ROLE OF IMAGE PROCESSING IN DENTISTRY – A SYSTEMATIC REVIEW

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ABSTRACT

Image Processing plays an important role in many industries. One of those is 'Dentistry'. Image processing is always of great help to all dentists and clinicians for detecting and diagnosing the disease. To identify appropriate treatment the digital dental image must have better contrast of features. Usually, a dental image process is a tedious process and also a time-dragging process because normally human teeth are uneven and non-structural. Moreover, the X-ray images vary due to intensity, noise and contrast leading to more challenges in employing image processing. A dental X-ray is always pre-processed to give a good contrast image. To evaluate the dental disease, segmentation of image features plays a vital role. This paper reviews the image processing techniques, its features along with their applications and gives the comparative study about how the techniques are used.

KEYWORDS

Image Processing, X-rays, dentistry, Applications of Image Processing, Dental radiography.

1. INTRODUCTION

The General definition of "Image Processing is a method to perform operations on an image, in order to get an enhanced image or to extract useful information from it". This was first developed in 1960s, at Bell Laboratories [1]. The main aim of image processing is to enhance or to improve an image. These days dental radiographs can be taken from both inside and outside i.e., intra-oral and extra-oral which helps to detect, diagnose, treat and monitor the problem for future use. Image processing has evolved with time and now adaptive methods based on ANN are more prominent. There are many scenarios in which image processing is predominant [2]. In dental by using X-ray detection along with image processing techniques, can identify the exact location of cavity. It also helps us in finding the impacted teeth, to analyze the development of growing teeth, jaw movement and also the facial bones as they are inter connected [3]. In this work, a strategy is provided for choosing a detection algorithm that is superior to all other methods. And, rest of the paper portrays, Section II describes the different methods of image pre-processing in Section II and section III describes various methods of segmentation. Section IV concludes the paper.

2. METHODS IN PRE-PROCESSING

X-rays are a common diagnostic technique in the medical industry [4]. Different techniques of digital image processing are used on the input radiographs during the pre-processing phase. Because of the presence of different forms of electronic noise and X-ray beam statistical nature, the hospital radiographs obtained lack contrast and have embedded noise. Because of this,

David C. Wyld et al. (Eds): ARIN, CSITA, ISPR, NBIOT, DMAP, MLCL, CONEDU -2023
pp. 93-102, 2023. CS & IT - CSCP 2023 DOI: 10.5121/csit.2023.130709

generally the radiographs are preprocessed prior to analysis [5]. All medical imaging applications need image pre-processing before moving on to more complex tasks like segmentation and classification.

2.1. Image Acquisition

Image acquisition is the step of acquiring an image of any object. Dental image acquisition involves detecting the X-rays using digital detectors and geometrical setup to generate a digital radiogram. There are various X-ray imaging techniques available such as computed tomography (CT), magnetic resonance imaging (MRI) and ultrasound imaging. Each has its own benefits and drawbacks, so it is necessary to choose the right one for a particular application.

2.2. Image Resizing

Digital radiography is the conversion of an analogue image into a digital form or acquiring a digital image. It usually requires two stages: acquisition and resizing [6]. The goal of acquisition is to create a high-resolution, non-interpolated radiograph that will be suitable for subsequent preprocessing steps. However, due to their large size and high resolution, processing time for applications such as segmentation or classification are high. This necessitates the use to resize it appropriately so that it can reduce the time of computation.

2.3. Noise Removal

Medical imaging, including dental radiographs, is often plagued by image noise. There are several forms of image noise, including grainy texture, specular reflectivity, and opaque background. Grainy textures the most commonly seen type of noise, characterized by a blurry appearance and jagged edges. This noise occurs when new pixels are added to an image without removing the existing ones. Specular reflectivity and opaque background can also contribute to noise in dental radiographs. These noises can make certain areas of the image stand out and appear different from the surrounding pixels. Opaque backgrounds can be removed using techniques such as edge detection or convolutional neural networks, while specular reflectivity can be reduced by blurring the image. There are also several specific types of noise commonly seen in dental radiographs, including Poisson noise, salt and pepper noise, and speckle noise. Poisson noise is caused by the scattering of X-rays over the receptor surface, while salt and pepper noise results from high-contrast pixels scattered throughout the image. Speckle noise is a type of granular noise that results from random interference patterns in the image.

