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Using an Artificial Neural Network Model in Tooth Decay Diagnosis

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Abstract: - The current research aims to use the artificial neural network model in the diagnosis of tooth decay. The necessary data set was acquired from 3 groups including patients, dentists, and radiologists. Radiographic images of patients were fed as input to the DenseNet model, and the similarities and differences between the diagnosis of the proposed model and the dentist's diagnosis were evaluated. Contrast and detection of image edges were achieved by image processing techniques and filters. The key objective of this study was to develop a tooth decay detection system using DenseNet architecture as a special type of convolutional neural network (CNN). Subsequently, criteria such as precision, recall, accuracy, and F-measure of the DenseNet model were examined. According to the results, precision, recall, accuracy, and F-measure of the proposed model are equal to 83.33%, 80%, 91%, and 80.12% respectively. In general, the proposed method has a better performance than the compared methods regarding precision, transparency, detection speed, and accuracy.

Keywords: tooth decay, convolutional neural network, DenseNet architecture, artificial intelligence

I. INTRODUCTION

Tooth decay is a type of oral and dental disease that is prevalent in teenagers and adults all over the world. Dental radiography is considered a reliable and widely used diagnostic tool for detecting tooth decay and is considered the basis of most screenings and diagnoses based on empirical evidence. Over the past few years, artificial intelligence has been used in the medical field and achieved acceptable results. Deep learning methods, including CNN, have obtained interesting results in the field of tooth decay detection. There are various radiographs in the field of dentistry. One of the methods of detecting tooth decay is the use of Bitewing radiography. Many tooth cavities and deep decay can be detected in this method. Another method is periapical radiography used to monitor the whole teeth.

X-ray images such as OPG and RVG are the most widely used tools for diagnosing dental diseases. OPG image represents both upper and lower teeth in the form of one image. On the other hand, RVG X-ray images are used to identify individual teeth. It seems necessary to develop specific methods for designing and implementing CNN, choosing an appropriate training convolutional network, and collecting, and modifying dental and oral radiographic data sets in order to deal with tooth decay problems. Today, computer-aided design (CAD) systems are frequently used in clinical operations. In most cases, their key purpose is to assist medical professionals, not to replace them.

The influence of factors such as lighting intensity, radiation angle, shadows, noise, etc. in imaging resolution is also involved in radiography. It is difficult to accurately diagnose tooth decay using pure radiography. In addition, only when the lesion has affected half the thickness of the tooth enamel, it is possible to detect enamel decay using radiographic images.

In (Chiuchisan, 2015), a real-time system for improving the quality of medical images is presented. This system improves the quality of images by using edge detection, sharpening operation, and adjusting the brightness and contrast of images. In (Rajendran & Et al 2016), a method of enhancing the quality of medical images by preserving the edges using a guided filter is proposed. Researchers improve medical images by using filtering and image edge enhancement as well as contrast adjustment in order to analyze and detect salient symptoms. In (Zhou, 2016), medical images have been improved by using logarithmic image processing models. Researchers focused on nonlinear mathematical frameworks to solve common problems of linear optimization methods. For this purpose, a non-linear overlay algorithm based on logarithmic image processing models is presented. In (Hodgson & et al. 2017) using a semi-supervised fuzzy technique and spatial constraint algorithm, processing of dental

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images has been achieved. The combination of fuzzy logic algorithms and spatial constraint has achieved relatively good results in the field of image processing and resolution improvement.

Despite the significant progress achieved in dental science, the timely diagnosis of tooth decay is still one of the concerns of dentists and people. The reason is that most people notice decay after deep decay, tooth destruction, and severe pain. In recent years, oral and dental hygiene and its quality have been one of the key topics in studies and are considered one of the most effective solutions in the field of health. As a result, many studies seek to reveal the role of effective factors in tooth decay or health.

Accurate diagnosis of tooth decay can reduce the costs of oral health management and increase the possibility of maintaining natural teeth in the long term. The findings of the present study show that the CNN algorithm based on deep learning along with other deep techniques can provide significant performance in the detection of tooth decay in radiography. Improved deep learning algorithms and quantitative and qualitative datasets may be useful for tooth decay detection in dental clinical operations. In conclusion, the development of a tooth decay detection system using the DenseNet artificial neural network model is an inspiring topic to improve early diagnosis and intervention for oral health problems. Relying on deep learning techniques and appropriate datasets and results, this system has the potential to help dental professionals provide better patient care.

