Segmentation of Large Scale Medical Images using HPC: Classification of Methods and Challenges

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***Abstract*— *Medical imagining is one of the major disciplines for analyzing human tissues non-invasively. Image segmentation is a sub-process in image processing that divides the given image into meaningful regions that can used for further classification and analysis. This step is challenging, as it difficult to identify precisely and extract that portion of the image having abnormal tissues for further diagnosis and analysis. There are several methods and techniques that exist for image segmentation. But not all algorithms and techniques can be applied on medical images. Owing to the growth of medical image corpus and the need for automated image techniques, there is a need for large scale image segmentation techniques that can precisely identify the region-of-interest in real-time for diagnosis. This paper presents a comprehensive survey and review of the medical image segmentation models, techniques, algorithms and challenges that exists from medium and large scale image processing perspectives. We have explored the large scale segmentation using parallel and distributed computing platforms for handling data with ease with reduced cost.*

Keywords*— *Medical image analysis, Medical image segmentation, Large scale image processing.

I. INTRODUCTION

Medical Imaging is the most primary disciplines that are used to non-invasively access human tissues. It is used extensively in oncology for screening, diagnosis and treatment at various stages. This aids the doctors and radiologists in planning the treatment and response monitoring. Medical imaging modalities such as MRI, CT, Ultrasound, PET scans produce quality images that are further assessed by the radiologists qualitatively.

In medical image analysis, the image passes through several stages before being analyzed. Figure 1 [4] showing the flow of medical image analysis. The process begins with medical image acquisition from various sources. The images are then segmented or partitioned to identify the region-of-interests using different algorithms that are either semi-automated or automated. In the next phase, images specific features are extracted and analyzed by applying different analysis models that allows integrated analysis of image features, annotations and generic data. Finally, the classification of images, anomalies and abnormalities are presented.

Image segmentation is the mechanism of separating a digital image into multiple segments that is set of pixels. Sinha et.al [3] defines segmentation as an important process to extract suspicious region form complex medical images.

Pixels that are locate in the region are identified and classified according to some uniformity criteria such as intensity, color or texture; so as to locate and identify objects and boundaries.

Automatic image segmentation means automated extraction of region-of-interest of the image and performs a fundamental role in understanding content for mining and searching in medical image dataset. Many methods are exists for automatic and semi-automatic image segmentation. However, even with these methods, it is not guaranteed that it will work with all images. It is time consuming to interactively segment a large quantity of images or examine the segmentation results one-by-one. Some factors such as poor image contrast, unknown noise, and weak boundaries in medical image are responsible for image segmentation process very difficult. Further, complicated structures are been contained by medical images. To simplify the image and representation of the image into meaningful and easier form for analysis is the main goal of segmentation.

Withey [7] has categorized past researches into three different generations pushing towards fully automated segmentation with high accuracy and improved performances. Image Segmentation can be broadly categorized in semi-automated and fully-automated approaches. Most of the algorithms, techniques and models, which are used for medical image segmentation are lies either in two of these categories.

This paper presents a comprehensive literature survey in the arena of medical images segmentation and associated challenges that exist in both serial and parallel implementations. The remaining sections of the paper are organized as follows. Section II presents related work that includes the state of art in medical image segmentation, methods, algorithms and techniques and challenges. Section presents the state of art in handling large scale image segmentation using high performance and parallel computing. Section presents limitations and challenges and lastly section presents conclusion of the paper.

II. RELATED WORKS

Researchers have applied a variety of automated and semi-automated machine learning and computational intelligent techniques to extract region-of-interest from a given image. Segmentation plays an important role in medical imaging to closely examine the region for further prognosis. The images can be segmented based on different image features such as color, texture, region and size [2] Different method and techniques have evolved over years, that each of these methods caters to specific needs. Khan et.al [9] presents a detailed survey of the segmentation techniques. Rajaei et.al [5] proposed medical image texture segmentation using texture filtering. Dass et.al [2] described few techniques of the segmentation that are used in the field of ultrasound and SAR image processing.

