Cluster computing performances using virtual processors and mathematical software

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Abstract

In this paper I describe some results on the use of virtual processors technology for parallelize some SPMD computational programs in a cluster environment. The tested technology is the INTEL Hyper Threading on real processors, and the programs are MATLAB 6.5 Release 13 scripts for floating points computation. By the use of this technology, I tested that a cluster can run with benefit a number of concurrent processes double the amount of physical processors. The conclusions of the work concern on the utility and limits of the used approach. The main result is that using virtual processors is a good technique for improving parallel programs not only for memory-based computations, but in the case of massive disk-storage operations too.

1 Introduction

The processors virtualization technology permits to split a real physical processor into two virtual chips, so that the operating system, as MS Windows or Linux, of a computer can use the virtual processors as two real chips. Example of such technology is Intel’s Hyper Threading [1]. The hardware can
so be considered as a symmetric multi-processor machine and the software can use it as a true parallel environment.

In this work I show some results obtained with parallel computations using Matlab [2] programs on Intel technology. A previous paper [3] describes the same cases for an older Matlab version and for a single dual processor machine. The physical and logical characteristics of the used cluster are presented in the following tables:

| Hardware       | Type                        |
|----------------|-----------------------------|
|                | 2 nodes HP Compaq ProLiant DL360 |
| Processors     | 2 Intel Xeon 3.20 GHz for each node |
| Ram            | 2 GB for each node          |
| Network        | 1 Gb switch for nodes connection |
| Storage        | 4 SCSI disks 36.5 GB - Raid 5 for each node |

| Software       | Operating System            |
|----------------|-----------------------------|
|                | MS Windows Server 2000 partition, SuSE Linux 8.1 partition |
| Matlab         | v. 6.5.0 release 13         |

The Matlab programs used for these experiments was based on cycles of floating-point computations.

2 The parallel Matlab environment

The package Matlab has not a native support for parallel elaboration and multithreading [4]. Yet, there are some extensions, as tools and libraries [5], for the use of a parallel environment on multi-processors hardware. With the cluster I have used the method of splitting a given computation on multiple instances of the runtime Matlab program. A single master instance starts the slave copies on nodes and assigns to each of them the same set of instructions on different sets of data. Hence in the cluster I have simulated a SPMD computation.

In this way the parallel environment is simple, because there is not need of external libraries or calls to interfaces, and flexible, because to a single slave copy it can be assigned a set of different instructions for realizing a MPMD computation.
With this method the exchange of messages among independent processes is a problem. The only way to communicate from one Matlab copy to another is the use of shared files. In a second type of experiments I show that this method is not critical for the time execution if one uses fast mass-storage as SCSI or FiberChannel systems, and the nodes are connected in a fast private Lan.

2.1 The SPMD programs

In the experiments I have defined a master Matlab function which writes to a shared file system the .m scripts to be executed by slaves Matlab copies. These copies are launched in background mode for the parallel execution. The master program controls the end of the computations using a simple set of lock-files. The slaves finish their work, save on files the results and cancel the own lock-file. The master reads the sets of data from these files for other possible computations. Now I describe the principal code of the program.

This is the declaration of the function masterf. The lockarray variable is an array for testing the presence of the lock-files during the slaves computation. The finalres is an array for the collection of the partial results from slaves. The string computing is the mathematical expression to use in the computation. The array nodes contains the names of the cluster’s machines and it’s used for the remote startup of the Matlab engines.

```matlab
function [elapsedtime,totaltime,executiontime]=masterf(nproc,maxvalue,step,computing)

% MASTERF: master function for parallel background computation.

% sintax:
% [elapsedtime,totaltime,executiontime]=masterf(nproc,maxvalue,step,computing)
% % input parameters:
% % nproc = number of processes;
% % maxvalue = sup-limitation of the data-array to process; the inf-limitation is 0;
% % step = difference from two consecutive numbers in the data-array;
% % computing = the string of the mathematical expression to compute;
% % % output parameters:
% % % elapsedtime = total elapsed time to complete the execution of the computation;
% % totaltime = sum of the single slaves CPU-time to complete the single computation;
% % executiontime = single slaves CPU-time to complete the assigned computation;

ostype=computer;
tottime=0.;
```
lockarray=0:nproc-1;
numbervalues=maxvalue;
computingstring=[' ', 'computing'];
finalres=[]; nodes=[node01 node02];

After the assignment of the own value to variable `workdir`, working directory of Matlab, a cycle writes on storage the slaves lock-files.

```matlab
for i=0:nproc-1
    filelock = strcat(workdir,'filelock',int2str(i));
    fid=fopen(filelock,'wr');
    fwrite(fid,');
    fclose(fid);
end
```

In the next fragment of program, the master sets the commands for the writing of an appropriate Matlab .m script for every slave process. Such script contains the instruction for determining the CPU-time spent on calculus, the expression of the mathematical computation, the instruction to save on storage the data computed and the CPU-time, finally the instruction to delete the lock-file.

```matlab
for i=0:nproc-1
    if (i==0) middlestep=0; else middlestep=1; end
    infdata=i*(numbervalues/nproc) + middlestep*step;
    supdata=(i+1)*(numbervalues/nproc);
    fileworker = strcat(workdir,'fileworker',int2str(i),'.m');
    commandworkertmp = ...
        strcat('x=',num2str(infdata),':',num2str(step),'; t1=cputime; ',computingstring,...
        '; t2=cputime-t1; save out',int2str(i));
    commandworker = ['cd ', workdir '; commandworkertmp ...
        ' y t2; ' 'delete filelock\int2str(i) '; exit;'];
    fid = fopen(fileworker,'wt');
    fwrite(fid,commandworker);
    fclose(fid);
end
```

