



**MARA University of Technology**

**HEAT EQUATION ANALYSIS  
USING  
PARALLEL PROGRAMMING TOOLS**

**Emilia Binti Mohamad Shukree**

**2004617904**

Thesis submitted in fulfillment of the requirements for  
**Bachelor of Science (Hons) Data Communications  
and Networking**

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And  
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## DECLARATION

I certify this thesis and the research to which it refers are the product of my own work and that any ideas or quotation from work of the other people, published or otherwise are fully acknowledge in accordance with the standard referring practices of the discipline.

DECEMBER 3, 2007

.....  
EMILIA BINTI MOHAMAD SHUKREE

2004617904

## **APPROVAL**

### **HEAT EQUATION ANALYSIS USING PARALLEL PROGRAMMING TOOLS**

**BY**

**EMILIA BINTI MOHAMAD SHUKREE**

This thesis was prepared under the supervision of thesis coordinator, En. Adzhar Abd. Kadir, Department of Computer Technology and Networking and has been approved by the thesis supervisor, Pn. Siti Arpah Ahmad. It was submitted to the Faculty of Information and Quantitative Science and was accepted in partial fulfillment of the requirement for the degree of Bachelor of Science.

Approved by:

..........

**Siti Arpah Ahmad**

**Thesis Supervisor**

**Date: DECEMBER 3, 2007**

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## ABSTRACT

Many new technologies, in terms of software and hardware had been introduced that had made computing power doubles every year. Programmers and software developers had introduced more high quality software's, vivid and clear animations, more real time simulations, and any other programs that need more powerful processing. Sequential processing and computing is a thing of the past and cannot afford to today's software's and programs that has the quality as mentioned earlier. That's what had made parallel computing and processing is the choice in the world of today. However, due to cost constrains, some organizations could not afford to have today's parallel supercomputers. Hence, urging developers and programmers to come up with a solution which is to virtualize the use of parallel processing which is why the Parallel Virtual Machine had come out as of today, to benefit organizations by connecting a few personal computers (PC's) via today's standard networking architectures.

This research project is conducted to find the time difference between the parallel heat equation program that was built by the author derived from the former parallel coding by using C language and the modified sequential heat equation program in peer-to-peer (P2P) network and star topology network. SSH communications standard via RSA key will be used between those PC's in both network architecture to ensure that the PVM daemons on those PC's can be contacted and making sure that the PVM run smoothly. It is expected that the parallel heat equation programming will execute faster than the latter sequential heat programming code.

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## LIST OF ABBREVIATION

| <b><u>Abbreviation</u></b> | <b><u>Full Text</u></b>                                 |
|----------------------------|---|
| 2D                         | <b>2 Dimensions</b>                                     |
| 3D                         | <b>3 Dimensions</b>                                     |
| AMD                        | <b>Advanced Micro Devices</b>                           |
| CPU                        | <b>Central Processing Unit</b>                          |
| DAEMON                     | <b>Disk And Execution Monitor</b>                       |
| DDR                        | <b>Double Data Rate</b>                                 |
| DDR2                       | <b>Double Data Rate 2</b>                               |
| FORTRAN                    | <b>FORmula TRANslation</b>                              |
| FTMSK                      | <b>Fakulti Teknologi Maklumat dan Sains Kuantitatif</b> |
| G++                        | <b>GNU C++ Compiler</b>                                 |
| GCC                        | <b>GNU C Compiler</b>                                   |
| GNU                        | <b>GNU's Not Unix</b>                                   |
| GTK                        | <b>GIMP Tool Kit for C++</b>                            |
| IP                         | <b>Internet Protocol</b>                                |
| IT                         | <b>Information Technology</b>                           |
| LCD                        | <b>Liquid Cristal Display</b>                           |
| MIMD                       | <b>Multiple Instruction, Multiple Data</b>              |
| MISD                       | <b>Multiple Instruction, Single Data</b>                |
| MPI                        | <b>Message Passing Interface</b>                        |
| NIC                        | <b>Network Interface Card</b>                           |
| OS                         | <b>Operating System</b>                                 |
| P2P                        | <b>Peer-to-Peer</b>                                     |

|      |   |
|------|---|
| PC   | <b>P</b> ersonal <b>C</b> omputer   |
| PU   | <b>P</b> rocessing <b>U</b> nit   |
| PVM  | <b>P</b> arallel <b>V</b> irtual <b>M</b> achine                          |
| RAM  | <b>R</b> andom <b>A</b> ccess <b>M</b> emory                              |
| RSA  | <b>R</b> ivest, <b>S</b> hamir, & <b>A</b> dleman                         |
| RSH  | <b>R</b> emote <b>S</b> hell  |
| SIMD | <b>S</b> ingle <b>I</b> nstruction, <b>M</b> ultiple <b>D</b> ata         |
| SISD | <b>S</b> ingle <b>I</b> nstruction, <b>S</b> ingle <b>D</b> ata           |
| SMP  | <b>S</b> ymmetric <b>M</b> ulti <b>P</b> rocessor                         |
| SSH  | <b>S</b> ecure <b>S</b> hell  |
| UNIX | <b>U</b> N <b>I</b> ple <b>X</b> information and computer services        |
| UTP  | <b>U</b> nshielded <b>T</b> wisted <b>P</b> air                           |
| XPVM | <b>E</b> xecutable <b>P</b> arallel <b>V</b> irtual <b>M</b> achine (GUI) |



