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Medical Image Registration Using Curvelets

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Abstract: As Medical Image Registration using wavelets has already been studied and talked about by many researchers. Thesis started to find out the possibility to deploy next generation wavelets (i.e. complex wavelets or curvelets) in the field of medical image registration. Wavelets are suffering from some problems like shift variance, lack of phase information, oscillations and aliasing. So, these shortcomings pose difficulty in processing of geometric image features like ridges and edges. Medical images are basically textured images and contain ridges and edges. These problems are dealt with curvelets.

Keywords: Image Registration, Wavelet, Curvelet, Image Processing, MATLAB

"Image registration is the process of overlaying two or more images of the same scene taken at different times, from different viewpoints, and/or by different sensors. It geometrically aligns two images—the reference and sensed images"

I. INTRODUCTION

As Medical Image Registration using wavelets has already been studied and talked about by many researchers. Thesis started to find out the possibility to deploy next generation wavelets (i.e. complex wavelets or curvelets) in the field of medical image registration. Wavelets are suffering from some problems like shift variance, lack of phase information, oscillations and aliasing. So, these shortcomings pose difficulty in processing of geometric image features like ridges and edges. Medical images are basically textured images and contain ridges and edges. These problems are dealt with complex wavelets.

Integration of information to facilitate better usage and productivity is a key activity in today's scenario. It is not much different in the biomedical field either. With the advent of different methodologies for diagnosing different aspects of a patient's situation, it becomes important to integrate all this information in a way that allows the physician to get a better idea of the exact nature of the problem. At the same time this will save his precious time by providing an integrated piece of information rather than analyzing each one separately and then trying to relate their information to get to a conclusion. In the field of medical imaging, proper integration of the information derived from various scanning techniques like MRI scan, CT scan, SPECT scan etc. is of paramount importance. Before integrating this information obtained from various modalities we need to align them properly and this process is called as image registration.

The entire procedure of image registration makes sense if the participant images have been taken well and contain the relevant information. The images of different modalities are obtained using different prevalent methods are the MRI scan and the CT scan. These are different modalities that are dealt with in this paper.

A. *Medical Image Registration*

Medical Image Registration generally refers to the process of identifying and subsequently aligning corresponding structures or objects from two medical images. To register two images, correspondence and a transformation (spatial mapping) must be found so that each location in one image can be mapped to a new location in the second. This mapping should "optimally" align the two images wherein the optimality criterion itself depends on the actual structures or objects in the two images that are required to be matched.

The need for image registration arises as a practical necessity in many diverse fields. Image registration has a significant impact on a wide range of various research fields, such as computer vision, pattern recognition, medical image analysis and remotely sensed data processing.

In medical image registration process accuracy and efficiency is highly required to get exact and timely results. Medical image registration problem can be categorized mainly in two categories

(i) using geometrical features and

(ii) using pixel or voxel intensity values.

So in this process finding out the correspondences in features or intensity values is a main issue of consideration.

B. *Applications of Image Registration*

A good alignment of images is necessary for integrating information from different images of different modalities, e.g. for finding changes in images taken at different times or under different conditions and model based matching for the purpose of segmentation or object recognition. Image registration can be applied in the various domains like motion tracking, motion analysis data integration or fusion and change detection.

Including all these fields registration process has got its application in machine vision and pattern recognition.

II. A REVIEW OF REGISTRATION TECHNIQUES

Medical Image Registration is not a new area and a lot of work has been done in this particular area. Image registration is widely used for many years in X-ray angiography. It is common to acquire x-rays before and after injection of intravascular contrast and then subtract these images in order to visualize the blood vessels in isolation [3]. Initially instruments to acquire images, technology in medical sciences were not so enhanced so these simple methods were sufficient and effective. As technology and science have progressed in this field need for more robust and effective algorithms arose.

Image guided surgery was the first application of medical image registration. Rapid advances in the power of computing technology, display devices, image manipulations algorithms and tools, softwares and storage resulted in a significant speedup in the research of this field. As this field has long research history started basically from mid 1980s and a significant breakthrough in the mid of 1990s was the development of image alignment measures and registration algorithms based on entropy and in particular , mutual information –measures first derived from the information theory developed by Shanon in 1948 .

Complex Wavelets found their application in the fields as medical imaging, noise removal and deblurring, object tracking and object recognition applications. So these are being popular day-by-day. Complex wavelets are being used to denoise and deblur the medical image but it is yet to be utilized in medical image registration.

After Complex Wavelets that has been introduced recently, advancement in the field has taken place and it caught attention of researchers towards them and a new generation of transforms resulted in curvelets, ridgelets and brushlets. The Curvelet transform is a higher dimensional generalization of the Wavelet transform designed to represent images at different scales and different angles.

