

A Prominent Analysis on Head Phantom Image using Correlation Coefficient

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Abstract- 2D projections of the real 3D space are the only available information in the imaging technics like in X- Ray and MRI. In this paper we study projections of images as generated by Radon transformation. We implemented an image reconstruction algorithm which receives different projections of the original image as input. We performed this experiment using artificially created image in order to test and verify the algorithm. The quality of images reconstructed by an algorithm is most prominent to check. So in this paper, we performed analysis on head phantom MRI image by calculating correlation coefficient, Cutoff rotation angle for an image and linearity of correlation coefficient.

Index Terms- Image processing, Radon Transform, Image Reconstruction, correlation Coefficient

I. INTRODUCTION

The determination of the 3D structure of macromolecules is an important field of interest for biology. Nowadays, two methods dominate this determination: X-ray crystallography and Magnetic Resonance Imaging (MRI) spectroscopy. They have the ability to produce a detailed picture of the 3D structure of biological macromolecules at atomic resolution [1,2]. We focus on the MRI approach.

MRI is a spectroscopic technique that reveals information about the environment of magnetically active nuclei. An external magnetic field is used to align them and this alignment is perturbed by an electromagnetic field.

Up to 2003, the number of 3D structures of macromolecules that has been deposited in the Protein Data Bank (PDB) [4] was greater than 3150. MRI is also very useful in Structural genomics. Many efforts are being made in this filed to supplement the knowledge on the sequence of proteins by structural information on a genome-wide scale, determined either experimentally or by theoretical homology modelling [2].

For many years, MRI has been dominated virtually exclusively by the Fourier Transformation (FT) [3,6]. FT gives a simple graphical picture of correlations among different molecular sites within a molecule. But as the spectra is getting more complex due to more intense magnetic fields, extension to three or even four dimensions is needed to resolve ambiguities. This result to an increase to the amount of data acquired and the required processing time [7].

Fig.1 illustrates a typical 2D parallel projection. We need to determine the position and quantity of white matter in brain

sample image. If we were able to look at the spectrum from different angles we could get this information.

Currently the only available information are projections of the spectrum from different angles. Using that 2D information, we try to reconstruct the correct 3D image [8]. This image reconstruction approach, using different projections and angles of views, is very popular in many fields such as x-ray scanning, tomography and determination of protein structure. If only two projections are used some resonances might be cut off by others. Thus, more projections may be required depending on the problem under study.

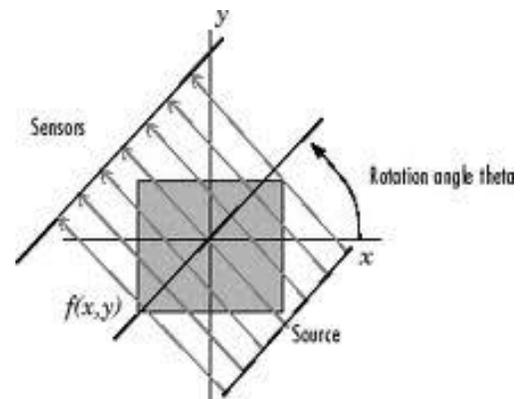


Figure 1: Example of a typical parallel projection

In this paper we present an image reconstruction algorithm introduced by E. Kupce and R. Freeman [18]. Inputs of the algorithm are 1D projection. They are acquired using the Radon transformation. The algorithm was implemented and verified on artificial image shown in figure 2. The correlation coefficient was chosen as a measurement for the resemblance between the reconstructed image and the original one.

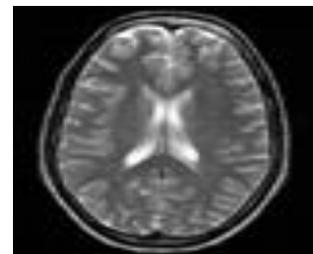


Figure 2: Head phantom artificial image

The rest of this paper is organized as follows: Section II presents a mathematical background of Radon transformation and the reconstruction algorithm. In section III, the acquired results are illustrated. Finally, we discuss about future work and conclude our paper in section IV.

