

Numerical Integrations with Fresnel Transform in Parallel on Cloud Computing Virtual Machines

May Myint Thwe*

Abstract

Infrastructure services (Infrastructure-as-a-service, IaaS) offered by the Clouds allow a programmer to utilize a large number of computing instances effectively and efficiently. Whether leased from Clouds or allocated from private Clouds, utilizing these virtual resources to perform data or computing intensive analyses requires employing different parallel or high performance computing (HPC) runtimes. Multi-dimensional Integration needs extra computing power and therefore is a scientific application to be run in parallel on the HPC cluster installed in IaaS virtual machines (VMs). This work describes a computer simulation technique of generating Fresnel diffraction of arbitrary dimensions by using Fresnel integrals. This simulation has been performed on HPC cluster in the virtualization environment using Excel VBA. The HPC system provides users speed-up in Excel calculations on it by reducing in size, complexity and calculation time. The system is operated by Windows® HPC Server 2008 R2 under which Microsoft Office Excel 2010 process is used to calculate the workbook and Visual Basic for Applications (VBA) tool is used to control Excel's action.

Keywords: Multi-dimensional Integration, Cloud Computing, Virtual Machines, High-Performance Computing, Internet, Windows® HPC Server 2008 R2

1. Introduction

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction^[2] Scientists are provided by cloud computing with a completely new model of utilizing the computing infrastructure. Cloud infrastructure services allow users to provision compute clusters fairly easily and quickly. IaaS is term that refers to the practice of delivering IT infrastructure based on virtual resources as a commodity to customers. One important feature of Cloud Computing is the ability to scale up and down the infrastructure according to resource requirements of the users or applications^[3] Utilizing cloud virtual resources to perform data or computing intensive analyses requires employing different parallel or HPC runtimes. Multi-dimensional Integration needs extra computing power and therefore is a scientific application to be run in parallel on the HPC cluster installed in IaaS virtual machines.

This work is parallel processing of numerical integrations for Fresnel transform for faster calculation time and better performance on a virtualized HPC cluster with Excel VBA. It also implements Excel 2010 workbook calculation of Numerical Integration in Windows HPC Server 2008 R2 by using HPC on virtual machines. Numerical Methods in engineering may be implemented well using Excel/VBA.^[4] These methods provide a way to solve problems quickly and easily compared to analytic solutions.

2. Cloud Computing Concepts

Cloud computing is considered the evolution of a variety of technologies that have come together to change an approach for building the IT infrastructure. The Internet is a necessary foundation for the cloud. The cloud can be both software and infrastructure. The cloud services can be categorized into software services and infrastructure or hardware services.^[5]

* Dr, Lecturer, Department of Computer Studies, Yadanabon University

2.1. The Ideology of Cloud Computing

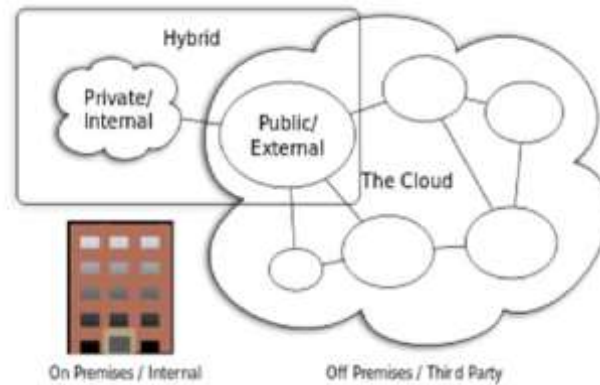


Figure 1. Types of Cloud

Cloud computing provides a modern alternative to the traditional on-premises datacenter. A **public cloud** vendor is completely responsible for hardware purchase and maintenance and typically provides a wide variety of platform services. It also allows customers to lease access to hardware and software resources.

Cloud environments typically provide an online portal experience, making it easy for users to manage compute, storage, network, and application resources. A user can use the portal to create a virtual machine configuration.

In a **private cloud**, a cloud environment can be created in own datacenter and provide self-service access to compute resources to users in their organization. This offers a simulation of a public cloud to users, but the provided hardware and software services must be purchased and maintained.

A **hybrid cloud** integrates public and private clouds that allow users to host workloads in the most appropriate location.^[5]

The ideology of cloud computations lies in transferring, to a considerable extent, the arrangement for computations and the processing of data from personal computers to Worldwide Web servers.^[6]

2.2. Cloud Offerings

Cloud Computing contains a specialized spectrum of processing and transferring data technologies with computer resources being provided to the user as internet services. One can identify several basic technologies (models) of Cloud Computing:

2.2.1. Infrastructure as a Service

IaaS provides basic storage and computing capabilities as standardized services over the network. Servers, storage systems, networking equipment, data centre space etc., are pooled and made available to handle workloads. The customer would typically deploy his own software on the infrastructure. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, deployed applications.^[5]

2.2.2. Platform as a Service

A layer of software or development environment is encapsulated and offered as a service, upon which other higher levels of service can be built. The customer has the freedom to build his own applications, which run on the provider's infrastructure.^[7] The consumer does not manage or control the underlying cloud infrastructure, but has control over the deployed applications and possibly application hosting environment configurations.

