Performance Analysis of Image Segmentation Using Parallel Processing

Supriya Gupta, Mujeeb Rahman

***Abstract*—This paper presents a study on Fuzzy C Means (FCM) based segmentation technique via different modes over a number of images. This research work includes development of simulation models in both sequential and parallel modes. The proposed FCM based segmentation method is tested extensively by subjective and objective evaluation via both modes. Various image and performance parameters are evaluated such as serial time, parallel time, overheads, efficiency, MMSE, PSNR and Percentage of Tumour. The results show that leveraging of multi-core platforms can speed up the processing of images considerably through the use of parallel computing tools in MATLAB. The parameters like PSNR, MMSE, and image quality have not been compromised while increasing the time efficiency through parallel mode. This information can be utilized in the fields where real time processing of image data is required.**

***Index Terms*— Fuzzy C-Means, Comparison, Segmentation, Parallel Techniques**

I. INTRODUCTION

The principal objective of image segmentation is to improve the quality of an image and to make it more suitable for a given task and a specific observer. Image segmentation forms an integral part of computer vision systems and is more an area of computer vision than image processing. [1]

Image segmentation is the processing procedure to assign an image level to each pixel in an image such that pixels having same image level share some visual features and it enhances clarity in the interested region and supports better object recognition. [2] Image segmentation can be applied to many applications like medical imaging, diagnosis, computer guided surgery, face recognition, fingerprint detection.[4] From the segmented results, we can easily identify region of interest (ROI), object recognition and subsequent image analysis. Many general purpose algorithms are reported for image segmentation. The optimal way of deriving better techniques is to combine suitable algorithms within specific domain.

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It is always challenging for researchers to decrease the computation time for segmenting complex image structures. [3] The computation time to segment a complex image increases a lot. Therefore, here we are going to implement image segmentation using parallel techniques and evaluate performance of the results and their speedups. During this

process, an image is equally distributed among the workers. The main objective of use of the parallel computers is to speed up computations and improve efficiency and response time by using multiple cores of a CPU, or to perform larger computations which are not possible or are very large time consuming on single core systems. [5] The perception of having more than one computation resources for solving certain time consuming problems seems more interesting and valid. Although, coordination among multiple computation resources and work distribution among them place major challenges on system designer.

II. SEQUENTIAL IMPLEMENTATION OF FCM

There are already compared the different algorithm of segmentation like threshold base, k means , region growing FCM over different parameters and FCM is better than all algorithms.[6] This paper section comprises of FCM algorithm definition and outlines major parameters which would be analyzed and compared against parallel mode implementation. The hardware and software requirements for sequential implementation of FCM are listed out and an introduction to MatLab tool is provided along with input and output of the developed system.

2.1 FUZZY C MEANS ALGORITHM

Fuzzy C Means algorithm which is in general termed as FCM this is a kind of iterative algorithm which is derived from the fuzzy clustering logic. Each and every image data element in various classes is classified in a membership degree. The objective of FCM is to minimize J, the objective function J which can be expressed as follows:-

$$J(X, Y, U) = \sum_{j=1}^{K} \cdot \sum_{i=1}^{N} U_{ij}^{m} \, d^2(X_i, Y_j) \qquad 2.1$$

Where –

X = (Xi, i=1…...N)

K: Number of clusters;

N: Total number of image pixels

Yj: Centre of i^{th} cluster

d^2(Xi,Yj): Distance between the pixel Xi and Yj

U_{ij}^m: Degree of membership and
m: the fuzzy degree.
The spatial matrix U satisfies the conditions as detailed in following equations -

$$0 \le U_{ij} \le 1, \forall i \in \{1, \dots, N\} \text{ and } \forall j \in \{1, \dots, K\} \quad 2.2$$

$$\sum_{j=1}^{K} U_{ij} = 1 \ \forall i \in \{1, \dots N\} \quad 2.3$$

$$U_{ij} = \left[\sum_{l=1}^{K} \left(\frac{d^2(X_i, Y_j)}{d^2(X_i, Y_l)} \right)^{\frac{1}{m-1}} \right]^{-1} \ \forall i \in \{1, \dots, N\} \quad 2.4$$

$$Y_j = \frac{\sum_{i=1}^{K} U_{ij}^m X_i}{\sum_{i=1}^{K} U_{ij}^m}, \forall j \in \{1, \dots, K\} \quad 2.5$$

FCM Algorithm
Step 1:
Initialize the parameters:
X = (Xi, i =l ….. N)
K: Number of clusters
m: Fuzzy degree
ε: Threshold value which represents the convergence error

Step 2:
Initiate and process the matrix U for initialization using different random values of degree membership in the given interval [0, 1] where it also satisfies the condition in equation (2.3).

