# Visibility Enhancement of Digital Dental X-Ray for RCT Application Using Bayesian Classifier and Two Times Wavelet Image Fusion

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**Abstract:** This paper presents the developing of digital dental X-ray by using the wavelet image fusion and Bayesian classifier. One of the bases of such systems are generating better concepts of location of teeth and canals in dentistry applications such as Root Canal Treatment (RCT), and Boneless which are common in dental treatments. Beside, many scientific and clinical decisions need to be made on these grounds. The aim of this paper will be summarized by improving the visibility of teeth, bone and canals in digital dental X-ray. For this purpose, the Laplacian transform will be applied to the image, and then structure element along with morphological operation will be used. Afterward, the obtained image will be fused by using wavelet transform with input image and the next step will be Bayesian classifier classifies teeth and canals from achieved image. Finally, the outcome image will be fused second time to original image by wavelet image fusion technique. The proposed approach applied to the 30 dental radiographs from 30 dental patients. Experiments of this novel technique indicate promising results which demonstrate efficiency of the proposed method for improvement algorithm of the X-ray images.

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## 1. Introduction

RCT (Root Canal Treatment) is a common treatment done for the exposure of pulp. One of the major hurdles during the RCT is to find the canal of the effected tooth. The dental X-ray images are the one of the famous technique uses for better performing these dental operations [10]. Denis Laurendeau et al. in 1991 used computer-vision technique for the acquisition and processing of 3-d profiles of wax dental imprints in the automation of diagnosis in orthodontics [1]. An explanation for applying the digital image analysis for the description of periapical bone lesion in dental radiography was presented in [1]. S. Keem and M. Elbaum shown a method to detect and monitor dental caries, using light, a charge-coupled device (CCD) camera, and computer-controlled image acquisition and representations of wavelet for monitoring changes in teeth imaged with digital imaging fiber-optic trans-illuminating [3]. In [4] orthoscope - digital images in dentistry and dermatology is considered. The segmentation of the teeth from the digitized representation of a dental study model is proposed by T. Kondo et al [5]. In [6] parallelized Bayesian inversion for three-dimensional (3-D) information that is not available in a single X-ray projection image. A technique for identifying people based upon shapes and appearances of their teeth from dental X-ray radiographs proposed in [7, 8]. Also tooth dimensions in hypodontia patients, their unaffected relative and a control group measured by a new image analysis method and new image segmentation are presented in [9, 17, 18, 30, 31, 32]. Carmody D P et al. [11] has presented machine classification of dental images with visual search and 3D-FE analysis of micro-XCT dental-images shown by Flávia P. Rodrigues et al. [12]. Dale et al. (1987) used computed diametral measurements using conventional radiography and xeroradiography for making the images impeccable for canal instrumentation. Using the image processing techniques are very beneficiary regarding the area of Endodontic and other fields of dentistry. Blasković et al. [14] allow three-dimensional imaging of root canals utilizing computer images, there technique appears to be highly accurate in determining the anatomy of the root canal system and may also be applied in other fields of dental research.

Dental X-rays have been used for very long time by the dental surgeons for many diagnostic purposes. It was used by the surgeons for detecting many tumors, abscess, and jaw anomalies. Dental X-

[1] These patients were treated by Dr. Nasiha Motahir in her clinic.

rays were used not only for the diagnostic purposes but also used as the guidance for treatment of various dental problems. One of the most common dental problem solved by the aid of dental x-rays are for the exposed tooth. When the tooth is exposed it requires RCT. Diagnosis, Cleaning and shaping of the canals, and also the length determination are done with help of dental x-rays. Digital Dental x-rays nowadays improved and updated, according to the requirements of the dentists and complications of the case to be treated. Still there are certain conditions which require further improvement of the digital dental x-rays. For instance, sometime curved canals, calcified canals, and accessory canals have problems in being diagnosed or being misdiagnosed and leads to difficulty in treatment of the effected tooth.

