

**ENHANCEMENT AND SEGMENTATION OF
DENTAL STRUCTURES IN DIGITIZED
PANORAMIC RADIOGRAPHY IMAGES**

Matheus Rodrigues Ribeiro¹, Maurício Araújo Dias^{2 §}, Ruben de Best³,
Erivaldo Antonio da Silva⁴, Cynthia Der Torossian Torres Neves⁵

^{1,2,3,4}Faculty of Science and Technology

Univ. Estadual Paulista - UNESP (São Paulo State University)

Roberto Simonsen Street, 305

Presidente Prudente, SP, 19060-900, BRAZIL

⁵Faculty of Odontology

University of São Paulo - USP

Professor Lineu Prestes Avenue, 2227

Cidade Universitária, São Paulo, SP, 05508-000, BRAZIL

Abstract: The dental radiography is one of the most useful dental exams performed by dentists and coroners, as it allows the identification of structures which are not revealed on the surfaces of the teeth. However, the gum, and the jaw, chest and clavicle bones may interfere in the exams, since in some cases, their shades can get confused with the roots of the teeth, making in difficult to identify their boundaries. Therefore, this article proposes a method for the treatment of panoramic dental radiography images, helpful for both dentists and coroners. The proposed method highlights and segments dental structures present in digitized panoramic radiography images. The method is based on using the average and the standard deviation for the highlighting, and Mathematical Morphology for the segmentation. This article presents the results achieved by applying this method. The method presented by this article helps dentists, by highlighting the dental structures present in panoramic radiographies of the mouth, and coroners, by helping in the process of individuals

Received: July 9, 2014

© 2014 Academic Publications

[§]Correspondence author

identification through the dental arch.

AMS Subject Classification: 03E99, 68U10, 62P10

Key Words: automation, mathematical morphology, panoramic radiography, enhancement, dentistry, segmentation

1. Introduction

The dental radiography is an important resource used by dentists and coroners for, respectively, taking care of oral health and identifying corpses, since it allows the identification of structures that are not revealed on teeth's surfaces. Despite of helping those professionals to do their work, generally radiographies have a lot of noise and variations of brightness and contrast. Furthermore, there is also the interference of the gums, and the bones of the face, the spine and the clavicle which are also displayed in the radiography, causing doubts about the teeth's position and their structures, as roots, canals, among others, making it difficult to identify where a teeth starts and another ends.

The most used solution to improve the quality of the radiography images is the equalization of the histogram. In [1] and [2], statistical researches were proposed to verify how satisfactory the use of histogram equalization for dental radiography images would be. The results of these articles show that in many cases they achieved success in obtaining dental information after the process of histogram equalization of the images. However, we can observe that despite of increasing the sharpness of the image, it causes noise, which can lead to wrong diagnoses.

In the case of teeth segmentation, most proposed articles focus on the problem of identifying people based on the size of teeth, their angulation and their dental treatments. In [11], Mathematical Morphology is used to identify the position of each tooth. However, the shape used to separate the teeth is a rectangle. This results, in some cases, due to the position of the roots of some teeth, to the segmented area of one teeth containing the root or the crown of another tooth.

The proposal presented by [5] is adding outlines to the teeth allowing them to stand out in the radiography. The experiments presented in this work show a relatively satisfactory result, however, despite of the process being mostly automatized, an initial human interaction is necessary to mark a point on each tooth.

In [8], the wavelet transformation and an erosion process were used to perform the segmentation of the teeth. However, the results of these processes can cause teeth's roots to be erased from the final image.

The proposal presented by [6] was the one with the best segmentation results. After an image improvement process, the watershed algorithm is applied. Thereafter, a *split* function is applied, drawing lines that go through the central positions of regions with darker shades, thus segmenting the teeth from the radiography. The crown regions were separated very well. The teeth's roots, however, in some cases, are run through by the segmentation lines. The areas that separate the teeth are not the outline of the tooth.

