A Comprehensive Exploration of Neural Networks for Dental Caries Detection

[1]Vimalarani G, [2]Kandukuru Swaroop Krishna, [3]Mallempati Uday Kiran, [4]Shaik Nihal, [5]Kiruthika V and [6]Uppu Ramachandraiah

[1,2,3,4]Electronics and Communication Engineering, Hindustan Institute of Technology & Science Chennai, India.
[5]School of Electronics Engineering, Vellore Institute of Technology Chennai, India.
[6]SRM Group of Institutions, Ramapuram Campus Chennai, India.
[1]gvrani@hindustanuniv.ac.in,[2]19121064@student.hindustanuniv.ac.in,[3]19121051@student.hindustanuniv.ac.in,
[4]19121001@student.hindustanuniv.ac.in,[5]kiruthika.v@vit.ac.in,[6]uppuriitm@gmail.com

Article Info
A. Haldorai et al. (eds.), *2nd International Conference on Materials Science and Sustainable Manufacturing Technology,* Advances in Computational Intelligence in Materials Science.
Doi: https://doi.org/10.53759/acims/978-9914-9946-9-8_22

Abstract – Dental caries, an illness due to bacteria that worsens with time, is the most common cause of tooth loss. This occurs as an outcome of least oral hygiene, which in addition contributes to a variety of dental disorders. Children's dental health will benefit considerably if caries can be detected at an early stage via tele-dentistry technology. Because severe caries causes disease and discomfort, tooth extraction may be necessary. As a result, early detection and diagnosis of these caries are the researchers' priority priorities. Soft computing techniques are commonly employed in dentistry to simplify diagnosis and reduce screening time. The goal of this study is to employ x-ray scanned images to detect dental cavities early on so that treatment can be completed promptly and effectively. As a tele-informatic oral health care system, this classification also applies to tele-dental care. We used a convolution neural network (CNN) deep learning model in the suggested work. We trained several CNN deep learning models. Training and testing were performed on a binary dataset with and without caries photos. The classification precision of CNN models is noted.

Keywords – Dental Caries, Oral Care, CNN, Tele-Dental Care, Binary Dataset, Oral Health Care.

I. INTRODUCTION

Dental caries, also referred to as tooth decay, is a frequent oral condition brought on by the interplay of oral microbes with fermentable carbohydrates. To effectively manage dental caries and stop further erosion of the tooth's structure, early identification of the condition is essential. The precision and sensitivity of conventional caries detection techniques, such as eye inspection and radiographic imaging, are constrained. In recent years, there has been a surge in interest in the application of neural network technology to improve the precision and effectiveness of oral caries diagnosis. The shape and operation of the human brain served as inspiration for neural networks, a machine learning Programme. They can learn from massive volumes of data and uncover trends that human professionals may find difficult to identify.

Using a large collection of dental pictures, such as X-rays or intraoral photos, that have been classified as either carious or non-carious, neural networks are trained to identify dental caries. The network then gains the ability to spot patterns in caries-related pictures, and it employs these patterns to determine whether a new image includes caries. The ability to supplement more established techniques to increase their precision is one benefit of neural network-based caries diagnosis. A dentist might, for instance, perform a visual inspection to spot possible caries-causing regions before using a neural network algorithm to corroborate the diagnosis.

Image processing refers to any kind of signal processing that incorporates the input as an image, such as a photograph or paused frame of a video and creates either a picture or a collection of metrics or attributes related to the visual picture. Many approaches treat the image as a dimensional signal that is then subjected to standard procedures of signal-processing. Even though optical and conventional image processing are other viable options, digital image processing is the most used.

This post provides general tactics that are applicable to all of them. The process of acquiring photographs that results in the formation of the initial image is known as imaging. To extract relevant information about the scenario from the augmented image, image elements of interest might be increased while unrelated detail is reduced. This introduction serves as a useful primer on the difficulties and the tools and methods that have been developed to address them.