Curvelets enjoy two unique mathematical characteristics, as specified in the lines below: -

Curved singularities can be well approximated with very few coefficients and in a non-adaptive manner, hence the name "curvelets."

Curvelets remain coherent waveforms under the action of the wave equation in a smooth medium.

This paper classifies the registration algorithm into category based on dimensionality, transformation, modalities, interaction, optimization procedure and subject, object basis.

III. DESIGN

Design of an efficient solution after understanding and reviewing the methods and algorithms used in this field is next milestone in the pathway. To find out the solution, the whole task i.e. Medical Image registration problem is divided into five phases:

1. Preliminary investigation of Image Registration problem.

2. Study of literature related to this field.

3. Finding a Solution for Medical Image Registration.

4. Implementation of Solution using any programming language or Toolbox.

5. Performance Evaluation or Comparative Study.

To find out correspondence between two images so that transform model can be calculated using these correspondence points is very important part of overall problem. As I am using multi-resolutionary approaches so feature matching will also be done on multilevel.

In this part two metrics will be used

(i) Mutual Information

(ii) Sum of Absolute Differences.

IV. IMPLEMENTATION

Medical images are of various modalities and basically are gray scale images. Gray scale images are easy to work with and are represented by 8 bits and on the other hand true color images use 24-bit representation. Grayscale images intended for visual display are typically stored with 8 bits per sampled pixel, which allows 256 intensities (i.e., shades of gray) to be recorded, typically on a non-linear scale. The accuracy provided by this format is barely sufficient to avoid visible banding artifacts, but very convenient for programming. Technique uses (e.g. in medical imaging or remote sensing applications) which often require more levels, to make full use of the sensor accuracy (typically 10 or 12 bits per sample) and to guard against round off errors in computations. Sixteen bits per sample (65536 levels) appears to be a popular choice for such uses. The PNG image format supports 16 bit grayscale natively, although browsers and many imaging programs tend to ignore the low order 8 bits of each pixel.

Using MATLAB 'imread' command image can be read into MATLAB workspace as a matrix. One of the formats of this command is as given below:

A = imread (filename,fmt) reads a grayscale or color image from the file specified by the string filename, where the string fmt specifies the format of the file. If the file is not in the current directory or in a directory in the MATLAB path, specify the full pathname of the location on your system (for an example: IM1=imread('im53.jpg')). If imread cannot find a file named filename, it looks for a file named filename.fmt. It supports jpg, gif, png, tif, bmp, ppm and many other formats.

After reading both the images in workspace, save them as matrices using save command i.e. save ('image10.mat','IM1','IM2') so that these images can be reloaded to workspace whenever needed.

Images can be converted to gray scale for simplification and less space utilization using simple one line command IM1= 0.2990*IM1(:,:,1) + 0.5870*IM1(:,:,2) + 0.1140*IM1(:,:,3) and this will equip us with gray scale image, just simply multiplying some values on each RGB or HSV dimensions of images. Now images are ready to be registered after this initial processing and if they are noisy (noise can be due to equipment to capture image or can be due to inappropriate angle and positioning dependent on the environment and device accuracy), some preprocessing (smoothening or filtering) is done before registration.

A. Complex Wavelet Coefficients

Complex wavelet is next generation wavelet transforms. Real wavelets suffer from four problems:

1. Oscillations
2. Shift Variance
3. Aliasing
4. Lack of Directionality

These shortcomings are dealt with new generation of wavelet that is complex wavelets. Complex wavelet has both real and imaginary parts. Dual tree complex wavelets are used in my algorithm. Application to images is achieved by separable complex filtering in two dimensions. The 2: **1** redundancy in one dimension translates to 4: l redundancy in two dimensions with the output from each filter and its conjugate forming six orientated subbands at each scale. Complex wavelets are able to separate positive and negative frequencies thus differentiating and splitting the subbands of a dyadic decomposition into subbands.

B. ***Algorithm for Registration***

Take two images Source and Target as input.

Initialize the level to 0 and assign max_level as 4.

Use Curvelet Transformation on the source image.

Increment the value of the level by 1.

Repeat step 3 and 4 until level < max_level.

Calculate SAD and MI, from the transformed source image using Direct Search Method with respect to target image.

Take SAD and MI as input and apply Inverse Curvelet Transformation on the transformed source image.

Decrement the value of the level by 1.

Repeat step 7 and 8 until level > 0.

- Apply transformation on the Transformed source image using Optimal Parameters to get the Registered Image.