Step 3:
Repetition
Update the degree of membership for matrix U in equation (2.4)
For getting the stability of the matrix (Y) - $(Y^{new} - Y^{old}) < \varepsilon$
It has been observed that 'm' parameter, introduced by Bezdek, refers to the fuzziness degree of the partition. As per Bezdek, the value of 'm' must be greater than 1 since the choice of m plays an influential role in processing of FCM algorithm. [7]

III. Parallel Implementation of FCM

3.1 PARALLEL COMPUTING

Parallel computing is an alternative to solve problems that require large times of processing or handling amount of information in acceptable time. In parallel processing, the program is able to create multiple tasks that work together to solve problem. The main idea is to divide the problem into simple tasks and solve them concurrently so that time is divided. Depending upon the requirement of the application and available budget, the selection of architecture is done.
A parallel program must have some features for correct and efficient operation. These features include the following:

1. Granularity: It is defined as the number of basic units and it is classified as:
Coarse – grained: Few tasks of more intense computing.
Fine – grained: A large number of small parts and less intense computing.

2. Types of parallel processing:
Explicit **-** The algorithm includes instructions to specify which processes are built, executed in parallel way.
Implicit **-** The compiler has task of inserting necessary instructions to run the program on parallel computer.

3. Synchronization: This prevents the overlap of two or more processes.

4. Latency: This is the time transition of information from request to receipt.

5. Scalability: It is defined as the ability of an algorithm to maintain its efficiency by increasing the number of processors and the size of the problem in same proportion.

6. Speedup and efficiency are metrics to assess the quality of parallel implementation.

7. Overheads: Extra time needed for the computation

3.2 PARAMETERS EVALUATED USING BOTH SEQUENTIAL AND PARALLEL IMPLEMENTATION OF FCM

Various image characteristics have been studied and 4 basic parameters are analyzed during sequential execution of the enhanced FCM algorithm on medical images inheriting tumour regions in them. These parameters are:

Time Consumption – This is the total time taken by the simulator system in image partitioning and creation of segmented output image using FCM clustering algorithm.

Percentage of Tumour – This depicts the percentage of area of tumour with respect of whole image area.

PSNR **- Peak Signal-to-Noise Ratio (PSNR) –** The PSNR block computes the peak signal-to noise ratio, in decibels between two images. This ratio is often used as a quality measurement between the original and an enhanced image. PSNR represents a measure of the peak error. The block computes the PSNR using the following equation: [8]

$$\mathbf{PSNR} = 10 \log_{10} \left(\frac{R^2}{MMSE} \right)$$

R is the maximum fluctuation in the input image data type. For example, if the input image has a double precision floating-point data type, then R will be 1.

MMSE - The Minimum Mean Square Error (MMSE) represents the cumulative squared error between the reconstructed image and the original image. The MMSE can be evaluated using the following equation:

$$\mathbf{MMSE} = \frac{\sum_{M,N} [I_1(m,n) - I_2(m,n)]^2}{M * N}$$

In the previous equation, M and N are the number of rows and columns in the input images, respectively. The lower value of MMSE designates lower error.

There are few more parameters which would play an important factor while parallel implementation of FCM algorithm. They are mentioned below-

Speed up: It is the ratio between sequential execution time and parallel execution time where the sequential time execution time is sum of total computation time of each task and parallel time execution is the scheduling length on limited number of processors.

$$Sp=(\sum_{i=1}^{n} T_i) / Tp \quad 3.1$$

Efficiency: The efficiency of a parallel program is a measure of processor utilization where Sp = Speedup, Np = Number of processors.

$$EFF=Sp / Np \quad 3.2$$

Overheads: Overheads of the parallel program can be measured as the extra time needed for performing the computations.

