

A New Approach towards Detection of Periapical Lesions using Artificial Intelligence

Vaishali Latke¹ and Vaibhav Narawade²

¹⁻²Dept of Computer Engineering, Ramrao Adik Institute of Technology, Nerul, India
Email: vaishali.latke@pccoer.in, vaibhav.narawade@rait.ac.in

Abstract—Dentists detect abnormalities in tooth with dental X-ray imaging techniques. Due to a wide variation in human tooth shapes, sizes, and abnormalities, processing a dental image is difficult and time-consuming task. Evaluation of dental anomalies using manual observation and inference remains to be a challenge till date. In order to make perfect analysis and formulate suitable treatment plan, automation in the field of dental picture segmentation and evaluation is crucially important. On reviewing a few approaches in the existing literature, a hybrid model has been proposed to detect Periapical lesions from an input X-ray image. Research has been segregated into three primary areas viz. Image Processing, Machine Learning and Deep Learning methodologies. The model has been tested on several X-ray images and accuracy of the same has been ascertained. Future research scope towards refinement of endodontic treatment has been proposed.

Index Terms— Segmentation of dental X-rays, deep learning, convolutional neural networks, machine learning.

I. INTRODUCTION

Across the globe about 36% of the population suffers from Dental caries disease in their enduring teeth. Most studies have found that people who are socially and economically disadvantaged, are illiterate or have little education are more likely to develop dental caries. In India, tooth decay is one of the most prevalent dental issues. Over 30% of male adults in India and over 34% of female adults in India have dental decay. When persons of all ages are included, including teenagers and seniors, 49 percent of Indians have dental cavities. This is far higher than in other countries, and a fundamental cause for this is a lack of oral hygiene and periodic dental examinations.

Since the 1960s, various preservation and reinstallation procedures have been successfully applied and used to improve the treatment of caries. However, diagnostic approaches for detecting caries have made little progress due to the wide range of tooth anatomy. Dental X-ray imaging (DXRI) has been adopted as the standard by dentists all over the world to identify irregularities in tooth structures. Dentists rely heavily on radiography image evaluation. Though the tooth anomalies may be identified from x-ray images, it calls for the consumption of time and judgment of experienced dentists. Quantum, photons, electronic and quantization noises degrade dental X-ray images. In uneven exposure, it is difficult to distinguish between tooth and bone areas. Hence, pre-processing of dental radiographs is essential to sharpen dental caries boundaries and increase the contrast between image background and tooth. Due to the inherent limitations of visual inspection and complexities in tooth structure, human observation may miss a sizable percentage of caries. Computer-assisted medical

diagnostics rely heavily on the human eye's ability to interpret subtle differences between objects, making segmentation algorithms invaluable. In recent years, researchers' attention has been increasingly focused upon DL and ML approaches in DXRI analysis.

II. RELATED WORK

Anita Aminoshariae et al [1] have highlighted A.I.'s potential to imitate human intellect to conduct forecast and complicated decision-making in well-being care, particularly in endodontics and predicted that A.I. can enhance diagnosis and therapy, increasing the achievement rate of endodontic handling. Frank C. Setzer et al [2] have split all photographs repeatedly based on five-fold cross-validation into a working set and an authentication set using Deep Learning segmentation (DLS) and the results have been averaged. The precision of dichotomized cut detection sensitivity, specificity, positive analytical value, negative analytical value, and voxel-matching precision for each of the five labels has been analyzed.

