AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Computer and Systems Engineering

Parallel Implementation of an Oil Reservoir Data Visualization Tool

A Thesis submitted in partial fulfillment of the requirements
of
Master of Science in Electrical Engineering
(Computer and Systems Engineering)

by

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Statement

This thesis is submitted as a partial fulfillment of Master of Science in Electrical Engineering, Faculty of Engineering, Ain shams University. The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Abstract

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Technology of High Performance Computing (HPC) has improved quickly in latest years. HPC becomes necessary for the efficient processing of the scientific and industrial applications which need to run within reasonable time. At the same time HPC infrastructure (computing nodes, networks and storage) is expensive and needs frequently special maintenance. Today, advantages of cloud computing such as reliability, scalability and resource pooling have attracted researchers to run applications of HPC on the Cloud. To take benefits of HPC and cloud computing, it has become reasonable and practical to considerably enhance the running of single application speed by parallelization of its hotspots calculations with preserving the same level of computations accuracy.

One of the applications which needs applying parallel algorithm in the field of reservoir engineering is 3D (three dimensions) oil reservoir data visualization tool which can render and visualize the output of reservoir simulator (such as pressure, oil saturation and water saturation) in 3D environment to assist the decision maker in statistical analysis, historical matching and recovery of hydrocarbons of the oil reservoir.

In this thesis, we introduce new parallel techniques of intensive calculations for 3D oil reservoir data visualization tool using Message Passing Interface (MPI), Multi-threaded and hybrid (MPI/Multi-threaded) parallel programming model. The presented parallelization algorithms can be abstracted into a generalized paradigm for other applications that need parallel techniques for distributed and shared memory models.

Our parallel techniques for 3D oil reservoir data visualization tool is tested on two platforms, traditional HPC platform and Virtual Cluster on Cloud to enable users of the tool to deploy the suitable parallel technique on their available infrastructure.

Our results indicate that, MPI (Distributed Memory) parallelism is more appropriate with coarse-grain data decomposition technique due to avoid small and frequent data exchanges among MPI tasks over the network. Moreover, distributed memory model provides efficient hardware scaling with the Data grid scaling. On the other hand, Multi-threading(Shared Memory) parallelism gives high performance with fine-grain

data decomposition technique although hardware scalability of shared memory model is limited due to its resources sharing of hardware. Hybrid (shared/distributed memory) approach that uses coarse-grain and fine-grain data decomposition techniques concurrently is the best customed parallelism which is suitable for the nature of 3D grid data set in addition to use of mixture system of parallel processing units (Threads and processors). Our hybrid parallelism on Electronics Research Institute (ERI)-HPC (144 Intel Xeon cores support Hyper-Threading Technology) provides on average 284X speedup over serial implementation on single PPU (Power Processor Unit) of IBM cell BE (Broadband Engine)and can scale exceptionally very well with massive data sets.

Thesis Summary

This thesis proposes five parallel algorithms for 3D oil reservoir data visualization tool. The proposed algorithms depend on shared, distributed and hybrid memory models and it can be used as general parallel algorithms for other applications. The suggested parallel implementations are tested by different data sizes using two real platforms, ERI-HPC and Virtual Cluster on ERI-OpenStack cloud.

This thesis provides five contributions. First, developing scalable and reusable parallel algorithms for 3D oil reservoir data visualization tool which depend on shared, distributed and hybrid memory models. Second, testing the parallel implementations on traditional HPC system. Third, building Virtual Cluster on OpenStack Cloud as a virtual system and elaborate the network traffic between virtual machines. Fourth, studying the performance of parallel 3D oil reservoir data visualization tool on the Virtual Cluster. Finally, Comparing the performance of parallel oil reservoir data visualization tool on HPC system and virtual cluster.
This thesis is divided into six chapters in addition to the lists of contents, tables and figures as well as list of references and appendices.

Chapter 1

This chapter is the introduction of the thesis and provides a brief summary of High Performance Computing (HPC) is presented whether it is used as a traditional infrastructure or used on cloud computing. This chapter also includes the previous related works, outlines and objectives of the thesis.

Chapter 2

This chapter demonstrates an overview of the structure and types of parallel computers (distributed, shared and hybrid memory) in addition to the parallel programming models which is used for each structure and some metrics for parallel applications performance.

Chapter 3

This chapter provides an overview of cloud computing and its features, and introduces the architecture of OpenStack cloud computing which is the most popular open source cloud platform, OpenStack Network Operationalization is demonstrated to have clear vision about the network traffic flow between virtual machines.

Chapter 4

This chapter shows a detailed illustration about the serial 3D oil reservoir data visualization tool and its most important functions. The parallel algorithms for complex calculations of this tool is presented, which depend on different memory model (shared, distributed and hybrid).

Chapter 5

This chapter explains the platforms which are used for testing our proposed parallel algorithms in details way. The results of each platform are presented and compared with each other and with other results published about the 3D oil reservoir data visualization tool.

Chapter 6

This chapter ends the thesis by conclusions, summary and future work.

Key words: Data Visualization Tool, Oil Reservoir, Parallel Programming, MPI, Multithreading, Hybrid (Distributed/ Shared)-Memory, HPC, Cloud Computing.

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