

# Parallel Evaluation of Mathematica Programs in Remote Computers Available in Network

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## Preface

Mathematica is a powerful application package for doing mathematics and is used almost in all branches of science. It has widespread applications ranging from quantum computation, statistical analysis, number theory, zoology, astronomy, and many more. Mathematica gives a rich set of programming extensions to its end-user language, and it permits us to write programs in procedural, functional, or logic (rule-based) style, or a mixture of all three. For tasks requiring interfaces to the external environment, mathematica provides mathlink, which allows us to communicate mathematica programs with external programs written in C, C++, F77, F90, F95, Java, or other languages. It has also extensive capabilities for editing graphics, equations, text, etc.

In this article, we explore the basic mechanisms of parallelization of a mathematica program by sharing different parts of the program into all other computers available in the network. Doing the parallelization, we can perform large computational operations within a very short period of time, and therefore, the efficiency of the numerical works can be achieved. Parallel computation supports any version of mathematica and it also works as well even if different versions of mathematica are installed in different computers. The whole operation can run under any supported operating system like Unix, Windows, Macintosh, etc. Here we focus our study only for the Unix based operating system, but this method works as well for all other cases.

# 1 Introduction

Mathematica, a system of computer programs, is a high-level computing environment including computer algebra, graphics and programming. Mathematica is specially suitable for mathematics, since it incorporates symbolic manipulation and automates many mathematical operations. The key intellectual aspect of Mathematica is the invention of a new kind of symbolic computation language that can manipulate the very wide range of objects needed to achieve the generality required for technical computing by using a very small number of basic primitives. Mathematica is now emerging as an important tool in many branches of computing, and today it stands as the world's best system for general computation.

Parallelization is a form of computation in which one can perform many operations simultaneously. Parallel computation uses multiple processing elements simultaneously to finish a particular job. This is accomplished by breaking the job into independent parts so that each processing element can execute its part of the algorithm simultaneously with the others. The processing elements can be diverse and include resources such as a single computer with multiple processors, several networked computers, specialized hardware, or any combination of the above.

In this article, we narrate the basic mechanisms for parallelizing a mathematica program by running its independent parts in several computers available in the network. Since all the basic mathematical operations are performed quite nicely in any version of mathematica, it does not matter even if different versions of mathematica are installed in different computers those are required for the parallel computing. For our illustrative purposes, here we describe the parallelization technique for the Unix based operating system only.

## 2 How to Open Slaves in Local Computer ?

In parallel computation, different segments of a job are computed simultaneously. These operations can be performed either in a local computer or in remote computers available in the network. Separate operations are exhibited in separate mathematica slaves. In order to emphasize the basic mechanisms, let us now describe the way of starting a mathematica slave in a local computer. To do this, first we load the following package in a mathematica notebook.

```
Needs["Parallel`Parallel`"]
```

To enable optional features, then we load the package,

```
Needs["Parallel`Commands`"]
```

Now we can open a mathematica slave in the local computer by using the command,

```
LaunchSlave["localhost", "math -noinit -mathlink"]
```

Using this command, several mathematica slaves can be started from the master slave. Now it becomes much more significant if we specify the names of different slaves so that independent parts of a job can be shared into different slaves appropriately. For our illustrations, below we give some examples how different slaves can be started with specific names.

```
link1=LaunchSlave["localhost", "math -noinit -mathlink"]  
link2=LaunchSlave["localhost", "math -noinit -mathlink"]  
link3=LaunchSlave["localhost", "math -noinit -mathlink"]
```

Here link1, link2 and link3 correspond to the three different slaves. The details of these slaves can be available by using the following command,

```
TableForm[RemoteEvaluate[{$ProcessorID, $MachineName, $SystemID,  
$ProcessID, $Version}], TableHeadings→{None,{ "ID", "host", "OS",  
"process", "Mathematica Version" }}]
```

The output of the above command becomes (as an example),

ID	host	OS	process	Version
1	tcmpibm	AIX-Power64	463002	5.0 for IBM AIX Power (64 bit) (November 26, 2003)
2	tcmpibm	AIX-Power64	299056	5.0 for IBM AIX Power (64 bit) (November 26, 2003)
3	tcmpibm	AIX-Power64	385182	5.0 for IBM AIX Power (64 bit) (November 26, 2003)

The results shown in this table are for the above three slaves named as link1, link2 and link3 respectively, where all these slaves are opened from the local computer named as 'tcmpibm' (say). To get the information about the total number of slaves those are opened, we use the command,

Length[\$Slaves]

For this case, the total number of slaves becomes 3.

