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Generation of Teeth Caries Features for Human Dental Caries Classification

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Abstract:
Many dental diseases are experienced by humans, one of which is dental caries. There are three types of human dental caries, namely: email caries, dentin caries, and pulp caries. Dental caries features can be used as an object to develop a feature reference as data learning process. Caries detection, as known as segmentation steps in Matlab, is an important part. This study focuses on the detection and identification of caries disease in human teeth using two dimensional images and every image dataset that has a number of pixels between 374x288 and 672x514 pixels with an image resolution of 96 DPI. The original data was processed using Matlab language through three stages of the process: the preprocessing stage, the process of extracting dental caries features, and the process of building learning or reference data. This research aims to develop a dental caries feature extraction process and a feature learning process to generate reference features from dental caries. The result of this research was a developed generation of tooth features, which by calculating the caries area is 1023.25 pixels (270.7375 mm2) and the average value of the distance between email caries and the nerve canal is 64,635 pixels (17.1025 mm), dentin caries is 1461 pixels (386.555 mm2) and the average between dentin caries and the nerve canal is 38.445 pixels (10.1725 mm), pulp caries is 3783.5 pixels (1001.053 mm2) and the average between caries pulp and the nerve canal is 32.2125 pixels (8.525 mm). The references were to features for classifying human dental caries.

Keywords:
Dental Image;
Detection;
Features;
Learning Data;
Dental Caries;
Periapical Radiograph;

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1. INTRODUCTION

Imaging technology in the medical field is used to analyze data sets related to health data. Medical imaging in fields such as ophthalmology, cardiology, gynecology, orthopedics, periodontics, and neurology is increasingly playing an important role. Oral disease diagnosis in dentistry has used image processing actively in recent years. Intraoral and extraoral radiography is a diagnostic technique used in dentistry. Various types of dental infections can be identified and found using this imaging system. Using dental radiographs, experts can detect a number of diseases such as: dental caries, gum disease, abscesses, and others [1].

An image is a representation of the information contained therein so that the human eye can analyze and interpret the information in accordance with the expected goals. Image information content can be divided into two parts, namely basic information and abstract information. Basic information is information that can be processed directly without the need for special knowledge. This basic information is color, shape, and texture. Abstract information is information that cannot be processed directly except with the help of additional special knowledge. An image can be defined mathematically as a two-dimensional function f(x, y), where x and y are the spatial coordinates (plane) and f is the color intensity value at the x and y coordinates.The values of x and y are all finite values [2].

A radiograph is a tool to provide treatment solutions to patients by doctors in diagnosing a disease. The use of radiographs can display a lot of information contained in various diseases in the patient's body, including detecting various forms of bone, including fractures and other bone abnormalities, so that it can help provide treatment solutions that suit the needs. Detection of dental caries can also be done using this technique [3].

There are two types of radiographic techniques, namely intraoral radiographic techniques and extraoral radiographic techniques. An intraoral radiograph technique is a technique for examining teeth and tissues around the teeth using radiographs placed in the patient's oral cavity. One of the intraoral radiographic techniques is the periapical radiograph technique, which is a radiographic technique that clearly displays four teeth as a whole, with bone and surrounding tissue [4].

A dental image is a part of the data that is used to assist in detecting a dental disease. Dental images are obtained from x-rays, which can now be in the form of softcopy or files in *BMP and *JPG file formats. Dental x-ray images are usually used to identify various problems related to dental, mouth, and jaw diseases [5].

Teeth are one part of the oral cavity. The main functions of teeth are to chew food, give shape to the mouth, and also be used for speech. The main parts of a tooth are the crown and root. Each tooth is an organ consisting of three layers, namely email, dentin, and pulp. Dental caries is one of the chronic dental diseases that exist in humans and is one of the most common global dental and oral health problems in the world today. Worldwide, about 2.43 billion people (36% of the population) have dental caries in their permanent teeth, while in baby teeth, about 620 million people, or 9% of the population, have dental caries [6].

