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Registration and Fusion of CT and MRI Images

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Abstract: Image processing is growing day by day and it has an important role in medical imaging field. Medical imaging provides a better diagnosis of various diseases which will help in an early and exact detection of the disease, Thus help in curing faster and more accurately. In this paper, trying for an accurate registration and after that fusion of Computed Tomography (CT) and Magnetic Resource Imaging(MRI) images. This will help to get the tissues, blood vessels and bone structures combined in a single image rather than two different images.

Keywords : Registration, Image fusion, Computed Tomography (CT), Magnetic Resource Imaging(MRI)

I. INTRODUCTION

In medical image registration process in order to spatially match 2 or more images. What it does to recover the spatial transformation between images then after this image can be spatially transformed into a common space. In layman's words this is a rigid transformation; where the images depict the same subject, but were acquired at different time points and from different modalities [1]. There are flexible deformation models (affine, non-rigid) when different subjects have to be matched, or when other possible spatial distortions come into play.

Image fusion is referred as the process of combining information from different images. This can be defined in terms of different modalities [2], but also to different subjects, or different time points, or different resolutions, overall it can be said anything different that provides unique information the information not present in one single image. For fusion to be performed on any medical image registration is a necessary step without it fusion cannot be performed[3]. The fusion is combining the information over the different sources, matched spatial locations, specific positions etc.

II. MATERIAL AND METHODOLOGY

A. Dataset

The dataset for the registration and fusion was taken from the AIIMS lab which comprised of a patient containing approximately 120 MRI and CT images. These images were first pre-processed and then the process of registration and fusion.

B. Pre-processing of data

Each set of images were pre-processed using two algorithms namely median filtering and morphological process.

1) Median Filtering – It is a nonlinear filter method used to remove noises and is widely used as it preserves edges while removing noise in various conditions [4]. The basic idea of median filtering is to replace each entry of the signal by the median of the neighboring entries. The median of odd number of elements is nothing but the middle value when all the entries is arranged in increasing order but for the case of even number of elements there is more than one possibility for the median[5]. The ability of median filter to eliminate effect of input noises with very large values makes it better than other linear filters. The output of the median filter at any particular instant is given by:

$$y(s)=\text{median}((x(s-T+2),x(s-T+1),\ldots,x(t),..,x(s+T+2))$$

where s is the size of the window of the median filter. The described above is for one dimensional filter which could be extend to two dimensional filters for processing images. The images can be represented as 2D array of pixels in form of a set of non-negative Bij values where i represents row and j as column ranging from 1 to N. Like mean filter it operates each pixel value in a window and replace it with the median value[6]. In order to calculate median first all the elements are sorted in increasing order and then the middle of the series is the median of the value. Fig. 1 shows the illustration to calculate the median.

With the help of median filter we are able to remove the artifacts present on the images thus removing the unwanted noise present on the image.

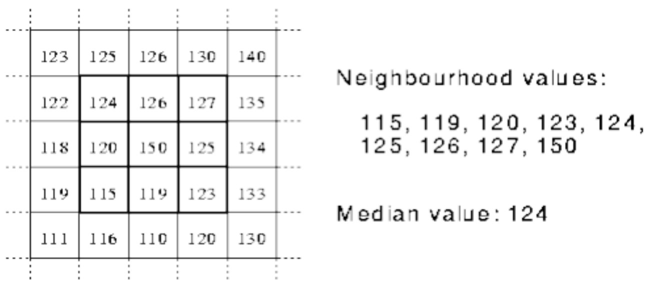

Fig. 1: an example for median filter

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2) Morphological Mathematical Operation- The set of non-linear operations that are associated to the morphology of features in an image is called morphological image processing. All are especially appropriate for binary images as they rely on relative ordering of pixel values. It probes the image with a structuring element (which is basically a small segment or shape), [7] which can be of any size or shape.
This structuring element here was taken in a oval form and was positioned at all possible locations of the image and was compared with the corresponding pixel values. Mainly two operations were performed namely "fits" and "hits". After morphological operation on binary image has non-zero pixel value if and only if the test was successful at input image. The new binary image $h=g \ominus s$ formed after erosion of a binary image g by a structuring element s (denoted $g \ominus s$) [8] will comprises of ones in all locations (i, j) the structuring element s fits the input image g, i.e. h(i,j) = 1 is s fits g and 0 otherwise. This is repeated for each and every pixel coordinate (i, j). The process of erosion by a 3x3 structuring element is shown in fig. 2 and that of dilation in fig.3.