V. RESULTS

Curvelet transform is applied on the two base images and the registration rules are used on the resulting coefficients. Taking the affine transform gives the registered result given below:

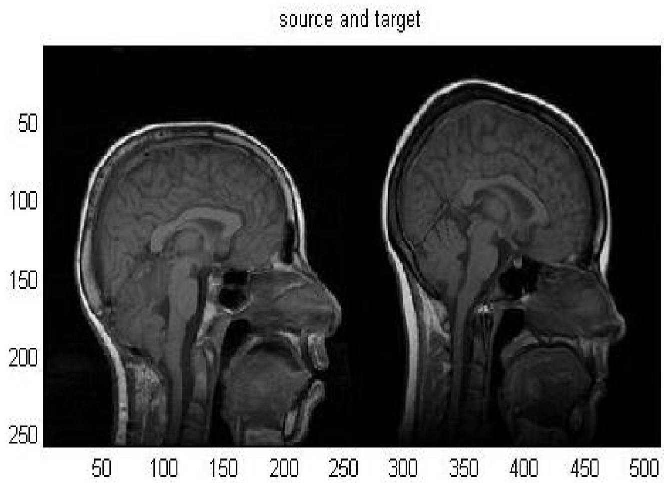

Figure: 1(Source and Target Images)

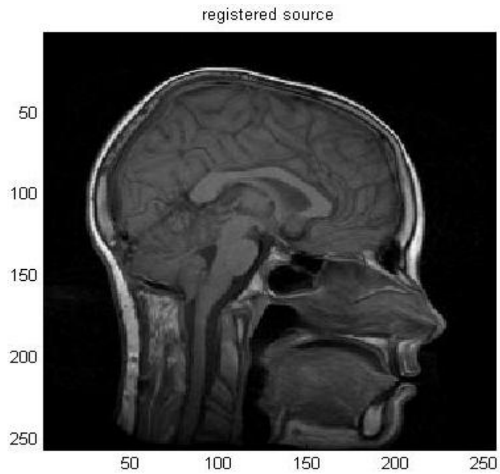

Figure 2:(Registered Source Image)

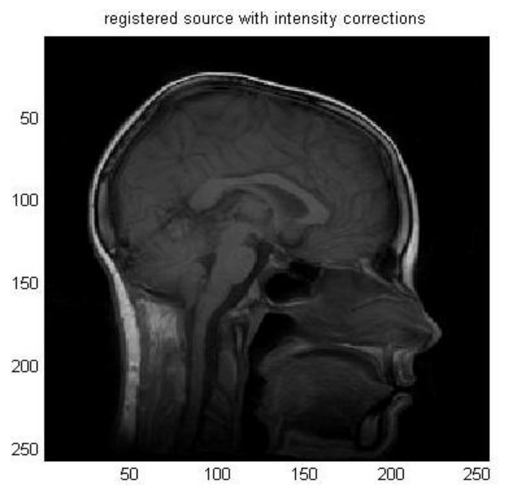

Figure 3: (Registered Source With Intensity Corrections)

In the above figures Fig1. Is an input image and Fig 2 and 3 are the outputs of my paper.

VI. VI. PERFORMANCE EVALUATION

Complex Wavelets are shift invariant and contains phase information. So, it gives better results in several cases observed. This method is also able to register images which have been slightly cut or obscured due to instrumental or procedural error while obtaining. But, there is a limit in clipping after that image can not be registered properly.

VII. CONCLUSION

This whole paper is a small work towards deployment of complex wavelets in the field of medical imaging to get better results as compare to previous implementations. So, this whole thesis talks about a new method based on previous approach but using different tool named as complex wavelets.

Multi-resolution is used and matching criteria is optimized at various levels using simplex search method and then particular output is fed to one upper level of resolution. This whole process is repeated till higher level (i.e. level 1 is achieved). In complex wavelet case, we got low SAD values which should be minimum in case of maximum alignment. After experimenting on number of images with complex wavelet and wavelets we get good results with complex wavelets in maximum number of cases.

After all these observations it can be said that complex wavelets is outperforming on wavelets in medical imaging and gave good alignment results. Complex wavelet is very useful and gave birth to a new application in medical imaging. More methods using complex wavelets can be discovered and can give a new turn to research in the field of medical image registration.

Medical images have lot of curves, phase information and textured information. So, use of complex wavelets gave better output in comparison to wavelets without leaving any good qualities of the previously described method, which were its robustness, accuracy and multimodality.

Hence, next generation of wavelets (i.e. complex wavelets) give robust and accurate solutions and can be used in multimodal registration too. But this is an initial effort using Dual Tree Complex Wavelets, for which software is available as open resource to be used for research purpose; some other complex wavelets can also be tried on this method.

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