Caries is a disease of the teeth that is often experienced by humans. Dental caries can affect humans in various ways, namely through toothache, infection, or stomatognathic dysfunction. Signs and symptoms of caries differ depending on the

location and area of caries experienced. Dental caries based on the location and area of the tooth layer are divided into three, namely: email caries, which is visible caries with loss of the surface of the enamel, dentinal caries, which is visible caries with loss of radiopacity of dentin, and pulpa caries, which is visible caries due to extensive damage to the canal nerve. Dental caries based on the tooth surface is divided into two, namely recess and fissure caries, and smooth surface caries [7].

The selection of features from a number of variables contained in the available datasets can help improve the performance of the algorithm model that will be used so that it is faster. This feature will later be extracted so that it gets features that will be used for the development of the classification algorithm [8].

Classification is a group formed from the results of systematically arranging datasets based on categories of features. Image classification is formed to reduce the difference between the ability of the machine (computer) perspective and the ability of the human perspective. Image classification builds image data groups as reference data for machine learning based on the results of feature extraction [9].

Image processing uses color features which are important features. It is common in determining an object of research because it is not sensitive to size, rotation, zoom, and image. The features in the image are divided into two, namely texture features, which contain a collection of pixels from the image that have certain characteristics, shape features use region-based and contour-based methods. The contour method performs feature calculations from its boundaries regardless of its contents, while the region or area method performs feature calculations from the entire region or area [10].

Learning data or reference data is an in-depth study of image data that will find in-depth knowledge of the image data. Classification is easily done by humans directly but will be a major problem if done by machines. This learning data, or reference data, that will be used for machine learning from an image object with an unknown pattern is compared with how to detect it so that the right category is found and can be used in the classification process [11]. This research will build the features data reference that can be used for machine learning from an image object. This result will help to identify dental caries and make the identification process fast.

2. METHOD

Processing stages to obtain caries dental features and generate reference features are: preprocessing stage, caries extraction features stage, and stage of building learning data or dental caries reference. This research has obtained ethical approval from the medical faculty of Padjajaran University with ethics number 0620080779. Scientific research has stages of a scientific approach that is used to gain knowledge, which can be in the form of steps, methods, or procedures using methods that are clearly described objectively, so that this scientific research is produced and can be used and be held accountable [12]. Reference caries features were developed from multiple individual features from known dental images based on expert opinion (learning data). These stages can be seen in Figure 1.

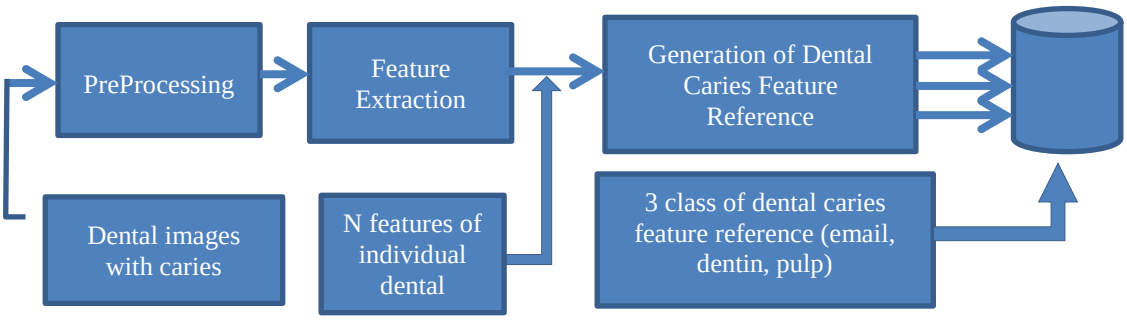


Figure 1. Dental Caries Features Generation Schema

The first stage of the process carried out is the preprocessing stage, because the available dataset is raw data taken from different sources or devices and data formats, so the existing data still has noise or data, others that is not needed. The data is processed first before entering various algorithms for use in research [13].