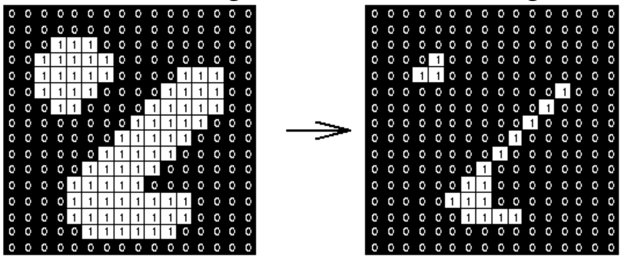

Fig. 2: Erosion process by a 3x3 structuring element

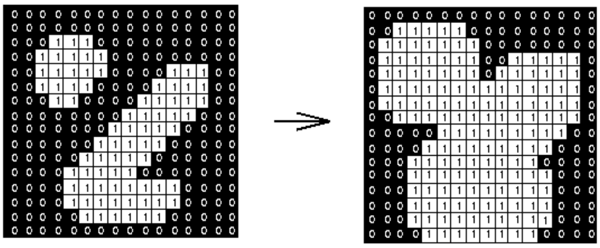

Fig. 3: Dilation by 3x3 structuring element

The new binary image $h= g \oplus s$ formed after dilation of a binary image g by a structuring element s (denoted $g \oplus s$) [12] will comprises of ones in all locations (i,j) the structuring element s hits the input image g, i.e. h(i,j) = 1 is s hits g and 0 otherwise. This is repeated for all the pixel coordinates (i,j). With the help of erosion and dilation of the images we were able to remove the skull parts in the images which are of no use during registration and fusion of the images.

3) Registration

The merging of the various information from different into a normalized frame of reference is done efficiently by multi-modal image registration.These datasets provides with the structural and functional information of an individual image. There can be two types of multi model based on structure i.e. rigid or non-rigid. Rigid models are the images that are the product of techniques that introduces rigid deformations, a combination of translation, rotation and scaling, which together define affine motion. The more general objects deformation between the images are provided by non-rigid models [11]. In order to optically align the two given images based on the specified similarity index, there should be an optimization method which must be used to search the parameter space for such a set of transformation parameters.

Consider there are two images which needed to be registered. One of the image is considered to be the fixed image (say FI),that is declared on image coordinates f and the other is considered to be the moving image (say MI), and is defined on image coordinates m. The image formed after the registration of the moving and the fixed image is defined by Mr and is called the registered image.

It is given that FI(f) and MI(m) are observed, hence the following relationship between Mr (f) and MI(m) was defined:

$$Mr(f) = M(A(m))$$

$$\Leftrightarrow M(m) = Mr(A^{-1}(f)) \qquad (1)$$

where A is the affine transformation and f and m are sampled on R2.

The main idea lying here is to find Aˆ ≈ A that gives a mapping from m to f such that the mutual information is maximized. The product of translation, rotation, scaling and skew transformations(four geometric transformations) is defined as the affine transformation A. The various relationship between the geometric parameters α = {px, py, θ, qx, qy, k} and the transformation parameters a = [a1, a2, a3, a4, a5, a6], are given in equation 3.

$$f = Am \qquad (2)$$

$$A_\alpha = \begin{bmatrix}1 & 0 & px\\ 0 & 1 & py\\ 0 & 0 & 1\end{bmatrix} \cdot \begin{bmatrix}\theta c & -\theta s & 0\\ \theta s & \theta c & 0\\ 0 & 0 & 1\end{bmatrix} \cdot \begin{bmatrix}1 & k & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{bmatrix} \cdot \begin{bmatrix}qx & 0 & 0\\ 0 & qy & 0\\ 0 & 0 & 1\end{bmatrix}$$

$$= \begin{bmatrix}qx\theta c & qy(k\theta c - \theta s) & px\\ qx\theta s & qy(k\theta s + \theta c) & py\\ 0 & 0 & 1\end{bmatrix}$$

$$= \begin{bmatrix}a1 & a2 & a3\\ a4 & a5 & a6\\ 0 & 0 & 1\end{bmatrix}$$

where

px = the shift in positive value of image to the left
py = the shift in positive value of image to up
θ = rotation angle, measured counterclockwise from the x-axis (θc = cos(θ) and θs = sin(θ))
k = shear factor along the x-axis = tan(skew angle) (the skew angle is measured from the y-axis)
qx = scale change in x direction
qy = scale change in y direction

The equation 3 specified above corresponds to the affine transformation with respect to the center pixel (xc,yc) which could be easily written as the transformation at the top-left pixel with a different translation parameter B shown in equation 4.

