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X-Ray Image Acquisition and Analysis

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ABSTRACT

Medical images are pictures of distributions of physical attributes captured by an image acquisition system. Most of today's images are digital. They may be post processed for analysis by a computer-assisted method. Edges are important features in an image. Edge detection extracts salient features from an image such as corners, lines and curves. These features are used by higher level computer vision algorithms. Segmentation plays a crucial role in extraction of useful information and attributes from medical images. Different edge detection methods are applied on dental images. It is implemented using MATLAB.

Keywords – Edge Detection, Dental Image, Canny

1. INTRODUCTION

Images are acquired using x-ray modality and various edge detection methods are applied onto the images. This process reveals the edge detection method which gives minute anatomical details and good resolution.

2. X-RAY IMAGE ACQUISITION

Medical images come in one of two varieties: Projection images project a physical parameter in the human body on a 2D image, while slice images produce a one-to-one mapping of the measured value. Medical images may show anatomy including the pathological variation of anatomy if the measured value is related to it or physiology when the distribution of substances is traced.

2.1 X-Ray Imaging:

This technique measures the absorption of short wave electromagnetic waves, which is known to vary between different tissues. X-ray imaging uses the dependency of photoelectric absorption on the atomic number for producing a diagnostically meaningful image. Diagnostic equipment for x-ray imaging consists at least of a cathode ray tube emitting x-rays and a receptor with the patient placed between the emitter and receptor. The receptor may be film, an image intensifier, or a flat panel detector with the latter two producing digital images. A physical property measured by an imaging device and presented as a picture must meet three conditions to be useful. It has to penetrate the human body, it must not unduly interfere with it, and it must be meaningful for answering some medically relevant question.

X rays are electromagnetic waves with a wavelength above the visible spectrum. Electromagnetic radiation has the characteristics of waves, but is actually travelling as clusters of energy called photons with a given wavelength. Electromagnetic waves do not need a carrier such as sound waves and travel at the speed of light c. The energy of a photon measured in electron volts (eV) is the energy that a single electron acquires when moving through a potential of 1 V. The energy of a photon is characterized by its wavelength. It is given by

$$e = 1.24/\lambda \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

X rays are generated as excess energy from electrons in the material of a cathoderay tube (CRT).when heating the cathode. Energy from heating causes electrons to be released from the

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cathode and accelerated toward the anode. In the anode, electrons lose their kinetic energy by excitation, ionization, and radiation. Excitation and ionization cause electrons of the anode material to move from an outer shell to an inner shell. For excitation, this happens directly, whereas ionization causes the electrons of an outer shell to be released, which then excites the electrons of another atom.

-1	0	1
-2	0	2
-1	0	1

1	2	1
0	0	0
-1	-2	-1

The excess energy being released as x rays depends on the energy difference between the outer and the inner shells. Hence, the radiation from this process is monochrome. This kind of x ray is called characteristic or monochrome radiation. Most of the x-ray radiation, however, is polychrome. An incident electron is slowed down by passing the nucleus of an atom. Slowing down means that the frequency of the electron changes. The excess energy is emitted as a photon. Its amount depends on how close the incident electron passes to the nucleus. All its energy is released as x rays if it annihilates in the nucleus. If it passes the nucleus, more energy is released for an inner shell passage than for an outer shell passage. This type of radiation is called bremsstrahlung and it is inherently polychrome.

2.2 Edge Detection:

Edge detection is by far the most common approach for detecting meaning discontinuities in gray level. Edges are significant local changes of intensity in an image. Edges typically occur on the boundary between two different regions in an image. An edge point is a point at the location of a local intensity change. An edge detector is an algorithm that computes the edges in an image.

3. METHODS

3.1 Sobel Operator:

The Sobel operator performs a 2-D spatial gradient measurement on an image and so emphasizes regions of high spatial gradient that correspond to edges. Typically it is used to find the approximate absolute gradient magnitude at each point in an input grey scale image. One the most commonly used edge operators.