II. METHODOLOGY

To train and evaluate the tooth decay detection model, a dataset of dental images is needed. In the process of data collection, it has been tried to ensure that all images are up-to-date and in accordance with the latest technology of photography devices.

In the standard ConvNet network, the input image is subjected to several convolutions, and its high-level features are extracted. The Identity mapping function is used to enhance gradient propagation in ResNet. The addition operation is assumed in the form of an algorithm that transfers a state from one ResNet module to another module. Each layer of the dense convolutional network receives additional inputs from all previous layers and passes its feature mappings to subsequent layers. The concatenation method can also be used. It means that each layer receives the collective knowledge of all its previous layers. Since each layer receives feature maps from all previous layers, the resulting network is narrower and more compact, with fewer channels. The growth rate (k) is a measure indicating the number of channels added in each layer. Therefore, the dense convolution network is more efficient regarding computing and memory.

Before training the DenseNet model, appropriate pre-processing is applied to the dental images. This process may include resizing, normalization, and enhancement techniques to increase the robustness and generalization of the model. In addition, data was divided into training, validation, and testing sets to evaluate the performance of the model.

The DenseNet model is implemented using popular deep learning frameworks such as TensorFlow or PY-Torch. The tooth decay detection model is trained using a dataset of labeled dental images. During training, the model learns to classify dental images into healthy or decayed classes. The performance of the model is evaluated using appropriate evaluation criteria such as accuracy, precision, recall, and F1-Score. It is also desirable to use cross-validation techniques to ensure the robustness and generalization of the model. To improve the performance of the model, different optimization techniques can be used, such as setting hyper-parameters such as learning rate, and batch size, and regularization techniques such as dropout or weight reduction. Furthermore, transfer learning can be applied to large-scale image datasets such as ImageNet using pre-trained models. Once the tooth decay detection model achieves satisfactory performance, it is possible to use it as a stand-alone application or together with existing dental imaging systems.

The images used in this study are based on the Bite-wing imaging technique in dentistry. The pre-processing, reading, and processing of images are simulated and implemented in MATLAB software using functional codes. Finally, criteria such as precision, F1-score, recall, Micro Avg, Macro Avg, and accuracy were examined in the results. Figure (1) represents the general process of image processing (Gonzalez et al., 2007).