A photograph is digitalized so that it can be preserved in the memory of a computer or on a recording medium such as a CDROM or hard drive. A scanner or a video camera attached to a frame capture device in a computer can perform this digitization process. A picture can be treated to a variety of image processing processes after it has been digitized. picture

compression, picture enhancement and restoration, and measurement extraction are the three basic types of image processing methods. Most people are familiar with picture compression. It entails lowering the memory requirement for digital picture storage. Image enhancement methods can be used to correct image faults caused by the digitization process or problems in the imaging setup (for example, bad lighting). Once the image is in good quality, the Measurement Extraction techniques can be utilized to extract valuable information from it.

The suggested system functions as a digital system that effectively disseminates every piece of information required to determine tooth caries so that the therapy can be carried out quickly and efficiently.

II. LITERATURE SURVEY

The current section reviews a couple of varieties of prior study on dental caries detection and associated subjects. In the era of large medical data, machine learning has the advantage of being able to anticipate and diagnose through the analysis of numerous clinical data points, and its ability to perform is extremely similar to or even better than that of medical practitioners. [1] In-depth information on how machine learning techniques have been used to the treatment of instances of malignant oral conditions, dental scale caries, per-e-o-don-TIE-tis, reversible and irreversible pulpitis, or mild inflammation of the pulp, peri-radicular (PA) barriers, implants of endosteal, subperiosteal, and zygomatic, and orthodontics is covered in this work, which primarily aims on the use of these procedures in the widespread area of dentistry. An innovative methodology for purely automatic dental caries evaluation on an infants' first permanent tooth molars has been developed using a unique caries detection and assessment (UCDA) technology. The suggested UCDA architecture primitively consists of a backbone network that is initialized with ResNet-FPN and two concurrent task-specific subnets for region regression and region classification. [2] These subnets were inspired by a constructive in-network feature pyramid and anchor boxes. Furthermore, it provides a brand-new "children's oral image database" named "Child-OID," that is loaded with 1,368 oral pictures of elementary and pre schooling students with ubiquitous diagnostic labeling and indications, in order to assess the efficiency of the "UCDA" approach owing to the lack of such image database. Studies on the "Child-OID database" show that the suggested UCDA framework can more precisely identify frequently occurring caries on permanent tooth which grows first.

By finding the bacterial population that exists in a person's oral cavity, machine learning along with 16s rRNA sequencing have the ability to forecast tooth decays. [3] A few recent studies have used the 16s rRNA sequencing of oral samples to show machine learning predictive modeling, but they did not consider the multiple factorial character of tooth decays or the function of fungi in their algorithm. Here, a multiple factorial model of ML based on the "LASSO-penalized" logistical reduction was created by combining the mouth microbiomes of mother and a child compatibility (both hygienic and carious), demographic-environmental variables, and pertinent fungi. [4] A system using artificial intelligence was created to recognize the existence of cavities in photographs and to graphically describe each diagnosis. The method used in this research identifies cavities on photos of numerous teeth and four tooth surfaces, unlike earlier systems that could only detect cavities on one removed tooth with one tooth surface. [5] This study produced a dataset with many mixtures of dental pictorial (both color and medical scans) frames, implemented a deep weighted adaptive approach to improve the localization of carious portions in dental images, and created a fully functional tool to automatically present carious portions via basic dental depicting pictures.

III. METHODOLOGY

Eight distinct pre-processing methods were applied to increase the precision of feature extraction. Before turning a picture into a grayscale version, the RGB numbers are extracted. [6] CNNs are computer programs created with pattern detection in mind. CNN has made inroads into a number of industries, including healthcare, and plays a significant part in the diagnosis of images taken at the earliest phases of illness. To make the features of the infected area more distinct, a sharpening filter is applied to the grayscale picture. [7-9] The addition of advanced characteristics like entropy, kurtosis, skewness, etc. Finally, voice comments based on dental phases will be available. The functional block diagram of the proposed model is shown in **Fig 1**.

