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Image Registration Using Wavelet Transform

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Abstract: ***Image Registration is an elementary step in many image processing tasks such as medical image analysis, remote sensing, pattern recognition, face detection, motion tracking etc. In this paper, wavelet transform is used to extract features from image. The extracted features are then used to train Neural Network. Affine transformation parameters are used to evaluate the similarity measure between the reference and sensed image sets. Neural Network produces registration parameters (translation, rotation and scaling) with respect to reference and sensed image. Mean Absolute Registration Error and Mutual Information is used as evaluation parameters. Proposed technique for image registration is accurate and robust for distorted and noisy images than using DCT and FFT for image registration as shown by experimental results.***

Keywords: DCT, FFT, Wavelet Transform, Neural Network, Image Registration

1. Introduction

Image registration is a process of adjusting two or more images taken at different time or from different viewpoints or from different sensors [1]. It is often helpful to have sequence of images taken from different viewpoints to have complete information. So, image registration becomes necessary to draw a conclusion. It plays an important role in diagnosis of medical images. Alignment and integration of images from different sources and environment helps to gain complementary information not available from independent images.

Distorted and noisy images are difficult to align. Different techniques have been used for registration of noisy inputs. They are broadly classified as- Area based methods (cross-correlation, Fourier methods, and mutual information), control point methods based on identification of points, lines, edges etc., elastic models and wavelet-based methods [1][2]. Wavelet transform has been commonly used in image processing.

In this paper, we present image registration technique which performs well for noisy and distorted images. This image registration technique employs wavelet transform to extract features from images. These feature vectors form input vectors for feed forward neural network (NN).

Section II gives brief introduction of affine transformation, wavelet transform and neural network. In Section III we describe the proposed registration technique. Section IV discusses the experimental results for noiseless and noisy images. Conclusions are given in section V.

2. Background and Related Work

Neural Network has been used widely for image registration using different feature extraction mechanisms. I.Elhanany *et al.* [6] proposed feedforward NN using discrete cosine transform DCT for feature extraction. The extracted DCT coefficients from the lowest frequency band and used as input feature vectors to NN. Feedforward NN has been also used for image registration using Fourier transform for medical image registration in [9]. Radial basis function [8], self-organizing maps [10] and Hopfield networks [11] have been used for different computational aspects in image registration. Wavelet transform has been used for feature extraction in [12]. Dual-Tree Complex Wavelet Transform (DT-CWT) as pyramidal approach was used in [5]. Gabor wavelet and support vector machine (SVM) was used as registration of deformable image registration [13].

A. Affine Transformation

Affine transformation is a linear transformation in which the geometrical relationship between the points does not change. It is composed of scaling, rotation and translation changes, which maps the pixel (x_1, y_1) of image I_1 to the pixel (x_2, y_2) of another image I_2:

$$\begin{pmatrix} x_2 \\ y_2 \end{pmatrix} = sR * \begin{pmatrix} x_1 \\ y_1 \end{pmatrix} + T \quad (1)$$

here, s is the scale factor, R is rotation matrix and T is the translation matrix.

$$R = \begin{pmatrix} \cos\theta & -\sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix}, \quad T = \begin{pmatrix} t_x \\ t_y \end{pmatrix} \quad (2)$$

where, θ is the rotation angle and t_x , t_y are the translation parameters [6] .

B. Discrete Cosine Transform (DCT):

The Discrete Cosine Transform (DCT) represents an image as a sum of sinusoids of different magnitudes and frequencies. DCT is often used in image compression because most of the visually significant information about the image is concentrated in just a few of coefficients. In this work, 2-D DCT is used to extract features from images.

C. Fast Fourier Transform:

The Fourier transform, decomposes a waveform or function into sinusoids of different frequency which sum to the original waveform. It identifies or distinguishes the different frequency sinusoids and their respective amplitudes. The Fourier transform plays a vital role in image processing applications, including enhancement, analysis, restoration, and compression.

