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RESEARCH CENTRE IN COMPUTER SCIENCE

Ph.D PUBLIC VIVA VOCE

As per the regulations of Madurai Kamaraj University, Madurai, **Mrs.A.Bharathi Lakshmi, (Reg. No. P8888)**, Part Time Research Scholar, Department of Computer Science, V.H.N.Senthikumara Nadar College (Autonomous), Virudhunagar, will defend her thesis at a Public Viva-Voce Examination through Video Conference mode using Google Meet Platform.

Title of the Thesis

PARALLELIZATION OF IMAGE RECONSTRUCTION METHODS OF MEDICAL IMAGING MODALITIES ON A SHARED MEMORY COMPUTATION PLATFORM

Date & Time

10.07.2020 (Friday) at 11.00 A.M

Venue

Research Centre in Computer Science,

V.H.N.Senthikumara Nadar College (Autonomous),

Virudhunagar.

Video Conference Platform

Google Meet

Meeting ID

https://meet.google.com/mje-digf-rer

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The Synopsis of the thesis is available in the college Website and a copy of the thesis is available in the Department Library for reference. Faculty members, Scholars and Students are most welcome to attend the Viva-Voce.

ALL ARE CORDIALLY INVITED

Place: Virudhunagar

Date : 22/06/2020

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Parallelization of Image Reconstruction methods of Medical Imaging Modalities on a Shared Memory Computation Platform

Synopsis Submitted to
Madurai Kamaraj University
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By
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Synopsis

Parallelization of Image Reconstruction methods of Medical Imaging Modalities on a Shared Memory Computation Platform

Image Reconstruction Technique (IRT) is a mathematical process that produces images from the projection data obtained at various angles around an object with the help of some of the medical imaging modalities like Computed Tomography (CT), Magnetic Resonance Imaging (MRI) or Positron Emission Tomography (PET). The image reconstruction is one of the significant applications of the projection technique. It is interrelated with the medical image processing technique. The scanning or data acquisition is the very first and significant stage of image reconstruction from projection (IRP). Converting image acquired from projections into digital form by performing some operations with the image is known as Digital Image Processing (DIP).

Image reconstruction is the process of converting a blur image into normal image. The reconstruction shows an energetic role in image processing method. It increases the quality and the accuracy of the image. Image reconstruction has been conceded using various reconstruction algorithms. IRT can be implemented by both analytically or iteratively. The analytical method differs from iterative method in its computational efficiency and numerical stability. The analytical methods require relatively less calculation and can reconstruct the image in a shorter time than the iterative method, even though they offer low resistance to measurement noise.

Analytical method such as Back Projection (BP) or Filtered Back Projection (FBP) is used for different imaging modalities such as CT and PET in clinical settings because of the speed and easy implementation. The analytical image reconstructing method assume that the images are noise free, there is chance to find a exact mathematical representation for the known projections. For noisy projection data as well as for limited number of projections, the FBP method of image reconstruction shows very poor performance. Hence currently there is considerable interest to evaluate the use of other reconstruction methods for medical imaging techniques.

On other hand Iterative Methods are based on optimization strategies incorporating specific constraints about the object and the reconstruction process. The iterative reconstruction techniques perform better than the FBP method when reconstruction is attempted with limited number of projection data. Iterative method is further classified into Algebraic and Statistical Method. The linear system problems are effectively solved under Algebraic method. Algebraic Reconstruction Technique (ART), Multiplicative Algebraic Reconstruction Technique (MART), Simultaneous Iterative Reconstruction Technique (SIRT), Simultaneous Algebraic Reconstruction Technique (SART) are some of the Algebraic algorithms. Statistical image reconstruction plays a vital role in medical field as it is a kind of iterative method that can be divided into weighted and likelihood.