Teruhiko Hiraiwa et al [3] have assessed the diagnostic efficiency of a deep learning system for root morphology categorization of early mandibular molars on panoramic radiography. For benchmarking, [full-form] CBCT has been used. Homes Ekert et al [4] have used panoramic dental radiographs CNN for finding apical lesions on. Grid search has been used to fine-tune the hyper parameters. Validation has been accomplished by repeatedly shifting the groups. Metrics include the area under the curve (AUC), sensitivity, specificity, and positive/negative analytical results. Shivani Mallishery et al [5] have presented a machine-learning algorithm to predict the complexities of the case on the basis of the American Association of Endodontists (AAE) Endodontic Case Difficulty Assessment Form. On diagnosing 500 probable root canal patients, it was observed that the machine learning algorithm achieves a sensitivity of 94.96%. Man Hung Maren et al [6] offer research that aims to use machine learning techniques in conjunction with artificial intelligence to identify the most significant factors for categorizing the incidence and nonappearance of root caries and to assess the representation's performance. Machine learning algorithms developed perform accurately suggesting that dentists and pathologists should adopt proposed algorithms for the early detection of root caries for elderly patients to attain precision in diagnosis. F. Schwendicke et al [7] have discussed the applications, limits, and potential imminent of AI-based dental diagnosis, treatment schedule, and conduct, including image processing, forecast making, record keeping, and dental study and discoveries. It is anticipated that AI-based apps would simplify treatment by relieving the dental staff of tedious regular duties, improving health for a larger population at a cheaper cost and ultimately enabling customized, predictive, preventative, and participative dentistry. Noteworthy contributions have also come from Kailai Zhanga et al [8], Clare Rainey et al [9], Yang Qu et al. [10], Ruben Pauwels [11], Wei Zhan et al [12], Romany F. Mansour et al [13], V. Geetha et al [14], Hu Chen et al [15], F. Casalegno et al. [16], Paras Tripathi et al. [17], Lavanya L et al. [18], Vivek K Verma et al. [19], Jae-Hong Lee et al. [20], Laura A. Zanella-Calzada et al. [21], Jae-Hong Lee et al. [22], Anupama Kalappanavar et al. [23], Sharanjit Kaur et al. [24], Sunali S Khanna et al. [25] and Ramzi Ben Ali et al. [26] among others.

In the present work, it is proposed to explore an AI approach for automation of the analysis of dental radiographs to improve endodontic procedures to help the general practitioner dentist, endodontist and relevant pathology laboratories to achieve more accuracy in diagnosis and procedures.

III. PROBLEM DOMAIN

The usual treatments adopted for dental caries are fluoride, filling of tooth, root canal and tooth extraction, the root canal being the most effective and retrofitting treatment. A root canal is the standard procedure prescribed in the dental treatment of caries. Root canal treatment eliminates bacteria from the infected tooth, stops bacterial infection of the tooth again and natural tooth is saved. During root canal procedure, the infected pulp from the tooth is removed and the tooth is carefully cleaned and disinfected from inside. Then it is filled with bio-compatible material and sealed. However, there are several complexities in the anatomy of the teeth, viz. narrow canals, long roots, curve canals, multi-curvature, bifurcated canals, abnormal anatomy and calcified roots.

The conventional DXRI has several shortcomings. The two- dimensional x-ray image has no prescribing or statistical output. Dentist judgment involves a human element based on the trial-and-error method. Dentist's diagnosis and prescription are not universal and vary from dentist to dentist. Some teeth, mainly 3rd Molar (wisdom teeth) may have additional roots not visible in x-ray images culminating in to failure of root canal procedure, leading to a repeat procedure or tooth extraction. X-ray images cannot depict the exact canal profile, which may lead to misjudging of the length of the canal, failing the treatment. Further, the traditional method cannot predict the success probability of repeat root canal procedures.

All these lacunas may be rectified using AI. Various strategies of AI, including - Machine Learning and Neural Networks, play an essential role in analyzing complex medical data to get more accurate results than its counterpart, i.e., human intelligence. Thus, it is possible to develop an algorithm wherein the X-ray images will be processed, giving exhaustive output with diagnosis and prognosis.

An image's quality is heavily dependent on its noise, artifact and visual contrast levels. Different aspects, such as the sensor's dynamic range, the lighting, the amount of alteration and the artifact itself, all contribute to the final image quality. Images captured with poor resolution can be improved by pre-processing techniques by adjusting the spatial resolution and performing local modifications. Grayscale, noisy and low-resolution X-ray images are commonly observed in practice. This leads to low levels of visual contrast and a minimal sense of border depiction. Characteristics extraction from these X-rays is challenging because of the lack of resolution and poor image quality. Some contrast augmentation methods can greatly improve image quality. Therefore, segmentation and feature extraction from such images can be carried out more precisely and easily. Because of this, contrast stretching has been broadly used to improve the quality of digital X-rays. By taking advantage of local homogeneity, adaptive local contrast stretching eliminates the issue of excessive or insufficient amplification. The histogram equalization (HE) technique is often used to enhance image contrast. Although HE's artificial picture effects detract from its utility for scientific images like satellite shots, CT scans and X-rays, the technique is beneficial for expanding the dynamic range of an image's histogram. One problem with the method is that it is not selective. It can make the ambient noise more noticeable while dulling the other redeeming qualities.