To remove these types of noise, various algorithms and techniques can be employed. For example, Poisson noise can be reduced through the use of noise reduction algorithms, while salt and pepper noise can be removed by applying median filtering or morphological processing. [7][8]. The specific approach used to remove noise in dental radiographs will depend on the type of noise and the desired outcome for the image.

$$F^{k+1} = F^k - \gamma * C * A^T * R * (A * F^k - P)$$

Wherein:

$$\begin{cases} A_{M\,x\,N} = a_{i,j}\big|_{i=[1,M],j=[1,N]} \\ C_{i,i} = \dfrac{1}{\sum_{j=1}^{M} a_{i,j}}, and\ R = \dfrac{1}{\sum_{j=1}^{N} a_{i,j}}, where\ C\ and\ R\ are\ diagonal \\ B_{i,j} = \dfrac{A_{i,j}}{\sqrt{A_{i+} * A_{j+}}}, converge\ when{:}\ B^T * B < 2, and\ (V_0^{calib} - V_{SIRT}^{GD}) < \varepsilon \end{cases}$$

where k is the iteration number, F denotes Filtererd Projection , P denotes Measured Projection, γ is a noise reduction relaxation parameter, $C = \{C□,□\}$ and $R = \{R□,□\}$ are weighted coefficients for the back-projection and correction computation of the projection, successively, and $(A*F□ - P)$ is the correction computation based on the forward projection [8]. The $B = \{B□,□\}$ is the convergence condition advocated by Byrne et al.

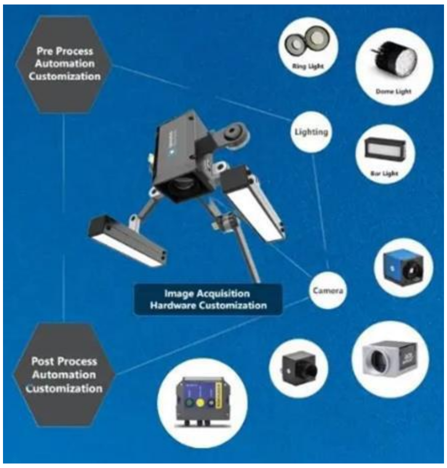


Fig: 1.1 Image Acquisition Components

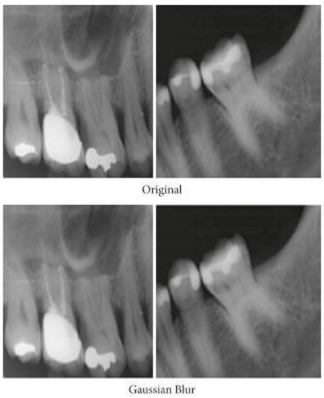


Fig: 1.2 Blur Filter Remove Noises

2.4. Image Enhancement

A crucial action in many image processing applications is radiograph enhancement. A variety of image enhancement techniques are used to increase the quality of the input radiographs [8]. The method of image enhancement may be defined as the process of making a radiographic feature more distinct. After this process, the result is an improved radiograph that functions better segmentation and automatic detection processes. There are two major categories of radiograph enhancement methods, namely those that operate in the spatial domain and those that operate in the frequency domain [9]. When working with a radiograph in the Spatial Domain, operations are done on the individual pixels. Frequency domain methods first calculate an image's Fourier transform, then apply a filter to that result, and lastly use the Inverse Fourier transform to get an improved version of the original [10].

One potential drawback of histogram equalization (HE) is that it might enhance the contrast of background noise, leading to a weaker useable signal, since it works on the overall contrast of the radiograph [10]. As a result, Adaptive histogram equalization (AHE) is implemented through a wide variety of locally-scaled window sizes, with the result that local rather than global contrast is emphasized [11].