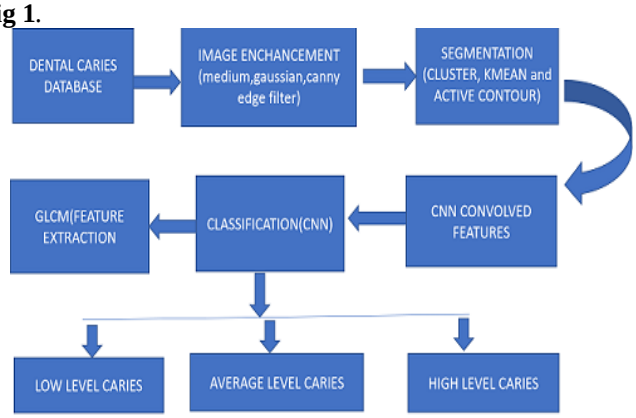

Fig 1. Block diagram

The three deep learning models confusion matrix form, feature extraction, and Labels presented in this article can help the doctor concentrate on the critical areas that might have been overlooked. The information was split into 20% for testing and confirmation and 80% for training. To get rid of artifacts and noise, the pictures were adjusted. The pictures are multiplied during the training part of the data augmentation technology to achieve high precision. Shape, color, and material characteristics are extracted by convolutional layers.

When analyzing images, a process called feature extraction creates derived values (features) from a starting set of measured data that are meant to be useful and nonredundant. [10] This technique accelerates the generalization and learning processes and, in some cases, enhances human interpretations. There is a connection between feature extraction and dimension reduction. It is possible to condense an algorithm's input data to a more manageable set of characteristics when it is too large to process or seems to be duplicated (for example, when the same measure is supplied in feet and meters or when pixels are used to portray images). (Also referred to as a features vector. [11-12] The method in consideration is feature evaluation. It is hoped that the selected features will include what is required from the information that comes in in order to complete the intended task utilizing this reduced representation as opposed to the entire starting data.

IV. RESULTS AND DISCUSSION

Here in order to detect caries in dental image an image of the tooth is taken as an input and passed through the system. The input image of teeth for processing is shown in **Fig 2**.

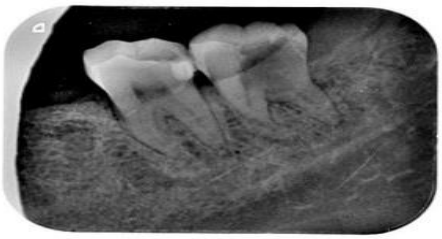

Fig 2. Input Image of Teeth for Processing

Now the input images are preprocessed and enhanced using various manipulation techniques in order to extract and strengthen the features.

Resize

Resizing your image allows you to make it smaller or larger without taking anything away. Resizing changes, the proportions of the image, which usually influences the file size and image quality. The common typical reason for the resizing of images is to convert large files to smaller ones in order to email or share them online or in other ways.

I = imresize (G, scale) yields image I, which is the size of picture G multiplied by scale. G can be a grayscale, RGB, binary, or categorical image as the input image. If G has more than two measurables or variables, resize will only resize the first two. If the scale is between 0 and 1, “I” is less than G.

Contrast

Contrast enhancements boost object visibility in a scenario by increasing the luminous variations between objects and their backgrounds. Contrast improvements are usually done in two steps: a contrast stretching followed by tonal enhancement, though they might be done in the same step. Color image contrast is often improved by transformation of the image to a color field that includes image lighting as one of its major factors, such as the L*I*G* color space. The contrast in picture is adjusted exclusively on the “luminosity layer L”, and the image is then transformed back to the RGB domain of colors. The contrast enhanced image looks as such shown in **Fig 3**.

Fig 3. Contrast Enhanced Image.

Canny edge detector

An approach for removing valuable details about structure off a variety of visual elements called canny edge detection significantly reduces the quantity of data that has to be processed. It is frequently utilized in many different artificial intelligence systems. The clever edge detection algorithm provides images that are smoother, thinner, and cleaner than the Sobel and Prewitt filters. The input image is smoothed, and the Sobel filter is used to detect the image's edges. Three stages of the Canny edge detector-Image Smoothing, Differentiation, and Non-maximum Suppression.

Median filter

The median filter is a filtering technique for removing noise from pictures and signals. The median I filter is particularly important in image processing since it is well known for preserving edges during noise removal as shown in Fig 4.

