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Mobile App for Dental Caries Detection by Deploying Deep Learning Model

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ABSTRACT
A dataset of images of human teeth, both with and without cavities, is gathered via Kaggle. An equal number of images representing each category are selected for testing, training and validation from each of the three compartments of this dataset. The selected images undergo three preprocessing techniques: Image scaling, image scaling and image upscaling. At the same time, we use convolution neural network techniques to develop deep learning models. Then the model is trained on the preprocessed dataset. Accuracy and loss are used to evaluate the effectiveness of training. The values are also tabulated to understand the behavior of the model. The verification process follows the same phases. Analyze and display training and validation data in bar charts. Training and validation results show that the model can analyze images and predict the presence of caries with a short evaluation. Both training and validation yield high accuracy scores and very low loss scores. The model is trained and validated and finally he is tested once. The final accuracy of the model is determined to be 96% with a loss value of 11%. We found this deep learning model to have good accuracy and loss values, so we used it to build his mobile application. Additionally, the functionality of the application is checked and found to be perfect.

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Key Words
Image processing, deep learning, data collection, accuracy, loss

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INTRODUCTION

A dental cavity or tooth decay is one of the most common health problems in the world. This is a phenomenon where the hard layer of the teeth is cracked or developed into tiny holes. These holes act as bowls or carriers of germs and it worsens with time. Tooth decay is caused by various parameters like a bacterial infection, increased sugar intake and poor hygiene. What is the worst part about dental cavity is that it has no age or gender boundaries. People will get affected by cavities no matter how young or old they are. When a dental cavity is left unattended it increases in size and even leads to severe consequences like tooth loss. Most of the time a dental cavity requires medical attention like teeth cleaning. When the cavity worsens to deep carries dentists often recommend having the teeth removed to protect the nearby tooth. In some rare cases and unattended tooth decay can even lead to death. The preliminary test for two decay is pretty simple. This study aims the development a deep learning model using the convolutional neural network algorithm which is capable of predicting whether a person is affected by a dental cavity or not by analyzing the image of his or her tooth. This process is also simplified by the development of a mobile application that allows the user to do so. The design and development of this mobile application and the deep learning model are clearly explained in the upcoming chapters.

REVIEW OF LITERATURE

The field of dentistry has greatly evolved with the development of technology in the medical field. Scientists and researchers, with different methods and ways to predict and cure various dental problems[1]. The results propose the ideology of ultrasound Doppler effect in dentistry to measure pulpal blood flow. The researchers stated that the analysis of this blood flow will greatly increase the finding of the most appropriate treatment procedure for teeth. They also stated that the method proposed in this study will be able to detect problems like fistula, tooth loss, abscess, etc. The study of Skakodub and Varlamova[2] proposed the idea of identifying rheumatoid diseases by analyzing dental problems.

For this process, they stated that the signals generated in the human body can be resolved in the creation of a mathematical model which is capable of identifying certain diseases. The researchers also tested this model on children and the resource were found satisfactory. A dental arch is one of the most important aspects of dentistry.

A study of Rijal[3] proposed a new shape representation of a dental arch using MATLAB software. For this process, 47 digital images of dental arch are analyzed using MATLAB software to extract the basic qualities to design the new cast with the novel feature. Other techniques like clustering or also use in this study to increase the reliability of the dental cast. From time-to-time researchers also provide a new solution to dental cavities.

Lakshmi and Chitra[4] suggested the usage of the deep CNN algorithm in the classification of dental cavities. The searches stated that the model developed in the study can analyze the X-ray image of a tooth and successfully classify the type of the dental cavity present. The accuracy of the model developed in this study is greater than 96% making it more efficient.

Hashem *et al*.[5] even stated that there is a connection between the oral cavity and neurological disorders. This research was done by a group of researchers from Saudi Arabia. They said that the mouth and face region consist of 30-40% of the sensory nerves of the human body. So, when oral cavities are examined for a problem and found positive it might be the preliminary stage or maybe related to some other neurological disorder. The researchers used the internet of things technology to analyze and transfer the data required. When the model is successfully developed it can predict the presence of some neurological disorders just by analyzing the oral features of a man. The accuracy of the model is also found to be greater than 98% which again is great for a prediction algorithm.