The second stage is the stage of the dental caries feature extraction process, where the results of the preprocessing process are used as an input. The extraction process can be done after detection, which is a process to distinguish the object of research from the background of other objects, so that the difference can be seen [14].

The third stage is the stage of the process of building dental caries feature references (learning process using learning data). The results of the caries extraction process stage are processed to obtain references that will be used for the classification process. This reference data becomes a data group for the process of determining an object's correct category by the machine [15]. All dental images in this study or dental image dataset are categorized by dental caries disease, namely email caries, dentin caries, and pulp caries.

2.1 Periapical Image Data of Human Teeth

This study used a collection of test data obtained from the patient's original tooth image which was used as input data. The original image of the patient's teeth used is a periapical image (Periapical Radiograph) in the form of a file in *.BMP or *.JPG format and includes a two-dimensional color image stored in three RGB channels. The number of pixels of dental images is between 374x288 to 672x514 pixels, with an image resolution of 96 DPI.

The entire original tooth image dataset used is Periapical Dental X – Ray from the radiology installation section of the Dental and Oral Hospital (RSGM) Universitas Padjadjaran Bandung. Figure 2 is an example of a periapical image of a healthy tooth and a tooth with caries.

There are two explanations related to dental image, namely teeth with black markings are healthy teeth, while teeth objects with red marks are identified as having caries, see Figure 2. In this study, twelve (12) human tooth periapical data sets were used, with the following details: four (4) periapical data for teeth with email caries, four (4) periapical data for teeth with dentin caries, and four (4) periapical data for teeth with pulp caries. Table 1 is a picture of twelve dental periapical image test data.

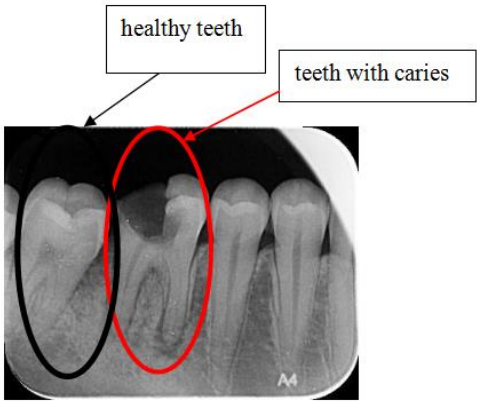


Figure 2. Periapical image data of healthy teeth and teeth with caries (Source: Radiology Installation of RSGM Padjadjaran University Bandung)

Table 1. Original periapical image of human teeth (Source: Radiology Installation of RSGM Padjadjaran University Bandung)

1.	Original image of caries email	Image of caries email 1a	Image of caries email 1b
			
2.	Original Image of caries dentin	Image of caries dentin 2a	Image of caries dentin 2b
			
3.	Original image of caries pulp	Image of caries pulp 3a	Image of caries pulp 3b
			

Table 1 is a table of original periapical images of human teeth, which contains three groups of periapical images. The first group is original periapical images of human teeth with email caries: Caries email image 1a, Caries email image 1b. The second group of original periapical images of human teeth with dentinal caries

includes: dentin caries image 2a, dentin caries image 2b. The third group is the original periapical image of a human tooth with pulp caries: caries pulp image 3a, caries pulp image 3a. Training data from this research consists of the development of general features of dental caries that can be used in dental classification.

2.2 Preprocessing Stage

The preprocessing stage for caries detection is to convert data from a two-dimensional color image (row/height, column/width) that is stored using three channels, Red, Green, and Blue (RGB), into a grayscale image with one channel. The process begins by entering the original image data as input data and then checking that the data is included in the color image or not, and how many channels it has. The entered image is checked for how many channels it has. If it has three channels, then the image conversion is carried out into one grayscale channel (imbin), but if the image entered already has one channel, it is immediately entered into the next process (imbin).