Only a small number of pixels are noisy, but those that are noisy are extremely loud. This is known as salt and pepper noise, and it applies to a variety of mechanisms that all lead to the same basic image deterioration. The result resembles the image being sprinkled with salt and pepper (little white and black particles).

Fig 4. Noise Reduced Image Using Median Filter.

Image segmentaion

The methodology of image segmentation divides an image into series of bitmapped pixel areas of each have a mask or tagged image representing them. By segmenting an object, we can deal with only the essential areas of its content instead of handling the complete image as shown in Fig 5. Since it separates the objects that are relevant for additional processing, such description or authorization, segmentation is a critical phase in the image comprehending process. For the categorization of picture pixels, segmentation of an image is used in practice. Focusing marketing efforts on your ideal customer profile (ICP), or the consumers who are most likely to buy your product or service, is the aim of segmentation. For instance, a customer in an organic food store is probably going to exhibit any or all of the traits listed below: Gender: Regardless of gender The main categories of image segmentation methods are as follows: based on threshold segmentation. Segmentation based on the edges. Segmentation by region.

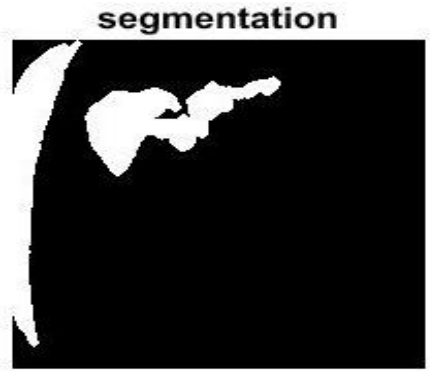

Fig 5. Segmentation

Active contour is a segmentation approach that separates the pixels of interest from a picture using energy forces and restrictions for further processing and analysis. The term “active contour” refers to an active model for the segmentation process. Contours are the lines that define an image’s region of interest. The main difference between the two is that

clustering is driven by machine learning, and segmentation is human-driven. This difference has caused more than a few folks to be clustering-averse and to cling to their own customer knowledge. That reluctance touches upon the familiar battle of man versus machine.

MIFNET

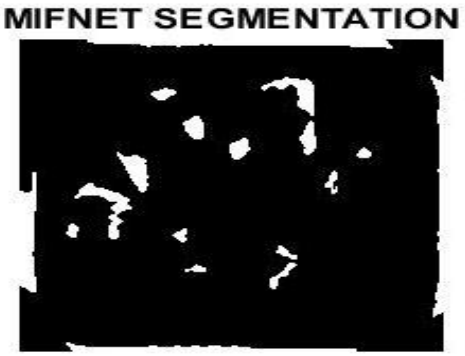

Fig 6. MIFNET

Sea-Land Segmentation Using a Multi-Information Fusion Network (MIFNET) as shown in Fig 6. Market segmentation is the practice of dividing a target market into smaller groups with comparable characteristics, such as age, income, personality traits, behavior, interests, demands, or location. Knowing your market segmentation allows you to better target your product, sales, and marketing approaches.

Feature extraction

Feature extraction is the conversion of un-processed fresh raw data into features with weights that is handled while preserving the original data set's contents. Instead of only using machine learning on raw data, it yields superior results.

The GLCM operations determine the rate of combinations of cells with specific values occurring in a picture in a given positional association, creating a GLCM, after which retrieving statistical parameters off this array. Extraction of Characteristics: Python Gray-Level Co-occurrence Matrix (GLCM). In the approach of processing digital images , the it is a texture analysis approach for evaluating weights of the traits. This approach depicts the relationship between two adjacent pixels with grey intensity, distance, and angle. The GLCM is used to compute 2^{nd} ordered textural features of statistics and such angular 2^{nd} moment, entropy, variations, correlation, inverse difference moment, energy, mismatch, homogeneity, and contrast, among others. Taking the square root of the angular second moment yields the energy. The features extracted from the given images are shown below in **Table 1**.