# CHAPTER 1

## INTRODUCTION

### 1.1 Background

Back to these past several years, there are many new technologies has been launched to the computer technology field. This is due to the evolution of technological advances of information technology and people are getting excited to have a better performance in terms of speediness as time passed by. The eagerness of these peoples have encourage the IT (Information Technology) experts to produce much better equipment with low price but boost up the performance and generates faster speed time rather than higher price equipment with the same performance. As a result, we can see the significant growth in multiprocessing computing and it has been the introduction to the parallel computing.

Parallel computing is the simultaneous execution of the same task (split up and specially adapted) on multiple processors in order to obtain results faster. The idea is based on the fact that the process of solving a problem usually can be divided into smaller tasks, which may be carried out simultaneously with some coordination.<sup>1</sup> Today, many large companies or labs need to solve complicated tasks which require large amount of processing. Parallel computing could truly help them to solve their problems with processing and many of developed parallel programming tools such as Parallel Virtual Machine (PVM) could be used in order to the implementation of parallel computing system.

---

<sup>1</sup> [http://en.wikipedia.org/wiki/Parallel\\_computing](http://en.wikipedia.org/wiki/Parallel_computing)

PVM is a software tool for parallel networking of computers. It is designed to allow a network of heterogeneous machines to be used as a single distributed parallel processor.<sup>2</sup> PVM permits a heterogeneous collection of Unix and/or Windows computers hooked together by a network to be used as a single large parallel computer. Thus, large computational problems can be solved more cost effectively by using the aggregate power and memory of many computers rather than we use a supercomputer which needs a higher cost. PVM is free software and could be downloaded from the internet and easy to use. Furthermore, the source code freely available and people can use the existing source code and modify it so that it can be used for their similar project or work area.

In this research project, two types of network architecture; P2P and star topology will be used. In P2P network, two personal computers (PC's) will be networked together and parallel programming tool; PVM will be installed and configured for parallelization of both PC's while three (3) PC's will be used for star topology network and also will be parallelized using PVM. By using networked PC rather than supercomputer or new PC with high performance, this could provide large benefits to companies or labs. The sample of parallel heat equation program will be compared between the developed sequential heat equation program in terms of speed and performance on both types of network architecture. Large or complex computational problem could be solved by utilize the use of old computers and put it together and parallelized them.

## **1.2 Problem Statement**

The idea of the come out with this research project is derived from the problems encountered in sequential computing. Sequential computing may lead to low performance for large computational problems such as the complex calculation of heat equation. For sequential computing, complex calculations needs extremely high of CPU (Central

---

<sup>2</sup> [http://en.wikipedia.org/wiki/Parallel\\_Virtual\\_Machine](http://en.wikipedia.org/wiki/Parallel_Virtual_Machine)

Processing Unit) usage and if just a single processing is used, it will burden and may lead to the damage of the machine. These kinds of problems will increase the time taken and slower the production of the results especially when the machine were crashed or hanged.

If we networked together the old machine and parallelized them, we may utilize the used of many processors and share the tasks where it could increase the performance and no problems will occur if new tasks were added. The cost also could be decreased if we networked together the old or used machines rather than we use a supercomputer with single high performance processor which is extremely expensive. By gathering many workstations like the one that we use for personal computing today, we can save the cost but have almost the same performance as a supercomputer.

### **1.3 Objective of the project**

This project is done to achieve three main objectives:

1. To install and configure parallel programming tools in Linux environment for three hosts which will be used in two types of network architectures which are peer-to-peer and star topology networks in order to run the parallel heat equation program.
2. To modify the sample of parallel heat equation program in order to build a sequential heat equation program.
3. To analyze the performance and time consumed between both of the parallel and sequential program in those two types of network architecture.

## **1.4 Scope of the project**

The scope that has been considered in this project:

1. The entire project will be limited to Linux environment because those PC's were installed with Linux-based operating system.
2. The modification of sequential heat equation program is limited to C language because the sample of parallel heat equation program is written in C language.
3. This project also limited to simple heat equation program.