Avinash M et al. [15] in their study used direct digital radiograph (DDR) foe measuring the length of the curved canal. In their study they recommended that DDR systems are used in lieu of the conventional radiograph technique for obtaining advantages and good results, such as reduced exposure to the radiation, ability to manipulate images for example, and adjustments enhancements etc, image acquisition, the elimination of a radiographic film and the related processing errors and easier documentation. Brüllmann et al. [16] in their study mentioned that imaging software are developed to detect the orifices of the root canal and this open the new options for the dental treatment.

In our approach, we apply the Laplacian transform. After image enhancement, image Laplacian and size are used as features to discriminate teeth and canals based on the Bayesian rule. Bayesian classifier is presented and afterwards our experimental results and conclusion.

## 2. Methodology

The proposed approach is a technique for increasing the visibility and illustration of teeth and root canals in dental radiography images. This disease is one of the most common diseases in the area of dentistry and early detection and diagnosis of this problem can significantly help to better treatment. This condition is found when the tooth became grossly caries then the tooth pulp is exposed and requires root canal treatment. Using the image processing and machine vision techniques for enhancement of teeth and canal images in the digital dental X-ray can be as important help for dentists. Such papers which represent the co-work regarding image processing and dentists are rare and especially there is no paper for helping about root canal treatment. First we apply the Laplacian filter to the original radiography image then we try to classify the teeth and canal parts by Bayesian classifiers by help of wavelet image fusion technique. The mentioned method aims to utilize Laplacian filtering for extraction of strong features to demonstrate the image components as well as extracting the edge of image components. For describing this approach, techniques which use in this project will be described as well as the relationship between them will be considered.

### *2.1 Laplacian*

The first stage consists of the extraction of features from dental X-ray images. Image intensity variations give beneficial information from the image objects. Generally, to achieve intensity variations, various filters are proposed in literature. Choosing an appropriate feature for an application is context information dependent. Here, the information of input image intensity variations is obtained from the Laplacian image. One of the most significant advantages of Laplacian among other edge detection methods is its second derivative action as a powerful mean to detect the edges. Furthermore, the provided edges using Laplacian do not need to be thinned because the zero crossings themselves define the edges location. The Laplacian operator is defined as:

$$\nabla^2 I_L(x,y) = \frac{\partial^2 I_x(x,y)}{\partial x^2} + \frac{\partial^2 I_x(x,y)}{\partial y^2} \quad (1)$$

Where $I_L(x,y)$ indicates Laplacian and $I(x,y)$ whole input image.

### *2.2 Structure Element (SE)*

After applying Laplacian in the image, morphological operation and structure element will be used. Totally, we couldn't separate morphological operation and structure element from all steps of this approach and put them to the separated block because it is joined with other parts. As it results, in the block diagram of mentioned algorithm, size variety step has been considered for structure element. It will be done as first step primary size for structure element has been determined which it fit for extraction of tooth and root canal from X-ray images. The size of structure elements are attained by experimental testing and have less variation in our database. Each object of X-ray image, it needs to have a relevant size of structure element. It means that the sizes of image objects are directly related to size of structure element. For instance, for finding some teeth, we should find a structure element which has rectangle shape or its shape more closed to a quadrangular shape. The structure element form will be changed to find other teeth and root canals in the shape of oblong. At the end of extraction of teeth pattern by means of structure element, second shape of structure elements classifies the root canals. As it is mentioned before these objects have elongated shape and oblong shape of structure element can help to extract more efficient. Applying structure element to output of Laplacian filter will be done as following steps; first, structure element apply to image, then morphological operation profile will be applied to achieved image. It will help to appear the target elements on the image. As an initial step, the primary size structure element is used to decide that which size is suitable for eliciting the dental images. This size of structural element was obtained by training set or experiment. The object of dental image (different teeth) was needed to be in applicable size of structural element. The size of the dental image object is appropriate to the size of the structural element. For instance, different stages of teeth and root canals need to have different size of structure element. Application of the structure element through the morphological operation will be done. After this, wavelet fusion and Bayesian classifier will be applied for detection and classifying the dental objects in the image.