Table 1. Features of Images

Features	**Image 1**	**Image 2**	**Image 3**
Accuracy	0.992	0.992	0.992
Contrast	0.228	0.232	0.206
Correlation	0.092	0.1	0.118
Energy	0.754	0.729	0.752
Homogeneity	0.9302	0.9242	0.9327
Entropy	3.4966	3.669	3.6932
Mean	0.0027	0.0051	0.0033
Kurtosis	6.424	5.6521	5.7449
Skewness	0.4384	0.5032	0.2811
RMS	0.0898	0.0898	0.0898

Clustering

After preprocessing the binary picture with K-Means clustering, the clustered image with Caries is displayed. Image segmentation is the process of turning a picture frame into a group of cell regions shown by a mask or a labelled image. By segmenting a picture, one can extract only the critical portions of the image as shown in **Fig 7** compared to that of the complete image.

Fig 7. Cluster

Classification

The task of providing a label or class to a complete image is known as image classification. Images are expected to have no more than one class. Image classification models accept an image as input and estimate which class the image belongs to.

CNN is a neural network structure for the use of deep learning technologies that is typically employed for tasks that analyze pixel input and perform identification of images as shown below in **Fig 8.** CNNs are the preferred network architecture for object detection and recognition among the several neural network types used in deep learning.

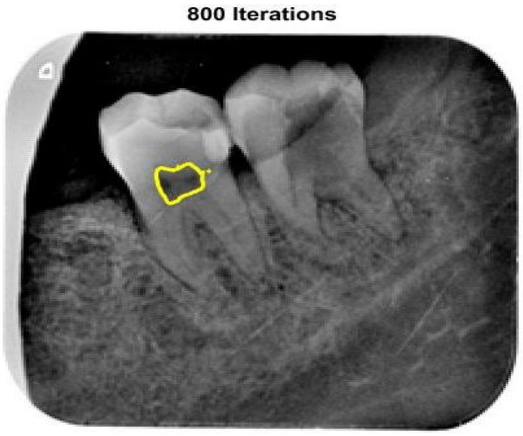

Fig 8. Detection/Classification

The binary segmented teeth, After the Segmentation and classification process the binary image is passed through the convolutional Layer for prediction. The Level of caries is detected and shown in the message dialog box as shown in Fig 9.

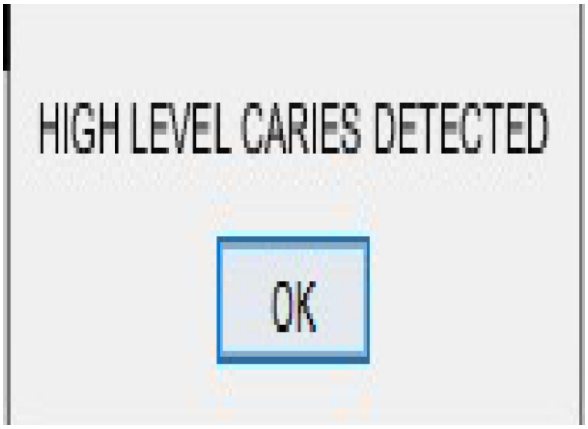

Fig 9. Output dialog box with High Level of Carries

If the level of the caries is less or moderate the output message dialogue box will be shown as in **Fig 10** and **Fig 11.**

As a result, the various levels of the dental cavity(scales) are detected using the proposed model. This data can be used in treating dental illness.

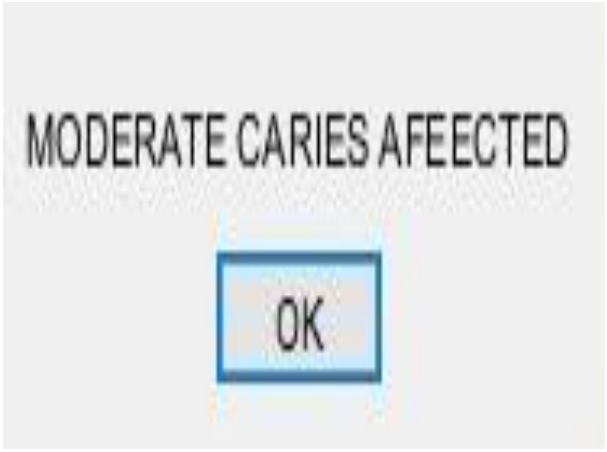

Fig 10. Moderate Level of Caries

Fig 11. Low Level of Caries

V. CONCLUSION

The main objective of our work to use digital radiographic images to catch dental caries is achieved using the CNN DL network. This helps to treat various oral or dental diseases at a prior stage effectively. The proposed model shows the level of cavity or scales of caries which may cause dental cancers. As a further scope, this system can be developed as a web or mobile application in order to provide cutting edge technology in treatment of Oral Diseases.