Overheads = Parallel time– (Serial time/ No. of processors)

3.3

3.3 IMPLEMENTATION OF FCM IN PARALLEL MODE

The main objective of the research is to reduce the execution time and waiting time of the users. To achieve this we have used fork and join policy of parallel algorithms which will enable given job to run in parallel so that maximum speed of the cores can be achieved provided by the multi-core systems. Image enhancement algorithm is applied to achieve the objectives of this research work. MATLAB simulator is used to simulate the desired behavior. [9] Enhancement algorithm is executed in both sequential and parallel manner for comparison of performance. Matlabpool is utilized to implement the algorithm in parallel mode. Proposed algorithm will be implemented in Matlab and uses the feature of image processing tool box.

3.3.1 Basic introduction of Matlab and Matlabpool

Matlab is a general algorithm development environment with powerful image processing and other supporting toolboxes. With the rapid development of multi-core CPU technology, using multi-core computer and Matlab is an intuitive and simple way to speed up the computing for image enhancement algorithm. The results show that the parallel versions of former sequential algorithm with simple modifications achieve the speedup. Matlabpool enables the parallel language features in the MATLAB language (e.g., parfor) by starting a parallel job that connects this MATLAB client with a number of labs. Matlabpool open starts a worker pool using the default parallel configuration, with the pool size specified by that configuration. You can also specify the pool size using matlabpool open pool size, but most schedulers have a maximum number of processes that they can start (8 for a local scheduler). If the configuration specifies a job manager as the scheduler, matlabpool reserves its workers from among those already running and available under that job manager. If the configuration specifies a third-party scheduler, matlabpool instructs the scheduler to start the workers.

3.3.2 Implementation Methodology

We consider a grey scale image represented by two –dimensional integer valued array im(H, W), where H and W are the height and the width of the image.

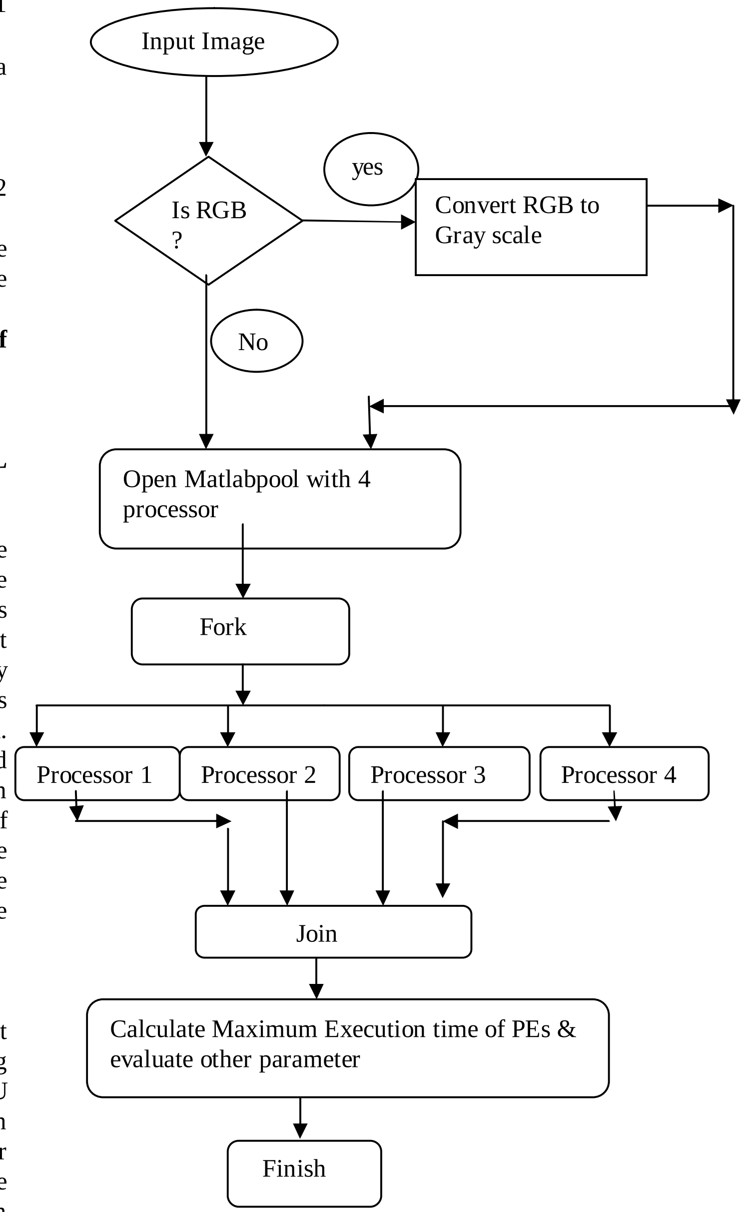


Fig 1: Parallel approach of Fuzzy c means

Grey scale images are discriminations of real black and white photographs. Grey scale image is passed to matlab pool which consists of 4 processors created by fork policy.