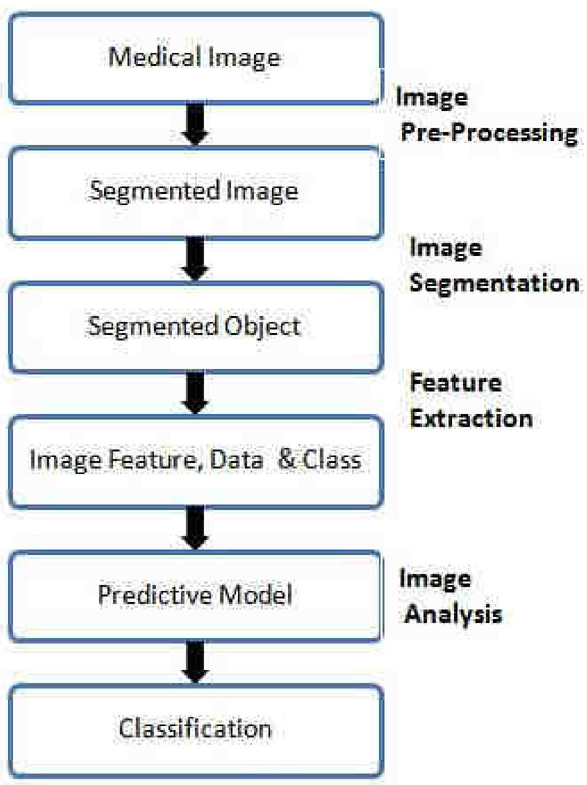

Fig.1: Image Analysis Workflow

Ahirwar [8] tested some region based fuzzy techniques for automated segmentation of brain MRI images. Neeraj Sharma [14] has mentioned automated medical image segmentation techniques for the CT and MR images. Lowe [26] extracts distinctive invariant features from images using fast nearest-neighbor algorithm followed by Hough transform to identify clusters.

Parmar [19] introduced 3D-Slicer semiautomatic segmentation technique that can extract more Radiomics features. Here, the imaging feature robustness extracted from tumor segmentation manually is compared with semi-automated tumor segmentation.

Figure 2 presents the classification of medical image segmentation methods based on different parameters such as edge, texture, pixel, region etc. This classification is based on based on image features as given in [10].

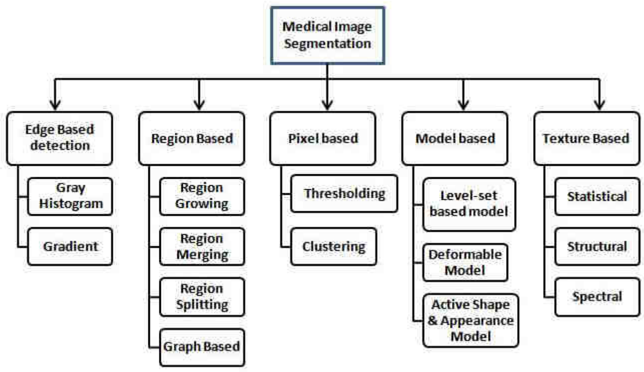

Fig. 2: Image Segmentation Methods

Table 1 presents overview of different approaches that have been used in segmentation. Table 2 presents the segmentation algorithms. It is evident from Table 2 that different attempts have been made that uses machine learning and computational algorithms for addressing issue in segmentation. There also exist dominant mathematical models such as region-growing, thresholding, edge detection and grouping, level-sets etc.

Table 1: Segmentation Techniques

Methods	Techniques
Region based	☐ Seeded region growing [9] ☐ Unseed region growing method [9] ☐ Normalized cut[6] ☐ Markov Random Field graph cut[7] ☐ Watershed Segmentation technique [22]
Edge Based	☐ Active Contour tech.[9] ☐ Canny edge detection[9] ☐ LoG edge detection[9] ☐ Marr-hildreth technique[9] ☐ Robinson edge detection technique [9] ☐ Kirsch edge detection technique [9] ☐ Prewitt edge detection technique [9] ☐ Robert edge detection technique [9] ☐ Sobel edge detection technique [9].

