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CT Scan Reconstruction from Back Scattering Images for Maximum Convergence

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Abstract: *Computerized tomography (CT) plays an important role in medical imaging, especially for diagnosis and therapy. However, higher radiation dose from CT will result in increasing of radiation exposure in the population. Therefore, the reduction of radiation from CT is an essential issue. Expectation maximization (EM) is an iterative method used for CT image reconstruction that maximizes the likelihood function under Poisson noise assumption.*

Total variation regularization is a technique used frequently in image restoration to preserve edges, given the assumption that most images are piecewise constant. Here, we propose a method combining expectation maximization and total variation regularization, called EM+TV. This method can reconstruct a better image using fewer views in the computed tomography setting, thus reducing the overall dose of radiation. The numerical results in two and three dimensions show the efficiency of the proposed EM+TV method by comparison with those obtained by filtered back projection (FBP) or by EM only.

Keywords*: computerized tomography, image reconstruction, energy minimization, total variation, expectation maximization, Poisson noise, compressive sensing, Radon transform.*

I. Introduction

X-ray computed tomography, also **Computed tomography** (**CT**) or Computed axial tomography (CAT) can be used for medical imaging and industrial imaging methods employing tomography created by computer processing. Digital geometry processing is used to generate a three-dimensional image of the inside of an object from a large series of two-dimensional X-ray images taken around a single axis of rotation. CT produces a volume of data that can be manipulated, through a process known as "windowing", in order to demonstrate various bodily structures based on their ability to block the X-ray beam. Although historically the images generated were in the axial or transverse plane, perpendicular to the long axis of the body, modern scanners allow this volume of data to be reformatted in various planes or even as volumetric (3D) representations of structures. Although most common in medicine, CT is also used in other fields, such as nondestructive materials testing, another example is archaeological uses such as imaging the contents of sarcophagi.

As a group of methods for reconstructing two dimensional and three dimensional images from the projections of the object, iterative reconstruction has many applications such as in computerized tomography (CT), positron emission tomography (PET), and magnetic resonance imaging (MRI). This technique is quite different from the filtered back projection (FBP) method, 15 which is the most commonly used algorithm in practice by manufacturers. The main advantages of the iterative reconstruction technique over the filtered back projection are insensitivity to noise and flexibility.8 the data can be collected over any set of lines, the projections do not have to be distributed uniformly in angle, and these can be even incomplete.

We proposed a method combining expectation maximization and total variation minimization for image reconstruction in computerized tomography, in the presence of Poisson noise. This method provides comparable results when using very few views, comparing to filtered back projection with many more views; also, the proposed method provided much improved results without artifacts, by comparison to those obtained by the expectation maximization only. In conclusion, the proposed method needs much fewer measurements to obtain a good quality image, which results in the decrease of the radiation dose. The method has been easily extended to three dimensions. Future work includes faster implementation using the advantage of graphics processing units (GPUs), parallel computing, and applications to real data.

Computerized tomography (CT) plays an important role in medical imaging, especially for diagnosis and therapy. However, higher radiation dose from CT will result in increasing of radiation exposure in the population. Therefore, the reduction of radiation from CT is an essential issue. Expectation maximization (EM) is an iterative method used for CT image reconstruction that maximizes the likelihood function under Poisson noise assumption. Total variation regularization is a technique used frequently in image restoration to preserve edges, given the assumption that most images are piecewise constant. Here, we propose a method combining expectation maximization and total variation regularization, called EM+TV. This method can reconstruct a better image using fewer views in the computed tomography setting, thus reducing the overall dose of radiation. The numerical results in two and three dimensions show the efficiency of the proposed EM+TV method by comparison with those obtained by filtered back projection (FBP) or by EM only.

II. Tomography

Tomography refers to imaging by sections or sectioning, through the use of any kind of penetrating wave. A device used in tomography is called a tomograph, while the image produced is a tomogram. The method is used in radiology, archaeology, biology, geophysics, oceanography, materials science, astrophysics and other sciences. In most cases it is based on the mathematical procedure called tomographic reconstruction. The word was derived from the Greek word tomos which means "part" or "section", representing the idea of "a section", "a slice" or "a cutting". A tomography of several sections of the body is known as a polytomography.