On the presented needs: the improvement of the quality of the teeth radiography images, the segmentation of teeth in the same images, of an automated solution with minimum interference in the information contained in the images, this article proposes a method for the treatment of dental panoramic radiography images, useful for both dentists and coroners. The proposed method highlights and segments dental structures present in digitized panoramic radiography images. It is based on using average and standard deviation for the enhancement, and Mathematical Morphology for the segmentation. This work implements, in Matlab, a method capable of improving the quality of the images and also automatically segmenting the teeth, interfering the least possible in the information present in the images, thereby reducing the limitations previously cited.

In order to clear up our proposal, this article is organized as described ahead. Section 2 contains the theoretical basis that was used in this paper. Section 3 explains how the proposed methodology was implemented. The results achieved by this work are shown in Section 4. Section 5 presents the discussions and conclusions.

2. Mathematical Morphology

Mathematical Morphology is based on the idea of performing operations that fit geometric shapes (structuring elements) on structures present in images, thereby transforming certain features of those structures [3]. The Mathematical Morphology operations used in this work were: erosion, dilation, opening and closing. Each one of those operations will be explained ahead, first for binary images, and thereafter for gray-scale images.

2.1. Erosion

Erosion is a morphological transformation that decreases the size of structures present in images. The symbol used to represent erosion is $\ominus$.

For an image A and a structuring element B , a pixel x will belong to the resulting image only if all pixels of the structuring element, translated to the x

position, fit inside of some structure present in the image A . Since all points of B must be contained in the structures present in A , we have the removal of the pixels from the borders of the structures present in the image, causing them to be reduced [7].

Erosion can be represented by:

$$A \ominus B = \{x : B_x \subset A\}, \quad (1)$$

where B_x is a structuring element B translated by x .

The steps for performing the erosion on binary images do not differ for gray-scale images. However, its mathematical representation is given by:

$$(A \ominus B)(x) = \max\{y : B_x + y \leq A\}, \quad (2)$$

where B is a structuring element and A is a gray-scale image.

2.2. Dilation

Dilation is a morphological transformation that increases the size of structures present in images. The symbol used to represent dilation is $\oplus$.

Having an image A and a structuring element B , the dilation consists of translations of the set B by x , reflected in its origin ($(\check{B})_x$), that intersect A [3].

The binary dilation is represented by:

$$A \oplus B = \{x : (\check{B})_x \cap A \neq \emptyset\}. \quad (3)$$

The steps for performing the dilation operation on gray-scale images are not different from the operation on binary images, however the dilation on gray-scale is mathematically represented by:

$$(A \oplus B)(x) = \min\{y : -\check{B}_x + y \geq A\}, \quad (4)$$

where B is a structuring element and A is a gray-scale image.

2.3. Opening

The opening operation consists of performing the erosion operation followed by the dilation operation. The result of the opening, generally, is an image with smooth contours of its structures and the absence of noise [4].

The opening is denoted by $A \circ B$, where A is an image and B is a structuring element. It is represented by:

$$A \circ B = (A \ominus B) \oplus B. \quad (5)$$

2.4. Closing

For the closing operation, first the dilation operation is executed on the image, and thereafter the erosion operation. This operation merges small areas, widens narrow regions, eliminates noise and fills faults in the contour of structures present in the image [4].

Mathematically this operation is denoted by $A \bullet B$ and can be represented by:

$$A \bullet B = (A \oplus B) \ominus B. \quad (6)$$

3. Materials and Methods

In this section we will detail the materials used and the methods applied to develop the proposal.

3.1. Materials

The proposal was coded using Matlab, running on a Dell Inspiron 5420 notebook, with an i5-3210M Inter Core Processor and 6 GB of RAM. The operating system used was Windows 7 Home Basic 64 Bits.

The images were provided by a Sirona Orthophos XG radiography machine. Those images are generated by the software provided by the machine manufacturer after the X-Rays are taken. They do not present any type of treatment. The *bitmap* format was chosen because it does not use image compression, which would cause the risk of creating false cavities in the panoramic radiography image. The *jpeg* format was tested and we observed that, due to adding white point to the image during the compression's processing, this would be a problem, since we need an image that is as compatible as possible with the reality of the patient's teeth, so an erroneous diagnosis is not given by the dentist.