The convolutional neural network algorithm is found to be one of the most widely used and efficient algorithms in the field of image processing and computer vision. The CNN algorithm has been widely used in medical applications.

Montaha *et al*.[6] uses a combination of CNN and LSTM to identify brain tumors by analyzing the MRI images of a brain. The model developed in this study is capable of predicting brain tumors in all stages. The model uses three- dimensional images making it more reliable. The CNN algorithm is efficient on its own and when combined with another algorithm it can produce great results. The accuracy value of the model developed in this study is greater than 98.9%. The model is also fast and has a good generalization capability. Researchers use this algorithm for almost every type of application not only limited to medical.

Kollias and Zafeiriou[7] use the CNN algorithm along with the RNN algorithm to design a model that is capable of detecting human emotions from an image. An advanced data set named the 1 min gradual emotion data set is used to train the model. Again, the combination of two different algorithms resulted in great accuracy values. This research also used a novel pre-processing technique of normalization to increase the performance of the CNN model and achieve doing so. The recent times can be termed as the smartphone era. Smartphones and mobile applications have a great impact and usage in the current society. Various

mobile applications have been developed throughout the years for various requirements and use various techniques.

The study of Guerrero *et al*.[8] has developed a mobile application that can be used to teach analytical chemistry to students virtually. Various lab tasks and projects were previously installed in this application to make learning easier. This application serves as a virtual laboratory for analytical chemistry. The application is also designed in a way that is interactive making it easier for the students to understand. When the advantage of a particular technology is very high it also comes with certain disadvantages which are inevitable in most cases.

An experiment of Abdullah and Zeebaree[9] developed by researchers has listed the vulnerability of mobile applications along with the prevention methods. They stated that the security and privacy of data are at risk with a lot of applications. They also stated that with the increase in the usage of Android applications the number of attacks is also increasing. They concluded the study by stating that one can protect themselves from these attacks when they are aware of what one is getting into.

MATERIALS AND METHODS

A dataset consisting of 1500 images of human teeth is collected from Kaggle. This data set is then divided into 3 parts. For data balance, 400 images of each type are taken for further procedures. The biggest part is used for training the algorithm and the rest of the data set is divided into two halves and they are used for validation and testing. The chosen images are there preprocessed using three different techniques.

The techniques include resizing, rescaling and image augmentation. A deep learning model is developed using the convolutional neural network algorithm. This model is then drained using the preprocessed data set. The model is also tested and validated to find the final accuracy and the loss value. Once accuracy is found satisfactory the model is used as a backend for a mobile application which was also designed in this study. The application then analyses the uploaded image by the user and displays whether the user is affected by a dental cavity or not.

DATA COLLECTION AND PREPROCESSING

A dataset consisting of 1155 images of a human tool that is affected by a dental cavity and 399 images of a healthy human tooth is collected from Kaggle. About 400 of each type is taken for further proceeding to maintain a data balance.

A sample of the images from that data set is shown in Table 1.

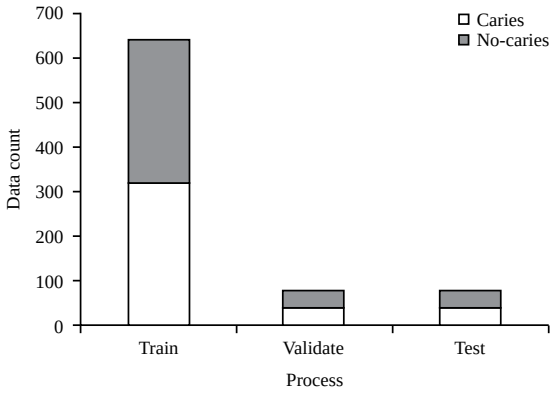

Fig. 1: Data split-up

Table 1: Sample data

Dental type	Image	Raw data	Balanced data
Caries		1155	400
No-caries		399	400

Table 2: Data split-up

Data	Train	Validate	Test
Caries	320	40	40
No-caries	320	40	40

The split-up data of the image are also shown in Table 2 and Fig. 1 for a clearer understanding.

