



Stage-wise Dental Caries Detection Using Deep Learning

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Abstract

Dental caries, also known as tooth decay, is one of the most common long-term oral health problems that affects people of all ages, especially children. Catching dental caries early and accurately is very important to stop serious tooth damage, pain, and expensive treatments. Usually, dentists use visual checks and X-rays to look for caries, but these methods can be subjective, take a long time, and are not always available in many areas. Recently, there have been large improvements in deep learning and computer vision, which have made it possible to use automated tools for analyzing dental images and also making accurate diagnoses. This paper introduces a step-by-step system for detecting dental caries with the help of deep learning, built as a web-based tool. The system uses a convolutional neural network with a ResNet-50 structure and adds Feature Pyramid Network (FPN) to better capture detailed features using dental images. The network is designed to not only find if there is caries but also to classify it into three different levels, such as early, moderate, and severe. To make the model more reliable as well as effective, image preprocessing and data enhancement techniques have been used. The web interface allows users and dentists to upload images to get quick diagnostic results, along with visual heatmaps that show the areas of concern. The results of the experiments show that this method has a high accuracy of about 95%, which is far better than traditional approaches. The system offers an efficient, scalable, and easy-to-use solution for early detection of dental caries, helping to promote preventive care and reduce the need for manual diagnosis by dental professionals.

Keywords: Tooth decay, Deep learning in dentistry, Dental image analysis, Convolutional neural networks (CNN), ResNet-50, Feature Pyramid Network (FPN).

1. Introduction

Oral health is important for general well-being, but dental problems are still common and often ignored around the world. Dental caries, which is also called tooth decay, is one of the most common long-term diseases that affect people of all ages, especially children and teenagers. It happens when bacteria on the teeth cause the enamel and dentin to lose minerals, leading to damage. If not treated on time, it can cause pain, infections, and even tooth loss. Even though there have been improvements in dental care, finding early signs of tooth decay is still hard in both rich and poor areas. Traditionally, dentists use visual checks and tools to examine teeth, and X-rays to diagnose dental issues. These methods are widely used but depend a lot on the dentist's skill and

their experience. Early stages of tooth decay can be hard to spot just by looking at it, since the signs might be too small or hidden under the tooth surface. X-rays are effective but may not always be available and also can be expensive, and they also expose people to radiation. So many cases of tooth decay are found too late, when the damage is already done and needs complicated treatments. The growing problem of dental caries shows the need for better and more accessible ways to detect caries. In many rural and under-served areas, there are not enough trained dentists and proper diagnostic tools. This lack of access leads to delayed treatment and also to worse oral health outcomes. Manual checks are also slow and can have differences in results, which making it



hard to plan treatment properly. These issues show us how important it is to develop tools that can help in early detection and improve accuracy. Recent progress in artificial intelligence, especially deep learning, has been very helpful in medical imaging. Deep learning models, such as convolutional neural networks, are very good at image classification, object detection, and also disease recognition. In healthcare, these models are being used to detect diseases like cancer, pneumonia as well as eye problems with accuracy that is sometimes better than human experts. These advances open the way for using AI also in dental diagnosis. Dentistry is one of the industries where deep learning could be used to study dental images and identify diseases, such as caries. These models are able to identify trends that will be overlooked in normal exams. These models can identify the caries in various sizes as well as stages using sophisticated methods such as ResNet and Feature Pyramid Networks. This assists in not only the diagnosis of the disease but also categorization into early, moderate and severe cases. The modern medical care focuses on the simplicity and accessibility. Web applications are a decent approach to the utilization of AI models, as diagnostic tools can be used anywhere through basic internet. Through deep learning model to detect caries in web app, one can provide automatic, quick, and simple caries screening. These systems may assist dentists to decide and to provide simple self-examination or distance visits to those in those places where dentists are not accessible easily. This project forms a web-based system, which applies deep learning to identify three phases of dental caries. This is based on a model which comprises a combination of a ResNet-50 network and a Feature Pyramid Network to detect, as well as to classify caries. The model is made to work with various images by image processing and enhancement of data. The system provides a deep result and visual explanation such as heatmaps to indicate the location of the caries and enhance the understanding as well. The key objective of this piece of work is to aid in early screening, avoiding dental problems by providing an automatic, precise and accessible system of locating caries. The system will be

beneficial by enhancing oral health awareness and aid dentists in decision-making, as well as minimizing the impact of caries on individuals and health care systems in the long run, by increase the level of automation and stage-by-stage classification of data. The given research also preconditions the advances in dental diagnostics (with the help of AI) in the future, as well as the development of intelligent healthcare applications.