D. Wavelet Transform

The basic idea of the wavelet transform is to represent any arbitrary function *(t)* as a superposition of a set of such wavelets or basis functions. This basis function is generated from a single prototype wavelet called the mother wavelet, by scaling and shifts. If the mother wavelet is denoted by $\Psi(t)$ and other wavelets as $\Psi_{a,b}(t)$ can be represented as[7]-

$$\Psi_{a,b}(t) = \frac{1}{\sqrt{|a|}} \Psi((t-a)/b) \tag{3}$$

where a represents dilation factor and b represent translation; the wavelet $\Psi_{a,b}(t)$ is computed from the mother wavelet. Two dimensional discrete wavelet transform (DWT) is used to extract features from image. To compute wavelet features the image is decomposed to approximation and detailed signal.

E. FeedForward Neural Network

Feedforward neural network (FNN) is the simplest type of network. Figure 1 depicts the structure of a standard feedforward neural network with three layers i.e., the input layer, the hidden layer and the output layer. In this network, information moves in only one direction, forward, from the input nodes, to the output nodes through hidden nodes. There are no cycles or loops in the network. Feedforward neural network has following characteristics:

1) All neurons in one layer are connected to all the neurons in the next adjacent layer with uni-directional branches. The information is constantly „fed-forward" from one layer to next; hence, it is called as feedforward neural network.
2) All the neurons are connected through unidirectional branches, and each branch has associated weight that can be adjusted according to defined learning rule.
3) The training of feedforward network is accomplished by *backpropagation (BP)* algorithm. The goal of backpropagation algorithm is to minimize the energy function representing instantaneous error.
4) There is no connection among the neurons in the same layer.

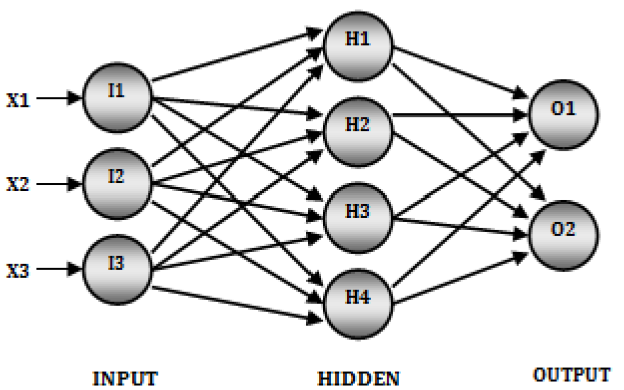


Figure 1: Structure of FeedForward Neural Network with 3 Layers

3. Proposed Registration Technique

The proposed technique for registration works in two stages. In the first stage, affine transformation is applied and some noise is appended to the reference image. Additive White Gaussian Noise is added to improve the performance for distorted inputs. Wavelet transform is used to extract the features. In paper [12], wavelet has been used for feature extraction. In the training phase, these extracted features are fed to feedforward neural network (NN) as an input. The NN produces affine transformation parameters as target outputs. In test phase, we extract the features and feed them to the trained NN, and we get the estimated parameter values as output. The complete procedure is shown in in figure 2.

For two-dimensional digital signals, such as digital image two-dimensional DWT is used. A two-dimensional digital signal can be represented by a two-dimensional array X[M, N] with M rows and N columns, where M and N are nonnegative integers. For two-dimensional implementation of the DWT, one-dimensional DWT is applied row-wise to produce an intermediate result and then the same one-dimensional DWT is performed column-wise on this intermediate result to produce the final result. This is shown in Figure 3.2(a). Two subbands are produced in each row after applying one-dimesional transform. When the low-frequency subbands of all the rows (L) are put together, it looks like a thin version (of size M x N/2) of the input signal. Similarly put together the high-frequency subbands of all the rows to produce the H subband of size M x N/2, which contains mainly the high-frequency information around discontinuities (edges in an image) in the input signal. Then applying a one-dimensional DWT column-wise on these L and H subbands (intermediate result), four subbands LL, LH, HL, and HH of size M/2×N/2 are generated. Figure 3.2(a) comprehends the idea describe above.

