Parallel Matlab(*)

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(*)=and other tools

Version: ~~4/11/2018~~, 4/10/2019

Agenda

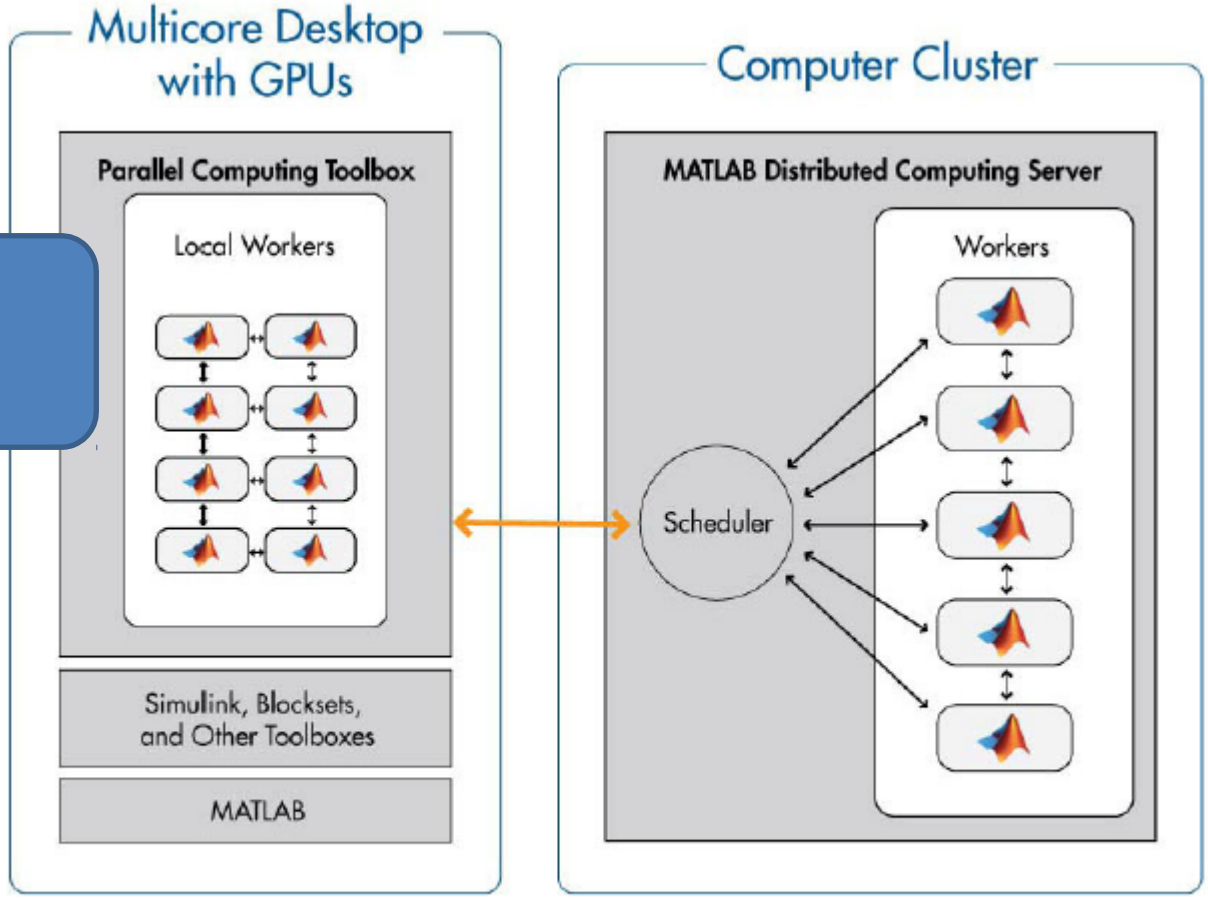
- Mathworks – Parallel Computing toolbox
- Parallel Computing with Matlab on Amazon Cloud
- Matlab over GPGPU
- Matlab (Octave) + HTCondor (we will have to learn HTCondor first)
- Parallel Matlab (Octave) using MatlabMPI
- Parallel Matlab (Octave) using pMatlab

Mathworks – Parallel Computing toolbox

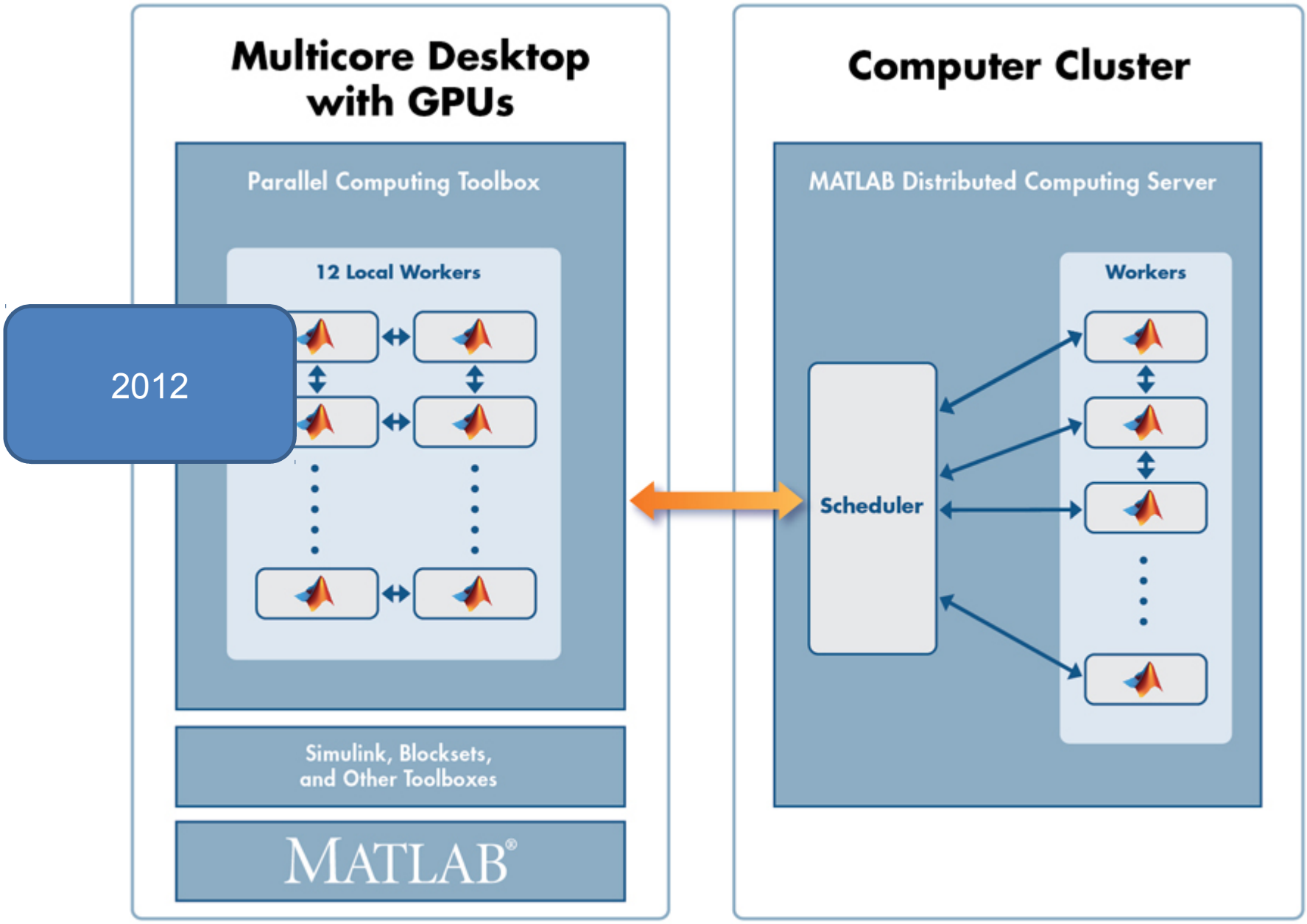
- Parallel Computing without CUDA or MPI(…)
- The toolbox provides “workers” (MATLAB computational engines) to execute applications locally on a multicore desktop
- Parallel for-loops (**`parfor`**) for running task-parallel algorithms on multiple processors
- Computer cluster and grid support (with MATLAB Distributed Computing Server)

Parallel Computing toolbox

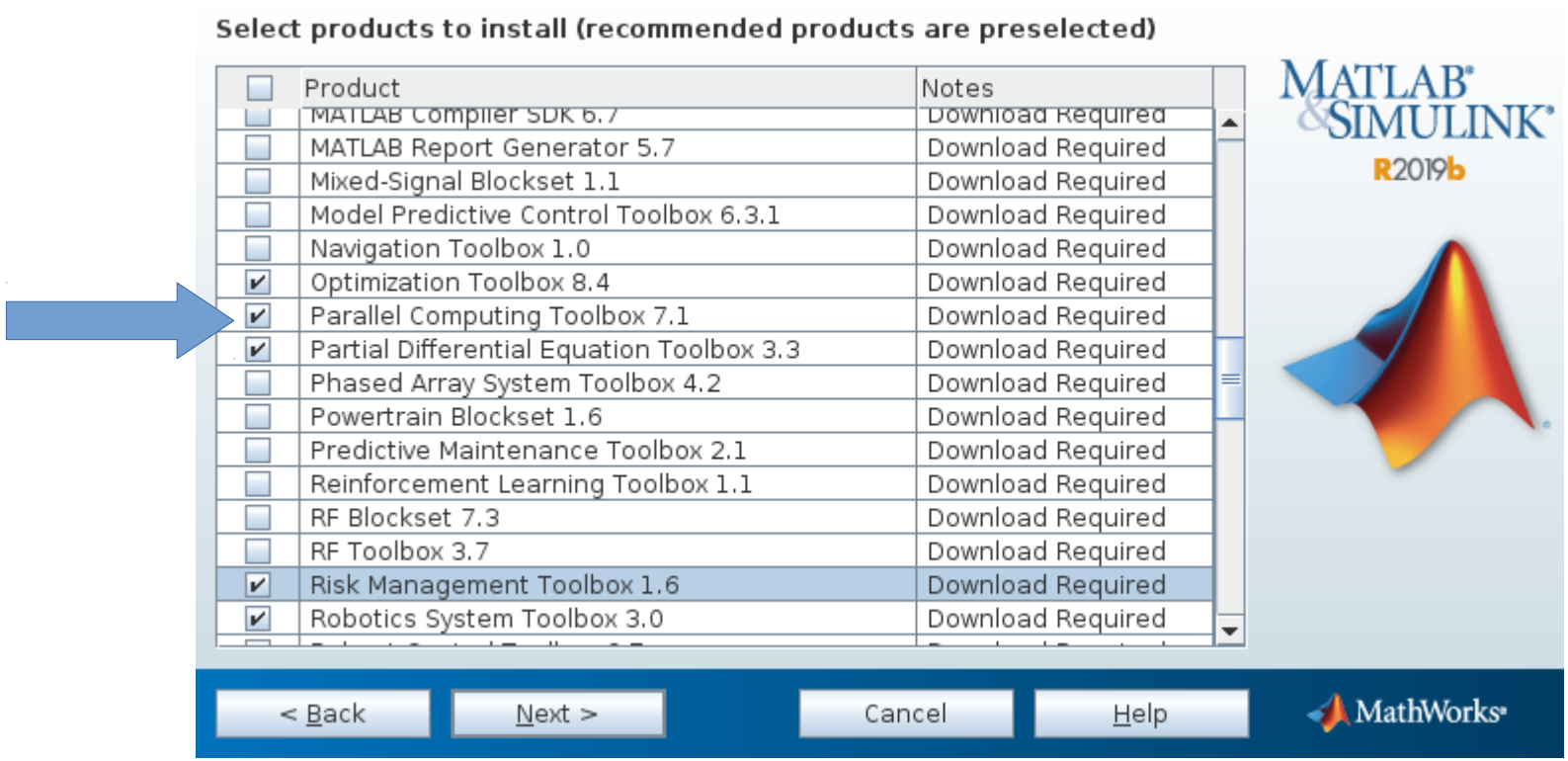
2011

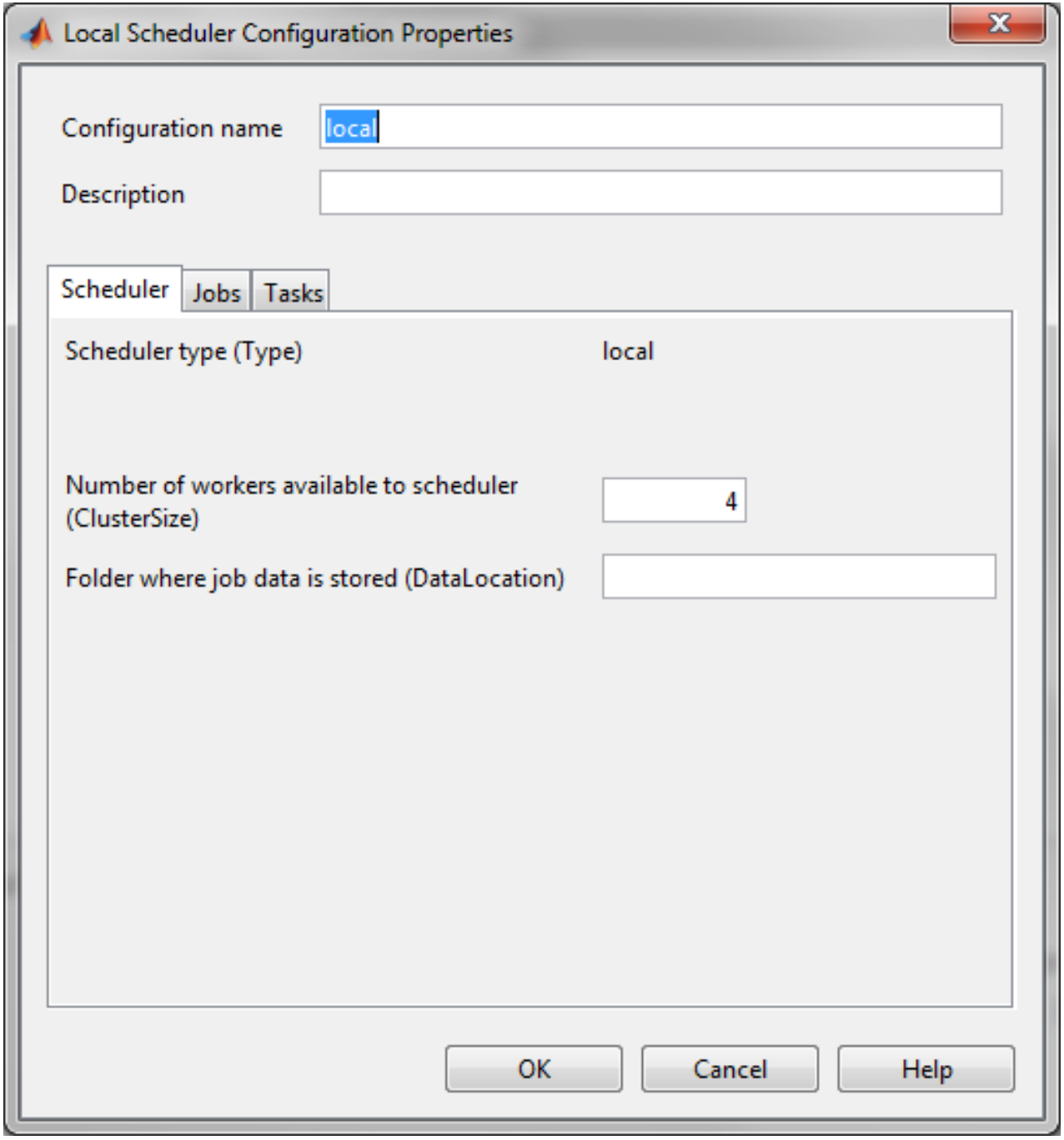


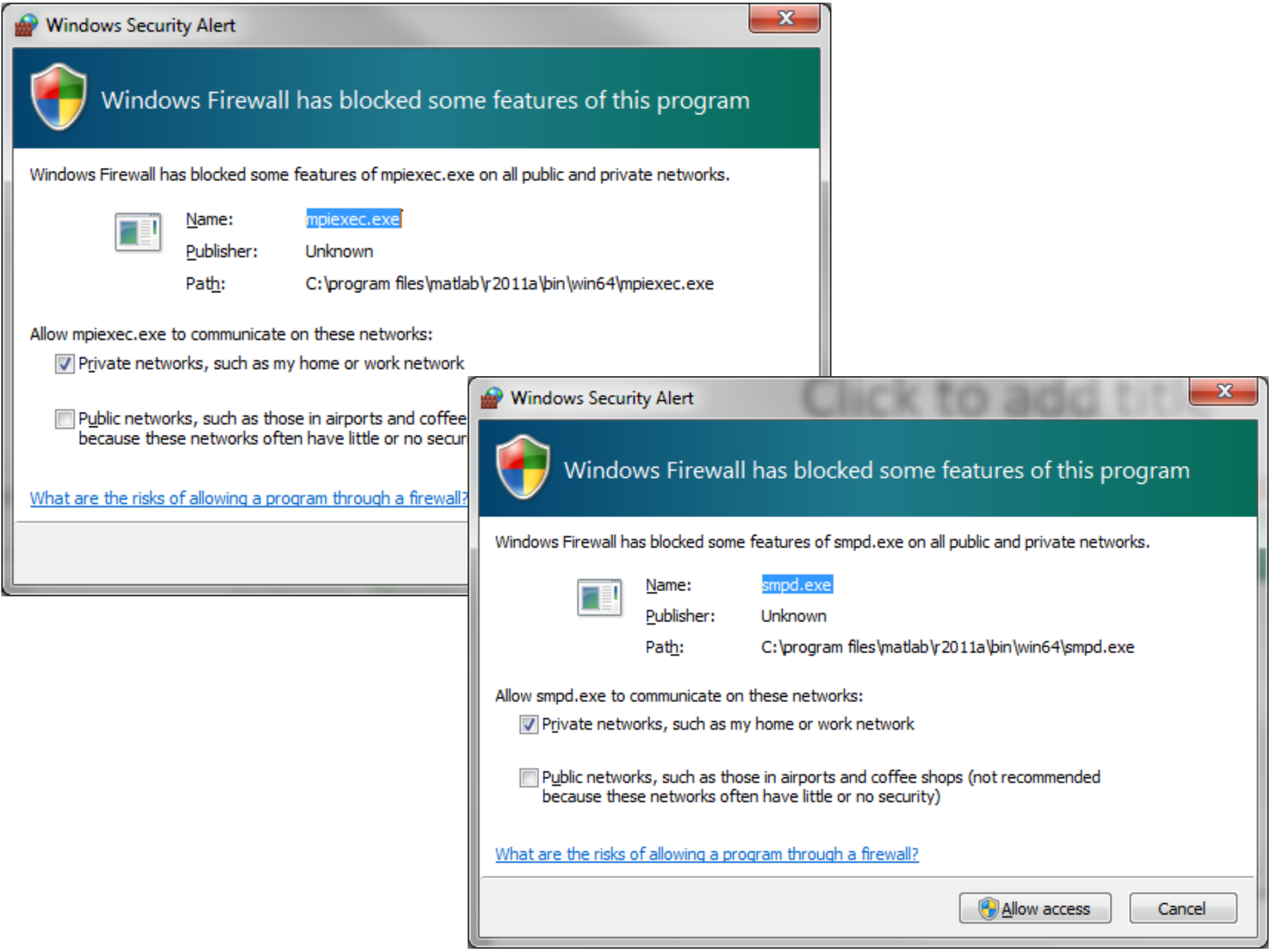
Parallel computing with MATLAB. You can use Parallel Computing Toolbox to run applications on a multicore desktop with eight workers available in the toolbox, take advantage of GPUs, and scale up to a cluster (with MATLAB Distributed Computing Server).

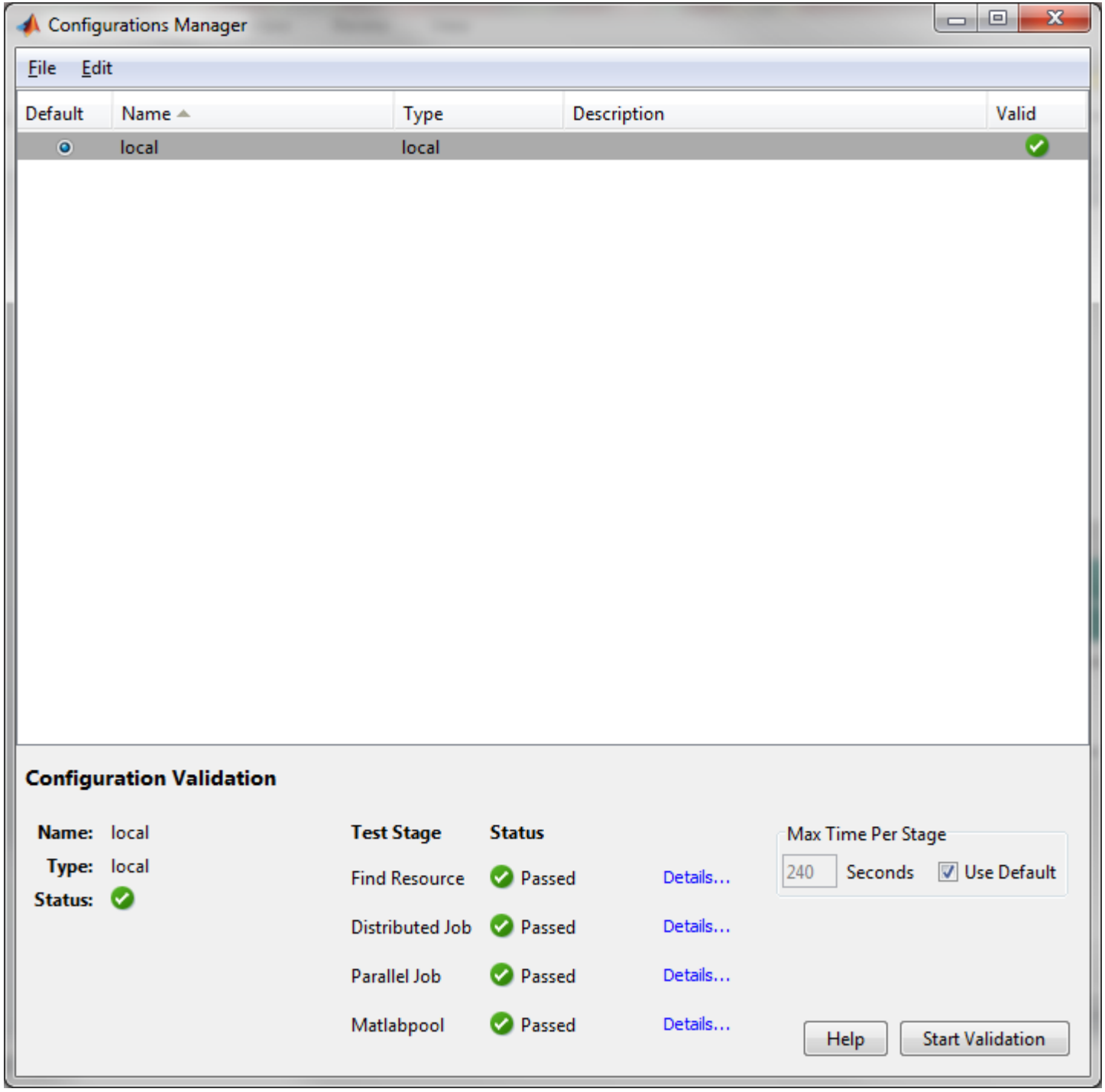

Multicore Desktop with GPUs
Parallel Computing Toolbox
12 Local Workers
Simulink, Blocksets, and Other Toolboxes
MATLAB®
Computer Cluster
MATLAB Distributed Computing Server
Workers
Scheduler
2012

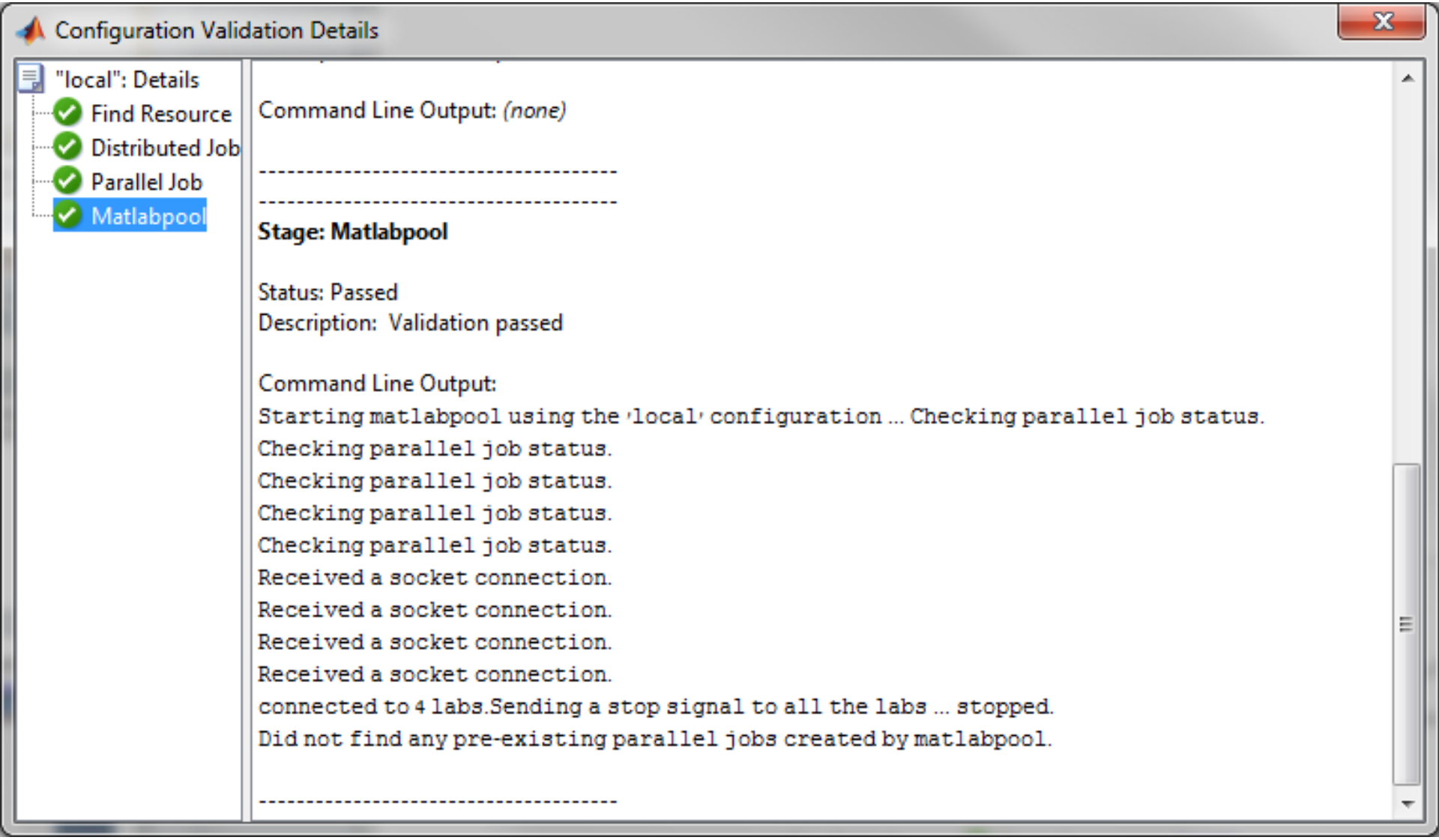
When installing Matlab check the Parallel Computing Toolbox




Local Scheduler Configuration Properties
Configuration name
local
Description
Scheduler
Jobs
Tasks
Scheduler type (Type)
local
Number of workers available to scheduler (ClusterSize)
4
Folder where job data is stored (DataLocation)
OK
Cancel
Help

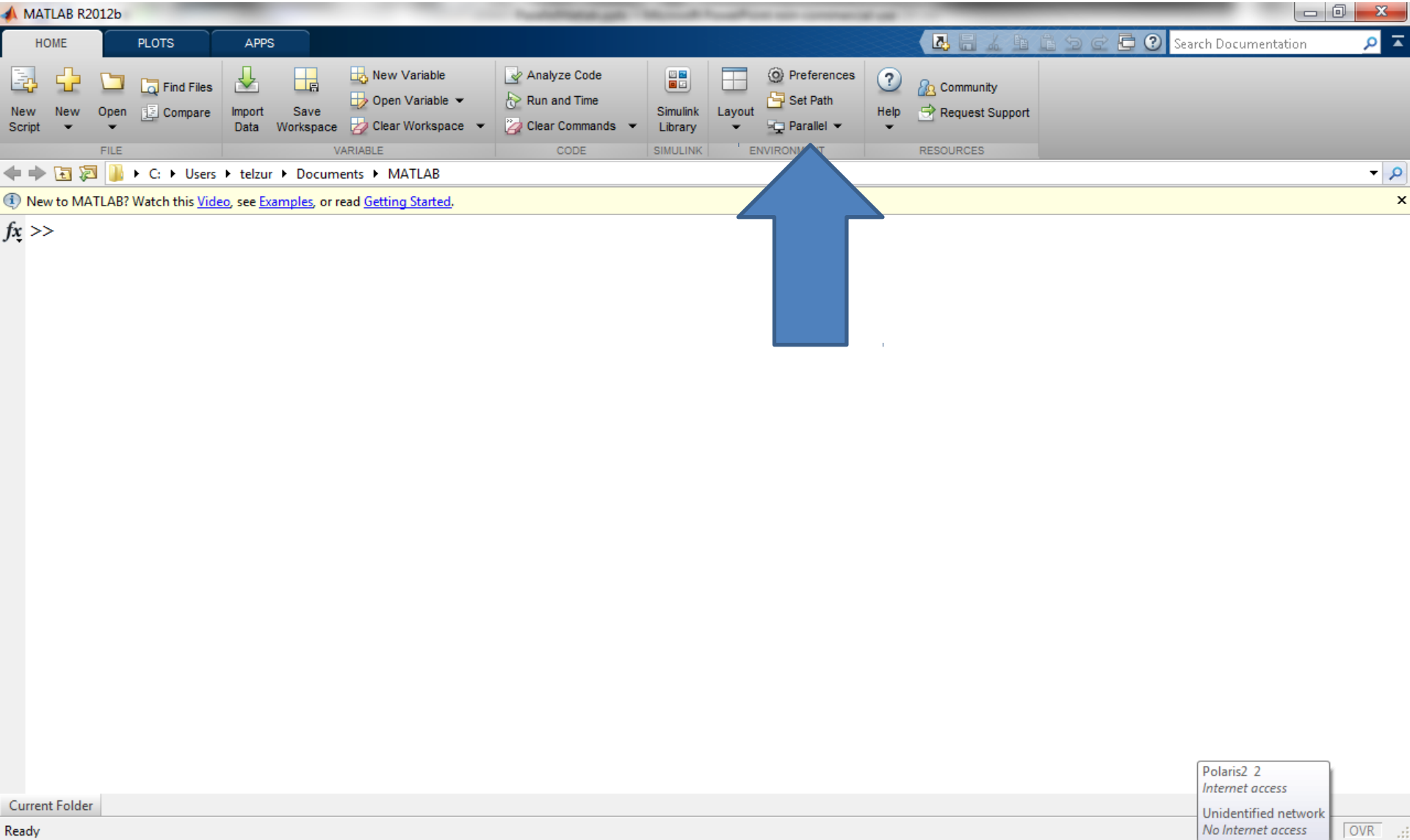

Windows Security Alert
Windows Firewall has blocked some features of this program
Windows Firewall has blocked some features of mpiexec.exe on all public and private networks.
Name: mpiexec.exe
Publisher: Unknown
Path: C:\program files\matlab\r2011a\bin\win64\mpiexec.exe
Allow mpiexec.exe to communicate on these networks:
Private networks, such as my home or work network
Public networks, such as those in airports and coffee
because these networks often have little or no secur
What are the risks of allowing a program through a firewall?
Windows Security Alert
Windows Firewall has blocked some features of this program
Windows Firewall has blocked some features of smpd.exe on all public and private networks.
Name: smpd.exe
Publisher: Unknown
Path: C:\program files\matlab\r2011a\bin\win64\smpd.exe
Allow smpd.exe to communicate on these networks:
Private networks, such as my home or work network
Public networks, such as those in airports and coffee shops (not recommended because these networks often have little or no security)
What are the risks of allowing a program through a firewall?
Allow access
Cancel