### 3 How to Open Slaves in Remote Computers Available in Network ?

To start a slave in remote computer, the command ‘ssh’ is used which offers secure cryptographic authentication and encryption of the communication between the local and remote computer. Before starting a slave in a remote computer, it is necessary to check whether ‘ssh’ is properly configured or not, and this can be done by using the prescription,

ssh remotehost math

For example, if we want to connect a remote computer named as ‘tcmpxeon’, we should follow the command as,

ssh tcmpxeon math

Since ‘ssh’ connection for a remote computer is password protected, it is needed to insert proper password, and if ‘ssh’ is configured correctly, the above operation shows the command ‘In[1]:=’. Once ‘ssh’ works correctly, a mathematica slave can be opened in a remote computer through this command,

LaunchSlave[“remotehost”, “ssh -e none `1` math -mathlink”]

For our illustrative purposes, below we describe how different slaves with proper names can be started in different remote computers.

```
link1=LaunchSlave[“tcmpxeon.saha.ac.in”, “ssh -e none `1` math -mathlink”]  
link2=LaunchSlave[“tcmp441d.saha.ac.in”, “ssh -e none `1` math -mathlink”]  
link3=LaunchSlave[“tcmpxeon.saha.ac.in”, “ssh -e none `1` math -mathlink”]  
link4=LaunchSlave[“tcmp441d.saha.ac.in”, “ssh -e none `1` math -mathlink”]
```

Here link1, link2, link3 and link4 are the four different slaves, where the link1 and link3 are opened in a remote computer named as ‘tcmpxeon’ (say), while the other two slaves are started in another one remote computer named as ‘tcmp441d’ (say). Using this

prescription, several mathematica slaves can be started in different remote computers available in the network. The details of the above four slaves can be expressed in the tabular form as,

ID	host	OS	process	Version
1	tcmpxeon	Linux	5137	5.0 for Linux (November 18, 2003)
2	tcmp441d	Linux	11323	5.0 for Linux (November 18, 2003)
3	tcmpxeon	Linux	5221	5.0 for Linux (November 18, 2003)
4	tcmp441d	Linux	11368	5.0 for Linux (November 18, 2003)

Thus we are now able to start mathematica slaves in local computer as well as in remote computers available in the network, and with this above background, we can describe the mechanisms for parallelizing a mathematica program.

## 4 Parallelizing of Mathematica Programs by using Remote Computers Available in Network

In order to understand the basic mechanisms of parallelizing a mathematica program, let us begin with a very simple problem. We set the problem as follows:

***Problem:*** Construct a square matrix of any order in a local computer and two other square matrices of the same order with the previous one in two different remote computers. From the local computer, read these two matrices those are constructed in the two remote computers. Finally, take the product of these three matrices and calculate the eigenvalues of the product matrix in the local computer.

To solve this problem we proceed through these steps in a mathematica notebook.

Step-1 : For the sake of simplicity, let us first define the names of the three different computers those are needed to solve this problem. The local computer is named as ‘tcmpibm’, while the names of the other two remote computers are as ‘tcmpxeon’ and ‘tcmp441d’ respectively. Opening a mathematica notebook in the local computer, let us first load the package for parallelization, and to get the optional features, we load another one package as mentioned earlier in Section 2. Then we start two mathematica slaves named as ‘link1’ and ‘link2’ in the two remote computers ‘tcmpxeon’ and ‘tcmp441d’ respectively by using the proper commands as discussed in Section 3.

Step-2 : Next we make ready three programs for the three separate square matrices of same order in the local computer. Out of which one program will run in the local

computer, while the rest two will run in the two remote computers. These three programs are as follows.

I. 
$$\begin{aligned} \text{sample1[ns\_]} &:= \text{Block}[\{\text{esi} = 0, t = 1.2, p = 2.1, \text{vacuum1} = \{\}\}, \\ &\quad \text{Do}[\text{Do}[\text{a1} = \text{If}[i == j, \text{esi}, 0]; \\ &\quad \text{a2} = \text{If}[i < j \ \&\& \ \text{Abs}[i - j] == 1, t, 0]; \\ &\quad \text{a3} = \text{If}[i > j \ \&\& \ \text{Abs}[i - j] == 1, p, 0]; \\ &\quad \text{a4} = \text{a1} + \text{a2} + \text{a3}; \\ &\quad \text{a5} = \text{AppendTo}[\text{vacuum1}, \text{a4}], \{j, 1, ns\}], \{i, 1, ns\}]; \\ &\quad \text{a6} = \text{Partition}[\text{a5}, ns]] \end{aligned}$$

II. 
$$\begin{aligned} \text{sample2[ns\_]} &:= \text{Block}[\{\text{esi} = 0, q = 2.6, r = 1.8, \text{vacuum2} = \{\}\}, \\ &\quad \text{Do}[\text{Do}[\text{a1} = \text{If}[i == j, \text{esi}, 0]; \\ &\quad \text{a2} = \text{If}[i < j \ \&\& \ \text{Abs}[i - j] == 1, q, 0]; \\ &\quad \text{a3} = \text{If}[i > j \ \&\& \ \text{Abs}[i - j] == 1, r, 0]; \\ &\quad \text{a4} = \text{a1} + \text{a2} + \text{a3}; \\ &\quad \text{a5} = \text{AppendTo}[\text{vacuum2}, \text{a4}], \{j, 1, ns\}], \{i, 1, ns\}]; \\ &\quad \text{a6} = \text{Partition}[\text{a5}, ns]] \end{aligned}$$