2.2.3. Software as a Service

In this model, a complete application is offered to the customer, as a service on demand. A single instance of the service runs on the cloud and multiple end users are serviced. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities.^[5]

2.3. Cloud Computing in internet

The transferring process of computational complexes conventionally involved the purchase of computer codes, from the developers, by the future user and their installation on his computer. The Cloud form of using the computational complexes solves all problems related to the installation of the acquired program product. The electronic forms of trade in the internet, including the trade of computer programs, are already fairly well developed. Cloud Computing provides appealing advantages regarding the "consumption" of program products compared to conventional commercial sales.^[12]

3. Virtual Machines

Virtual Machine is a scalable, on-demand IaaS platform and it can be used to quickly provision and deploy server workloads into the cloud. Once deployed, those virtual machines then can be configured, managed, and monitored, load-balance traffic between them, and connect them to other Cloud Services running web roles and worker roles.^[9] Figure 2(a) and Figure 2(b) depict what happens after a traditional computer has been virtualized.

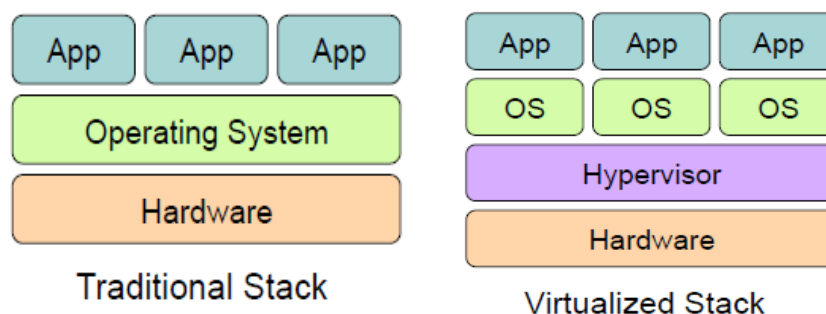


Figure 2(a). Traditional computer

Figure 2(b). After virtualization

3.1. Implementation Levels of Virtualization

Most large Infrastructure as a Service (IaaS) providers rely on virtual machine technology to deliver servers that can run applications. Virtual machines are containers that are assigned specific resources. The software that runs in the virtual machines is what defines the utility of the cloud computing system.^[11]

3.1.1. Hardware Requirements

Hyper-V requires a 64-bit processor. Hardware-assisted virtualization is available in processors that include virtualization option_specifically processors with Intel Virtualization Technology (Intel VT) or AMD Virtualization (AMD-V) technology. Intel XD bit(execute disable bit) or AMD NX bit(no execute bit) must be enabled.

3.1.2. Software Requirements

Hyper-V includes a software package for supported guest operating systems that improves integration between the physical computer and the virtual machine. This package is referred to as integration services. Supported Windows Guest OS for Hyper-V is Windows Server 2008 R2 and Windows 8.1.

3.1.3. Windows Server 2008 R2

Windows HPC Server 2008 R2 provides a general description of three features of Windows HPC Server: the HPC Pack SDK, the management system, and the jobs scheduling system.^[8]

3.1.4. HPC Pack SDK

There are different programming models for different needs and HPC resources. HPC Server offers three models; MPI model based on message passing, SOA-based model, and Excel HPC Service.

3.1.4.1. SOA-based model

HPC Server supports the service-oriented programming model based on Windows Communication Foundation (WCF), with the general SOA programming model based on .NET Framework. Programmers can package business logic to a service, then deploy the service on clusters and call the services in a parallel way. These parallel calls are distributed evenly on different compute units, nodes, cores, and slots.^[8]

3.1.4.2. Excel HPC Service

Microsoft Office Excel contains the ability to create complex analytical models and good scalability. With the complexity of the model growing, computing time is greatly increased. The Excel 2010 and HPC Server solution is to distribute Excel calculation workloads to multiple cluster nodes and run in parallel, which reduces the processing time efficiently.^[8]

3.2. Implementation of Virtualized HPC Cluster

As shown in Figure 3, a virtualized HPC cluster composed of one head node, one broker node and three compute nodes was deployed on DELL Inspiron 14R laptop computer. VMM (Hyper V Manager; Version: 6.3) enables Windows 8 (Version 8.1) and Windows HPC Server 2008 R2 operating system (OS).