Texture Based	One/two/high statics of gray level of image Pattern optimization[5]
Pixel based	Local thresholding[2] Global thresholding[2] Hard Clustering[2] Fuzzy Clustering[2]
Model based	Active-shape &appearance model[7] Deformable model[18] Level set based model[2] Atlas based[14]

Cigdem Gunduz-Demir [13] has mentioned two different context of segmentation for histopathological images where the images are classified as tissues or cell/ gland. They have also proposed GraphRLM and ObjectSEG segmentation algorithms based on the features, color and size respectively.
Mohapatra et.al [27] presented acute leukemia detection using functional link neural architecture on lymphocyte images. Jiang [29] presents the survey of using artificial neural network in medical image analysis at different stages. It also presents using ANN in different diseases including cancers of the breast and lung.
[30] Compared three Genetic algorithms (GA), Particle Swarm Optimization (PSO) and ant colony optimization (ACO) for medical image segmentation for measuring their accuracy, training time and testing time for optimization and tabulated the results. Here GA performed better in learning during the training phase. Liu et.al [31] has proposed an improved ant colony algorithm for edge detection with high accuracy and implementation efficiency. They have used fuzzy cluster in the initial stages of segmentation and later used edge detection strategy to the edge of the image.

Table 2: Segmentation Algorithms

Methods	Used Algorithms
Region based	Swarm Optimization Algorithm Partial Volume effect correlation [18]
Edge based	Edge relaxation[18] Boarder detection[18] Hough Transform based algorithm [18]
Texture based	Probabilistic/Deterministic algorithm[14] Intensity/In-homogeneity correlation[18]
Pixel based	Active Shape model [7] Intensity-In-homogeneity correlation[18]
Model based	Atlas selection[14] Atlas registration[14] Manual tracing protocol[14] K- means algorithm[9] C- means algorithm[9]

Ye et.al [32] applied ACO algorithm to select image threshold automatically which is a combinatorial problem have given promising results. [33] presents a brief survey of application of ACO in image segmentation for classifying images. [34] present a generic survey of the image segmentation techniques using AI and evolutionary approaches.
[35] presents a study and comparison of Otsu algorithm, watershed algorithm, and global region based segmentation for detecting lung nodules in lung cancer. They have also performed a comparative study of variants of ACO algorithm for reducing false alarms. Additionally they have proposed a black circular neighborhood approach to detect nodule centers from the edge detected image.

III. HANDLING LARGE SCALE MEDICAL IMAGE SEGMENTATION USING HIGH PERFORMANCE COMPUTING

The growth of amount of medical image data produced on a daily basis. The number of images and their dimensionality increased dramatically during past 20 years. To improve performance the applications with serial algorithm cannot be rely on technology scaling. With the improved programming support, the rapidly enhancing performance of graphics processor and the price to performance ratio of graphics processor has emerged as a parallel computing platform for computationally expensive and demanding task. Medical images are continuously increased in size and volume. In real time clinical application for high-scale image segmentation, we can parallelize the code to increase performance and execution time of segmentation process.
To parallelize code, we can use OpenMP, MPI, CUDA, MIMD etc. techniques on multi core GPU. In [21], they have taken 128*128 sized image, on that they have applied wavelet segmentation method and parallelize code using OpenMP. The results of the experiments are tabulated in Table 3. Table 3 has three sections with each sections A, B [22] and C [23] showing the performances for varying image sizes (128 *128, 2048*2048 and 512*512) by applying

wavelet and watershed based algorithms with varying implementations using MPI, OpenMP and MPI and MIMD.
From the Table 3, it is clear that, as the number of processors increases, the execution time is decreased. Also we can get the efficient result of the use of parallelization over serial execution in the segmentation process.