### *2.3 Wavelet Fusion*

The fundamental approach of all fusion in multi-resolution schemes is stimulated by the human visual system being principally sensitive to changes in local contrast, e.g. the edges or corners. In case of wavelet transformation fusion all particular wavelet coefficients are combined using the fusion rule $\phi$ derived from the input images. Since, wavelet coefficients have large absolute values therefore they contain the information about the significant features of the images like edges and lines. For a good fusion a rule is to be taken, that is the maximum of the [absolute values of the] corresponding wavelet coefficients. Another advanced rule named area based selection rule is proposed in [19].

The maximum absolute value used within a window for measuring the activity of the central pixel of window. A binary decision map of same size as DWT is constructed to record the selection results which are based on a maximum selection rule, a similar method was recommended by Burt and Kolczynski [23]. Besides using a binary decision, the resulting coefficients are specified by a weighted average which supports the local activity levels in each of the images' subbands. A supplementary method called contrast sensitivity fusion is given in [27]. This method uses a weighted energy in the human perceptual domain, where as the perceptual domain is based on the frequency response, that is contrast sensitivity of the human visual system. This wavelet transformation of image fusion scheme is an addition to the pyramid based scheme which is illustrated by the same authors. Finally, a recent work done by Zhang and Blum [28] provides a comprehensive classification and comparison of multi-scale image fusion schemes.

Figure 1 expresses the fusion of two images by means of the wavelet transformation. The areas of images which are in focus provide larger magnitude coefficients within that region. An easy technique is chosen to maximize the scheme to produce the combined coefficient map. The resultant fused image produced by applying the technique of transforming the combined coefficient map by means of inverse complex wavelet transform. The wavelet coefficient images demonstrate the orientated nature of the intricate wavelet sub-bands. Each of the clocks' hands which are directing in various directions is selected out via different orientated sub-bands. Every coefficient fusion rules are applied with the discrete wavelet transformation, which can be executed with the complex wavelet transform. In this case, they should be applicable to the magnitude of the DT-CWT coefficients as they are multifaceted and complex.

Though very computationally proficient, the discrete wavelet transformation is not altered invariant. This altered invariance in wavelet transformation image fusion is important for the efficient contrast of coefficient magnitudes used by the fusion rule. Since, the magnitudes of a coefficient within an altered variant transform will not often reflect the true transforming components at this point. An altered variance within a DWT is an effect of the sub-sampling, which is essential for significant decimation. The shift invariant discrete wavelet transform (SIDWT) was a preliminary attempt to incorporate shift invariance or altered invariance into DWT by leaving all sub-sampling. The SIDWT is then completed by controlling. Also, it has been applied for image fusion as described in [25] with much better results than the standard DWT methods. The inspiration for applying the DT-CWT for image fusion is its quality of shift invariance or altered invariance along with its reduced over-completeness when evaluated with the SIDWT. The enhanced directional selectivity of DT-CWT also provides superior results than the SIDWT. The complex wavelet transform with filters in [21] are intended for superior shift invariance.

Wavelet image fusion is one of the common type of image transform fusion [19, 20, 22, 24, 25, 27, 29]. The common strategy regarding the fusion is converting to the specific domain and fusing and then transform back to present the fusing results in spatial domain. Meanwhile, fusion after transforming the input images in the fusion domain will be happened