3.2. Methods

This section is divided in two subsections. In the first, we explain how the sharpness adjustment for the image was developed and, in the second, we detail how the process of teeth segmentation was developed.

3.2.1. Sharpness adjustment

As a first step to adjust the sharpness of the image, we instantiated two parameters. The first one is related to the average and has a value of $cMed = 0.4$. The second one is related to the standard deviation and has a value of $cDes = 0.3$.

The greater the difference between those two factors and the closer to zero, the smaller the interference of the sharpness improvements processes will be on the resulting image. After this step, it is necessary to convert the shades of the original image in a matrix with *double* values, which represent the shade of gray of each pixel on the original image. This matrix is stored in variable *matDouble*.

The next step is calculating the average value of the gray-scale shades in the image. For this task, we use the Matlab's method *mean2(matDouble)*, using the matrix as a parameter. This method will return the average of the values of the matrix, which will be stored in variable *med*. The next step is calculating the standard deviation of the matrix. For that we will use Matlab's *std2(matDouble)* method, using the matrix as a parameter again. The resulting value of the execution will be stored in *dev*.

Now that the variables are instantiated with their due values, our code executes the processes which make the image visually sharper. First we subtract from the *matDouble* matrix the average value stored in *med*. By doing this process, we obtain a picture in the standards illustrated in Figure 1.

We can observe that now the image only has the black and white shades. Besides that, the image also presents something that we can call an "Inverted T", in a black tint, with the base of the "T" in the center of the image and the arms of the "T" at the base of the image. This "Inverted T" leaves the lower jaw and the center of the mouth regions with little visible teeth. This is due to the overlapping of the chest, the clavicle and the spine bones. In this central region, only the canine and a portion of the frontal teeth stand out and get a white tonality. The next step is represented by the following equation:

$$y = matDouble - med. \quad (7)$$

The result we obtain parting from Equation (7) will be divided by the standard deviation of the image, as shown in Equation 8, resulting in what is shown in Figure (2). The resulting image of this process shows that one of the problems created by the prior process was solved: the gray-scale shades return to the image and we can now observe the teeth with a larger contrast. However, the "Inverted T" still persists, consuming almost the whole lower jaw and the central region of the mouth. There is also an excessive brightness at the molar and premolar teeth region, almost uniting their crowns in one unique crown,

$$y = y/dev. \quad (8)$$

To solve the problems that still persist, our code applies the parameters instantiated at the beginning of its execution. First, our code multiplies the result

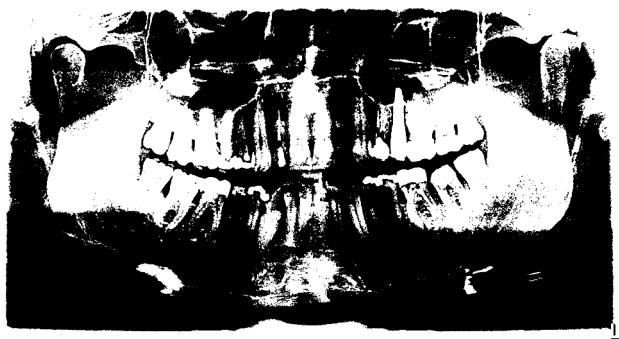


Figure 1: Result of the subtraction of the average.



Figure 2: Result of the division of Figure 1 by the standard deviation.

obtained until the present moment by the parameter relative to the standard deviation, as shown in Equation (9). With that we obtain the image shown in Figure 3.

$$y = y * cDev . \quad (9)$$



Figure 3: Result of the multiplication of Figure 2 by $cDev$.