The conversion algorithm from a Red Green Blue (RGB) color image to a greyscale image is:

1. Read the original image
2. Get information about the channel in the periapical input image, if the input image is a single channel image, then go to number 4. The input image has three channels, then go to number 3
3. Change the three-channel input image to a single-channel input image
4. Save the image input single-channel (imbin)
5. Show the input image from one channel.

2.3 Feature Extraction Stage

The process from periapical images of human teeth is to calculate the caries area of the tooth, which is to calculate the caries area of the email, the area of caries dentin and the area of the caries pulp. The next step is to calculate the distance between each caries area and the dental nerve canal, namely the distance from the caries email area to the nerve canal, the distance from the caries dentin area to the nerve canal, and the distance from the caries pulp area to the nerve canal. Feature extraction is the step of training data to get knowledge from the data and can be used in the next process.

The algorithm for determining the image of the dental caries detection area by determining the seed point (SP) of the growing region (RG) is:

1. Read the resulting image with the selected ROI and region growing (RG).
2. Show the image of the caries detection area.
3. Calculate the caries area in the caries area image with the region growing.
4. Calculate the distance from the caries area to the nerve canal (pulp).

2.4 Generation of Feature Reference

The process of determining the study data or dental caries reference will later be used as data to support the classification process of caries. Dental image data that has been identified as caries by experts will be processed using Matlab prototypes, namely: twelve (12) reference data consisting of four (4) data on teeth with email

caries, four (4) data on teeth with dentin caries, and four (4) data on teeth with pulpal caries. The process is carried out to obtain learning data or references from processing the original dental image data using the Matlab program on the twelve-learning data, namely the area and distance of the caries area from the nerve canal. The results are: the results of processing data from the calculation of the area of four teeth with enamel caries, the results of processing data from the calculation of the distance from four teeth with email caries to the nerve canal, teeth with dentin caries to the nerve canal, the results of processing data from the calculation of the area of four teeth with pulp caries and the results of the processing of the data from the calculation of the distance between four teeth with caries pulp to the nerve canal.

Actually, this stage is a training process to obtain feature reference based on statistical calculation from known image data according to expert opinion. The testing process is the stage to obtain the accuracy of the classification algorithm, and this stage will be conducted in the next step.

3. RESULTS AND DISCUSSION

3.1 Pre-processing stage result

In the programming language Matlab, an algorithm is implemented to convert the input image color RGB three-channel into the input image greyscale one channel, and the image grayscale conversion results are shown in Table 2.

Table 2. Periapical Image Resulting From The Preprocessing Process (Source: Radiology Installation RSGM Padjadjaran University, Bandung)

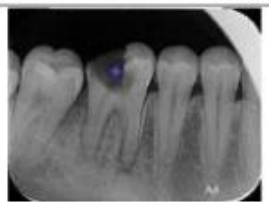
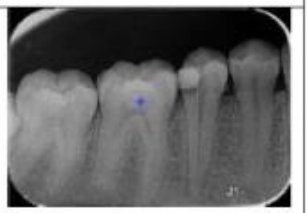
1.	Image of preprocessed image of caries email	Image of caries email 1a	Image of caries email 1b
			
2.	Image of preprocessed image of caries dentin	Image of caries dentin 2a	Image of caries dentin 2b
			
3.	Image of preprocessed image of caries pulp	image of a caries pulp 3a	image of a caries pulp 3b
			

Table 2 is a table of periapical images resulting from the preprocessing process. It contains three groups of periapical images, namely the first group of periapical images resulting from the preprocessing process with caries email: email caries image 1a, email caries image 1b. The second group of periapical images results from the preprocessing of dentinal caries: dentin caries image 2a, dentin caries image 2b. The third group of periapical images resulting from the preprocessing of pulp caries includes: caries pulp images 3a, caries pulp images.

3.2 Individual Dental Caries Feature

The results of the caries detection process by calculating the caries area and calculating the distance from the caries area to the nerve canal can be seen in Table 3. The details of calculating the result for the caries area and calculating the distance from the caries area to the nerve canal can be seen in Table 4, Table 5, and Table 6.

