Parallel Performance of Pure MATLAB "M-files" versus "C-code“ as applied to formation of Wide-Bandwidth and Wide-Beamwidth SAR Imagery

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Parallel Performance of Pure MATLAB "M-files" versus "C-code" as applied to formation of Wide-Bandwidth and Wide-Beamwidth SAR Imagery

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Outline

- MatlabMPI Overview
- Possible modifications/customizations
- SAR Imagery
- Parallel Performance “M” vs “C”
- Future Work and activities

MatlabMPI Overview

References:

- http://www.mathworks.com/
- The latest MatlabMPI information, downloads, documentation, and information may be obtained from

http://www.ll.mit.edu/MatlabMPI

MPI & MATLAB

- Message Passing Interface (MPI):
  - A message-passing library specification
  - Specific libraries available for almost every kind of HPC platform: shared memory SMPs, clusters, NOWs, Linux, Windows
  - Fortran, C, C++ bindings
  - Widely accepted standard for parallel computing.
- MATLAB:
  - Integrated computation, visualization, programming, and programming environment.
  - Easy matrix based notation, many toolboxes, etc
  - Used extensively for technical and scientific computing
  - Currently: mostly SERIAL code

What is MatlabMPI?

- It is a MATLAB implementation of the MPI standards that allows any MATLAB program to exploit multiple processors.
- It implements, the basic MPI functions that are the core of the MPI point-to-point communications with extensions to other MPI functions. (Growing)
- MATLAB *look and feel* on top of standard MATLAB file I/O.
- Pure M-file implementation: about 100 lines of MATLAB code.
- It runs anywhere MATLAB runs.
- Principal developer: Dr. Jeremy Kepner (MIT Lincoln Laboratory)

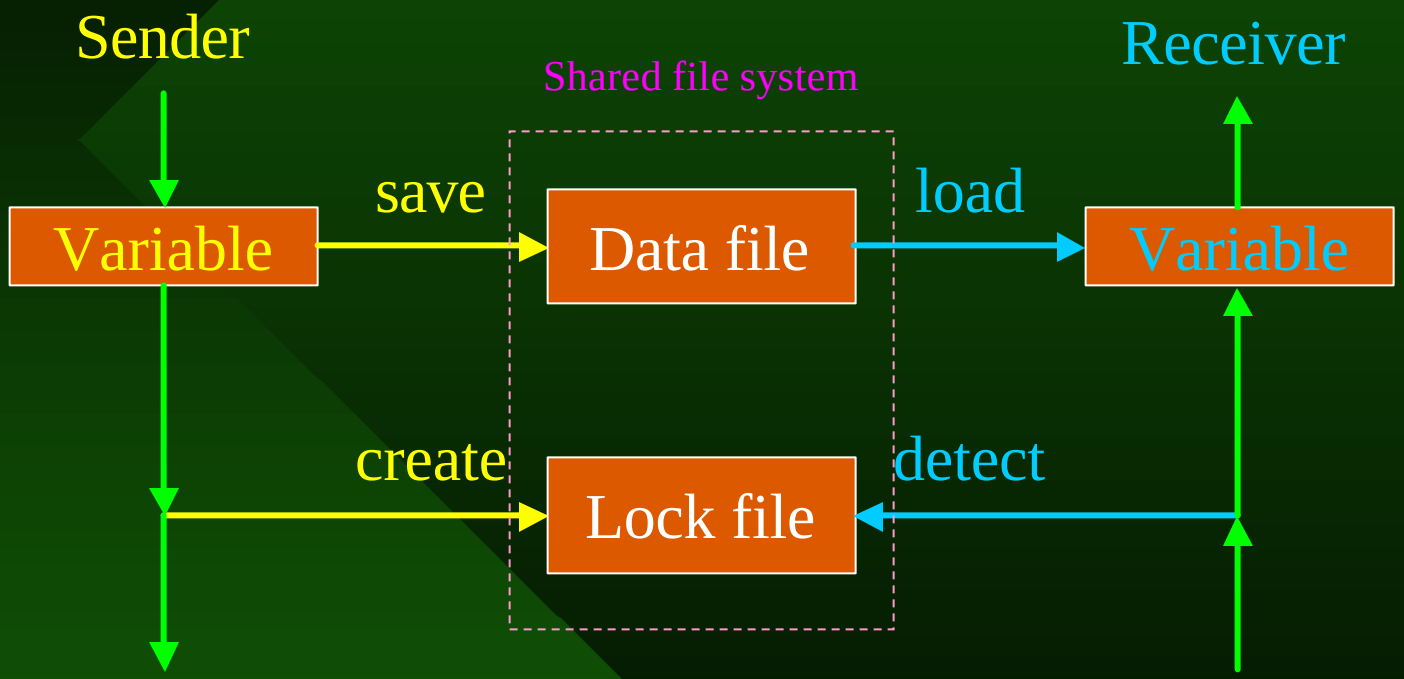
General Requirements

- As MatlabMPI uses file I/O for communication, a common file system must be visible to every machine/processor.
- On shared memory platforms: single MATLAB license is enough since any user is allowed to launch many MATLAB sessions.
- On distributed memory platforms: one MATLAB license per machine / node.
- Currently Unix based platforms only, but Windows support coming soon.

Basic Concepts

- Basic Communication:
  - Messages: MATLAB variables transferred from one processor to another
  - One processor sends the data, another receives the data
  - Synchronous transfer: call does not return until the message is sent or received
  - SPMD model: usually MatlabMPI programs are parallel SPMD programs. The same program is running on different processors/data.

Communication architecture



- Receiver waits until it detects the existence of the lock file.
- Receiver deletes the data and lock file, after it loads the variable from the data file.

Possible modifications/customizations

- ssh vs rsh
- Path variables
- System dependent information required to run MATLAB.

Master scripts

MatlabMPI creates 2 sets of scripts

Unix_Commands.sh – master script
This contains instructions for launching scripts on each desired node.

Unix_Commands.node_alias.sh –
This contains instructions for “what” is to be run on node_alias.

Unix_Commands.ssh example

```
ssh hpc11-1 –n ‘cd
   /work1/nehrbass/D_6_3x6; /bin/sh
   ./MatMPI/Unix_Commands.hpc11-1.0.sh
   &’ &

ssh hpc11-3 –n ‘cd
   /work1/nehrbass/D_6_3x6; /bin/sh
   ./MatMPI/Unix_Commands.hpc11-3.0.sh
   &’ &
```

Unix_Commands.hpc11-3.0.ssh example NCPU=6

matlab –display null –nojvm –nosplash < myprog.m > MatMPI/myprog.5.out &
touch MatMPI/pid.hpc11-3.$!
matlab –display null –nojvm –nosplash < myprog.m > MatMPI/myprog.4.out &
touch MatMPI/pid.hpc11-3.$!
matlab –display null –nojvm –nosplash < myprog.m > MatMPI/myprog.3.out &
touch MatMPI/pid.hpc11-3.$!
matlab –display null –nojvm –nosplash < myprog.m > MatMPI/myprog.2.out &
touch MatMPI/pid.hpc11-3.$!
matlab –display null –nojvm –nosplash < myprog.m > MatMPI/myprog.1.out &
touch MatMPI/pid.hpc11-3.$!
matlab –display null –nojvm –nosplash < myprog.m > MatMPI/myprog.0.out &
touch MatMPI/pid.hpc11-3.$!

 # Possibly add code to prevent early batch termination

Batch termination problem

Problem: Master script finishes before all the spawned processes are done and thus the batch job terminates prematurely.

Solution: Add the following code at the end of each node_alias script

```
mystat=`ls MatMPI |grep Finished.done|wc –l`
while [[ $mystat –lt 1 ]];
do
   mystat=`ls MatMPI |grep Finished.done|wc –l`
   sleep 15;
done
```

Batch termination problem

Solution: create a file called "Finished.done" at any place in the MatlabMPI code when code termination is desired.

This file can be created when ever the desired global answer is available, however; it is strongly suggested that a clean termination, (i.e. all processes are finished), be implemented.

Executable Implementation

Problem: There are insufficient licenses when running on a distributed system of n nodes.
(Recall – each node requires a valid license.)

Solution: Convert the working part of the MATLAB code to an executable that can run without a license requirement and modify the existing scripts.

Implementation Steps

1.) Modify the Matlab MPI code so that the scripts are automatically modified to run an executable code.

2.) Create an executable code from “M-file” scripts.

3.) Run MatlabMPI to generate all the required scripts automatically.

4.) Submit a batch job to start the scripts.