Image enhancement algorithm is applied among the 4 processors. The result is captured such as maximum completion time of the processing elements is accounted. Computation of performance parameters and image processing parameters are done at the end. The image processing tasks are executed in parallel at the same time simultaneously. The output of these worker job threads are again joined and produced as a combined output. The maximum execution time of processing elements is evaluated along with other image parameters. Below table contains the output of all parameters when different images are processed by FCM algorithm in sequential and parallel modes.

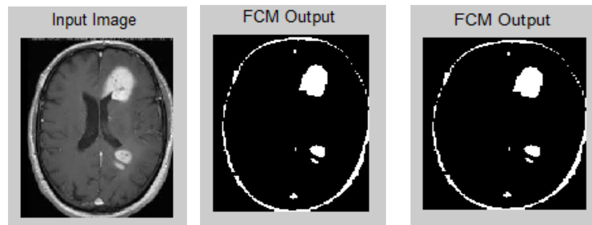
Table 1 : Comparison between various colored and grey scale images in different parameters of FCM in sequential and parallel mode

I. No.	Cluster Centers	Sequential Time (sec.)	Parallel Time (sec.)	Speed up	Efficiency (%)	Over Head	MMSE	PSNR (db)	% of Tumour
1	ccc1=48.7202 ccc2=139.548	12.90	6.82	1.891	47.3	3.595	5430.70	10.78	7.32
2	ccc1=6.9548 ccc2=139.621	10.39	4.51	2.304	56.7	1.9125	4708.86	11.40	12.02
3	ccc1=13.1975 ccc2=120.012	13.35	5.33	2.505	62.6	1.9925	7045.03	9.65	9.63
4	ccc1=8.7665 ccc2=83.8757	13.20	5.36	2.463	61.6	2.06	4530.39	11.57	3.19
5	ccc1=55.0497 ccc2=184.148	13.19	5.58	2.364	59.1	2.283	5736.44	10.54	10
6	ccc1=14.7660 ccc2=103.516	7.30	2.95	2.745	61.9	1.125	3763.16	12.38	1.68
7	ccc1=17.9859 ccc2=121.308	13.08	5.70	2.295	57.4	2.43	3476.68	12.72	1.64
8	ccc1=8.5497 ccc2=137.921	13.20	5.63	2.345	58.6	2.33	5578.74	10.67	25.29
9	ccc1=59.9366 ccc2=163.801	12.83	5.42	2.367	59.2	2.213	5841.76	10.47	10.15
10	ccc1=21.8514 ccc2=122.324	13.17	5.95	2.213	55.3	2.657	6138.16	10.25	8.06

IV. ANALYSIS OF DIFFERENT APPROACHES

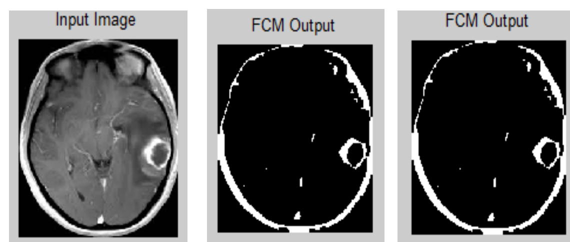
Extensive qualitative and quantitative analysis is done for comparing the clustering and segmentation results obtained using the algorithms, under different modes. The algorithms are tested on images having brain tumor, liver tumor and few other medical images.

The algorithms are implemented on Matlab 7.0 (The Mathworks Inc.). An Intel i5 core 2 processor is used having 2.53 Ghz (clock), 4GB (RAM), and Windows 7 64 bit operating system.



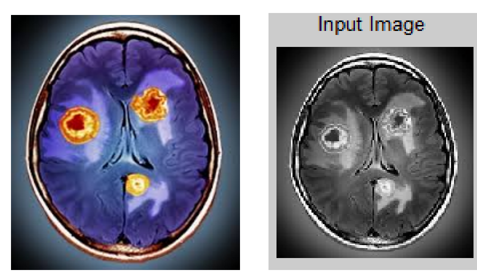
(a) (b) (c)

Fig. 2: (a) is a MRI image of human brain when viewed from the top containing tumour. Fig. 2(b) is the FCM segmented output in sequential mode. Fig. 2(c) shows the result of applying FCM segmentation in parallel mode on the input grey scale image.