Table 3 is a table of images resulting from the caries detection process, which contains three groups of periapical images, namely the first group of periapical images resulting from the caries detection process with email caries: email caries image 1a, email caries image 1b. The second group of periapical images resulting from the caries detection process with dentinal caries are: dentin caries image 2a and dentin caries image 2b. The third group of periapical images resulting from the caries detection process with pulp caries are: pulp caries image 1a, pulp caries image 2a, pulp caries image 3a, and pulp caries image 4a.

Table 3. Periapical image of the caries detection process (Source: Radiology Installation of RSGM Padjadjaran University Bandung)

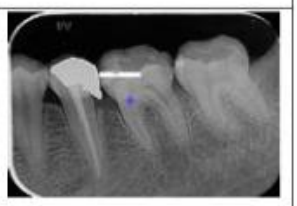
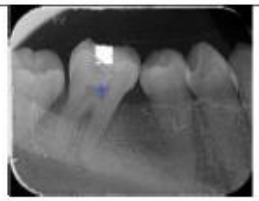
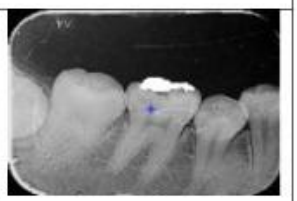
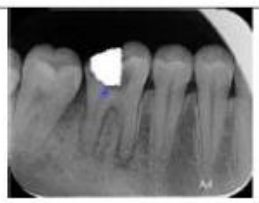
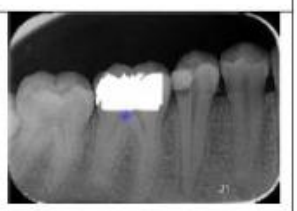
1.	Image of caries email detection process	Image of caries email 1a	Image of caries email 2a
			
2	Image of caries dentin detection process	image of dentin caries 1a	image of dentin caries 2a
			
3	Image of caries pulp detection process	Image of pulp caries 1a	Image of pulp caries 2a
			

Table 4 describes the result of the average number of pixels for the caries area of the email, that is 1023.25 pixels (270.7375 mm^2) and the distance from the caries area of the email to the nerve canal (pulp), that is 64,635 pixels (17.1025 mm).

Table 4. Features of the area and distance of the tooth periapical image with caries email

No	Patient image files	Size (Pixels)	Area (mm^2)	Distance (Pixels)	Distance (mm)
1.	Karies_email_1a	1073.00	283.90	47.89	12.67
2.	Karies_email_2a	1154.00	305.33	98.49	26 06
3.	Caries_email_3a	824,00	218.02	32.76	8.67
4.	Karies_email_4a	1042.00	275.70	79.40	21.01
	The average value of caries email	1023.25	270.7375	64.635	17.1025

Table 5 describes the results of the mean values. The average number of pixels for the dentinal caries area is 1461 pixels (386.555 mm^2) and the distance from the dentin caries area to the nerve canal (pulp) is 38.445 pixels (10.1725 mm).

Table 5. Features of the area and distance of the tooth periapical image with caries dentin

No.	Patient image file	Area (Pixels)	Area (mm^2)	Distance (Pixels)	Distance (mm)
1.	Caries_dentin_1a	2080.00	550.33	69.35	18.35
2.	Caries_dentin_2a	1034.00	273.58	28.28	7, 48
3.	Caries_dentin_3a	384.00	101.60	20.81	5.51
4.	Caries_dentin_4a	2346.00	620.71	35.34	9.35
	The average value of caries dentin	1461	386.555	38.445	10.1725

Table 6 describes the results of the average number of pixels for the caries pulp area. It was shown that 3783.5 pixels (1001.053 mm2) and the distance from the caries pulp area to the nerve canal (pulp) was 32.2125 pixels (8.525 mm).