Fig: 1.3 Dental Radiography

B. Techniques of Post-processing in Image Processing

3. Methods in Segmentation

3.1. Thresholding Technique

The thresholding technique is a simple but effective way of identifying objects and boundaries in an image. It involves choosing a value for the threshold parameter, which determines how much contrast the object or boundary have to be detected. Objects that fall below this threshold are considered to be objects and are excluded from further analysis. By default, the algorithm uses a fixed threshold value, but it can also accept user input in terms of values for both sensitivity (lowest acceptable intensity) and specificity (percentage of detections). By applying a threshold to a grayscale radiograph, it is possible to get a binary representation of the original. Space regions, or radiograph features, form the basis of this method [12]. When it comes to segmenting images, thresholding is the basic operation. Bi-level thresholding, also known as binarization [13]. The multistage adaptive thresholding algorithm is based on the idea of dividing an image into zones and assigning different thresholds to each zone. First, a global threshold is set for all zones. This means that no objects will be considered if they fall below this value. If there are no objects in any particular zone, then the second threshold (T1) will also be set to this global value and processing will terminate at this point. However, if an object falls below T0 but not under T1, it will be considered a pixel belonging to this zone and processed accordingly. This process is repeated for each zone until one of the zones has an object which falls below the second threshold

(T1). At this point, that zone's threshold will be used instead of T0 for future processing operations.

Multistage Adaptive Thresholding: Multistage Adaptive Thresholding (MAT) is a common technique used for thresholding pictures, and it works as follows:

- Preprocessing.
- It is necessary to establish two global thresholds, T0 and T1, which will be employed in the next step of the threshold value computation.
- Each image is segmented into separate areas, or zones.
- The first threshold (T0) is computed for each zone, and it identifies the smallest object within that zone.
- If there are no objects in a particular zone, then T1 will be set to the global threshold value of T0 and processing will terminate.
- If an object falls below the second global threshold (T1), then it will be considered a pixel belonging to that zone and processed accordingly. Keep in mind that if there are several small objects within a zone, the one that falls below T1 will be chosen as the object pixel.[14].

Locally Adaptive Thresholding: Thresholding, given an input radiograph f(x), may be thought of as a procedure involving checks against a function of t. (x). When an image is subjected to a thresholding process, the resulting g(x) is characterized as

$$g(x) = \int_0^1 \begin{matrix} if\ f(x) \geq 0 \\ if\ f(x) < 0 \end{matrix}$$

An item has a 1 on its label, whereas the backdrop has a 0. The threshold function is defined after a preset threshold T is calculated in the global threshold procedure.

3.2. Texture-based Segmentation

Texture-based segmentation is a very important process in dentistry because it allows the dentist to more accurately diagnose and treat dental problems. By understanding how textures are mapped onto specific anatomical features, the dentist can improve their diagnostic skills by better noticing subtle changes in surface texture. Additionally, textured images can be used as an accurate map of tooth anatomy for 3D printing or surgical planning.

Furthermore, textural analysis can be used to differentiate between healthy and damaged teeth. For example, areas of high tooth surface texture may indicate that a tooth is in good condition while areas with low surface texture may be indicative of decay or other damage.

There are various ways that textures can be captured and analyzed. The most common method is to take a photo of the inside surfaces of teeth using a dental camera or scanning laser scanner. This allows for high-resolution images which can then be easily processed into textured maps. Alternatively, photos taken from outside the mouth could also be used if they contain sufficient detail about the tooth's surface. [15].