1.1. Methods of Dental Caries Detection

1.1.1. Dental Image Input

Accurate caries can only be detected when there is correct and clear dental image input. The system needs to have the intraoral images or dental X-rays that are well captured with good lighting and focus. Minor alterations in the quality of the image, angle or resolution can influence the detection and classification output.

1.1.2. Image Preprocessing and Enhancement

Dental images are resized, normalized and enhanced during pre-processing before analysis in order to minimize noise and sharpen contrast. The preprocessing stages aid the deep learning model to concentrate on critical tooth features and the pattern of decay resulting in more accurate predictions.

1.1.3. Caries Stage Interpretation

The dental caries can be divided into three stages, namely, early, moderate and severe. The precision of the stage-wise interpretation is essential since it can assist dentists to comprehend the severity of the issue and determine whether the prevention care is necessary, some minor treatment, or a complex intervention.

Flow of Detection and Classification:

The system has a structured flow of detection. It initially detects the existence of caries, followed by examination of the affected area and its last step is classifying the level of severity. The process is performed in stages and is also carried out to provide easy and precise diagnosis and overlook small or early cavities.

Multi-Scale Feature Learning:

A caries may be of various shapes and sizes. Through a ResNet-50 model with a Feature Pyramid Network (FPN) the system can capture the small details (early

decay) and bigger damaged regions (severe decay) and this enhances the overall detection accuracy.

Visualization and Explainability;

The system also predicts depending on the features of the teeth revealed in the image. The indication of similar tooth patterns can be assigned different classifications based on the depth of the decay and the texture, so that stage-by-stage diagnosis can be applied as opposed to merely identifying the presence.

Disease-Aware Analysis:

The system adapts its predictions based on dental characteristics visible in the image. Similar tooth patterns may be classified differently depending on decay depth and texture, ensuring accurate stage-wise diagnosis rather than simple presence detection.

1.1.4. Figures

The Stage-wise Dental Caries Detection system is a case study of a deep learning-based dental diagnostic system that aims to overcome the major shortcomings of the conventional caries detection systems. This system is based on the ResNet-50 model that incorporates a Feature Pyramid Network (FPN) to analyze dental images automatically and categorize caries by early, moderate, and severe caries.

2. Results and Discussion

2.1. Results

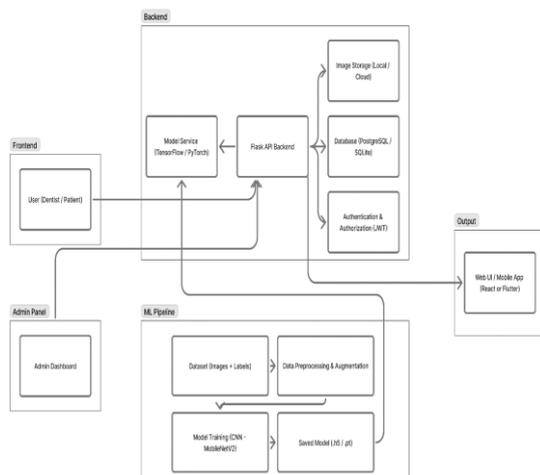


Figure 1 System Architecture

To evaluate the dental caries detection system of proposed Stage-wise Dental Caries Detection system, several dental images were used to test the system to

determine the accuracy of detection and classification. The deep learning model was able to detect the occurrence of dental caries and correctly categorize them into early, middle, and severe levels of caries. Image preprocessing and multi-scale feature learning enhanced reliability in detection of the various image qualities. On the whole, system accuracy (approximately 95%), predictability, and the ability to visualize the affected areas with the help of heatmaps were effective.

2.2. Discussion

These findings suggest that the suggested deep learning-based solution is significantly better at detecting caries in the mouth than the old manual techniques. ResNet-50 with Feature Pyramid Network (FPN) provides the possibility to effectively identify caries in various stages and sizes. This visualization of heatmaps increases credibility and clinical confidence. Although the system is reliably working, its accuracy is contingent on the quality of input dental images, implying that improvements in the system can be achieved by use of larger datasets, real-time clinical validation and adaptive learning models in the future.

Conclusion

This review has presented the massive developments that have occurred in AI-based dental caries detection systems, and there is a evident trend that movements towards the application of deep learning and explainable AI in the current dental diagnostics. The analysis of the suggested system shows how CNN structures like ResNet-50 and Feature Pyramid Networks could be integrated with the web-based solutions to cover the real-life dental healthcare requirements. Although the issue of data quality, model interpretability, and clinical validation still persist, the future of AI-assisted dental diagnosis is very promising. The further adoption of artificial intelligence, medical imaging, and digital healthcare services can allow the early phase, preventive treatments, and the availability of dental screenings, which can transform the oral health outcomes and accompany the stable healthcare systems around the world.

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