4. Traditional (CNN) Model accuracy and loss comparison graphs

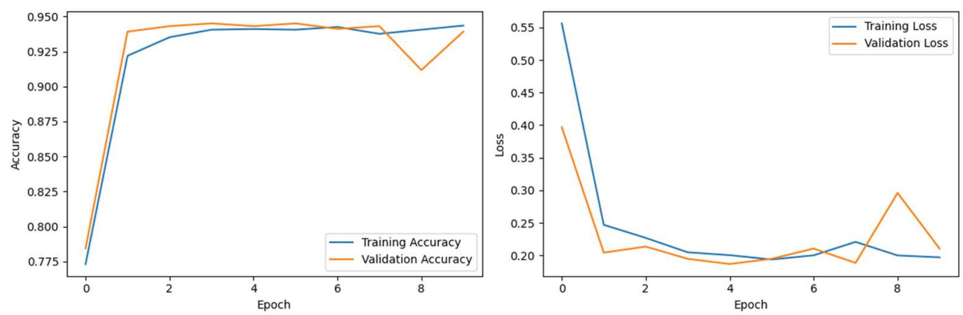

Figure 5. Present (LCNN) Model accuracy and loss comparison graphs

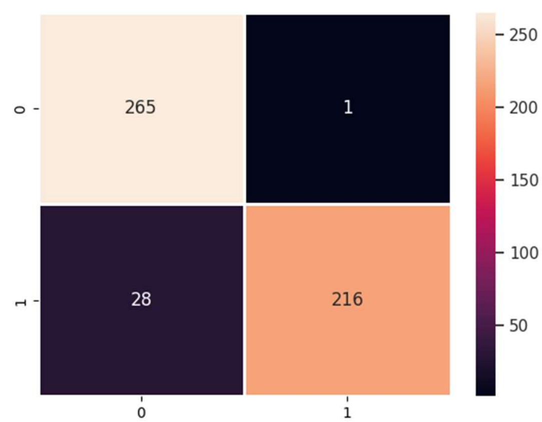

Figure 6. Confusion matrix

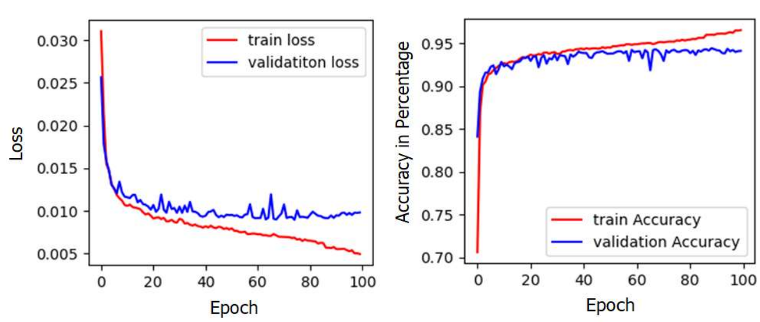

Figure 7. Training and Validation Loss and Accuracy of U-Net Technique

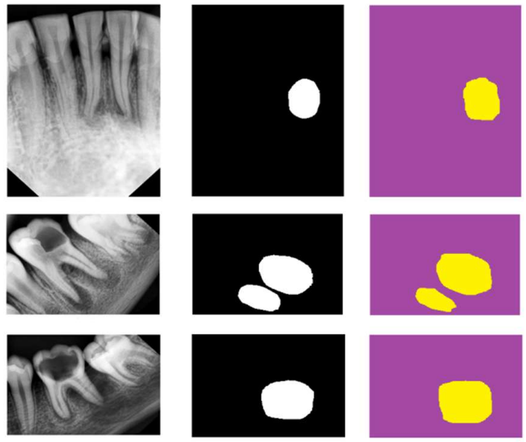

Figure 8. Original image, the truth mask and the predicted mask

V. CONCLUSION

This study introduces a novel approach to overcoming challenges in identifying dental periapical lesions. By incorporating Retinex-based techniques, the issues of inconsistent lighting and contrast in radiographic images are effectively addressed. The use of a LCNN model allows for accurate finding and sorting of these lesions, showcasing efficient feature extraction. The U-Net segmentation technique further enhances the isolation and highlighting of specific areas in X-ray images. The model demonstrates high accuracy, with a accuracy of 0.961, recall of 0.952, and F1 score of 0.955. Comparisons with expert diagnoses further validate the effectiveness of the model. Overall, this research offers a promising solution for improving the identification and diagnosis of dental periapical lesions.

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