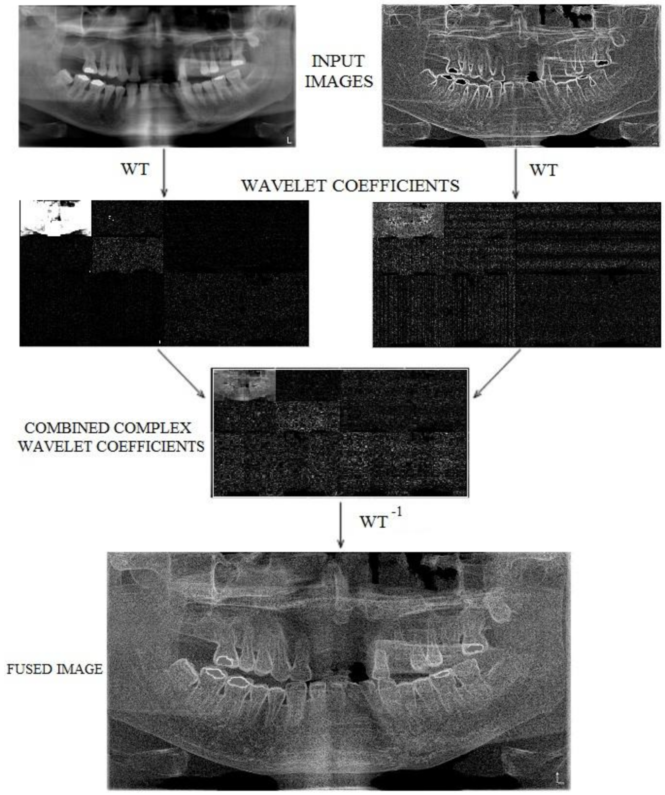


Figure 1. Recent graph is represented the wavelet fusion from the approach.

concerning pre-defined rules. Fusion using the wavelet transform is officially introduced by $\omega$. Also two distinct input images $I_o(x,y)$ as original digital dental X-ray and $I_{L-MO}(x,y)$ as output of previous parts together with the fusion rule $\phi$. $I_{WF}(x,y)$ symbolizes the inverse of wavelet transform $\omega^{-1}$ is calculated, and the final fused image which is reconstructed:

$$I_{WF}(x,y)=\omega^{-1}\left(\phi\left(\omega\left(I_o(x,y)\right),\omega\left(I_{L-MO}(x,y)\right)\right)\right) \quad (2)$$

### *2.4 Bayesian Classifier*

Previous sections was regarding application of Laplacian filter along with morphological operation, structure element, and wavelet image fusion in order to extract some objects in dental X-ray images. It has an essential role to obtain image's features and it will prepare image for classification. Based on data in the field of dentistry, for detecting the root canal as a part of teeth in radiological images should be considered. Root canals are divided into 2 types: Angular and Vertical types. The most important part of RCT is finding the root canal part from the dental X-ray images for accurate diagnosis. The proposed approach can be used for both types of root canals. Using the Laplacian filter, the selected features considering the edges and finding the teeth are angularly independent. It means that both kinds of canals will be detected by proposed method.

$\lambda$ is the feature which represents amount of the edges for detection of teeth by considering the phase of image signal that it was attained from Laplacian filter and morphological operation profile function for classifying teeth. $\gamma$ reveals features related to canals. The features for this approach are chosen in such a way that the teeth and canals detected based on each other. The advantage of this strategy is to make system independent regarding directions. The obtained information gathered for classification of the parts of teeth and canals in X-ray images.

Following explanation which considered above and from Bayesian classification rule, we have:

$$\begin{cases} C_T & S(C_{Teeth}) \\ C_{nT} & S(C_{non-Teeth}) \end{cases} \Rightarrow$$

$$\begin{cases} C_{Teeth} & if \quad P(C_T \mid \lambda) > P(C_{nT} \mid \lambda) \\ C_{non-Teeth} & O.W \end{cases}$$

$$S(C_{Teeth}) \Rightarrow P(C_T \mid \lambda) > P(C_{nT} \mid \lambda) \quad ,$$

$$S(C_{non-Teeth}) \Rightarrow P(C_T \mid \lambda) < P(C_{nT} \mid \lambda) \quad (3)$$

If $P(C_T \mid \lambda) > P(C_{nT} \mid \lambda)$, it is possible that $C_T$ or $C_{Teeth}$ belong to teeth class and $S$ shows sets of classes. The parameters used for classifying the critical bone-loss from non-critical bone-loss are $\gamma$ and we have:

$$P(C_C \mid \gamma) \geq P(C_{nC} \mid \gamma) \quad (4)$$

Where the $C_{nC}$ and $C_C$ belong to the canal and non-canal classes, respectively. $\gamma$ reveals discriminator for Bayesian classifier in the features obtained through Laplacian and related to canals. Figure shows the flowchart of mentioned approach.