From Table 2, the data used for all the processes like training, validation and testing a balanced. The balance of the data is maintained during the split-up to increase the efficiency of the model and to reduce the biased result. The chosen images are then preprocessed using the below techniques.

Image resizing: Image resizing is a technique where all the images of the data set or crop into the same dimension making it easier for the algorithm to process[10]. When the images are different sizes, it impacts the efficiency of the algorithm. In this study, the images are resized into the dimension 128×128.

Image rescaling: Image rescaling is also a technique that is similar to image resizing except for the fact that scaling is done on a pixel level. Instead of cropping out the unwanted parts of an image free scaling scales down the features of the image to maintain uniformity[11].

Image resizing and image resealing or one of the most important and mandatory procedures in the field of computer vision.

Image augmentation: Sometimes the number of images available in the dataset is not enough to train the model to obtain the required accuracy level. To

avoid such scenarios the image augmentation process is used on the existing dataset. Image augmentation is a process in which the existing data set multiplies itself with minor changes so that the model will have a bigger data set to work with[12].

This image augmentation is done on both parts of the data set so that the images required for training are equal and balanced. In this study, three steps are involved in image augmentation. They rotate flip and zoom. The steps are self-explanatory. The images rotated to their axis. The flip step creates a mirror image of the image from the existing dataset. The image is zoomed further to create a similar image in the final step of augmentation. It is also noted that augmentation is only done for the training images to increase the performance of the deep learning model.

CONSTRUCTION OF THE CNN MODEL

The deep learning model is the most significant aspect of this work. This model analyses and predicts the text that is contained in the image using training data and text that has been extracted. To do this, the CNN algorithm, also known as a convolutional neural network, is used in this study. The CNN algorithm is a deep learning technique made especially for categorizing images.

The CNN algorithm performs better since it is supervised[13]. One of the major benefits of this approach is the reduction in the number of layers that need to be defined thanks to the integrated convolutional layer. This is a premade layer, so there is no need to start from scratch; only a minor adjustment is needed[14]. Four layers make up the finished CNN model most of the time. The architecture of the CNN model is shown in Fig. 2.

From Fig. 2 it can be seen with the first layer of the architecture is the sequential layer. This layer consists of four edges and zero parameters. The second layer is the convolutional layer and this layer also consists of 4 edges and 896 parameters. This layer is followed by the max pulling layer and in this layer, the edges are reduced in values but not in number. The set of a convolutional and the masculine layer is repeated twice with the drop out there in the middle. For every descending layer, the number of parameters and all the value of parameters is reduced and the final layer of the architecture is the dense layer. This layer consist of only two edges and the value is also significantly reduced. The same set of layers is repeated for every image and by the end of the training, the model is completely trained to predict the presence of dental cavities by analyzing the input image and classifying the image into caries and non-caries.

RESULT AND DISCUSSION

A dataset consisting of images of a human tooth both cavities affected and the normal is collected from Kaggle. This data set is divided into 3 parts and an equal number of images of each type is taken for testing training and validation. The chosen images are