The problem of excessive brightness on the molar and premolar teeth regions was solved. The image has a more uniform shade and a greater contrast among structures. Now we can observe each tooth individually. The next step adds the average parameter to the image, obtaining Figure 4. We can observe that the last problem, the “Inverted T”, was solved. Equation 10 represents all the last steps executed.

$$y = (((matDouble - med)/desv) * cDev) + cMed . \quad (10)$$



Figure 4: Result of the sum of the matrix of Figure 3 with $cMed$.

3.2.2. Teeth segmentation

The second functionality of our method is segmenting the teeth in panoramic radiography images, to help at the identification of corpses. To perform this segmentation, we apply Mathematical Morphology operations on the image.

After adjusting the sharpness, our code uses a jaw mask. The format of this mask allows us to partially remove the human jaw from the image. Figure 5 illustrates the shape of this mask. By applying the mask on the image, our code removes a part of the bones present in the image. On the same loop where the mask is being applied, the code substitutes the shades of the pixels in the interval $[0.50, \dots, 0.75]$ for the value zero. This way, some points of the edge of the remaining jaw are removed. After this loop, an opening function is applied, using a disk of eight pixels in diameter as a structuring element. At the end of this process, the resulting image is dilated with a disk of fifty pixels in diameter. The code converts the result of the dilation to a binary image, resulting in a second mask as exemplified in Figure 6. This second mask is applied on the image with sharpness treatment. Figure 7 is the result of the application of the second mask.

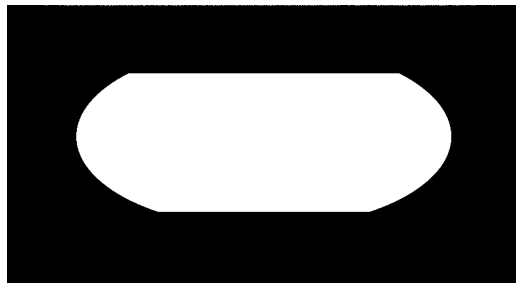


Figure 5: Mask to remove a part of the jaw from the image.

We can observe that, when those procedures are applied, our code was able to remove a large part of the jaw, and the facial and chest bones.

The code applies another pixel by pixel process on the image, as explained in the previous paragraphs, however, with another parameters. The interval of pixel shades to be substituted now varies from higher than zero and lower than 0.1250. The disk structuring element used in the opening function now has ten pixels in diameter. In the dilation function the structuring element is exchanged for a rectangle of dimensions $[60, 10]$.



Figure 6: Result of the application of Figure 5 as a mask and the processes of opening and dilation.



Figure 7: Result of the application of Figure 6 as a mask.

The result of this second pixel by pixel process is a third mask, with some areas separating some teeth, as can be seen in Figure 8.



Figure 8: Mask of the second application of the pixel by pixel process.

The application of this third mask results in an image with spaces between some teeth. Figure 9 is an example of the application of the third mask.



Figure 9: Result of the application of Figure 8 as mask.

The next step is solving the low brightness intensity in the central region, caused by the overlapping of the spine bones. Because images are always of the same size, and because the central point of a panoramic radiography of the mouth is always in the center of the image, our code increases the brightness by twenty percent of all the pixels that have a tonality lower than 0.8 and are in a rectangular region with the dimensions [250, 900, 750, 600], which represent the y position, the x position, the height and the width, respectively.

The next step divides the image in four equal and rectangular subareas, as shown in Figure 10.

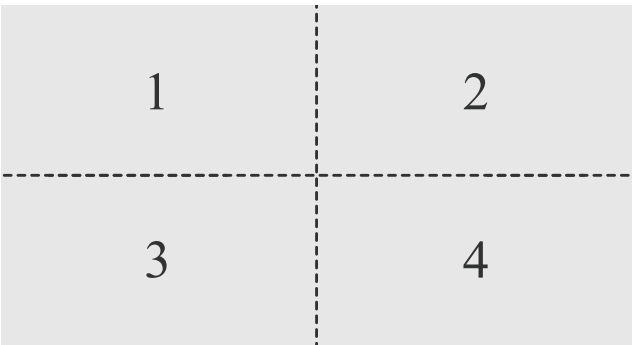


Figure 10: Illustration of how the division of the image is done.

