TWO DEGREE GRAYSCALE DIFFERENTIAL
METHOD FOR TEETH IMAGE RECOGNITION

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ABSTRACT

This paper proposes a new method to find a specific tooth from the digital picture of multiple teeth. The two degree grayscale differential method can significantly simplify the pattern recognition process for teeth. Compared to the popular recognition method like PCA and LDA, this method is a lot more simple, runs faster and the identification rate is better. The new approach will reduce the traditional reliance on X-ray image to get information and make dental decision. The new approach is tested and will be used in the dental decision making software to do preliminary dental advising for potential patients. An image of a molar is used as an example here; all other teeth can be processed the same way.

KEY WORDS : Image Recognition, teeth image processing, teeth recognition, pattern recognition, Matlab.

1. INTRODUCTION

The technology of medical image recognition is comprehensive and is composed of multiple subjects such as Medical, Electronics, Physics, Computer Hardware, Software and many others. The technology is highly intelligent and can acquire the targets quickly and accurately, analyze and process the target image automatically, collect the useful image information for clinical
diagnostics, which is of high value. With the development of medical digital image recognition technology, the visual dental diagnose system and dental image recognition for clinical usage have become practical now. There are many theories and methods of pattern recognition that can be used for teeth image recognition, this paper will present a new way to serve for these purposes. In this paper, we can identify a specific tooth from the picture of occlusal view of maxillary tooth surface and provide an easier and more reliable algorithm to capture object from a still picture. A set of teeth images will be used as template and saved in the template database. These templates offer 3-D information for a model tooth. By identifying the specific tooth position, a 3D tooth can be virtually planted in the position of real tooth and serve as the basis of computer assisted dental diagnosis software. This dental virtualization system can provide opportunity for patients to try various ways of orthodontics and view the new looking of them on the computer screen.

Extensive research has been done in the field of medical image recognition, such as the classification of enzymes, blood cells, tissue cells, X-ray photo analysis, etc [1]. There are also models that utilize BAYESIAN learning theory and can understand the semantics of lung cancer diagnose. These models have been successfully used in the early lung cell pathological diagnosis system (LCD) [2]. The researches on teeth imaging are the research on teeth imaging method [3] [4], the research on teeth repairment based on image processing technique [5]. Currently, it is still a virgin land doing teeth image recognition. There area few teeth recognition approach doing abroad, but none of them is perfect [6]. Most traditional biometric approaches generally utilize a single image for personal identification. Research in [6] proposes a recognition approach based on multiple frame images that are implemented in mobile devices, which can improve the recognition accuracy and to reduce computational complexity through multiple attempts. While a lot of people are doing the image recognition research based on differential image entropy or traditional recognition algorithms including PCA, LDA, and EHMM, the
recognition rate is limited by the threshold and other parameters chosen. The same method can also be used to detect tooth from the target area, by doing first grayscale difference and apply PCA later. The additional benefit of PCA can not be matched by the benefit of second difference. Also, the purpose of anterior view and those of occlusal view different, the previous is for human ID detection, a global characteristic of teeth, the later is for single ID detection. The theoretical basis of single tooth detection is that everyone’s molar (or incisor, etc) has a similar configuration, so a standard set of templates can be used to 3D-lize the 2D digital image. The performance evaluation of proposed method is performed using a molar template to match different areas in the target image. The image can be slightly in-proportional to the target, this will result some unmatchable area at the sides. Rotation compensation is not considered in this paper as it is not the focus of this paper. It can be seen that 90% or more similar can be easily reached.

2. TEETH IMAGE PREPROCESSING

In order to improve the visual effects of the image for further image recognition, dental image preprocessing is needed, mainly including color image grayscale, image smoothing and sharpening and so on. Image smoothing is to eliminate noise and improve image quality. The purpose of image sharpening is to make the teeth edges, contour lines and image details clearer. Same process will be applied to the real target image and dental model of teeth.

![Figure 1: Tooth Image Preprocessing](image-url)


2.1 Teeth imaging and Information Collection

At present, the dental imaging technology has mainly been relying on the digital X-ray imaging technology in the dental medical imaging. It can produce high-quality and high-resolution images of the teeth, can clearly show teeth, alveolar bone and periodontal structure of the fine structure of film and pathological changes in the information needed to provide clinical diagnosis by the application of digital X-ray imaging system. But the exposure to X-ray may trigger cancer, leukemia or other genetic diseases. It would do a great harm to human health. Therefore, this paper uses digital optical imaging technology to get teeth images. The imaging method has the advantages that of lower cost, fast speed of imaging, and the best results which were achieved under the required shooting condition.