However, filters applied to medical photographs help get rid of the noise. Artifacts of noise such as Gaussian noise, Poisson noise and quantum noise are frequently seen in X-rays and CT scans, especially when the image is captured at a low enough resolution. The test's accuracy is maximized with the use of noise-free images, which produce the greatest results. Reducing one source of background noise may disrupt another. Recent studies have employed a wide range of filtering procedures, but the two most popular—and effective—are the Gaussian filter and the median filter.

Recent years have seen a rapid increase in the sophistication of both ML and AI. Computer-aided diagnosis and treatment, X-ray picture interpretation, image-guided therapy, infected area detection and information demonstration are all areas where ML and AI algorithms have made major contributions to dental imaging. Through the use of ML and AI, doctors are able to better diagnose and forecast the likelihood of sickness.

As a result of AI, ML and DL, medical imaging professionals can now discover anomalies and make diagnoses in a fraction of the time it used to take. Artificial neural networks (ANNs) have been improved by DL, which utilizes more layers to make more precise predictions.

Self-learning back-propagation algorithms have been developed as part of the field of deep learning, and these methods have been shown to enhance data outcomes and computational efficiency in small, incremental steps. The topic of deep learning is expanding rapidly and it has many uses in the medical field. For accurate results in ML and DL applications, having access to high-quality datasets is essential. Integrating different datasets and employing DL models to boost accuracy parameters is made easier with the use of information fusion. The prediction performance of deep learning algorithms in medical imaging much surpasses that of humans, making computer-assisted diagnosis a more collaborative process.

IV. SOLUTION METHODOLOGY

The present study employs a variety of image processing algorithms to explore the architecture of teeth, cavities and anomalies to aid dentists in making the correct diagnosis. It incorporates numerous pre-processing, separation and classification techniques to provide an automated dental documentation scheme that makes clinicians' job more reachable, transparent and efficient. A dataset of 172 patients was collected from practitioners, of which, 80% was used to train the present model and remaining was used to test the model.

An uploaded image is pre-processed in the present model through two techniques; viz. resizing (Fig. 1), augmentation (Fig. 2) and gray-scaling (Fig. 3). Resizing is essential to bring uniformity in the X-ray images so that identification of dental anomalies becomes efficient.

After resizing the image Data Augmentation is applied to the input image, which involves rotation of the image through different perspectives to identify the lesions efficiently.

After data augmentation, comes the part of Feature Extraction, where important features are extracted from the input image by converting the uploaded image into Grayscale. This helps in highlighting the important region of image required for the model to detect smoothly the Periapical lesion.

After the Feature Extraction, comes the part of lesion detection, where the model is trained on 7 different classifiers which are Support Vector Machine (SVM), K-Nearest Neighbour (KNN), Artificial Neural Network

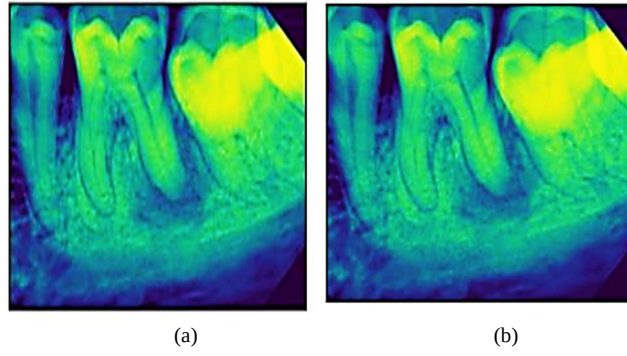


Figure 1. Resizing of Image (a) Original size (300, 1), (b) Edited size (224, 1)