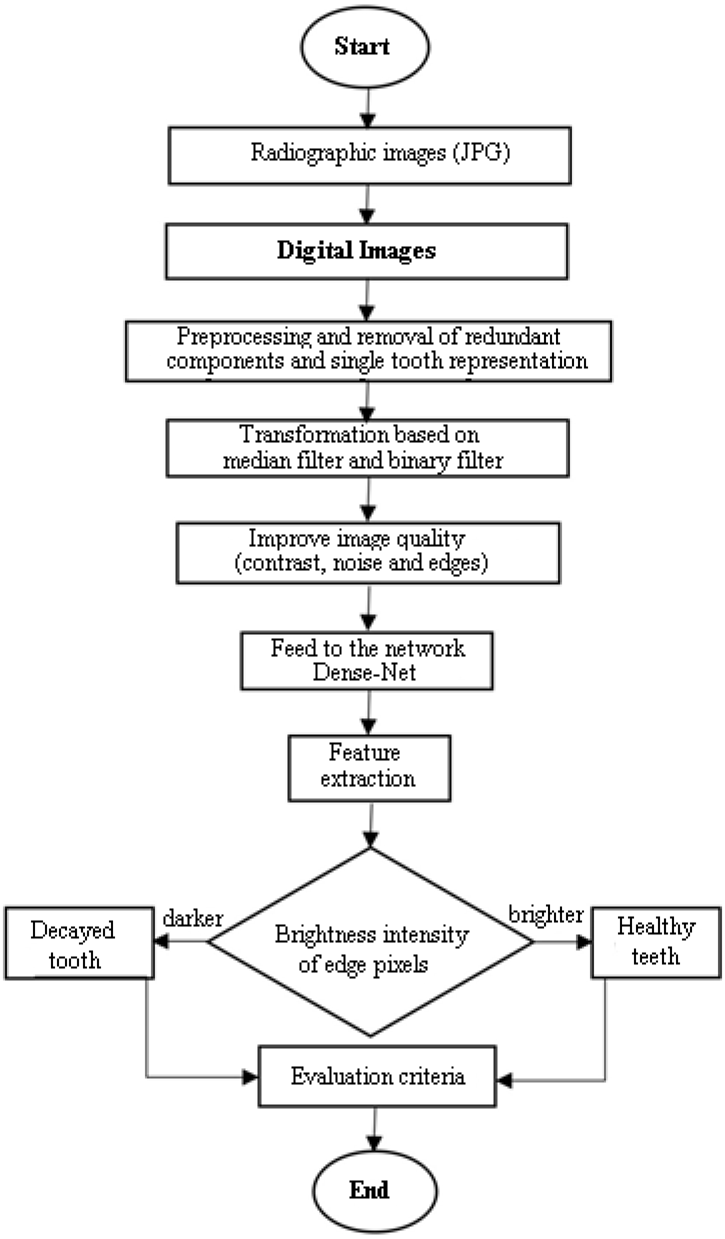

Figure 1: Algorithm of the proposed method

III. RESULTS

Simulation and evaluation of images

At this stage, images are processed by clustering rules and algorithms, and spatial filters in MATLAB software. The processing process consists of 7 distinct steps. In each step, the center of clusters is determined. After the completion of the scanning time of all the pixels of the image, a window will appear showing the processed images with the center of the defined clusters. If each of them is processed, in each image with a different center c, edges with different shapes and coordinates are revealed. Below, examples of original images and images processed by the system are shown.

Figure 2: Original image

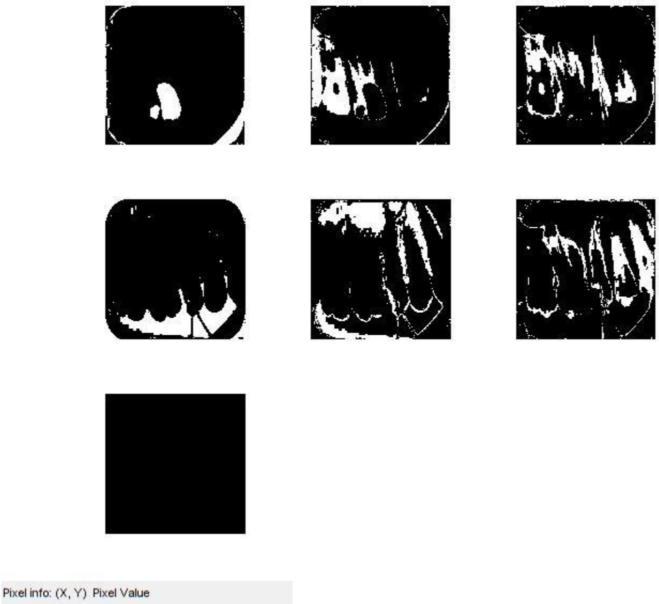

Figure 3: Processed images with different cluster centers

In the subimages inserted in Figure (3) (from left to right), the centers of the clusters are 1, 0.6, 0.4, 0.2, 0.1, and 0 respectively. In the next example, the steps and results of image processing on a new image are described in detail.