The following instructions are OS-dependent, and are necessary for the right setting of the command for remote startup of Matlab engines on nodes:

```matlab
switch ostype
    case 'PCWIN'
        osstring = 'dos';
        workdir=strcat(matlabroot,'\work\');
        startcommand='rcmd';
    case 'LNX86'
        osstring = 'unix';
        workdir=strcat(matlabroot,'/work/');
        startcommand='rsh';
end
```
After the instructions for determining the CPU-time and the elapsed-time  
(tic) spent by the master program, a cycle launches the same number of slaves
Matlab runtimes on each node. In the case of Windows operating system, the
startcommand string is ”rcmd”, the OS command for the background running
of an executable program on a remote machine, and the osstring string is
”dos”. In the case of Unix-like operating system, the string are ”rsh” and
”unix” respectively. Each slave executes immediately the fileworker script,
as shown by the Matlab ”-r” parameter. The basic remote command is
integrated by the name of the node, alternating the order of startup for a
simple reason of load balancing.

```matlab
t1 = cputime;
tic;
for i=0:nproc-1
    if (mod(i,2)==0), startcommand = [startcommand node02]; else ...
        startcommand = [startcommand node01]; end;
    fileworker = strcat('fileworker',int2str(i));
    commandrun = [startcommand ' matlab -minimize -r ' fileworker];
    eval(strcat([osstring,'(',')','commandrun',']'));
end
```

In the next fragment of code the master program executes a cycle for de-
termining the end of slaves computations. It controls if the lockarray variable
has some process’s rank non negative. In this case, it attempts to open the
relative lock-file; if the file still exists, the master closes it, else the lockarray
process position is set to -1. The pause instruction can be useful for avoiding
an excessive frequency, hence an high cpu-time consuming, in the ”while”
cycle.

```matlab
lockarraytmp=find(lockarray > -1);
while (length(lockarraytmp) > 0)
    pause(.1);
    for i=lockarraytmp
        fid = fopen(strcat('filelock',int2str(i-1)),'r');
        if (fid < 0)
            lockarray(i) = -1;
        else
            fclose(fid);
        end
    end
    lockarraytmp=find(lockarray > -1);
end
```

At the end, the master reads the partial slaves computation outputs and
stores them in an array. At this point the master cpu-time and elapsed time
are registered too. The total execution time is defined as sum of the slaves
computation cpu-time, and is useful for comparison with the execution time in the case \( nproc = 1 \). The single slave execution time is defined as the arithmetic mean of all the partial execution times.

```matlab
for i=0:nproc-1
    partialres = load(strcat('out',int2str(i)));
    finalres = [finalres partialres];
end
elapsedtime = toc;
totaltime = cputime - t1;
for i=0:nproc-1
    tottime = tottime + partialres(i).t2;
    executiontime = tottime/nproc;
end
```

### 3 Tests and results

For the tests I have used the following values for the \( masterf \) parameters:

- \( nproc \): from 2 to 16, step=2 (even numbers only, for right balancing of the nodes load);
- \( maxvalue \): \( m \times 10000 \), where \( m = 2, 4, 6 \);
- \( step \): 0.001;
- \( computing \): \( y = 5432.060708 \times \cos((\sin(x^{9.876}))^{-1.2345}) \).

I have also tested the program without the slaves saving of partial computations results and their final master load, for determining the influence of the I/O storage operations on the times of execution.

In the following table, the values are expressed in seconds. The number 2,...,16 are the values of the \( nproc \) parameter. I have not reported the elapsed-times, because they weren’t different from the cpu-times registered, probably due to the fact that, during the experiments, the cluster was dedicated only to the computations.

In the case of no storage writing and reading of data results, the times are 20%-30% lower. The time values are those of MS-Windows case; in the Linux case the registered times are in general 15%-20% higher. This fact is probably due to a non optimized installation of Linux distribution on nodes.
### Table 1. Total execution cpu-times, with data storage:

| m | 2  | 4  | 6  | 8  | 10 | 12 | 14 | 16 |
|---|----|----|----|----|----|----|----|----|
| 2 | 48.29 | 27.70 | 32.51 | 22.56 | 31.34 | 33.28 | 35.04 |
| 4 | 126.53 | 65.21 | 74.79 | 54.27 | 63.17 | 74.29 | 83.01 | 91.34 |
| 6 | 263.37 | 109.48 | 121.30 | 78.41 | 116.23 | 125.69 | 138.51 | 145.93 |

#### 4 Analysis of results

From the results of the previous section, I deduce the following observations:

1. The case $nproc=8$, hence the number of possible Hyper-Threading virtual processors based on the four physical chips, has the better performances for all the values of the $m$ parameter;

2. The case $nproc=4$, the number of physical processors in the cluster, has a local peak of performances for all the values of the $m$ parameter;

3. The speedup [6] seems to be better for increasing values of the parameter $m$, hence for larger amount of data to be computed; in the case $m=2$ the speedup of 8 running processes over the case of 2 processes is about 2.14, while in the case $m=6$ the same speedup is about 3.35 (quasi-linear speedup).

In the Fig. 1 the graphs are interpolations of the Table 1. data. The peaks of performances at $nproc=4$ and $nproc=8$ are well visible, specially in the case $m=6$.

#### 4.1 Conclusions

From the previous facts one can deduce that a virtual processors technology as Hyper Threading on a cluster environment can be a good choice for running SPMD programs in the case that
- the number of parallel processes is equal to the number of virtual processors;
- the data to be computed have a large amount, particularly when their distribution among processes and the merging of final results are based on files stored on fast storage system.

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its technical aspects; it focuses on the Message Passing Interface.