Script changes – 1

Change the script from

matlab –display null –nojvm –nosplash < myprog.m > MatMPI/myprog.5.out &
touch MatMPI/pid.hpc11-3.$!
:

To
myprog.exe 5 > MatMPI/myprog.5.out &
touch MatMPI/pid.hpc11-3.$!
:

MatlabMPI Changes – 1

This is most easily done by editing the file MatMPI_Commands.m

Change the line

From

matlab_command = [matlab_command ‘ < ‘ defsfile ‘ > ’ outfile];

To

matlab_command = [‘myprog.exe ‘ num2str(rank) ‘ > ‘ outfile];

Create an Executable – 2

Change the “M-file” to a function and add the 3 lines of code below.

```
function dummy=myprogf(my_cpu)

    % The function myprogf.m was created by converting the
    % MATLAB “M-file” script myprog.m to this function.
    %
    % Other comments
    %

    % Create MatlabMPI setup commands
    global MPI_COMM_WORLD;
    load MatMPI/MPI_COMM_WORLD;
    MPI_COMM_WORLD.rank = my_cpu;

    % The rest of the code myprog.m is appended without change
```

Executable wrapper – 2

```
#include <stdio.h>
#include <string.h>
#include “matlab.h”
#include “multpkg.h”

int main( int argc, char *argv[])    /* Used to call mlfMyprogf  */
{
  mxArray *my_cpu;
  int rank;
  rank=atoi(argv[1]);
  multpkgInitialize();
  my_cpu=mlfScalar(rank);
  mlfMyprogf(my_cpu);
  multpkgTerminate();
  return(0);
}
```

Generate All Scripts – 3

- Begin Matlab
- Add the path of MatlabMPI src *(ie addpath ~/MatlabMPI/src)*
  Hint: If the code is having problems seeing the src directory, either copy the src files to a local directory, or add the above line inside the source code.
- *Add a machine list as desired*
  (ie machines={};)
- *Run the MatlabMPI code to generate the required scripts.*
  (ie eval(MPI_Run('myprogf',64,machines));)

Generate All Scripts – 3

- Note that this will automatically launch the codes and scripts and thus this will run interactively.
- To save all scripts and submit via batch edit the MPI-Run.m function.

  Comment out the last two lines of this function as

  ```
  % unix(['/bin/sh ' unix_launch_file]);
  % delete(unix_launch_file);
  ```

- This prevents the code from running from within MATLAB and also saves all the scripts generated by MatlabMPI.

Submit to batch – 4

- Dilemma:

  MatlabMPI generates scripts specific to a list of machines (nodes).

  Batch only provides machine information when execution starts.

- It is therefore possible to generate a set of scripts that are not matched to the resources available at run time.
- A solution to this problem is given on the next few slides.

Submit to batch – 4

•Place inside a batch script to create the file mat_run.m

```
echo “[s,w]=unix(‘hostname’);” > mat_run.m
echo “is(s==0)” >> mat_run.m
echo “    machines{1}=w(1:end-1)” >> mat_run.m
echo “    eval(MPI_Run(‘myprogf’,${NCPU},machines));” >> mat_run.m
echo “end” >> mat_run.m
echo “exit” >> mat_run.m
```

•Run the file “mat_run.m” in MATLAB and capture the output

```
matlab –nojvm –nosplash < mat_run.m >& mat_run.out
```

Recall that this only created the required scripts

Submit to batch – 4

Run the master script on the correct node

```
If ($UNAME == “hpc11-0”) then
   /bin/sh ./MatMPI/Unix_Commands.hpc11-0.0.sh
endif

If ($UNAME == “hpc11-1”) then
   /bin/sh ./MatMPI/Unix_Commands.hpc11-1.0.sh
endif

If ($UNAME == “hpc11-2”) then
   /bin/sh ./MatMPI/Unix_Commands.hpc11-2.0.sh
endif

If ($UNAME == “hpc11-3”) then
   /bin/sh ./MatMPI/Unix_Commands.hpc11-3.0.sh
endif
```

MatlabMPI ssh & rsh

- Some UNIX systems require ssh over rsh.
- To avoid problems with having to enter username / password pairs when launching a script from a master system to be run on other systems do the following:
- Step 1. Generate new key pairs:

ssh-keygen –t dsa

Hit enter when prompted for a pass phrase

MatlabMPI ssh & rsh

- ***This creates a public private key pair located in the .ssh directory. The public key (id_dsa.pub) needs to be copied to a common location***
- ***Step 2***
  cd ~/.ssh
  cat id_dsa.pub >> ~/.ssh/authorized_keys2
  chmod 644 ~/.ssh/authorized_keys2
- **For more information please visit http://www.bluegun.com/Software/ssh-auth.html**

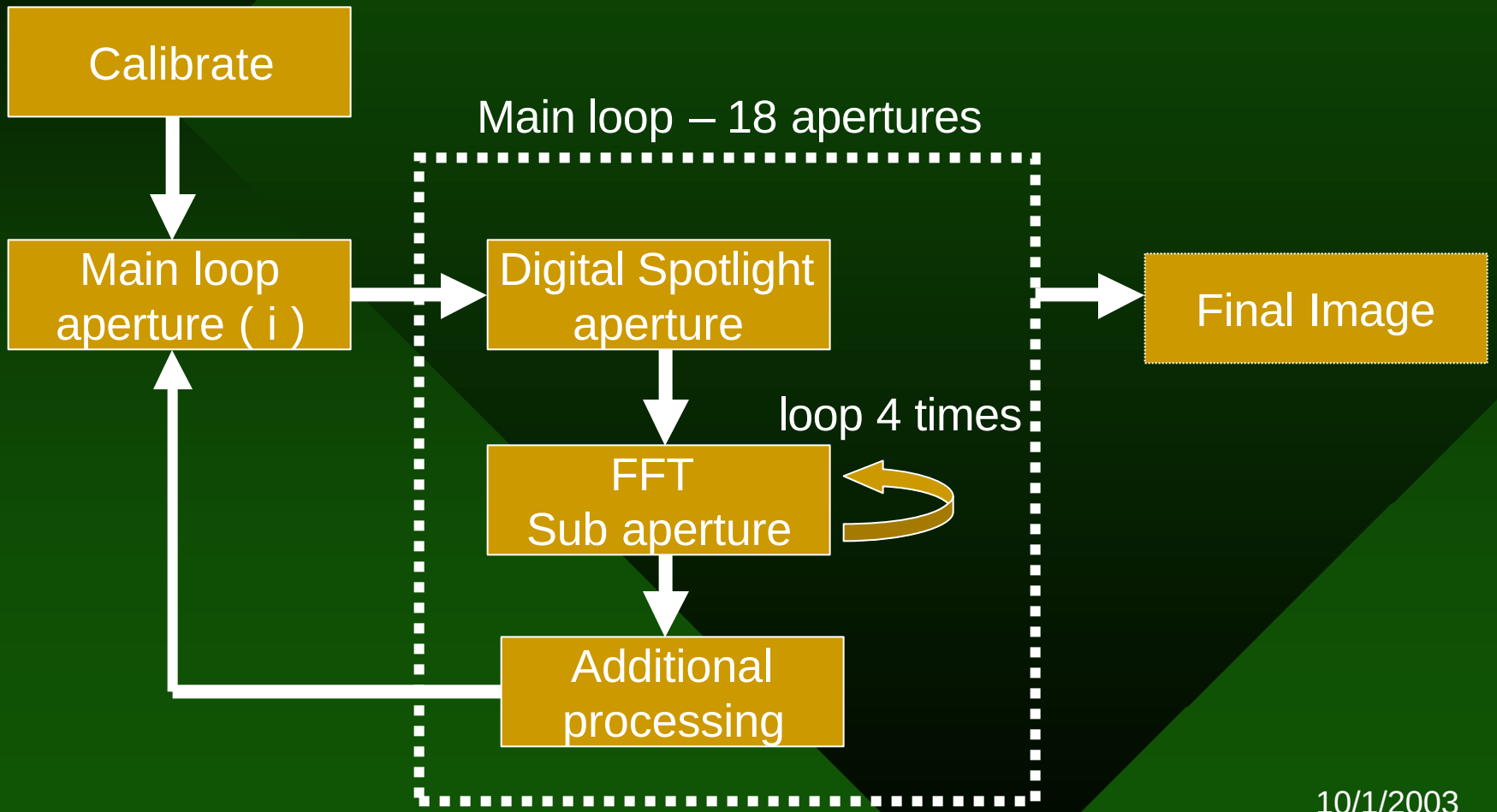
MatlabMPI ssh & rsh

- The HPCMP resources use kerberos. http://kirby.hpcmp.hpc.mil/
- When forwarding of credentials is used, one may be able to launch scripts on remote systems without implementing the previous steps.
- On ASC and ARL systems, ssh is sufficient.