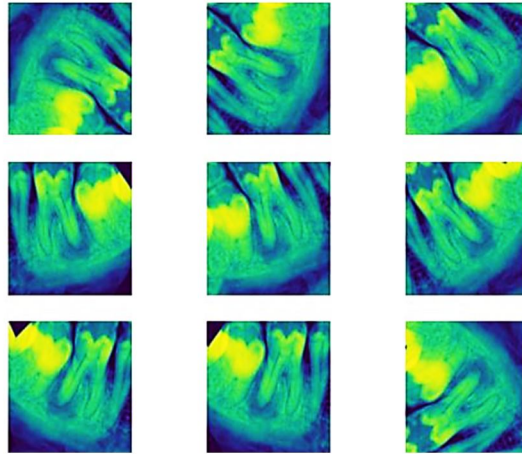


Figure 2. Data augmentation

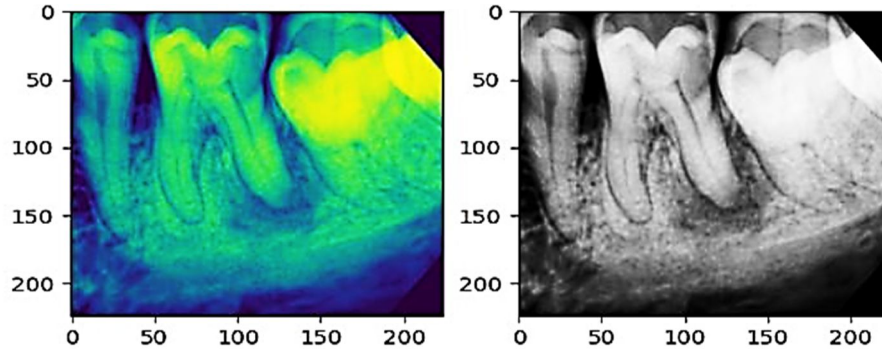


Figure 3. Gray-scaling of Image

(ANN), Decision Tree (DT), Convolutional Neural Network (CNN) and present approach viz. Hybrid (SVM+ANN). These classifiers are further trained to display the results metrics for parameters like precision, recall, F1 score, micro-average and weighted average along with graphical visualization. These parameters have been evaluated using the equations;

$$\text{precision} = \frac{TP}{TP + FP} \quad (1)$$

$$\text{recall} = \frac{TP}{TP + FN} \quad (2)$$

$$F1_score = 2 \times \frac{\text{precision} \times \text{recall}}{\text{precision} + \text{recall}} \quad (3)$$

$$\text{accuracy} = \frac{TP + TN}{TP + FN + TN + FP} \quad (4)$$

Table I gives results obtained for Periapical lesion detection using present model and Table II gives comparison of the accuracy obtained by present model with the existing models.

TABLE I. PERFORMANCE METRIC OF PRESENT MODEL

Parameter	Lesion	Normal	Accuracy	Macro average	Weighted average
Precision	1.0	0.25	0.90	0.62	0.97
Recall	0.90	1.0	0.90	0.95	0.90
F1-score	0.94	0.4	0.90	0.67	0.93
Support	31.0	1.0	0.90	32.0	32.0

TABLE II. COMPARISON OF ACCURACY OBTAINED BY PRESENT MODEL WITH EXISTING MODELS

Model	Accuracy
KNN	100.00
DT	100.00
SVM	99.61
ANN	99.56
Present (Hybrid)	95.85
CNN	16.09

V. RESULTS & DISCUSSION

The present research focuses upon detection of Periapical lesions using a hybrid model comprising of SVM and ANN. The fundamental approach in pre-processing is CNN. In pre-processing, resizing and augmentation of Periapical X-ray has been done. X-ray images usually vary in size and hence before inputting to CNN, resizing is essential for giving uniformity to achieve efficiency in the analysis. 140 X-ray images were resized in the present research, without distortion in original features. Fig. 1 – (a), (b) show an X-ray image in size (300, 1), which is resized to (224, 1). After resizing, the image was rotated through various angles under augmentation process as shown in Fig. 2. In the feature extraction, the black and white image was converted into grayscale image (Fig. 3). The present algorithm received grayscale image as the input, which on processing gave the desired output, which consists of a clear positive or negative indication of presence of lesions.