Figure 1 illustrate the steps involved in the iterative image reconstruction, in which the initial image estimate is acquired using the projection. With the intial image the unfilled values are calculated using any one of the iterative algorithms and compared with the measured data. The Discrepancies between them is applied with backprojection to form the new image and new image acts as an initial image for next iteration. This process is repeated till the error between the data has been reduced.

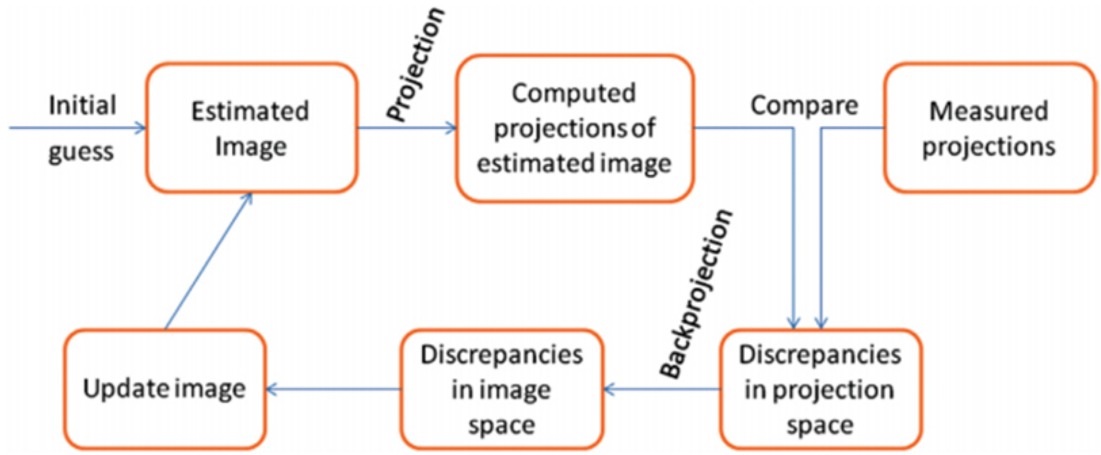

Figure 1: Steps involved iterative image reconstruction methods

Iterative process includes different methods for statstical reconstruction technique in the form of poission process. The poission statistical model supports the maximum posterior work, maximum likelihood and context based bayesian frame work. Expectation Maximization (EM) is one type of staistical method for image reconstruction process. The statistical model supports the iterative proecess to identify maximum posteriori paramaters. EM Algorithm is an iterative algorithm that is often used for estimating parameters of Gaussian Mixture Model. The gaussian mixture method allows the expecation maximazition model to reconstruct the image. Large scale information sets are not appropriate in reconstruction process, as of the computational cost is high. Maximum likelihood is a techinique to analyse the missing data in the multiple datasets. The best fit models can easily analyse in the multiple data sets. The anlaytical procedure is hard to solve maximum likelihood problem, when the value is set as zero for the partial derivatives. The expectation process can access the different equations instead of the mathematical process.

One of the major issues in the iterative image reconstruction is time complexity. The size of data sets acquired by the different techniques of EMRI is usually huge because of the complex data type of the raw collection data, multiple gradients in the experiments, high dimensions of the resultant 3-D images, higher k-space requirement of whole body imaging and the number of points collected from the imager. Hence, the reconstruction algorithms implemented in a sequential processor takes long time to compute a data set. Since most of the iterative algorithms take more than 60 iterations, the reconstruction time is still high. To reduce the reconstruction time parallel computing system has been implemented. The research study, focuses on reducing the computational time complexity of the processes of the core algorithms using parallel programming techniques.

The Parallel computing divides the given problem into subproblems and in turn each subproblems are broken into number of instructions that are excuted sequentially under a processor. In such a way each subproblems perform concurrently with multiple processors. This is implemented with the help of computers generally referred as parallel computers or multi-core processors. It also requires Programming languages, Operating Systems, parallel algorithm and compiler that support parallel processing. This computation process helps to solve the issues like computation of more iterations by splitting them into small number of processes and computes them concurrently. In the research study, the focus is on reducing the computational complexity of the processes of the core algorithms using parallel programming techniques. OpenMP is the latest software technology to express parallelism in sequential algorithms. OpenMP is now a major programming model for multiplatform shared memory multiprocessing systems from multi-core machine to large scale servers.