Dental radiographs, commonly referred to as X-ray films, or informally, X-rays, are pictures of the teeth, bones, and surrounding soft tissues to screen for and help identify problems with the teeth, mouth, and jaw. X-ray pictures can show cavities, cancerous or benign masses, hidden dental structures (such as wisdom teeth), and bone loss that cannot be seen during a visual examination. Dental X-rays may also be done as follow-up after dental treatments.

A radiographic image is formed by a controlled burst of X-ray radiation which penetrates oral structures at different levels, depending on varying anatomical densities, before striking the film or sensor. Teeth appear lighter because less radiation penetrates them to reach the film. Dental caries, infections and other changes in the bone density, and the periodontal ligament, appear darker because X-rays readily penetrate these less dense structures. Dental restorations (fillings, crowns) may appear lighter or darker, depending on the density of the material.

The dosage of X-ray radiation received by a dental patient is typically small (around 0.005 mSv), equivalent to a few days’ worth of background
environmental radiation exposure, or similar to the dose received during a cross-
country airplane flight (concentrated into one short burst aimed at a small area).
Incidental exposure is further reduced by the use of a lead shield, lead apron,
sometimes with a lead thyroid collar. Technician exposure is reduced by
stepping out of the room, or behind adequate shielding material, when the X-ray
source is activated.

Once photographic film has been exposed to X-ray radiation, it needs to be
developed, traditionally using a process where the film is exposed to a series of
chemicals in a dark room, as the films are sensitive to normal light. This can be a
time-consuming process, and incorrect exposures or mistakes in the
development process can necessitate retakes, exposing the patient to additional
radiation. Digital x-rays, which replace the film with an electronic sensor,
address some of these issues, and are becoming widely used in dentistry as the
technology evolves. They may require less radiation and are processed much
quicker than conventional radiographic films, often instantly viewable on a
computer. However digital sensors are extremely costly and have historically
had poor resolution, though this is much improved in modern sensors.

2.2 Grayscale

In photography and computing, a grayscale or greyscale digital image is an
image in which the value of each pixel is a single sample, that is, it carries only
intensity information. Images of this sort, also known as black-and-white, are
composed exclusively of shades of gray, varying from black at the weakest
intensity to white at the strongest.

Grayscale images are distinct from one-bit black-and-white images, which
in the context of computer imaging are images with only the two colors, black,
and white also called bilevel or binary images. Grayscale images have many
shades of gray in between. Grayscale images are also called monochromatic,
denoting the absence of any chromatic variation.
Grayscale images are often the result of measuring the intensity of light at each pixel in a single band of the electromagnetic spectrum e.g. infrared, visible light, ultraviolet, etc, and in such cases they are monochromatic proper when only a given frequency is captured. But also they can be synthesized from a full color image.

The intensity of a pixel is expressed within a given range between a minimum and a maximum, inclusive. This range is represented in an abstract way as a range from 0 means total absence, black and 1 means total presence, white with any fractional values in between.

Another convention is to employ percentages, so the scale is then from 0% to 100%. This is used for a more intuitive approach, but if only integer values are used, the range encompasses a total of only 101 intensities, which are insufficient to represent a broad gradient of grays. Also, the percentile notation is used in printing to denote how much ink is employed in halftoning, but then the scale is reversed, being 0% the paper white or no ink and 100% a solid black or full ink.

In computing, although the grayscale can be computed through rational numbers, image pixels are stored in binary, quantized form. Some early grayscale monitors can only show up to sixteen (4-bit) different shades, but today grayscale images as photographs intended for visual display both on screen and printed are commonly stored with 8 bits per sampled pixel, which allows 256 different intensities i.e., shades of gray to be recorded, typically on a non-linear scale. The precision provided by this format is barely sufficient to avoid visible banding artifacts, but very convenient for programming due to the fact that a single pixel then occupies a single byte.

Technical uses in medical imaging or remote sensing applications often require more levels, to make full use of the sensor accuracy typically 10 or 12 bits per sample and to guard against roundoff errors in computations. Sixteen
bits per sample (65,536 levels) is a convenient choice for such uses, as computers manage 16-bit words efficiently. The TIFF and the PNG among other image file formats supports 16-bit grayscale natively, although browsers and many imaging programs tend to ignore the low order 8 bits of each pixel.

No matter what pixel depth is used, the binary representations assume that 0 is black and the maximum value 255 at 8 bpp, 65,535 at 16 bpp, etc. is white, if not otherwise noted.

2.3 Converting Color to Grayscale

Conversion of a color image to grayscale is not unique; different weighting of the color channels effectively represents the effect of shooting black-and-white film with different-colored photographic filters on the cameras. A common strategy is to match the luminance of the grayscale image to the luminance of the color image.