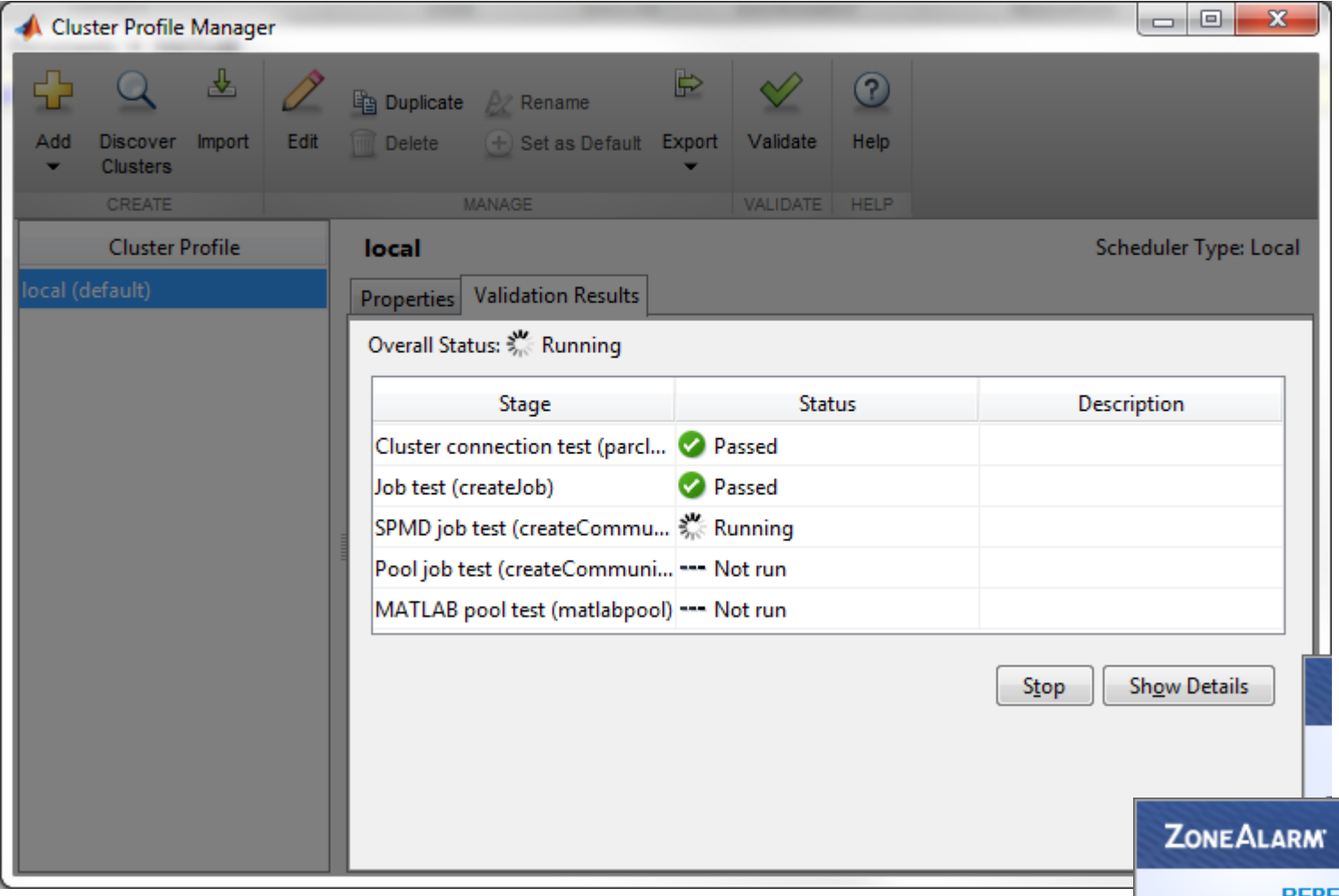

Configurations Manager
File
Edit
Default
Name
Type
Description
Valid
local
local
Configuration Validation
Name: local
Type: local
Status:
Test Stage
Status
Find Resource
Passed
Details...
Distributed Job
Passed
Details...
Parallel Job
Passed
Details...
Matlabpool
Passed
Details...
Max Time Per Stage
240
Seconds
Use Default
Help
Start Validation

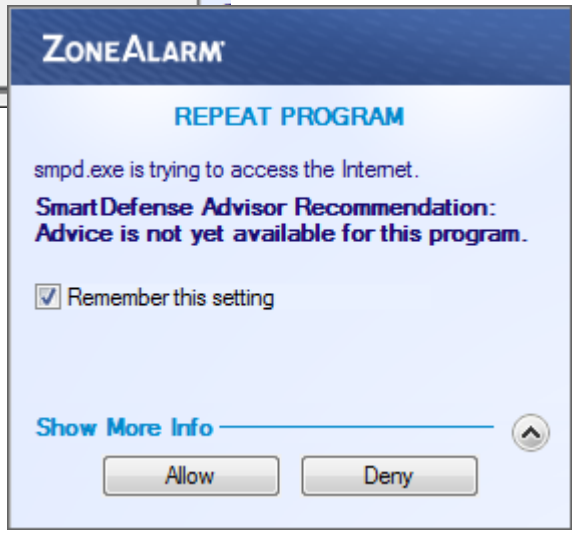

Configuration Validation Details
"local": Details
Find Resource
Distributed Job
Parallel Job
Matlabpool
Command Line Output: (none)

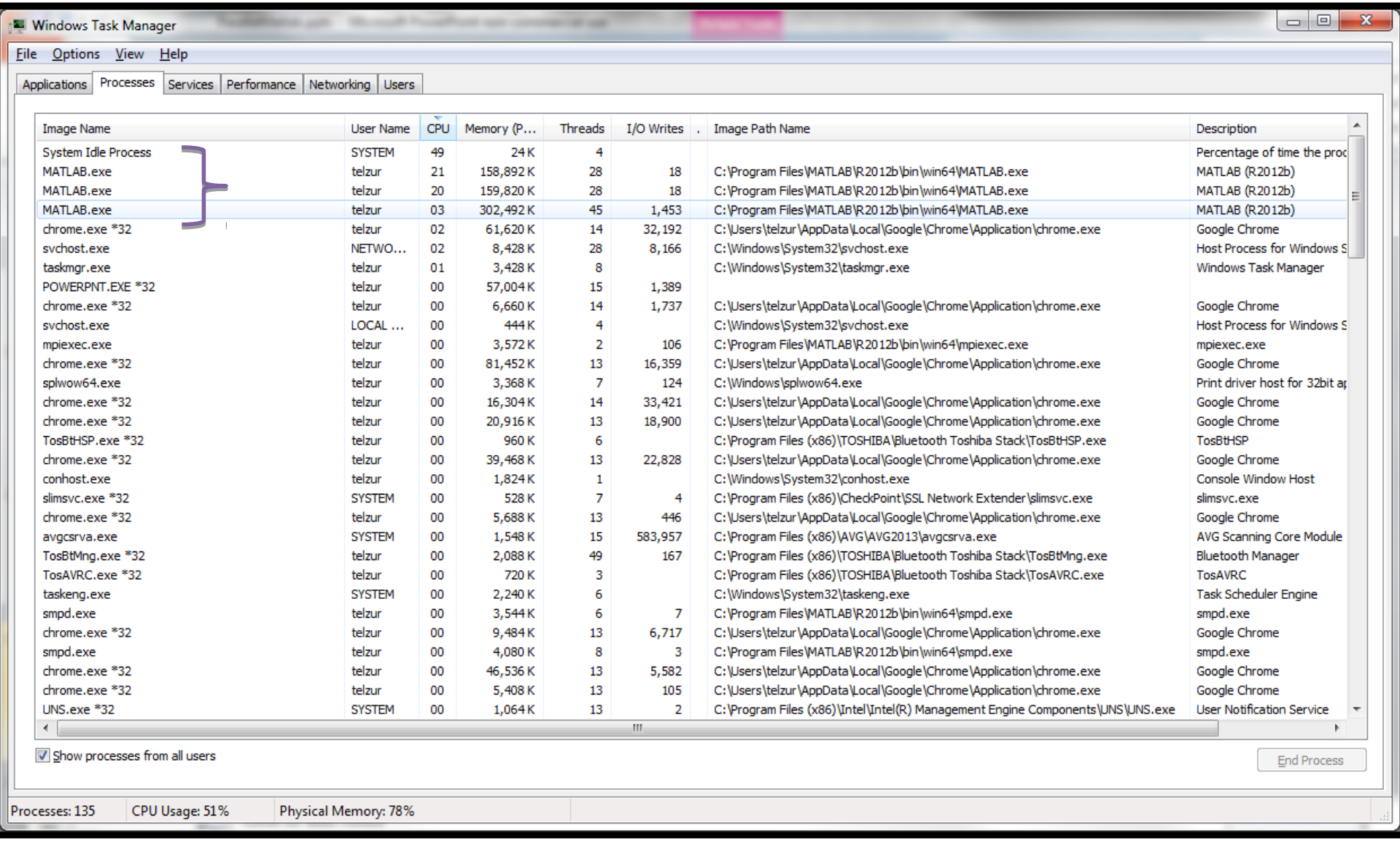
Stage: Matlabpool
Status: Passed
Description: Validation passed
Command Line Output:
Starting matlabpool using the 'local' configuration ... Checking parallel job status.
Checking parallel job status.
Checking parallel job status.
Checking parallel job status.
Checking parallel job status.
Received a socket connection.
Received a socket connection.
Received a socket connection.
Received a socket connection.
connected to 4 labs.Sending a stop signal to all the labs ... stopped.
Did not find any pre-existing parallel jobs created by matlabpool.

Matlab 2012B

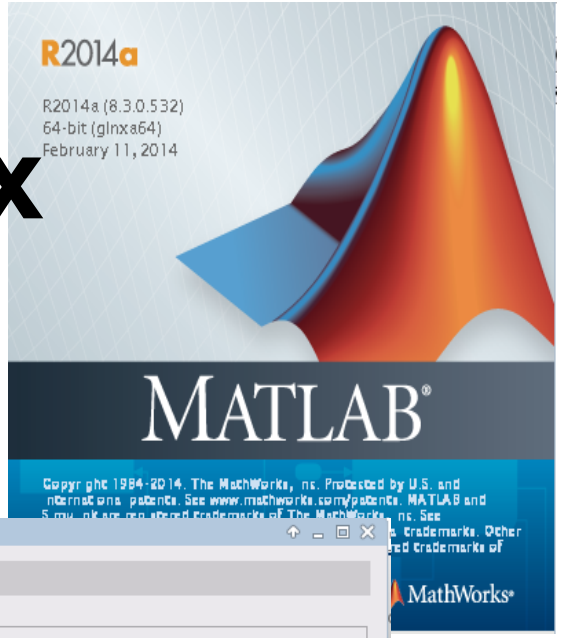


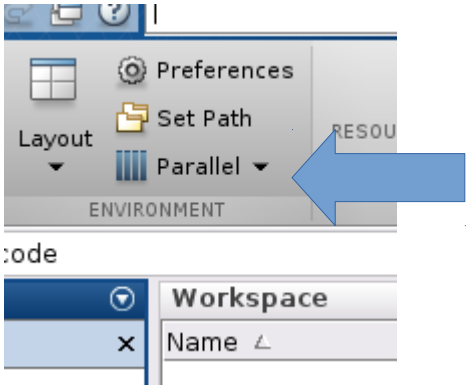

Cluster Profile Manager
Add
Discover Clusters
Import
Edit
Duplicate
Delete
Rename
Set as Default
Export
Validate
Help
CREATE
MANAGE
VALIDATE
HELP
Cluster Profile
local (default)
local
Scheduler Type: Local
Properties
Validation Results
Overall Status: Running
Stage
Status
Description
Cluster connection test (parcl...
Passed
Job test (createJob)
Passed
SPMD job test (createCommu...
Running
Pool job test (createCommuni...
Not run
MATLAB pool test (matlabpool)
Not run
Stop
Show Details

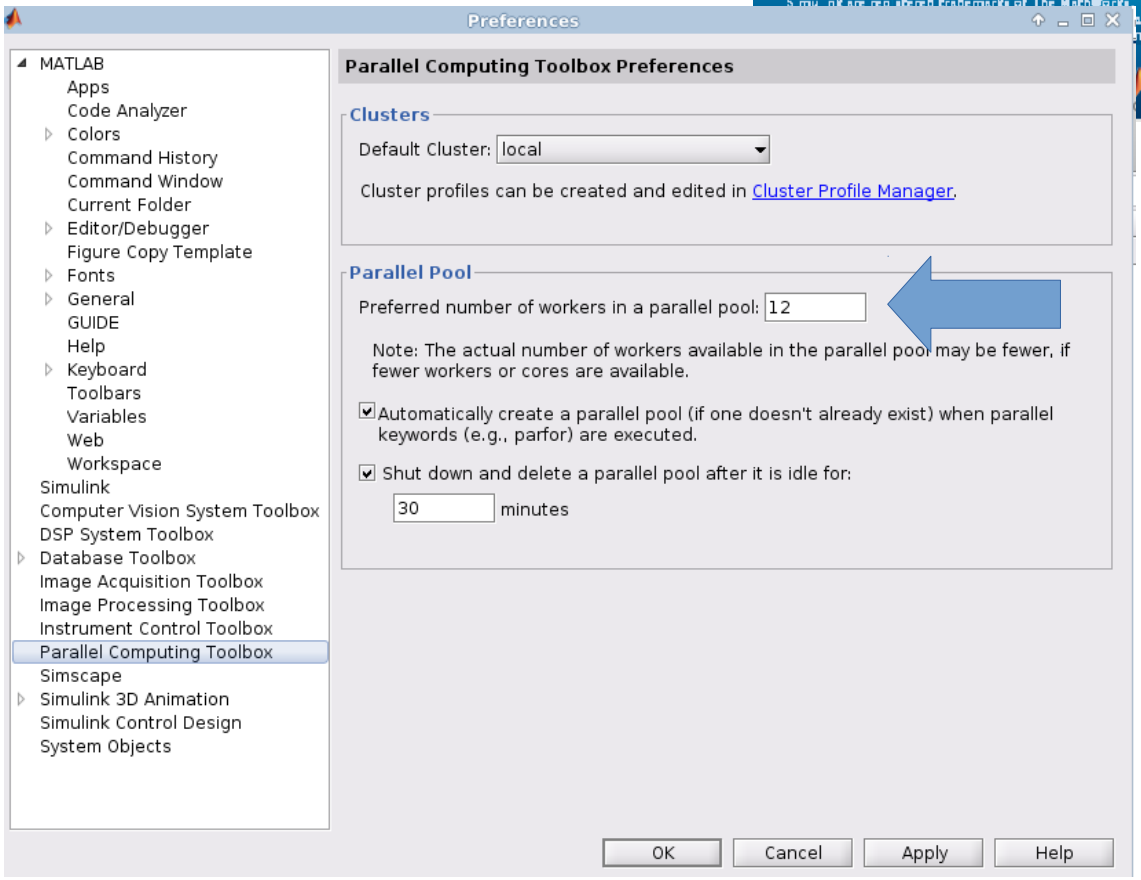

ZoneAlarm
REPEAT PROGRAM
smpd.exe is trying to access the Internet.
SmartDefense Advisor Recommendation:
Advice is not yet available for this program.
Remember this setting
Show More Info
Allow
Deny


Windows Task Manager
File Options View Help
Applications Processes Services Performance Networking Users
Image Name User Name CPU Memory (P... Threads I/O Writes . Image Path Name Description
System Idle Process SYSTEM 49 24 K 4 Percentage of time the proc
MATLAB.exe telzur 21 158,892 K 28 18 C:\Program Files\MATLAB\R2012b\bin\win64\MATLAB.exe MATLAB (R2012b)
MATLAB.exe telzur 20 159,820 K 28 18 C:\Program Files\MATLAB\R2012b\bin\win64\MATLAB.exe MATLAB (R2012b)
MATLAB.exe telzur 03 302,492 K 45 1,453 C:\Program Files\MATLAB\R2012b\bin\win64\MATLAB.exe MATLAB (R2012b)
chrome.exe *32 telzur 02 61,620 K 14 32,192 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
svchost.exe NETWO... 02 8,428 K 28 8,166 C:\Windows\System32\svchost.exe Host Process for Windows S
taskmgr.exe telzur 01 3,428 K 8 C:\Windows\System32\taskmgr.exe Windows Task Manager
POWERPNT.EXE *32 telzur 00 57,004 K 15 1,389
chrome.exe *32 telzur 00 6,660 K 14 1,737 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
svchost.exe LOCAL ... 00 444 K 4 C:\Windows\System32\svchost.exe Host Process for Windows S
mpiexec.exe telzur 00 3,572 K 2 106 C:\Program Files\MATLAB\R2012b\bin\win64\mpiexec.exe mpiexec.exe
chrome.exe *32 telzur 00 81,452 K 13 16,359 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
splwow64.exe telzur 00 3,368 K 7 124 C:\Windows\splwow64.exe Print driver host for 32bit ap
chrome.exe *32 telzur 00 16,304 K 14 33,421 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
chrome.exe *32 telzur 00 20,916 K 13 18,900 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
TosBtHSP.exe *32 telzur 00 960 K 6 C:\Program Files (x86)\TOSHIBA\Bluetooth Toshiba Stack\TosBtHSP.exe TosBtHSP
chrome.exe *32 telzur 00 39,468 K 13 22,828 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
conhost.exe telzur 00 1,824 K 1 C:\Windows\System32\conhost.exe Console Window Host
slimsvc.exe *32 SYSTEM 00 528 K 7 4 C:\Program Files (x86)\CheckPoint\SSL Network Extender\slimsvc.exe slimsvc.exe
chrome.exe *32 telzur 00 5,688 K 13 446 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
avgcsrva.exe SYSTEM 00 1,548 K 15 583,957 C:\Program Files (x86)\AVG\AVG2013\avgcsrva.exe AVG Scanning Core Module
TosBtMng.exe *32 telzur 00 2,088 K 49 167 C:\Program Files (x86)\TOSHIBA\Bluetooth Toshiba Stack\TosBtMng.exe Bluetooth Manager
TosAVRC.exe *32 telzur 00 720 K 3 C:\Program Files (x86)\TOSHIBA\Bluetooth Toshiba Stack\TosAVRC.exe TosAVRC
taskeng.exe SYSTEM 00 2,240 K 6 C:\Windows\System32\taskeng.exe Task Scheduler Engine
smpd.exe telzur 00 3,544 K 6 7 C:\Program Files\MATLAB\R2012b\bin\win64\smpd.exe smpd.exe
chrome.exe *32 telzur 00 9,484 K 13 6,717 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
smpd.exe telzur 00 4,080 K 8 3 C:\Program Files\MATLAB\R2012b\bin\win64\smpd.exe smpd.exe
chrome.exe *32 telzur 00 46,536 K 13 5,582 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
chrome.exe *32 telzur 00 5,408 K 13 105 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
UNS.exe *32 SYSTEM 00 1,064 K 13 2 C:\Program Files (x86)\Intel\Intel(R) Management Engine Components\UNS\UNS.exe User Notification Service
Show processes from all users
End Process
Processes: 135 CPU Usage: 51% Physical Memory: 78%

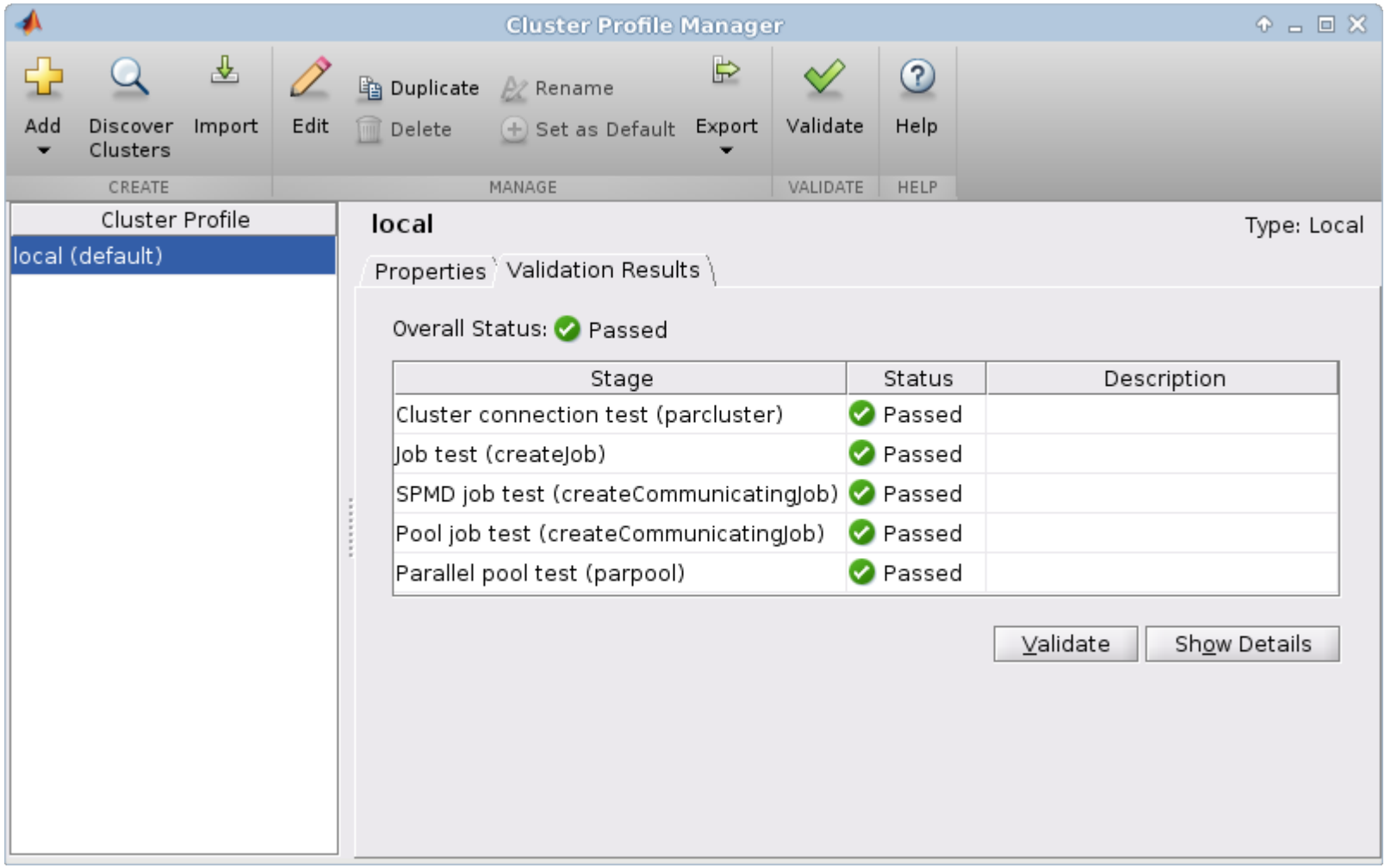
Version 2014a on Linux

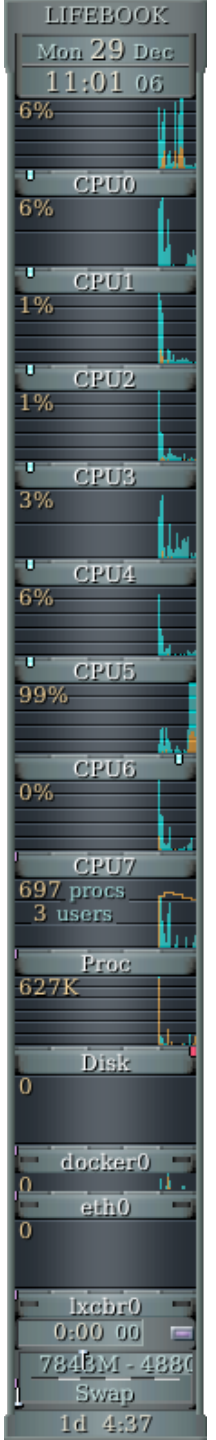






Version 2014a on Linux





parfor - Parallel for loop

parfor - Parallel for loop

Syntax

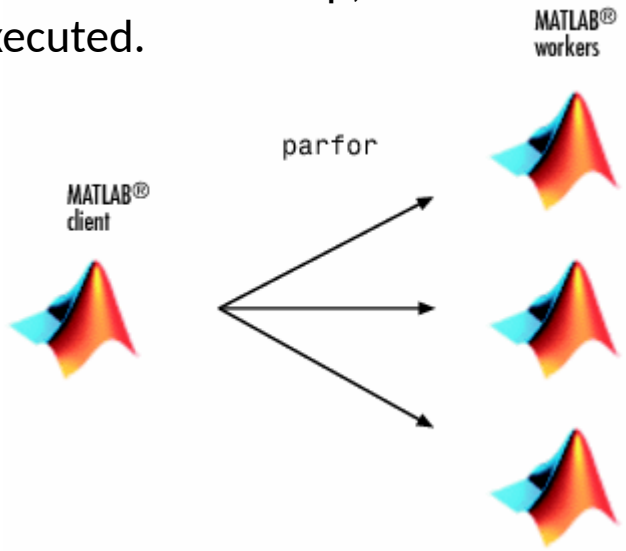
```
parfor loopvar = initval:endval; statements; end
parfor (loopvar = initval:endval, M); statements; end
```

Description

parfor loopvar = initval:endval; statements; end executes a series of MATLAB commands denoted here as statements for values of loopvar between initval and endval, inclusive, which specify a vector of increasing integer values. Unlike a traditional for-loop, there is no guarantee of the order in which the loop iterations are executed.

The general format of a parfor statement is:

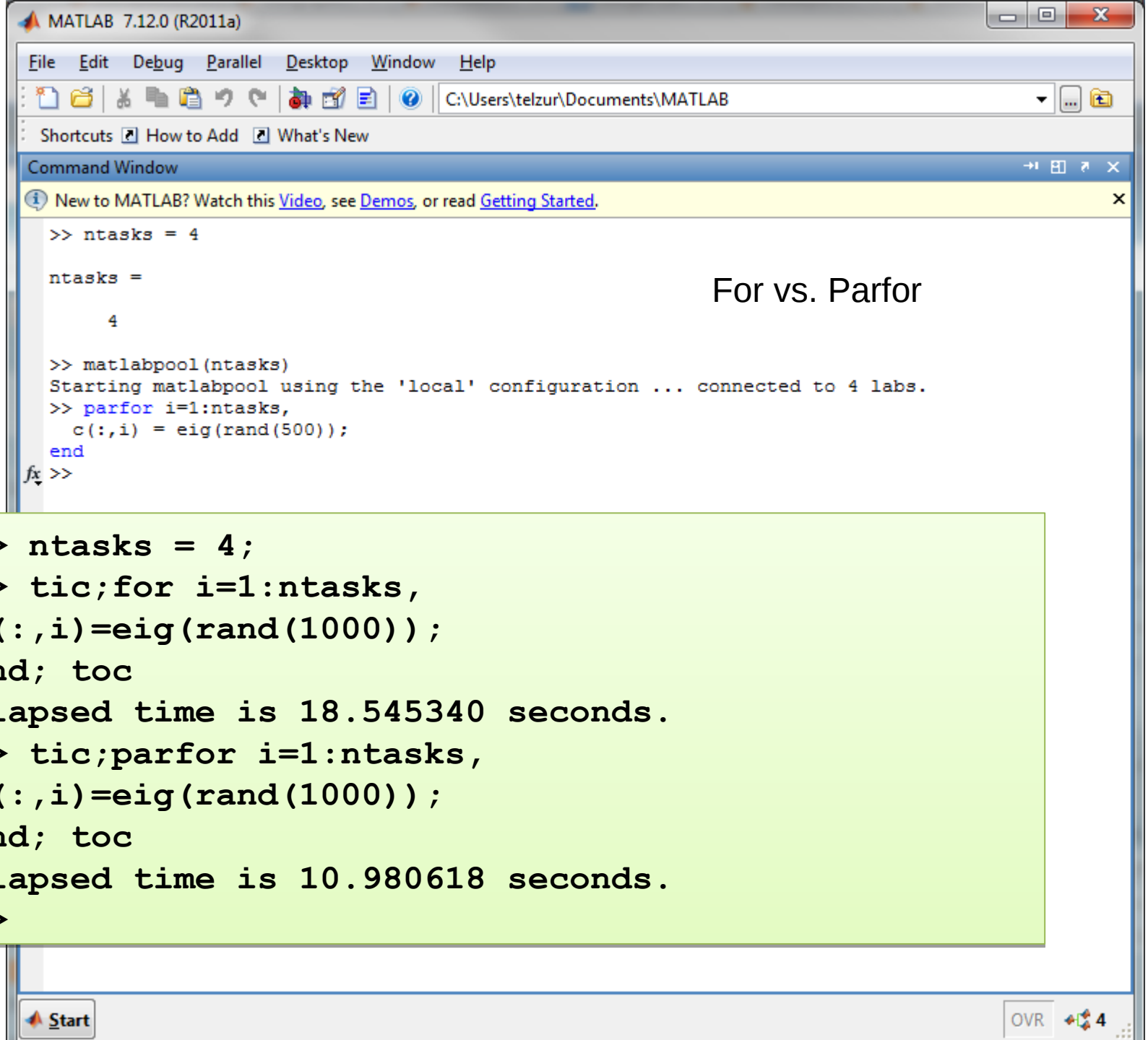
```
parfor loopvar = initval:endval
    <statements>
end
```



parfor – an example

Perform three large eigenvalue computations using three computers or cores:

```
ntasks = 4
matlabpool(ntasks)
parfor i=1:ntasks,
  c(:,i) = eig(rand(500));
end
```


MATLAB 7.12.0 (R2011a)
File Edit Debug Parallel Desktop Window Help
C:\Users\telzur\Documents\MATLAB
Shortcuts How to Add What's New
Command Window
New to MATLAB? Watch this Video, see Demos, or read Getting Started.
>> ntasks = 4
ntasks =
4
>> matlabpool(ntasks)
Starting matlabpool using the 'local' configuration ... connected to 4 labs.
>> parfor i=1:ntasks,
c(:,i) = eig(rand(500));
end
>>
For vs. Parfor
>> ntasks = 4;
>> tic;for i=1:ntasks,
c(:,i)=eig(rand(1000));
end; toc
Elapsed time is 18.545340 seconds.
>> tic;parfor i=1:ntasks,
c(:,i)=eig(rand(1000));
end; toc
Elapsed time is 10.980618 seconds.
>>
Start
OVR
4

Editor - /home/telzur/Documents/Teaching/BGU/PP/PP2015A/lect

parallel1.m | parallel0.m

```
1 -   disp('Serial computation');
2 -   ntasks=4;
3 -   tic; for i=1:ntasks, c(:,i)=eig(rand(1000));
4 -   end;toc
5
6 -   size(c)
7
8 -   disp('parallel computation');
9 -   delete(gcp);
10 -  parpool('local');
11 -  tic;parfor i=1:ntasks, d(:,i)=eig(rand(1000));
12 -  end;toc
13 -  matlabpool('close')
14
15 -  size(d)
```

Demo: …/lecture09/code/parallel0.m

4 tasks

```
>>
>> parallel0
Serial computation
Elapsed time is 3.374473 seconds.

ans =

        1000           4

parallel computation
Starting parallel pool (parpool) using the 'local' profile ... co
Parallel pool using the 'local' profile is shutting down.
Starting parallel pool (parpool) using the 'local' profile ... co
Elapsed time is 2.445419 seconds.
Warning: matlabpool will be removed in a future release.
To shutdown a parallel pool use 'delete(gcp('nocreate'))'
instead.
Parallel pool using the 'local' profile is shutting down.

ans =

        1000           4
```

Version 2014a on Linux (i7 processor)

8 tasks

Editor - /home/telzur/Documents/Teaching/BGU/PP/PP2015A/lectures/09/code/parallel0.m

parallel1.m | parallel0.m

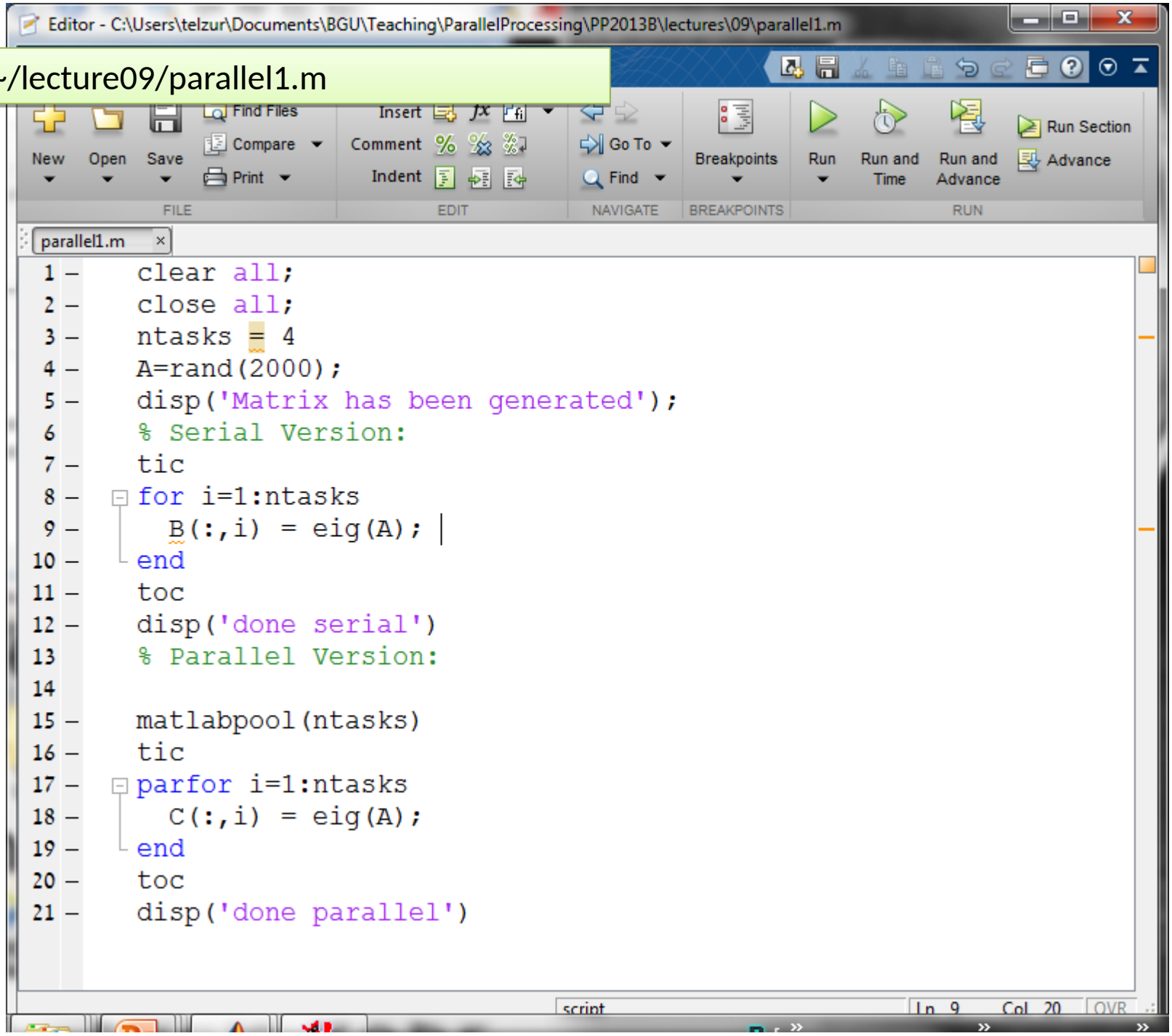
```
1 -    disp('Serial computation');
2 -    ntasks=8;
3 -    tic; for i=1:ntasks, c(:,i)=eig(rand(1000));
4 -    end;toc
5
6 -    disp('parallel computation');
7 -    delete(gcp);
8 -    parpool('local');
9 -    tic;parfor i=1:ntasks, d(:,i)=eig(rand(1000));
10 -   end;toc
11
```

```
>>
>>
>>
>>
>>
>>
>>
>>
>>
>> parallel0
Serial computation
Elapsed time is 7.800062 seconds.
parallel computation
Parallel pool using the 'local' profile is shutting down.
Starting parallel pool (parpool) using the 'local' profile ... conn
Elapsed time is 4.434908 seconds.
>>
```

Workspace

Name	Value
ans	1x1 parall
c	1000x8 co
d	1000x8 co
i	8
ntasks	8

Demo: ~/lecture09/parallel1.m



Profile Summary

Generated 26-May-2013 21:12:07 using cpu time.