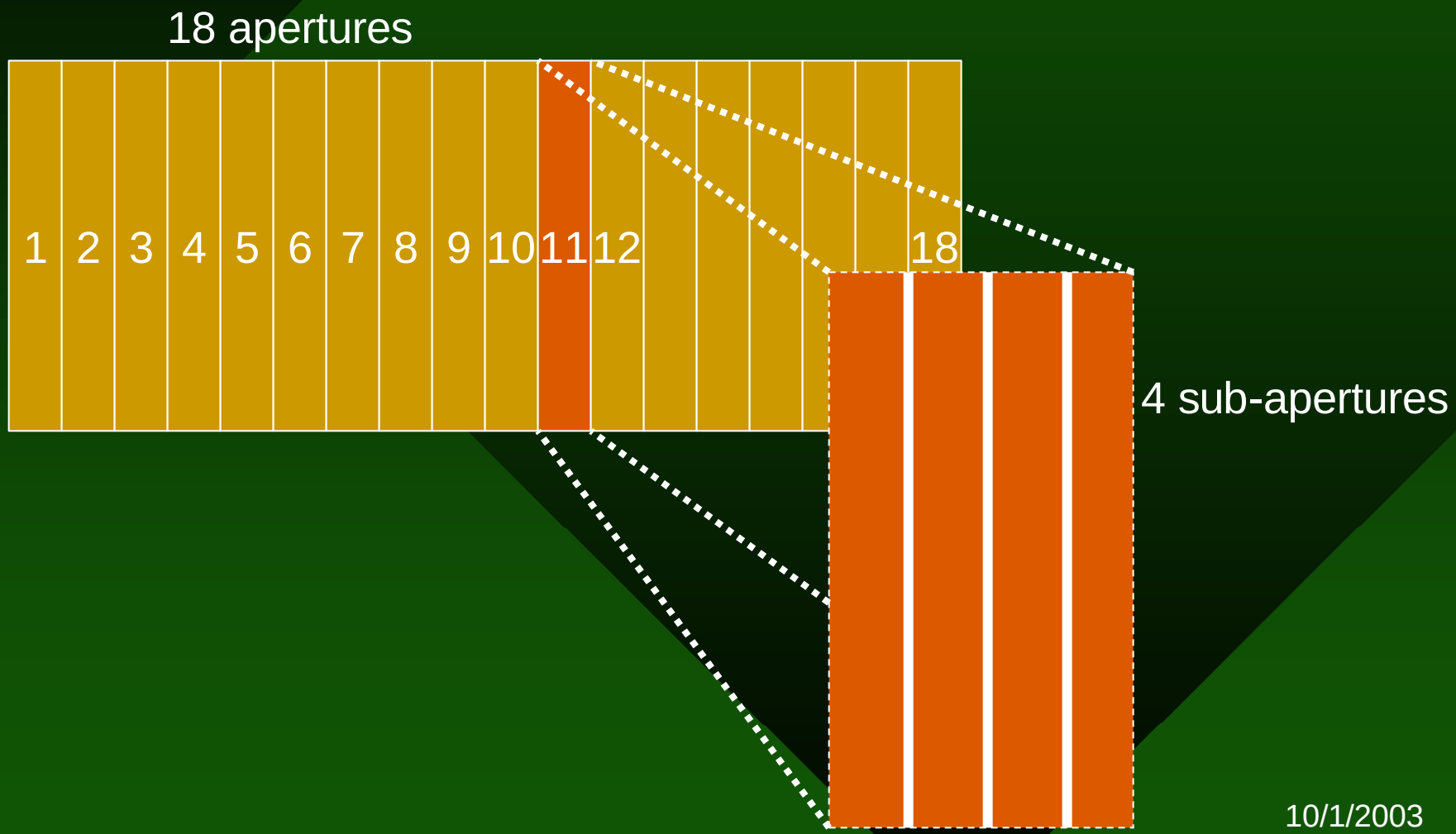
SAR Imagery

- Very large phase history data set are subdivided into 18 files (apertures).
- Auto focus through each file – independent of other files.
- Inner loop breaks aperture into 4 sub-apertures and performs FFT over each. Signal processing intense.

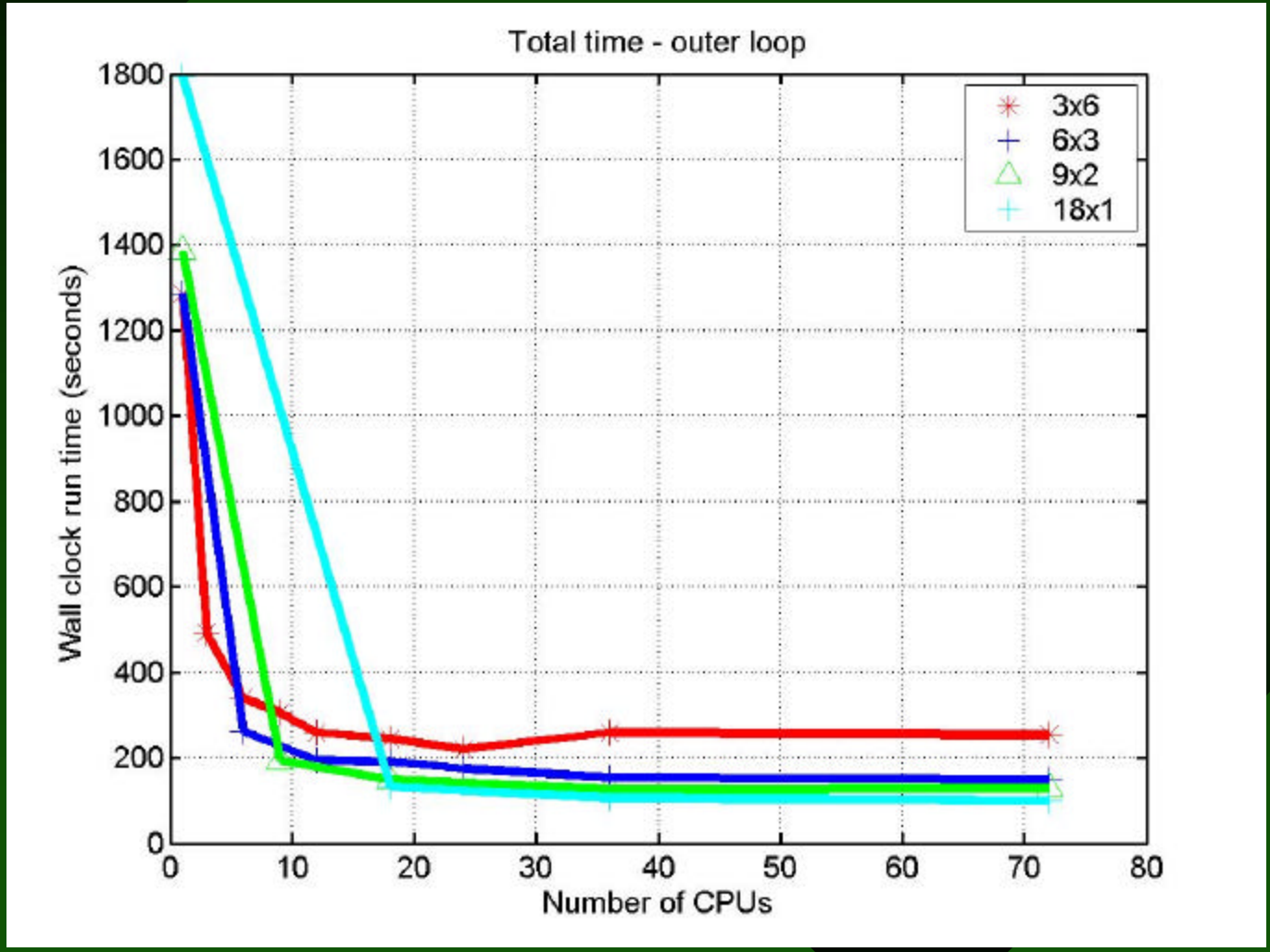
SAR Imagery


Calibrate
Main loop – 18 apertures
Main loop aperture (i)
Digital Spotlight aperture
Final Image
loop 4 times
FFT Sub aperture
Additional processing