Table 6. Features of the area and distance of the tooth periapical image with caries pulp

No.	Patient image file	Area (Pixels)	Area (mm^2)	Distance (Pixels)	Distance (mm)
1.	Caries_pulpa_1a	2169.00	573.88	17.03	4.51
2.	Caries_pulpa_2a	4623.00	1223.17	18.03	4, 77
3.	Caries_pulpa_3a	3844.00	1017.06	51.74	13.69
4.	Caries_pulpa_4a	4498.00	1190.10	42.05	11.13
	The average value of caries pulp	3783.5	1001.053	32.2125	8.525

This stage produces learning data features as presented in Table 4, Table 5, and Table 6. The results of processing four (4) email caries data are made by making the average results for email caries by adding up the four email caries data and dividing it with the total number of email caries data. The results of the processing of four (4) dentin caries data were carried out to make the average results for dentinal caries by adding up the four dentin caries data and dividing them by the total number of dentinal caries data. The results of processing four (4) pulp caries data are carried out to make an average result for pulp caries by adding up the four pulp caries data and dividing them by the total number of pulp caries data. Table 4, Table 5, and Table 6 can describe that the email caries area has a minimum result and the distance is far from the nerve canal, the dentin caries area has a middle

result and the distance is in the middle too from the nerve canal, and pulp caries has a large area and the distance is near the nerve canal.

3.3.Dental Caries Feature Reference

At this stage, based on learning data features, dental caries feature references are obtained as presented in Table 7. The results of the average data become learning data or references, which are feature data that will be used in the classification process. This feature data will be used as the basis to determine whether a dental caries is classified as: email caries, dentin caries or pulp caries, or not classified as dental caries.

Table 7 describes the results of calculating the average caries area and the distance from the caries area to the nerve canal. Based on these data, the area of dentin caries is the smallest, the area of dentin caries is moderate, and the area of caries is wide, with the largest pulp. When viewed from the data, the distance from the caries area to the nerve canal is the distance from the caries area of the email to the farthest nerve canal, and the distance from the caries area to the nerve canal is moderate, for the distance from the caries area of the pulp to the nerve tract is short.

Table 7. Calculation of The Average Caries Area and Distance in Pixels and mm^2

No.	The average value of caries	Area (pixels)	Area (mm^2)	Distance (pixels)	Distance (mm)
1.	Email caries	1023.25	270.7375	64,635	17.1025
2.	Dentin caries	1461	386.555	38.445	10.1725
3.	Pulp caries	3783.5	1001.053	32.2125	8.525

Table 4, Table 5, and Table 6, are the results of the caries area and distance to the nerve for each classification (3 classes). This result is then calculated to obtain the average value as presented in Table 7. These values are used as feature references in the classification step. Other researchers used color or texture to identify caries [13-15]. This article proposes another method as a feature reference used in the classification process.

4. CONCLUSION

Processing of human dental periapical image data using Matlab prototypes from the preprocessing process, dental caries feature extraction process, and the process of building a dental caries feature reference based on learning data has been carried out. The results of the caries feature extraction process are used for the process of forming a caries feature reference of the reference tooth by using the feature area and distance of the image from email caries, dentin caries, and pulp caries. This method produces the reference data formulation, which is: by calculating the caries area of the email, the average value of email caries is 1023.25 pixels (270.7375 mm2), and the average value of the distance between email caries and the nerve canal is 64,635 pixels (17.1025 mm). The average value of dentin caries by calculating the area of dentin caries is 1461 pixels (386.555 mm2) and the average value of the distance between dentin caries and the nerve canal is 38.445 pixels (10.1725 mm). The average value of pulp caries by calculating the carious area of the pulp is 3783.5 pixels (1001.053 mm2) and the average value of the

distance between the caries pulp and the nerve canal is 32.2125 pixels (8.525 mm). The results of the caries detection process are used for the process of building dental caries feature references using the features of area and distance images of email caries, dentin caries and pulp caries.

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