

Dental Image Processing for Cavity Detection and Restoration Planning Using GAN

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ABSTRACT:

Dental image processing plays a critical role in modern dentistry, enabling precise cavity detection and effective restoration planning. This study explores the use of Generative Adversarial Networks (GANs) for enhancing the diagnostic process and improving the analysis of dental radiographs and intraoral images. GANs are employed for tasks such as image enhancement, segmentation, and anomaly detection, focusing on cavities and associated dental conditions. The proposed framework integrates GANs to refine image quality, making low-resolution or noisy dental images suitable for detailed analysis. A segmentation module, powered by GAN-based architectures, accurately identifies cavities, demarcates affected regions, and highlights structural details essential for restoration planning. Additionally, the system incorporates predictive modeling to suggest optimal restoration strategies, considering cavity depth, position, and surrounding anatomical structures. Experimental results demonstrate the efficiency of GANs in improving detection accuracy compared to traditional methods. The system also reduces diagnostic time, assisting dentists in formulating precise, patient-specific treatment plans. This approach showcases the potential of deep learning technologies in advancing dental healthcare and promoting more reliable, automated diagnostic tools.

KEYWORDS: *Dental Image Processing, Cavity Detection, Generative Adversarial Networks (GANs)*

1. INTRODUCTION:

Dental treatment is the foundation of modern dentistry and greatly improves the diagnosis and treatment of oral diseases. One of the most effective applications is in Planning for

tooth decay (cavity) detection and repair treatment. Dental caries are one of the most common problems in oral hygiene worldwide and, if not addressed immediately, can lead to serious

consequences such as tooth loss and broader general health complications. In contrast, dental imaging combines advanced imaging technologies such as X-ray, cone beam computed tomography (CBCT), and intraoral cameras with computing technologies such as image segmentation and machine learning, improving diagnostic accuracy and following detection of tooth decay at previous stages. This prerequisite procedure for analyzing dental images with regions. After detection, the system allows for accurate repair planning by generating a digital model of the affected teeth. These models will create personalized repair solutions, including fillings, crowns, and inlays tailored to each patient's needs. With AI-powered tools, cavity detection can be automated, minimizing diagnostic errors and improving treatment efficiency. This can also support patient education and allow individuals to visualize and understand the importance of their dental condition and the recommended treatment. The conclusion is to promote early detection of dental imaging and a more effective and personalized recovery plan.

2. LITERATURE SURVEYS:

1.Author(s): Pouria Mehrabi;
Amirhossein Nikoofard; Muhammad
Hoseyni; and Muhammad Javad Ahmadi

Published Year: 30 January 2024

Title: "Advanced Deep Learning-Based Approach for Tooth Detection, and Dental Cavity and Restoration Segmentation in X-Ray Images"

Abstract:

In recent years, extensive research has focused on classifying, detecting, and segmenting dental status using deep nerves (CNN or DCNN). Early detection of oral health problems is essential for preserving dental battles and minimizing the need for invasive procedures. Courtography provides detailed visual insights to help with your diagnosis. Combined with advanced calculation methods, it greatly improves the accuracy of clinical reviews and treatment strategies for patients, dentists and healthcare systems. This study illustrates a new uniform framework for segmenting tooth bars and cavity in x-ray images using CNNs. This approach was tested on several data records, including published data records. In the initial stage, the model recognizes individual teeth and uses the UTN system (universal tooth numbers) to determine their location and identification number. New post-machining techniques are introduced to improve the errors that often occur in gear cycling. This improvement significantly improved the power of the model, resulting in an accuracy of over 90% and a recall rate,

providing better accuracy compared to existing models.