To convert any color to a grayscale representation of its luminance, first one must obtain the values of its red, green, and blue (RGB) primaries in linear intensity encoding, by gamma expansion. Then, add together 30% of the red value, 59% of the green value, and 11% of the blue value these weights depend on the exact choice of the RGB primaries, but are typical. Regardless of the scale employed 0.0 to 1.0, 0 to 255, 0% to 100%, etc., the resultant number is the desired linear luminance value; it typically needs to be gamma compressed to get back to a conventional grayscale representation.

This is not the method used to obtain the luma in the Y'UV and related color models, used in standard color TV and video systems as PAL and NTSC, as well as in the L*a*b color model. These systems directly compute a gamma-compressed luma as a linear combination of gamma-compressed primary intensities, rather than use linearization via gamma expansion and compression.
To convert a gray intensity value to RGB, simply set all the three primary color components red, green and blue to the gray value, correcting to a different gamma if necessary.

2.4 Filtering an Image

Image filtering is useful for many applications, including smoothing, sharpening, removing noise, and edge detection. A filter is defined by a kernel, which is a small array applied to each pixel and its neighbors within an image. In most applications, the center of the kernel is aligned with the current pixel, and is a square with an odd number 3, 5, 7, etc. of elements in each dimension. The process used to apply filters to an image is known as convolution, and may be applied in either the spatial or frequency domain.

Within the spatial domain, the first part of the convolution process multiplies the elements of the kernel by the matching pixel values when the kernel is centered over a pixel. The elements of the resulting array which is the same size as the kernel are averaged, and the original pixel value is replaced with this result. The CONVOL function performs this convolution process for an entire image.

Within the frequency domain, convolution can be performed by multiplying the FFT of the image by the FFT of the kernel, and then transforming back into the spatial domain. The kernel is padded with zero values to enlarge it to the same size as the image before the forward FFT is applied. These types of filters are usually specified within the frequency domain and do not need to be transformed. IDL's DIST and HANNING functions are examples of filters already transformed into the frequency domain.

Since filters are the building blocks of many image processing methods, these examples merely show how to apply filters, as opposed to showing how a specific filter may be used to enhance a specific image or extract a specific
shape. This basic introduction provides the information necessary to accomplish more advanced image-specific processing.

2.4.1 Low Pass Filtering

A low pass filter is the basis for most smoothing methods. An image is smoothed by decreasing the disparity between pixel values by averaging nearby pixels.

Using a low pass filter tends to retain the low frequency information within an image while reducing the high frequency information.

2.4.2 High Pass Filtering

A high pass filter is the basis for most sharpening methods. An image is sharpened when contrast is enhanced between adjoining areas with little variation in brightness or darkness.

A high pass filter tends to retain the high frequency information within an image while reducing the low frequency information. The kernel of the high pass filter is designed to increase the brightness of the center pixel relative to neighboring pixels. The kernel array usually contains a single positive value at its center, which is completely surrounded by negative values.

2.4.3 Directional Filtering

A directional filter forms the basis for some edge detection methods. An edge within an image is visible when a large change a steep gradient occurs between adjacent pixel values. This change in values is measured by the first derivatives often referred to as slopes of an image. Directional filters can be used to compute the first derivatives of an image.
2.4.4 Laplacian Filtering

A Laplacian filter forms another basis for edge detection methods. A Laplacian filter can be used to compute the second derivatives of an image, which measure the rate at which the first derivatives change. This helps to determine if a change in adjacent pixel values is an edge or a continuous progression.

2.5 Image sharpening

Sharpening is one of the most impressive transformations we can apply to an image since it seems to bring out image detail that was not there before. What it actually does, however, is to emphasize edges in the image and make them easier for the eye to pick out while the visual effect is to make the image seem sharper, no new details are actually created.

Paradoxically, the first step in sharpening an image is to blur it slightly. Next, the original image and the blurred version are compared one pixel at a time. If a pixel is brighter than the blurred version it is lightened further; if a pixel is darker than the blurred version, it is darkened. The result is to increase the contrast between each pixel and its neighbors. The nature of the sharpening is influenced by the blurring radius used and the extent to which the differences between each pixel and its neighbor are exaggerated.