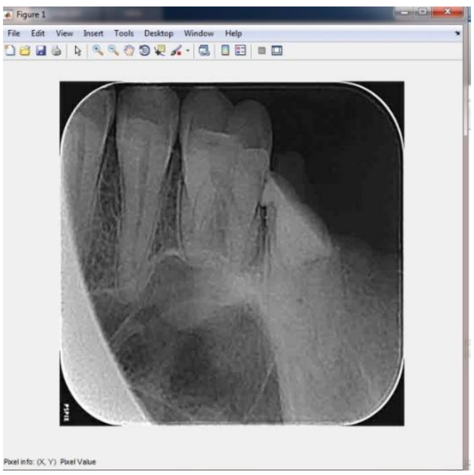

Figure 4: Original image

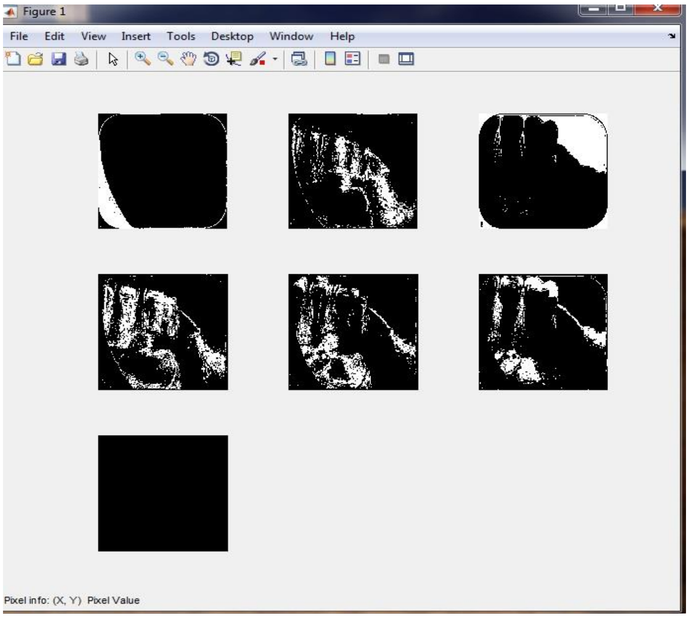

Figure 5: Processed images with different cluster centers

In the subimages inserted in Figure (5) (from left to right), the centers of the clusters are 1, 0.6, 0.4, 0.2, 0.1, and 0 respectively. The evaluation criterion of the proposed algorithm is precision, which is basically considered the main indicator in image processing and resolution improvement. Below is an example of the frequency of processed images.