## 3. Experimental Results

In this section, we demonstrate the application of proposed method to improve classification results. These approaches were applied to digital dental X-ray images and these images were obtained from 30 RCT patients whom have been treated by the dentists. Some of them had already been treated for RCT before taking the digital X-ray. Although, Superiority and novelty can not be compare with other papers because it is the first time that the root canal treatment is considered and ease the dentists operations by applying this method. Each image consists of components including teeth, gum, canals, and bones. The first step is the feature extraction by Laplacian and morphological operation functions and wavelet fusion. The second step is classification, using Bayesian discrimination function. And the next step is using wavelet image fusion for the second time with original image and outcome image. In order to the novelty of proposed approach, comparisons with the other techniques cannot be defined.

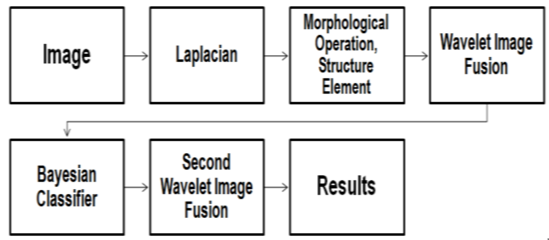


Figure 2. Flowchart of the proposed approach.

### *3.1 Property of Image Database in Testing Experiment*

To test the proposed approach and its benchmark a digital X-ray image database has been used. The image database is including 30 digital X-ray images 2860 × 1456 pixels in three color bands RGB and unit 8. The Bayesian training PDF function is obtained from marked images, namely training map. In the training map amounts of Laplacian, size, and intensity of each class was considered for evaluation. Appropriate levels of discriminated frequency, corresponding amounts of Laplacian, higher frequency components of the images

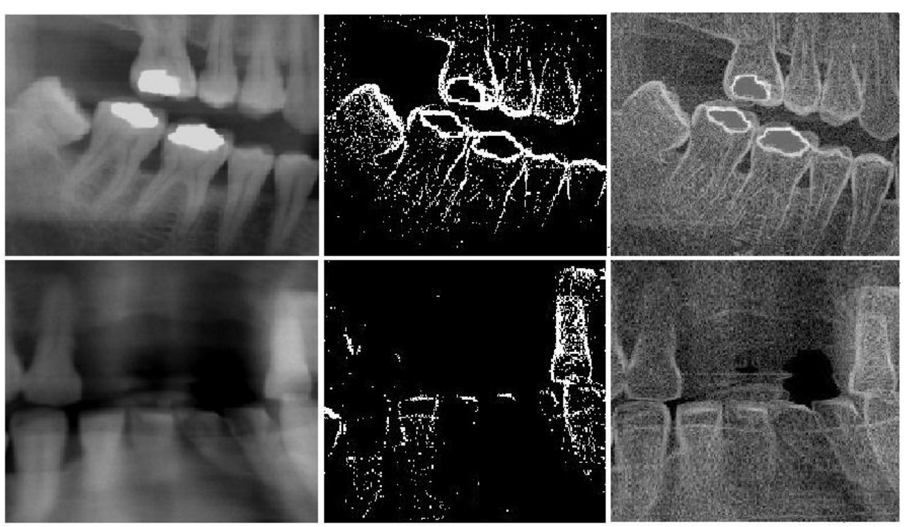

Figure 3. Two different samples from the digital dental X-ray and the output of each parts using the Bayesian classifier and wavelet fusion results have been shown in the figure. The first sample (upper one) has a good classification result. The result of wavelet fusion is significantely excellent. Whereas the second image illustrate bad classification outcome as compare with first one but the wavelet fusion has influencial improvement on the original image.