III. 
$$\begin{aligned} \text{sample3[ns\_]} &:= \text{Block}[\{\text{esi} = 0, u = 2, v = 3, \text{vacuum3} = \{\}\}, \\ &\quad \text{Do}[\text{Do}[\text{a1} = \text{If}[i == j, \text{esi}, 0]; \\ &\quad \text{a2} = \text{If}[i < j \ \&\& \ \text{Abs}[i - j] == 1, u, 0]; \\ &\quad \text{a3} = \text{If}[i > j \ \&\& \ \text{Abs}[i - j] == 1, v, 0]; \\ &\quad \text{a4} = \text{a1} + \text{a2} + \text{a3}; \\ &\quad \text{a5} = \text{AppendTo}[\text{vacuum3}, \text{a4}], \{j, 1, ns\}], \{i, 1, ns\}]; \\ &\quad \text{a6} = \text{Partition}[\text{a5}, ns]] \end{aligned}$$

Since we are quite familiar about the way of writing mathematica programs [1, 3], we do not describe here the meaning of the different symbols used in the above three programs further. Thus by using these programs, we can construct three separate square matrices of order ‘ns’.

Step-3 : We are quite at the end of our complete operation. For the sake of simplicity, we assume that, the program-I is evaluated in the local computer, while the program-II and program-III are evaluated in the two remote computers respectively. All these three programs run simultaneously in three different computers. To understand the basic mechanisms, let us follow the program.



```

sample4[ns_]:=Block[{},
ExportEnvironment["Global`"];
mat1 = sample1[ns];
RemoteEvaluate[Export["data1.dat", sample2[ns]], link1];
RemoteEvaluate[Export["data2.dat", sample3[ns]], link2];
mat2 = RemoteEvaluate[ReadList["data1.dat", Number, RecordLists→ True],
link1];
mat3 = RemoteEvaluate[ReadList["data2.dat", Number, RecordLists→ True],
link2];
mat4 = mat1.mat2.mat3;
Chop[Eigenvalues[mat4]]]

```

This is the final program. When it runs in the local computer, one matrix called as ‘mat1’ is evaluated in the local computer (3rd line of the program), and the other two matrices are determined in the remote computers by using the operations given in the 4th and 5th lines of the program respectively. The 2nd line of the program gives the command for the transformations of all the symbols and definitions to the remote computers. After the completion of the operations in remote computers, we call back these two matrices in the local computer by using the command ‘ReadList’, and store them in ‘mat2’ and ‘mat3’ respectively. Finally, we take the product of these three matrices and calculate the eigenvalues of the product matrix in the local computer by using the rest operations of the above program.

The whole operations can be pictorially represented as,

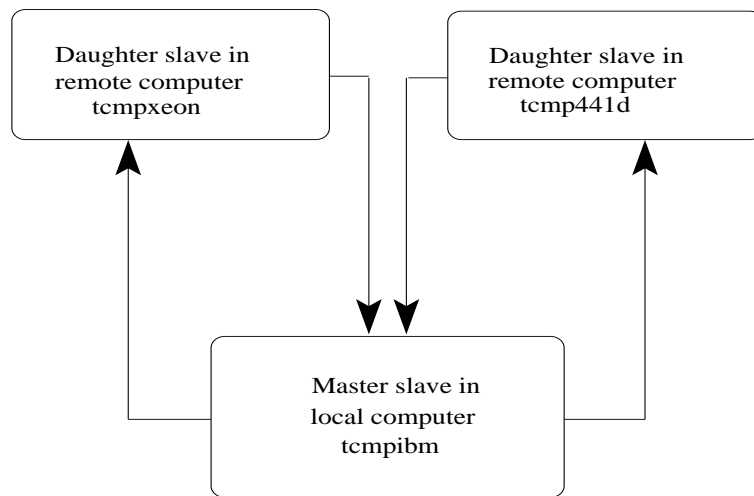


Figure 1: Schematic representation of parallelization.

At the end of all the operations, we close all the mathematica slaves by using the following command.

CloseSlaves[ ]

## Concluding Remarks

In conclusion, we have explored the basic mechanisms for parallelizing a mathematica program by running its independent parts in remote computers available in the network. By using this parallelization technique, one can enhance the efficiency of the numerical works, and it helps us to perform all the mathematical operations within a very short period of time. In this present discussion, we have focused the parallelization technique for the Unix based operating system only. But all these operations also work very well in any other supported operating system like Windows, Macintosh, etc. Not only that, all these operations can also be done quite significantly even if different versions of mathematica are installed in different remote computers those are used for parallel computation.

## Acknowledgment

I acknowledge with deep sense of gratitude the illuminating comments and suggestions I have received from Prof. Sachindra Nath Karmakar during the preparation of this article.

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