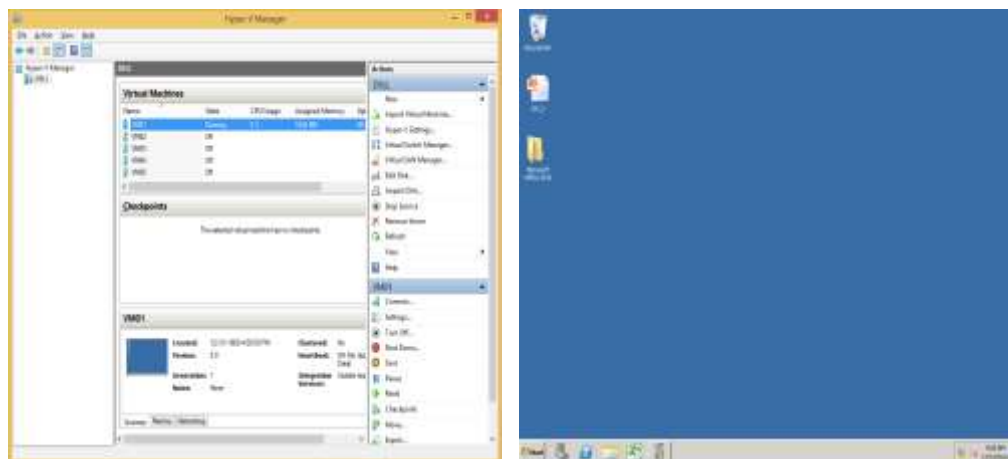


Figure 3. Virtualized HPC Cluster

4. Numerical Integration

Numerical methods are involved in almost every aspect of engineering. Scientific and engineering problems may be difficult or even impossible to obtain an expression for the integral of a particular function. But by using numerical methods, a value for the definite integral can always be obtained.^[1]

4.1. Numerical calculation for Fresnel transform

In linear optics, electromagnetic diffraction through a plane screen is described in good approximation with Fresnel transform.^[10] Let $V_0(s, t)$ the electromagnetic field on a point $(p, q, z=0)$ on a plane $z=0$ and $V(x, y, z)$ the electromagnetic field on point (x, y, z) as shown in Figure 4.

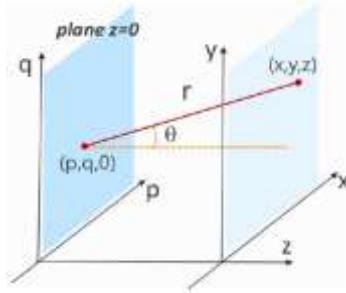


Figure 4. The electromagnetic field on point (x, y, z)

At distance $z \gg \lambda$ the electromagnetic field $V(x, y, z)$ is described with good approximation through the Fresnel transform:

$$V(x, y, z) = \iint V_0(p, q) e^{ikr} e^{\frac{i\pi}{\lambda z}((x-p)^2 + (y-q)^2)} dp dq \quad (1)$$

where $r = [(x-p)^2 + (y-q)^2 + z^2]^{1/2}$; i is the imaginary unit.

By substitution of Euler's formula,

$$e^{ikr} = \cos kr + i \sin kr$$

In Equation 1, the electromagnetic pattern $V(x, y, z)$ on a plan (x, y, z) is composed of real part and imaginary part:

$$V(x, y, z) =$$

$$\iint V_0(p, q) (\cos kr + i \sin kr) \left[\left(\cos \frac{\pi}{\lambda z} [(x-p)^2 + (y-q)^2] \right) + i \left(\sin \frac{\pi}{\lambda z} [(x-p)^2 + (y-q)^2] \right) \right] dp dq \quad (2)$$

Fresnel equation split up in real and imaginary parts

$$\text{Re}(x, y, z) = \iint V_0(p, q) (\cos kr) \times \left(\cos \frac{\pi}{\lambda z} [(x-p)^2 + (y-q)^2] \right) dp dq$$

$$\text{Im}(x, y, z) = i \iint V_0(p, q) (\sin kr) \times \left(\sin \frac{\pi}{\lambda z} [(x-p)^2 + (y-q)^2] \right) dp dq \quad (3)$$

To run a computer simulation, apply a sampling in plane $(p, q, z=0)$ and in plane (x, y, z) . Let consider a segment L_p centered around the p axis, and L_q centered around the q axis, a segment X_m centered around the x axis, and Y_n centered around the y axis.

N_p , the number of samples in the p axis, N_q , the number of samples in the q axis, N_m , the number of samples in the x axis, and N_n , the number of samples in the y axis.

$$V(x, y, z) = \iint V_0(p, q) (\cos kr + i \sin kr) \left[\left(\cos \frac{\pi}{\lambda z} [(x-p)^2 + (y-q)^2] \right) + i \left(\sin \frac{\pi}{\lambda z} [(x-p)^2 + (y-q)^2] \right) \right] dp dq$$

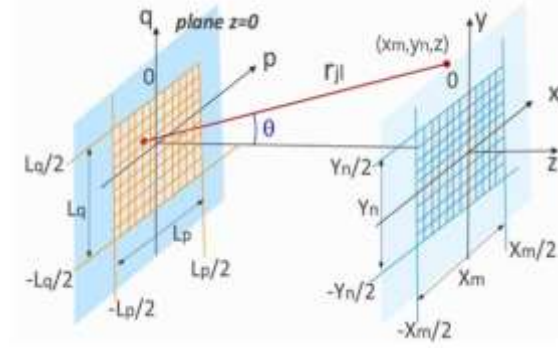


Figure 5. Sampling intervals on two planes

As shown in Figure 5, the sampling intervals and the relative ranges are as follow;

$$\begin{aligned}\Delta p &= \frac{L_p}{N_p} ; j = -\frac{N_p}{2}, \dots, -1, 0, +1, \dots, \frac{N_p}{2} ; p_j = j\Delta p \\ \Delta q &= \frac{L_q}{N_q} ; l = -\frac{N_q}{2}, \dots, -1, 0, +1, \dots, \frac{N_q}{2} ; q_l = l\Delta q \\ \Delta x &= \frac{L_x}{N_x} ; m = -\frac{N_x}{2}, \dots, -1, 0, +1, \dots, \frac{N_x}{2} ; x_m = m\Delta x \\ \Delta y &= \frac{L_y}{N_y} ; n = -\frac{N_y}{2}, \dots, -1, 0, +1, \dots, \frac{N_y}{2} ; y_n = n\Delta y\end{aligned}\quad (4)$$