according to the teeth and lower frequency levels according to the canals and other images components which are obtained by using the training map. It is considerable that, the teeth have higher frequency components on their Laplacian edges. Furthermore, canals have smooth texture in digital X-ray images. Particularly, the most important goal of enhancement methods is improving Bayesian discriminator efficiency in teeth and canals extraction in the image. This objective is achievable by adjusting frequency components of the images. It makes the teeth and canals more intensified rather than image background, discernable and improve local contrast of the images.

### *3.2 Consequences of the Method*

The method without preprocessing step is introduced in the first part of the methodology. Bayesian discrimination function has demonstrated substantial results. However, it does not focus on adjusting high or low frequency restrictions. The $\lambda$, $\gamma$ values are 0.57, 0.55, respectively. The experimental results illustrate a complementary behavior from machine and dentist improved. Figure 1 shows the fusion before applying the Bayesian classifier to the image. the fused image will be used as an input for Bayesian classifier part. Also the classifier outcome will be again fused by original image to improve the visibility of teeth and canals for dentists in root canal treatment operations.

### *3.3 Results of Methods*

The methods without preprocessing techniques are utilized with no enhancement processes to improve the image contrast. Thus, the Bayesian discriminator results in error because some image components have similar level of intensity to the level of background intensity. The proposed algorithm uses Laplacian, morphological profile, and wavelet image fusion as a step for enhancing the image to be segmented. Adjusting parameters for enhancing the digital X-ray image is a critical task which seriously affects the amount of extraction. The second wavelet image fusion part also extensively develops the visibility of dental image. Furthermore, X-ray image has some intrinsic characteristics which make distinction with other images.

### *3.4 Synthetic problems*

A considerable synthetic problem is the Low pass filter or High pass filter behavior. They change domain description, especially in the thin teeth and canals class. For example, when we apply a low pass filter on the input images, it reduces the classification rate of the thin teeth and canal. On the other hand, the detection of bigger teeth increased. This in fact is as a result of changes in image Laplacian and reverse relationship between size of classes and frequency components.

Proposed method alters various parts of image intensity to boost the local contrast. Improvement of image contrast in regions with very low or very high intensity results in the disappearance or saturation of the level of intensity in these parts. The proposed methods were tested and showed following problems:

1) A number of teeth having the same intensity as the background can not be detected.
2) The amount of intensity in a few canals, affects classification accuracy.
3) Some fine particles in dental X-ray images increase classification errors. Moreover, these components can be erroneously classified as canals.

To overcome such problems, morphological operation (MO) as filtering step along with wavelet image fusion and other methods are used. Determining the size of the structure element (SE) is significant for designing morphological filters. Comparison is needed to determine SE size. Big sizes of SE remove the thin teeth and canals while tiny sizes of SE cannot remove the redundant particles of the thin teeth and canal (non-canal components). In this circumstance, these particles are classified as the thin teeth and canals. As it was mentioned before, the SE size needs a trade-off between small and large sizes. Also, the SE sizes depend on the resolution of the digital dental X-ray image. In this paper, the SE sizes in MO-filtering are equal to a 3-by-3 square matrix, and 1-by-4 matrix.

## 4. Conclusion

In this paper, a method for the developing of digital dental X-ray by using the wavelet image fusion and Bayesian classifier is presented. Firstly Laplacian transform applied to the image. Then, morphological profile and the structure elements enhance the images along with wavelet image fusion to increase the feature classification accuracy. Afterward, the Bayesian classifier applied to the attained feature and classified the teeth and canals in the images. Finally, the second time wavelet image fusion makes the digital dental X-ray reliable for the operation of RCT. Experiments expose promising results and the efficiency of the proposed approach, in the task of teeth and canals visibility in the outcome images. This approach will assist the dentists during the RCT dental operations.

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