Function Name	Calls	**Total Time**	Self Time*	Total Time Plot (dark band = self time)
parallel1	1	56.691 s	28.421 s	
parallel_function	1	18.380 s	0.022 s	
parallel_function>distributed_execution	1	18.230 s	0.079 s	
...omp.remoteparfor.getCompleteIntervals	3	18.125 s	0.038 s	
java.util.concurrent.LinkedBlockingQueue (Java method)	20	18.067 s	18.067 s	
matlabpool	1	9.890 s	0.076 s	
MatlabpoolHelper>MatlabpoolHelper.doOpen	1	9.152 s	0.018 s	
...lHelper>MatlabpoolHelper.doMatlabpool	1	9.152 s	0.000 s	
distcomp.interactiveclient.start	1	9.123 s	0.051 s	
distcomp.interactiveclient.pGetSockets	1	8.145 s	0.001 s	
...ient.pGetSockets>iGetSingleConnection	2	8.144 s	7.808 s	
...parseInputsAndCheckOutputsForFunction	1	0.649 s	0.001 s	
...atlabpoolHelper.parseMatlabpoolInputs	1	0.636 s	0.008 s	
...er>ProfileConfigHelper.buildScheduler	1	0.459 s	0.003 s	
parcluster	1	0.456 s	0.080 s	
...lusterAdaptor>iCreateCommunicatingJob	1	0.311 s	0.005 s	
Job.Job>Job.submit	1	0.308 s	-0.000 s	
...gJob>CJSCommunicatingJob.submitOneJob	1	0.297 s	0.011 s	
Local.hSubmitCommunicatingJob	1	0.280 s	0.013 s	
Local.Local>Local.Local	1	0.209 s	0.018 s	
Cluster.createCommunicatingJob	1	0.184 s	0.002 s	
...hworks.toolbox.distcomp.pmode.Session (Java method)	25	0.174 s	0.174 s	
CJSCluster>CJSCluster.CJSCluster	1	0.169 s	0.048 s	
etime	1036	0.169 s	0.169 s	
CJSSupport>CJSSupport.getProperties	31	0.153 s	0.012 s	
ProfileConfigHelper>iGetDefaultProfile	1	0.149 s	0.000 s	
...er>ProfileConfigHelper.getDefaultName	1	0.149 s	0.000 s	
...Helper>MatlabpoolHelper.checkConfigOk	1	0.149 s	0.000 s	
...oolHelper.checkConfigOk(profHelper,x)	1	0.149 s	0.000 s	
CJSJobMixin>CJSJobMixin.hGetProperty	26	0.146 s	0.003 s	

parallel1 (1 call, 56.691 sec)

Generated 26-May-2013 21:15:20 using cpu time.
script in file C:\Users\telzur\Documents\BGU\Teaching\ParallelProcessing\PP2013B\lectures\09\parallel1.m
Copy to new window for comparing multiple runs

This function changed during profiling or before generation of this report. Results may be incomplete or inaccurate.

Refresh

☑ Show parent functions ☑ Show busy lines ☑ Show child functions
☑ Show Code Analyzer results ☑ Show file coverage ☑ Show function listing

Parents (calling functions)
No parent

Lines where the most time was spent

Line Number	Code	Calls	Total Time	% Time	Time Plot
9	`B(:,i) = eig(A);`	2	28.011 s	49.4%	
17	`parfor i=1:ntasks`	1	18.471 s	32.6%	
15	`matlabpool(ntasks)`	1	9.894 s	17.5%	
1	`clear all;`	1	0.195 s	0.3%	
4	`A=rand(2000);`	1	0.085 s	0.1%	
All other lines			0.035 s	0.1%	
Totals			56.691 s	100%	

Children (called functions)

Function Name	Function Type	Calls	Total Time	% Time	Time Plot
parallel_function	function	1	18.380 s	32.4%	
matlabpool	function	1	9.890 s	17.4%	
parfor_endpoint_check	function	2	0 s	0%	
parfor_sliced_fcnhdl_check	function	1	0 s	0%	
close	function	1	0 s	0%	
Self time (built-ins, overhead, etc.)			28.421 s	50.1%	
Totals			56.691 s	100%	

Editor - /home/telzur/Documents/Teaching/BGU/

parallel1.m* | parallel0.m

```
1 -   clear all;
2 -   close all;
3 -   delete(gcp);
4 -   ntasks = 8
5 -   A=rand(2000);
6 -   disp('Matrix has been generated');
7     % Serial Version:
8 -   tic
9 -   for i=1:ntasks
10 -    B(:,i) = eig(A);
11 -  end
12 -  toc
13 -  disp('done serial')
14    % Parallel Version:
15 -  matlabpool('local',ntasks)
16 -  tic
17 -  parfor i=1:ntasks
18 -    C(:,i) = eig(A);
19 -  end
20 -  toc
21 -  disp('done parallel')
```

Parallel1.m
8 tasks on core i7

```
>> close all
>> clear all
>> parallel1
Parallel pool using the 'local' profile is shutting
down.

ntasks =

     8

Matrix has been generated
Elapsed time is 31.812732 seconds.
done serial
Warning: matlabpool will be removed in a future
release.
Use parpool instead.
Starting matlabpool using the 'local' profile ...
connected to 8 workers.
Elapsed time is 19.150792 seconds.
done parallel
>>
```

MATLAB 7.12.0 (R2011a)

File Edit Debug Parallel Desktop Window Help

C:\Users\telzur\Documents\MATLAB

Shortcuts How to Add What's New

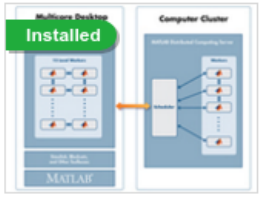
Command Window

```
>>
>> spmd
R=rand(4);
end
>> R

R =

   Lab 1: class = double, size = [4  4]
   Lab 2: class = double, size = [4  4]
   Lab 3: class = double, size = [4  4]
   Lab 4: class = double, size = [4  4]

>> R{1}

ans =

    0.7324    0.6533    0.4855    0.4802
    0.8273    0.1966    0.1460    0.0414
    0.5708    0.0701    0.4374    0.0343
    0.0286    0.7294    0.8261    0.8813

>> R{2}

ans =

    0.3403    0.0352    0.1909    0.3058
    0.9855    0.4162    0.4921    0.1040
    0.1635    0.8936    0.7235    0.4481
    0.1263    0.6937    0.8305    0.3101

>> R{3}

ans =

    0.3499    0.5849    0.2805    0.6119
    0.5549    0.0615    0.6036    0.1658
    0.8473    0.8638    0.1458    0.9970
    0.1063    0.5371    0.7924    0.0217

>> R{4}

ans =

    0.3395    0.9410    0.4371    0.4194
    0.8902    0.5437    0.6271    0.9787
    0.8345    0.4181    0.4030    0.5508
    0.8874    0.6705    0.9059    0.8437
```

Start OVR 4

optional

Search for add-ons



Tutorials: Parallel and GPU Computing with MATLAB: All in one (9 parts)

version 1.5.0.1 (12.7 KB) by MathWorks Parallel Computing Toolbox Team STAFF

Tutorials on Parallel and GPU Computing with MATLAB

★★★★★ 1 Rating
18 Downloads
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Collection

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Overview | Functions

This submission contains all code examples used in tutorial series for Parallel and GPU Computing with MATLAB available here:
http://www.mathworks.com/products/parallel-computing/tutorials.html
Topics covered:
1. Product Landscape (no code examples)
2. Prerequisites and Setup (no code examples)
3. Quick Success with parfor
4. Deeper Insights into Using parfor
5. Batch Processing
6. Scaling to Clusters
7. spmd - Parallel Code Beyond parfor
8. Distributed Arrays
9. GPU Computing with MATLAB

Requires

Parallel Computing Toolbox

A NVIDIA CUDA GPU with compute capability 2.0 or above is required for running GPU computing example code

MATLAB Release Compatibility

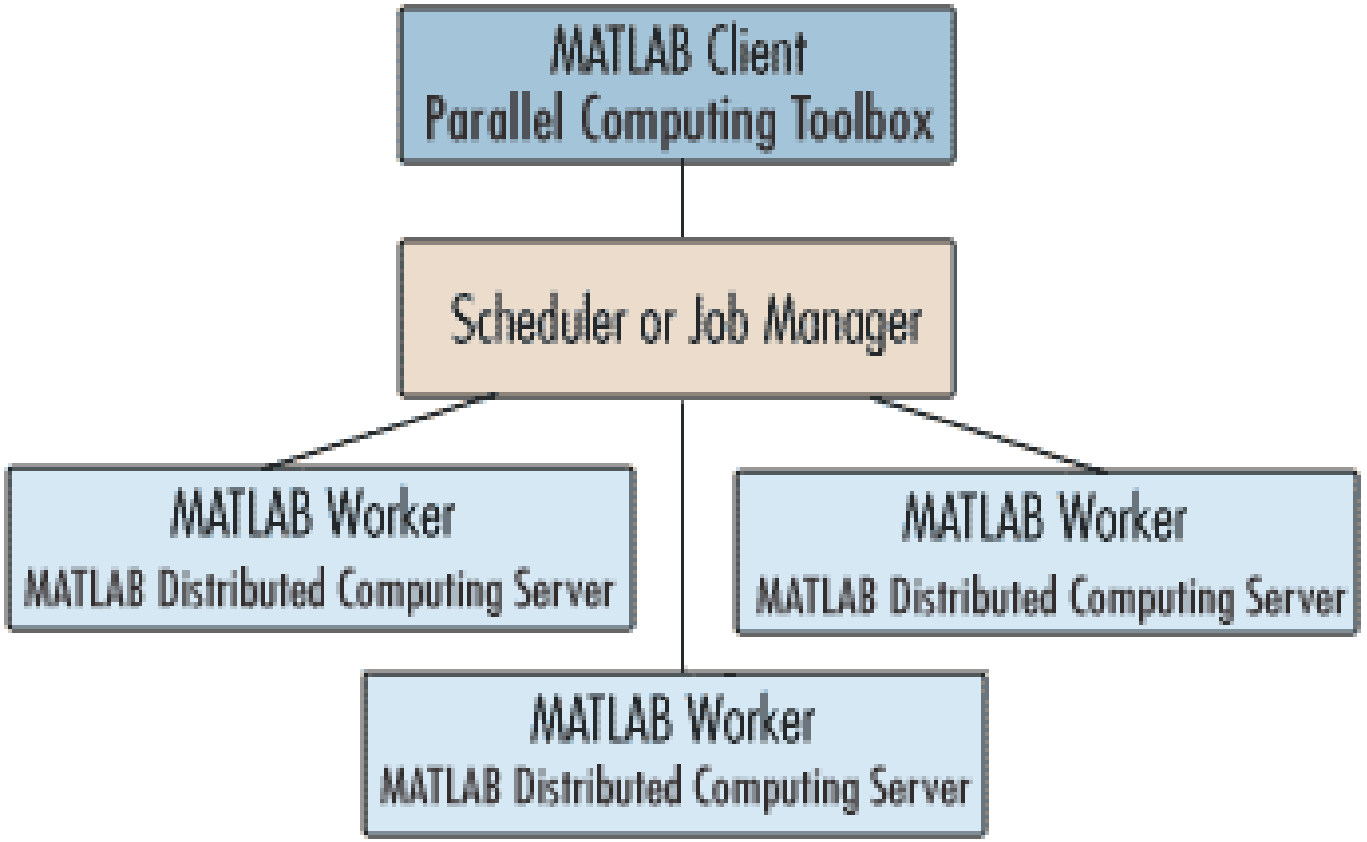
Created with R2014b
Compatible with any release

Platform Compatibility

☑ Windows ☑ macOS ☑ Linux

https://www.mathworks.com/videos/series/parallel-and-gpu-computing-tutorials-97719.html

Parallel Computing Toolbox and MATLAB Distributed Computing



Parallel Computing with Matlab on Amazon Cloud

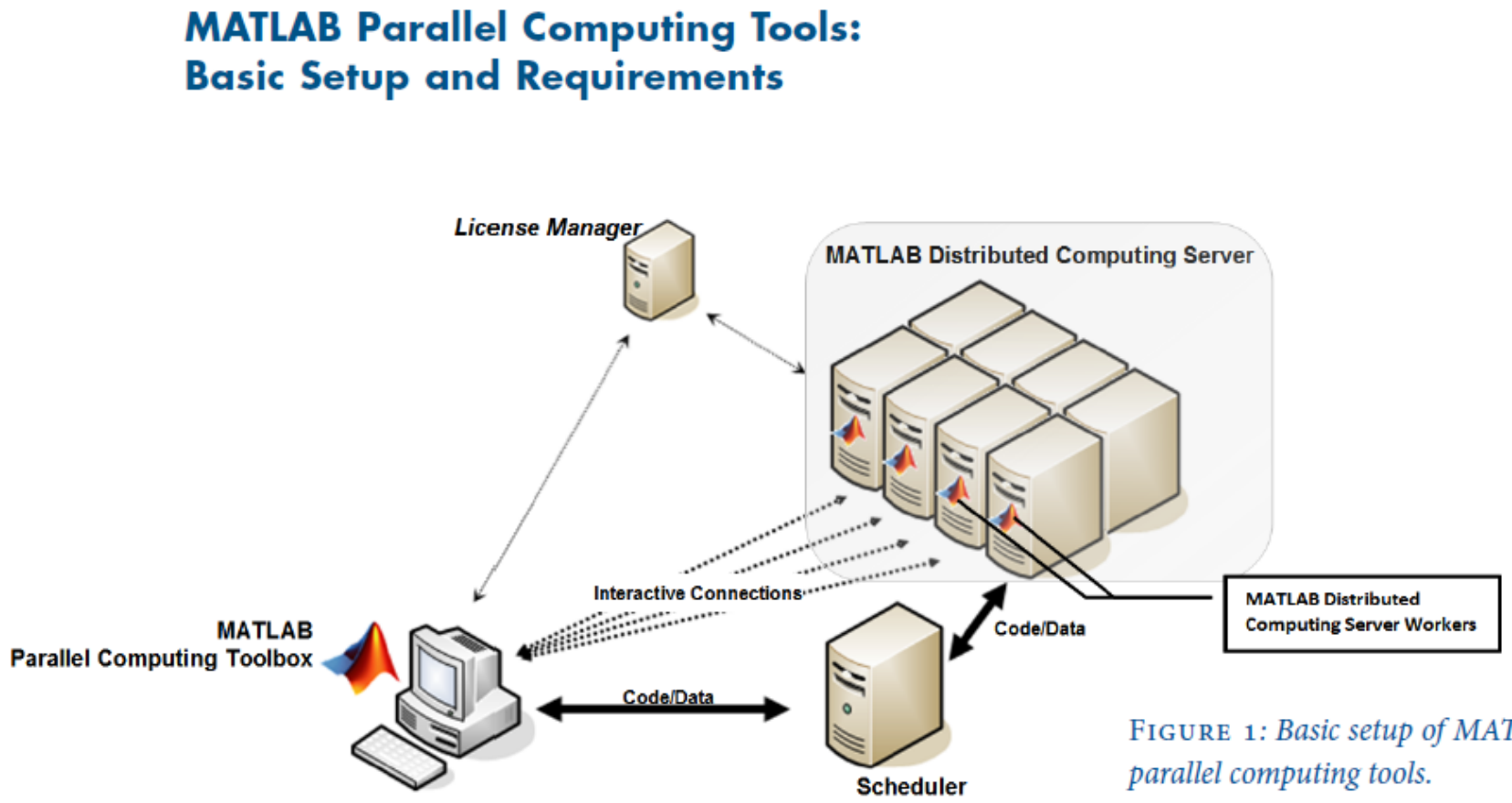


FIGURE 1: *Basic setup of MATLAB parallel computing tools.*

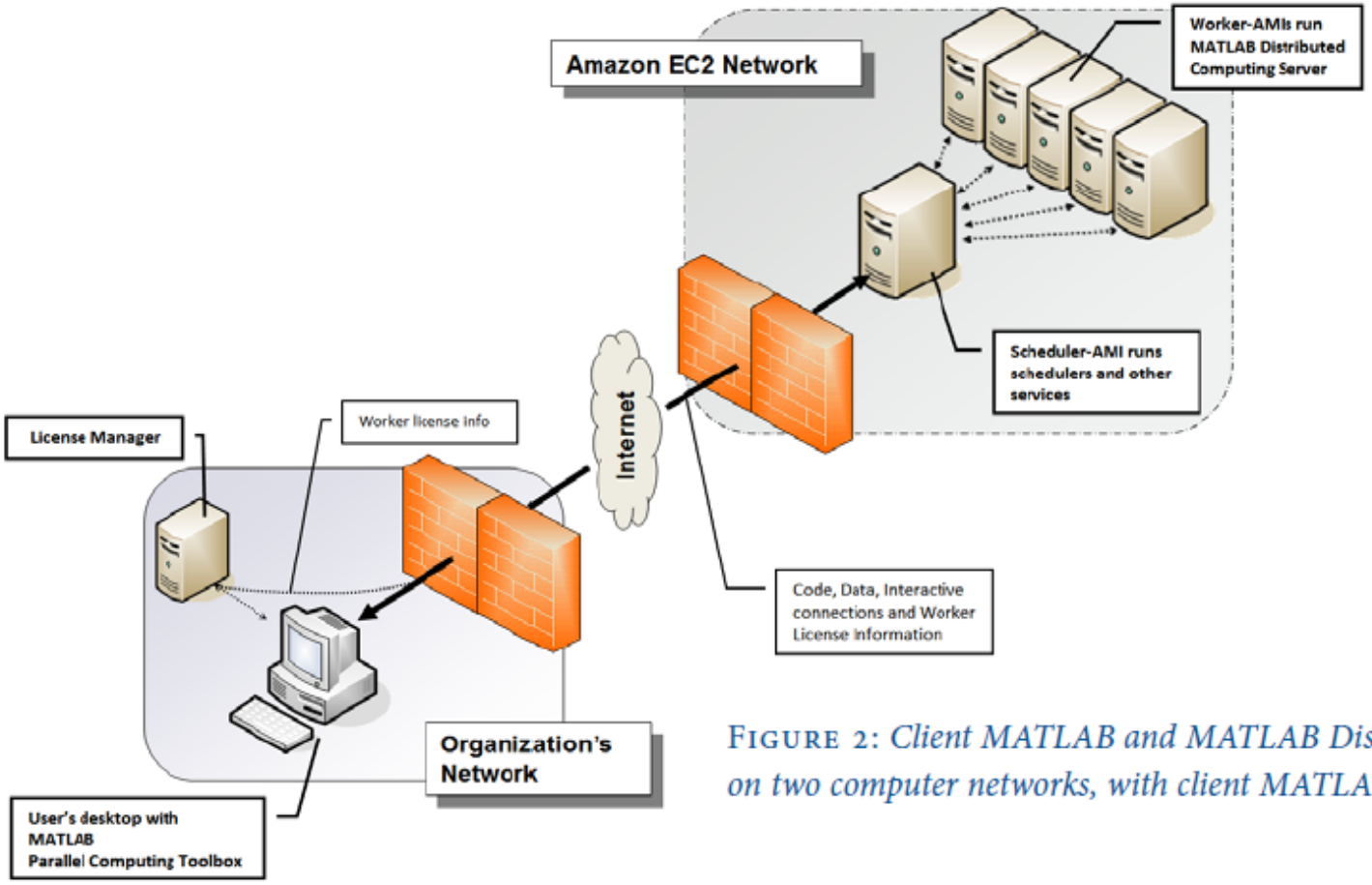


FIGURE 2: *Client MATLAB and MATLAB Distributed Computing Server on two computer networks, with client MATLAB on a user's desktop.*

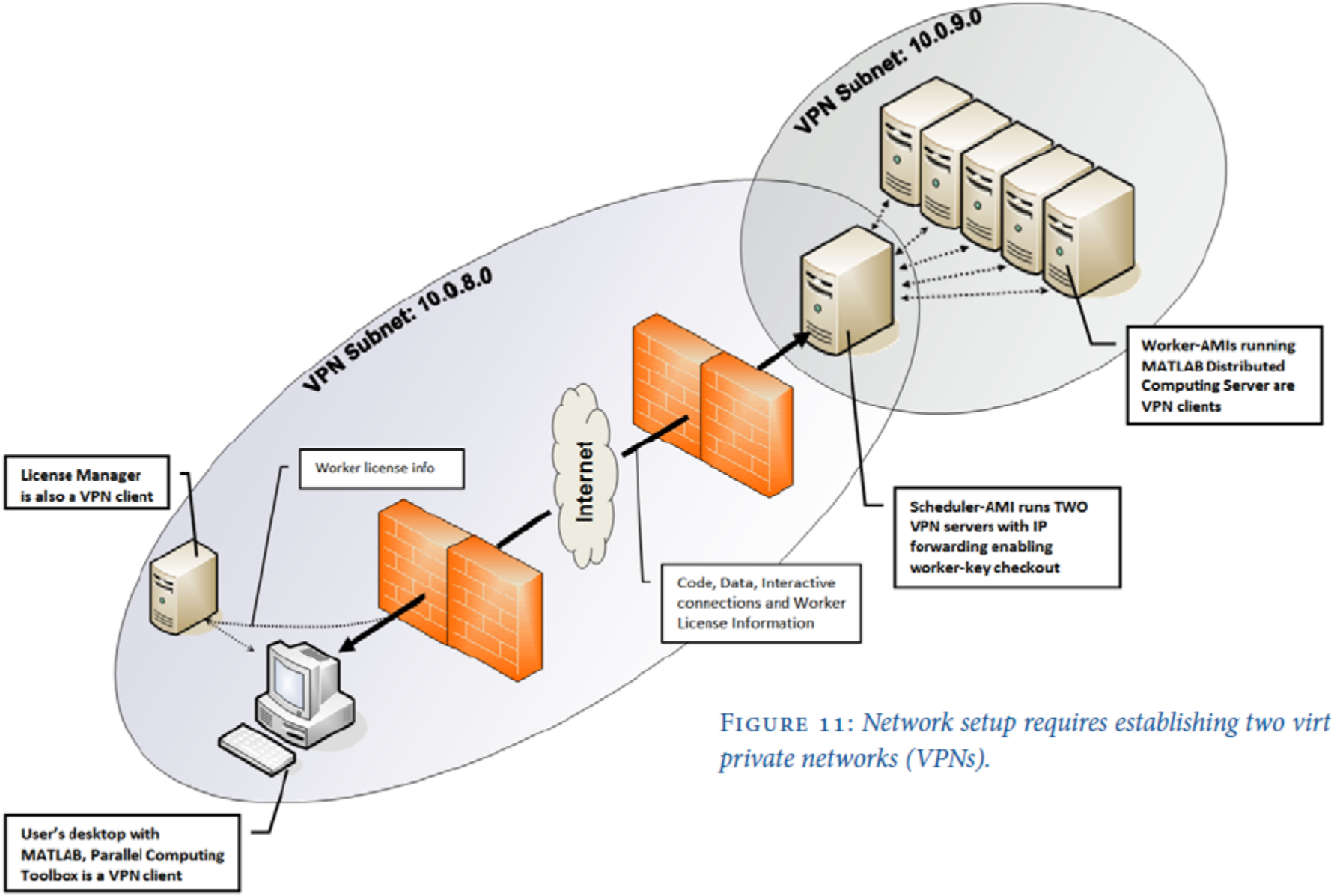


FIGURE 11: *Network setup requires establishing two virtual private networks (VPNs).*

Matlab and GPU computing

~/.../lectures/08/matlab_code

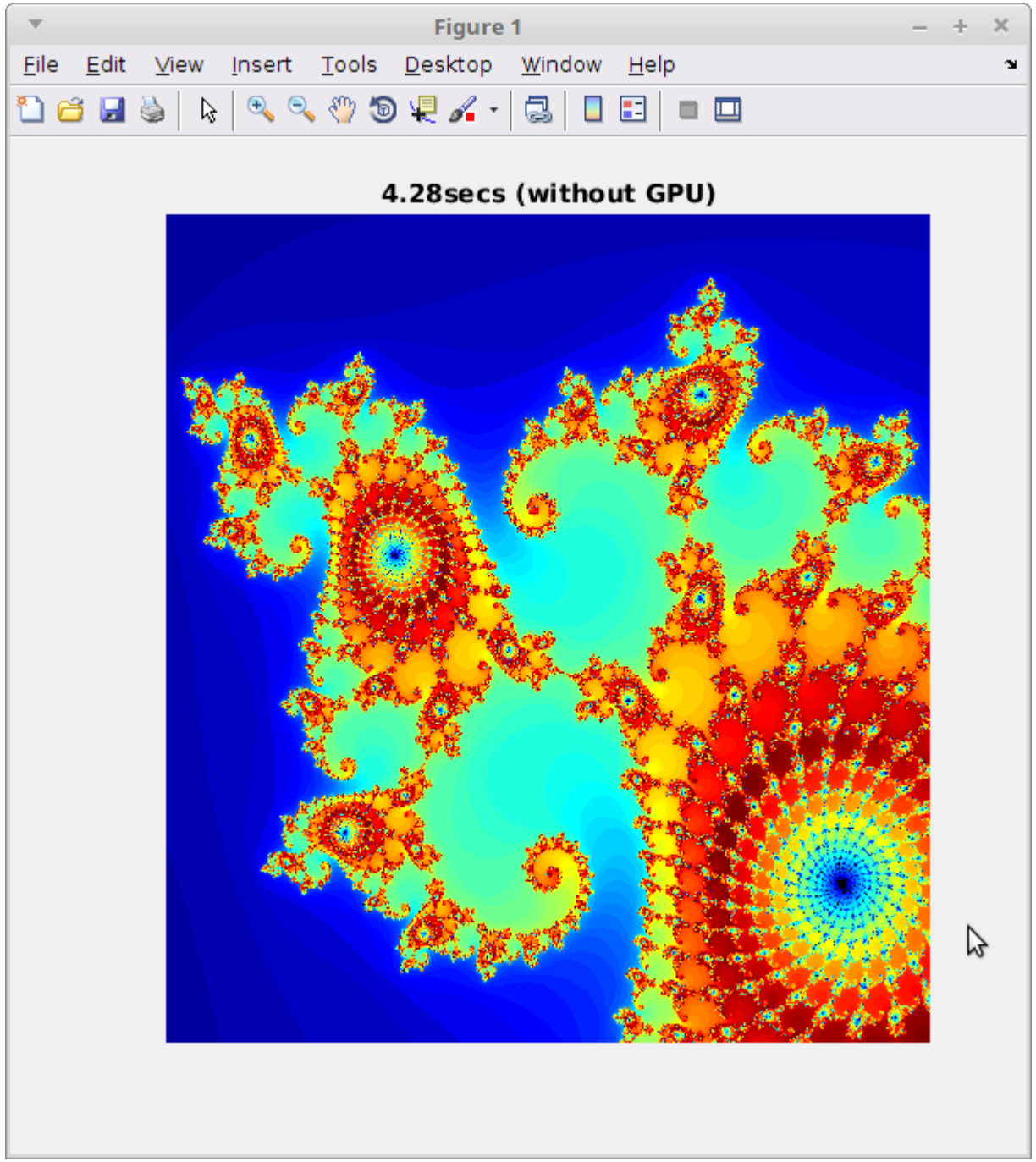


Figure 1
File Edit View Insert Tools Desktop Window Help
4.28secs (without GPU)

Figure 2

File Edit View Insert Tools Desktop Window Help

3.151secs (naive GPU) = 1.4x faster

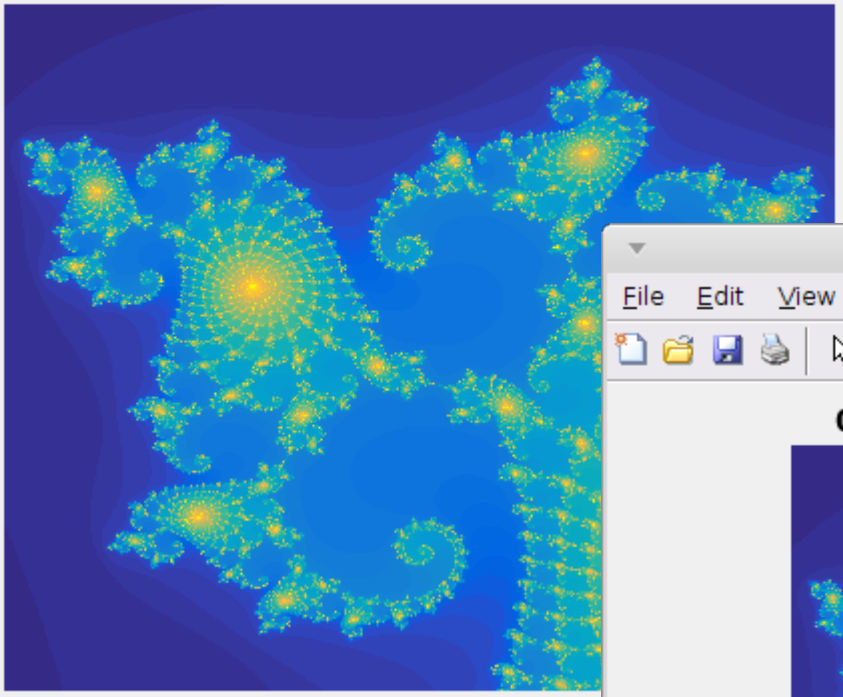
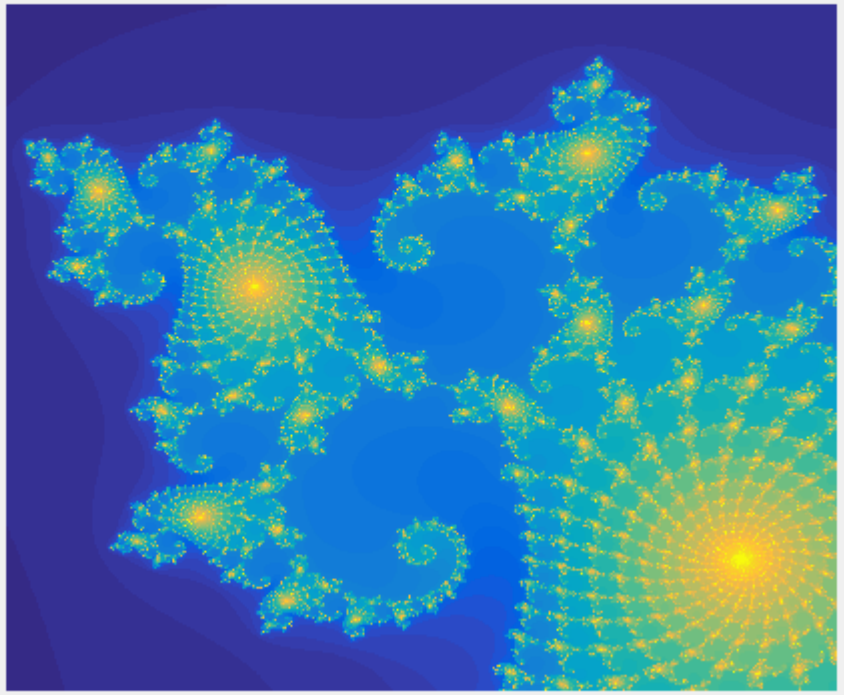