The distance r_{jl} between the sample $(p_j, q_l, z = 0)$ and the sample (x_m, y_n, z) is shown in Equation 5:

$$r_{jl} = \left[(x_m - p_j)^2 + (y_n - q_l)^2 + z^2 \right]^{1/2} \quad (5)$$

The discrete expression for real and imaginary parts of electromagnetic field are shown in the Equation 6:

$$\begin{aligned}\text{Re}(x_m, y_n, z) &= \sum_{l=-\frac{N_q}{2}}^{\frac{N_q}{2}} \sum_{j=-\frac{N_p}{2}}^{\frac{N_p}{2}} V_0(p_j, q_l) (\cos kr_{jl}) \times \left(\cos \frac{\pi}{\lambda z} \left[((m\Delta x) - (j\Delta p))^2 + ((n\Delta y) - (l\Delta q))^2 \right] \right) \Delta p \Delta q \\ \text{Im}(x_m, y_n, z) &= \sum_{l=-\frac{N_q}{2}}^{\frac{N_q}{2}} \sum_{j=-\frac{N_p}{2}}^{\frac{N_p}{2}} V_0(p_j, q_l) (\sin kr_{jl}) \times \left(\sin \frac{\pi}{\lambda z} \left[((m\Delta x) - (j\Delta p))^2 + ((n\Delta y) - (l\Delta q))^2 \right] \right) \Delta p \Delta q\end{aligned}\quad (6)$$

The intensity $I(x_m, y_n, z)$ of electromagnetic field is equal to the square of module of electromagnetic field $V(x_m, y_n, z)$

$$I(x_m, y_n, z) = \text{Re}(x_m, y_n, z)^2 + \text{Im}(x_m, y_n, z)^2 \quad (7)$$

5.

6. Results and Discussion

The Excel workbook contains the four modules and reference to HPC library (Microsoft_Hpc_Excel) is added and it may be ready to run on Windows HPC cluster. Through the job template, the HPC administrator can specify which resources. To evaluate the performance of the Excel worksheet running many times the same discrete Fresnel transform with same simulation input parameters but with different number of HPC cores, it is created for this purpose by the HPC management console HPC job template with different number of usable cores. The results of Local and HPC with different cores for the number of samples of 128×128 are shown in Figures 6, 7, 8, 9, 10 and 11.