II. METHODS

A. The Radon Transformation

The 2D Radon transformation is the projection of the image intensity along a radial line oriented at a specific angle as shown in fig. 1. Radon expresses the fact that reconstructing an image, using projections obtained by rotational scanning is feasible. His theorem is the following: The value of a 2-D function at an arbitrary point is uniquely obtained by the integrals along the lines of all directions passing the point. The Radon transformation shows the relationship between the 2-D object and its projections [8].

The Radon Transformation is a fundamental tool which is used in various applications such as radar imaging, geophysical imaging, nondestructive testing and medical imaging [9]. Many publication exploit the Radon Transformation. Meneses-Fabian et al. [10] describe a novel technique for obtaining border-enhanced tomographic images of a slice belonging to a phase object. Vitezslav [11] examines fast implementations of the inverse Radon transform for filtered backprojection on computer graphic cards. Sandberg et al. [12] describe a novel algorithm for tomographic reconstruction of 3-D biological data obtained by a transmission electron microscope. Milanfar [13] exploits the shift property of Radon transformation to image processing. Barva et al. [14] present a method for automatic electrode localization in soft tissue from radio-frequency signal, by exploiting a property of the Radon Transform. Challenor et al. [15] generalize the two dimensional Radon transform to three dimensions and use it to study atmospheric and ocean dynamics phenomena.

Figure 3 illustrates several 1D projections from different angles at an image consisting of white spots in the 2D domain. In some of the projections, only partial spot is shown. This reveals the importance of the selection of the “correct” projections for image reconstruction.

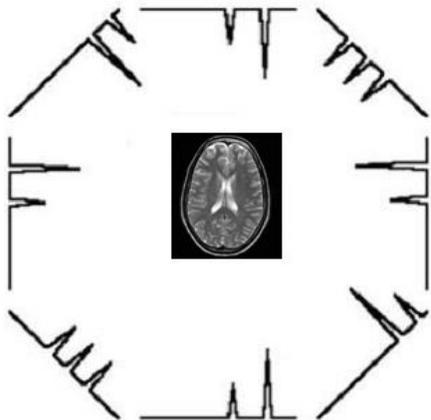


Figure 3: Different projections on a head image example.

Suppose a 2-D function $f(x, y)$ (Fig. 4). Integrating along the line, whose normal vector is in θ direction, results in the $g(s, \theta)$ function which is the projection of the 2D function $f(x, y)$ on the axis s of θ direction. When s is zero, the g function has the value $g(0, \theta)$ which is obtained by the integration along the line passing the origin of (x, y) -coordinate. The points on the line whose normal vector is in θ direction and passes the origin of (x, y) -coordinate satisfy the equation:

$$\frac{y}{x} = \tan\left(\theta + \frac{\pi}{2}\right) = \frac{-\cos \theta}{\sin \theta} \quad \dots(i)$$

$$\Rightarrow x \cos \theta + y \sin \theta = 0 \quad \dots(ii)$$

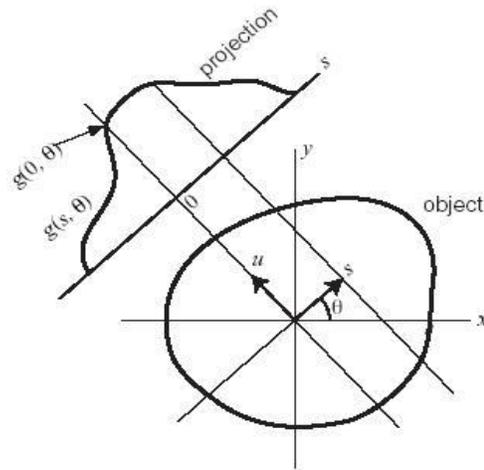


Figure 4: The Radon Transform computation.