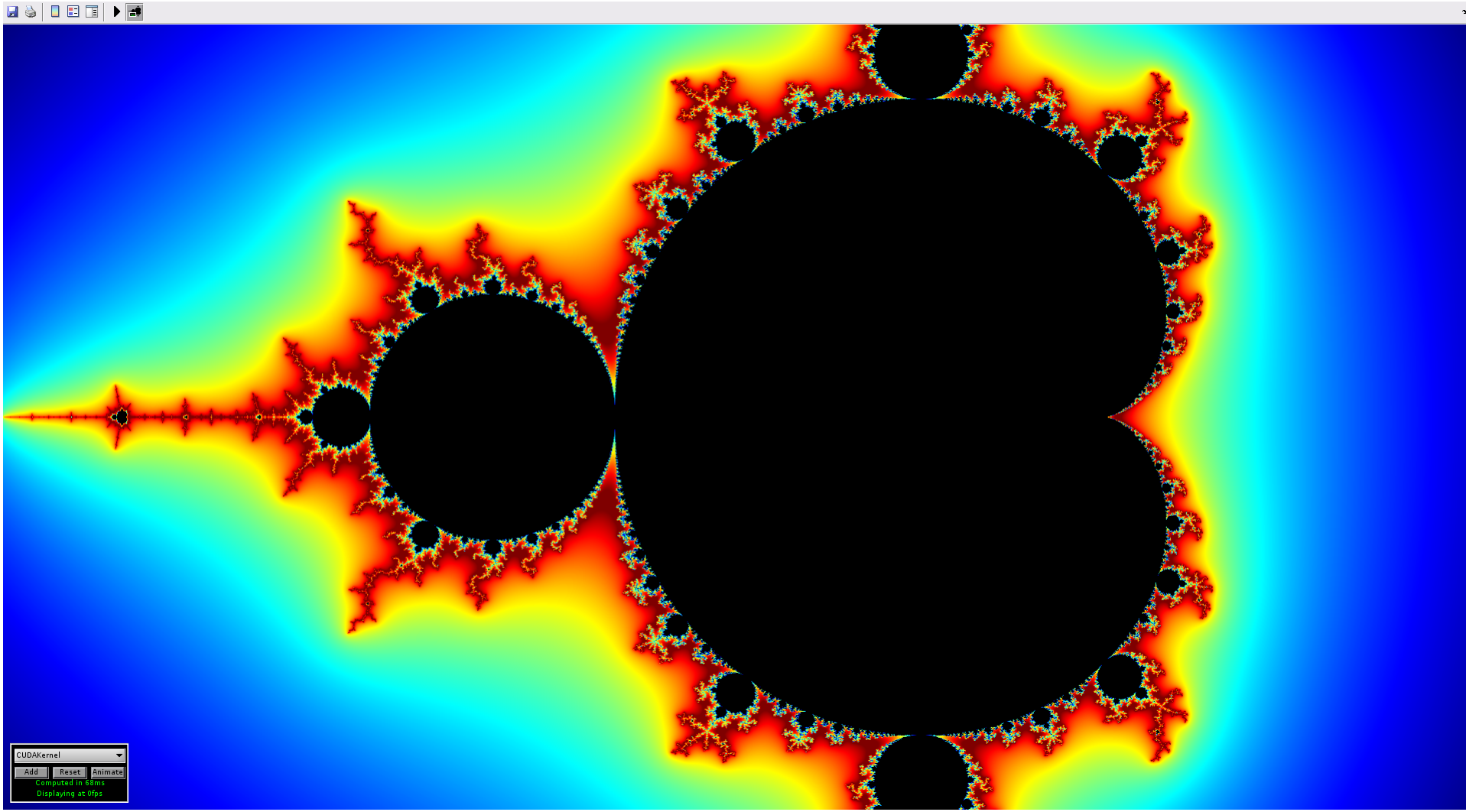
Figure 3

File Edit View Insert Tools Desktop Window Help

0.157secs (GPU CUDAKernel) = 27.2x faster



MandelbrotViewer



Let's try this

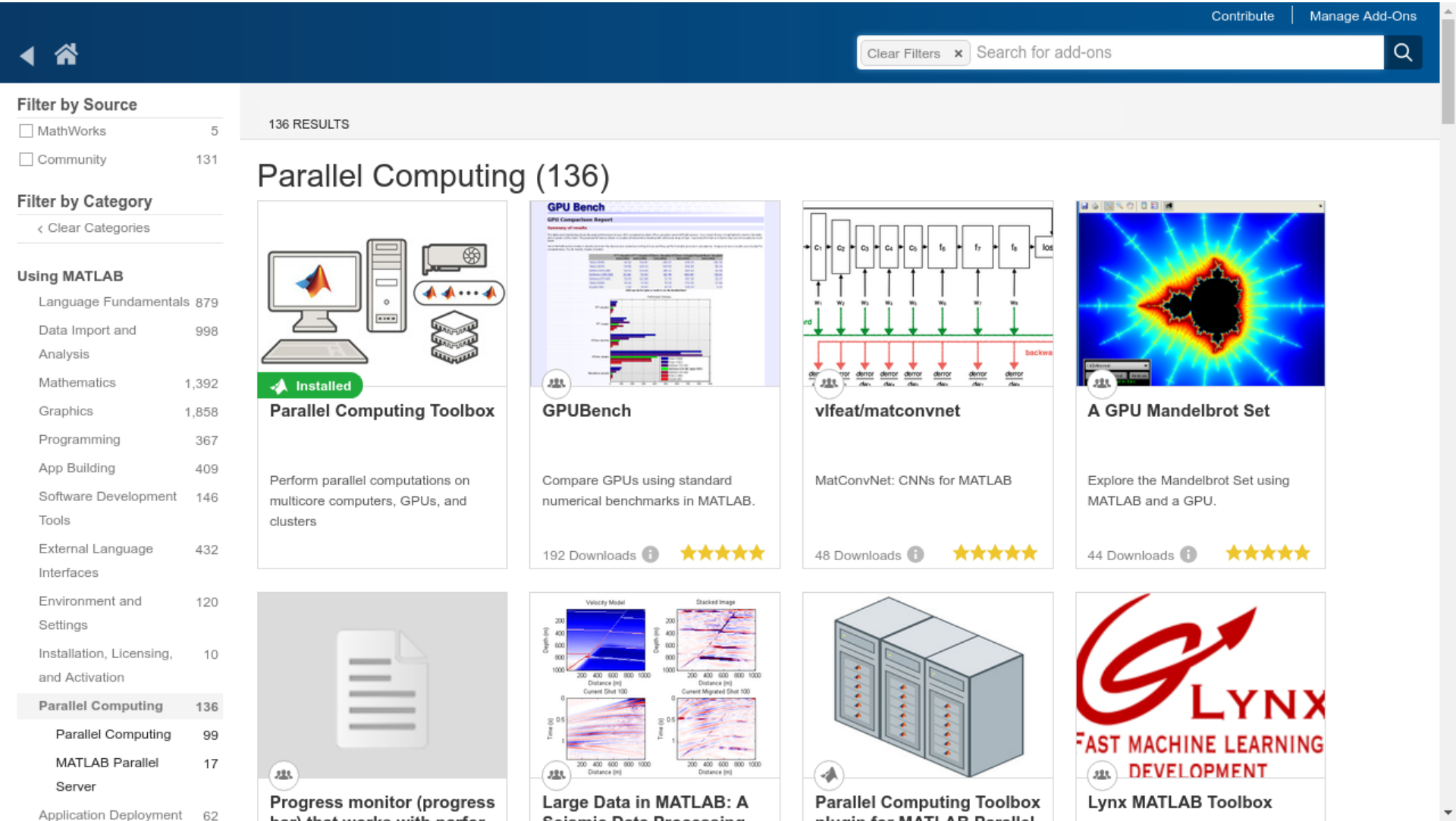
```
A = rand(100, GPUsingle); % A is on GPU memory
B = rand(100, GPUsingle); % B is on GPU memory
C = A+B; % executed on GPU.
D = fft(C); % executed on GPU
```

Executed on GPU

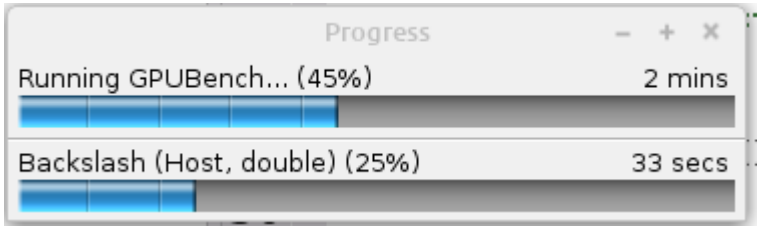
```
A = single(rand(100)); % A is on CPU memory
B = single(rand(100)); % B is on CPU memory
C = A+B; % executed on CPU.
D = fft(C); % executed on CPU
```

Executed on CPU

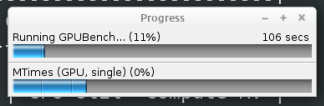
Matlab Parallel Addons



gpuBench




```
+-----------------------------------------------------------------------------+
| Processes:                                                       GPU Memory |
|  GPU       PID   Type   Process name                             Usage      |
|=============================================================================|
|    0      2295      G   /usr/lib/xorg/Xorg                           732MiB |
|    0      7182      G   ...equest-channel-token=815668599560060867   216MiB |
|    0     21154    C+G   ...afa3f6f93/opt/MATLAB/bin/glnxa64/MATLAB   313MiB |
|    0     21831      G   ...-token=2ED3348AA2873F9C2157CE208F1F8CA6     1MiB |
|    0     21979      G   ...-token=301B7597A0DDCD1D126B2777E7CEA836    17MiB |
+-----------------------------------------------------------------------------+
Fri Oct  4 14:30:31 2019
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 430.26       Driver Version: 430.26                              |
|-------------------------------+----------------------+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|===============================+======================+======================|
|   0  GeForce GTX 1050    Off  | 00000000:01:00.0 Off |                  N/A |
| N/A   62C    P0    N/A /  N/A |   1986MiB /  4042MiB |    100%      Default |
+-------------------------------+----------------------+----------------------+
+-----------------------------------------------------------------------------+
| Processes:                                                       GPU Memory |
|  GPU       PID   Type   Process name                             Usage      |
|=============================================================================|
|    0      2295      G   /usr/lib/xorg/Xorg                           732MiB |
|    0      7182      G   ...equest-channel-token=815668599560060867   216MiB |
|    0     21154    C+G   ...afa3f6f93/opt/MATLAB/bin/glnxa64/MATLAB  1015MiB |
|    0     21831      G   ...-token=2ED3348AA2873F9C2157CE208F1F8CA6     1MiB |
|    0     21979      G   ...-token=301B7597A0DDCD1D126B2777E7CEA836    17MiB |
+-----------------------------------------------------------------------------+
```




```
File  Edit  View  Search  Terminal  Help
top - 13:14:28 up 10 days, 19:09,  1 user,  load average: 3.86
Tasks: 424 total,   1 running, 333 sleeping,   0 stopped,   5
%Cpu0  : 98.7 us,  1.0 sy,  0.0 ni,  0.3 id,  0.0 wa,  0.0 hi,
%Cpu1  : 98.7 us,  1.0 sy,  0.0 ni,  0.3 id,  0.0 wa,  0.0 hi,
%Cpu2  :  5.2 us,  1.4 sy,  0.0 ni, 93.4 id,  0.0 wa,  0.0 hi,
%Cpu3  : 99.0 us,  0.7 sy,  0.0 ni,  0.3 id,  0.0 wa,  0.0 hi,
%Cpu4  :  4.8 us,  1.7 sy,  0.0 ni, 93.5 id,  0.0 wa,  0.0 hi,
%Cpu5  :  4.1 us,  3.4 sy,  0.0 ni, 92.1 id,  0.3 wa,  0.0 hi,
%Cpu6  : 98.7 us,  1.3 sy,  0.0 ni,  0.0 id,  0.0 wa,  0.0 hi,
%Cpu7  :  4.4 us,  2.7 sy,  0.0 ni, 92.6 id,  0.3 wa,  0.0 hi,
KiB Mem : 16304712 total,   323108 free, 14073992 used,  1907612 buff/cache
KiB Swap: 16659452 total, 15949552 free,   709900 used.  1235908 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU %MEM     TIME+ COMMAND
21154 telzur    20   0 23.497g 3.097g 191124 S 399.0 19.9   9:20.86 MATLAB
 2295 root      20   0 1278804 365348 116224 S   7.9  2.2  71:46.78 Xorg
 6325 netdata   20   0   18976   5708   2040 S   3.3  0.0   2:03.39 apps.plugin
25268 telzur    20   0  422408  30760  24132 S   2.6  0.2   0:00.43 mate-scree+
20259 telzur    20   0  533660  30808  12976 S   1.7  0.2   1:38.82 wnck-applet
13327 telzur    20   0 4837236 1.286g  73004 S   1.3  8.3  12:24.06 soffice.bin
20245 telzur    20   0  878104  35008  10948 S   1.3  0.2   8:37.05 marco
 2715 netdata   20   0  206856  56076   3032 S   1.0  0.3  57:20.62 netdata
 7894 telzur    20   0 2092164 227316  16952 S   1.0  1.4   4:06.71 chromium-b+
23053 telzur    20   0  598156  39100  21508 S   1.0  0.2   1:41.75 mate-termi+
```

GPU Bench

GPU Comparison Report: Intel(R) Core(TM) i7-7700HQ CPU @ 2.80GHz

Summary of results

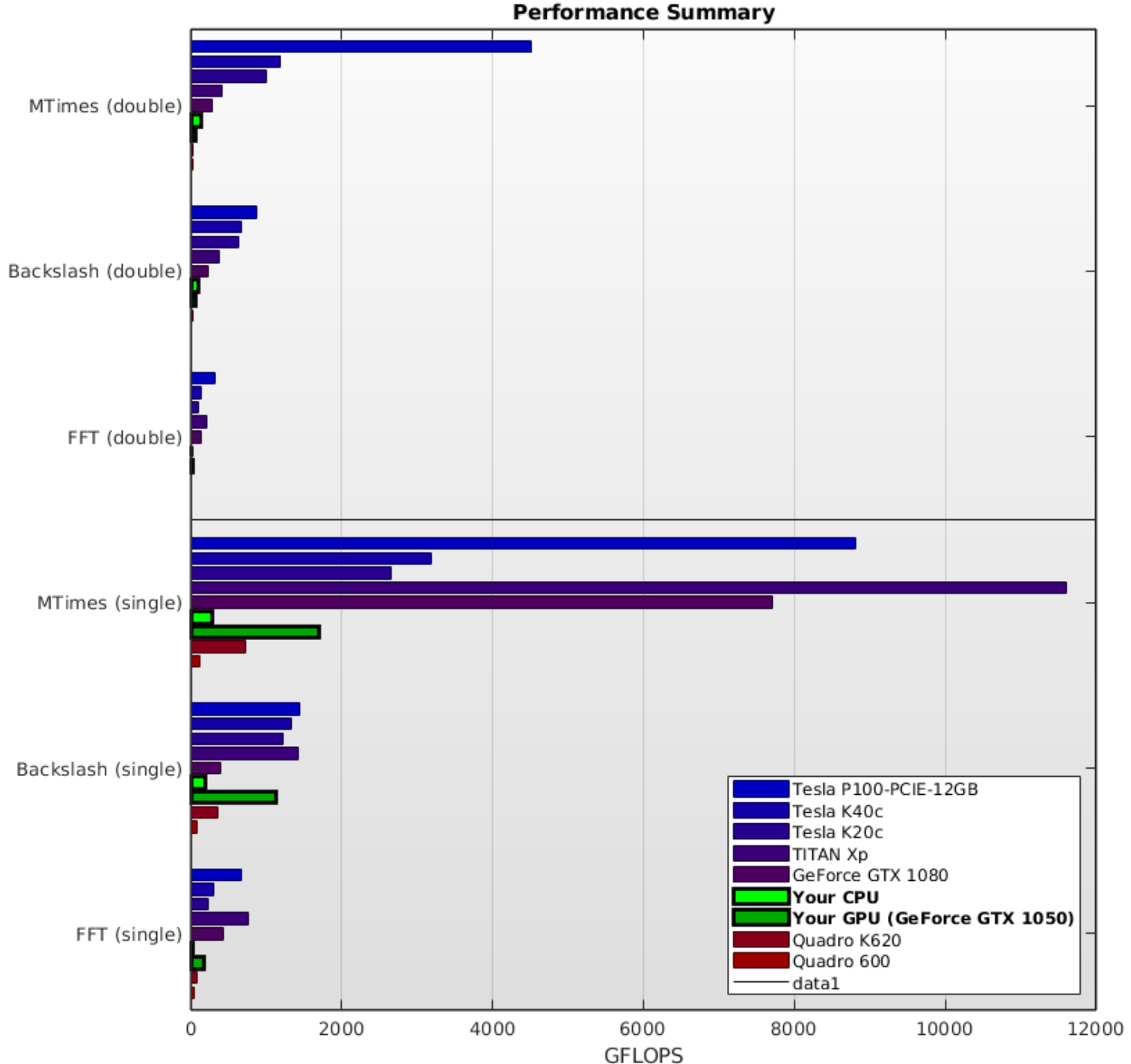
The table and chart below show the peak performance of various GPUs using the same MATLAB version. Your results (if any) are highlighted in bold in the table and on the chart. All other results are from pre-stored data. The peak performance shown is usually achieved when dealing with extremely large arrays. Typical performance in day-to-day use will usually be much lower.

Results captured using the CPUs on the host PC (i.e. without using a GPU) are included for comparison.

Since MATLAB works mostly in double precision the devices are ranked according to how well they perform double-precision calculations. Single precision results are included for completeness. For all results, higher is better.

	Results for data-type 'double' (In GFLOPS)			Results for data-type 'single' (In GFLOPS)		
	MTimes	Backslash	FFT	MTimes	Backslash	FFT
Tesla P100-PCIE-12GB	4518.23	878.97	313.43	8807.20	1439.15	676.20
Tesla K40c	1189.54	677.12	135.88	3187.76	1334.17	294.86
Tesla K20c	1004.06	641.42	106.09	2657.01	1230.28	235.20
TITAN Xp	422.47	371.37	207.24	11607.69	1426.76	763.56
GeForce GTX 1080	280.84	223.05	137.66	7707.01	399.37	424.60
Your CPU	**137.45**	**96.16**	**14.72**	**285.93**	**199.74**	**21.16**
Your GPU (GeForce GTX 1050)	**61.24**	**55.61**	**31.65**	**1699.35**	**1131.12**	**181.04**
Quadro K620	25.45	22.77	12.75	716.71	350.31	75.00
Quadro 600	19.71	17.55	7.62	117.99	88.64	38.58

(click any device name or result to see the detailed data)


Performance Summary
MTimes (double)
Backslash (double)
FFT (double)
MTimes (single)
Backslash (single)
FFT (single)
Tesla P100-PCIE-12GB
Tesla K40c
Tesla K20c
TITAN Xp
GeForce GTX 1080
Your CPU
Your GPU (GeForce GTX 1050)
Quadro K620
Quadro 600
data1
0
2000
4000
6000
8000
10000
12000
GFLOPS

GPU results

Results for Backslash (double)

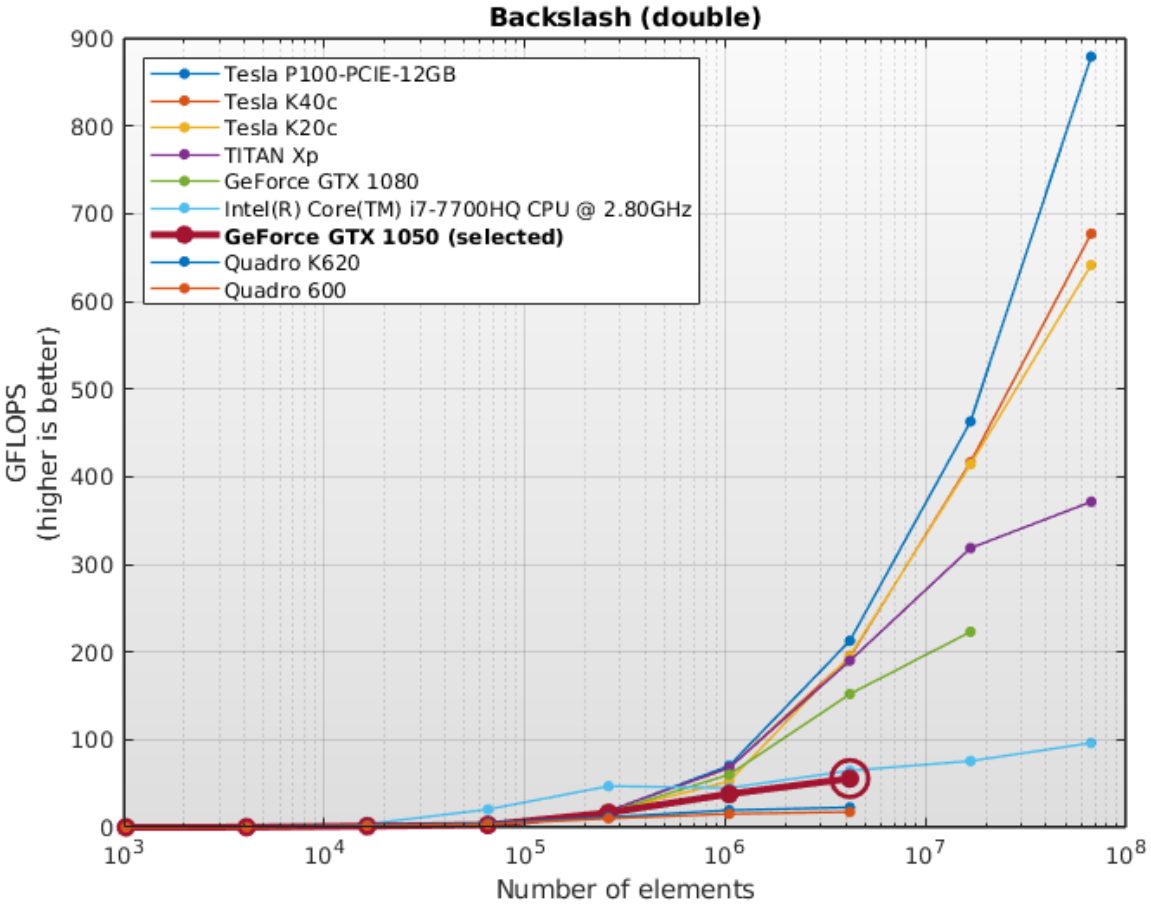
These results show the performance of the GPU or host PC when calculating the matrix left division of an `NxN` matrix with an `Nx1` vector. The number of operations is assumed to be `2/3*N^3 + 3/2*N^2`.

This calculation is usually compute-bound, i.e. the performance depends mainly on how fast the GPU or host PC can perform floating-point operations.

Raw data for GeForce GTX 1050 - Backslash (double)

Array size (elements)	Num Operations	Time (ms)	GigaFLOPS
1,024	23,381	2.94	0.01
4,096	180,907	1.22	0.15
16,384	1,422,677	1.02	1.40
65,536	11,283,115	4.17	2.71
262,144	89,871,701	5.41	16.62
1,048,576	717,400,747	18.84	38.07
4,194,304	5,732,914,517	103.10	55.61

(N gigaflops = $Nx10^9$ operations per second)



Results for Backslash (single)

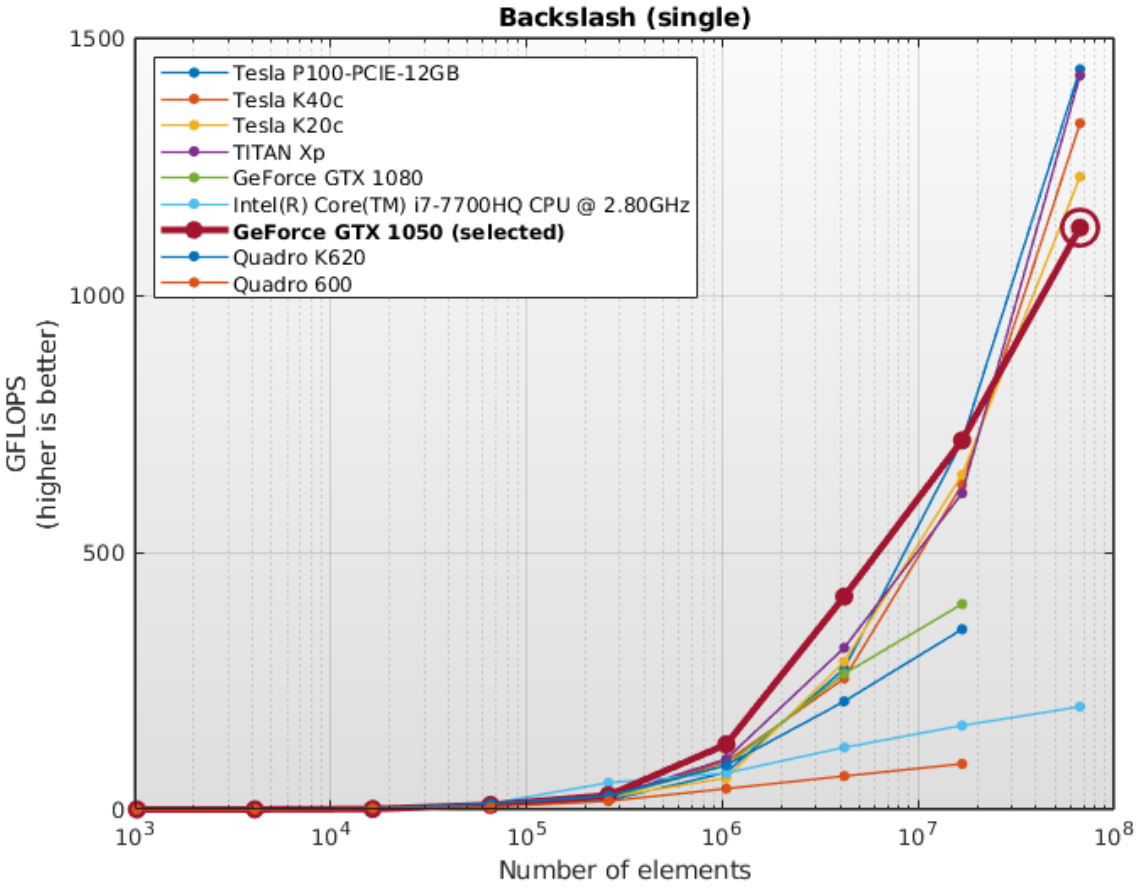
These results show the performance of the GPU or host PC when calculating the matrix left division of an `NxN` matrix with an `Nx1` vector. The number of operations is assumed to be `2/3*N^3 + 3/2*N^2`.

This calculation is usually compute-bound, i.e. the performance depends mainly on how fast the GPU or host PC can perform floating-point operations.

Raw data for GeForce GTX 1050 - Backslash (single)

Array size (elements)	Num Operations	Time (ms)	GigaFLOPS
1,024	23,381	3.47	0.01
4,096	180,907	1.84	0.10
16,384	1,422,677	1.66	0.86
65,536	11,283,115	1.28	8.79
262,144	89,871,701	3.27	27.45
1,048,576	717,400,747	5.67	126.57
4,194,304	5,732,914,517	13.85	413.83
16,777,216	45,838,150,315	63.88	717.55
67,108,864	366,604,539,221	324.11	1131.12

(N gigaflops = $Nx10^9$ operations per second)



Results for FFT (double)

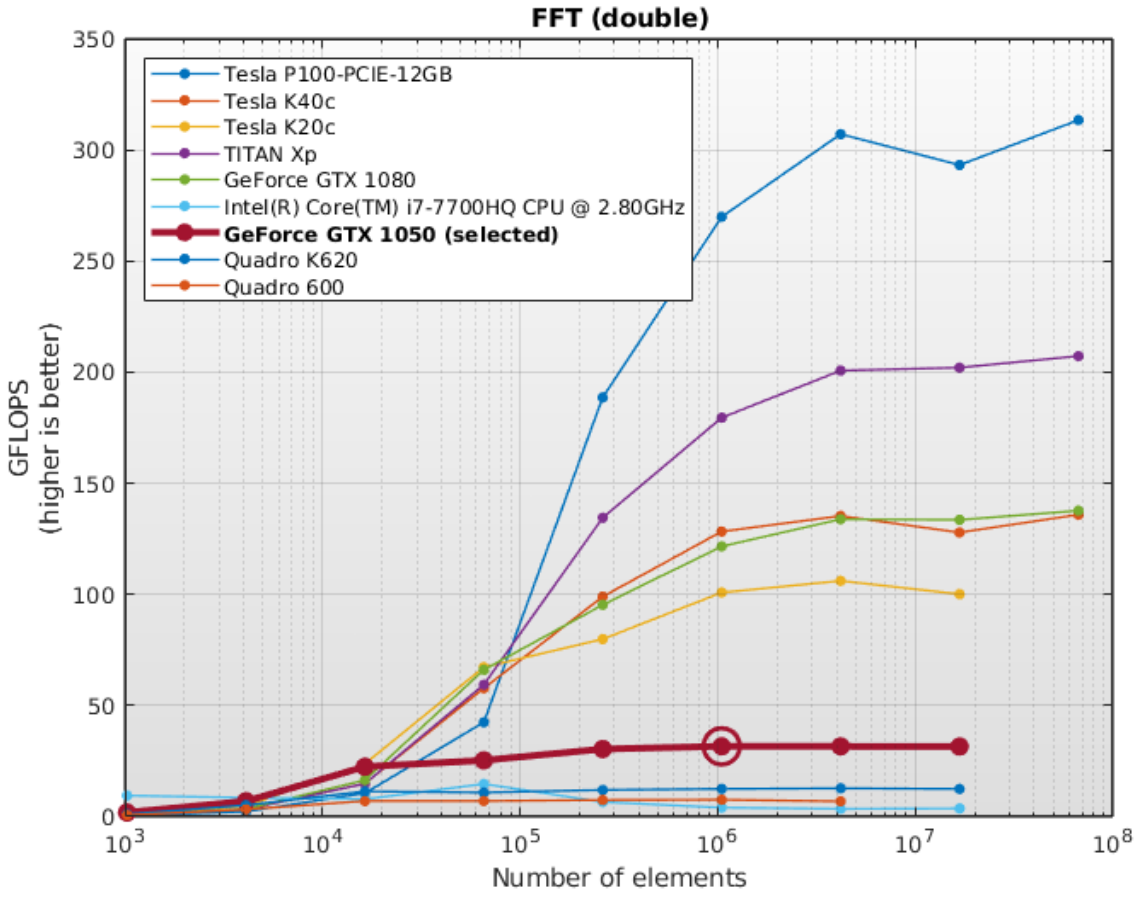
These results show the performance of the GPU or host PC when calculating the Fast-Fourier-Transform of a vector of complex numbers. The number of operations for a vector of length `N` is assumed to be `5*N*log2(N)`.

This calculation is usually memory-bound, i.e. the performance depends mainly on how fast the GPU or host PC can read and write data.