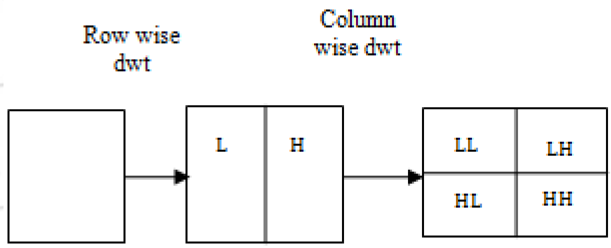


Figure 3.2(a): First Level Decomposition

The advantage of DWT over Fourier transformation is that it performs multiresolution analysis of signals with localization. As a result, the DWT decomposes a digital signal into different subbands so that lower frequency subbands will have finer frequency resolution and coarser time resolution compared to the high frequency subbands.

Wavelet transform is used to extract features from image. To compute wavelet features we have decomposed the image up to third level .The wavelet coefficients are calculated for the LL sub-band using Haar wavelet function. The resulting image after applying DWT is shown in figure 3.2(b).

Figure 3.2 (b): 3-level decomposition of Image

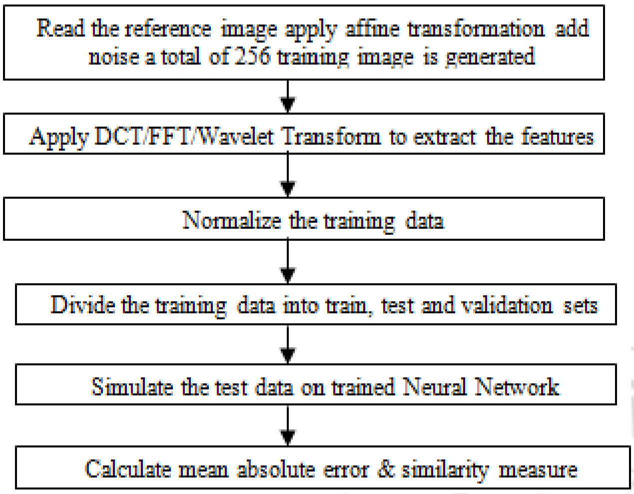


Figure 2: Block Diagram of Image Registration Process

4. Experimental Results

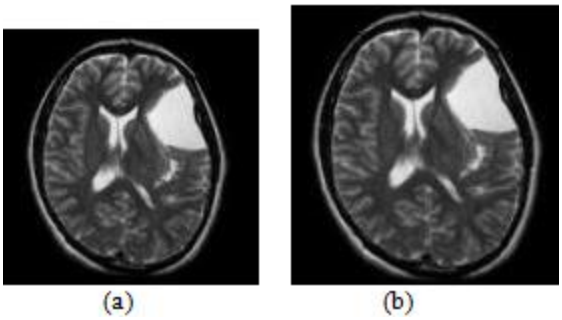
In the first stage i.e., training data set is generated using different parameter values for rotation, scaling, vertical translation and horizontal translation for a single image.

Table 1: Affine transformation parameter values for training set

Transform parameter	Values used for training set
Scale	0.9,0.965,1.035,1.1
Rotation (degrees)	-5,-2,2,5
Vertical translation (pixels)	-5,-2,2,5
Horizontal translation (pixels)	-5,-2,2,5

Table 2: Affine transformation parameter values for test set

Transform parameter	Values used for test set
Scale	0.93,1,1.07
Rotation (degrees)	-3,1,4
Vertical translation (pixels)	-4,0,3
Horizontal translation (pixels)	-3,1,4



For training images, transformation values are given in Table 1. A total of 256 images are generated, each of size 128 by 128 pixels. Wavelet transform, DCT and FFT are used for feature extraction. These feature vectors are used to train the neural network. For testing a total of 81 images are used. Features are extracted from the test images and fed to the trained NN.

The transformation parameter values for test images are given in Table 2. The transformation values for training and test sets are same that has been used by H. Sarnel [8]. Figure 4 shows the original image and transformed images after applying rotation, scaling and translations and also a noisy image.

NN has 7 neurons in one hidden layer and 4 neurons in the output layer. Hidden layer uses tangent sigmoid transfer function and linear function for the output layer neurons, and Levenberg Marquardt method was used for training.