The processing of each one of them is done in a different way. For the subareas on the left, the processing will advance line by line, from left to right, and for the subareas from the right, the processing will advance line by line, from right to left, until the middle of the image, as show in Figure 11.

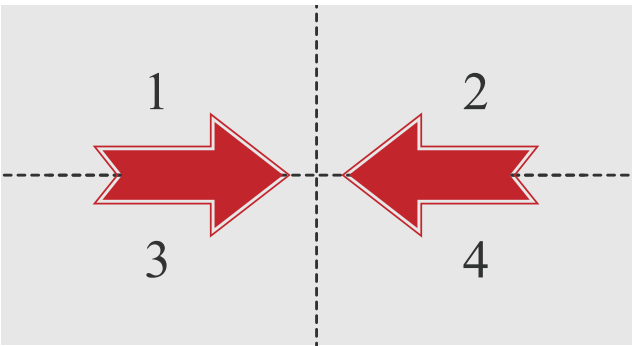


Figure 11: Segmentation advance on the horizontal lines.

In the code, the next two loops treat the left and right superior subareas. For each line, the code searches for the first pixel which intensity differs from zero. Thereafter, the code calculates the average of the next ten pixels from this line.

For the superior subareas, the code checks whether the calculated average is higher than the intensity of the base pixel added to the value 0.145 or if this average is lower than the intensity of the base pixel minus the value 0.08. While this verification is not true, in both cases, the intensity of the pixel will be substituted by zero. This way, the image will be corroded in lines until the point where there is a large intensity difference. Figure 12 shows the result of

the loops that worked on the superior subareas.



Figure 12: Result of the superior subareas processing.

This same procedure is repeated for the inferior subareas, however the values used are 0.115 and 0.04. They are lower, because the pixels from the inferior subareas have lower intensity than the pixels from the superior subareas. This intensity difference is caused by the overlapping of the bones from the chest and the clavicle. Figure 13 shows the final result of the horizontal lines segmentation processing.

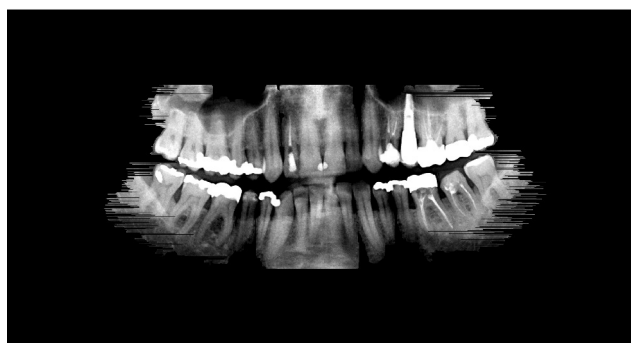


Figure 13: Result of the processing of the inferior subareas.

In the next phase, the processing advances column by column, from top to bottom in the “1” and “2” subareas, and from bottom to top in the “3” and “4” subareas, until the middle of the image, as shown in Figure 14. For each column, the code searches for the first occurrence of a pixel where the intensity differs from zero. Starting from this pixel, for each pixel in the same column, the code checks whether at least one of the next seven pixels from the same column has intensity equal to zero. If so, the intensity of the pixel prior to

the seven pixels is substituted by zero. This procedure is interrupted, for each column, when a sequence of seven pixels different from zero is found. Applying this procedure, the code is able to remove the narrow lines resulting from the application of segmentation in horizontal lines explained before. With that, the resulting image is shown in Figure 15.

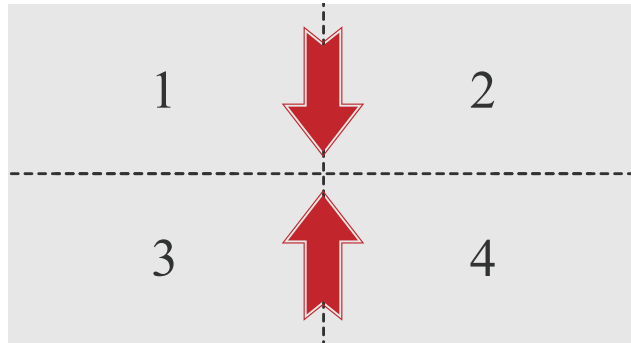


Figure 14: Column segmentation advance.