In conventional medical X-ray tomography, clinical staff makes a sectional image through a body by moving an X-ray source and the film in opposite directions during the exposure. Consequently, structures in the focal plane appear sharper, while structures in other planes appear blurred. By modifying the direction and extent of the movement, operators can select different focal planes which contain the structures of interest. Before the advent of more modern computer-assisted techniques, this technique, developed in the 1930s by the radiologist Alessandro Vallebona, proved useful in reducing the problem of superimposition of structures in projectional (shadow) radiography.

III. Computerized tomography (CT)

There are several advantages that CT has over traditional 2D medical radiography. First, CT completely eliminates the superimposition of images of structures outside the area of interest. Second, because of the inherent high-contrast resolution of CT, differences between tissues that differ in physical density by less than 1% can be distinguished. Finally, data from a single CT imaging procedure consisting of either multiple contiguous or one helical scan can be viewed as images in the axial, coronal, or sagittal planes, depending on the diagnostic task. This is referred to as multiplanar reformatted imaging.

CT is regarded as a moderate- to high-radiation diagnostic technique. The improved resolution of CT has permitted the development of new investigations, which may have advantages; compared to conventional radiography, for example, CT angiography avoids the invasive insertion of a catheter. CT Colonography (also known as Virtual Colonoscopy or VC for short) may be as useful as a barium enema for detection of tumors, but may use a lower radiation dose. CT VC is increasingly being used in the UK as a diagnostic test for bowel cancer and can negate the need for a colonoscopy.

The radiation dose for a particular study depends on multiple factors: volume scanned, patient build, number and type of scan sequences, and desired resolution and image quality. In addition, two helical CT scanning parameters that can be adjusted easily and that have a profound effect on radiation dose are tube current and pitch. Computed tomography (CT) scan has been shown to be more accurate than radiographs in evaluating anterior interbody fusion but may still over-read the extent of fusion.

Applications of CT:

1. CT is used in medicine as a diagnostic tool and as a guide for interventional procedures.
2. Sometimes contrast materials such as intravenous iodinated contrast are used. This is useful to highlight structures such as blood vessels
3. Using contrast material can also help to obtain functional information about tissues.

IV. Proposed EM+TV Reconstruction Method

The EM+TV Reconstruction Method is based on the algorithm, that can be explained as follows

Expectation Maximization and Total Variation Algorithm:

The objective is to reconstruct an image with both minimal total-variation and maximal probability, given fewer noisy projections in the sonogram domain. So we can consider finding a Pareto optimal point by solving a secularization of these two objective functions and the problem is to solve, with $\alpha > 0$ a tuning parameter. This is a convex constrained optimization problem and we can find the optimal solution by solving the Karsh-Kuhn-Tucker (KKT) conditions.

In two dimensions, we compare the reconstruction results obtained by the proposed EM+TV method with those obtained by filtered back projection (FBP). For the numerical experiments, we choose the two dimensional Sheep-Logan phantom of dimension 256x256. The projections are obtained using Sidon's algorithm. We consider both the noise-free and noise cases. With the FBP method, we present results using 36 views (every 10 degrees), 180 views, and 360 views; for each view there are 301 measurements. In order to show that we can reduce the number of views by using EM+TV, we only use 36 views for the proposed method.

We show in Figure 1 the sonogram data without noise corresponding to 360, 180 and 36 views respectively (the missing projection values are substituted by zero or black). The reconstruction results are shown in Figure 2. We notice the much improved results obtained with EM+TV using only 36 views (both visually and according to the root mean- square-error between the original and reconstructed images, scaled between 0 and 255), by comparison with FBP using 36, 180 or even 360 views. Using the proposed EM+TV method, with only few samples we obtain sharp results and without artifacts. We have seen that, in two dimensions, the proposed EM+TV method gives superior results over the standard filtered back projection. In three dimensions, we compare the reconstruction results obtained by the proposed.