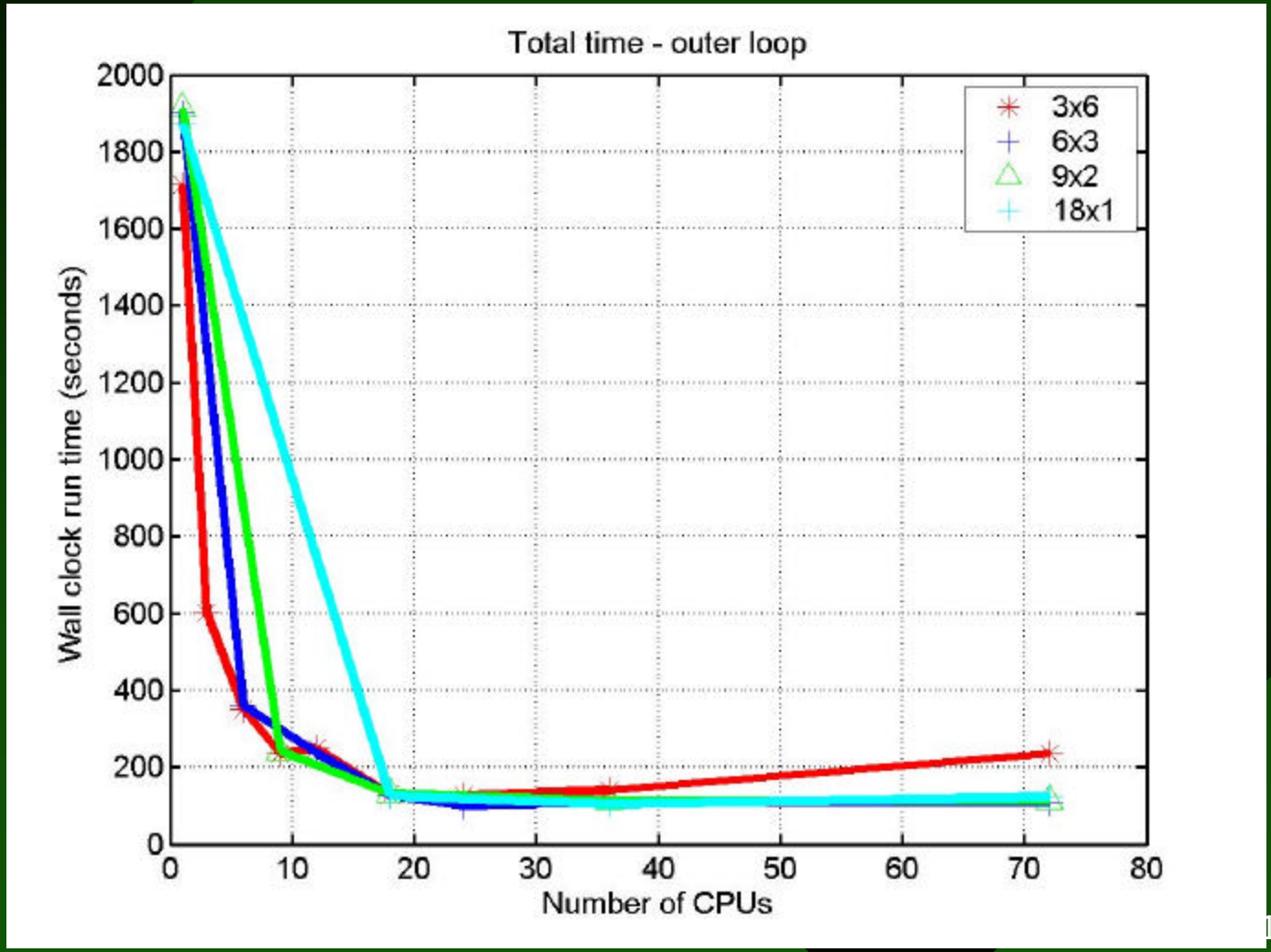
SAR Imagery



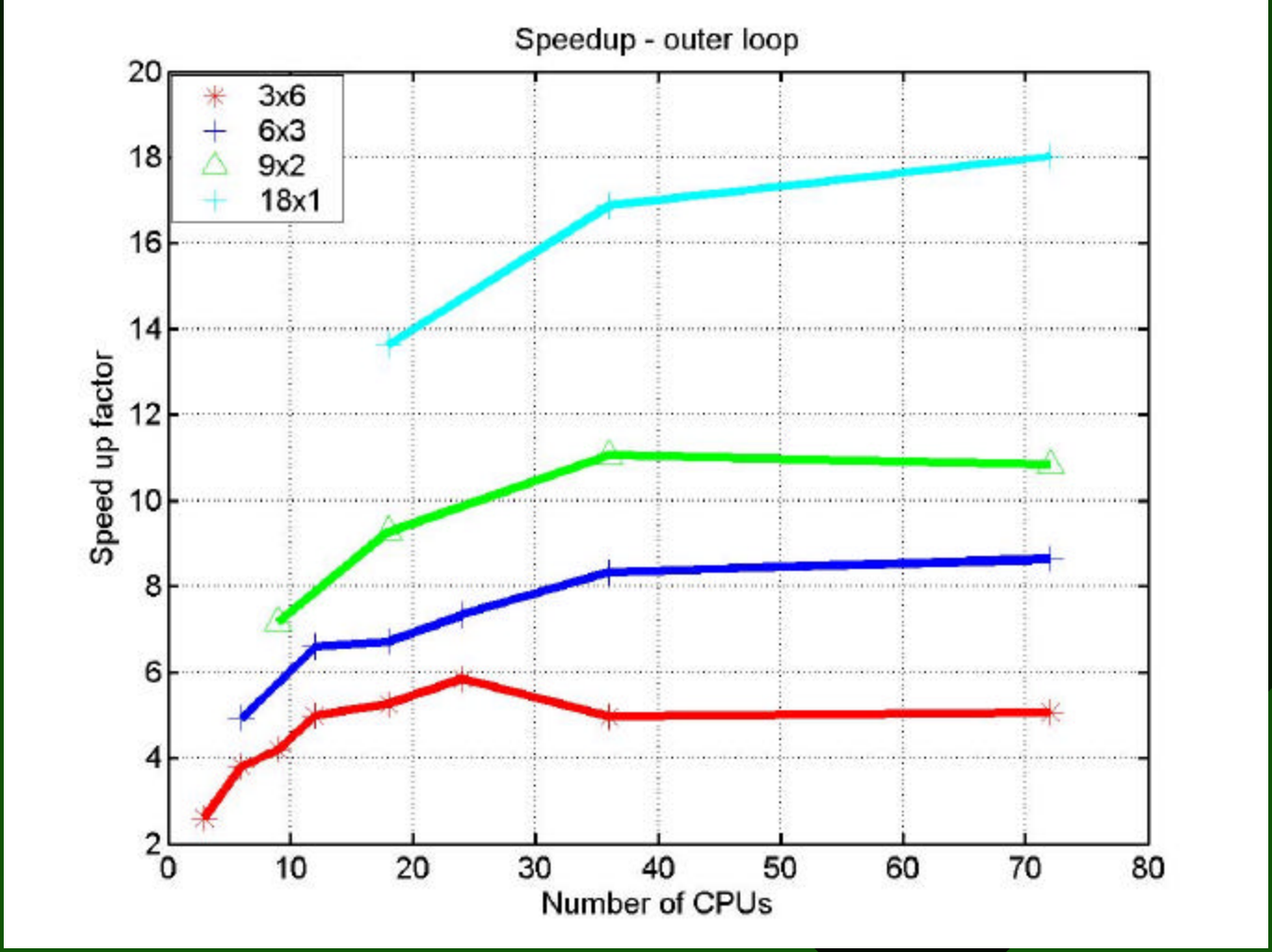
Parallel Performance “M” vs “C”
Total time “M code”



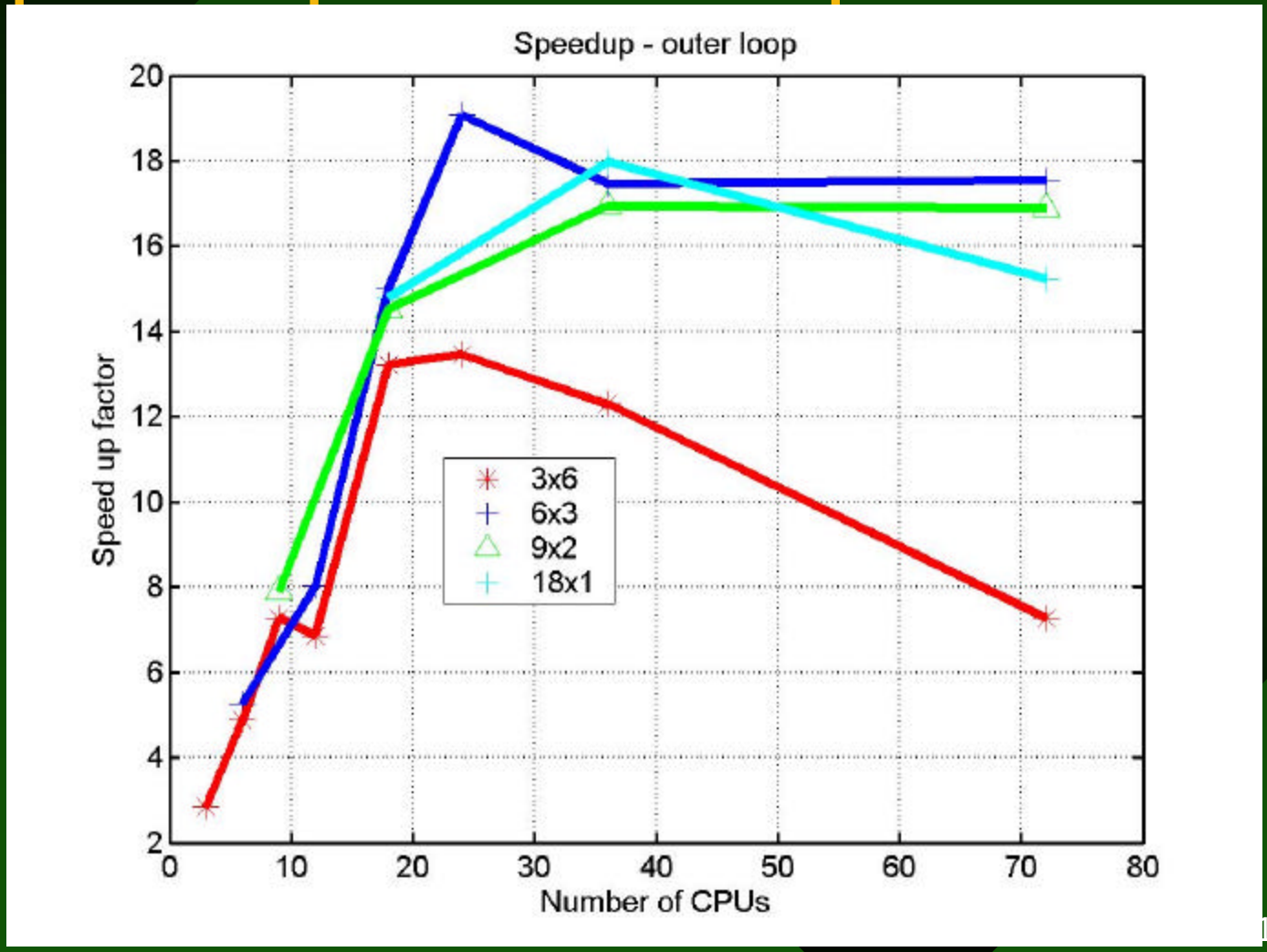
Total time “C code”