Table II shows comparison of accuracy of the present algorithm with the existing ones. Through extraction of only one feature so far, the model has performed very well, giving an accuracy of 95.85%, which will improve with exhaustive image processing feature extractions.

VI. CONCLUSION

Dental caries is one of the most prevalent and disastrous diseases in dentistry. The traditional methods involving observation of x-ray images and human judgment lead to failure due to lack of adequate and accurate data. The recent advances in A.I. have been a help in generic dental disease diagnosis. The present work focuses on endodontic treatment and speaks about partial development of a new hybrid model that enhances image interpretation precision. Periapical lesion detection has been carried out by a dataset input of more than 170 patients' intra-oral Periapical radiographic images. On pre-processing through resizing, augmentation and gray-scaling, the modified image was conveyed as input to the present hybrid model. The model detected the anomalies with an accuracy of 95.85%. It is proposed to develop the model further for refinement in endodontic treatment including identification of various abnormalities, root-fractures, working length measurements, repeat root-canal success rate, etc.

REFERENCES

- [1] A Aminoshariae, J Kulild and V Nagendrababu, "Artificial Intelligence in Endodontics: Current Applications and Future Directions", Journal of Endodontics, vol 47, Issue 9, Sept 2021, Elsevier. DOI: <https://doi.org/10.1016/j.joen.2021.06.003>.
- [2] F Setzer, K Shi, Z Zhang, H Yan, H Yoon, M Mupparapu, and J Li, "Artificial Intelligence for the Computer-aided Detection of Periapical Lesions in Cone beam Computed Tomographic Images", Journal of Endodontics, vol 46, Issue 7, July 2020, Elsevier. DOI: <https://doi.org/10.1016/j.joen.2020.03.025>
- [3] T Hiraiwa, Y Arij, M Fukuda, Y Kise, K Nakata, A Katsumata, H Fujita and E Arij, "A deep-learning artificial intelligence system for assessment of root morphology of the mandibular first molar on panoramic radiography", DentomaxillofacialRadiology, Published by the British Institute of Radiology, Vol 48, Issue 3, March 2019. DOI: <https://doi.org/10.1259/dmfr.20180218>.
- [4] H Ekert, J Krois, L Meinhold, K Elhennawy, R Emara, T Golla, and F Schwendicke, "Deep Learning for the Radiographic Detection of Apical Lesions", homasEkert, Joachim Krois, Leonie Meinhold, Karim Elhennawy, RamyEmara, Tatiana Golla, and Falk Schwendicke, Journal of Endodontics, Vol 45, Issue 7, June 2019. DOI: [10.1016/j.joen.2019.03.016](https://doi.org/10.1016/j.joen.2019.03.016)
- [5] S Mallishery, P Chhatpar, K Banga, T Shah, & P Gupta, "The precision of case difficulty and referral decisions: an innovative automated approach", J-Global, vol 24, Issue 6, ISSN 1432-6981, 2020.
- [6] M Hung, M Voss, M Rosales, "Application of machine learning for diagnostic prediction of root caries", Gerodontology. 2019; 36: 395– 404. DOI: <https://doi.org/10.1111/ger.12432>
- [7] F. Schwendicke, W. Samek, and J. Krois, "Artificial Intelligence in Dentistry: Chances and Challenges", Journal of Dental Research 2020, DOI: <https://doi.org/10.1177%2F0022034520915714>
- [8] K Zhang, Ji Wua, Hu Chenb, P Lyu, "An effective teeth recognition method using label tree with cascade network structure", Computerized Medical Imaging and Graphics, Sept 2018. DOI: [10.1016/j.compmedimag.2018.07.001](https://doi.org/10.1016/j.compmedimag.2018.07.001)
- [9] C Rainey, J McConnell, C Hughes, R Bond, S McFadde, "Artificial intelligence for diagnosis of fractures on plain radiographs: A scoping review of current literature", Intelligence-Based Medicine (2021), Vol 5, Elsevier, DOI: <https://doi.org/10.1016/j.ibmed.2021.100033>
- [10] Y Qu, Z Lin, Z Yang, H Lin, X Huang, L Gu, "Machine learning models for prognosis prediction in endodontic microsurgery", Journal of Dentistry, vol 18, March 2022, Elsevier, DOI: <https://doi.org/10.1016/j.jdent.2022.103947>
- [11] Zhang, W., Li, J., Li, ZB. "Predicting postoperative facial swelling following impacted mandibular third molars extraction by using artificial neural networks evaluation", Sci Rep 8, 12281 (2018). DOI: <https://doi.org/10.1038/s41598-018-29934-1>
- [12] R Pauwels, "A brief introduction to concepts and applications of artificial intelligence in dental imaging", *Oral Radiology*, vol 37, pp. 153–160 (2021). DOI: <https://doi.org/10.1007/s11282-020-00468-5>
- [13] Romany, F Mansour, A Al-Marghilnai and Z Hagas, "Use of artificial intelligence techniques to determine dental caries: A systematic review", International Journal of Neural Networks and Advanced Applications, Vol 6, 2019
- [14] V Geetha and K Aprameya, "Dental Caries Diagnosis in X-ray Images using KNN Classifier", Indian Journal of Science and Technology, Vol 12(4). DOI: [10.17485/ijst/2019/v12i4/139880](https://doi.org/10.17485/ijst/2019/v12i4/139880), January 2019.
- [15] Hu Chen, K Zhang, PeijunLyu, Hong Li, Ludan Zhang, Ji Wu & Chin-Hui Lee, "A deep learning approach to automatic teeth detection and numbering based on object detection in dental periapical films", (2019). DOI: <https://doi.org/10.1038/s41598-019-40414-y>
- [16] F. Casalegno, T. Newton, R. Daher, M. Abdelaziz, A. Lodi-Rizzini, F. Schürmann¹, I. Krejci², and H. Markram, "Caries Detection with Near-Infrared Transillumination Using Deep Learning", Journal of Dental Research 2019.
- [17] P Tripathi, C Malathy, M Prabhakaran, "Genetic Algorithms Based Approach for Dental caries Detection using Back Propagation Neural Network", IJRTE 2019.
- [18] L Lavanya, J Chandra, "Oral Cancer Analysis Using Machine Learning Techniques", International Journal of Engineering Research and Technology 2019.
- [19] V Verma, T Jain, H Kumar, "Machine Learning Perspectives for Dental Imaging", (IJITEE) 2019.