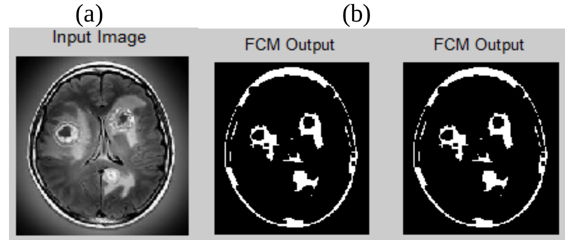


(a) (b) (C)

Fig. 3:(a) is a MRI image when viewed from the top containing tumour. Fig. 3(b) is the FCM segmented output in sequential mode. Fig. 3(c) shows the result of applying FCM segmentation in parallel mode on the input grey scale image.



(a) (b)



(c) (d) (e)

Fig. 4:(a) is a color image containing tumour in human brain. Fig. 4(b) is the grey scale image converted from the color image and provided as an input to the FCM code i.e. Fig. 4(c). Fig. 4(d) is the FCM segmented output in sequential mode. Fig. 4(e) shows the result of FCM segmentation in parallel mode on the input image.

Table 2: Analysis of Sequential time and mean square error

Image no.	Sequential Time	MMSE
4.3	13.35	7045.03
4.8	13.20	5578.74
4.1	12.90	5430.70
4.2	10.39	4708.86
4.6	7.30	3763.16

In Table 2, it is observed that MMSE value decreases with respect to the Sequential execution time. It seems like sequential execution time is more due to the increased level of error/noise.

Table 3: Analysis of FCM parallel execution time and Efficiency

Image no	Parallel Execution Time(FCM)	Efficiency in %
4.6	2.95	61.9 %
4.4	5.36	61.6%
4.5	5.58	59.1%
4.7	5.70	57.4%
4.10	5.95	55.3%

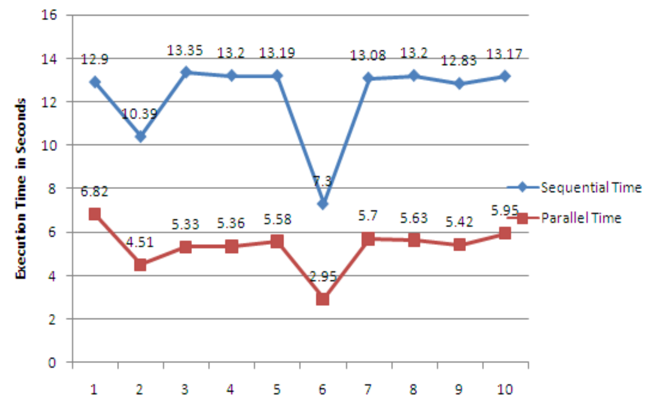
Table 3 lists down values obtained for parallel execution time and efficiency percentage. It is observed that when parallel execution time increases then the efficiency percentage takes a dip.

Table 4: Analysis of Parallel execution time of FCM and Speedup

Image no	Parallel Execution time for FCM	Speed up
4.1	6.82	1.891
4.10	5.95	2.213
4.7	5.70	2.295
4.5	5.58	2.364
4.3	5.33	2.505

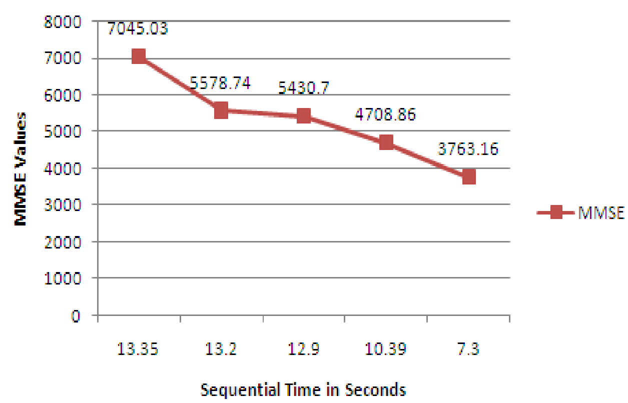
Table 4 contains parallel execution time for FCM segmentation and speed up values. It is observed that speed up gets enhanced when parallel execution time decreases.