The OpenMP supports Fortran, C and C++ that make Shared memory parallelism easier. OpenMP is based on the Unix pthreads implementation. The OpenMP defines a set of compile directives, environmental variables and Runtime Library that is based on the fork/join programming model.

The program starts as a single thread named as master thread. When parallel region begins the master thread forks the region to specified number of slave threads and when the parallel region ends it back joins all the slave thread to a master thread. The assigned task of the threads will be synchronized before joining. A Thread is an execution entity with a stack and associated static memory called a threadprivate memory. The master thread takes the responsibility to fork the task into specified number of slave threads and to divide the task among them. Figure 2 shows the functioning of Master and Slave threads that exists in OpenMP.

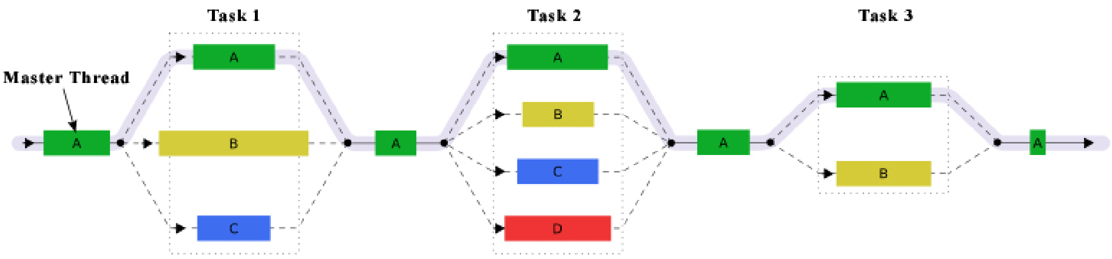

Figure 2: OpenMP Architecture

Chapter 1 provides an introduction to DIP, Medical Imaging, Phantom Imaging, existing reconstruction methodologies and shared memory environment. Image Reconstruction Technique available in current trend is discussed. The projection data acquisition procedures are also discussed briefly in radon transformation. Shepp-Logan Phantom on various sizes 64 x 64, 128 x 128 and 256 x 256 is considered for the research study. For each size the projection data from various angles at 6^0, 9^0, 12^0, 15^0 and 18^0 yielding 30, 20, 15, 12 and 10 number of projections has been taken into the research study. The projection data obtained from various angle is fed in to the algorithm as raw data to reconstruct an image using algebraic and statistical reconstruction algorithms. Problem has been identified as increase in reconstructing for the iterative algorithms and reducing the time is set as the ultimate goal of this research work.

Chapter 2 lists out the research study carried out on IRT and parallel computing technology implemented on image reconstruction techniques. This chapter throws light on ART, MLEM, MAPEM reconstruction algorithm contributed in various research works and journals.

Chapter 3 reconstructs Shepp-Logan phantom image using ART with limited number of procedures with fewer artifacts in limited number of projections. ART is an IRT reconstructed using algebraic technique. The number of iteration required to reconstruct an image is optimized. The proposed parallel Algebraic Reconstruction Technique (pART) adopts the parallel computing environment like OpenMP approach for reducing the number of iterations. The main aim of this work is to improve the ART technique computation complexity. The proposed work objective is achieved by implementing three different processes such as, Optimizing the Iteration, Reconstructing image sequentially and in parallel. The ART algorithm performance is analysed with analytical as well as other algebraic iterative algorithms.