Raw data for GeForce GTX 1050 - FFT (double)

Array size (elements)	Num Operations	Time (ms)	GigaFLOPS
1,024	51,200	0.03	1.87
4,096	245,760	0.04	6.92
16,384	1,146,880	0.05	22.47
65,536	5,242,880	0.21	25.33
262,144	23,592,960	0.78	30.42
1,048,576	104,857,600	3.31	31.65
4,194,304	461,373,440	14.59	31.62
16,777,216	2,013,265,920	63.81	31.55

(`N` gigaflops = $Nx10^9$ operations per second)



Results for FFT (single)

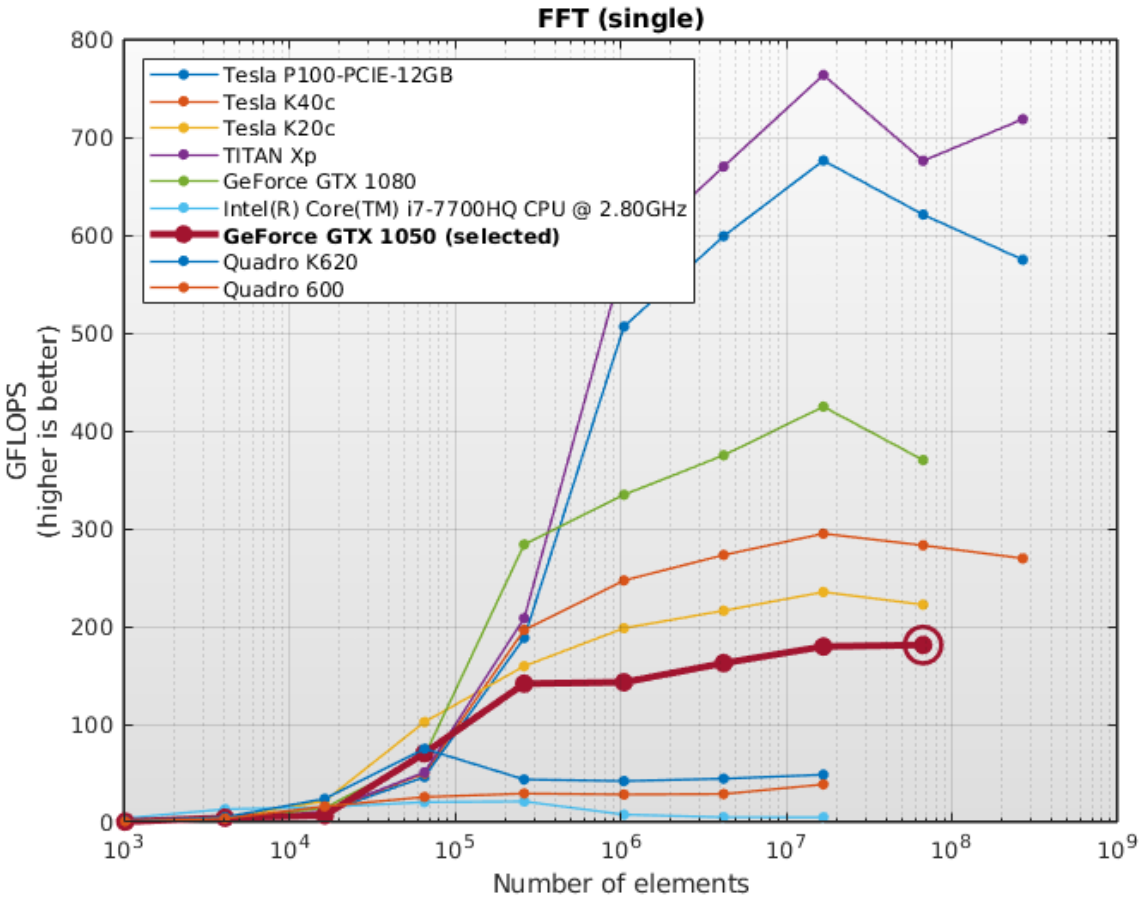
These results show the performance of the GPU or host PC when calculating the Fast-Fourier-Transform of a vector of complex numbers. The number of operations for a vector of length `N` is assumed to be `5*N*log2(N)`.

This calculation is usually memory-bound, i.e. the performance depends mainly on how fast the GPU or host PC can read and write data.

Raw data for GeForce GTX 1050 - FFT (single)

Array size (elements)	Num Operations	Time (ms)	GigaFLOPS
1,024	51,200	0.13	0.41
4,096	245,760	0.06	4.44
16,384	1,146,880	0.17	6.90
65,536	5,242,880	0.07	70.38
262,144	23,592,960	0.17	141.56
1,048,576	104,857,600	0.73	142.94
4,194,304	461,373,440	2.84	162.50
16,777,216	2,013,265,920	11.22	179.50
67,108,864	8,724,152,320	48.19	181.04

(`N` gigaflops = `Nx10`^{9} operations per second)



CPU results

GPU Performance Details: Intel(R) Core(TM) i7-7700HQ CPU @ 2.80GHz

Contents:

System Configuration

MATLAB Release: R2019b

Host

Name	Intel(R) Core(TM) i7-7700HQ CPU @ 2.80GHz
Clock	900.349 MHz
Cache	6144 KB
NumProcessors	4
OSType	Linux
OSVersion	buildd@lgw01-amd64-031

Results for Backslash (double)

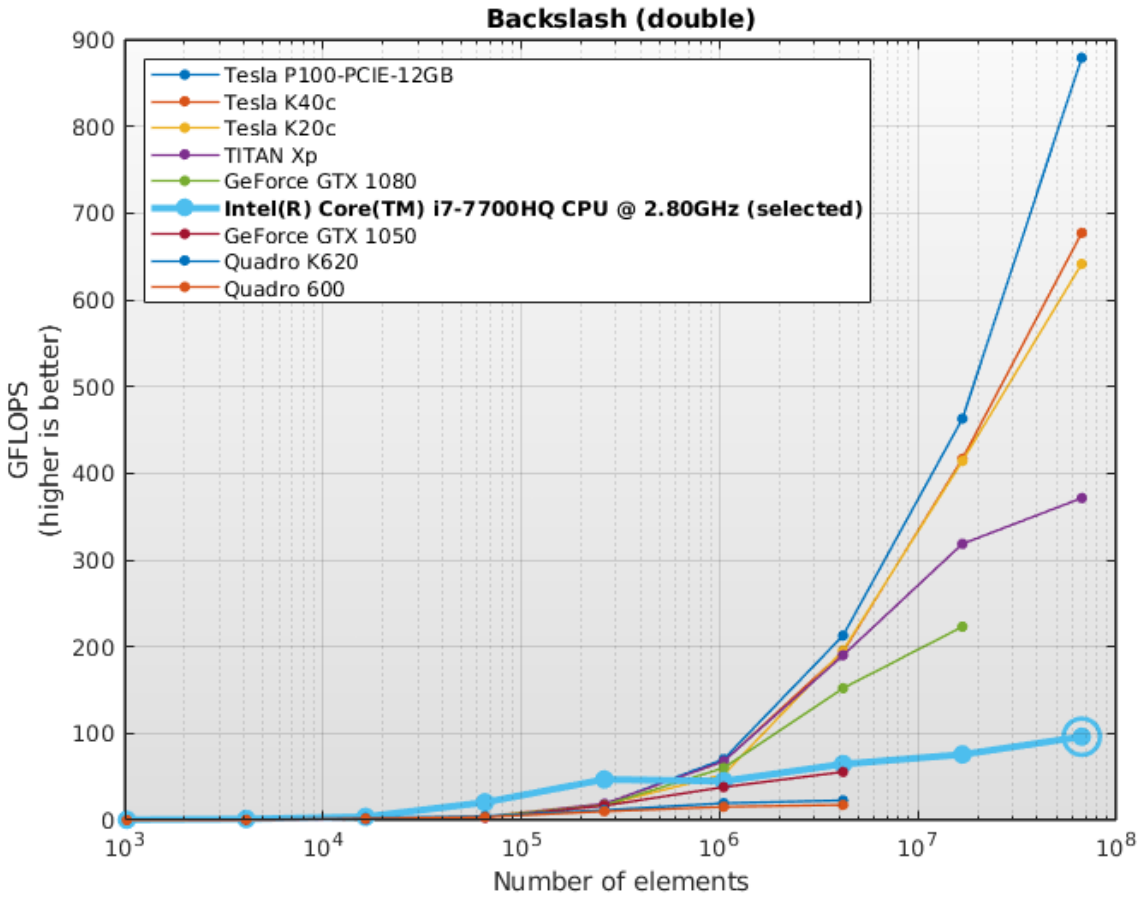
These results show the performance of the GPU or host PC when calculating the matrix left division of an `NxN` matrix with an `Nx1` vector. The number of operations is assumed to be `2/3*N^3 + 3/2*N^2`.

This calculation is usually compute-bound, i.e. the performance depends mainly on how fast the GPU or host PC can perform floating-point operations.

Raw data for Intel(R) Core(TM) i7-7700HQ CPU @ 2.80GHz - Backslash (double)

Array size (elements)	Num Operations	Time (ms)	GigaFLOPS
1,024	23,381	0.05	0.45
4,096	180,907	0.14	1.30
16,384	1,422,677	0.37	3.81
65,536	11,283,115	0.55	20.47
262,144	89,871,701	1.91	46.94
1,048,576	717,400,747	15.93	45.02
4,194,304	5,732,914,517	88.67	64.65
16,777,216	45,838,150,315	605.55	75.70
67,108,864	366,604,539,221	3812.38	96.16

(N gigaflops = $Nx10^9$ operations per second)



MatlabMPI and pMatlab

Parallel Matlab (Octave) using MatlabMPI

Files location: vdwarf - /usr/local/PP/MatlabMPI

Read the README there!

cd to the **examples** directory

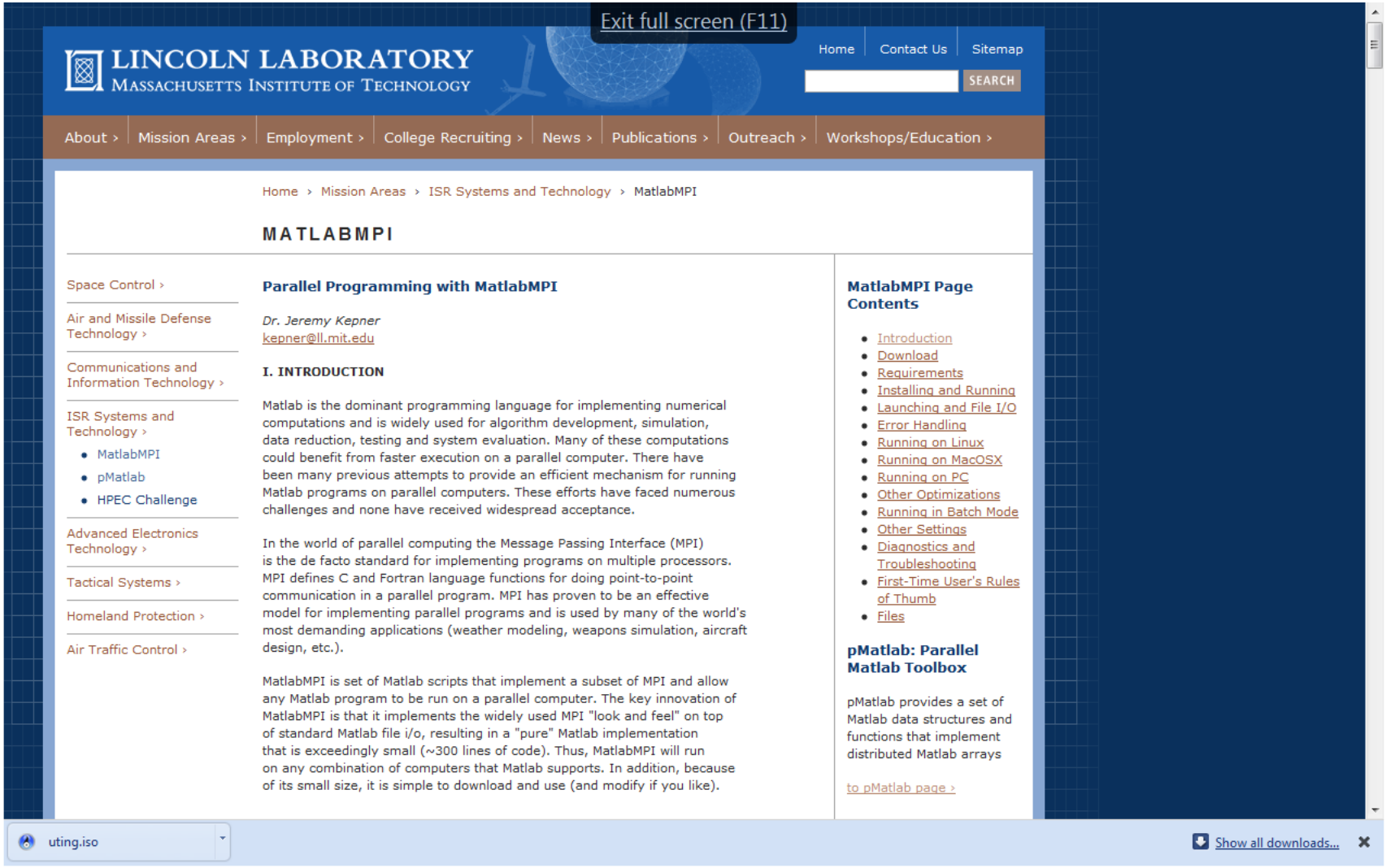
```
eval( MPI_Run('basic', 3,machines) );
```

where:

```
machines = {‘vdwarf1'  ‘vdwarf2‘ ‘vdwrf3’}
```

MatlabMPI

http://www.ll.mit.edu/mission/isr/matlabmpi/matlabmpi.html#introduction



Available examples:

xbasic.m Extremely simple MatlabMPI program that prints out the rank of each processor.

basic.m Simple MatlabMPI program that sends data from processor 1 to processor 0.

multi_basic.m Simple MatlabMPI program that sends data from processor 1 to processor 0 a few times.

probe.m Simple MatlabMPI program that demonstrates the using MPI_Probe to check for incoming messages.

broadcast.m Tests MatlabMPI broadcast command.

basic_app.m Examples of the most common usages of MatlabMPI.

basic_app2.m Examples of the most common usages of MatlabMPI.

basic_app3.m Examples of the most common usages of MatlabMPI.

basic_app4.m Examples of the most common usages of MatlabMPI.

blurimage.m MatlabMPI test parallel image processing application.

speedtest.m Times MatlabMPI for a variety of messages.

synch_start.m Function for synchronizing starts.

machines.m Example script for creating a machine description.

unit_test.m Wrapper for using an example as a unit test.

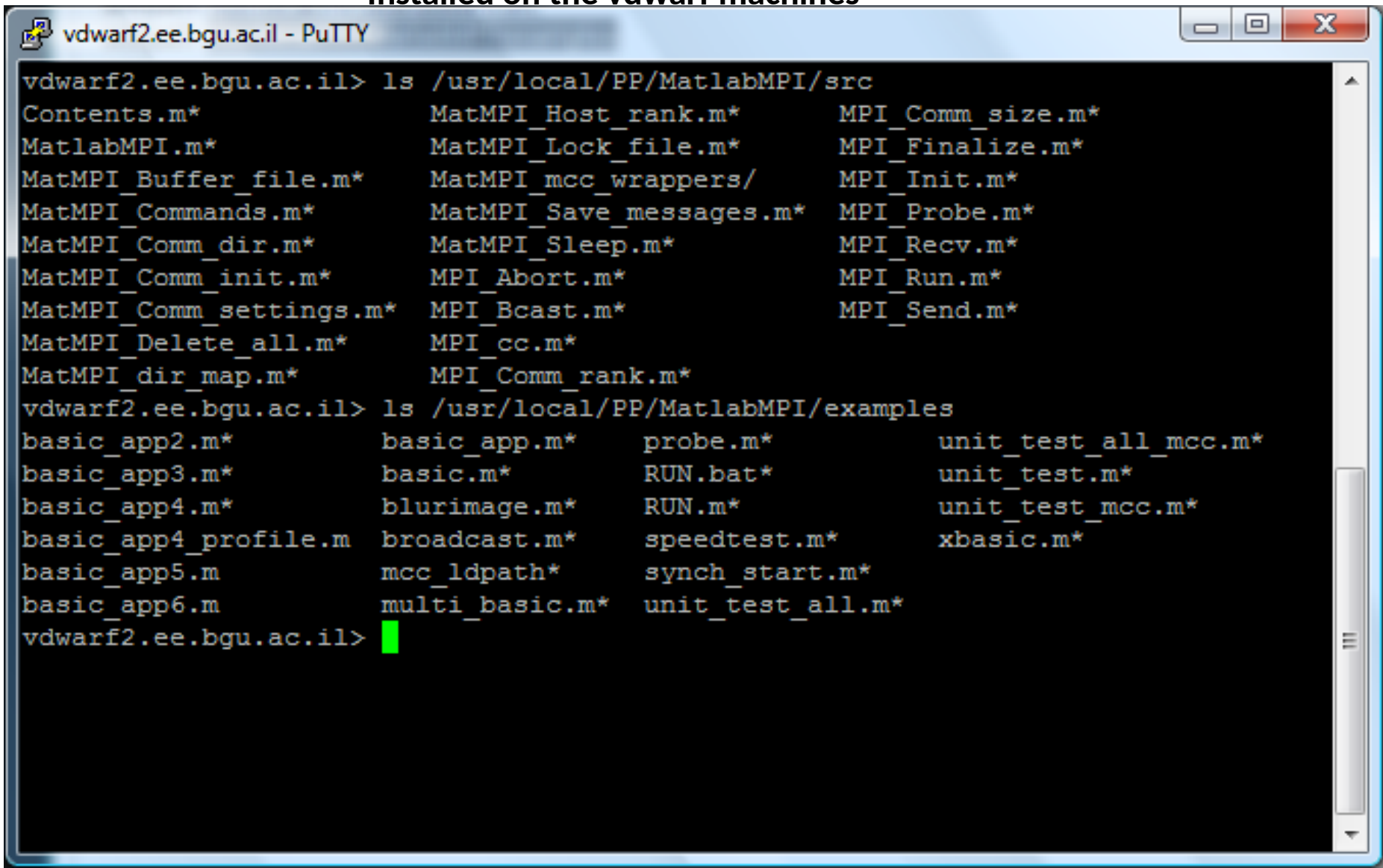
unit_test_all.m Calls all of the examples as way of testing the entire library.

unit_test_mcc.m Wrapper for using an example as a mcc unit test.

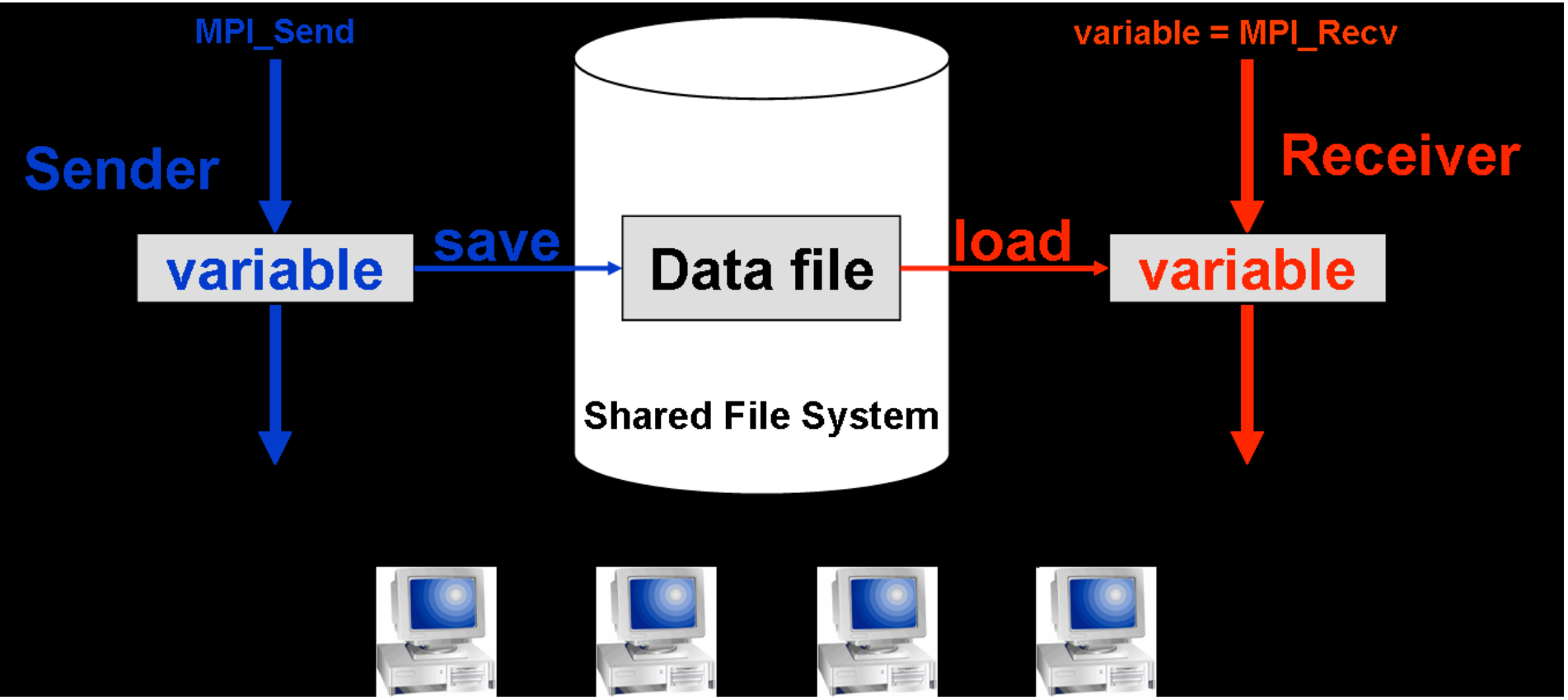
unit_test_all_mcc.m Calls all of the examples using MPI_cc as way of testing the entire library.

MatlabMPI Demo

Installed on the vdwarf machines

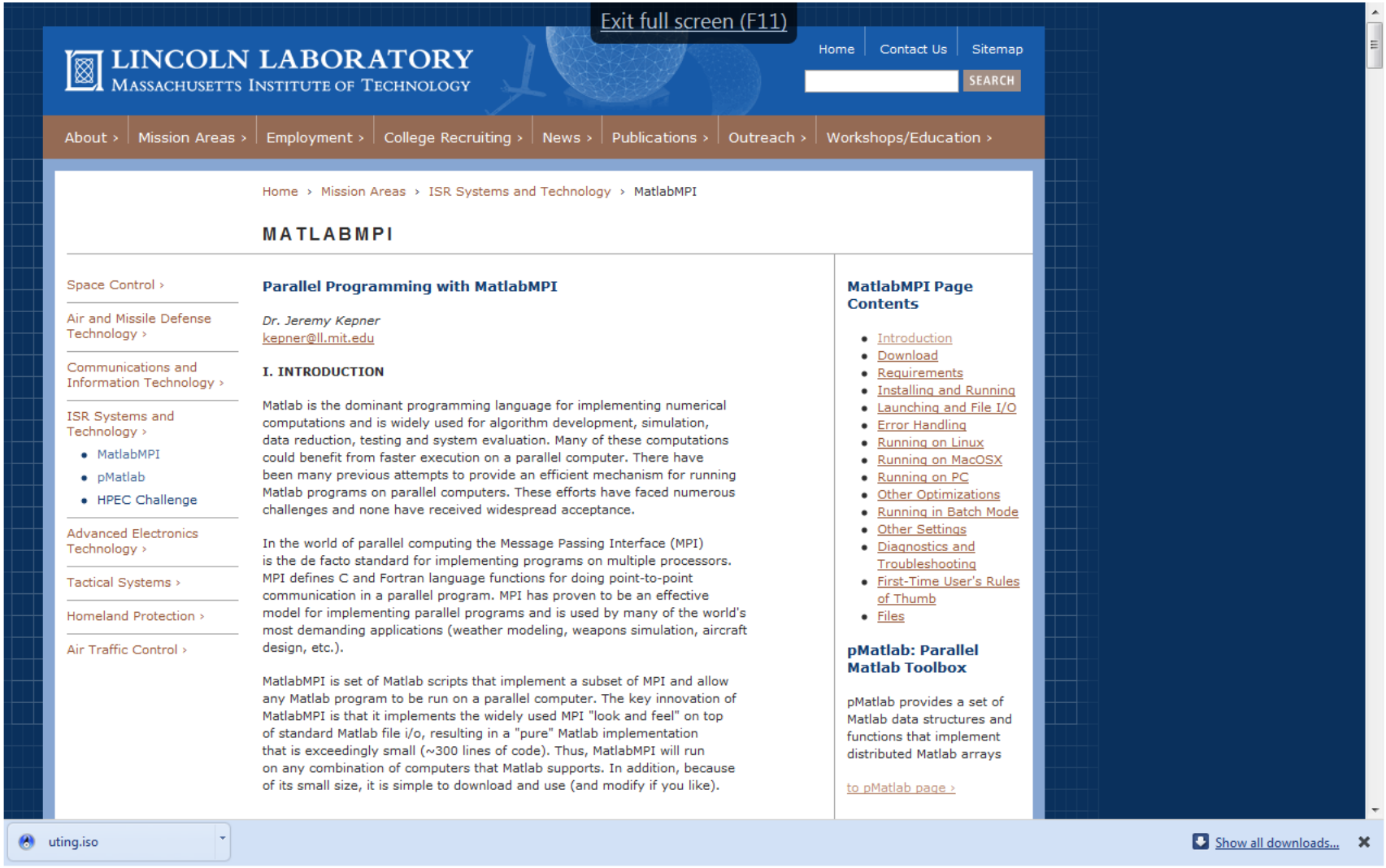


MatlabMPI implements the fundamental communication operations in MPI using MATLAB's file I/O functions.



MatlabMPI

http://www.ll.mit.edu/mission/isr/matlabmpi/matlabmpi.html#introduction



Add to Matlab path:

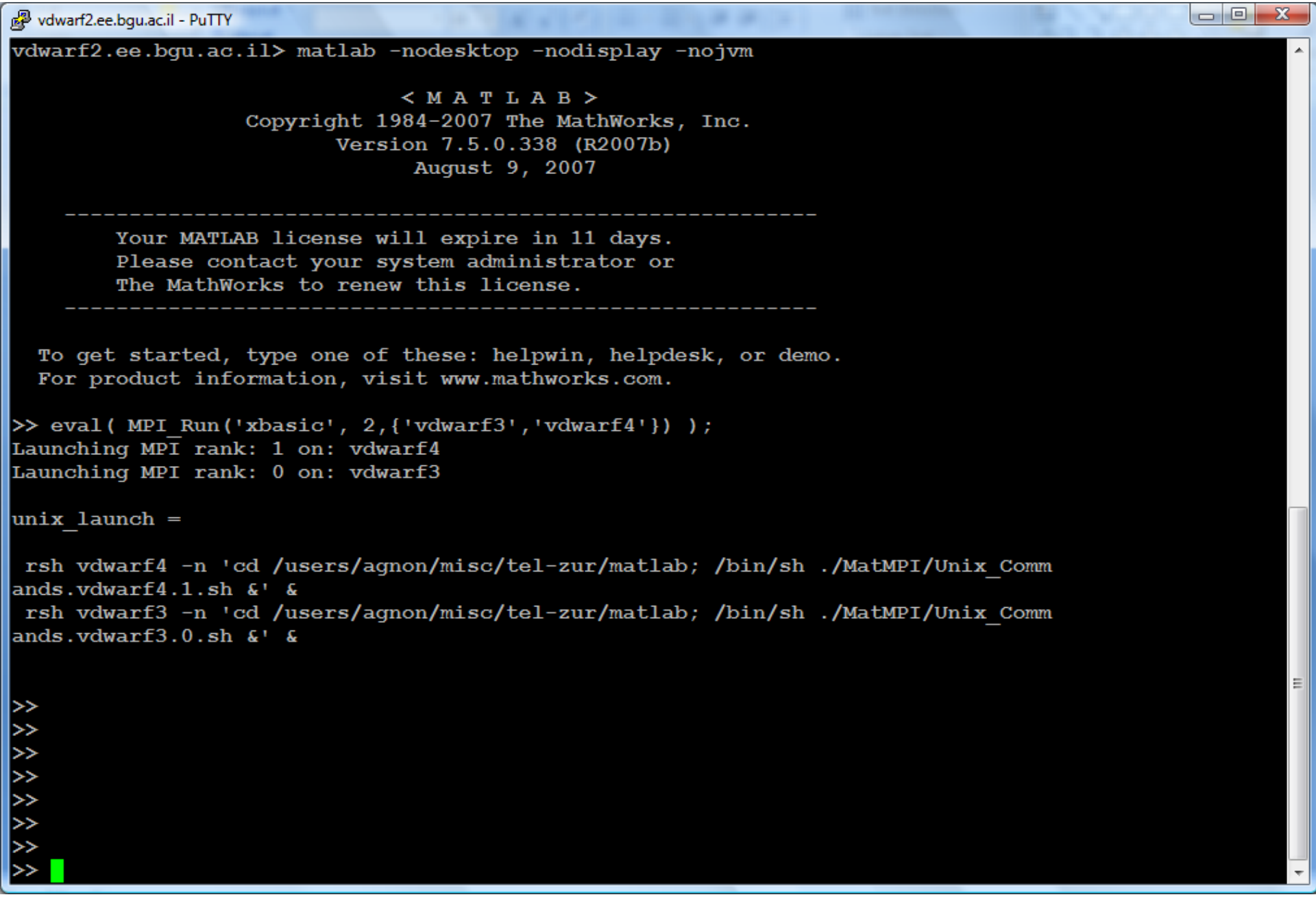
```
vdwarf2.ee.bgu.ac.il> cat startup.m
addpath /usr/local/PP/MatlabMPI/src
addpath /usr/local/PP/MatlabMPI/examples
Addpath ./MatMPI
```

xbasic

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Basic Matlab MPI script that
% prints out a rank.
%
% To run, start Matlab and type:
%
%   eval( MPI_Run('xbasic',2,{}) );
%
% Or, to run a different machine type:
%
%   eval( MPI_Run('xbasic',2,{'machine1' 'machine2'}) );
%
% Output will be piped into two files:
%
%   MatMPI/xbasic.0.out
%   MatMPI/xbasic.1.out
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% MatlabMPI
% Dr. Jeremy Kepner
% MIT Lincoln Laboratory
% kepner@ll.mit.edu
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
% Initialize MPI.
MPI_Init;

% Create communicator.
comm = MPI_COMM_WORLD;

% Modify common directory from default for better performance.
% comm = MatMPI_Comm_dir(comm,'/tmp');

% Get size and rank.
comm_size = MPI_Comm_size(comm);
my_rank = MPI_Comm_rank(comm);

% Print rank.
disp(['my_rank: ',num2str(my_rank)]);

% Wait momentarily.
pause(2.0);

% Finalize Matlab MPI.
MPI_Finalize;
disp('SUCCESS');
if (my_rank ~= MatMPI_Host_rank(comm))
  exit;
end
```

Demo folder ~/matlab/, watch top at the other machine



Parallel Matlab (Octave) using pMatlab

Global arrays – "…Communication is hidden from the programmer; arrays are automatically redistributed when necessary, without the knowledge of the programmer…"

"…The ultimate goal of pMatlab is to move beyond basic messaging (and its inherent programming complexity) towards higher level parallel data structures and functions, allowing any MATLAB user to parallelize their existing program by simply changing and adding a few lines,

Source: http://www.ll.mit.edu/mission/isr/pmatlab/pMatlab_intro.pdf

Instead of:

```
if (my_rank==0) | (my_rank==1) | (my_rank==2) | (my_rank==3)
  A_local=rand(M,N/4);
end

if (my_rank==4) | (my_rank==5) | (my_rank==6) | (my_rank==7)
  B_local=zeros(M/4,N);
end

tag = 0;
if (my_rank==0) | (my_rank==1) | (my_rank==2) | (my_rank==3)
   A_local=fft(A_local);
   for ii = 0:3
      MPI_Send(ii+4, tag, comm, A_local(ii*M/4 + 1:(ii+1)*M/4,:));
   end
end

if (my_rank==4) | (my_rank==5) | (my_rank==6) | (my_rank==7)
   for ii = 0:3
      B_local(:, ii*N/4 + 1:(ii+1)*N/4) = MPI_Recv(ii, tag, comm);
   end
end
```

Write using pMatlab:

```
mapA = map([1 4],{},[0:3]);
mapB = map([4 1],{},[4:7]);
A = rand(M,N,mapA);
B = zeros(M,N,mapB);
B(:,:) = fft(A);
```

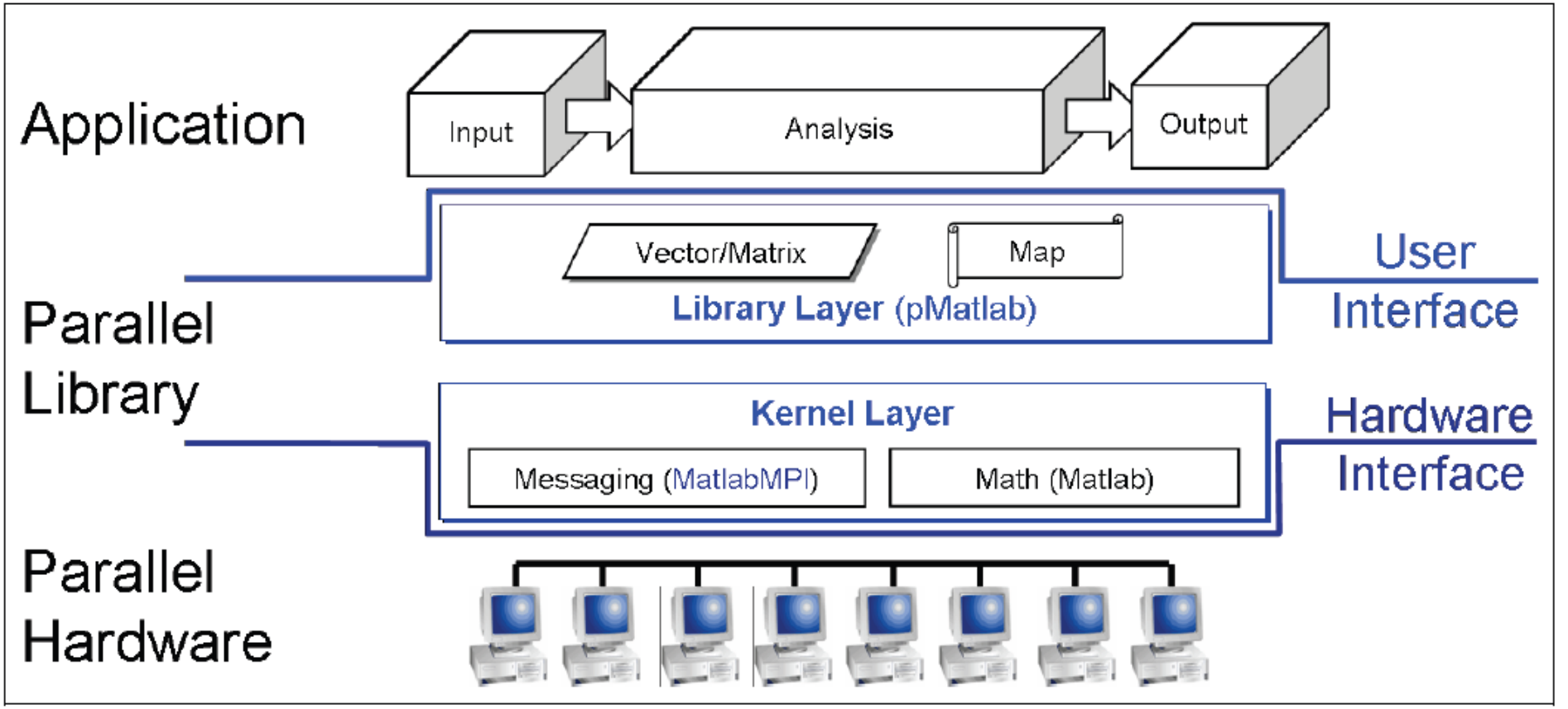


Figure 11 – Parallel MATLAB consists of two layers. pMatlab provides parallel data structures and library functions. MatlabMPI provides messaging capability.

eesrv.ee.bgu.ac.il - PuTTY

```
-bash-3.1$ matlab -npdisplay
Warning: Unrecognized MATLAB option "npdisplay".
MATLAB:I18n:InconsistentUiLanguage - The user UI language setting, C, is differe
nt from the user locale setting, en_US.UTF-8.
Warning: No display specified.  You will not be able to display graphics on the
screen.