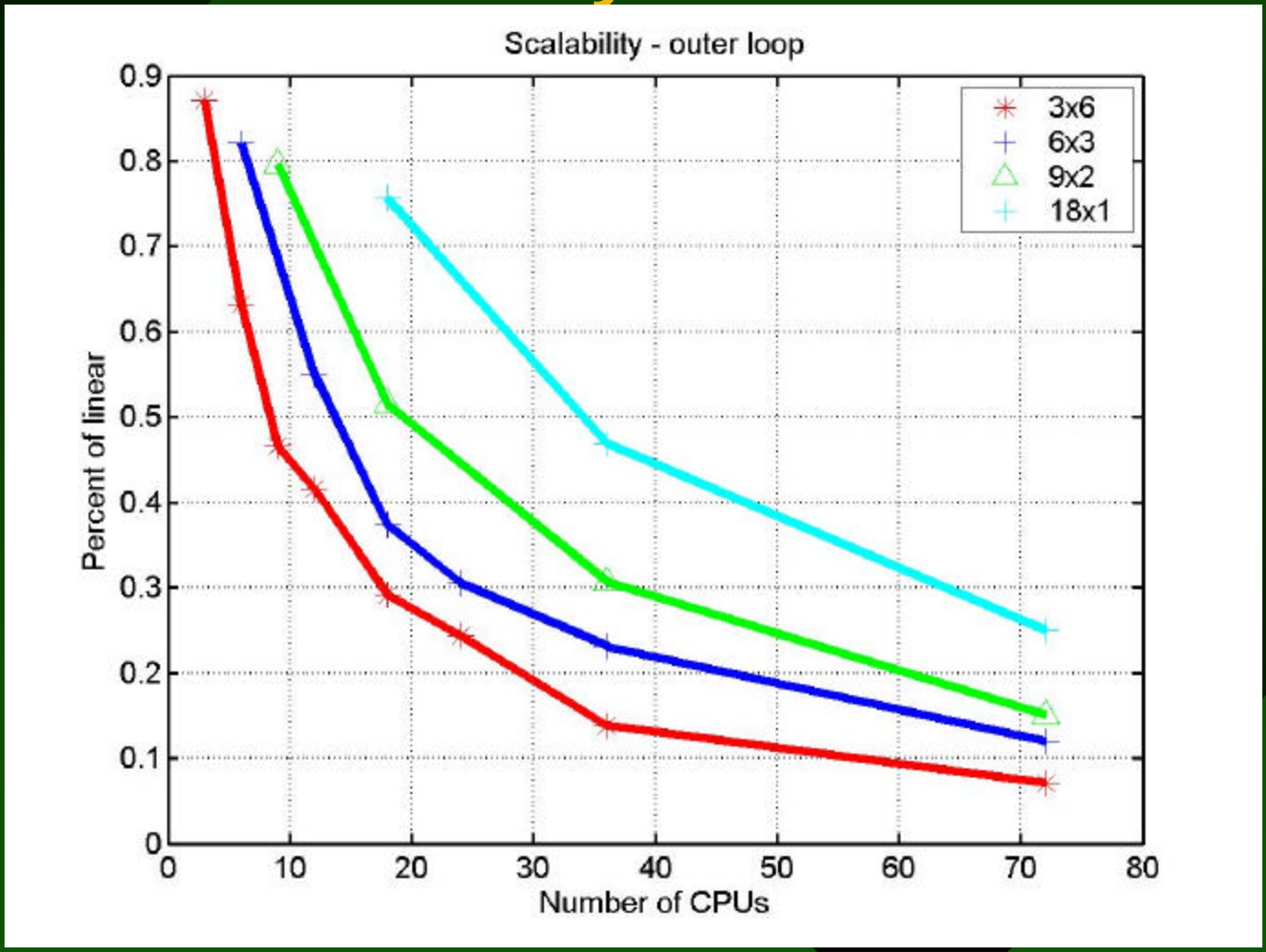
Speed up - outer loop “M code”



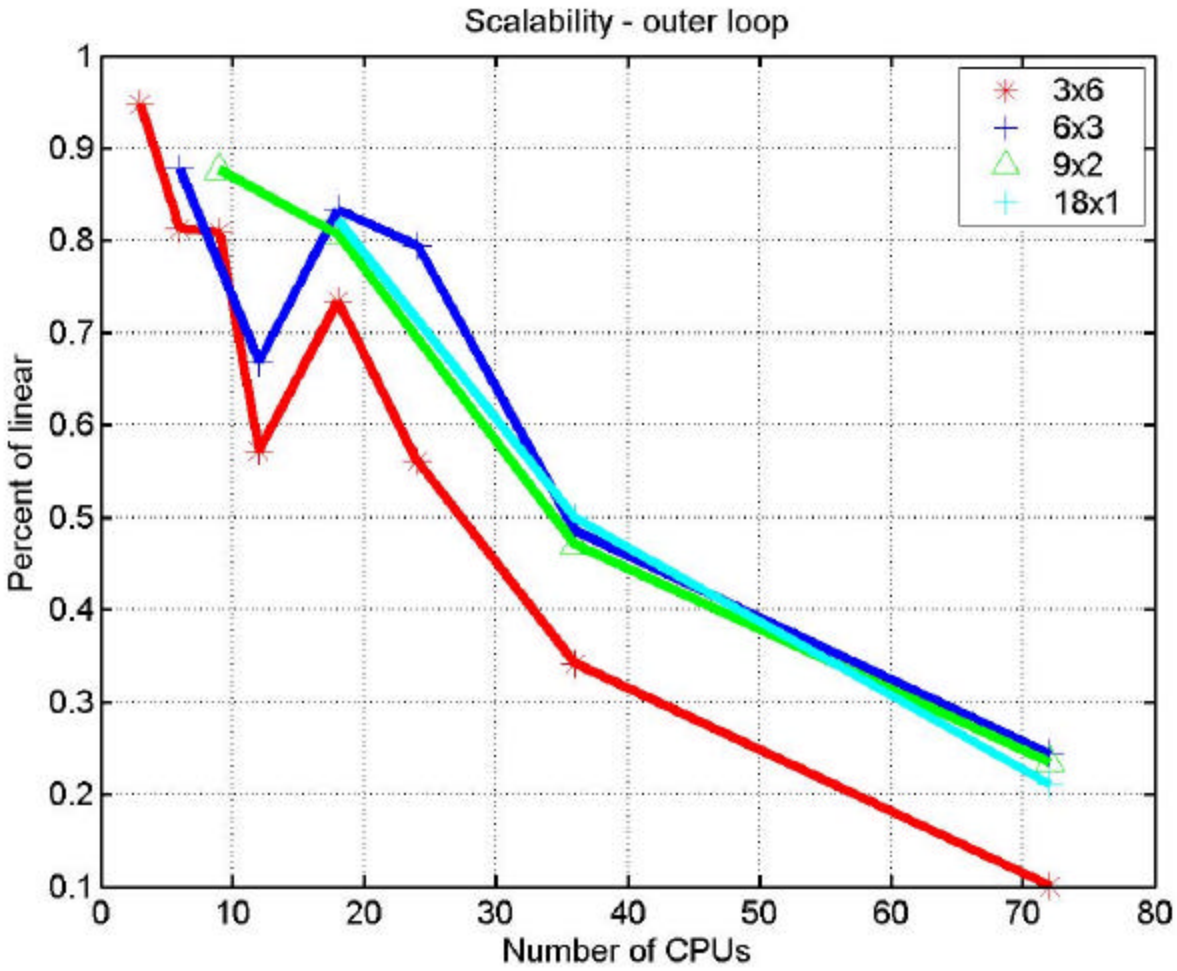
Speed up - outer loop “C code”