$$f = A \cdot m_{(xc,yc)} = \begin{bmatrix}a1 & a2\\ a4 & a5\end{bmatrix} \cdot \begin{bmatrix}mx - xc\\ my - yc\end{bmatrix} + \begin{bmatrix}a3 + xc\\ a6 + yc\end{bmatrix}$$

$$= \begin{bmatrix}a1mx + a2my + a3 - a1xc - a2yc + xc\\ a4mx + a5my + a6 - a4xc - a5yc + yc\end{bmatrix}$$

$$f = \begin{bmatrix}b1 & b4 & 0\\ b2 & b5 & 0\\ b3 & b6 & 1\end{bmatrix} \cdot q_{(1,1)}$$

$$= \begin{bmatrix} a1 & a2 & a3 - a1xc - a2yc + xc \\ a4 & a5 & a6 - a4xc - a5yc + yc \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} qx \\ qy \\ 1 \end{bmatrix}$$

$$B = \begin{bmatrix} a1 & a4 & 0 \\ a2 & a5 & 0 \\ a3 - a1xc - a2yc + xc & a6 - a4xc - a5yc + yc & 1 \end{bmatrix}$$

$$= \begin{bmatrix} b1 & b4 & 0 \\ b2 & b5 & 0 \\ b3 & b6 & 1 \end{bmatrix}$$

$$B\alpha = \begin{bmatrix} qx\theta c & qx\theta s & 0 \\ qy(k\theta c - \theta s) & qy(\theta c + k\theta s) & 0 \\ px + xc + qyyc(\theta s - k\theta c) - qx\theta cxc & py + yc - qyyc(\theta c + k\theta s) - sx\theta sxc & 1 \end{bmatrix}$$

4) Image Fusion : usion is the process of combining MRI/CT images into a single image thereby giving more data in comparison to data contained in a single MRI/CT image. The advantage of this step in image processing is that it gives better analysis and more accurate results when diagnosis is done .Fusion is basically combining the multi-sensor, multi-temporal and multi-view features into the new resultant image formed having high spatial and high spectral resolution.

The process of image fusion can be applied to remote sensing and in astronomy, multi-sensor , high spatial and spectral resolutions is obtained in combining images from two sensors, either of them having high spatial resolution[12,13] and high spectral resolution. The major advantage of image fusion exists in medical imaging which could comprise of the evaluation of the MRI, CT and PET scans simultaneously which factor is used here. Other applications of image fusion are used in military and surveillance areas where it uses the multi-sensor fusion of visible and infrared images.

In our study we have performed fusion using wavelet method ,it is one of the powerful signal processing method done using multimodality analysis .Below gives the description of DWT method using scaling function $\phi(x)$ and wavelet function $\psi(x)$.

$$\phi(x) = \sqrt{2}\sum_k l(k)\emptyset(2x-k)$$

$$\psi(x) = \sqrt{2}\sum_k h(k)\emptyset(2x-k)$$

where $l(k)$= low-pass coefficients and h(k)= high-pass coefficients

Forward wavelet analysis of signal F(x) at any scale J is denoted by

$$F(x) = \sum_k C(j,k)\,\phi_{j,k}(x) + \sum_j \sum D(j,k)\,\psi_{j,k}(x),$$

$C(j, k)$ and $D(j, k)$=scaling and wavelet coefficients

$$C(j,k) = \sum_k l(k-2m)\,C(j+1,k),$$
$$D(j,k) = \sum_k h(k-2m)\,C(j+1,k).$$

The above transform can be applied on the medical image in vertical , horizontal and diagonal dimension.

$$\phi_{LL}(x,y) = \phi(x)\,\phi(y),$$
$$\psi_{LH}(x,y) = \phi(x)\,\psi(y),$$
$$\psi_{HL}(x,y) = \psi(x)\,\phi(y),$$
$$\psi_{HH}(x,y) = \psi(x)\,\psi(y).$$

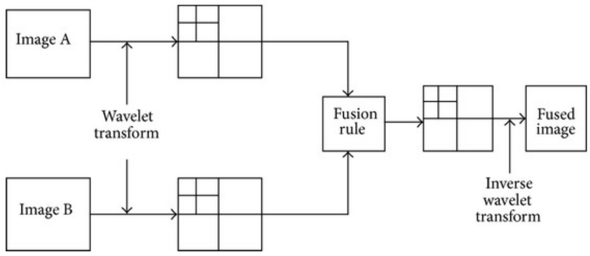

Fig 4: Block diagram representation of 2D DWT

III. RESULT AND DISCUSSION

In this study, all the images was first pre-processed. The pre-processing of the input image shown in figure 5(a) was done in two steps. In the first step the images was passed through median filter which removed the artifacts present in the image as shown in figure 5(b). In the next step the skull portion present in the input images which served no purpose was removed using morphological mathematical process which was done using erosion and dilation processes whose outputs are shown in figure 6.

After the pre-processing of the images was done then these images was registered using the affine transformation which structurally align the images and was a necessary need before the process of fusion. The registered image result are shown in figure 7. After this the registered images were fused using wavelet transformation method of fusion whose result are shown in figure 8.