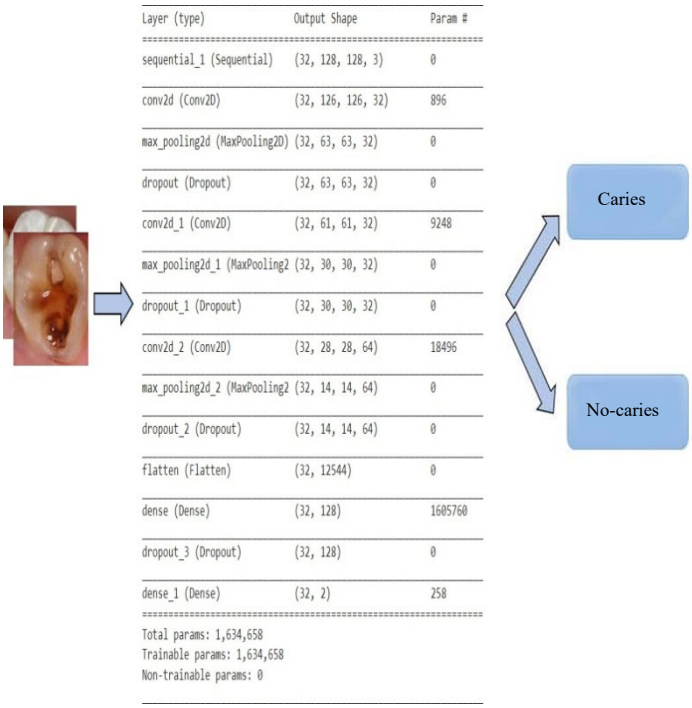

Fig. 2: The CNN architecture

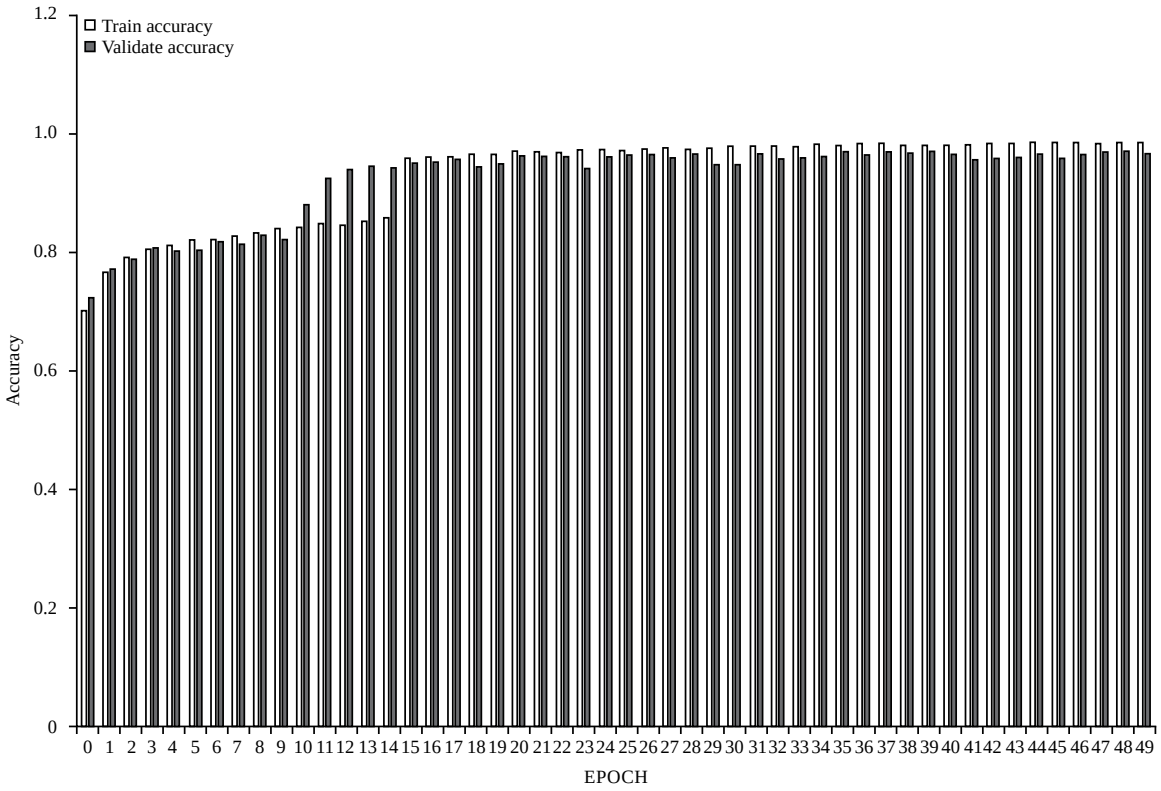

Fig. 3: Accuracy graph of the algorithm

then preprocessed using three methods named image resizing, image rescaling and image augmentation. Simultaneously a deep learning model is also developed using the convolutional neural network algorithm.