Figure 15: Example of the result of the application of two loops in the superior and inferior subareas.

As the possibility exists that those two segmentation processes have corroded a part of some of the premolar teeth, our code applies a dilation on the resulting image, using a 30 pixels diameter disk. This way, even though we lose a part of what was correctly segmented, we guarantee that no part of the tooth will be altered. After this procedure, the code transforms the resulting dilation image in a binary image, and uses it as a fourth mask on the image obtained before the segmentation in lines and columns. Figure 16 shows an example of a result of this procedure.



Figure 16: Result of the application of the dilated mask.

The next procedures are related to the reduction of the quantity of pixels around the teeth. First, the code attributes the values 2 and 0.23 respectively to two variables, *counter* and *level*, to treat the central region of the dental arch. After that, it checks all pixels of the columns in the central region of the image, to compare if each pixel is lower or equal to the value of the variable *level*. All pixels which satisfy this condition will now have intensity equal to 1, and the remaining 0. In the same iteration, it is verified if the variable *counter* has value equal to 0 and if the value of the variable *level* is higher than 0.01. If so, the value of 0.01 is subtracted from *level*, and *counter* receives the value 2. After traveling all columns of the image, our code subtracts 1 from the variable *counter*.

The same procedure is repeated to treat the peripheral regions of the dental arch, however with the values 7 and 0.01 attributed respectively to the variables *counter* and *level*. The code verifies all pixels in the columns in the peripheral region of the image, to compare if each pixel is lower or equal to the value of variable *level*. It also verifies if *counter* is equal to zero and if *level* is lower than 0.99. If yes, 0.01 is added to *level* and *counter* receives value seven. After totally verifying each column of the image, our code subtracts one of the *counter* variable.

The procedures cited above create a new mask, the fifth. The code applies an opening function on this fifth mask, with a thirty pixels in diameter disk structuring element, to generate another mask, the sixth. Thereafter, our code subtracts the sixth mask from the fifth mask, and applies a *not()* function on the result of this subtraction to create the seventh mask. The seventh mask is applied on the dental arch image to reduce the amount of pixels around the teeth. All there procedures are necessary to not segment the teeth more than

necessary. Figure 17 illustrates an example of the result of applying this seventh mask.

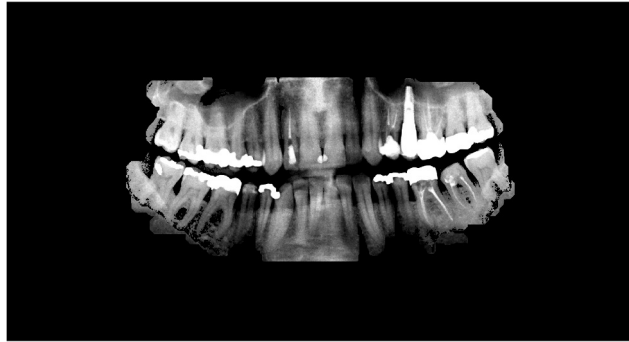


Figure 17: Result of the application of the seventh mask on the image of Figure 16.

Observe that the result of this procedure is an image with the more corroded regions between the teeth roots. However those same regions still have noise. To remove this noise, our code applies another mask, the eight, on the image of the teeth. This eight mask is created applying an opening function on the image, with a six pixels diameter disk structuring element. An example of the result of this operation is shown in Figure 18.



Figure 18: Result of the application of the mask obtained from the opening of Figure 17.