5.1 Run Time on HPC cluster with different number of cores

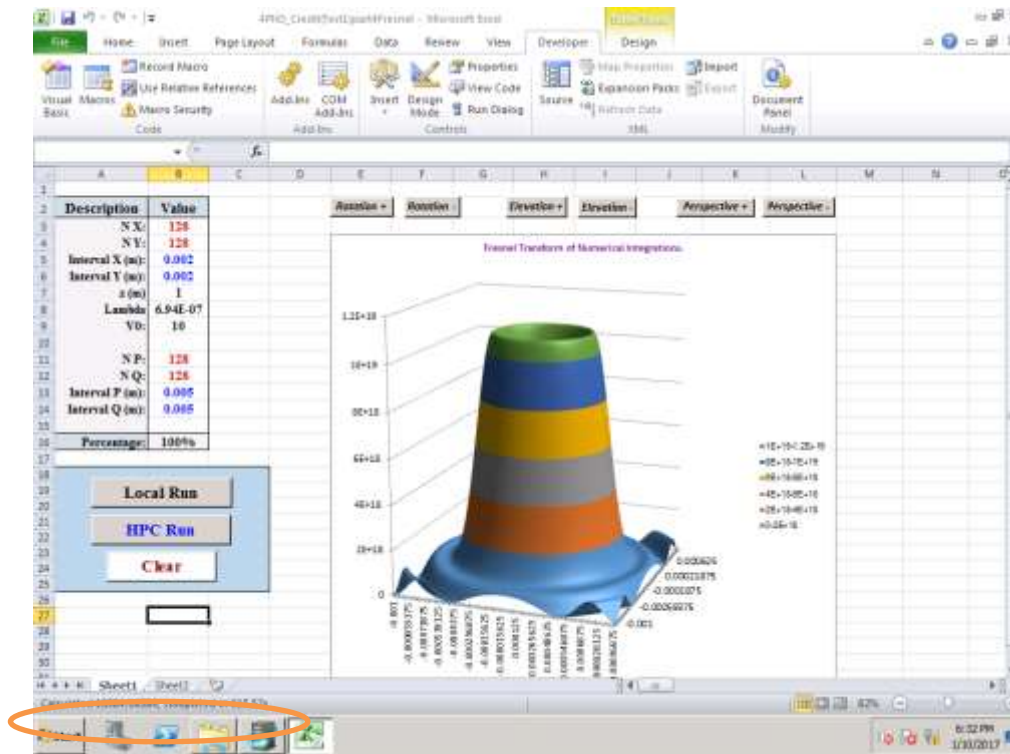


Figure 6. Run time of Local Run taking 615.52 s

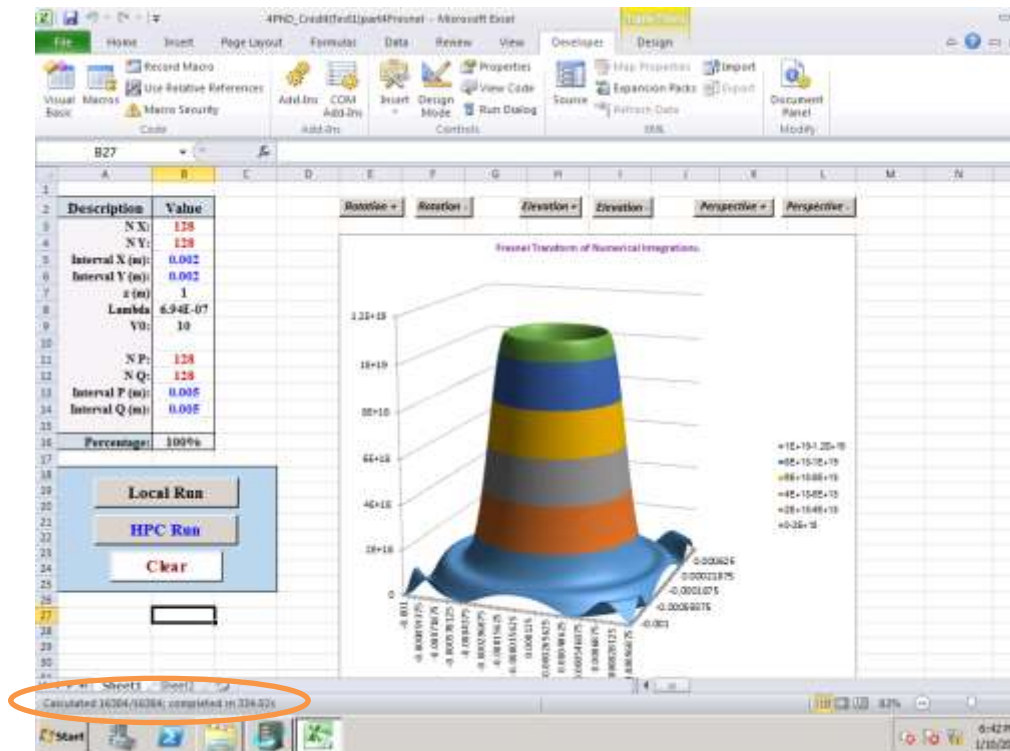


Figure 7. Run time of HPC with 2Cores taking 334.02 s

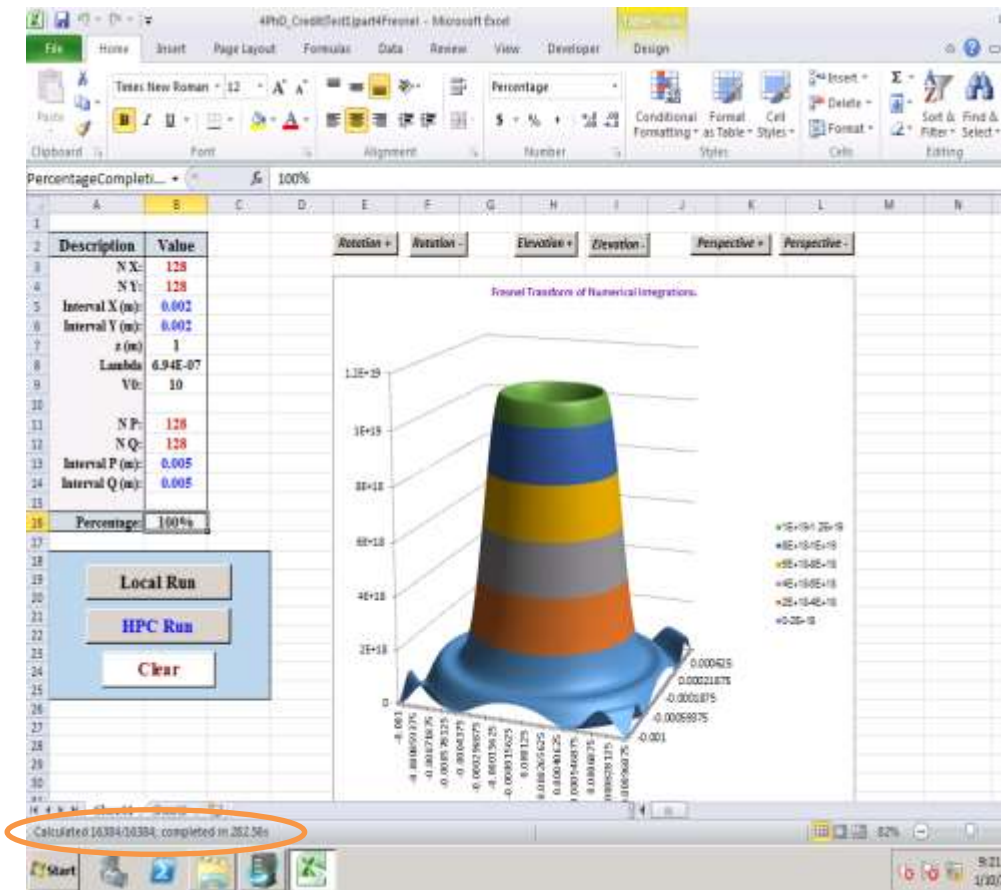


Figure 8. Run time of HPC with 4Cores taking 282.56 s

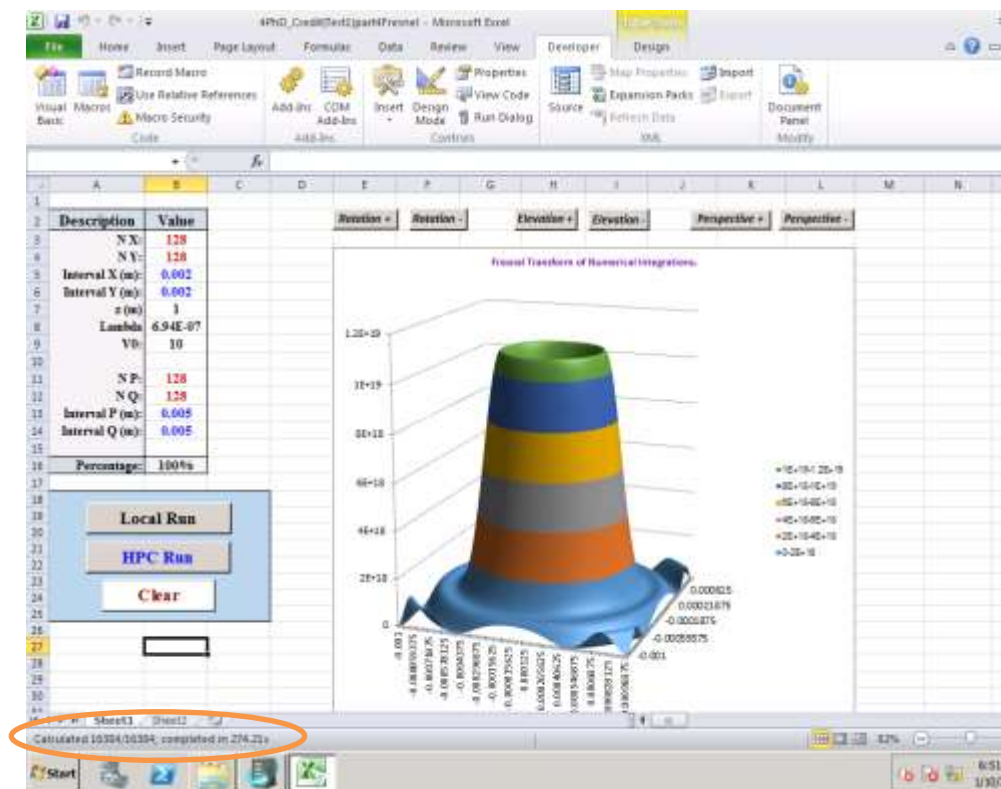


Figure 9. Run time of HPC with 8Cores taking 274.21s