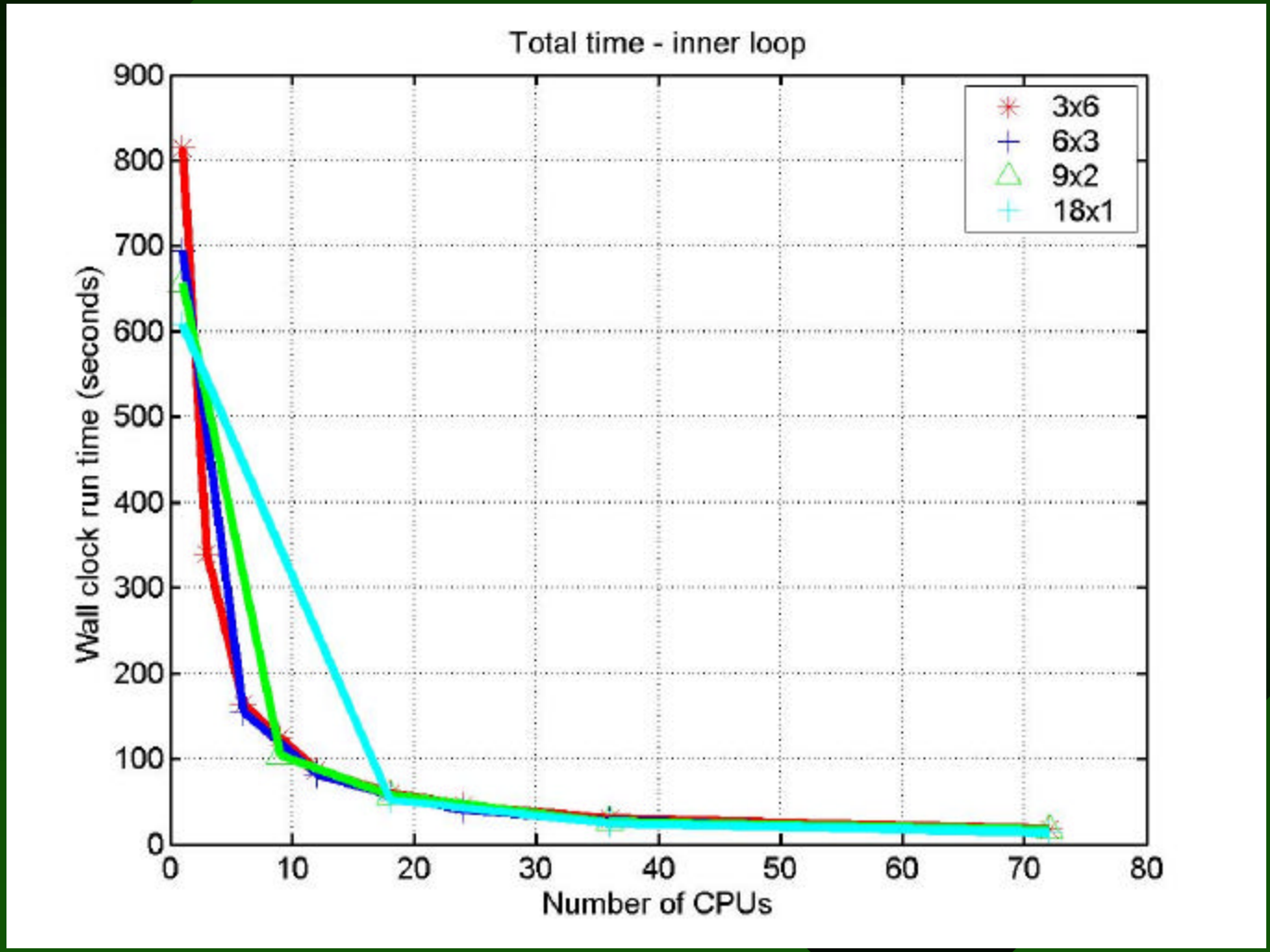
Scalability “M code”



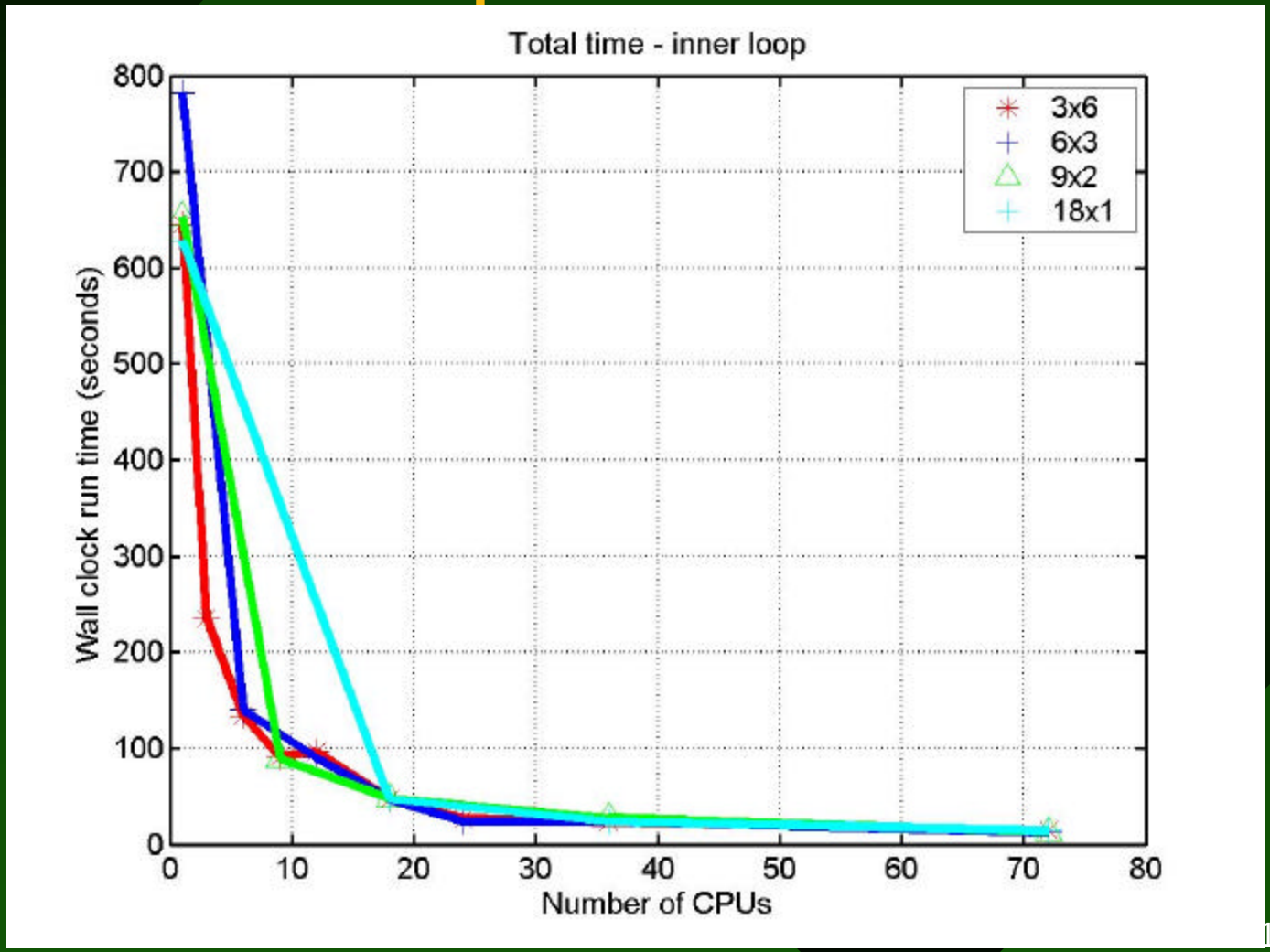
Scalability “C code”



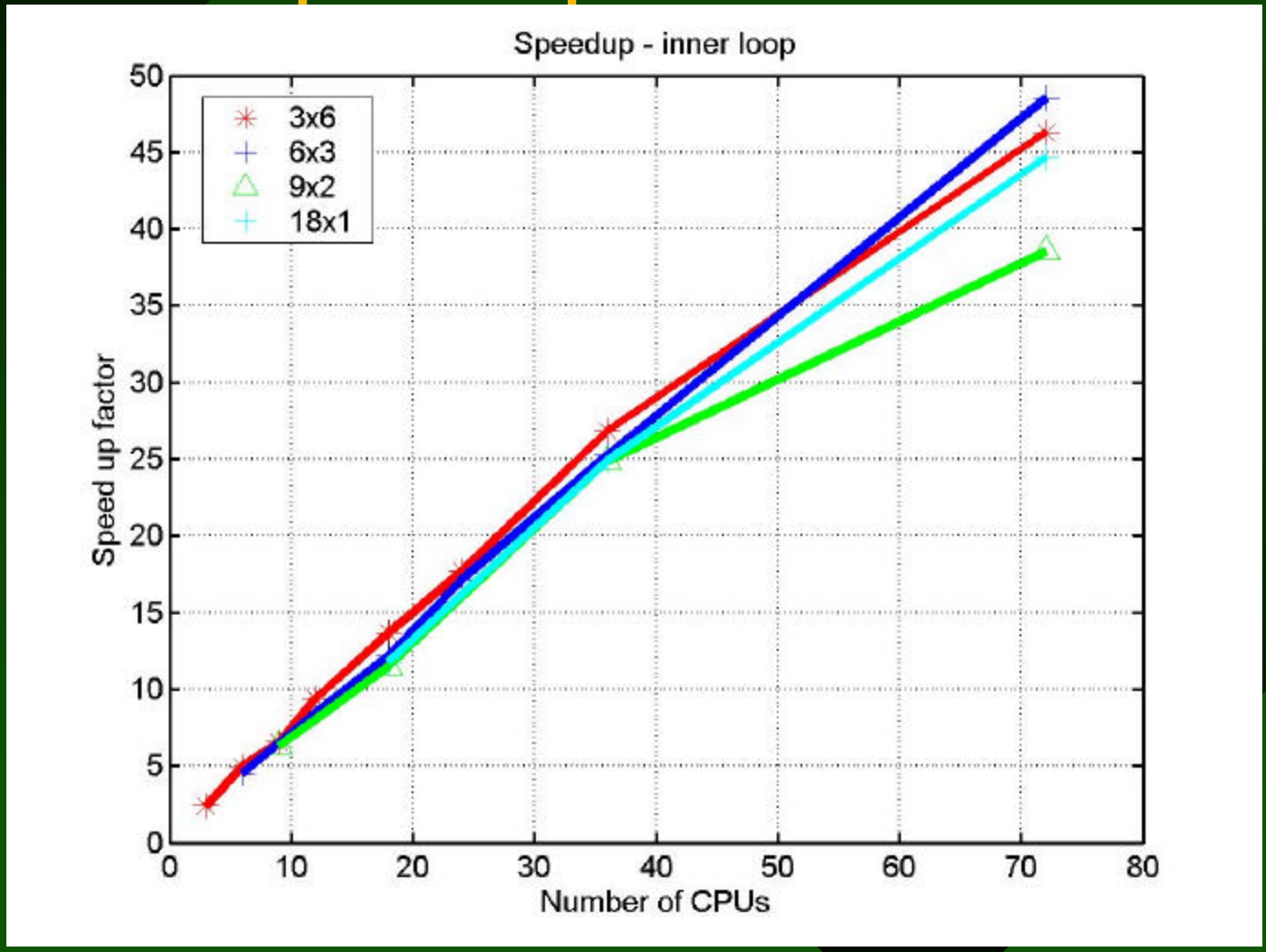
Inner loop time “M code”