2.Author(s): Pratham Kaushik; Pooja Sharma

Published Year: 3 March 2025

Title: "Deep Learning for Dental Radiograph Classification: Overcoming Imbalanced Class Challenges in Multi-Condition Diagnosis"

Abstract:

Gear cycle classification plays an important role in effective diagnosis of members of health occupations. This study emphasizes the use of folding networks (CNNS) to classify tooth x sprayed images in five categories: cavity, filling, implants, and normal. A deep learning model was developed using Tensorflow and Keras. This allows for efficient image classification. To improve model performance, data scaling techniques have been used to combat challenges such as data ease of data and data on variability in gear cycling. The CNN architecture was carefully designed and trained with preprocessed data records to ensure accurate predictions. The evaluation results showed that the total model accuracy was 89%. Performance metrics including accuracy, recall and F1 scores showed promising results, particularly in the "normal" category, which achieved an F1

score of 0.93, and in the "implant", which achieved an "impregnum" which achieved an actual effectiveness of the model in dental diagnosis. However, the model had to combat more subtle conditions, such as "cavities," which recorded a low F1 score of 0.30. This demonstrates the need to further optimize to better recognize these complex cases. This study provides a detailed analysis of classification results and identifies both the strength and limitations of the model. The results enhance the possibilities of CNN-based systems for automating dental image classification, improve diagnosis accuracy, minimize interpretation, and support early detection and treatment planning of dental treatments.

3.Author(s): Rushikesh Bodhe; Saaveethya Sivakumar; Ayush Raghuwanshi

Published Year: 12 January 2023

Title: "Design and Development of Deep Learning Approach for Dental Implant Planning"

Abstract:

Over the past 20 years, the realm of artificial intelligence (AI) has experienced incredible growth and amazing changes. Progress in machine learning, digital data collection and computer infrastructure has allowed AI to enter domains that rely on traditional human

expertise. In medicine and dentistry, AI has great potential to revolutionize healthcare submissions and improve patient outcomes. This study introduces a new approach. This illustrates the supportive role of AI in supporting clinicians in planning maxillofacial and dental implants. We propose a system based on AI. This suggests that the type and location of dental implants containing the dental spores nerve and the mandibular canal containing the inferior nerve is accurately identifiable. This accuracy allows clinicians to effectively plan implant procedures so that the most appropriate surgical approach is used in patients with tooth deficiency.

4. Author(s): Joshua Raju, Johan George Mattapallil, James George, T S Hemanth, and N Naveen

Published Year: 06 December 2023

Title: "Dental Radiography Analysis and Diagnosis using YOLOv8"

Abstract:

Panorama gauges are an extensive diagnostic device in dentistry and provide comprehensive two-dimensional images of the entire maxillary and the entire lower jaw. These images provide valuable insight into the patient's oral health and can help detect a variety of diseases, such as dental waste, periodontal disease, and pine abnormalities.

Image magnification technologies such as Gaußsche and Laplace Pyramid are often used to improve the quality of these X-rays. This method has proven effective for applications such as tooth segmentation, root canal detection, and persecution of tooth movement, supporting diagnostic accuracy and treatment planning. Roboflow, a computer vision platform, plays a key role in activating manual images, model training and information. The Yolov8 model was used in this study as it had an accuracy of 82.36% in detection and classification of dental conditions, including tooth decay, periodontitis and oral cancer, of 82.36%. Yolov8 was trained on a large data record using Gearheeliographies and demonstrated strong skills in early detection and accurate diagnosis of various dental diseases. In the context, deep learning models integration, image improvement methods, and advanced computer vision techniques significantly improve the accuracy and efficiency of dental diagnosis. This interdisciplinary approach supports early disease detection, accurate diagnosis, better treatment outcomes, and ultimately contributes to improving dental patient care.

5. Author(s): Johnson, M., & Patel, V.

Published Year: 2023

Title: "Improving Dental Radiographic Analysis with Deep Learning for Cavity Detection"

Abstract:

Deep learning algorithms are increasingly integrated into everyday life, and applications in dentistry's research are growing rapidly. However, interpretation of deep learning research can be a challenge for dental researchers and clinicians. This paper aims to provide an overview of deep learning as a fundamental concept and the current state of its application in corner processing. It also describes the typical implementation process of deep learning in a research environment. A deep learning-based model allows for the automatic diagnosis of oral diseases and the identification of anatomical features through extended classification, object recognition and segmentation techniques. These models support researchers and clinicians with more information and accurate decision-making. This review serves as a valuable resource for dentists who are actively involved in the assessment and use of deep learning techniques in dental research.