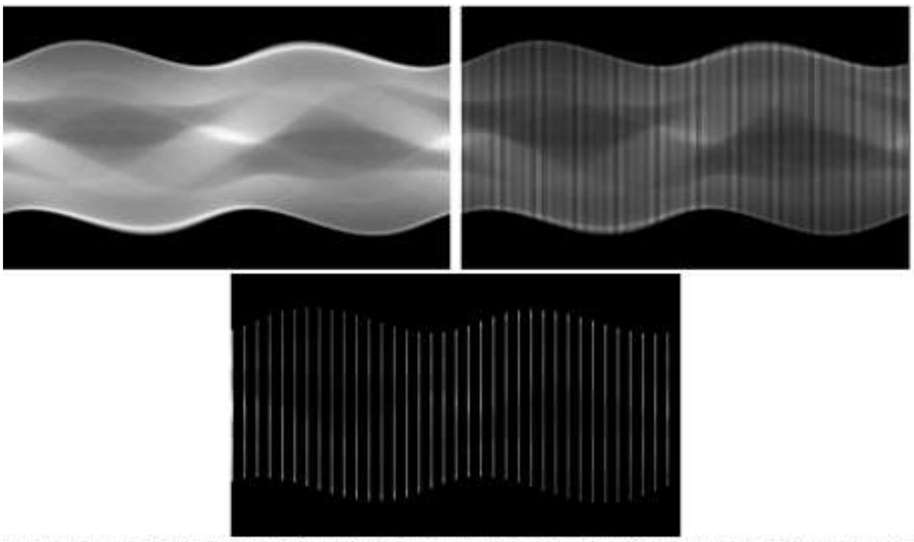

Figure 1. The sinogram data without noise in two dimensions, generated from the two-dimensional Shepp-Logan phantom. From left to right, top to bottom: 360 views, 180 views, 36 views. The x-scale is [0,360] in angle, and the y-scale is [1,301] for the second line parameter.

Advantages

- Iterative reconstruction technique over the filtered back projection is insensitivity to noise and flexibility.
- The data can be collected over any set of lines,

  The projections do not have to be distributed uniformly in angle, and thin complete.

Execution Results

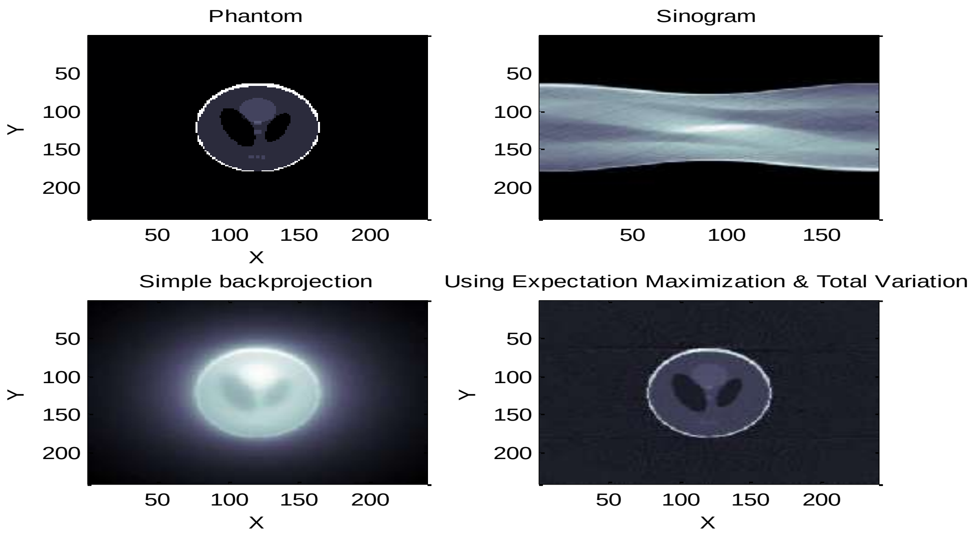

Figure shows different types of images Reconstruction results in two dimensions.

(a)Top: original image (the Shepp-Logan phantom). Middle from left to right: reconstruction results in the noise-free case using FBP with 36, 180 and 360 views, and result using proposed EM+TV with 36 views. Bottom from left to right: reconstruction results in the noisy case using FBP with 36, 180 and360 views, and result using proposed EM+TV with 36 views. The root mean square errors are also given.

V. Conclusion

The proposed method is combination of expectation maximization and total variation minimization for image reconstruction in computerized tomography, in the presence of Poisson noise. This method provides comparable results when using very few views, comparing to filtered back projection with many more views; also, the proposed method provided much improved results without artifacts, by comparison to those obtained by the proposed method needs much fewer measurements to obtain a good quality image, which results in the decrease of the radiation dose. The method has been easily extended to three dimensions. Future work includes faster implementation using the advantage of graphics processing units (GPUs), parallel computing, and applications to real data.

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