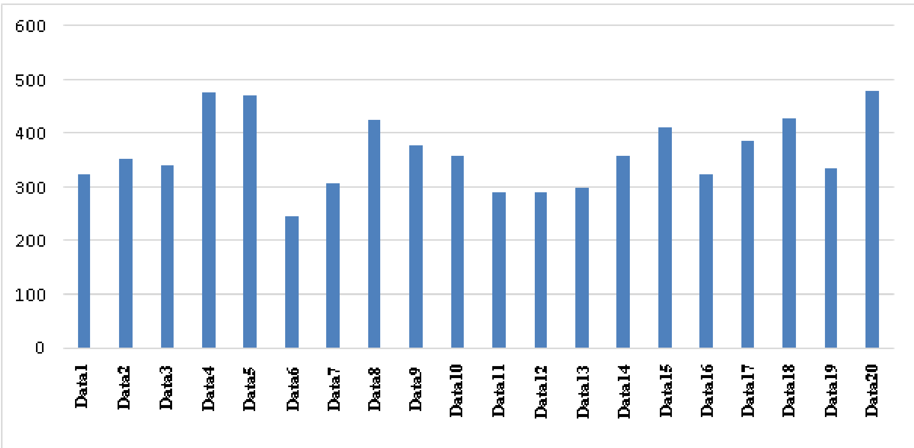

Figure 6: The frequency of processed images

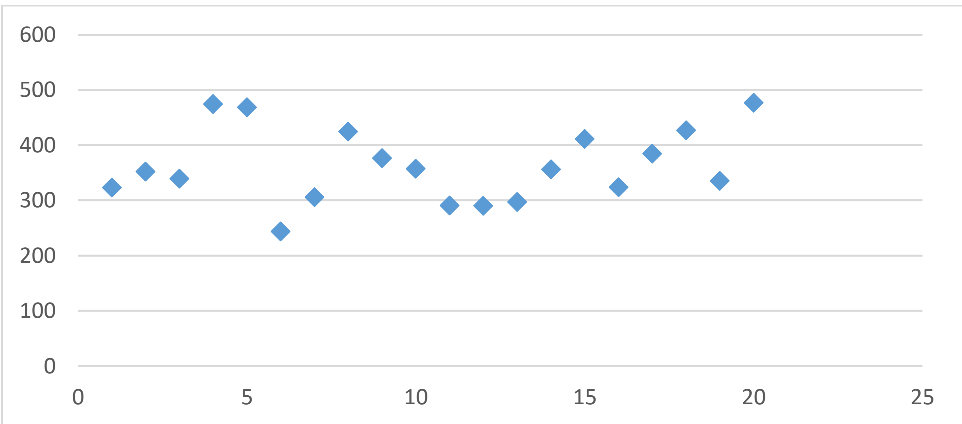

Figure 7: The frequency of processed images

In this section, the proposed method is compared with the state of the art in dental image processing. The main criterion for comparison is accuracy. The accuracy values obtained from the proposed method and other studies (Gnana Soundari et al., 2023 and Bouchahma et al., 2019) are shown as percentages in Table (1).

Regarding the quality of diagnosis, the better the accuracy and clarity of the images, the faster the dentists will diagnose the disease and existing problems and achieve the desired result.

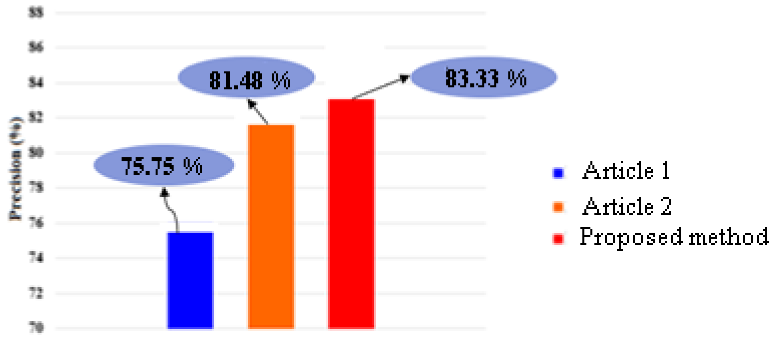

Figure 8: Comparison of the proposed model with basic Models 1 and 2 regarding precision

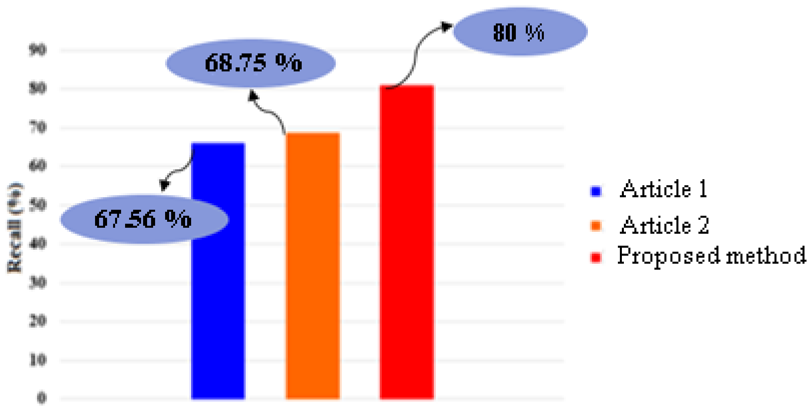

Figure 9: Comparison of the proposed model with Models 1 and 2 regarding recall

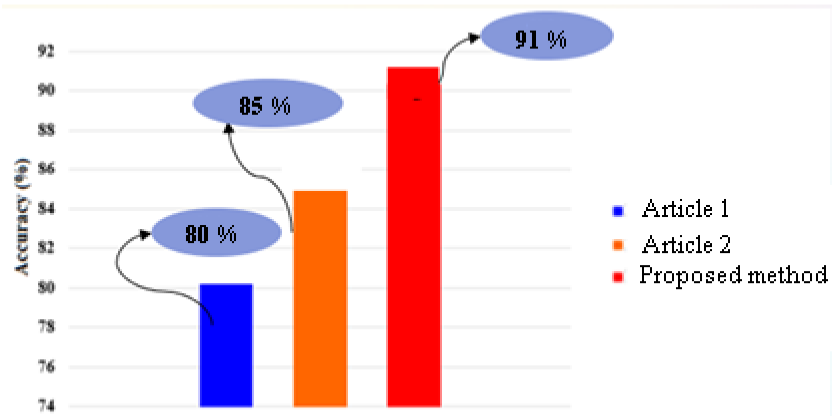

Figure 10: Comparison of the proposed model with Models 1 and 2 regarding accuracy