                            < M A T L A B >
                Copyright 1984-2007 The MathWorks, Inc.
                       Version 7.5.0.338 (R2007b)
                             August 9, 2007


  To get started, type one of these: helpwin, helpdesk, or demo.
  For product information, visit www.mathworks.com.

>> eval(pRUN('pHPL',4,{'vdwarf1','vdwarf2','vdwarf3','vdwarf4'}))
Submitting pHPL on 4 processor(s).
 ssh vdwarf1 -n  'kill -9 22302'
bash: line 0: kill: (22302) - No such process
 ssh vdwarf2 -n  'kill -9 22946'
bash: line 0: kill: (22946) - No such process
 ssh vdwarf3 -n  'kill -9 4082'
bash: line 0: kill: (4082) - No such process
 ssh vdwarf4 -n  'kill -9 12431'
bash: line 0: kill: (12431) - No such process
Launching MPI rank: 3 on: vdwarf4
Launching MPI rank: 2 on: vdwarf3
Launching MPI rank: 1 on: vdwarf2
Launching MPI rank: 0 on: vdwarf1

unix_launch =
```

Proceed to pMatlab slides...

Matlab (Octave) + Condor

Sample 1:

submit file (cp.sub)

```
-------------------------
universe         = vanilla
executable       = cp1.bat
initialdir       = C:\user\CondorMatlab
log              = matlabtest.log
error            = matlabtest.err
input            = CondorMatlabTest.m
getenv           = true
requirements     = (NAME == "slot1@remotePC")
queue
---------------------------
```

cp1.bat

```
----------------
cd "C:\PROGRA~1\MATLAB\R2007b\bin\win32"
matlab.exe  -r  "CondorMatlabTest"
```

Condor Demos

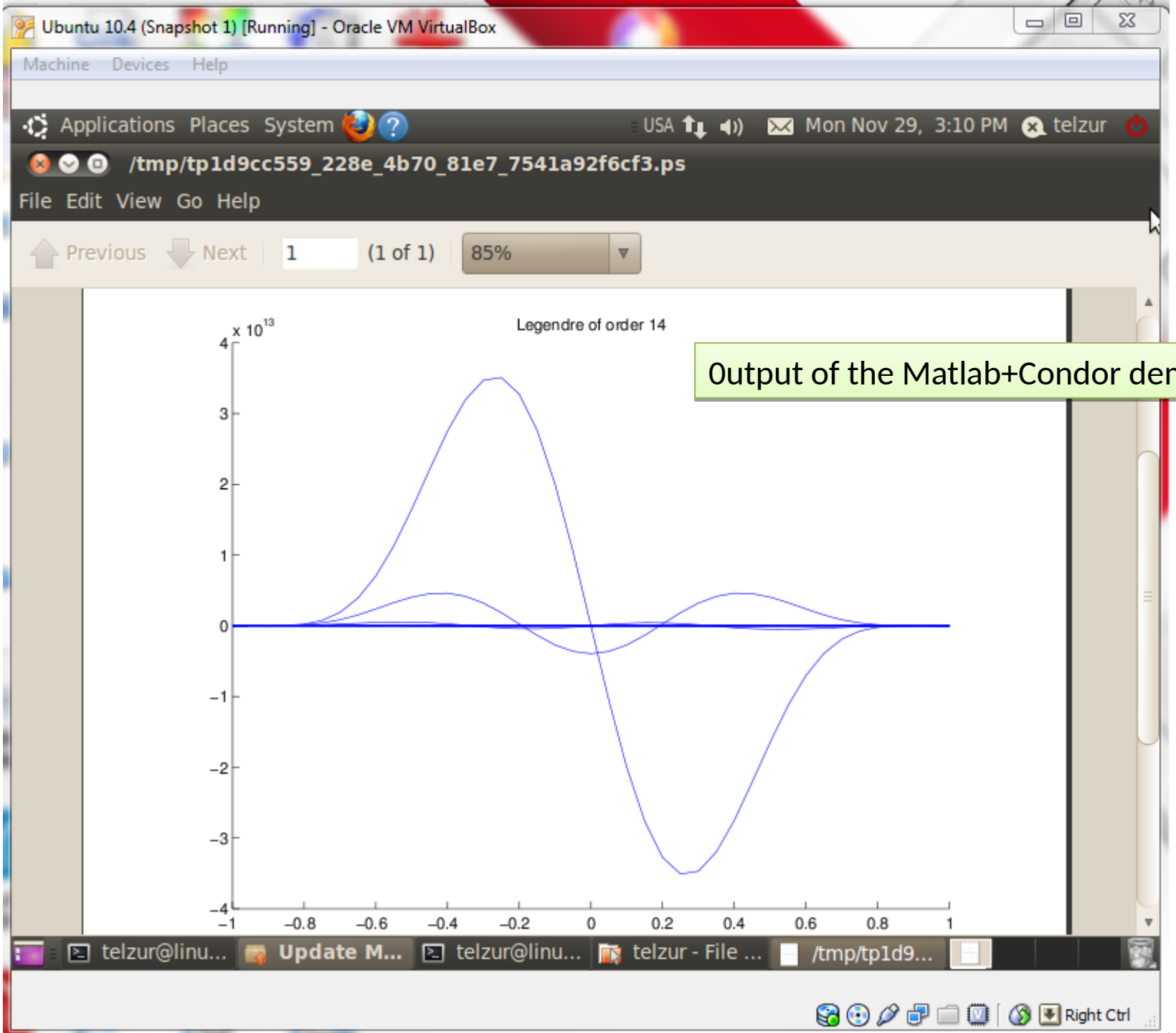
- On my PC: `C:\Users\telzur\Documents\BGU\Teaching\ParallelProcessing\PP2011A\Lectures\06\condor_demo_2010`
- *** has a bug ***

On the Linux vdwarf – Condor + Octave

`/users/agnon/misc/tel-zur/condor/octave`

- On the Linux vdwarf – Condor + Matlab

`/users/agnon/misc/tel-zur/condor/matlab/example_legendre`



0utput of the Matlab+Condor demo

Parallel Matlab(*)

Dr. Guy Tel-Zur

(*)=and other tools

Version: ~~4/11/2018~~, 4/10/2019

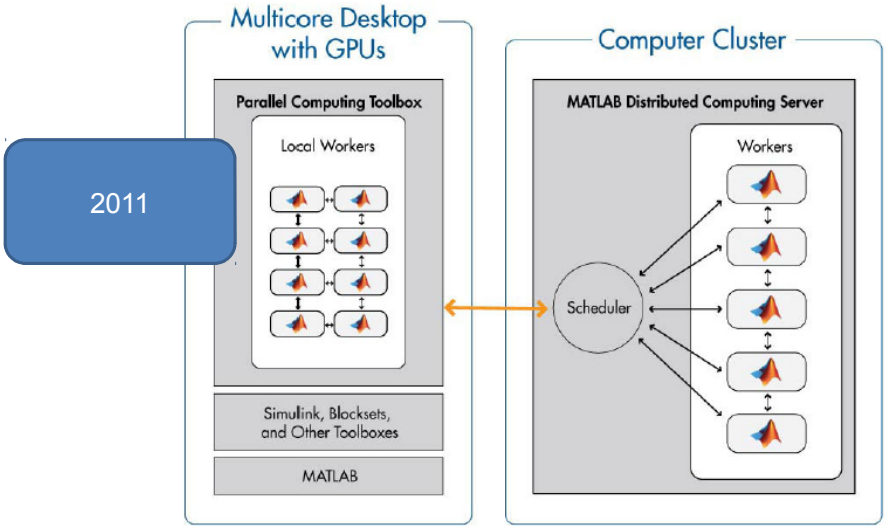
Agenda

- Mathworks – Parallel Computing toolbox
- Parallel Computing with Matlab on Amazon Cloud
- Matlab over GPGPU
- Matlab (Octave) + HTCondor (we will have to learn HTCondor first)
- Parallel Matlab (Octave) using MatlabMPI
- Parallel Matlab (Octave) using pMatlab

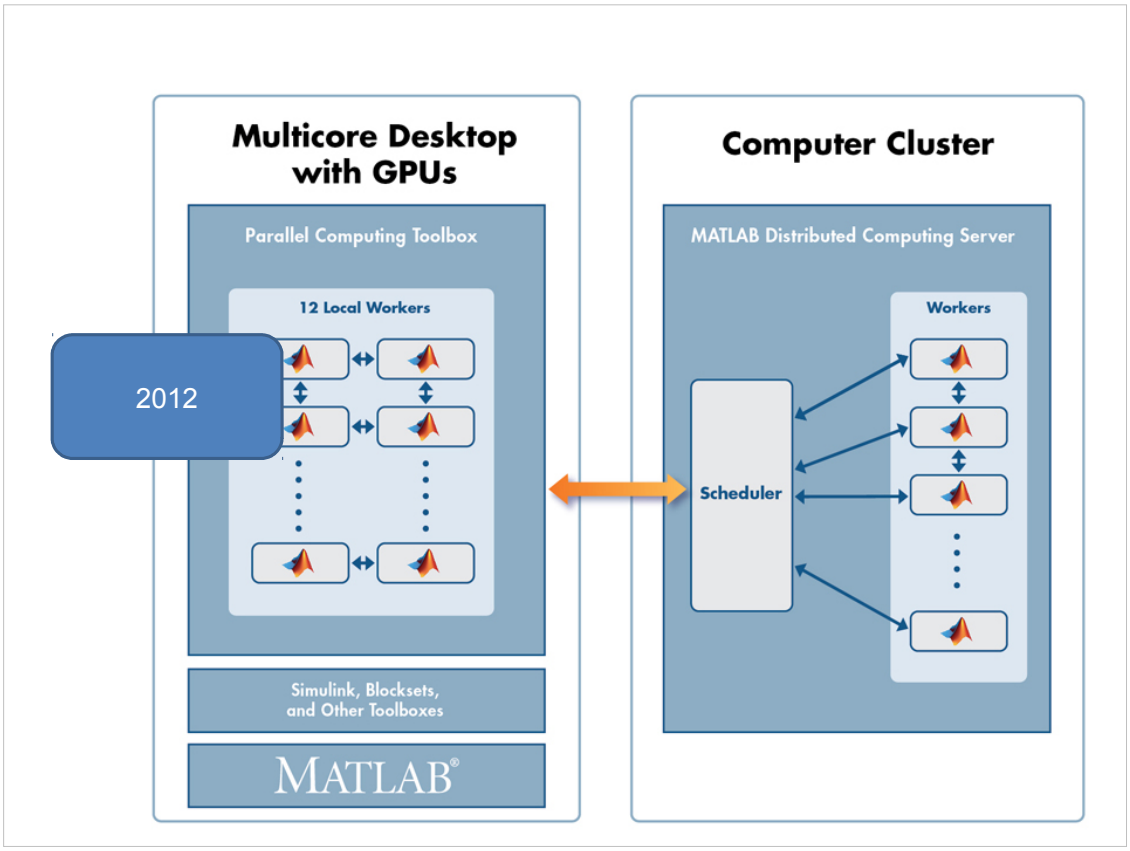
Mathworks – Parallel Computing toolbox

- Parallel Computing without CUDA or MPI(…)
- The toolbox provides “workers” (MATLAB computational engines) to execute applications locally on a multicore desktop
- Parallel for-loops (**`parfor`**) for running task-parallel algorithms on multiple processors
- Computer cluster and grid support (with MATLAB Distributed Computing Server)

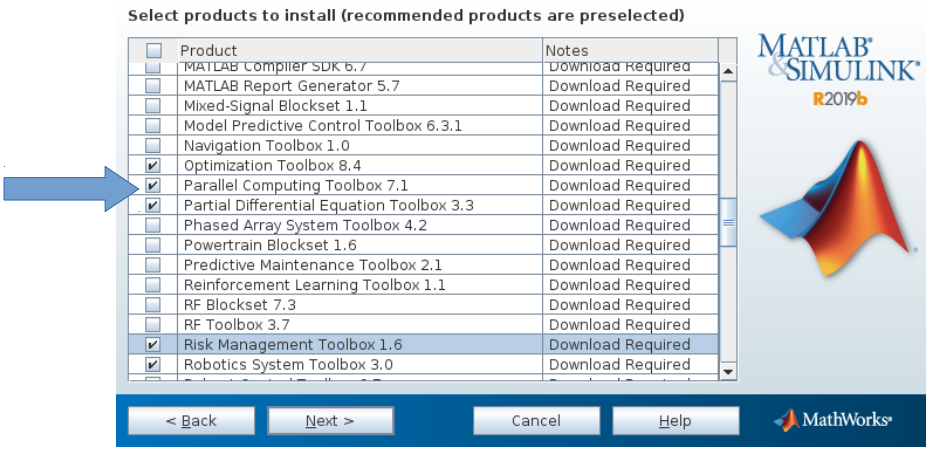
Parallel Computing toolbox

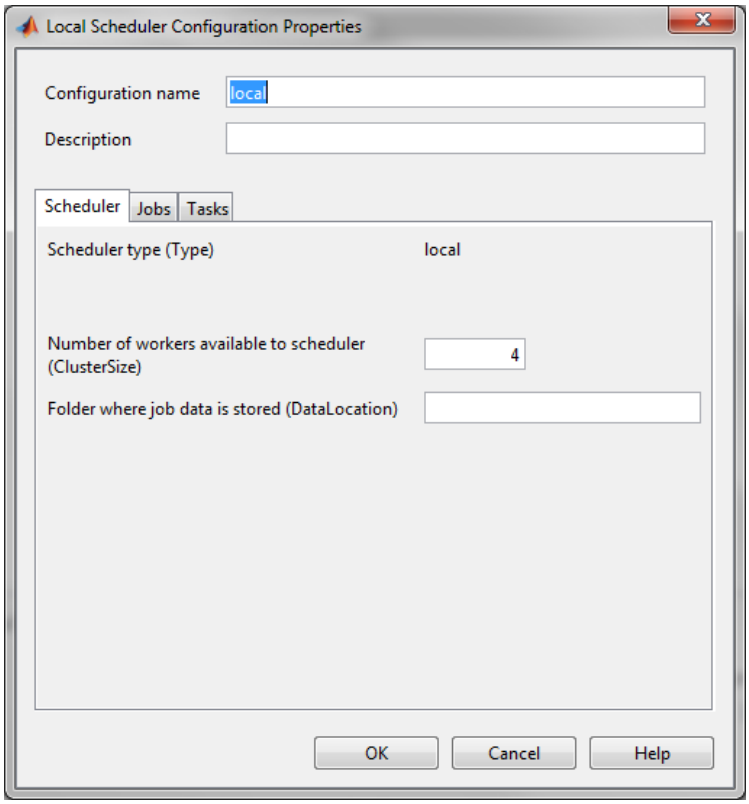


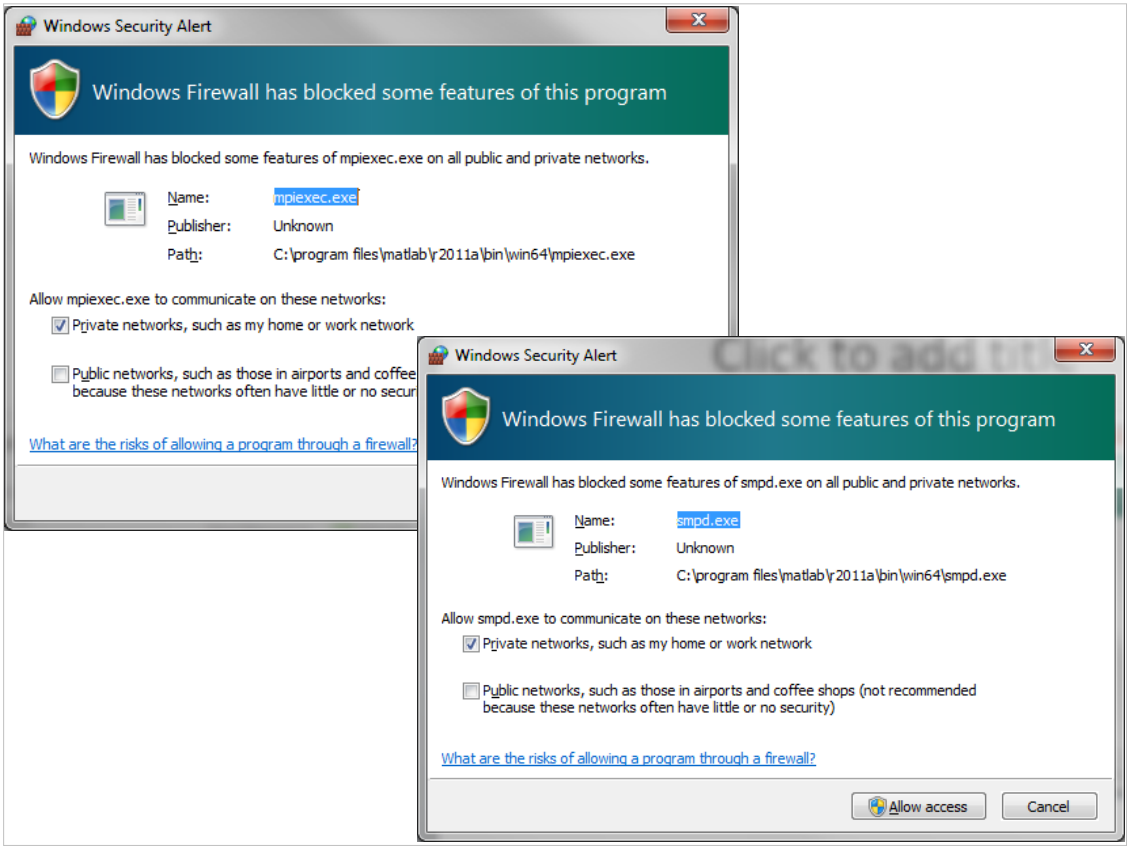
Parallel computing with MATLAB. You can use Parallel Computing Toolbox to run applications on a multicore desktop with eight workers available in the toolbox, take advantage of GPUs, and scale up to a cluster (with MATLAB Distributed Computing Server).

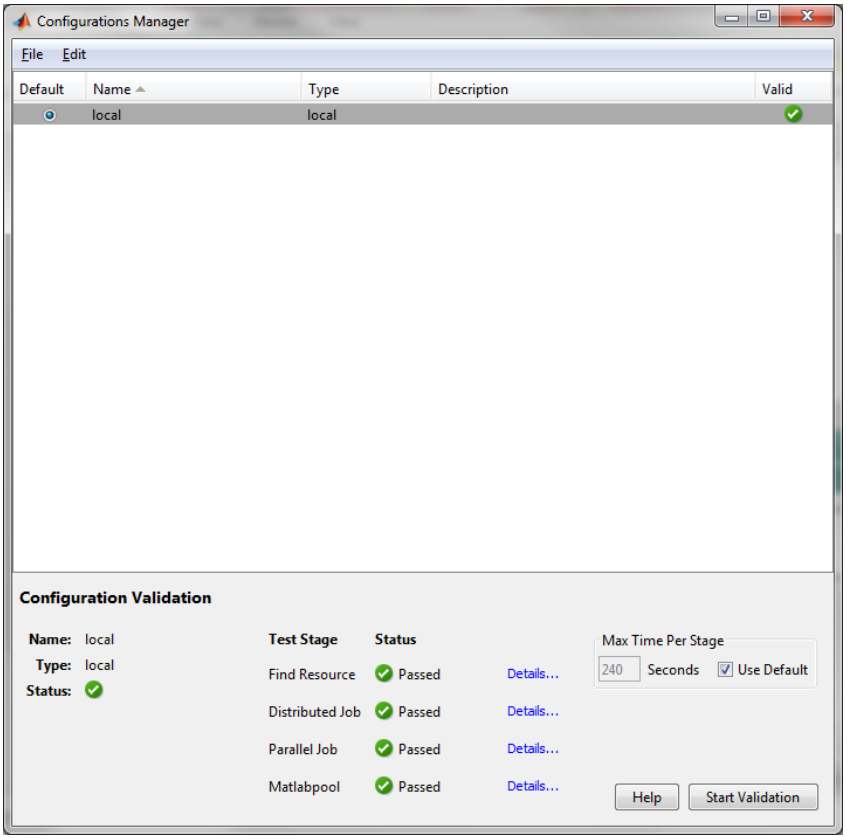

Multicore Desktop with GPUs
Parallel Computing Toolbox
12 Local Workers
Simulink, Blocksets, and Other Toolboxes
MATLAB
Computer Cluster
MATLAB Distributed Computing Server
Workers
Scheduler
2012

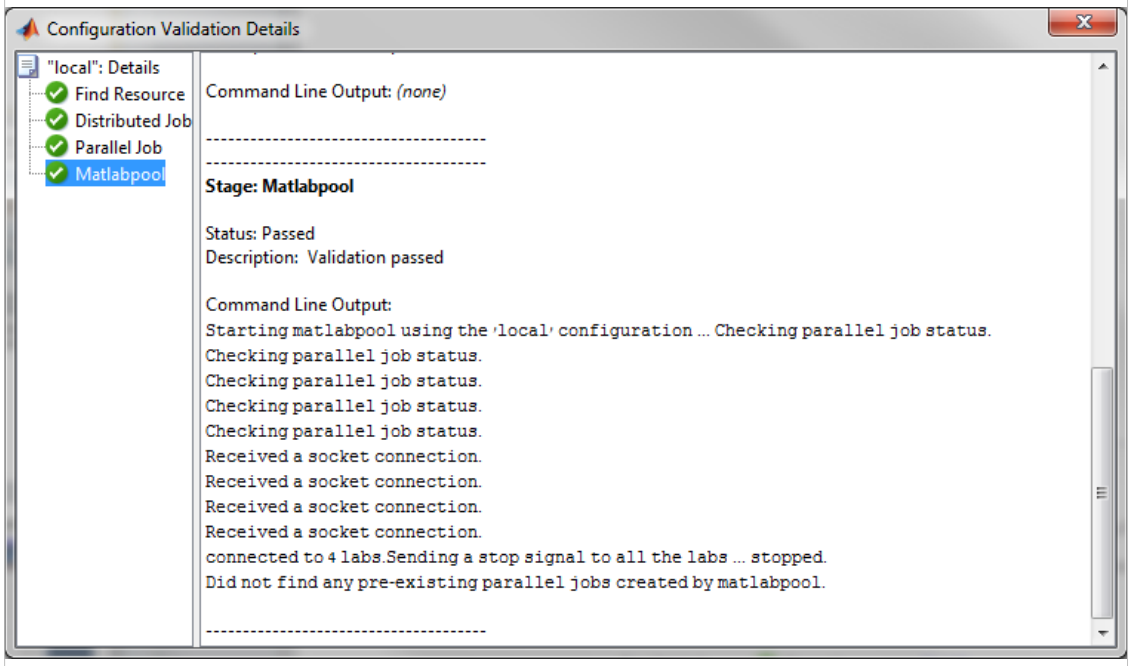
When installing Matlab check the Parallel Computing Toolbox




Local Scheduler Configuration Properties
Configuration name
local
Description
Scheduler
Jobs
Tasks
Scheduler type (Type)
local
Number of workers available to scheduler (ClusterSize)
4
Folder where job data is stored (DataLocation)
OK
Cancel
Help

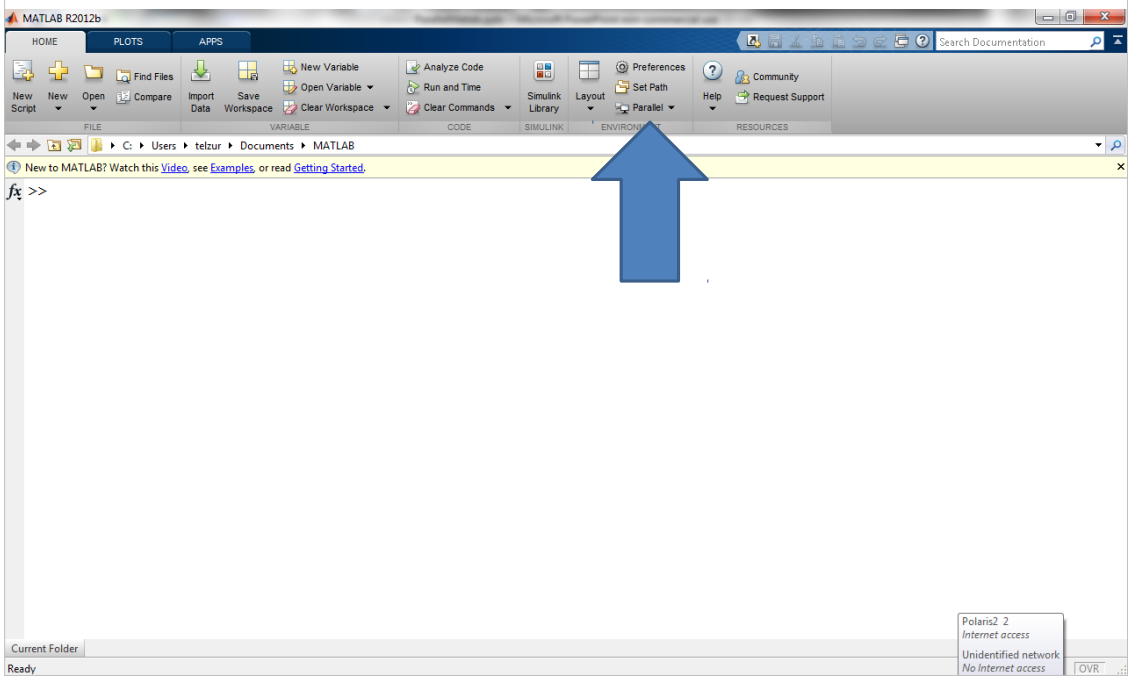

Windows Security Alert
Windows Firewall has blocked some features of this program
Windows Firewall has blocked some features of mpiexec.exe on all public and private networks.
Name: mpiexec.exe
Publisher: Unknown
Path: C:\program files\matlab\r2011a\bin\win64\mpiexec.exe
Allow mpiexec.exe to communicate on these networks:
Private networks, such as my home or work network
Public networks, such as those in airports and coffee
because these networks often have little or no secur
What are the risks of allowing a program through a firewall?
Windows Security Alert
Windows Firewall has blocked some features of this program
Windows Firewall has blocked some features of smpd.exe on all public and private networks.
Name: smpd.exe
Publisher: Unknown
Path: C:\program files\matlab\r2011a\bin\win64\smpd.exe
Allow smpd.exe to communicate on these networks:
Private networks, such as my home or work network
Public networks, such as those in airports and coffee shops (not recommended because these networks often have little or no security)
What are the risks of allowing a program through a firewall?
Allow access
Cancel

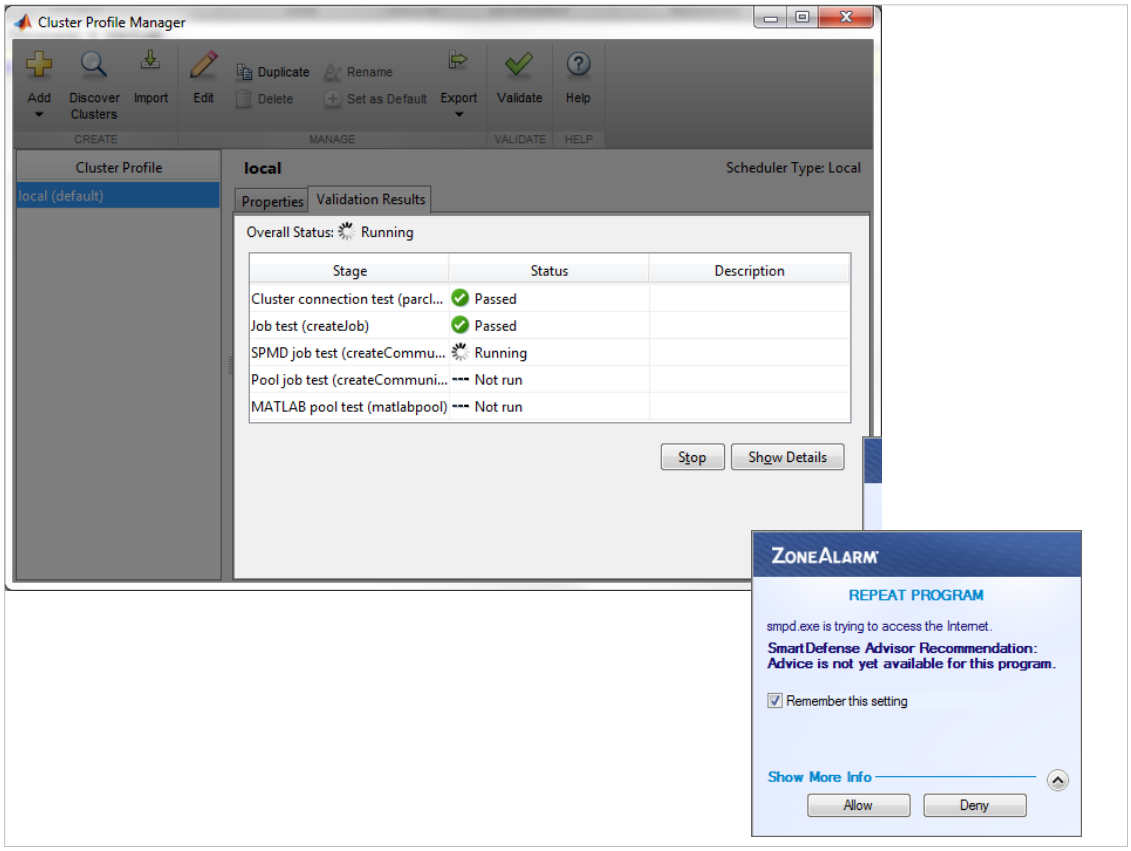

Configurations Manager
File
Edit
Default
Name
Type
Description
Valid
local
local
Configuration Validation
Name: local
Type: local
Status:
Test Stage
Status
Find Resource
Passed
Details...
Distributed Job
Passed
Details...
Parallel Job
Passed
Details...
Matlabpool
Passed
Details...
Max Time Per Stage
240
Seconds
Use Default
Help
Start Validation

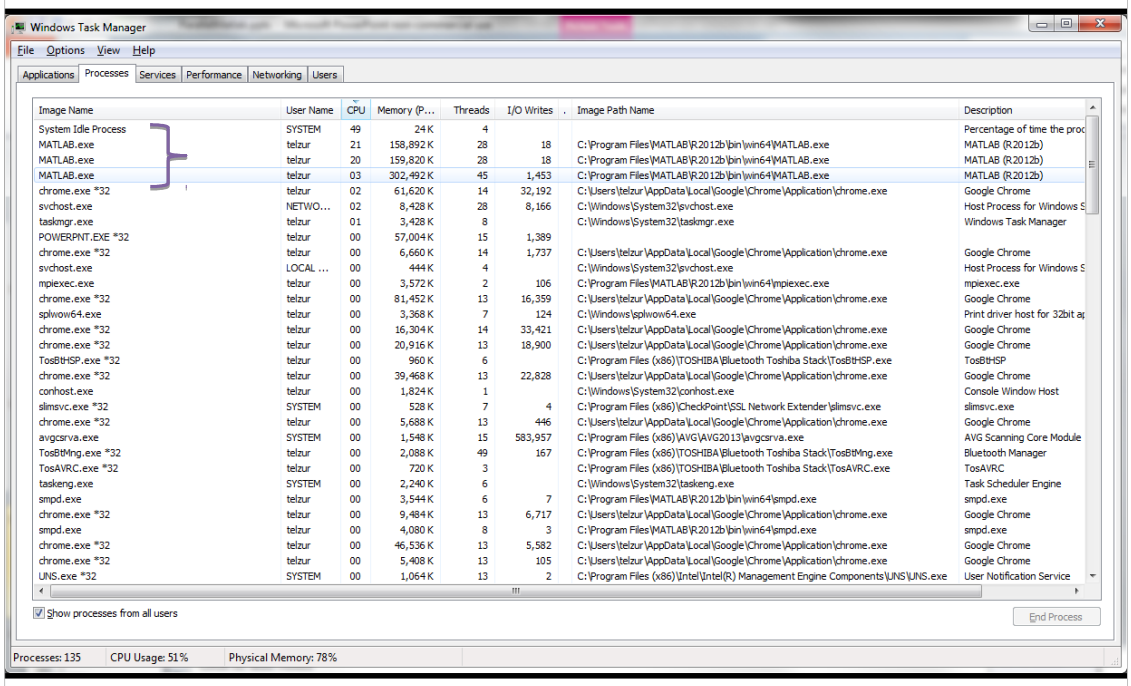

Configuration Validation Details
"local": Details
Find Resource
Distributed Job
Parallel Job
Matlabpool
Command Line Output: (none)

Stage: Matlabpool
Status: Passed
Description: Validation passed
Command Line Output:
Starting matlabpool using the 'local' configuration ... Checking parallel job status.
Checking parallel job status.
Checking parallel job status.
Checking parallel job status.
Checking parallel job status.
Received a socket connection.
Received a socket connection.
Received a socket connection.
Received a socket connection.
connected to 4 labs.Sending a stop signal to all the labs ... stopped.
Did not find any pre-existing parallel jobs created by matlabpool.

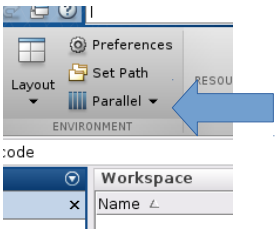
Matlab 2012B

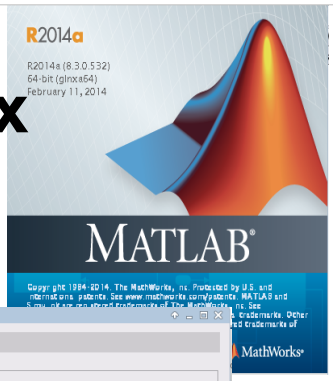


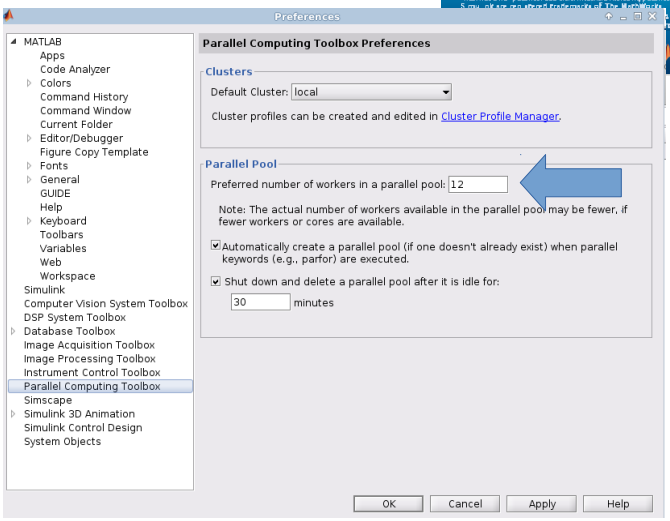

Cluster Profile Manager
Add
Discover Clusters
Import
Edit
Duplicate
Delete
Rename
Set as Default
Export
Validate
Help
CREATE
MANAGE
VALIDATE
HELP
Cluster Profile
local (default)
local
Scheduler Type: Local
Properties
Validation Results
Overall Status: Running
Stage
Status
Description
Cluster connection test (parcl... Passed
Job test (createJob) Passed
SPMD job test (createCommu... Running
Pool job test (createCommuni... Not run
MATLAB pool test (matlabpool) Not run
Stop
Show Details
ZONEALARM
REPEAT PROGRAM
smpd.exe is trying to access the Internet.
SmartDefense Advisor Recommendation:
Advice is not yet available for this program.
Remember this setting
Show More Info
Allow
Deny


Windows Task Manager
File Options View Help
Applications Processes Services Performance Networking Users
Image Name User Name CPU Memory (P... Threads I/O Writes Image Path Name Description
System Idle Process SYSTEM 49 24 K 4 Percentage of time the proc
MATLAB.exe telzur 21 158,892 K 28 18 C:\Program Files\MATLAB\R2012b\bin\win64\MATLAB.exe MATLAB (R2012b)
MATLAB.exe telzur 20 159,820 K 28 18 C:\Program Files\MATLAB\R2012b\bin\win64\MATLAB.exe MATLAB (R2012b)
MATLAB.exe telzur 03 302,492 K 45 1,453 C:\Program Files\MATLAB\R2012b\bin\win64\MATLAB.exe MATLAB (R2012b)
chrome.exe *32 telzur 02 61,620 K 14 32,192 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
svchost.exe NETWO... 02 8,428 K 28 8,166 C:\Windows\System32\svchost.exe Host Process for Windows S
taskmgr.exe telzur 01 3,428 K 8 C:\Windows\System32\taskmgr.exe Windows Task Manager
POWERPNT.EXE *32 telzur 00 57,004 K 15 1,389
chrome.exe *32 telzur 00 6,660 K 14 1,737 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
svchost.exe LOCAL ... 00 444 K 4 C:\Windows\System32\svchost.exe Host Process for Windows S
mpiexec.exe telzur 00 3,572 K 2 106 C:\Program Files\MATLAB\R2012b\bin\win64\mpiexec.exe mpiexec.exe
chrome.exe *32 telzur 00 81,452 K 13 16,359 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
splwow64.exe telzur 00 3,368 K 7 124 C:\Windows\splwow64.exe Print driver host for 32bit ap
chrome.exe *32 telzur 00 16,304 K 14 33,421 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
chrome.exe *32 telzur 00 20,916 K 13 18,900 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
TosBtHSP.exe *32 telzur 00 960 K 6 C:\Program Files (x86)\TOSHIBA\Bluetooth Toshiba Stack\TosBtHSP.exe TosBtHSP
chrome.exe *32 telzur 00 39,468 K 13 22,828 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
conhost.exe telzur 00 1,824 K 1 C:\Windows\System32\conhost.exe Console Window Host
slimsvc.exe *32 SYSTEM 00 528 K 7 4 C:\Program Files (x86)\CheckPoint\SSL Network Extender\slimsvc.exe slimsvc.exe
chrome.exe *32 telzur 00 5,688 K 13 446 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
avgcsrva.exe SYSTEM 00 1,548 K 15 583,957 C:\Program Files (x86)\AVG\AVG2013\avgcsrva.exe AVG Scanning Core Module
TosBtMng.exe *32 telzur 00 2,088 K 49 167 C:\Program Files (x86)\TOSHIBA\Bluetooth Toshiba Stack\TosBtMng.exe Bluetooth Manager
TosAVRC.exe *32 telzur 00 720 K 3 C:\Program Files (x86)\TOSHIBA\Bluetooth Toshiba Stack\TosAVRC.exe TosAVRC
taskeng.exe SYSTEM 00 2,240 K 6 C:\Windows\System32\taskeng.exe Task Scheduler Engine
smpd.exe telzur 00 3,544 K 6 7 C:\Program Files\MATLAB\R2012b\bin\win64\smpd.exe smpd.exe
chrome.exe *32 telzur 00 9,484 K 13 6,717 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
smpd.exe telzur 00 4,080 K 8 3 C:\Program Files\MATLAB\R2012b\bin\win64\smpd.exe smpd.exe
chrome.exe *32 telzur 00 46,536 K 13 5,582 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
chrome.exe *32 telzur 00 5,408 K 13 105 C:\Users\telzur\AppData\Local\Google\Chrome\Application\chrome.exe Google Chrome
UNS.exe *32 SYSTEM 00 1,064 K 13 2 C:\Program Files (x86)\Intel\Intel(R) Management Engine Components\UNS\UNS.exe User Notification Service
Show processes from all users
End Process
Processes: 135 CPU Usage: 51% Physical Memory: 78%

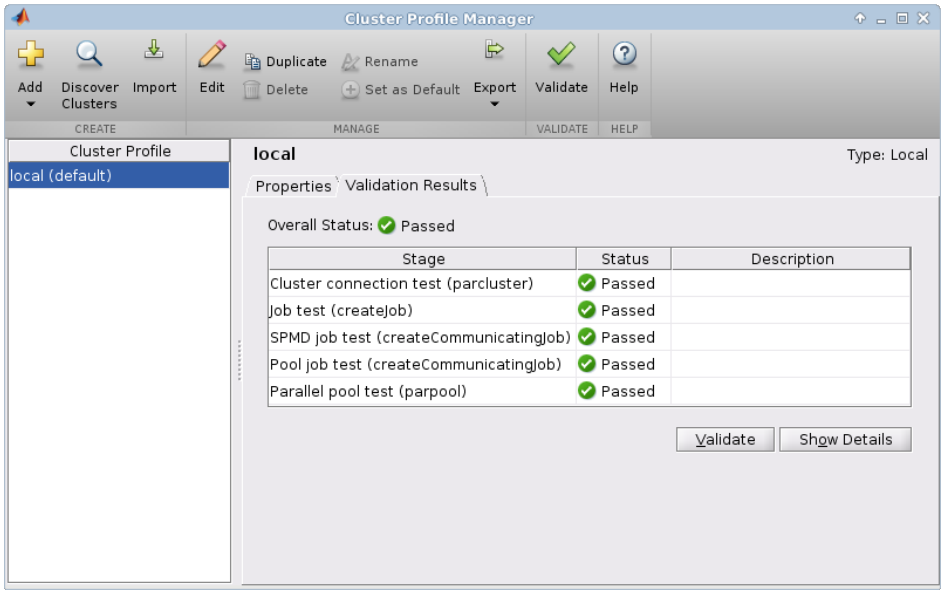
Version 2014a on Linux

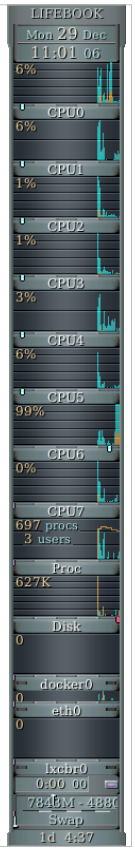






Version 2014a on Linux





parfor - Parallel for loop

parfor - Parallel for loop

Syntax

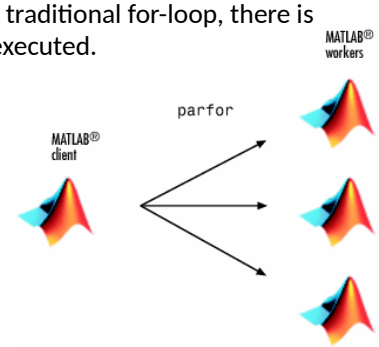
```
parfor loopvar = initval:endval; statements; end
parfor (loopvar = initval:endval, M); statements; end
```

Description

parfor loopvar = initval:endval; statements; end executes a series of MATLAB commands denoted here as statements for values of loopvar between initval and endval, inclusive, which specify a vector of increasing integer values. Unlike a traditional for-loop, there is no guarantee of the order in which the loop iterations are executed.

The general format of a parfor statement is:

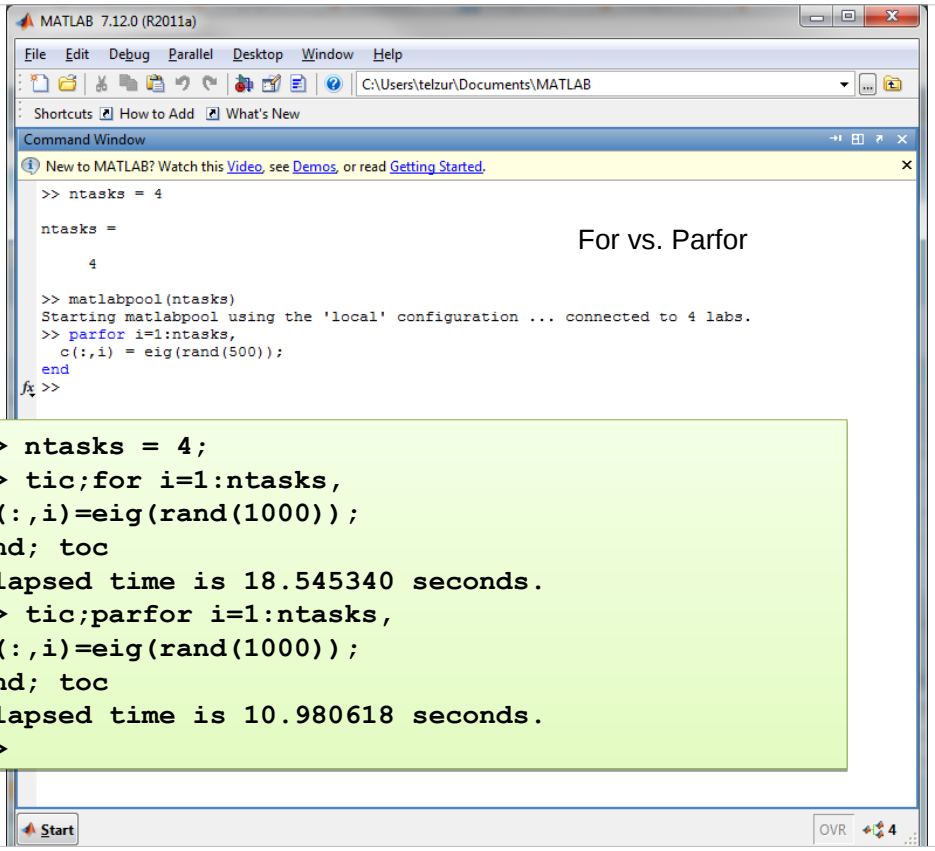
```
parfor loopvar = initval:endval
    <statements>
end
```



parfor – an example

Perform three large eigenvalue computations using three computers or cores:

```
ntasks = 4
matlabpool(ntasks)
parfor i=1:ntasks,
  c(:,i) = eig(rand(500));
end
```



For vs. Parfor

```
>> ntasks = 4;
>> tic;for i=1:ntasks,
c(:,i)=eig(rand(1000));
end; toc
Elapsed time is 18.545340 seconds.
>> tic;parfor i=1:ntasks,
c(:,i)=eig(rand(1000));
end; toc
Elapsed time is 10.980618 seconds.
>>
```

Editor - /home/telzur/Documents/Teaching/BGU/PP/PP2015A/lect

parallel1.m | parallel0.m

```
1 -   disp('Serial computation');
2 -   ntasks=4;
3 -   tic; for i=1:ntasks, c(:,i)=eig(rand(1000));
4 -   end;toc
5
6 -   size(c)
7
8 -   disp('parallel computation');
9 -   delete(gcp);
10 -  parpool('local');
11 -  tic;parfor i=1:ntasks, d(:,i)=eig(rand(1000));
12 -  end;toc
13 -  matlabpool('close')
14
15 -  size(d)
```

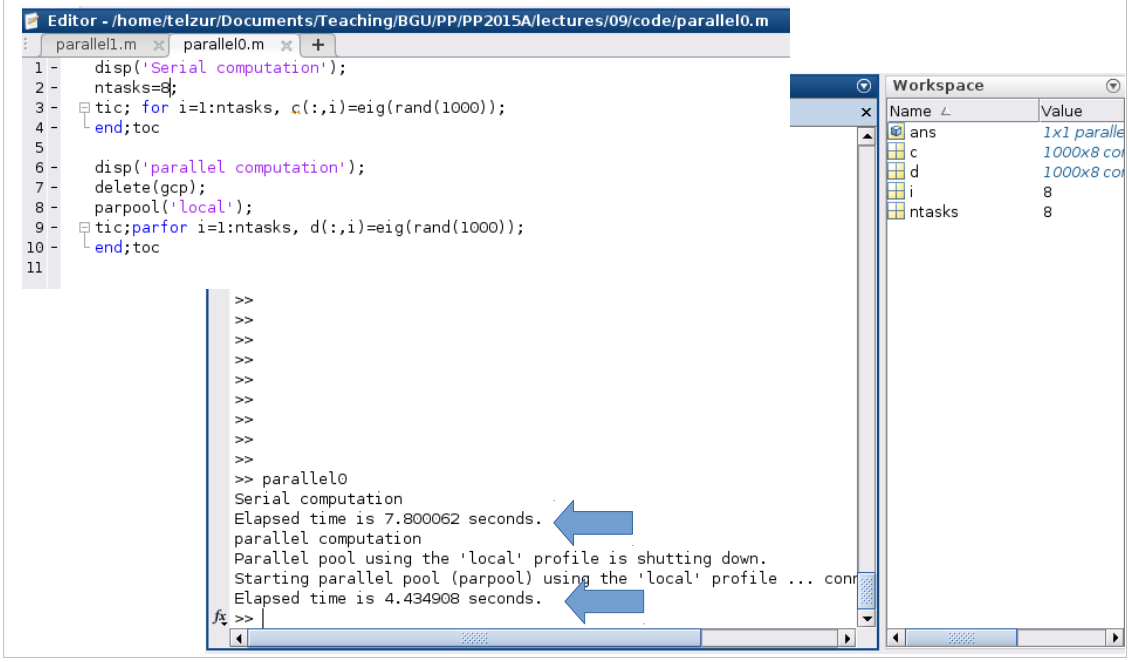
Demo: …/lecture09/code/parallel0.m

4 tasks

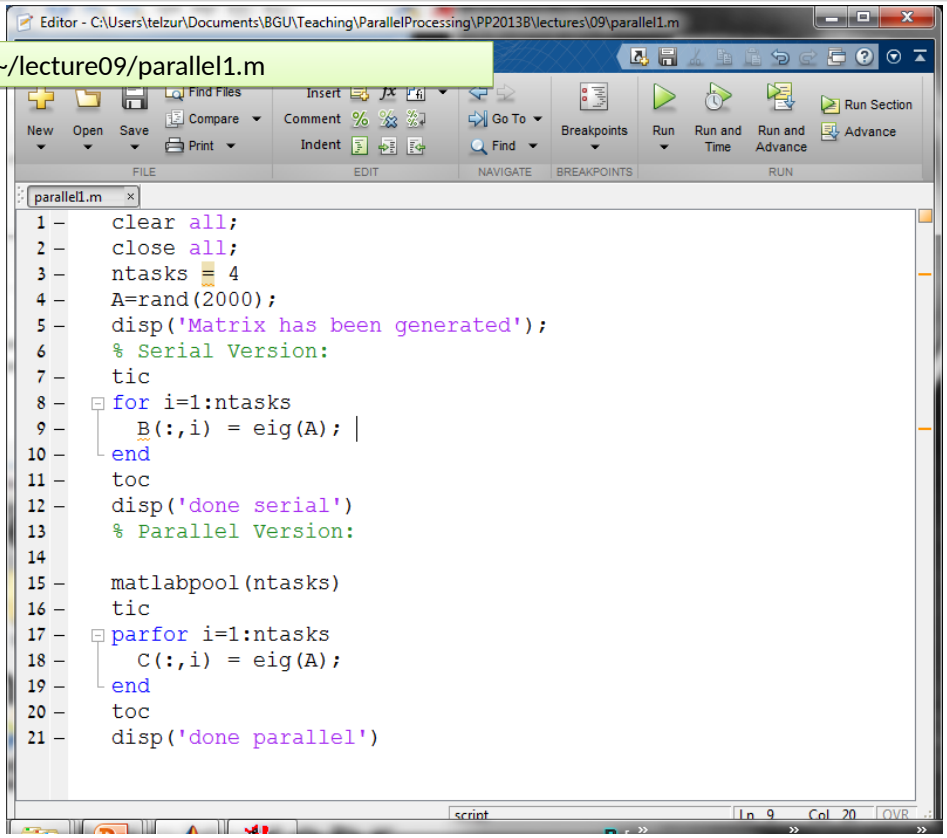
```
>>
>> parallel0
Serial computation
Elapsed time is 3.374473 seconds.

ans =

        1000           4

parallel computation
Starting parallel pool (parpool) using the 'local' profile ... co
Parallel pool using the 'local' profile is shutting down.
Starting parallel pool (parpool) using the 'local' profile ... co
Elapsed time is 2.445419 seconds.
Warning: matlabpool will be removed in a future release.
To shutdown a parallel pool use 'delete(gcp('nocreate'))'
instead.
Parallel pool using the 'local' profile is shutting down.

ans =

        1000           4
```

Version 2014a on Linux (i7 processor)

8 tasks



Demo: ~/lecture09/parallel1.m



Profile Summary

Generated 26-May-2013 21:12:07 using cpu time

Function Name	Calls	**Total Time**	Self Time*	Total Time Plot (dark band = self time)
parallel1	1	56.691 s	28.421 s	
parallel_function	1	18.380 s	0.022 s	
parallel_function>distributed_execution	1	18.230 s	0.079 s	
...omp.remoteparfor.getCompleteIntervals	3	18.125 s	0.038 s	
java.util.concurrent.LinkedBlockingQueue (Java method)	20	18.067 s	18.067 s	
matlabpool	1	9.890 s	0.076 s	
MatlabpoolHelper>MatlabpoolHelper.doOpen	1	9.152 s	0.018 s	
...lHelper>MatlabpoolHelper.doMatlabpool	1	9.152 s	0.000 s	
distcomp.interactiveclient.start	1	9.123 s	0.051 s	
distcomp.interactiveclient.pGetSockets	1	8.145 s	0.001 s	
...ient.pGetSockets>iGetSingleConnection	2	8.144 s	7.808 s	
...parseInputsAndCheckOutputsForFunction	1	0.649 s	0.001 s	
...atlabpoolHelper.parseMatlabpoolInputs	1	0.636 s	0.008 s	
...er>ProfileConfigHelper.buildScheduler	1	0.459 s	0.003 s	
parcluster	1	0.456 s	0.080 s	
...lusterAdaptor>iCreateCommunicatingJob	1	0.311 s	0.005 s	
Job.Job>Job.submit	1	0.308 s	-0.000 s	
...gJob>CJSCommunicatingJob.submitOneJob	1	0.297 s	0.011 s	
Local.hSubmitCommunicatingJob	1	0.280 s	0.013 s	
Local.Local>Local.Local	1	0.209 s	0.018 s	
Cluster.createCommunicatingJob	1	0.184 s	0.002 s	
...hworks.toolbox.distcomp.pmode.Session (Java method)	25	0.174 s	0.174 s	
CJSCluster>CJSCluster.CJSCluster	1	0.169 s	0.048 s	
etime	1036	0.169 s	0.169 s	
CJSSupport>CJSSupport.getProperties	31	0.153 s	0.012 s	
ProfileConfigHelper>iGetDefaultProfile	1	0.149 s	0.000 s	
...er>ProfileConfigHelper.getDefaultName	1	0.149 s	0.000 s	
...Helper>MatlabpoolHelper.checkConfigOk	1	0.149 s	0.000 s	
...oolHelper.checkConfigOk(profHelper,x)	1	0.149 s	0.000 s	
CJSJobMixin>CJSJobMixin.hGetProperty	36	0.144 s	0.003 s	

parallel1 (1 **call**, 56.691 **sec**)

Generated 26-May-2013 21:15:20 using cpu time.

script in file C:\Users\telzur\Documents\BGU\Teaching\ParallelProcessing\PP2013B\lectures\09\parallel1.m

Copy to new window for comparing multiple runs

This function changed during profiling or before generation of this report. Results may be incomplete or inaccurate.

Refresh

☑ Show parent functions ☑ Show busy lines ☑ Show child functions

☑ Show Code Analyzer results ☑ Show file coverage ☑ Show function listing

Parents (calling functions)

No parent

Lines where the most time was spent

Line Number	Code	Calls	Total Time	% Time	Time Plot
9	`B(:,i) = eig(A);`	2	28.011 s	49.4%	
17	`parfor i=1:ntasks`	1	18.471 s	32.6%	
15	`matlabpool(ntasks)`	1	9.894 s	17.5%	
1	`clear all;`	1	0.195 s	0.3%	
4	`A=rand(2000);`	1	0.085 s	0.1%	
All other lines			0.035 s	0.1%	
Totals			56.691 s	100%	

Children (called functions)

Function Name	Function Type	Calls	Total Time	% Time	Time Plot
parallel_function	function	1	18.380 s	32.4%	
matlabpool	function	1	9.890 s	17.4%	
parfor_endpoint_check	function	2	0 s	0%	
parfor_sliced_fcnhdl_check	function	1	0 s	0%	
close	function	1	0 s	0%	
Self time (built-ins, overhead, etc.)			28.421 s	50.1%	
Totals			56.691 s	100%	

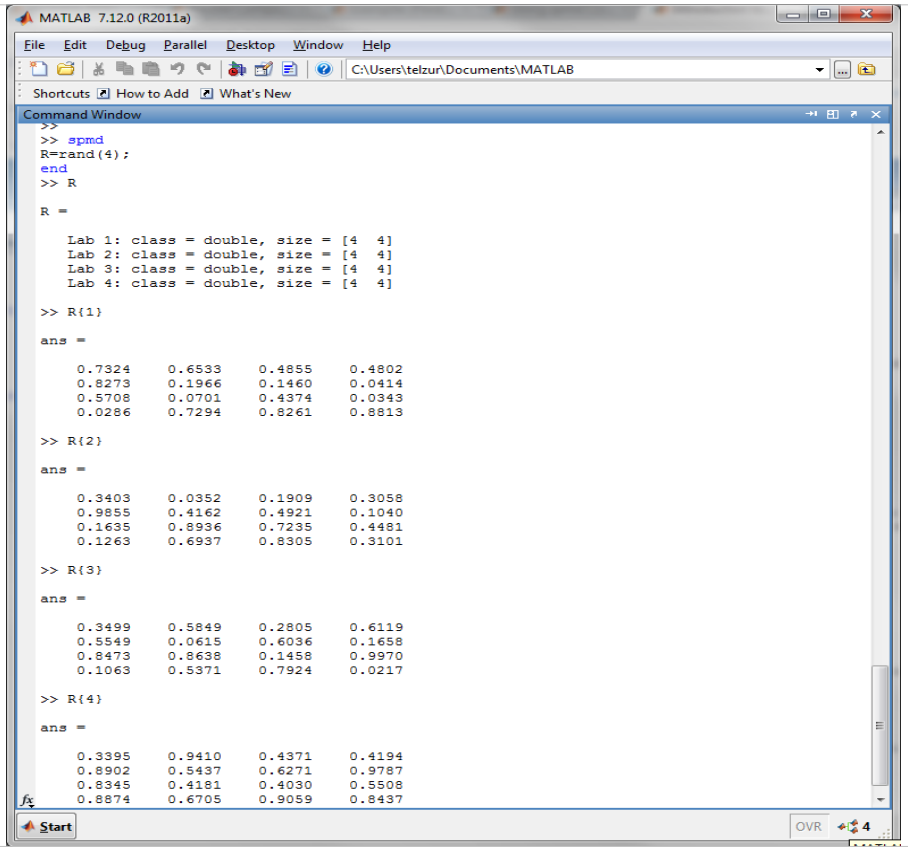
Parallel1.m
8 tasks on core i7

Editor - /home/telzur/Documents/Teaching/BGU/

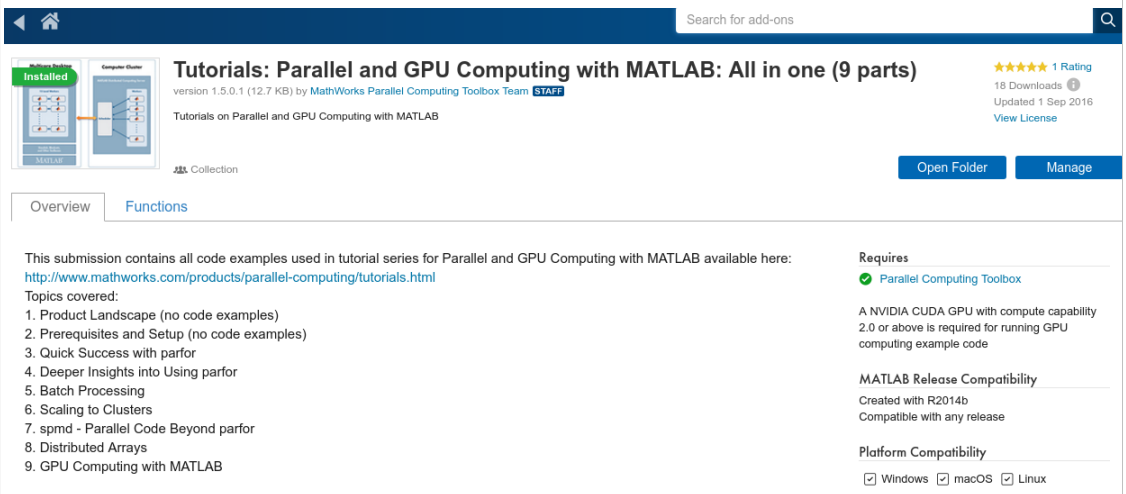
parallel1.m* | parallel0.m

```
1 -   clear all;
2 -   close all;
3 -   delete(gcp);
4 -   ntasks = 8
5 -   A=rand(2000);
6 -   disp('Matrix has been generated');
7     % Serial Version:
8 -   tic
9 -   for i=1:ntasks
10 -    B(:,i) = eig(A);
11 -  end
12 -  toc
13 -  disp('done serial')
14    % Parallel Version:
15 -  matlabpool('local',ntasks)
16 -  tic
17 -  parfor i=1:ntasks
18 -    C(:,i) = eig(A);
19 -  end
20 -  toc
21 -  disp('done parallel')
```

```
>> close all
>> clear all
>> parallel1
Parallel pool using the 'local' profile is shutting
down.