This model is then trained using the preprocessed data set. The results of the training are measured in terms of accuracy and loss. The values are also tabulated to understand the behavior of the model. The same procedures are also repeated for validation. The recorded values are then plotted into a bar graph for clear understanding and easier analysis. The accuracy graph of the convolutional neural network algorithm during both training and validation is shown in Fig. 3.

From Fig. 3, it can be seen the accuracy of the deep learning model has been consistent and higher throughout the 15th epoch of training. In the case of validation, the accuracy value has reached its maximum during the 11th iteration itself. After a certain period and several iterations, the accuracy of the model has been constantly maintained above 90 making the model more effective. Just like that accuracy, the loss value of the model also plays a major role in determining the efficiency and performance of the deep learning algorithm. The loss value of the model is also analyzed in this study and the results of the loss value analysis during both training and validation are shown in Fig. 4.

Though the loss value of the algorithm is a bit higher than 40% during the initial iterations of the training it has significantly reduced to a value lesser than 10% during the final iterations of the training. However, in the case of the validation, the loss value does not maintain a behavior. The lost value oscillates throughout the validation process yet it does not reach a higher value than 15% after a few epochs. After training and validation, the model is tested to find the final accuracy and the loss value. The results of this testing are shown in Fig. 5.

From Fig. 5 can be seen that the accuracy value is close to 96% and the loss value is approximately 11%. The said accuracy value is said to be one of the best accuracy values in the field of deep learning and image processing. As for the lost value, it is so small that it cannot be considered important. As the test results of good enough, this deep learning model is deployed into a mobile application.

This application allows the user to upload an image of his/her teeth analyze it and predicts whether the person is affected by a dental cavity or not. The homepage of this website is shown in Fig. 6. The application consists of the name of the application at the top.

Below that, an upload image button is found to allow the user to upload an image of his or her teeth. Once the image is uploaded the CNN model analyses