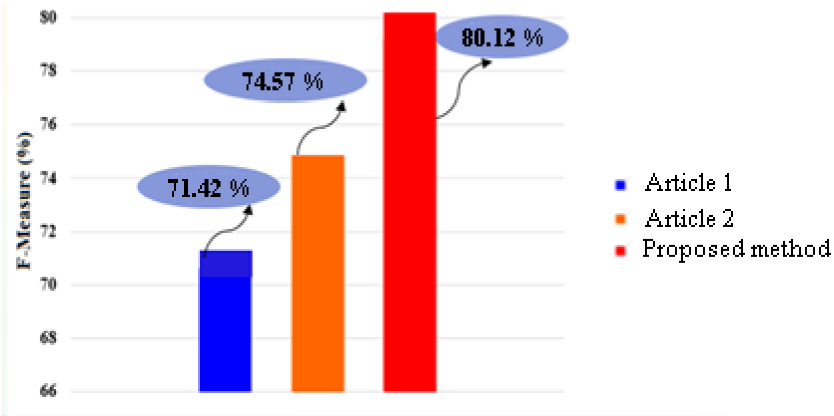

Figure 11: Comparison of the proposed model with Models 1 and 2 regarding F-measure

Table 1: Comparison of the proposed model with the basic models regarding all criteria

Basic studies	TP	TN	FP	FN	Recall	Precision	Accuracy	F-measure
Bouchahma et al. 2019	25	55	8	12	67.56%	75.75%	80%	71.42%
Gnana Soundari et al. 2023	22	63	5	10	68.75%	81.48%	85%	74.57%
Proposed method	20	71	4	5	80%	83.33%	91%	80.12%

Table 2: Improvement of evaluation criteria compared to basic models

-	Recall	Precision	Accuracy	F-measure
Improvement of the proposed method compared to Bouchahma et al. 2019	12.44%	7.58%	11%	8.7%
Improvement of the proposed method compared to Gnana Soundari et al. 2023	11.25%	1.85%	6%	5.55%

IV. DISCUSSION

This study aims to use an artificial neural network model in tooth decay detection. In recent studies, intelligent techniques have been used to propose different methods of tooth decay detection. Some studies used a charged couple device to record radiographic images from inside the mouth to implement a neural network. The main disadvantage of this method was the manual addition of artificial decay to the images. This is because artificial decayed teeth are completely different from natural decayed teeth. Also, in another study, a new method for early detection of tooth decay based on histogram and power spectrum analysis was presented.

In this study, first, radiographic images were fed as input to the DenseNet artificial neural network. DenseNet model is one of the new and improved models. DenseNet networks perform better than ResNet and Pre-Activation ResNet due to dense connections, fewer parameters, and higher accuracy. DenseNet is a type of convolution neural network using dense connections between layers. DenseNet is one of the discoveries in the field of neural networks for visual recognition of objects. DenseNet is quite similar to ResNet with a few minor differences. ResNet uses an incremental method to merge the previous layer with the next layer. In DenseNet, each layer is connected to all other layers in the depth of the network, that is, the first layer is connected to layers 2, 3, 4, etc., and the second layer is connected to layers 3, 4, and 5. The main structure of DenseNet includes a dense block, transmission layer, convolution layer, and fully-connected layer. For each layer, the number of parameters in

ResNet is directly proportional to the value of C × C. At the same time, the number of parameters in DenseNet is directly proportional to l × k × k. Since k<<C, the size of the dense convolutional network is much smaller than ResNet. This model has many advantages, including robust gradient propagation, high efficiency in calculations and parameters, more diverse and richer features, and maintenance of features with less complexity. The results of the experiments proved the efficiency of the proposed method compared to other methods.

According to the deeper examination of the results of the proposed method for processing all types of dental images, it is recommended to use other methods such as cellular learning to process dental images and also to use artificial intelligence algorithms to process images in all medical fields.

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