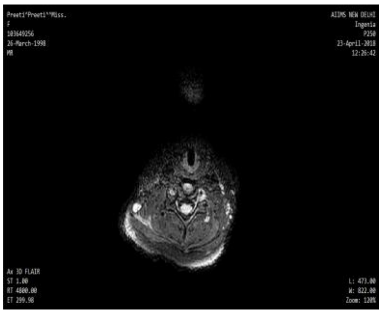

Fig 5: (a) the input image given to median filter

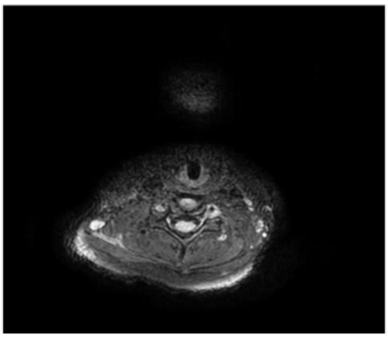

Fig 5 (b) the output of the median filter with no artifacts

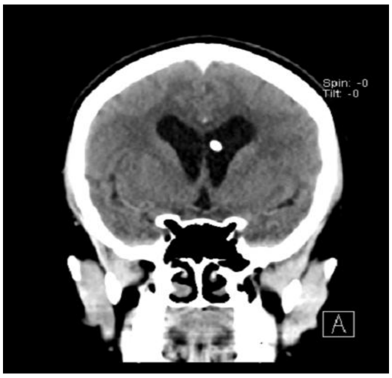

Fig. 6: (a) input image to morphology process with bones

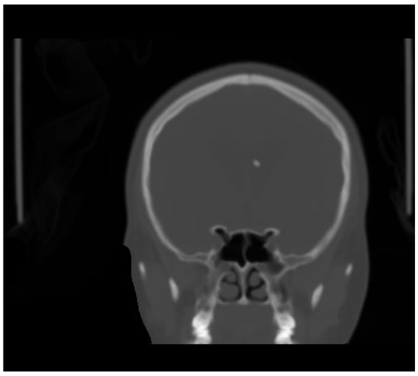

Fig. 6: (b) output after the morphology process containing no bone

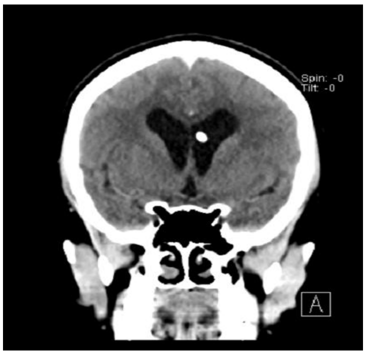

Fig. 7: (a) input image which is fixed

Fig. 7 (b) input image taken to be moving

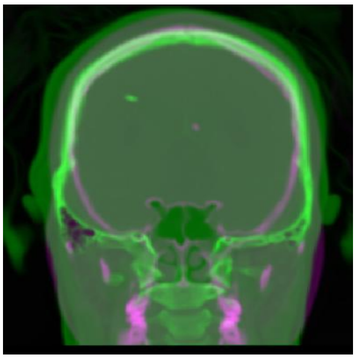

Fig. 7 (c) output registered image

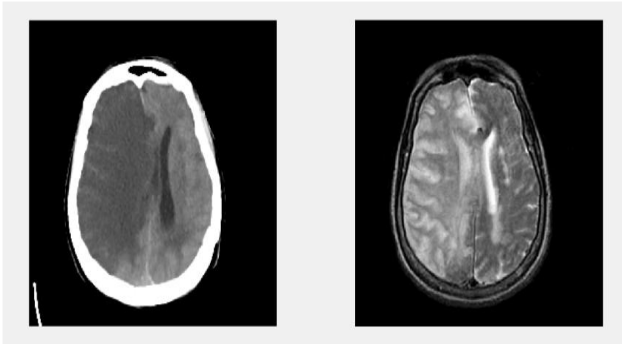

Fig. 8: (a) input CT image (b) input MRI image

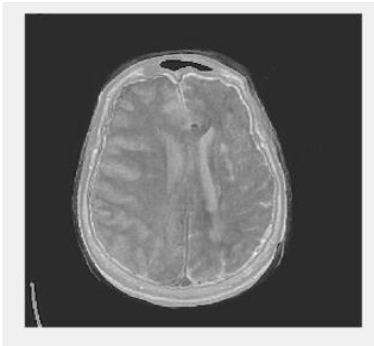

Fig. 8 (c) fused image

IV CONCLUSION

After the acquisition of data of a patient comprising of CT and MRI images, each of the image was pre-processed through median filter and mathematical morphological process. The pre-processed data no longer contained the artifacts of the patients and the bony structures if any present in the original image. This processed image was then undergone through the

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