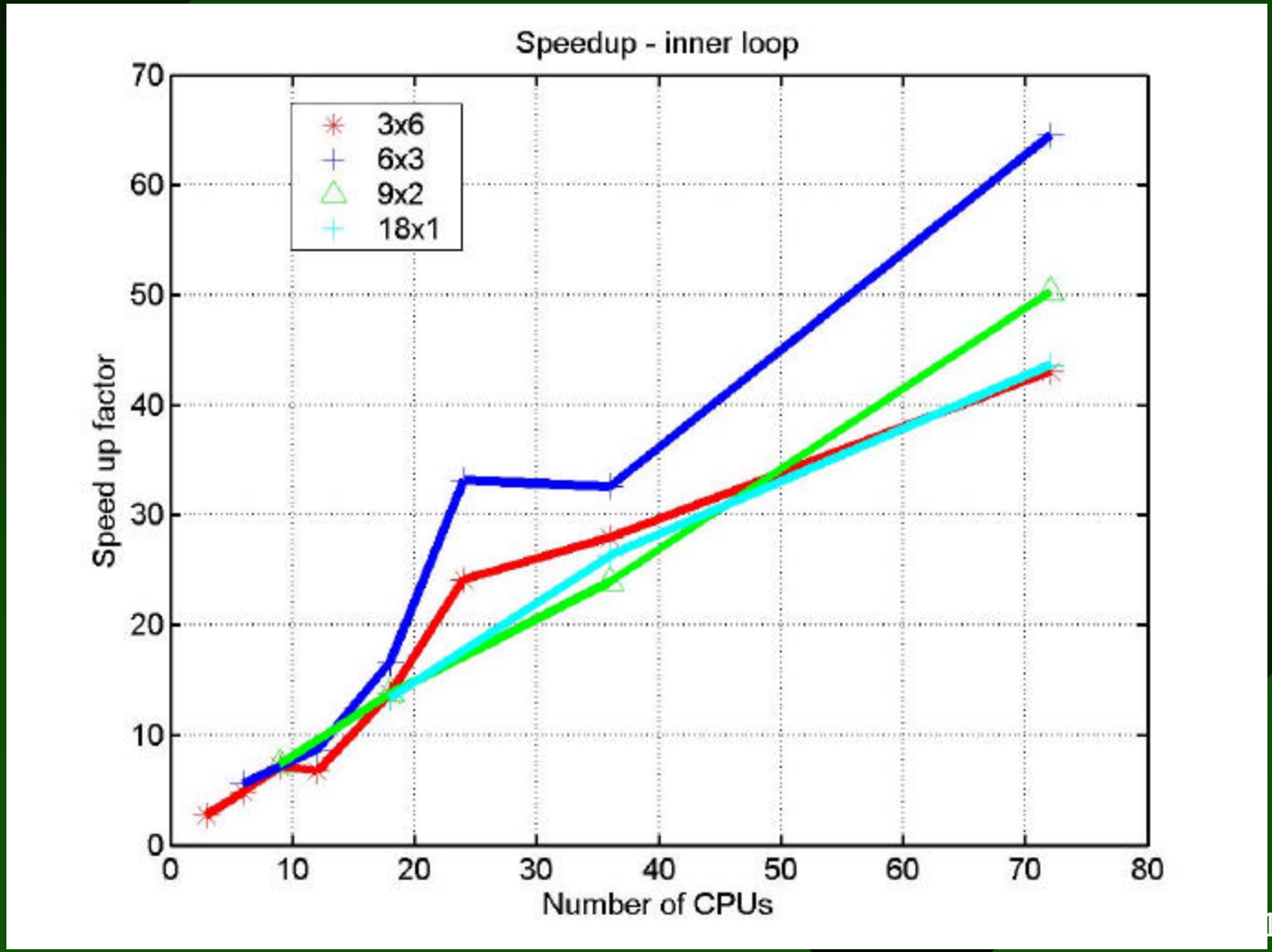
Inner loop time “C code”



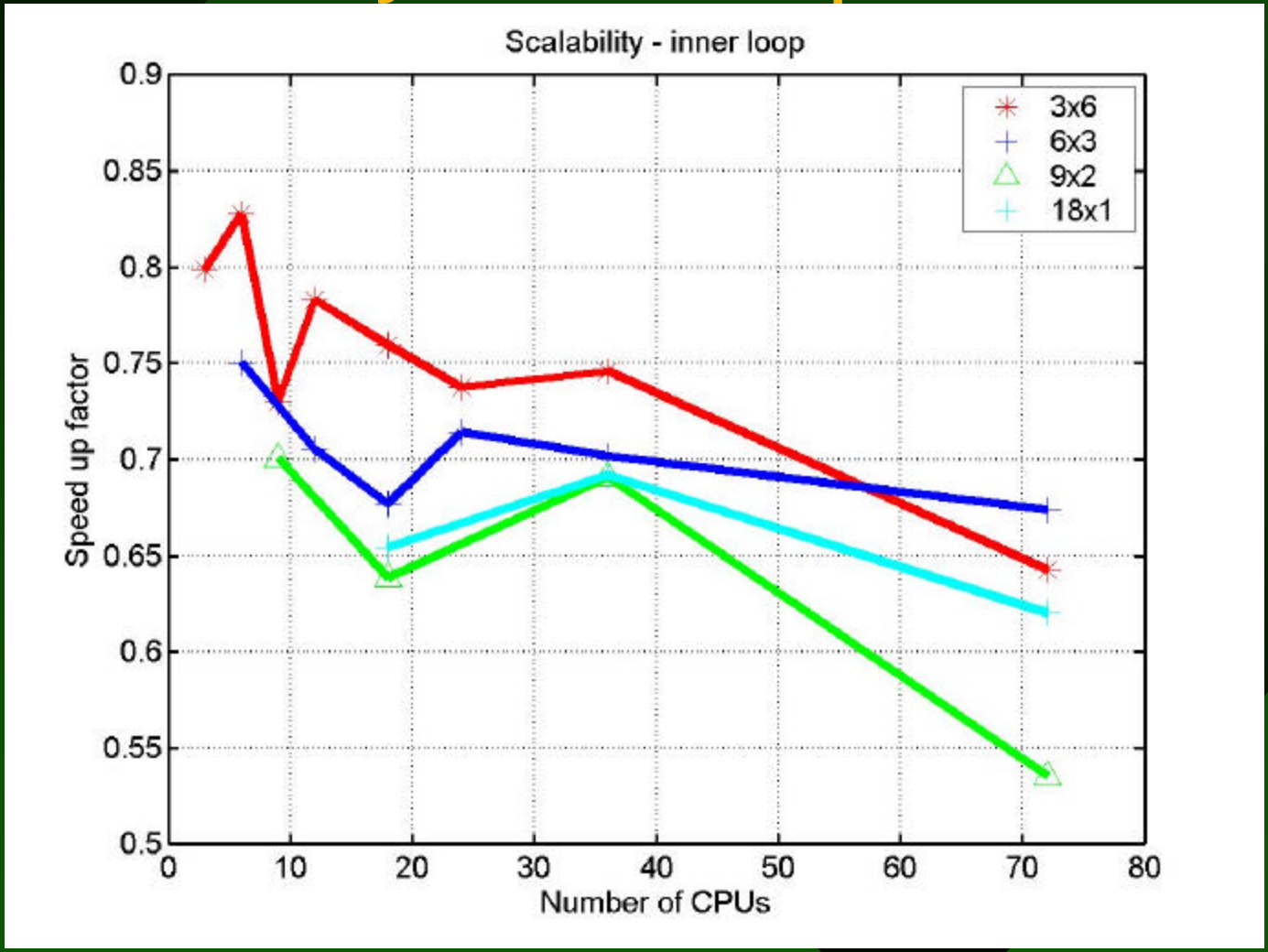
Speedup “M code”