The one-dimensional image data is projected with the help of the Radon transformation method. The images are reconstructed sequentially as well as in parallel environment by using different projection data sets. The parallel computation environment adopts the OpenMP architecture to improve the reconstruction process efficiency. Then, the proposed pART method is compared with the ART reconstructed sequentially. The speed up metrics is used to prove the efficiency of the shared memory environment. The speed up metrics shows a promising result.

Chapter 4 throws light on the statistical image reconstruction algorithm, MLEM is applied to make progress the emission intensity. The first phase implements Algebraic technique as it is applied to all imaging modalities. But as MLEM is based on statistical data the MLEM reconstruct better image for the ECT imagaing data. ART algorithm requires large number of iterations which leads to time complexity. The idea of this chapter is to reduce the number of iteration which in turn minimize the computation time. It is found that in case if MLEM is parallelised the computation time gets considerebly reduced.

The MLEM is applied for the object scanned using PET, SPECT or CT. The MLEM performs the reconstruction, followed by a maximum likelihood step to update the estimates. The popularity of MLEM is due to the high degree of accuracy in the compensation of non-uniform attenuation. For better accuracy the MLEM algorithms are extended by implementing a slight generalization in the statistical criterion to conclude the emission data. The MLEM algorithms could be used for PET, SPECT, and applications like photon boundless optical image rebuilding, astronomical research, electron microscopy, and nuclear imaging. Conventional reconstruction procedures similar to FBP cannot rebuild an image by means of an incomplete dataset. The probability matrix that enhances ML-EM, with simple substitutions has been outlined.

Diagonal elements related to the system matrix are given through the corresponding projection data elements. Therefore, to remove the detectors from the reconstruction procedure, the value is replaced by the average assessment of the diagonal matrix. The ML-EM algorithm is a good alternative to the filtered back projection algorithm and can be used successfully to reconstruct images with limited dataset.

The proposed parallel Maximization Likelihood Expectation Maximization (pMLEM) is implemented in SMP and shows a massive time reduction in reconstructing an image. Image quality is measured using PSNR value. As image size increases PSNR value increase. The PSNR value obtained for the reconstructed image is above 60 db even with limited number of projections. The image reconstructed both sequentially and in parallel produces same PSNR value but the reconstruction time is reduced. The speed up metric is calculated and it shows a good efficiency.

The performance measure of MLEM compared to ART shows that the iteration required to reconstruct an image is higher in MLEM. ART gives best PSNR value compared to MLEM. This is due to MLEM is designed for ECT images where as our data is just a weight of a projection data obtained using radon function.

The fifth chapter of the work is implementing parallel Maximum A Posteriori Expectation Maximization (pMAPEM) algorithm using parallel programming techniques in a shared memory processing environment. MAPEM is also a statistical iterative method similar to MLEM. The smoothed MLEM and MAPEM have same resolution and covariance. The number of iteration mandatory to reconstruct an image is optimized. An attempt to optimize the iteration required to reconstruct an image in various angle is performed. The images are reconstructed sequentially as well as in parallel environment using different projection data sets. In this study, the Shepp Logan Phantom data is reconstructed using MAPEM.

The present study has proven the time complexity reduction through speedup and efficiency calculated using Amdahl's law. This work exposes a parallel MAPEM algorithm that reconstructs an image on a multi-core parallel environment to reduce the execution time. The SMP environment consists of a number of processors accessing one or more shared memory modules. For processing the large size of data, the SMP has some benefit over the distributed memory parallelization.

The performance measure of MAPEM compared to first two algorithms MLEM and ART shows that the iteration required to reconstruct an image is lower than MLEM but higher than ART for small size of images. As MAPEM is similar to MLEM and the difference is the priori smoothening factor it gives minimum iteration than ART. PSNR values are similar for all three reconstructed images.

Based on the evaluation of the present work, the time complexity due to the presence of iterative methods has been reduced. Hence the objective of the work is fulfilled. The reconstruction process shows a constant speedup and efficiency when all the algorithms implemented in the parallel environment with the open MP architecture.