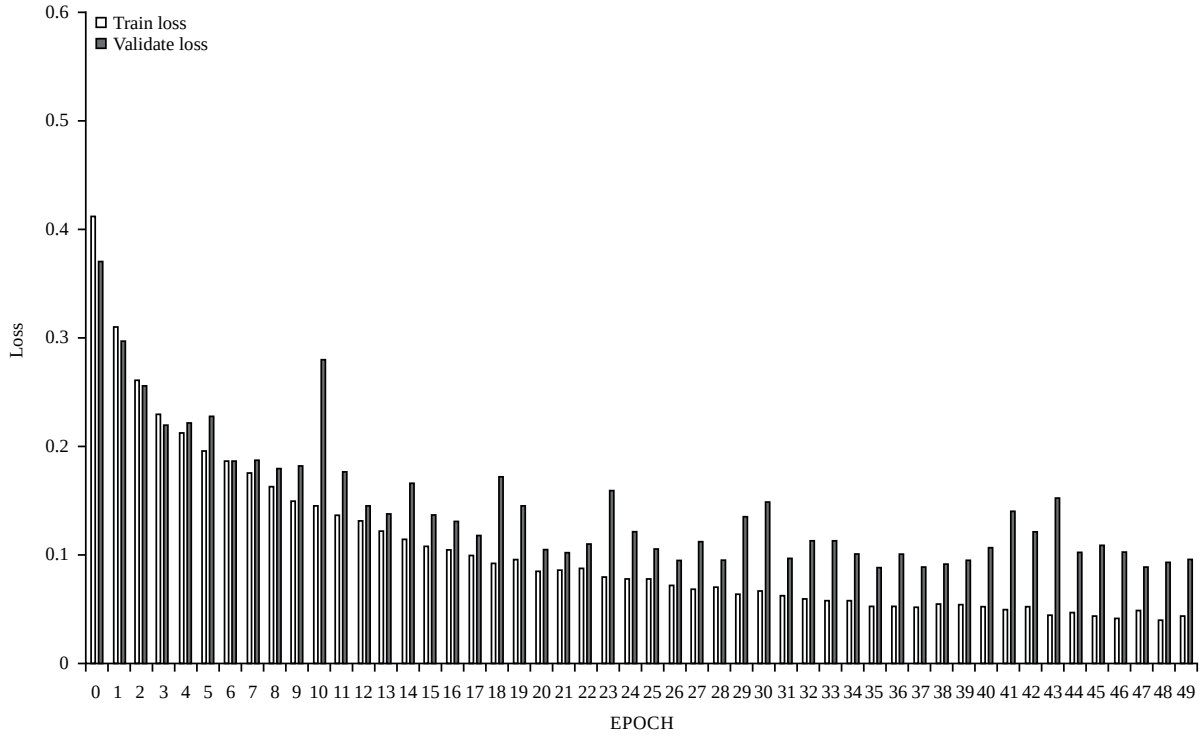

Fig. 4: Loss graph of the algorithm

```
model.evaluate(test_images)[1]

22/22 [==============================] - 14s 617ms/step - loss: 0.1145 -
accuracy: 0.9659
```

Fig. 5: Test results

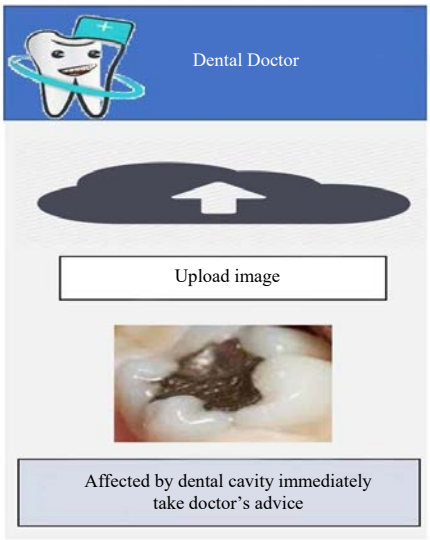

Fig. 6: The working website

the uploaded image for the dental cavity. In the case of the image shown in Fig. 6 the user is affected by the dental cavity and the CNN model correctly predicts it. The output is displayed with the alert message saying "Affected by the dental cavity. Immediately take doctors' advice".

CONCLUSION

Images of a human tooth, both with a cavity and without, are collected from Kaggle as a dataset. An equal number of photos of each category are taken for testing, training and validation from each of the three sections of this data set. Following that, three preprocessing techniques-image resizing, image rescaling and image augmentation-are applied to the selected images. Convolutional neural network technique is used concurrently to create a deep learning model. The preprocessed data set is then used to train this model. Accuracy and loss are used to evaluate the training's outcomes. The values are also tabulated to comprehend how the model behaves. The same steps are followed for validation as well. The results of both training and validation are analyzed and plotted into a bar graph. The results of the training and validation prove that the model is capable of analyzing the image and predicting the presence of dental cavities just by reviewing the image once. Both the training and the validation prove to produce a higher accuracy value and a very low loss value. Followed by training and validation the model is also tested for one last time. The final accuracy of the model is calculated as 96% and the loss value is 11%.

As the values of accuracy and loss of found to be satisfactory, this deep learning model is deployed into a mobile application. The working of the application is also tested. In the future, the mobile application can be updated with the addition of a few features. The features include the prediction of other dental diseases which includes but is not limited to the dental cavity, calculating the seriousness of the cavity.

Validation from each of the three sections of this data set. Following that, three preprocessing techniques-image resizing, image rescaling and image augmentation-are applied to the selected images.

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