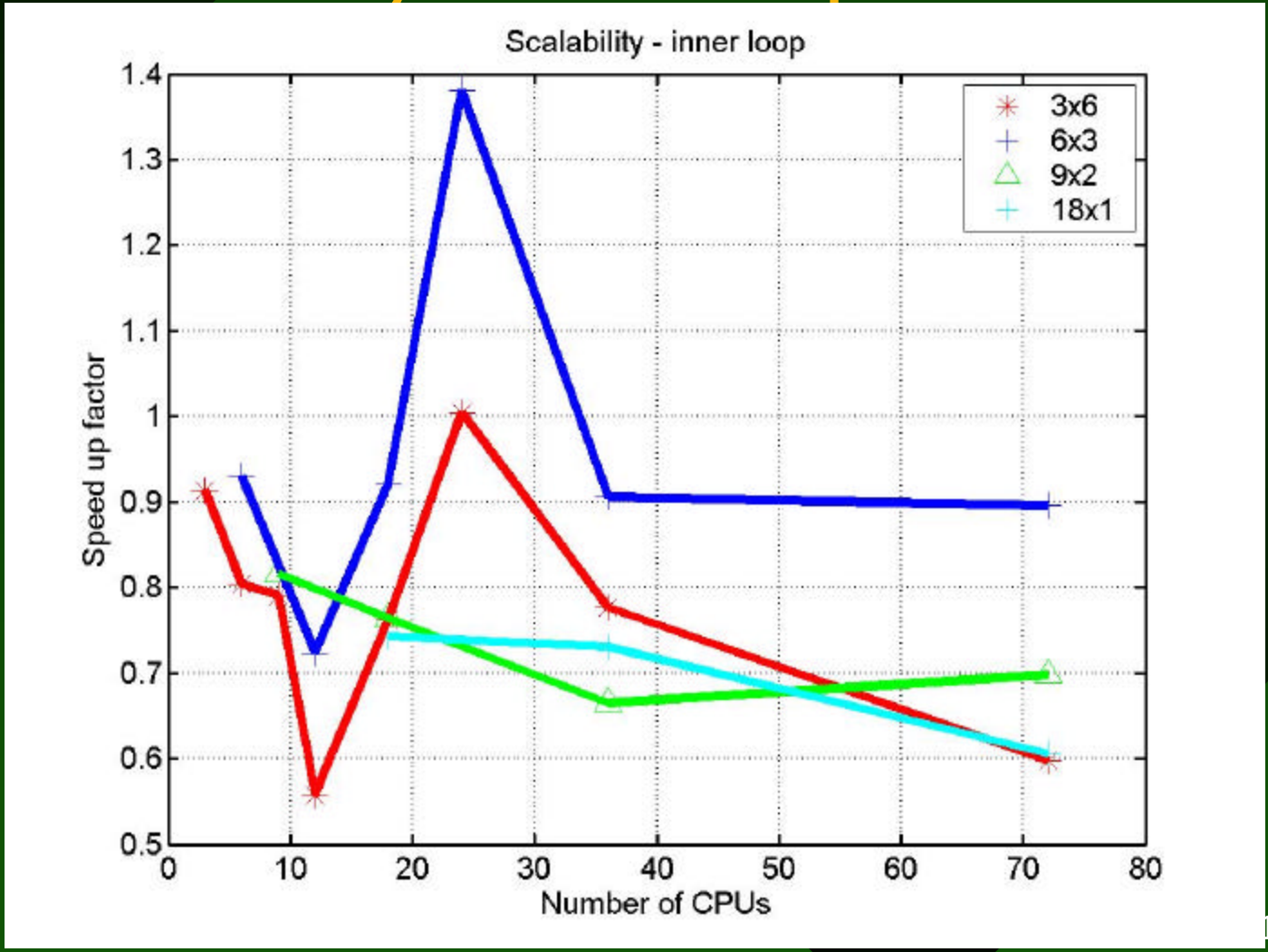
Speedup “C code”



Scalabililty-inner loop “M code”



Scalabililty-inner loop “C code”



Communication time

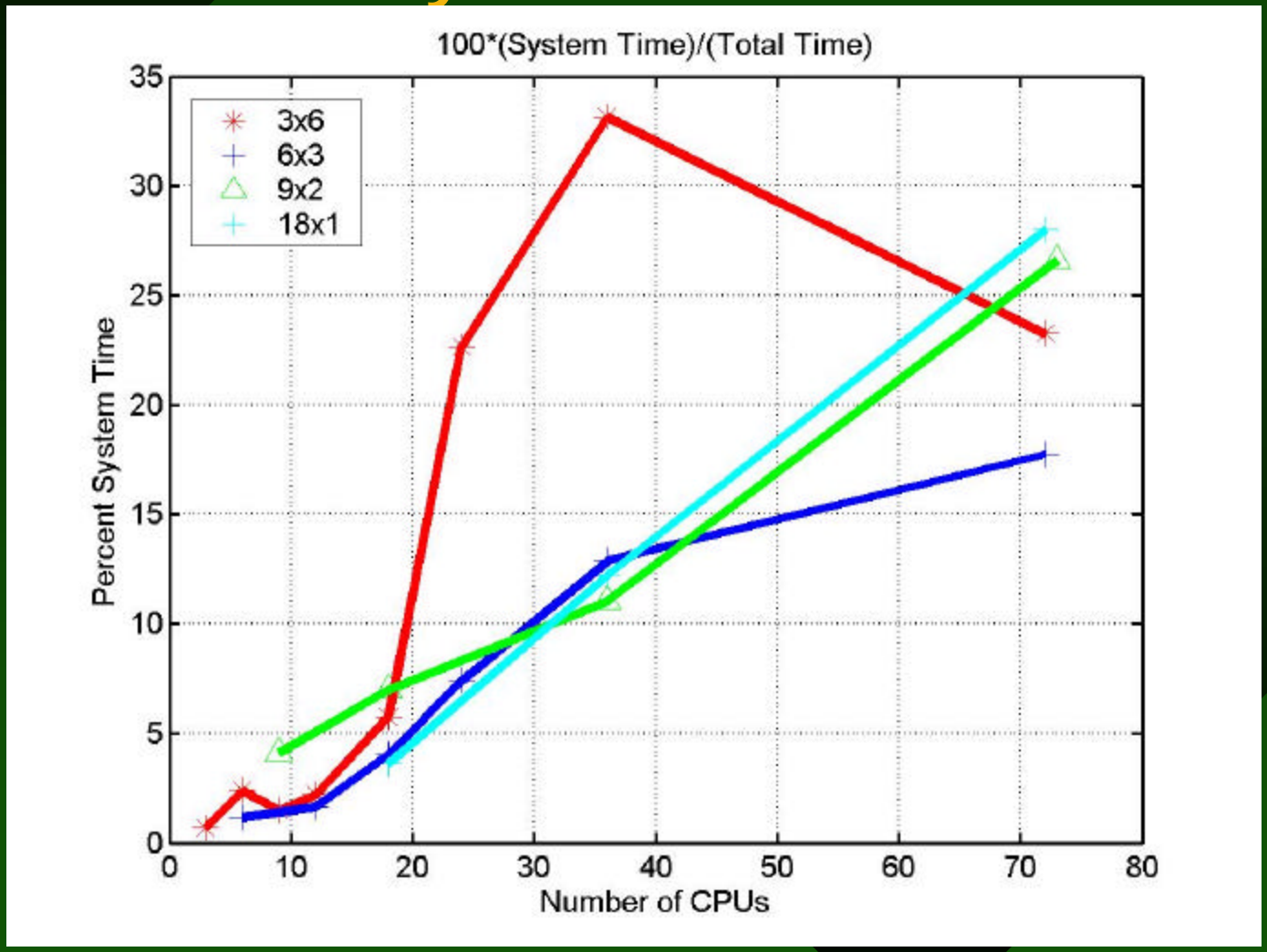
CPUs type seconds

72 3x6 = 48.9
36 3x6 = 4.35
72 6x3 = 6.09
36 6x3 = 4.71

Less than 0.3 seconds

24 18 12 9 6 3 1: 3x6
24 18 12 6 1: 6x3
72 36 18 9 1: 9x2
72 36 18 1: 18x1

System time


100*(System Time)/(Total Time)
Percent System Time
Number of CPUs
3x6
6x3
9x2
18x1
0
5
10
15
20
25
30
35
0
10
20
30
40
50
60
70
80

Summary

- "M-file" MatlabMPI code has comparable performance to compiled "C-code"
- Both methods can be submitted to batch
- "C-code" implementations allow an increase in processor use without the purchase of additional licenses.
- MatlabMPI scales well, but can be influenced when large file transfers are occurring.

Future Work and activities

- Automate the MatlabMPI suite for executable versions.
- Customize MatlabMPI to create batch scripts for all the HPCMP resources
- Matlab via the web – see "A Java-based Web Interface to MATLAB"
- Application to BackProjection & Wavefront theory codes.
- HPCMO SIP Benchmark / Profiling Study