Table 3: Performance Measurement

No. Of Processor	A		B		C
	Execution time	speed up	Execution time	speedup	Execution time
2	14.41	1.811	0.07381	1.575	1.333
4	7.49	1.872	0.052672	2.194	0.671
8	4.87	2.191	0.041968	2.754	0.357

(A) Image size: 128*128, wavelet based segmentation method using OPENMP (B) image size: 2048*2048, wavelet based segmentation using MPI (C) image size: 512*512, watershed algorithm of segmentation using MPI, MIMD and divide-conquer approach

From the Table 3, it is clear that, as the number of processors increases, the execution time is decreased. Also we can get the efficient result of the use of parallelization over serial execution in the segmentation process.
[25] presents a non-parametric parallel image segmentation algorithm that computes the equilibrium states of a Potts model in the super Para-magnetic phase of the system. The algorithm which was implemented using GPU and CUDA can be used for near real time processing. Comparison of the algorithms using CPU and GPU is also presented for different image dimensions.
[28] presents a robust segmentation using hierarchical voting and repulsive action contour to delineate region-of-interests. This framework was implemented using 4 core CPU machine, achieved an accuracy of 87.3% when applied to classify two different types of lung cancers.
The major challenge of parallel processing is not only high performance but also the speedup and better utilization of resources. Medical image need more computing power than the serial traditional computer can do. For medical imaging, it is necessary to image been clear and can be obtained as quickly as possible. We can achieve the need of less computing power in medical imaging by parallelizing. Parallelizing optimizes the speed at which the image is produced.

IV. LIMITATIONS AND CHALLENGES

Segmentation on medical images is a challenging task. Accurate and efficient extraction of quantifying image features from region-of-interest is challenging. Manually segmentation of images is time consuming and it is suffers from high inter-observer variability. Medical imaging requires the analysis of not only normal structure and function, but should also differentiate abnormal, pathological or disease states [15]. There is no specific technique that can perform better in scenarios. Hence, an algorithm development for one class of image may not be applied to other class of images. [19]Semiautomatic and automatic techniques take less time and improve uncertainty in manual delineation.
Medical image segmentation still remains a challenging due to image quality, cluttered objects, and image noise and image texture. Noise in medical image can change the intensity of the pixel and hence there is a chance of uncertainty in classification. The intensity of a tissue class changes continuously over the extent of the image. Since the images have limited pixel size and are suppose to partial volume averaging where individual pixel volumes contain a mixture of different classes of tissue so that the pixel intensity in the image may not be accordant with any single tissue class [7].
Any edge detection method needs a balance between two that are noise immunity in practice and detecting accuracy, if the level of accuracy is too high, noise may take in fake edges making the abstract of images reasonless. But if the degree of noise immunity is too high then some objects of the image outline may get not detected and the position of objects may be misguide. [2].
In thresholding, only two classes are generated and it cannot apply on multichannel is the limitation of thresholding. It doesn’t take into account of the spatial features of an image because that it is sensitive to noise, as both of these antiquity corrupt the histogram of the image, makes separation more difficult [2].
Only objects with edges defined by gradients can be segmented till the edge stopping function depends on the images gradient [2]. The curve may eventually pass through object boundaries as the function named edge-stopping never exact zero [2]. All the techniques are not suitable for medical image analysis because of complexity and inaccuracy [3].

V. CONCLUSION

Medical image processing is one of the main dynamic research topics in image processing. Most researches in medical imaging area are tied with many image segmentation techniques. Image segmentation has the promising future in various segmentation algorithms and has become the focus modern researches. This paper presents an overview, techniques and methods, challenges in image segmentation on medical images. This paper also covers survey of the large scale image processing using high performance computing paradigms.

With the growing need for real-time image processing and to handle large scale images and decision making, we can adopt CPU-GPU systems and parallel techniques such as OpenMP, MPI, MIMD, and CUDA etc. are in use to make efficient performance of segmentation technique.

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