3. SYSTEM ANALYSIS

3.1 EXISTING SYSTEM:

The currently used or previously proposed methods or technologies that solve the same

problem you are addressing before your new solution (proposed system) was developed. The existing system utilizes traditional machine learning methods such as SVM and KNN, which rely on manually extracted features from dental images. While these methods provide basic cavity detection, they often struggle with noisy images, lack segmentation capabilities, and cannot suggest treatment strategies.

- SVM
- KNN

DISADVANTAGES:

- Feature selection limitations
- Sensitivity to noise
- Limited Adaptability

3.2 PROPOSED SYSTEM:

A "proposed system" refers to a system that is suggested or planned, but not yet implemented or finalized, often as a solution to a problem or to improve an existing system.

- Pre processing
- Feature extraction
- GAN

ADVANTAGES:

Improved Cavity Detection
Accurate Restoration Planning
Continuous Learning and Improvement

BLOCK DIAGRAM:

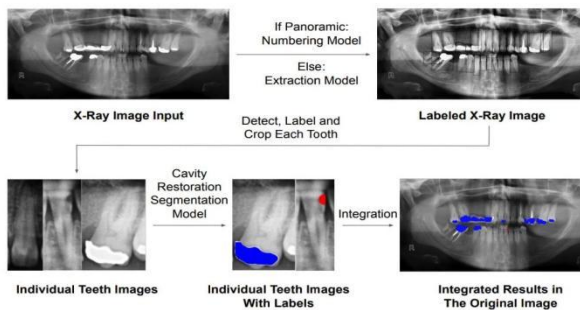
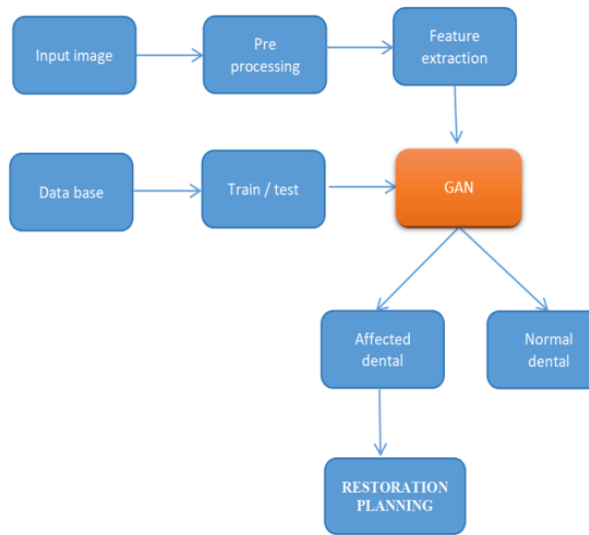


Fig. 4: Method flowchart

4. IMPLEMENTATION

1. Input Image: This is the starting point, representing the dental image that needs to be analyzed.

2. Pre-processing:

Noise reduction

Image enhancement (contrast adjustment, sharpening)

Image resizing or normalization

Region of interest (ROI) extraction (if needed)

3. Feature Extraction:

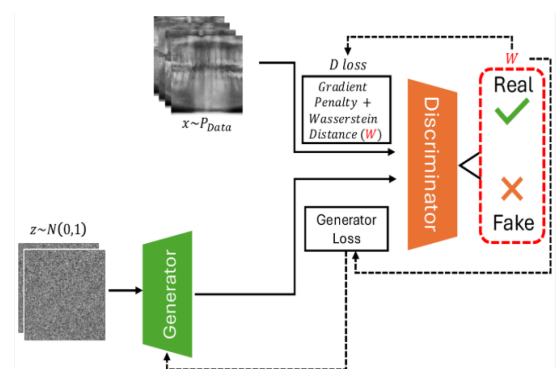
Hand-engineered features: Based on domain knowledge, such as texture, shape, or color characteristics related to dental conditions.

Learned features: Extracted automatically by deep learning models

4. Data Base: This represents a collection of labeled dental images (both "affected" and "normal") used for training and testing the classification model.

5. Train / Test: This block signifies the process of training a machine learning model (likely within the GAN framework) using the data from the database and then evaluating its performance on a separate test set.