- computes the edge at (i, j)
- Smoothing at the same time
- places emphasis on pixels closest to (i, j)

MASKS FOR SOBEL OPERATOR

$$\frac{\partial f(x,y)}{\partial x} = \Delta x = \frac{f(x+dx,y) - f(x,y)}{\partial x} \quad \dots (2)$$

$$\frac{\partial f(x,y)}{\partial y} = \Delta y = \frac{f(x,y+dy) - f(x,y)}{\partial y} \quad \dots. (3)$$

3.2 Prewitt Operator:

Prewitt operator is a discrete differentiation operator, computing an approximation of the gradient of the image. At each point in the image, the result of the prewitt operator is either corresponding gradient vector or the normal of this vector. Similar to Sobel but does not place any emphasis on pixels.

-1	0	1
-1	0	1
-1	0	1

G_x

1	1	1
0	0	0
-1	-1	-1

G_Y

MASKS FOR PREWITT OPERATOR

$$G = \sqrt{G_x^2 + G_y^2}$$

$$\theta = atan2(G_y, G_x)$$

Prewitt masks are easier to implement than sobel operator. But the later have slightly higher noise suppression characteristics.

3.3. Canny Operator:

The Canny edge detector is an edge detection operator that uses a multi-stage algorithm to detect a wide range of edges in images. Canny's aim was to discover the optimal edge detection algorithm. In this situation, an "optimal" edge detector means:

- Good detection – the algorithm should mark as many real edges in the image as possible.
- Good localization –edges marked should be as close as possible to the edge in the real image.
- Minimal response – a given edge in the image should only be marked once, and where possible, image noise should not create false edges.

The smoothing filter used in the first stage directly affects the results of the Canny algorithm. Smaller filters cause less blurring, and allow detection of small, sharp lines. A larger filter causes more blurring, smearing out the value of a given pixel over a larger area of the image. Larger blurring radii are more useful for detecting larger, smoother edges. The algorithm then tracks along the top of these ridges and sets to zero all pixels that are not actually on the ridge top so as to give a thin line in the output, a process known as nonmaximal suppression. The tracking process exhibits hysteresis controlled by two thresholds: T1 and T2 with T1 > T2. Tracking can only begin at a point on a ridge higher than T1. Tracking then continues in both directions out from that point until the height of the ridge falls below T2. This hysteresis helps to ensure that noisy edges are not broken up into multiple edge fragments.

Canny edge detection algorithm:

1. Compute f_x and f_y

$$f_x = \frac{\partial}{\partial x}(f * G)$$

$$f * \frac{\partial}{\partial x} G = f * G_x$$

$$f_y = \frac{\partial}{\partial y}(f * G)$$

$$f * \frac{\partial}{\partial y} G = f * G_y$$

G(x,y) is the Gaussian function

$G_x(x,y)$ is the derivative of G(x,y) with respect to x: $G_x(x,y)= \frac{-x}{\sigma^2} G(x,y)$

$G_y(x,y)$ is the derivative of G(x,y) with respect to y: $G_y(x,y)= \frac{-y}{\sigma^2} G(x,y)$

2. Compute the gradient magnitude

Mag (i,j) = $\sqrt{f_x^2 + f_y^2}$

3. Apply non-maximal suppression
4. Apply hysteresis thresholding/edge linking

3.4 Roberts Operator:

The Roberts cross operator provides a simple approximation to the gradient magnitude. In this cross operator, the detection of edges and their orientations is said to be simple due to the approximation of the gradient magnitude. The disadvantages of these cross operator are sensitivity to the noise, in the detection of the edges and their orientations. The increase in the noise to the image will eventually degrade the magnitude of the edges. The major disadvantage is the inaccuracy, as the gradient magnitude of the edges decreases. Most probably the accuracy also decreases. The operator consists of a pair of 2×2 convolution masks