## **1.5 Significance of the project**

This project could benefit mostly to the communities:

1. This project will contribute to scientific labs or non-profit organizations which do complex calculations due to the effectiveness of the project in terms of cost and performance.
2. This project will also contribute to the FTMSK (Fakulti Teknologi Maklumat & Sains Kuantitatif) students which could be exposed with parallel computing and they could expand the scope of this research.

## 1.6 Chapter overview

Following is the introductory of the chapters:

### *Chapter 1: INTRODUCTION*

Introduce and overview the background of the project and main objectives that need to be accomplish and achieve in finishing the project.

### *Chapter 2: LITERATURE REVIEW*

Covers literature review and general information of the technology and terminology that will be used in the development of the project. The related works also will be discussed in this chapter.

### *Chapter 3: METHODOLOGY*

Includes the methodology and design involved in this project. The techniques used to complete the project efficiently within time given will be explained further in this chapter.

### *Chapter 4: IMPLEMENTATION*

Explains the installation, configuration and testing of the project as a whole.

### *Chapter 5: FINDINGS AND DISCUSSION*

Contains the discussion of the results from project's output. The outputs are figured up based on implementation in the project, either it achieves the objective or not.

## *Chapter 6: CONCLUSION AND RECOMMENDATION*

Comprises the conclusion of the project as a whole and it will be evaluated based on the achievement of the goals and objective of the project.

*References:* Lists of further information sources.

*Appendices:* Collections of data and source code. This part also includes the project outline.

### **1.7 Conclusion**

With the understanding the concept of this project, the exploration of parallel computing could be implemented. It follows up by the problems aroused that might be solved by the existing of this research. The objectives of this research were stated to give a clear overview of what is need to be achieved within the area of the limited scope. The successful of this project will give benefits to the community especially to scientific labs and FTMSK students in parallelizing computers and gain benefits from it.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Introduction

This chapter will be a review on some literature that is related to the research area which includes the supporting technologies including its definition and explanations. This will follow by the review on the similar works and research from the other researchers will be included in this chapter. From the particular to the area of research, literature review is the documentation of a comprehensive review of the published and unpublished work from secondary source of information. Most of these articles or literatures are gathered on browsing through the internet and reference books.

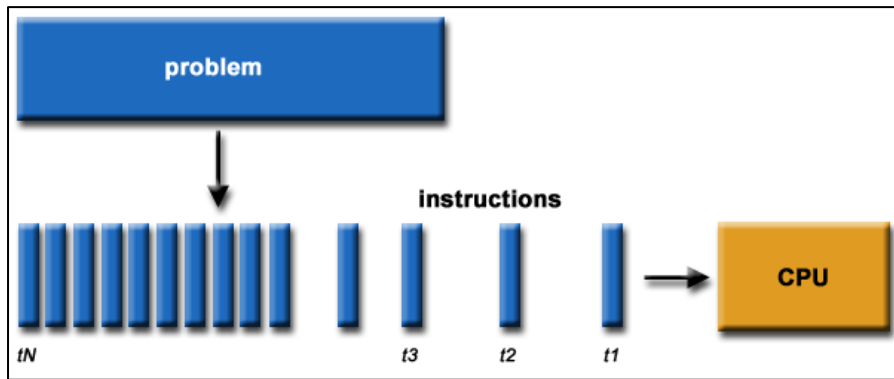
#### 2.2 Serial Computing

What is serial? Serial means one by one. Serial data transfer refers to transmitting data one bit at a time.<sup>3</sup> Serial computing which is also known as sequential computing means a single computer having a single Central Processing Unit (CPU) to be run on (*Barney, 2007*).<sup>4</sup> Traditionally, software has been written for serial computation. A problem is broken into a discrete series of instructions and it will be executed one after another. Only one instruction may execute at any moment in time. The example of serial computing is show in Figure 2.1 below:

---

<sup>3</sup> <http://www.webopedia.com/TERM/s/serial.html>

<sup>4</sup> [http://www.llnl.gov/computing/tutorials/parallel\\_comp/](http://www.llnl.gov/computing/tutorials/parallel_comp/)



*Figure 2.1: Process of serial computing*

## 2.3 Parallel Computing

Parallel computing is the simultaneous execution of some combination of multiple instances of programmed instructions and data on multiple processors in order to obtain results faster. The idea is based on the fact that the process of solving a problem usually can be divided into smaller tasks, which may be carried out simultaneously with some coordination.<sup>5</sup> In the simplest sense, parallel computing is the simultaneous use of multiple compute resources to solve a computational problem. A problem is broken into discrete parts that can be solved concurrently and each part is further broken down to a series of instructions. Those instructions from each part will execute simultaneously on different CPUs. Figure 2.2 below will be the detailed explanation of the process:

<sup>5</sup> [http://en.wikipedia.org/wiki/Parallel\\_computing](http://en.wikipedia.org/wiki/Parallel_computing)