References

[1] M.-L. Sun et al., "Application of machine learning to stomatology: A comprehensive review," IEEE Access, vol. 8, pp. 184360–184374, 2020.
[2] H. Yu, Z. Lin, Y. Liu, J. Su, B. Chen, and G. Lu, "A new technique for diagnosis of dental caries on the children's first permanent molar," IEEE Access, vol. 8, pp. 185776–185785, 2020.
[3] T. T. Wu et al., "Machine learning approach identified multi-platform factors for caries prediction in child-mother dyads," Front. Cell. Infect. Microbiol., vol. 11, p. 727630, 2021.
[4] N. Bhattacharjee, "Automated dental cavity detection system using deep learning and explainable AI," AMIA Annu. Symp. Proc., vol. 2022, pp. 140–148, 2022.
[5] U. Rashid et al., "A hybrid mask RCNN-based tool to localize dental cavities from real-time mixed photographic images," PeerJ Comput. Sci., vol. 8, no. e888, p. e888, 2022.
[6] "Top trends on the Gartner Hype Cycle for artificial intelligence, 2019," Gartner. [Online]. Available: https://www.gartner.com/smarterwithgartner/top-trends-on-thegartner-hype-cycle-for-artificial-intelligence-2019. [Accessed: 28Mar 2023].
[7] A. Krizhevsky, I. Sutskever, and G. E. Hinton, "ImageNet classification with deep convolutional neural networks," Commun. ACM, vol. 60, no. 6, pp. 84–90, 2017.
[8] C. Venkatesan, D. Balamurugan, T. Thamaraimanalan and M. Ramkumar, "Efficient Machine Learning Technique for Tumor Classification Based on Gene Expression Data," 2022 8th International Conference on Advanced Computing and Communication Systems (ICACCS), Coimbatore, India, 2022, pp. 1982-1986, doi: 10.1109/ICACCS54159.2022.9785294..
[9] D. H. Hubel and T. N. Wiesel, "Receptive fields of single neurones in the cat's striate cortex," J. Physiol., vol. 148, no. 3, pp. 574–591, 1959.
[10] Y. Lecun, L. Eon Bottou, Y. Bengio, and P. Ha, "GradientBased learning applied to document recognition," Stanford.edu. [Online]. Available: http://vision.stanford.edu/cs598_spring07/papers/Lecun98.pdf. [Accessed: 28-Mar-2023].
[11] O. Ronneberger, P. Fischer, and T. Brox, "U-Net: Convolutional Networks for Biomedical Image Segmentation," arXiv [cs.CV], 2015.

[12] S. Ren, K. He, R. Girshick, and J. Sun, "Faster R-CNN: Towards realtime object detection with region proposal networks," IEEE Trans. Pattern Anal. Mach. Intell., vol. 39, no. 6, pp. 1137–1149, 2017.
[13] S. Suwajanakorn, S. M. Seitz, and I. Kemelmacher-Shlizerman, "Synthesizing Obama: Learning lip sync from audio," ACM Trans. Graph., vol. 36, no. 4, pp. 1–13, 2017.
[14] S. Hochreiter and J. Schmidhuber, "Long short-term memory," Neural Comput., vol. 9, no. 8, pp. 1735–1780, 1997.
[15] K. Cho et al., "Learning phrase representations using RNN encoder– decoder for statistical machine translation," in Proceedings of the 2014 Conference on Empirical Methods in Natural Language Processing (EMNLP), 2014, pp. 1724–1734.
[16] G. Vimalarani, Uppu Ramachandraiah. "Automatic diagnosis and detection of dental caries in bitewing radiographs using pervasive deep gradient based LeNet classifier model". Microprocess. Microsyst. 94, 2022.