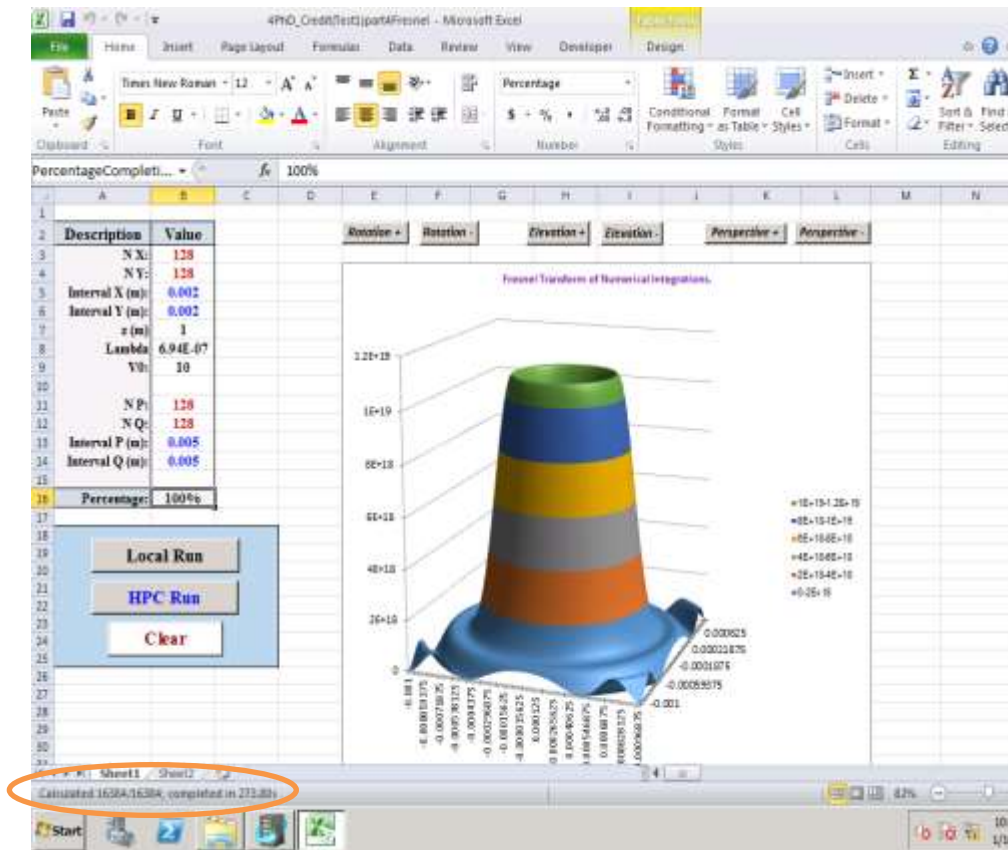


Figure 10. Run time of HPC with 16Cores taking 273.80 s

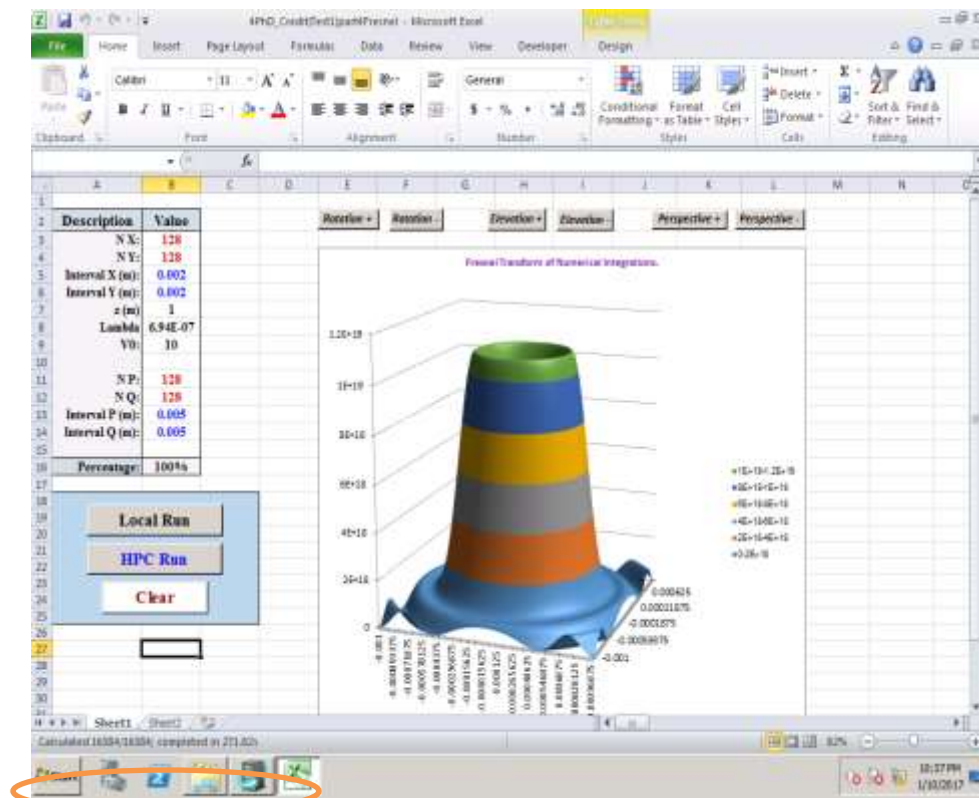


Figure 11. Run time of HPC with 32Cores taking 271.82 s
HPC with 2Cores is faster than Local by 281.5s.

HPC with 4Cores is faster than HPC with 2Cores by 51.46s and faster than Local by 332.96s.

HPC with 8Cores is faster than HPC with 4Cores by 8.35s, faster than HPC with 2Cores by 59.81s and faster than Local by 341.31s.

HPC with 16Cores is faster than HPC with 8Cores by 0.41s, faster than HPC with 4Cores by 8.76s, faster than HPC with 2Cores by 60.22s and faster than Local by 341.72s.

HPC with 32 Cores is faster than HPC with 16 Cores by 2.29s, HPC with 8 Cores by 2.7s faster than HPC with 4Cores by 11.05s, HPC with 2Cores by 62.51s and Local by 344.01s.

Figure 12 shows run time (seconds) taken by Local and HPC with the number of samples of 128 X 128.