Mean Absolute Registration Error (MAE) is calculated for 81 images. Table 3 shows MAE values and Table 4 shows MI values for without noise images, 5db noise images and 20db noise images. Results from Table 3 and Table 4 are pictorially represented in Figure 5 and Figure 6 respectively. From these results, it is apparent that the wavelet based approach gives the better performance for noisy and distorted images in comparison to DCT and FFT based approach.

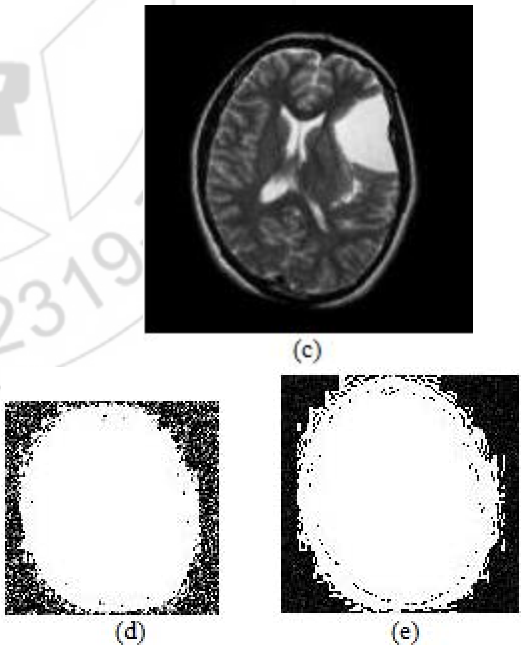


Figure 4: (a) Original Image (b)test image ,(c) Transformed, rotated and scaled Image (d) Translated, rotated, scaled images with 5db noise (e) 20db noise

Table 3: Mean Absolute Registration Error

S. No.	Image Registration Methods	Without Noise	5db Noise	20db Noise
1	DCT	1.4109418	2.0853555	1.4164335
2	FFT	1.5530205	1.587739	1.7901758
3	Wavelet	1.7493155	2.36973	2.258874

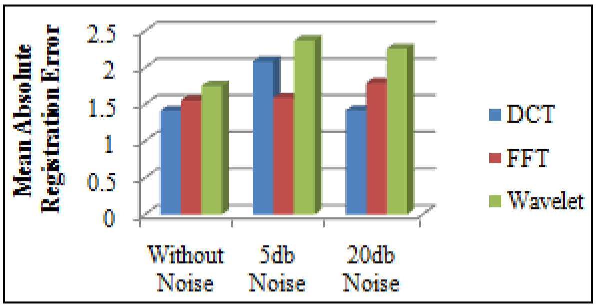


Figure 5: Mean Absolute Registration Error

Table 4: MI values for DCT, FFT and Wavelet

S. No.	*Image Registration Methods*	*Without Noise*	*5db Noise*	*20db Noise*
1	DCT	0.8052	0.8333	0.8233
2	FFT	0.7538	0.8235	0.8181
3	Wavelet	0.8277	0.8483	0.8446

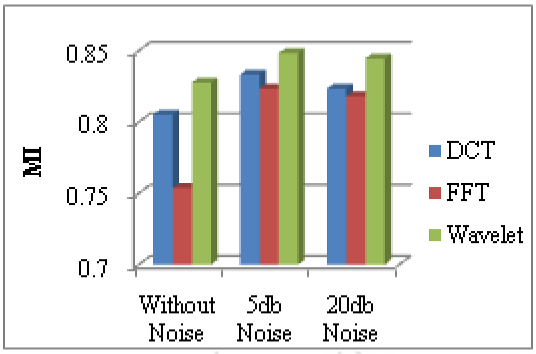


Figure 6: MI values for DCT, FFT and Wavelet

5. Conclusion

In this paper, we have used wavelet transform for feature extraction. The extracted features are then used to train the NN.

According to the experimental results, the proposed method is more efficient and robust to noise and distorted inputs. The results of the proposed image registration system are compared with the performance of the DCT and FFT techniques for image registration. Experimentally, we found that the proposed system performs better than the simple FFT and DCT for noiseless as well as noisy images.

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