- [20] J Lee, D Kim, S Jeong, S Choi, "Detection and diagnosis of dental caries using a deep learning-based convolutional neural network algorithm", 2018 Elsevier Ltd.
- [21] A Laura, Z Calzada, C Galván-Tejada, N Chávez-Lamas, J Rivas-Gutierrez, R Magallanes-Quintanar, J Celaya-Padilla, J Galván-Tejada and H Gamboa-Rosales, "Deep Artificial Neural Networks for the Diagnostic of Caries Using Socioeconomic and Nutritional Features as Determinants: Data from NHANES 2013–2014", *Bioengineering* 2018, vol 5, Doi:10.3390/bioengineering5020047.
- [22] J Lee, D Kim, S Jeong, S Choi, "Diagnosis and prediction of periodontally compromised teeth using a deep learning-based convolutional neural network algorithm", *J Periodontal Implant Sci.* Apr 2018, vol 48(2), pp.114-123.
- [23] A Kalappanavar, S. Sneha, R Annigeri, "Artificial intelligence: A dentist's perspective", *Journal of Medicine, Radiology, Pathology & Surgery* (2018).
- [24] S Kaur, N Kaur, "Automatic Approach for Detection of Abnormality within MRI Dental Images Using Gaussian Filtering and SVM Hybridization", *IJSRCSEIT* 2018.
- [25] S Khanna ,P Dhaimade, "Artificial Intelligence: Transforming Dentistry Today", *Indian Journal of Basic and Applied Medical Research*; June 2017.
- [26] R Ali, R Ejwali and M Zaied, "Detection and Classification of Dental Caries in X-ray Images Using Deep Neural Networks", *ICSEA 2016: The Eleventh International Conference on Software Engineering Advances*.
- [27] J. Premkumar, B Janney, J Nanda, S Divakaran, L Pavithra, "Detection of Caries in Dental X Ray Images using Multiclass SVM", *Pharm. Sci. & Res.* vol. 11(9), 2019.