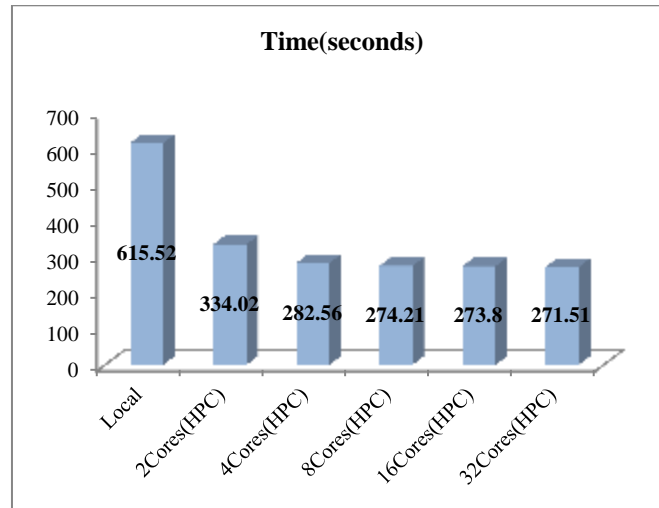


Figure 12. Comparison among run times taken by Local and HPC with different Cores for 128×128

Therefore, HPC with 32 Cores can make Excel workbook run **2.3 times faster** than Local Run.

Figure 13 shows run time (seconds) taken by Local and HPC with the number of samples of 100×100.

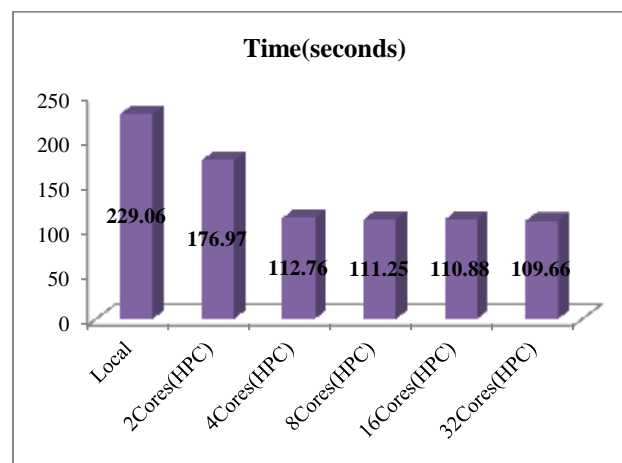


Figure 13. Comparison among run times taken by Local and HPC with different Cores for 100×100

HPC with 32Cores can make Excel workbook run **2.1 times faster** than Local Run.

Figure 14 shows run time (seconds) taken by Local and HPC with the number of samples of 150 X 150.

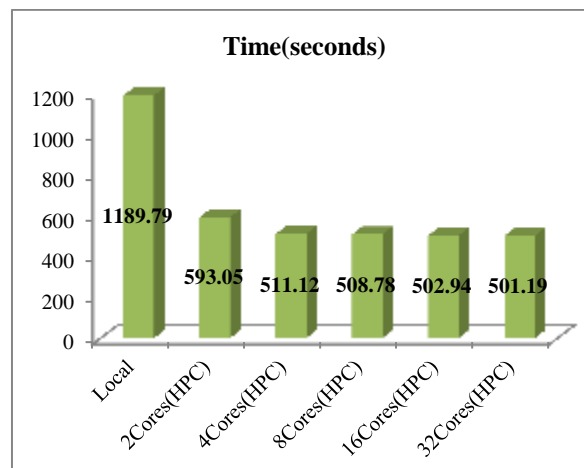


Figure 14. Comparison among Run times taken by Local and HPC with different Cores for 150×150

HPC with 32Cores can make Excel workbook run **2.4 times** faster than Local Run.

Table 5.1 Comparison among Run times taken by Local and HPCs

Number of data	source	Local Run Time(seconds)	HPC Run Time(seconds)	Faster Time of HPC than Local
1000	100×100	229.06	109.66	2.1 times
16384	128×128	615.52	271.51	2.3 times
22500	150×150	1, 189.79	501.19	2.4 times

Therefore, HPC Services for Excel with a Windows HPC cluster can improve calculation performance.

6. Conclusion

The basic objective of this system is to get the faster calculation time and better performance of the Excel VBA for numerical integration in parallel processing for cloud computing virtual machines. In running multiple processes, VMs can be utilized to reduce the need for several physical host machines. Faster execution of highly compute intensive tasks of multidimensional integration for advanced computation may be achieved by using HPC virtual machines. By using Windows HPC Server 2008 R2, the set-up of Virtualized HPC cluster, reduce calculation times for Excel 2010 workbooks. This system is able to remove all the complexity of hosting and managing the service and quickly make workbooks to be run on a virtualized cluster by applying SOA model on HPC virtual machines. To get efficient calculation on HPC cluster, the equations to be executed must be the distributed equations. This research also perform to reduce the calculation time required for long-running Spreadsheet Calculations and to get better performance for Fresnel transform of Numerical Integration by using High Performance Computing on VMs. Therefore, this system is able to obtain improved calculation performance and faster calculation time for numerical integration by applying the Excel VBA on virtualized HPC cluster.

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