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Wavelet based Image Registration Technique for Matching Dental x-rays

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***Abstract*—**Image registration plays an important role in the diagnosis of dental pathologies such as dental caries, alveolar bone loss and periapical lesions etc. This paper presents a new wavelet based algorithm for registering noisy and poor contrast dental x-rays. Proposed algorithm has two stages. First stage is a preprocessing stage, removes the noise from the x-ray images. Gaussian filter has been used. Second stage is a geometric transformation stage. Proposed work uses two levels of affine transformation. Wavelet coefficients are correlated instead of gray values. Algorithm has been applied on number of pre and post RCT (Root canal treatment) periapical radiographs. Root Mean Square Error (RMSE) and Correlation coefficients (CC) are used for quantitative evaluation. Proposed technique outperforms conventional Multiresolution strategy based image registration technique and manual registration technique.

***Keywords*—**Diagnostic imaging, geometric transformation, image registration, multiresolution.

I. INTRODUCTION

IMAGE registration is the process of overlaying two or more images of the same scene taken at different times[1]. Image registration plays a very important role in forensic dentistry [2] and also in diagnosing various dental pathologies. Many different types of algorithms are found in the literature for registering dental x-ray images. Some are based on correlating pixel gray values directly and some are based on correlating transform coefficients. George Lazaridis *etal* [3] registered images by correlating the numbers formulated by different combinations of extracted Walsh coefficients of the images. Anil.K.Jain *etal* [2] exploited the advantage of segmentation in registering images.

Two images to be registered are called as reference image I_R and floating image I_F. Differences between the reference and floating dental x-ray images can be considered as the effect of three mechanisms: a) local anatomical deformations due to progression or regression of a disease; b) geometric transformation due to projection errors (reversible and irreversible); and c) intensity transformation due to non-identical exposure or film processing parameters. Irreversible projection errors can not be eliminated [4]. Intensity transformation may be due to the film development, film scanning etc [5]. Dental radiographs are scanned using flatbed scanners for the digitization of the image. Most frequently used file formats are Tagged image file (TIF), Bitmap-windows pattern (BMP) and Joint photographic experts group (JPEG). The TIF format has been widely accepted as the standard for gray scale reference image resolution [6].

Section II deals with proposed registration technique. Section III deals with Test and Real experimentation. Results showing the accuracy of the proposed approach are compared with others in section IV. Conclusions and limitations are presented in Section V.

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II. PROPOSED TECHNIQUE

Two images considered here are I_R and I_F, where I_R is assumed to be the reference image while I_F is a floating image, which is to be matched to I_R. Two images are assumed to differ only by translation and rotation. Proposed technique consists of two stages: Preprocessing and Geometric transformation

A. Preprocessing

Quantum noise occurs inherently on low dose X-ray imaging due to very low x-ray quantum counts. Photon, electronics and quantization noises also contribute to degrade medical images [7].

These noises can be eliminated by smoothing. In this work Gaussian spatial filter is used for smoothening. It is preferred over Box filter since it preserves the edges. It is a low pass filter uses Gaussian function to create two-dimensional filter kernel. In this work Gaussian filter with size 5X5 and sigma=1.4 used. The two-dimensional digital Gaussian filter can be expressed as:

$$G(x, y) = \frac{1}{\sqrt{2\Pi}\sigma} \exp(-(x^2 + y^2)/2\sigma^2), \qquad (1)$$

where σ^2 is the variance of the filter, and the size of the filter kernel l $\left(-l \le x, y \le l\right)$ is often determined by omitting values lower than five percent of the maximum value of the kernel [8]. Fig.1a shows some of the x-rays corrupted by noise; filtered images are shown in Fig. 1b.

B. Geometric Transformation

It plays a very important role in any image registration technique. One of the most commonly used forms of spatial geometric transformations is the affine transform. The affine transform can be written in matrix form as shown in (2).

$$\begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} s\cos\phi & -s\sin\phi & \Delta x \\ s\sin\phi & s\cos\phi & \Delta y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} w \\ z \\ 1 \end{bmatrix} \quad (2)$$

where $\phi, s, \Delta x, \Delta y$ are the parameters of the transformation, where ϕ is the angle of rotation in counter clockwise direction, s is the scale factor, and $(\Delta x, \Delta y)$ is the translation[9]. I_F is transformed using set of affine parameters then matched with I_R to get the best match. In this work it is assumed that I_R and I_F differ by rotation and translation only. Hence scale factor is unity. Correlation coefficient (CC) that is used for matching floating image I_F with reference image I_R is shown in (3). Proposed geometric transformation technique uses 2-level affine transformation method.