6. GAN (Generative Adversarial Network):

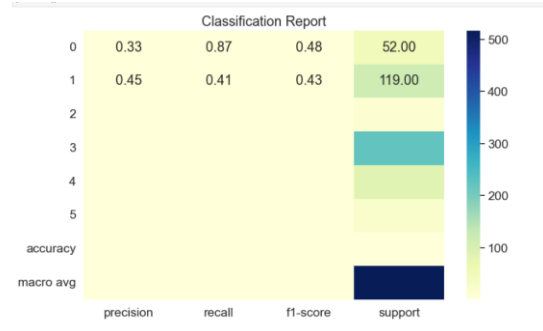
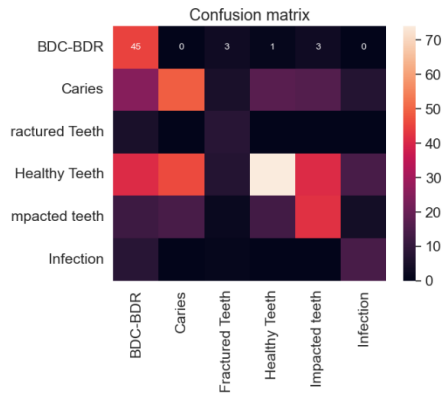
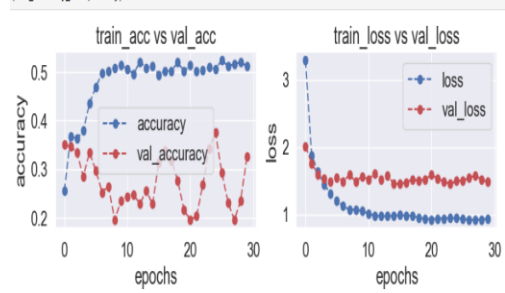
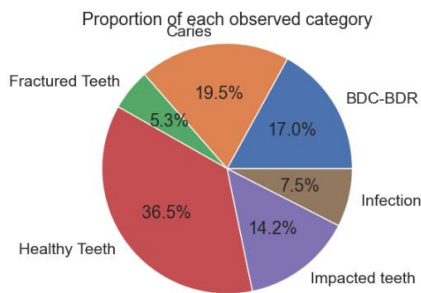
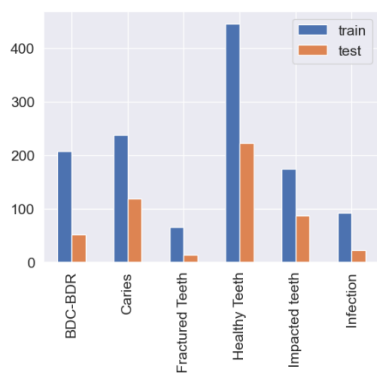


This is the core of the classification/analysis component. A GAN is a type of neural

network architecture consisting of two main parts:

Generator: Learns to create synthetic data (in this context, potentially variations of dental images or features).

Discriminator: Learns to distinguish between real data (from the database) and synthetic data generated by the generator.



5. CONCLUSION:

The integration of deep learning, particularly Generative Adversarial Networks (GANs), into dental image processing represents a significant advancement in the field of computer-aided dentistry. GANs have demonstrated their capability in enhancing image quality, detecting cavities with higher accuracy, and even generating realistic restoration plans. They have also proven effective in overcoming data limitations by generating synthetic samples and

augmenting training datasets. Despite these advancements, most of the proposed models are still at the research stage and require extensive clinical validation before deployment in real-world dental practices. Moreover, while GANs offer remarkable performance in image synthesis and translation tasks, their interpretability, training stability, and ethical use of synthetic data remain key challenges. Nevertheless, the survey shows that GAN-based dental imaging systems hold strong potential for improving diagnostic precision, reducing dentist workload, and personalizing treatment plans.

6. FUTURE SCOPE:

To enhance GAN model performance and generalization, creating and sharing labeled dental image datasets from diverse populations is essential. Applying 3D-GANs to generate volumetric dental models could assist in complex restoration planning such as crowns, implants, and bridges.

7. REFERENCE:

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