After so many mask applications and tonality adjustments, the central region of the image suffers some intensity changes. Those changes may harm the procedures of corpses identification and dental diagnoses, therefore our code performs the process of adjusting the intensity in the central region. This way,

each pixel of the central region of the image with intensity lower than 0.8 has its intensity multiplied by 1.2. After this procedure, all the intensities of the pixels of the whole image are divided by 1.3, so the image gets more homogeneous.

All values commented in Section 3 where determined empirically. Figure 19 shows the final result of the process of teeth segmentation. Figure 20 shows the panoramic radiography of the teeth source image, to be visually compared with Figure 19.

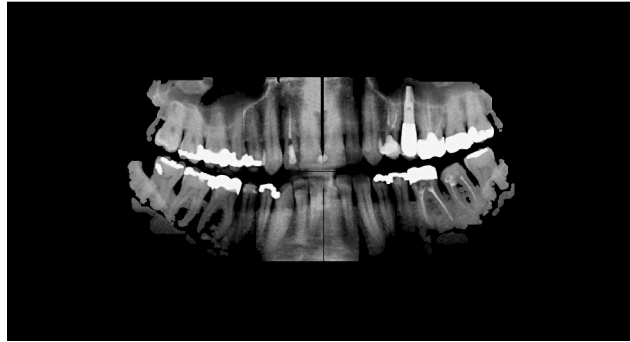


Figure 19: Result of the process of teeth segmentation.



Figure 20: Source image of the panoramic teeth radiography.

4. Results

In the experiments, we used an panoramic radiography images database from different people with different ages, however all obtained from the same equipment. Those radiographies were saved as images in *bitmap* format by the software made available by the equipment manufacturer, without going through

processes of compression or treatment. The capacity of our code to segment the teeth present in those panoramic radiography images was validated quantitatively using the metric described ahead [10], [9]:

$$M_r = (VP_r + VN)/(VP_r + VN + FN_r + FP_r). \quad (11)$$

In Equation (11), we have: M_r as the success rate; VP_r is the quantity of true positives, which correspond to the pixels which are being represented as teeth in the final image and really are teeth; VN is the quantity of true negatives, which correspond to the pixels that are represented as background in the final image and really are from the background; FN_r is the quantity of false negatives, which correspond to the pixels on the final image that should belong to the teeth, however are representing the background; FP_r is the amount of false positives, which correspond to the pixels that should represent the background, however are representing anything else.

Based on the metrics of Equation (11), our method obtained an average success rate for teeth segmentation of 90%. On the other hand, the enhancement of the dental structured happened in 100% of the cases.

Note that our method, automatically, treated the panoramic radiography images successfully, for both teeth segmentation using Mathematical Morphology, and for highlighting dental structures, using average and standard deviation, interfering the least possible in the information present in the images.

5. Discussion

This article proposed a method for the treatment of panoramic dental radiography images, useful for both dentists and coroners. The proposed method highlighted and segmented dental structures present in digitized panoramic radiography images. It used average and standard deviation for the highlighting, and Mathematical Morphology for segmentation.

Our method reduces limitations found in some other publications in scientific literature. In [1] and [2], the presented procedure leaves noise in the images, which can lead to incorrect diagnoses. Our work proposed a way to enhance the dental structures, interfering the least possible in the present information in the radiography image. The proposal made by [11] segments the teeth in the image using rectangles. This can cause the segmented areas of one tooth to contain the root or the crown of another tooth. Our method seeks to segment the teeth following their natural contours. In [5], despite of the segmentation being mainly automatized, an initial interaction is necessary to mark a point on the teeth. Our method is entirely automatic. In the proposal of [8], the used

transformations eliminate several roots from the teeth on the final image. Our method reduces the elimination of roots of the teeth. In [6], we can observe that in some cases the roots of the teeth are overridden by the segmentation lines from the teeth. Our work does not add any element which can interfere in the image. The proposal of this work presented an average success rate for the teeth segmentation of 90%, and it reduces the limitations present in the previously mentioned publications.