$$CC = \frac{\sum_{x,y}[I_R(x,y) - E(I_R(x,y))]\sum_{x,y}[I_F(T(x,y)) - E(I_F(T(x,y)))]}{\sqrt{\sum_{x,y}[I_R(x,y) - E(I_R(x,y))]^2}\sqrt{\sum_{x,y}[I_F(T(x,y)) - E(I_F(T(x,y)))]^2}} \quad (3)$$

Level 1: In the first level Discrete Wavelet coefficients corresponding to Db2 mother wavelet is computed for both I_R and I_F. Single step decomposition of DWT is shown in Fig.2. It gives two outputs, Details (High pass filter output, cD) and Coarse coefficients (Low pass filter output, cA). Coarse coefficients are used for affine transformation. For every set of affine parameters, cA coefficients of I_R and I_F are correlated using CC as given by (3). The optimization is performed first at this level by maximizing the correlation coefficient, and affine parameters corresponding to the best match are saved and they are called as optimal affine parameters. Because of the decimation, the number of wavelet coefficients is reduced to 25%. Therefore the technique will take less time for optimization.

Level 2: Optimal affine parameters obtained from level 1 are used as initial parameters for the second level transformation. Correlation is performed directly on the full resolution image pixels (gray values) rather than wavelet coefficients. This technique uses coarse to fine strategy. Starting optimization procedure from the coarse level, possibility of getting trapped into some local optima is reduced since the matching criterion employed is smoothed. After convergence, switching to finer levels enhances the accuracy [10].

Evaluation Performance: The registration accuracy can be quantitatively measured using correlation coefficient and Root Mean Square Error (RMSE) between the reference and geometrically aligned image [11]. Proposed method has been compared with two 2-D registration methods. The first method was similar to proposed method except that it uses gray level correlation technique [4] instead of wavelet coefficients. The other was manual registration technique which is based on locating landmarks in both the images.

III. Experimentation

A. Testing with Simulated Images

For the evaluation of proposed method, intra oral periapical dental x-rays are used. Fig. 3 shows deformed versions of x-ray images used for testing. First image is rotated by 10^0, second and third images both by 15^0.

B. Testing with Real Images

A series of experiments was performed using real dental x-ray images. Proposed algorithm is applied on many pre and post RCT and also crown x-ray images of male and female patients in the age group between 25 and 40.Images are collected from 3 different dental clinics. X-ray images are digitized using flatbed scanner and are stored as 8-bit gray level TIF files. The original size of these images is 128 X 128 pixels.

IV. Results

Table I summarizes the Gaussian filter working. Standard deviation (SD), Mean and Peak signal to noise ratio (PSNR) are used for quantitative evaluation. Table I shows that noise is almost eliminated by using Gaussian filter.

Fig. 3 shows in the first column the reference images, in the second column the images to be registered and in the third column registered images, after registration.

Table II compares proposed technique with manual registration technique. Second column indicates the number of landmarks used for manual registration. Third and Forth columns indicate the RMSE for proposed technique and manual registration technique respectively.

Table III compares the proposed technique with conventional registration technique given in [4]. X, Y and θ are the affine parameters used for transformation. For each set of affine parameters CC and RMSE are computed. RMSE and CC values show an improvement in the overall accuracy.

V. Conclusion

Method appropriate for registering dental x-rays has been presented here. The method is based on optimization of correlation coefficient function, where, instead of intensity values, wavelet coefficients are initially correlated. Results show that proposed technique gives a better result than conventional registration technique and manual technique.

The scheme in its present form works only for images that differ from each other by rotation and translation but not scaling. Future work will address this problem.

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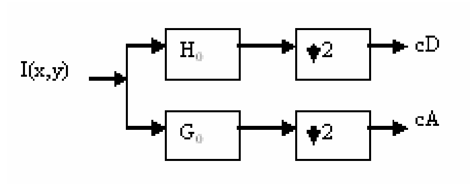