4. TOOTH RECOGNITION ALGORITHM

\[
\frac{\partial \text{GrayVal}}{\partial S} = G_{\text{mr}} - G_{\text{st}} \quad (1)
\]

\[
\frac{\partial^2 \text{GrayVal}}{\partial S^2} = \frac{(G_{\text{mr}})_{i} - (G_{\text{mr}})_{j}}{s_{i} - s_{j}} \quad (2)
\]

Here we utilize a new approach to detect corresponding sub-image from the big pictures the image of a whole upper jaw the occlusal view of maxillary tooth surfaces. A standard tooth occlusal view of molar was treated as the template.
This template is applied to the target picture to find similar object in the target. The template window will scan horizontally first and vertically later, will eventually cover the whole target, the area is similar to our template will be found in a certain location with minimum sum of second degree difference of gray values. Because of the shape similarity of the same kind of tooth and the uniqueness of each tooth, the specific tooth picture will be found and matched with acceptable tolerance and positioned, so the model tooth can be used to replace the position in the picture and served as the basis of computer-aided dental diagnosis system.

Given a specific location a dot in the digital picture covered by template window, the difference of grayscale between template picture and the original big picture can be given like:

\[
\Delta \text{GrayVal}
\]

In which \( G_{tm} \) represent related grayscale on the template picture point, \( G_{ot} \) represent related grayscale on the target original picture point, \( \Delta \text{GrayVal} \) represent the difference of gray value, \( i \) and \( j \) are the row numbers or column numbers if the matching is evaluated on the vertical line before and after the current image points. By applying euqation (2) to the template area, we found the value is the minimum compared to those in the different area. This is because that the color of the teeth are similar each other but are very different to other tissues in the mouth. If the template picture is of the same scale to that of the original target, euqation (1) will yield satisfied result. If the two are of different scale, euqation (2) will further compress the margin difference and thus make the major part easier to be seen.

5. IMPLEMENTATION

Experiment is done over an occlusal view of maxillary tooth surfaces. Picture is turned into grayscale. A molar window is extracted and processed to be used as the template for image recognition. It is further tanned with 0.9 factor
the grayscale to test the tolerance of color difference, template and tanned pictures.

![Flow Chart for Teeth Recognition](image.png)

**Figure 2: Flow Chart for Teeth Recognition**
Two Degree Grayscale Differential Method for Teeth Image Recognition

Figure 3: Original target (occlusal view)

Figure 4: Single molar template

Figure 5: Original template and tanned picture with a factor of 0.9
Garph 1: First degree differences when scale factor is 1.0 and gray scale is 0.9

The search result using tanned picture as template, when the first degree difference forms almost a straight line along $G_{\text{difference}}=10$. When the match window is located, the sum of difference will be the minimum among all the testing windows. This means the first degree difference will be enough to identify the tooth when the target and the template are of the same scale.

Figure 6: Template and resized template

Garph 2: First degree differences when the size scale factor is 0.9
Two Degree Grayscale Differential Method for Teeth Image Recognition

**Graph 3:** Second degree differences when size scale factor is 0.9

**Table 1:** Relations between grayscale tolerance and percentage of matched points

<table>
<thead>
<tr>
<th>Tolerance</th>
<th>8</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>First difference</td>
<td>72.58%</td>
<td>74.19%</td>
<td>88.71%</td>
<td>90.32%</td>
<td>91.94%</td>
</tr>
<tr>
<td>Second difference</td>
<td>75.81%</td>
<td>77.42%</td>
<td>90.32%</td>
<td>95.16%</td>
<td>95.16%</td>
</tr>
</tbody>
</table>

It shows the resized shrunk by factor 0.9 template. This template is used to match all the windows are the first and second degree difference when the match is found, it can be see that the second degree difference gives better results. Table 1 shows the at different grayscale tolerance (8-25), the percentage of point that meet the pairing rule.

**Graph 4** shows the relation between matching similarity and tolerance. It can be seen that when the tolerance is small, like 1 to 3 unnoticeable by human eyes, matching is poor, this is because the minor noise caused by the matlab processor. It can also be seen that when the tolerance is 20, which less than 10% of the 255, the matching is approaching the maximum.
So we can get the conclusion from Table I that by using second degree grayscale difference, when the grayscale matching tolerance is 5%, which is 12.5, the percentage of point that matches is more than 90%, which is better than PCA method. The bigger deviation at the edge is caused by different size of the windows, it can be seen that this effect is restricted on the side.

CONCLUSION

As the digital imaging device and the computer recognition algorithm are improving quickly, more effort will be spent on digital image recognition to facilitate the biometrics and medical decision-making process. By using the proposed two degree differential grayscale method, we can identify the occlusal view of a single tooth from the occlusal view of multiple maxillary teeth. The two degree differential method will isolate the un-matched part of the two images and give a satisfied similar rate when the matching location is found. If the matching location is not found, this method will enhance the difference and reduced the similar rate and help the move the window away. While the method is designed for the computerized dental consulting system, the method can also be used to other pattern recognition effort in addition to the popular PCA and LDA method.
REFERENCES