1	0
0	-1

0	1
-1	0

Masks for Roberts Operator

$$\frac{\partial f}{\partial x} = f(i,j) - f(i+1,j+1)$$

$$\frac{\partial f}{\partial x} = f(i+1,j) - f(i,j+1)$$

3.5 Zero Crossing Operator:

The zero crossing detector looks for places in the Laplacian of an image where the value of the Laplacian passes through zero i.e. points where the Laplacian changes sign. Such points often occur at `edges' in images i.e. points where the intensity of the image changes rapidly, but they also occur at places that are not as easy to associate with edges. Zero crossings always lie on closed contours and so the output from the zero crossing detectors is usually a binary image with single pixel thickness lines showing the positions of the zero crossing points. The advantages of the zero crossing operators are detecting edges and their orientations. The second advantage is the fixed characteristics in all directions. The disadvantage is sensitivity

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to the noise. The second disadvantage is that, the operation gets diffracted by some of the existing edges in the noisy image.

The starting point for the zero crossing detector is an image which has been filtered using the Laplacian of Gaussian filter. The zero crossings that result are strongly influenced by the size of the Gaussian used for the smoothing stage of this operator.

3.6 Log Operator:

(Laplacian of Gaussian)

Gaussian filter is used to filter out noise. Laplacian is used as the enhancement step. Enhancement is done by transforming edges into zero crossings. This is done using a 3x3 mask. Detection is done by finding the zero crossings. That is the detection criteria is the presence of a zero crossing in the second derivative with the corresponding large peak in the first derivative. To find a zero crossing it is possible to use a 3x3 mask that checks sign changes around a pixel.

0	0	-1	0	0
0	-1	-2	-1	0
-1	-2	16	-2	-1
0	-1	-2	-1	0
0	0	-1	0	0

Mask for log

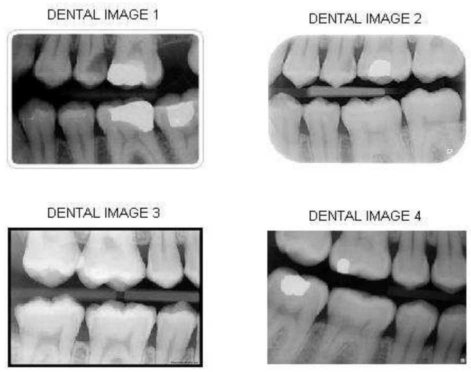
$$h(x,y) = \Delta^2[g(x,y) * f(x,y)]$$
$$= \Delta^2[g(x,y)] * f(x,y) \quad .... (4)$$

Where

$$\Delta^2[g(x,y)] = \frac{(x^2+y^2-2\sigma^2)^{\frac{-(x^2+y^2)}{2\sigma^2}}}{\sigma^4} \quad .... (5)$$

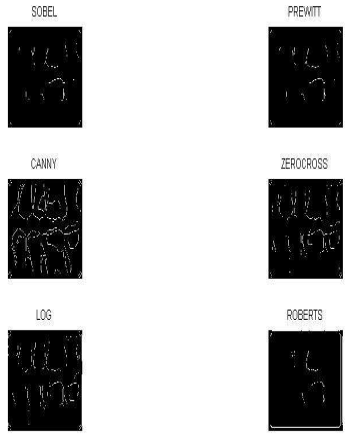
4. MATLAB CODING

```
a=imread('dental.jpg');
a1=rgb2gray(a);
t=edge(a1,'sobel');
t1=edge(a1,'prewitt');
h2=edge(a1,'canny');
h3=edge(a1,'zerocross');
h4=edge(a1,'log');
t2=edge(a1,'roberts');
subplot(3,2,1);imshow(t)
subplot(3,2,2);imshow(t1)
subplot(3,2,3);imshow(h2)
subplot(3,2,4);imshow(h3)
subplot(3,2,5);imshow(h4)
subplot(3,2,6);imshow(t2)
[x,y]=size(a1);
m=mean2(t)
m1=mean2(t1)
m2=mean2(h2)
m3=mean2(h3)
m4=mean2(h4)
m5=mean2(t2)
sd1=std2(t)
sd2=std2(t1)
sd3=std2(h2)
sd4=std2(h3)
sd5=std2(h4)
sd6=std2(t2)
```