The contributions of this work are: automatizes the highlighting and the segmentation of dental structures in radiography images; excludes the necessity of a manual treatment of the radiography images, allowing more time for dentists to exercise their profession; contributes with faster and more precise diagnoses, because the dental structures are highlighted and segmented automatically, suffering as little interference as possible; contributes to the process of identification of corpses done by coroners, because it isolates the structures which interest those professionals.

5.1. Conclusions

We can conclude that this work implemented, in Matlab, a method able to improve the quality of digital images of dental panoramic radiographies and also segment the teeth, everything automatically. We also conclude that the method proposed in this work interferes as little as possible with the information present in those images, and reduces limitations presented in other scientific works.

We intend to perform future works so improvements can be implemented. For example: the gum and jaw areas that surround some of the teeth must be removed; totally removing the problem caused by the overlapping of the chest and spine bones in the dental panoramic radiography; implement the program in a language that can reach faster processing speed and can be freely distributed.

References

- [1] S.A.B. Ahmad, M.N. Taib, N.E.A. Khalid, and M.N. Taib, The effect of sharp contrast-limited adaptive histogram equalization (sclahe) on intra-oral dental radiograph images, In: *IEEE EMBS Conf. on Biomedical Engineering and Sciences (IECBES)*, IEEE, Kuala Lumpur (2010), 400-405. DOI: 10.1109/IECBES.2010.5742270.
- [2] S.A.B. Ahmad, M.N. Taib, N.E.A. Khalid and H. Taib, Analysis of image quality based on dentists perception cognitive analysis and

- statistical measurements of intra-oral dental radiographs, In: *Intern. Conf. on Biomedical Engineering (ICoBE)*, IEEE, Perlis (2012), 379-384. DOI:10.1109/ICoBE.2012.6179042.
- [3] E.R. Dougherty and R.A. Lotufo, *Hands-on Morphological Image Processing*, SPIE Publications, Washington (2003).
- [4] R.C. Gonzalez and R.E. Woods, *Digital Image Processing*, Prentice-Hall, Upper Saddle River (2007).
- [5] A.K. Jain, H. Chen and S. Minut, Dental Biometrics: Human Identification Using Dental Radiographs, In: *4th Intern. Conf. on Audio and Video-Based Biometric Person Authentication (AVBPA)*, LNCS 2688, Guildford (2003), 429-437. DOI:10.1007/3-540-44887-X_51.
- [6] Hui Li, Guoxia Sun, Huiqiang Sun and Wei Liu, Watershed algorithm based on morphology for dental x-ray images segmentation, In: *IEEE 11th Intern. Conf. on Signal Processing (ICSP)*, **2**, IEEE, Beijing (2012), 877-880. DOI:10.1109/ICoSP.2012.6491720.
- [7] M.S. Nixon and A.S. Aguado, *Feature Extraction & Image Processing for Computer Vision*, Elsevier, Oxford (2012).
- [8] N. Patanachai, N. Covavisaruch and C. Sinthanayothin, Wavelet transformation for dental x-ray radiographs segmentation technique, In: *8th Intern. Conf. on ICT and Knowledge Engineering*, IEEE, Bangkok (2010), 103-106. DOI:10.1109/ICTKE.2010.5692904.
- [9] A. Prati, I. Mikic, M.M. Trivedi and R. Cucchiara, Detecting moving shadows: algorithms and evaluation, *IEEE Transactions on Pattern Analysis and Machine Intelligence*, **25**, No 7 (2003), 918-923. DOI:10.1109/TPAMI.2003.1206520.
- [10] R.J. Radke, S. Andra, O. Al-Kofahi and B. Roysam, Image change detection algorithms: a systematic survey, *IEEE Transactions on Image Processing*, **14**, No 3 (2005), 294-307. DOI:10.1109/TIP.2004.838698.
- [11] E.H. Said, D.E.M. Nassar, G. Fahmy and H.H. Ammar, Teeth segmentation in digitized dental x-ray films using mathematical morphology, *IEEE Transactions on Information Forensics and Security*, **1**, No 2 (2006), 178-189. DOI:10.1109/TIFS.2006.873606.