Fig. 2 Single step wavelet decomposition

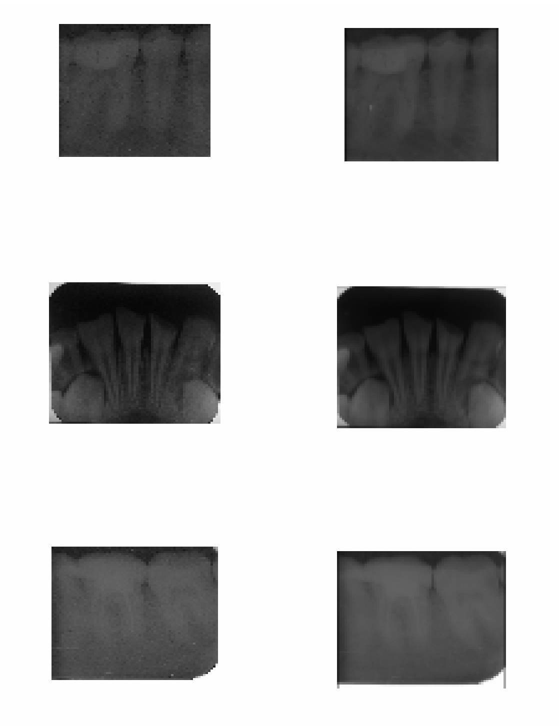

Fig. 1 X-ray images before (a) and after filtering (b)

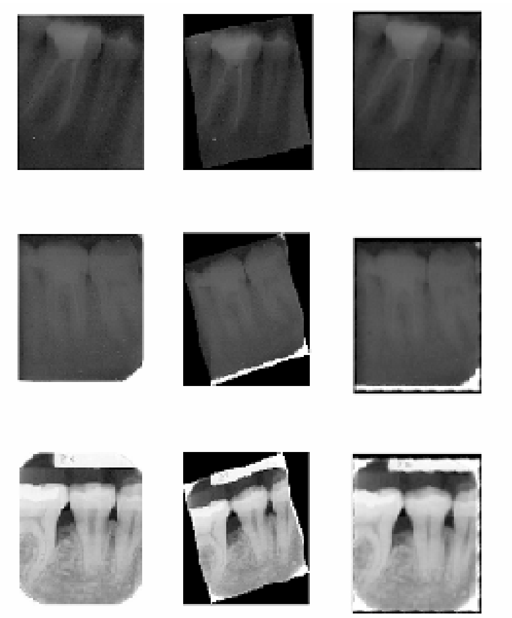

Fig. 3 (a) Reference image; (b) Image to be registered obtained by rotating Reference image by 10^o, 15^o and 15^o respectively. (c) is image after registration

TABLE I
MEAN, STANDARD DEVIATION (SD) BEFORE AND AFTER GAUSSIAN FILTERING AND PSNR AFTER FILTERING

Image	Before filtering		After filtering		PSNR
	MEAN	SD	MEAN	SD	
1	44.97	33.62	43.90	28.78	38.12
2	57.98	10.49	57.32	10.40	37.66
3	57.55	16.26	56.89	16	37.78
4	55.89	45.76	54.83	41.89	36.65
5	64.13	21.96	63.34	18.45	36.66
6	84.98	37	83.64	32.35	36.66
7	159.65	77.71	158.23	76.75	36.57
8	90.41	59	88.88	55.68	35.20
9	164.7	62.8	163.2	61.7	6.35
10	79.86	50	78.41	45.7	5.99

TABLE II
RMSE FOR PROPOSED AND MANUAL REGISTRATION TECHNIQUE

Pair No.	No. of Landmarks	Proposed Technique RMSE	Manual technique RMSE
1	4	7.63	7.68
2	5	7.45	7.53
3	4	7.56	7.84
4	4	3.48	3.56
5	5	9.69	9.73

TABLE III
CORRELATION COEFFICIENT (CC) AND RMS ERRORS OF PROPOSED TECHNIQUE ARE COMPARED WITH CONVENTIONAL TECHNIQUE

X	Y	θ	Conventional Technique CC	Proposed Technique CC	Conventional Technique RMSE	Proposed technique RMSE
0	5	5	0.5450	0.5550	38.82	38.68
0	10	5	0.6167	0.6338	45.48	44.47
-5	5	5	0.5830	0.5929	34.61	34.43
-10	10	5	0.6155	0.6368	44.63	43.89
-10	10	10	0.6728	0.6812	49.69	49.24
-15	10	20	0.2453	0.2541	37.16	36.68
-20	20	5	0.1846	0.2080	73.57	72.71
-20	20	15	0.4245	0.4421	54	53.01
-20	20	20	0.5038	0.5190	46.57	45.56
-25	10	5	0.4541	0.4646	58.15	57.48
-25	20	20	0.5620	0.5704	45.32	44.34
-30	15	19	0.6648	0.6772	38.46	37.85