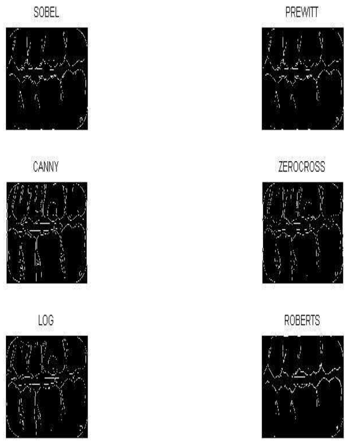


Input Images

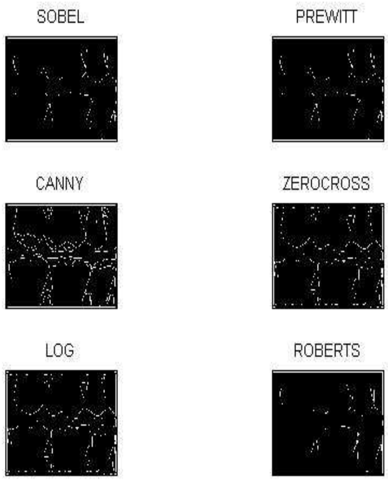
5. OUTPUT



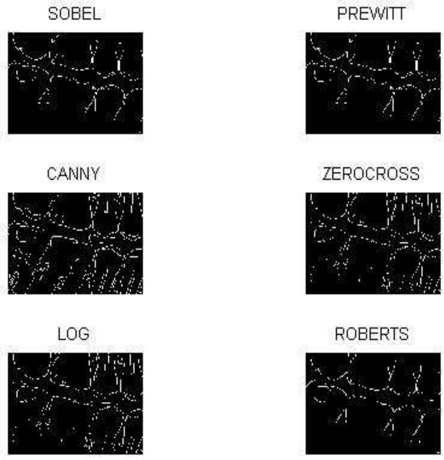
Dental Image-1



Dental Image-2



Dental Image-3



Dental Image-4

6.TABLE

Operators	1	2	3	4
Sobel	0.1593	0.1840	0.1653	0.1599
Prewitt	0.1586	0.1834	0.1644	0.1598
Canny	0.2719	0.2417	0.2384	0.2321
Roberts	0.1985	0.1908	0.1551	0.1578
Zerocross	0.2185	0.2081	0.2062	0.1945
Log	0.2185	0.2081	0.2602	0.1945

Table 1: Standard Deviation of Four Dental Images

Operators	1	2	3	4
Sobel	0.0261	0.0351	0.0281	0.0263
Prewitt	0.0258	0.0348	0.0278	0.0262
Canny	0.0804	0.0623	0.0605	0.0571
Roberts	0.0411	0.0378	0.0247	0.0255
Zerocross	0.0502	0.0454	0.0445	0.0394
Log	0.0502	0.0454	0.0445	0.0394

Table-2: Mean of Four Dental Images

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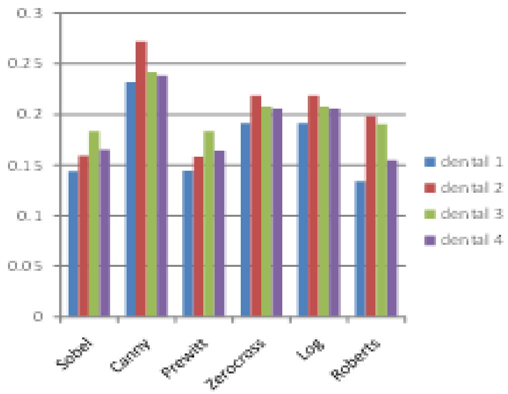
7. GRAPH



Graph-1: Graph for standard deviation of dental images corresponding to different operators

8. RESULT

Various Edge detection techniques were used and the Canny edge detector proves to be the best with its statistical values indicating its excellence from table 1. This multi-stage process clearly displays the edges of objects by controlling the amount of detail which appears in the edge image. Superior Noise suppression characteristics and better detection ability especially in noise conditions make it a widely preffered method.

9. REFERENCES

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