According to the outcome of image segmentation for various images, multiple graphs have been plotted. These graphs are very important for the actual analysis and understanding of new findings.



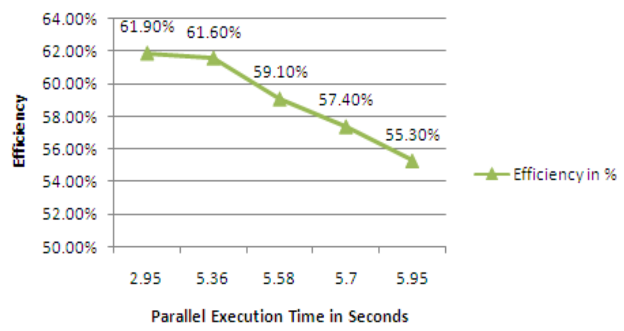
Graph 1: Analysis of Sequential and Parallel time of different images

Graph 1 is plotted for sequential and parallel execution time with respect to the various test images. X-axis shows specific image number and Y-axis represents the execution time of sequential and parallel execution time respectively. It is clearly evident that FCM image segmentation using parallel techniques is much faster and efficient than the sequential mode.



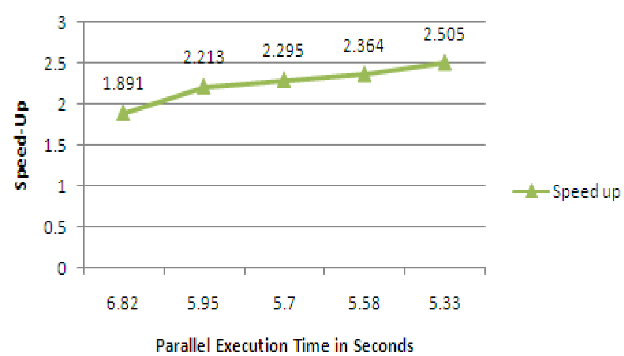
Graph 2: Analysis of Sequential execution time FCM & MMSE

Graph 2 is plotted in between MMSE values obtained from segmentation of different images and sequential execution time in seconds. X-axis represents sequential execution time in seconds and Y-axis represents obtained MMSE values for different images. It is clearly evident that MMSE values take a dip when the sequential segmentation execution time decreases for various images.



Graph 3: Analysis of Parallel execution time of FCM and Efficiency

Graph 3 is plotted in between Efficiency percentage for different images and parallel execution time in seconds. X-axis represents parallel execution time in seconds and Y-axis represents evaluated efficiency percentage values for different images. It is observed from the trend that the efficiency percentage increases when the parallel execution time keeps on decreasing for different FCM segmented images.



Graph 4: Analysis of Parallel execution time of FCM and Speed up

Graph 4 is plotted in between performance parameter speed-up and the parallel execution time in seconds. It is observed from the trend that speed-up enhances when the parallel execution time keeps on decreasing.

Various inferences for parallel performance parameters are postulated. The analysis suggests that usage of parallel techniques for image processing and segmentation is beneficial especially when diagnosis of complex image is required in quick timeframe. The outcome of experimental result points about relationship between various performance parameters and execution. This also suggests that other parameters are not compromised for obtaining increase in speed-up and efficiency in image processing which is an important factor.

V. Conclusion

In this research work, Fuzzy clustering based segmentation has been considered and modified to enhance the overall response time of the image processing system. The execution of FCM algorithm over parallel mode is observed to perform well on noisy images. The performance of the proposed parallel mode execution of FCM algorithm for segmentation has been compared with existing sequential mode of segmentation algorithm in MATLAB. The simulation can accommodate both color as well as grey scale images for evaluation of performance parameters. Parallel implementation of algorithm was developed using Matlab threads in order to leverage the parallel processing capability of current processors with multiple cores. Evaluation of various parameters like speed up, efficiency, parallel time etc are satisfactory and good. In terms of performance, parallel implementation was found to be approx. two times faster than the sequential processing. This is very promising result since it allows the exploitation of the vast processing power of current processors with multiple cores.

SCOPE OF FUTURE WORK

1. The existing noise in the parallel segmentation process by the proposed method is an area of concern. Hence other de-noising algorithms can be combined with the proposed system to filter out noisy errors during the image processing and segmentation. In the future, more image and performance parameters can be evaluated and further new ways can be proposed to utilize resources better.

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