The integration along the line whose normal vector is in θ direction and that passes the origin of (x, y) -coordinate means the integration of $f(x, y)$ only at the points satisfying the previous equation. With the help of the Dirac “function” δ , which is zero for every argument except to 0 and its integral is one, $g(0, \theta)$ is expressed as:

$$g(0, \theta) = \iint f(x, y) \cdot \delta(x \cos \theta + y \sin \theta) dx dy \quad \dots(iii)$$

Similarly, the line with normal vector in θ direction and distance s from the origin is satisfying the following equation:

$$(x - s \cdot \cos \theta) \cdot \cos \theta + (y - s \cdot \sin \theta) \cdot \sin \theta = 0 \quad \Rightarrow$$

$$x \cos \theta + y \sin \theta - s = 0 \quad \dots(iv)$$

So the general equation of the Radon transformation is acquired: [8, 9, 13, 14, 16]

$$g(s, \theta) = \iint f(x, y) \cdot \delta(x \cos \theta + y \sin \theta - s) dx dy \quad \dots(v)$$

The inverse of Radon transform is calculated by the following equation [12] :

$$f(x, y) = \int_{-\pi/2}^{\pi/2} \rho \cdot R_{\theta}(s(x, y)) d\theta \quad \dots(vi)$$

where R_{θ} is the Radon transformation, ρ is a filter and

$$s(x, y) = x \cos \theta + y \sin \theta \quad \dots(vii)$$

B. Image Reconstruction Algorithm

Kupce and Freeman [17] presented an image reconstruction algorithm from a limited set of projections. They suggest a method of implementing the inverse Radon transformation. Firstly, they get the projections from different perspectives. Then they expand every 1D projection at right angles, so as to create a 2D map that consists of parallel ridges. The superposition and the comparison of the created 2D projection maps result in the final reconstructed image.

Their technique can be explained by the following example: Suppose the existence of two perpendicular projections of four absorption peaks in each one (Fig. 5). From these two projections, the potential peaks are 16, but not all of them are true cross peaks. If we take into account another projection at a different angle and reapply the lower-value algorithm, we eliminate some potential as being false peaks and we get the image shown in Figure 5.

Another projection would refine the solution even further. Usually three projections are enough to have an accurate definition of the peaks, but if the original spectrum is complex more projections may be required. Because of the discrete nature of the MRI resonances, the problem converges very rapidly.

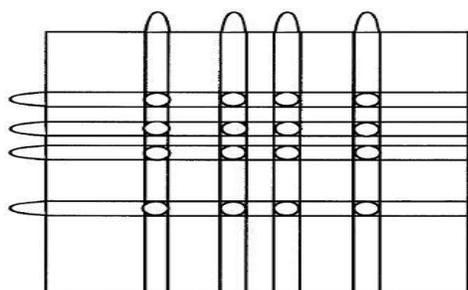


Figure 5: Peaks using two projections.

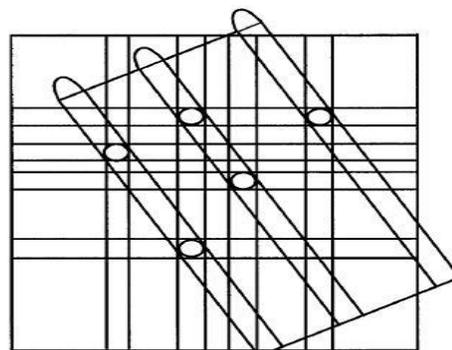


Figure 6: Peaks using three projections.

The algorithm we implemented is based on the previous described algorithm of Kupce and Freeman and its steps are:

- Step 1:** Acquisition of three different projections.
- Step 2:** Expansion of the 1D projection in 2D projection maps.
- Step 3:** Padding (with black) of the 2D projections maps in order not to lose information due to the next step.
- Step 4:** Rotation of the maps to the correct angle.
- Step 5:** Reconstruction of the original image by multiplying the maps pixel by pixel.

III. RESULTS

We studied the Radon transformation using Matlab and the Image Processing Toolbox in particular. Initially we created an artificial image and applied the Radon transformation in order to construct the corresponding projections. Fig. 2 presents an example of this image which is used in reconstruction for six different angles: 0, 2, 5, 10, 15, 20 degrees. Even though the image consists of also white spot, in some projections, there seem to be partial spots. This proves the need of several projections in order to verify the correct number of existing spots and their positions.

