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A LITERATURE SURVEY ON 3-D OPTOACOUSTIC TOMOGRAPHY AND ITS RECONSTRUCTION PATTERNS

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ABSTRACT- Optoacoustic tomography (OAT) is a hybrid, non invasive method which is also known as photo acoustic tomography, is an emerging computed biomedical imaging modality. Reconstruction method is used to reconstruct the OAT images, among which iterative reconstruction algorithm is the one that is designed to minimize the error between measured signals and signals from the reconstructed image. The Kaiser-Bessel window functions for iterative reconstruction are accomplished for the accurate computation of the system matrix. In this work we review the different types of reconstruction algorithm such as pseudo inverse reconstruction, filtered back projection, simple back projection and direct Fourier Transform method.

Keywords: Optoacoustic tomography, reconstruction algorithms, Kaiser-Bessel window.

I. INTRODUCTION

Optoacoustic tomography (OAT) [1] also referred to as photo acoustic computed tomography, is an emerging hybrid imaging modality that combines the high spatial resolution and ability to image relatively deep structures of ultrasound imaging with the high optical contrast of optical imaging [2], [3]. In photo acoustic imaging, non-ionizing laser pulses are delivered into biological tissues (when radio frequency pulses are used, the technology is referred to as thermo acoustic imaging). Some of the delivered energy will be absorbed and converted into heat, leading to transient thermo elastic expansion and thus wideband (e.g. MHz) ultrasonic emission. The generated ultrasonic waves are then detected by ultrasonic transducers to form images. It is known that optical absorption is closely associated with physiological properties, such as hemoglobin concentration and oxygen saturation.[2] As a result, the magnitude of the ultrasonic emission (i.e. photo acoustic signal), which is proportional to the local energy deposition, reveals physiologically specific optical absorption contrast. OAT has great potential for use in a number of biomedical applications, including small animal imaging [4]–[7], breast imaging [8], [9], and molecular imaging [10].

The acoustic wave fields propagate out of the object and are detected by use of a collection of wide-band ultrasonic transducers that are located outside the object. From these acoustic data, an image reconstruction algorithm is employed to obtain an estimate of A(r).

OAT iterative reconstruction algorithms are based on discrete-to-discrete (D-D) imaging models used to map a finite-dimensional approximation of A(r) to the measured data vector, which is inherently finite-dimensional in a digital imaging system [1]. Other 4 different types image reconstruction algorithms [11] are

- Pseudo inverse of the system matrix
- Filtered Back projection
- Simple Back projection
- Fourier transform method

The reconstructed images of the above methods are expanded using Kaiser-Bessel window function and it is converted in to 3-Dimensional geometry for better performance and analysis.

II. ITERATIVE RECONSTRUCTION ALGORITHM

Iterative reconstruction refers to iterative algorithms [12] used to reconstruct 2D and 3D images in computed tomography imaging techniques. The image must be reconstructed from projections of an object. The iterative reconstruction techniques are better, but computationally more expensive. Large number of algorithms are accomplished which works on assumption, computation and comparison of the original data updates of that images. There are typically five components to iterative image reconstruction algorithms:

- An object model that expresses the unknown continuous-space function f(r) that is to be reconstructed in terms of a finite series with unknown coefficients that must be estimated from the data.
- A system model that relates the unknown object to the "ideal" measurements that would be recorded in the absence of measurement noise. Often this is a linear model of the form $Ax+\epsilon$, where ϵ represents the noise.
- A statistical model that describes how the noisy measurements vary around their ideal values. Often Gaussian noise or Poisson statistics are assumed. Because Poisson statistics are closer to reality, it is more widely used.
- A cost function that is to be minimized to estimate the image coefficient vector. Often this cost function includes some form of regularization.
- An algorithm, usually iterative, for minimizing the cost function, including some initial estimate of the image and some stopping criterion for terminating the iterations.

Radon transform

The creation of an image from the cross sectional scans of an object from the different projections are performed in radon transforms [13]. The inverse radon transform can be used to reconstruct the density function related to image from the projected data and is known as image

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reconstruction. The radon transform data is called the sinogram because the distribution is supported on the graph of a sine wave. The projection-slice theorem tells us that if we had an infinite number of one-dimensional projections of an object taken at an infinite number of angles, we could perfectly reconstruct the original object ,f(x,y) So to get f(x,y) back, from the above equation means finding the inverse Radon transform. It is possible to find an explicit formula for the inverse Radon transform. However, the inverse Radon transform proves to be extremely unstable with respect to noisy data.