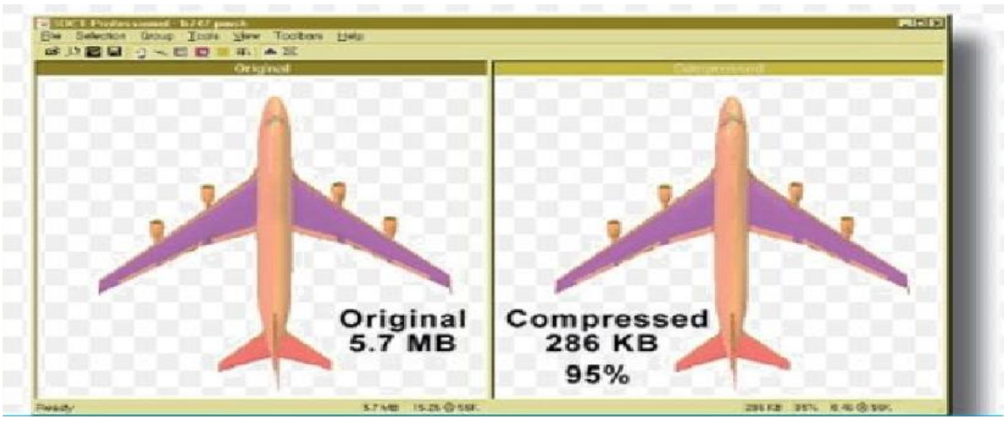
3.3. Region-Based Segmentation

The marker-controlled watershed transform is used to segment regions. Due to its capacity to generate a full partition of the radiograph, this approach has found extensive usage in medical image processing. Originating in geography, the region-based idea draws the line that establishes where a single water drop will land inside a certain area [16]. Grayscale radiographs are referred to as topographic relief in the field of mathematical morphology. If ‘I’ is a radiograph, then the intensity value of each pixel represents the elevationat that location in the topographic representation. Operating the region-based transformation independently causes the over-segmentation issue [17]. The watershed transformation has to go through a number of pre-processing steps before it can be used to get around this restriction. Incorporating a marker image into a region-based transformation in this research allowed for accurate and adaptable segmentation of closed-contour objects, with borders represented by ridges [18]. It is necessary to generate this marker radiograph in order to keep an eye on the transformation procedure before acquiring useful partitioning objects. Each linked marker is located inside an area of interest, and the radiograph is presented as a binary with two possible states (one containing just single marker points) [19].

3.4. Edge-Based Segmentation

Textural analysis can be used to identify different types of tissue and organ in an image. This is particularly useful when identifying abnormalities or diseases within the mouth, as it allows for a more accurate diagnosis.

One example of how textural analysis can be used in dentistry is during the identification of tumors. By comparing images from different angles and depths, dentists may be able to detect suspicious areas in a patient’s oral cavity that could potentially harbor a cancerous tumor. Additionally, textural analysis can also help determine the stage of cancerous cells by observing their characteristics such as density and shape. [20]. Another area where textural analysis can be helpful is in the assessment of tooth decay. By studying the differences in density and color across different areas of a tooth, dentists may be able to determine whether or not it has been affected by decay. Additionally, forensic dental investigations often use textural analysis to help identify victims who have had their teeth removed illegally. By comparison with images from before and after treatment, forensic investigators can track down suspects and recover stolen teeth. [21].



4. DISCUSSION

A Usage of Image Processing Techniques in Platform

4.1. Cephalometric Analysis

The dental use of cephalometry is known as cephalometric analysis. An examination of the dental structures of a human skull. Dentists use it regularly in the course of treatment planning. Analysis techniques used in orthodontics include the Steiner analysis and the Downs analysis. The following are some of the other options available. The link between bony and soft tissue landmarks is studied in cephalometric radiography, and the resulting analysis may be used to detect face growth anomalies before therapy, during treatment to assess progress, and after treatment to ensure treatment objectives have been fulfilled. [21] Radiographs of the skull are called cephalometric radiographs when they are obtained in a cephalometer (Cephalostat), a device developed in the United States by Holly Broadbent Sr. in 1931 [22]. The craniofacial images captured on radiographic films may then be compared and evaluated using the Cephalometer.

4.2. Forensic Applications

There are many uses in forensic technology. Like Image and video finger printing and watermarking, filtering, estimation of location and its identification [23]. As stated by [24] technically, depends on the situation, one can chose the type of application, like manual review, using watermarking etc. Those are commonly used in dead bodies after the approval of Government.

4.3. Lesion Detection

Caries is a chronic disease, usually when it is detected at an early stage it will easily be cured at a primary stage [25][26][27]. As per survey, 60-90% children, are affected and 100% adults are affected. First, it was reported since 1965 and it is in practice for more than 50 years. Only with the naked eye few of lesions can be detected. But few can be detected only with X-rays. Still the depth of lesion findings is under a talk [28]. Once can easily find the X-ray for many methods but it usually a failure when it comes to teeth-broken findings. Many Algorithms are onto the field of diagnose the actual accuracy [29]. Few algorithms have the satisfactory results but few are better. And the lesion detection in one algorithm was 41% and the other was more than that [30][31].

5. CONCLUSION

This paper provides a review of the need of dental image processing. This paper describes the various pre-processing steps from the data acquisition to image segmentation. A brief description of the requirement of image resizing to types of dental radiographic noises and their removal has been presented. Various segmentation techniques like thresholding, texture based, edge based and region based has been briefly analyzed. Application of dental image processing in various domains like Cephalometric, Forensic and lesion detection have been discussed to bring out the importance of image processing.

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