We implemented the reconstruction algorithm described in section II to reconstruct artificially created image. Six projections were used to reconstruct the original images. The quality of the reconstruction is measured by calculating the absolute value of the 2D correlation coefficient between the original image and the reconstructed one. This gives a value between 0 and 1. As the value increases, so does the resemblance that exists between the original image and the reconstructed one.

Figure 8: illustrates six different images that were reconstructed. Table 1 presents the correlation coefficient for the different values of the variable projection angle.

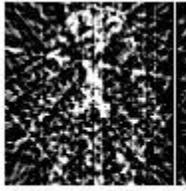


Image : Reconstructed by projection at 20 degree rotation

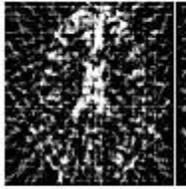


Image : Reconstructed by projection at 15 degree rotation

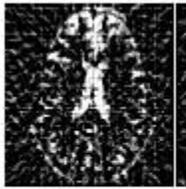


Image : Reconstructed by projection at 10 degree rotation



Image : Reconstructed by projection at 5 degree rotation

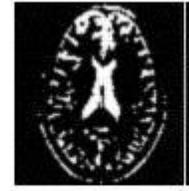


Image : Reconstructed by projection at 2 degree rotation

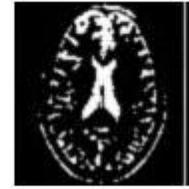


Image : Reconstructed by projection at 1 degree rotation

Figure 8: Image Reconstruction using 6 different projections

Table 1: Rotation Angle and corresponding Correlation Coefficient.

Rotation angle	Correlation Coefficient
1	1
2	0.992
5	0.8721
10	0.676
15	0.5585
20	0.4946

We also noticed that correlation coefficient becomes more linear as it reaches to 1 or we can say that more rotations in projection gives better reconstruction of the images. Which is shown in Figure 9.

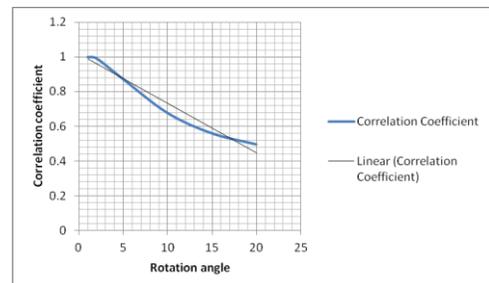


Fig. 9 linearity of correlation coefficient of head phantom image

In this paper we tried to define a new term 'cutoff rotation angle' which may be defined as the rotation angle at which almost 70% of reconstructed image resembles to original image. Here in our experiment it is 10 degree. Fig 10 represents this result.

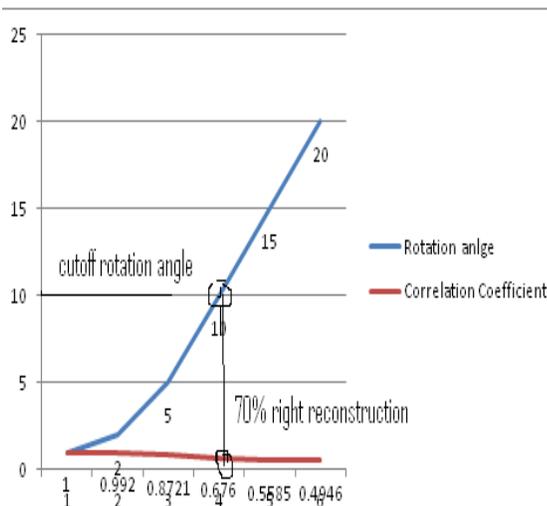


Figure 10: Cut off rotation angle for an image

IV. CONCLUSIONS

To summarize, in this paper we tried to reconstruct an image using projections from different perspectives, which we obtained with the use of the Radon transform. In order to achieve this, we implemented an algorithm, based on the one proposed by Kupce and Freeman [16]. In the presented examples we used six projections of the input image, reaching a correlation coefficient of 1. Future perspectives of the proposed work include the application of the implemented algorithm to real MRI data, the application of more projections for the image reconstruction and the development of heuristics for the determination of optimal projection angles.

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