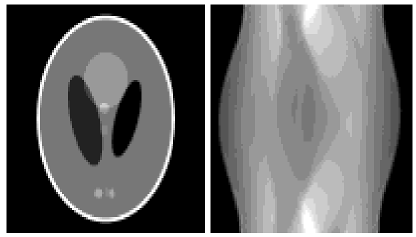

Figure1: Shepp-Logan phantom and its Radon transform.

III. PSEUDO INVERSE RECONSTRUCTION

An SVD was performed on the system matrix [11], which was then used to calculate the pseudo inverse. The SVD factors the system matrix into H = USV†, where U and V† are unitary matrices, the dagger represents conjugate transpose, and S is a diagonal matrix consisting of the singular values in decreasing order. The pseudo inverse is then given by $H^+ = VS^+U†$, where S^+ is a diagonal matrix consisting of the reciprocal of singular values above a threshold. The thresholding of the singular values serves as regularization. This method is also referred to as truncated SVD inversion. The image, which is an estimation of the initial pressure f, is then given by $f\^= H^+g$.

IV. FILTERED BACK PROJECTION

Filtered back projection [14] as a concept is relatively easy to understand. Let's assume that we have a finite number of projections of an object which contains radioactive sources. The projections of these sources at 45 degree intervals are represented on the sides of an octagon. The projections will interact constructively in regions that correspond to the emittive sources in the original image. A problem that is immediately apparent is the blurring (star-like artifacts) that occur in other parts of the reconstructed image. One would expect that a high-pass filter could be used to eliminate blurring, and that is the case. The optimal way to eliminate these patterns in the noiseless case is through a ramp filter [5]. The combination of back projection and ramp filtering is known as filtered back projection.

V. SIMPLE BACKPROJECTION

Back Projection is a way of recording how well the pixels of a given image fit the distribution of pixels in a histogram model [15]. For Back Projection histogram model of a feature is calculated and then it is used to find this feature in an image. Geometrically, the back projection operation simply propagates the measured sonogram back into the image space along the projection paths. Simple back projection, although not theoretically exact, is numerically equivalent to the delay-and-sum beam former method employed in ultrasound imaging systems, and hence is very readily implemented in combined ultrasound photo acoustic imaging systems. The simple back projection algorithm is equivalent to the filtered back projection algorithm except the pressure is not time-integrated or filtered with the Ram-Lak filter [11].

VI. DIRECT FOURIER RECONSTRUCTION

Once f (Vx,Vy) is obtained from p (ξ,Φ) using the CST, f(x,y) can be obtained by applying inverse FT to F (Vx,Vy) Issue of interpolation: To utilize the fast Fourier transform (FFT) algorithm, values of F (Vx,Vy) should be available at a rectangular grid. The values generated from the CST, however, are available at a polar grid. Fourier-space interpolation is therefore necessary. The Fourier method of image reconstruction is also based on inverting the solution to the photo acoustic wave equation, but this inversion is performed in the frequency domain.

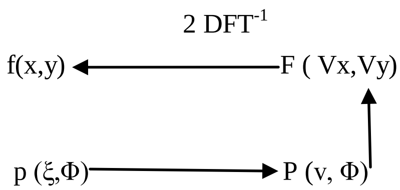

Figure 2: flow of direct Fourier transform

VII. KAISER-BESSEL WINDOW

It is also known as Kaiser Window [1]. It is a one parameter family of window functions used for digital signal processing. In frequency domain, it determines the trade-off between main-lobe width and side lobe level, which is a central decision, is window design. It is radially symmetric and it have finite boundary and also it is spatially support. It also supports smooth functioning which can rid of noisy signal. The reconstructed images are expanded using Kaiser-Bessel function which is centered at Body Centered Cubic [16].

VIII. CONCLUSION

The photo acoustic tomography is a method which accompanies both the optical contrast and the ultrasonic detection principles. Several methods are being used for the reconstruction of the OAT images and among that a review of most commonly used five are explained. The reconstructed images from the different method can be classified using the neural networks. Depending upon the specific system and task to be performed, the result of the different method may vary. So the optimization should be performed according to that. The modern post-processing methods such as total variance minimization, expectation maximization, and algebraic reconstruction can also be used for better results.

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