ntasks =

     8

Matrix has been generated
Elapsed time is 31.812732 seconds.
done serial
Warning: matlabpool will be removed in a future
release.
Use parpool instead.
Starting matlabpool using the 'local' profile ...
connected to 8 workers.
Elapsed time is 19.150792 seconds.
done parallel
>>
```

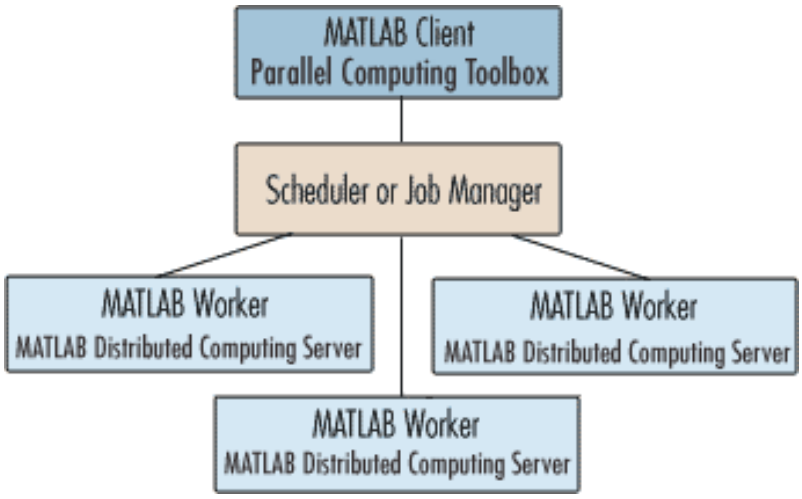

MATLAB 7.12.0 (R2011a)
File Edit Debug Parallel Desktop Window Help
C:\Users\telzur\Documents\MATLAB
Shortcuts How to Add What's New
Command Window
>>
>> spmd
R=rand(4);
end
>> R
R =
Lab 1: class = double, size = [4 4]
Lab 2: class = double, size = [4 4]
Lab 3: class = double, size = [4 4]
Lab 4: class = double, size = [4 4]
>> R{1}
ans =
0.7324 0.6533 0.4855 0.4802
0.8273 0.1966 0.1460 0.0414
0.5708 0.0701 0.4374 0.0343
0.0286 0.7294 0.8261 0.8813
>> R{2}
ans =
0.3403 0.0352 0.1909 0.3058
0.9855 0.4162 0.4921 0.1040
0.1635 0.8936 0.7235 0.4481
0.1263 0.6937 0.8305 0.3101
>> R{3}
ans =
0.3499 0.5849 0.2805 0.6119
0.5549 0.0615 0.6036 0.1658
0.8473 0.8638 0.1458 0.9970
0.1063 0.5371 0.7924 0.0217
>> R{4}
ans =
0.3395 0.9410 0.4371 0.4194
0.8902 0.5437 0.6271 0.9787
0.8345 0.4181 0.4030 0.5508
0.8874 0.6705 0.9059 0.8437
Start
OVR
4

optional



https://www.mathworks.com/videos/series/parallel-and-gpu-computing-tutorials-97719.html

Parallel Computing Toolbox and MATLAB Distributed Computing



Parallel Computing with Matlab on Amazon Cloud

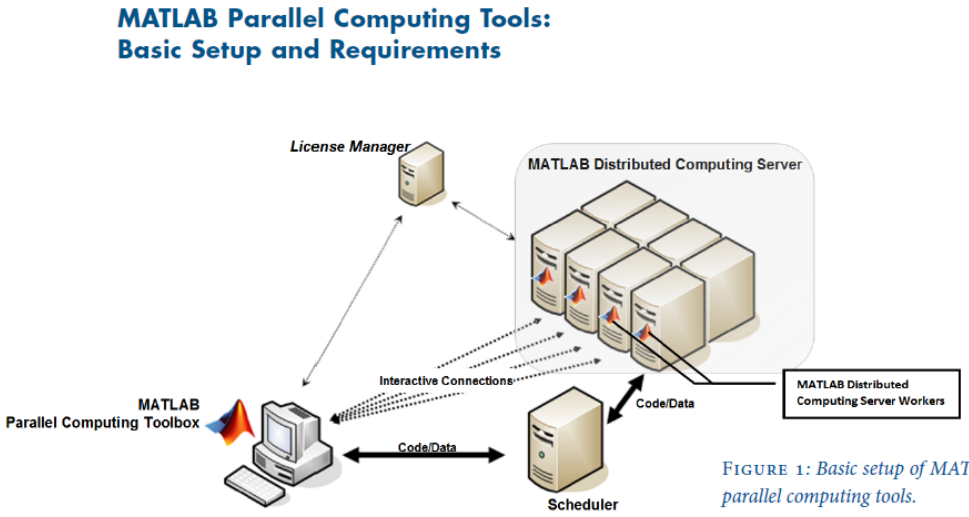


FIGURE 1: *Basic setup of MATLAB parallel computing tools.*

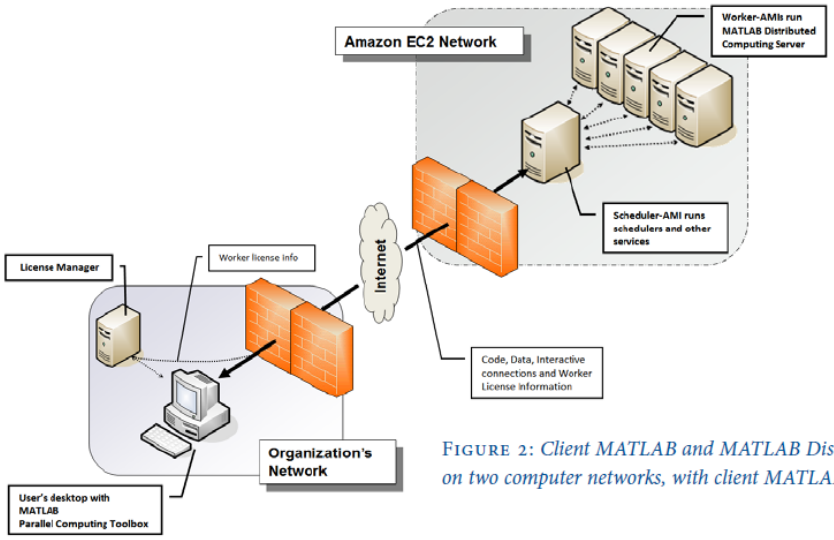


FIGURE 2: *Client MATLAB and MATLAB Distributed Computing Server on two computer networks, with client MATLAB on a user's desktop.*

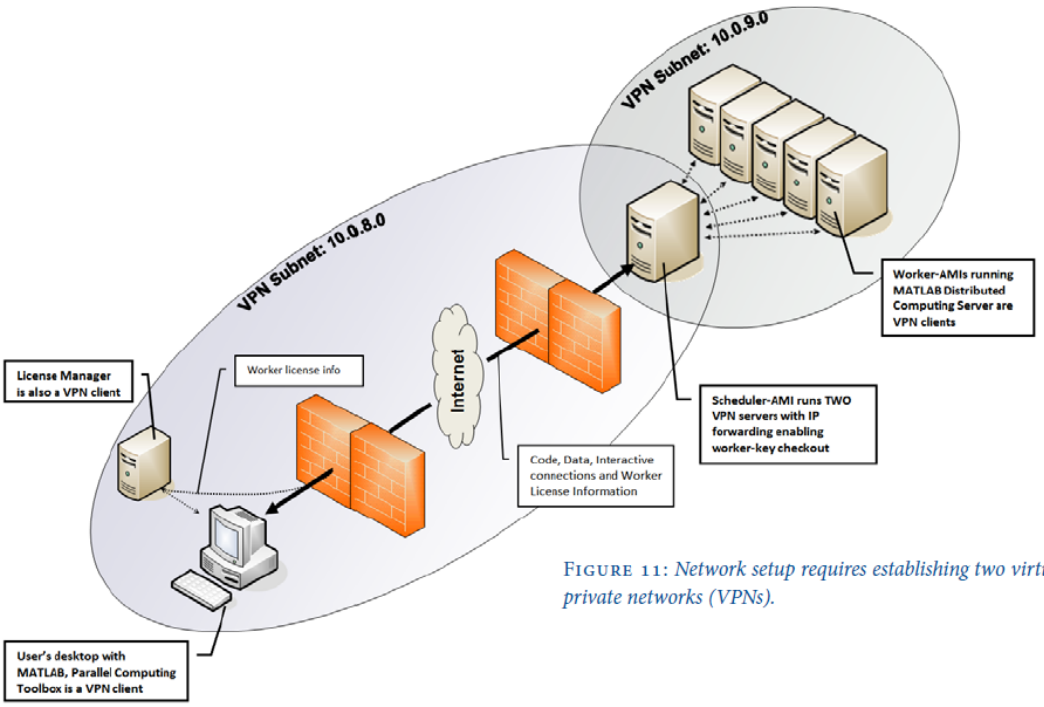


FIGURE 11: *Network setup requires establishing two virtual private networks (VPNs).*

Matlab and GPU computing

~/.../lectures/08/matlab_code

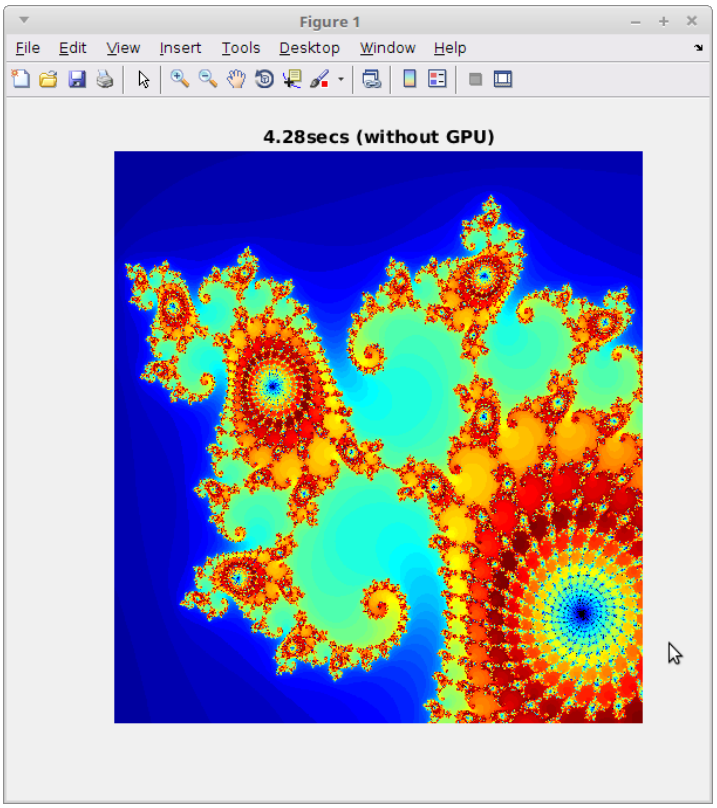


Figure 1
File Edit View Insert Tools Desktop Window Help
4.28secs (without GPU)

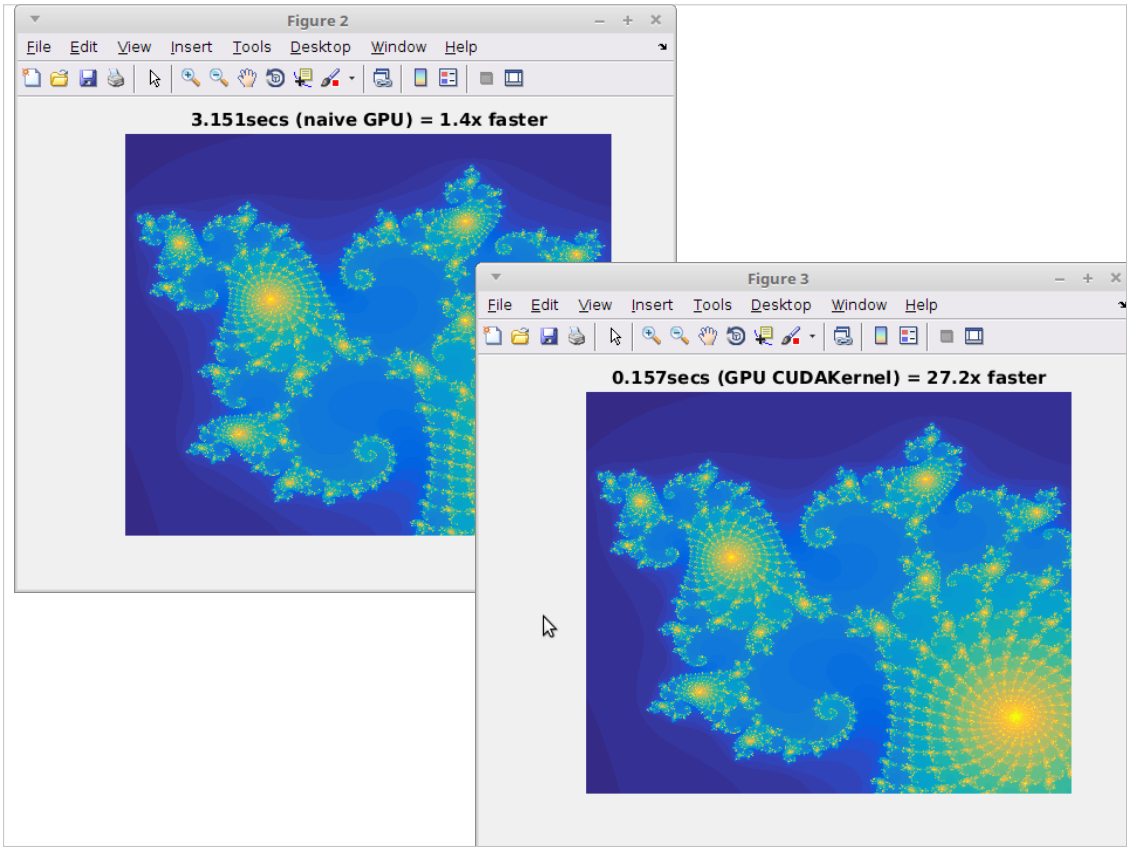
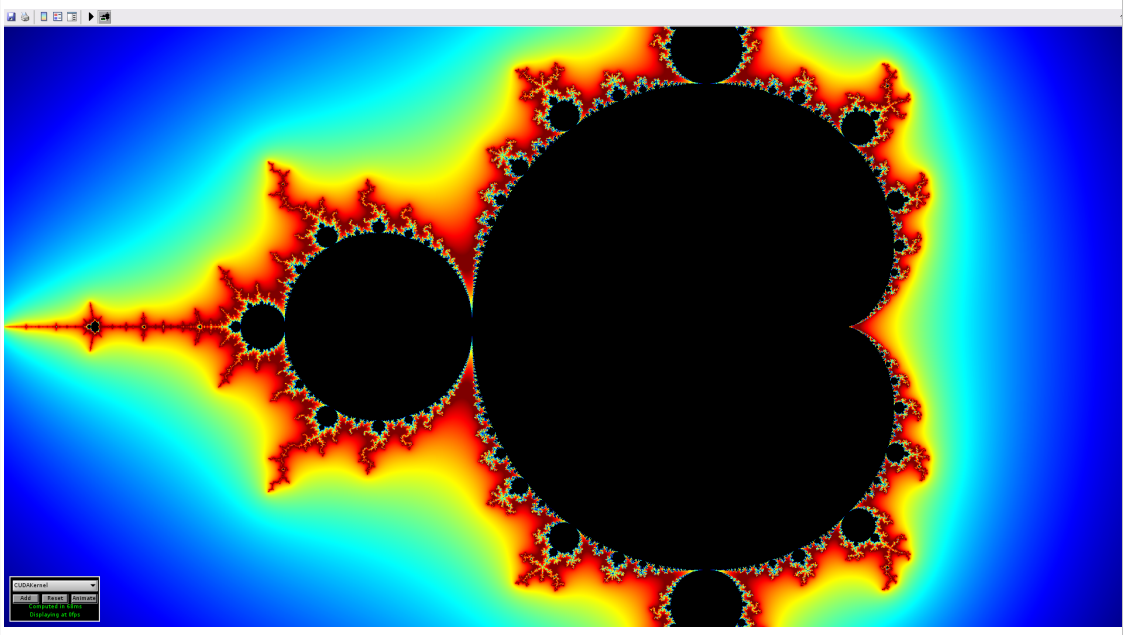


Figure 2
File Edit View Insert Tools Desktop Window Help
3.151secs (naive GPU) = 1.4x faster

Figure 3
File Edit View Insert Tools Desktop Window Help
0.157secs (GPU CUDAKernel) = 27.2x faster

MandelbrotViewer



Let's try this

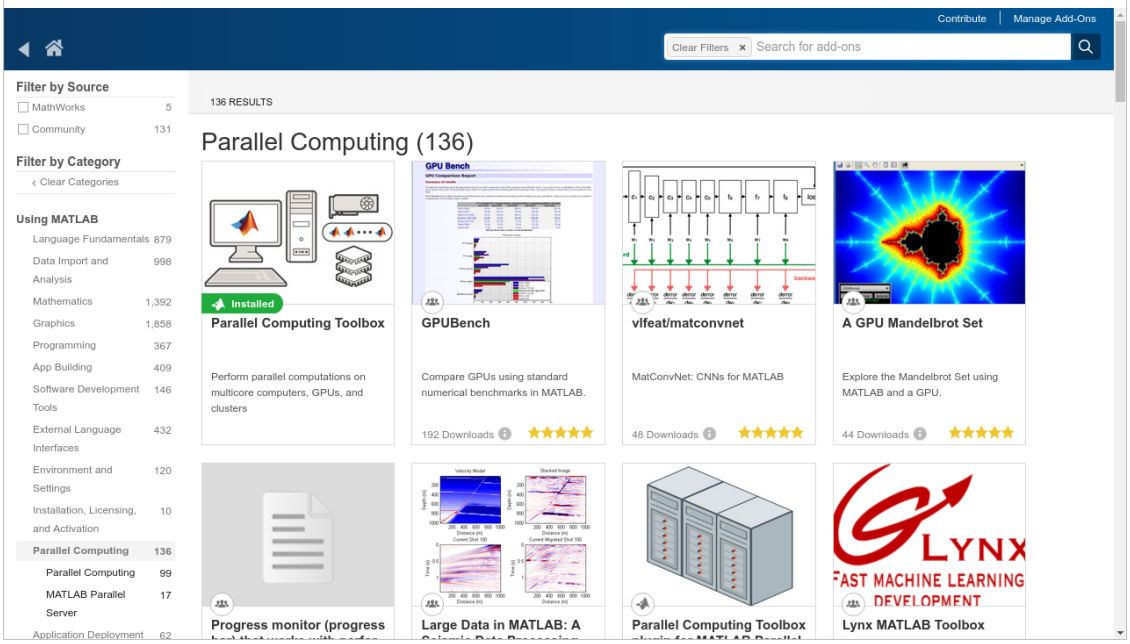
```
A = rand(100, GPUsingle); % A is on GPU memory
B = rand(100, GPUsingle); % B is on GPU memory
C = A+B; % executed on GPU.
D = fft(C); % executed on GPU
```

Executed on GPU

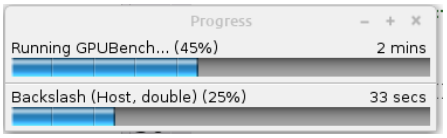
```
A = single(rand(100)); % A is on CPU memory
B = single(rand(100)); % B is on CPU memory
C = A+B; % executed on CPU.
D = fft(C); % executed on CPU
```

Executed on CPU

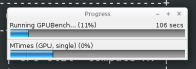
Matlab Parallel Addons



gpuBench




```
Processes:                                                       GPU Memory |
 GPU       PID   Type   Process name                             Usage      |
=============================================================================|
    0      2295      G   /usr/lib/xorg/Xorg                          732MiB |
    0      7182      G   ...equest-channel-token=815668599560060867   216MiB |
    0     21154    C+G   ...afa3f6f93/opt/MATLAB/bin/glnxa64/MATLAB   313MiB |
    0     21831      G   ...-token=2ED3348AA2873F9C2157CE208F1F8CA6     1MiB |
    0     21979      G   ...-token=301B7597A0DDCD1D126B2777E7CEA836    17MiB |
+-----------------------------------------------------------------------------+
Fri Oct  4 14:30:31 2019
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 430.26       Driver Version: 430.26                              |
|-------------------------------+----------------------+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|===============================+======================+======================|
|   0  GeForce GTX 1050    Off  | 00000000:01:00.0 Off |                  N/A |
| N/A   62C    P0    N/A /  N/A |   1986MiB /  4042MiB |    100%      Default |
+-------------------------------+----------------------+----------------------+
```




```
Processes:                                                       GPU Memory |
 GPU       PID   Type   Process name                             Usage      |
=============================================================================|
    0      2295      G   /usr/lib/xorg/Xorg                          732MiB |
    0      7182      G   ...equest-channel-token=815668599560060867   216MiB |
    0     21154    C+G   ...afa3f6f93/opt/MATLAB/bin/glnxa64/MATLAB  1015MiB |
    0     21831      G   ...-token=2ED3348AA2873F9C2157CE208F1F8CA6     1MiB |
    0     21979      G   ...-token=301B7597A0DDCD1D126B2777E7CEA836    17MiB |
+-----------------------------------------------------------------------------+
```

```
File  Edit  View  Search  Terminal  Help
top - 13:14:28 up 10 days, 19:09,  1 user,  load average: 3.86
Tasks: 424 total,   1 running, 333 sleeping,   0 stopped,   5
%Cpu0  : 98.7 us,  1.0 sy,  0.0 ni,  0.3 id,  0.0 wa,  0.0 hi,
%Cpu1  : 98.7 us,  1.0 sy,  0.0 ni,  0.3 id,  0.0 wa,  0.0 hi,
%Cpu2  :  5.2 us,  1.4 sy,  0.0 ni, 93.4 id,  0.0 wa,  0.0 hi,
%Cpu3  : 99.0 us,  0.7 sy,  0.0 ni,  0.3 id,  0.0 wa,  0.0 hi,
%Cpu4  :  4.8 us,  1.7 sy,  0.0 ni, 93.5 id,  0.0 wa,  0.0 hi,
%Cpu5  :  4.1 us,  3.4 sy,  0.0 ni, 92.1 id,  0.3 wa,  0.0 hi,
%Cpu6  : 98.7 us,  1.3 sy,  0.0 ni,  0.0 id,  0.0 wa,  0.0 hi,
%Cpu7  :  4.4 us,  2.7 sy,  0.0 ni, 92.6 id,  0.3 wa,  0.0 hi,
KiB Mem : 16304712 total,   323108 free, 14073992 used,  1907612 buff/cache
KiB Swap: 16659452 total, 15949552 free,   709900 used.  1235908 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU %MEM     TIME+ COMMAND
21154 telzur    20   0 23.497g 3.097g 191124 S 399.0 19.9   9:20.86 MATLAB
 2295 root      20   0 1278804 365348 116224 S   7.9  2.2  71:46.78 Xorg
 6325 netdata   20   0   18976   5708   2040 S   3.3  0.0   2:03.39 apps.plugin
25268 telzur    20   0  422408  30760  24132 S   2.6  0.2   0:00.43 mate-scree+
20259 telzur    20   0  533660  30808  12976 S   1.7  0.2   1:38.82 wnck-applet
13327 telzur    20   0 4837236 1.286g  73004 S   1.3  8.3  12:24.06 soffice.bin
20245 telzur    20   0  878104  35008  10948 S   1.3  0.2   8:37.05 marco
 2715 netdata   20   0  206856  56076   3032 S   1.0  0.3  57:20.62 netdata
 7894 telzur    20   0 2092164 227316  16952 S   1.0  1.4   4:06.71 chromium-b+
23053 telzur    20   0  598156  39100  21508 S   1.0  0.2   1:41.75 mate-termi+
```

GPU Bench

GPU Comparison Report: Intel(R) Core(TM) i7-7700HQ CPU @ 2.80GHz

Summary of results

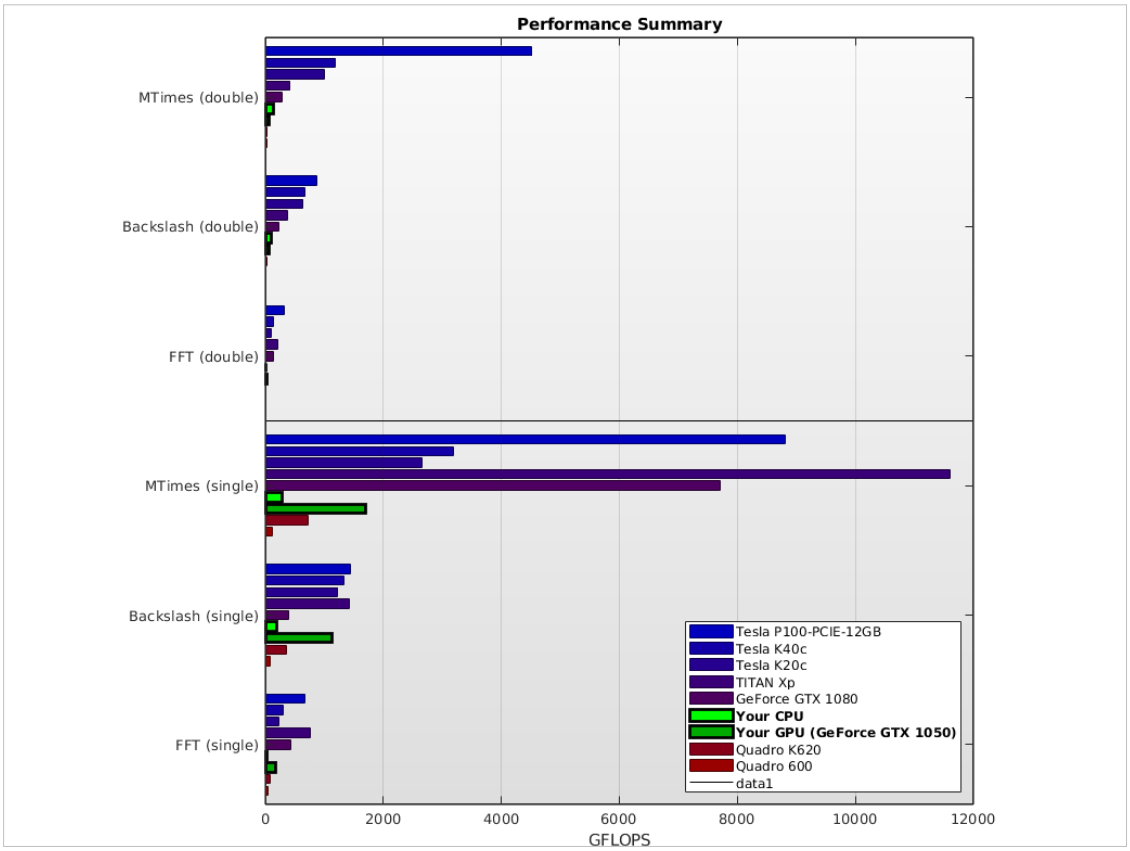
The table and chart below show the peak performance of various GPUs using the same MATLAB version. Your results (if any) are highlighted in bold in the table and on the chart. All other results are from pre-stored data. The peak performance shown is usually achieved when dealing with extremely large arrays. Typical performance in day-to-day use will usually be much lower.

Results captured using the CPUs on the host PC (i.e. without using a GPU) are included for comparison.

Since MATLAB works mostly in double precision the devices are ranked according to how well they perform double-precision calculations. Single precision results are included for completeness. For all results, higher is better.

	Results for data-type 'double' (In GFLOPS)			Results for data-type 'single' (In GFLOPS)		
	MTimes	Backslash	FFT	MTimes	Backslash	FFT
Tesla P100-PCIE-12GB	4518.23	878.97	313.43	8807.20	1439.15	676.20
Tesla K40c	1189.54	677.12	135.88	3187.76	1334.17	294.86
Tesla K20c	1004.06	641.42	106.09	2657.01	1230.28	235.20
TITAN Xp	422.47	371.37	207.24	11607.69	1426.76	763.56
GeForce GTX 1080	280.84	223.05	137.66	7707.01	399.37	424.60
Your CPU	**137.45**	**96.16**	**14.72**	**285.93**	**199.74**	**21.16**
Your GPU (GeForce GTX 1050)	**61.24**	**55.61**	**31.65**	**1699.35**	**1131.12**	**181.04**
Quadro K620	25.45	22.77	12.75	716.71	350.31	75.00
Quadro 600	19.71	17.55	7.62	117.99	88.64	38.58

(click any device name or result to see the detailed data)


Performance Summary
MTimes (double)
Backslash (double)
FFT (double)
MTimes (single)
Backslash (single)
FFT (single)
Tesla P100-PCIE-12GB
Tesla K40c
Tesla K20c
TITAN Xp
GeForce GTX 1080
Your CPU
Your GPU (GeForce GTX 1050)
Quadro K620
Quadro 600
data1
0
2000
4000
6000
8000
10000
12000
GFLOPS

GPU results

Results for Backslash (double)

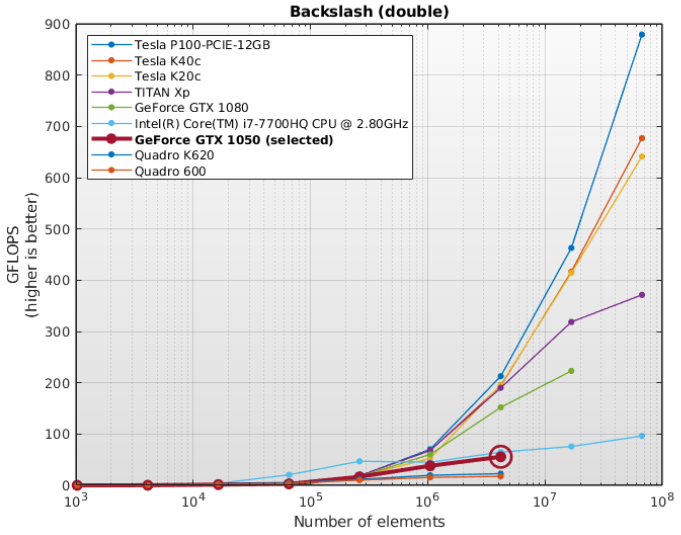
These results show the performance of the GPU or host PC when calculating the matrix left division of an `NxN` matrix with an `Nx1` vector. The number of operations is assumed to be `2/3*N^3 + 3/2*N^2`.

This calculation is usually compute-bound, i.e. the performance depends mainly on how fast the GPU or host PC can perform floating-point operations.

Raw data for GeForce GTX 1050 - Backslash (double)

Array size (elements)	Num Operations	Time (ms)	GigaFLOPS
1,024	23,381	2.94	0.01
4,096	180,907	1.22	0.15
16,384	1,422,677	1.02	1.40
65,536	11,283,115	4.17	2.71
262,144	89,871,701	5.41	16.62
1,048,576	717,400,747	18.84	38.07
4,194,304	5,732,914,517	103.10	55.61

(`N` gigaflops = `Nx10`^{9} operations per second)



Results for Backslash (single)

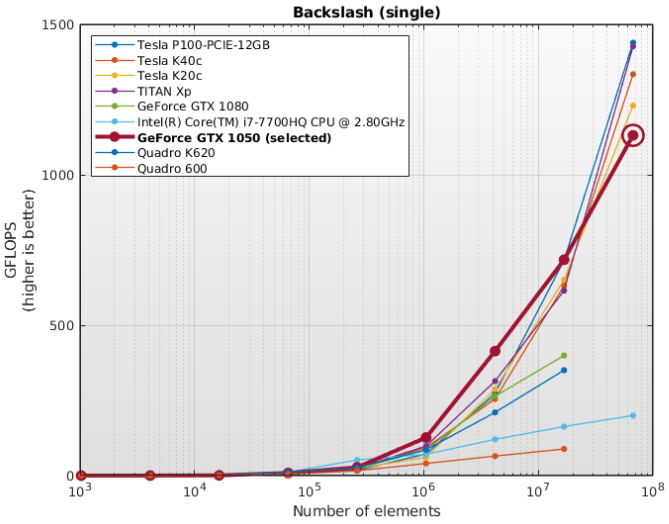
These results show the performance of the GPU or host PC when calculating the matrix left division of an `NxN` matrix with an `Nx1` vector. The number of operations is assumed to be `2/3*N^3 + 3/2*N^2`.

This calculation is usually compute-bound, i.e. the performance depends mainly on how fast the GPU or host PC can perform floating-point operations.

Raw data for GeForce GTX 1050 - Backslash (single)

Array size (elements)	Num Operations	Time (ms)	GigaFLOPS
1,024	23,381	3.47	0.01
4,096	180,907	1.84	0.10
16,384	1,422,677	1.66	0.86
65,536	11,283,115	1.28	8.79
262,144	89,871,701	3.27	27.45
1,048,576	717,400,747	5.67	126.57
4,194,304	5,732,914,517	13.85	413.83
16,777,216	45,838,150,315	63.88	717.55
67,108,864	366,604,539,221	324.11	1131.12

(N gigaflops = $Nx10^9$ operations per second)



Results for FFT (double)

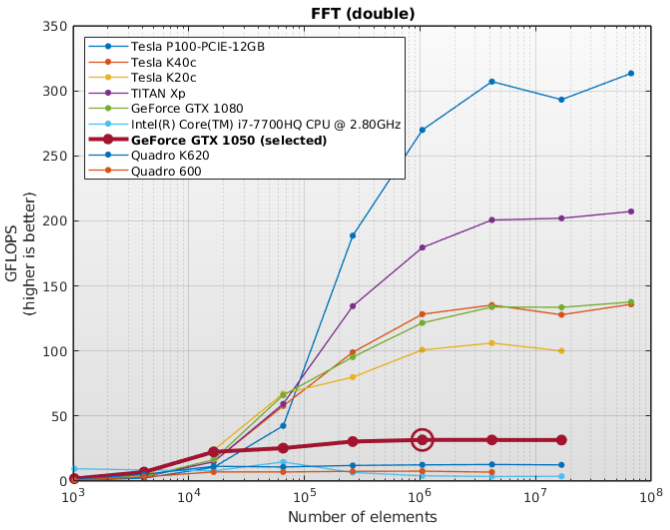
These results show the performance of the GPU or host PC when calculating the Fast-Fourier-Transform of a vector of complex numbers. The number of operations for a vector of length `N` is assumed to be `5*N*log2(N)`.

This calculation is usually memory-bound, i.e. the performance depends mainly on how fast the GPU or host PC can read and write data.

Raw data for GeForce GTX 1050 - FFT (double)

Array size (elements)	Num Operations	Time (ms)	GigaFLOPS
1,024	51,200	0.03	1.87
4,096	245,760	0.04	6.92
16,384	1,146,880	0.05	22.47
65,536	5,242,880	0.21	25.33
262,144	23,592,960	0.78	30.42
1,048,576	104,857,600	3.31	31.65
4,194,304	461,373,440	14.59	31.62
16,777,216	2,013,265,920	63.81	31.55

(`N` gigaflops = `Nx10`^{9} operations per second)



Results for FFT (single)

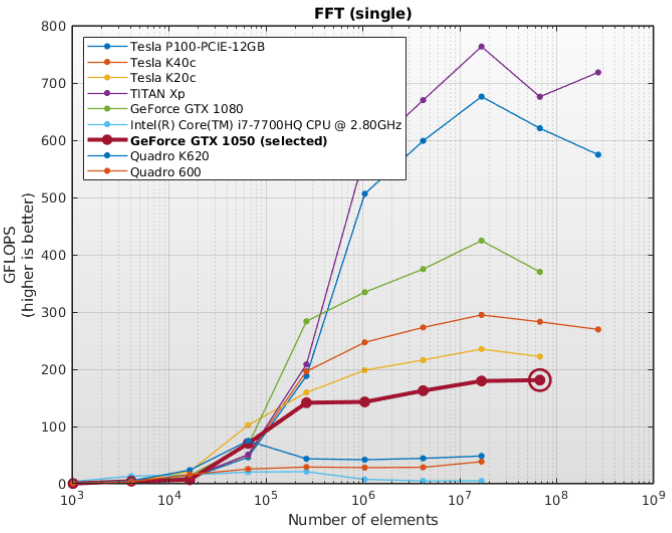
These results show the performance of the GPU or host PC when calculating the Fast-Fourier-Transform of a vector of complex numbers. The number of operations for a vector of length `N` is assumed to be `5*N*log2(N)`.

This calculation is usually memory-bound, i.e. the performance depends mainly on how fast the GPU or host PC can read and write data.

Raw data for GeForce GTX 1050 - FFT (single)

Array size (elements)	Num Operations	Time (ms)	GigaFLOPS
1,024	51,200	0.13	0.41
4,096	245,760	0.06	4.44
16,384	1,146,880	0.17	6.90
65,536	5,242,880	0.07	70.38
262,144	23,592,960	0.17	141.56
1,048,576	104,857,600	0.73	142.94
4,194,304	461,373,440	2.84	162.50
16,777,216	2,013,265,920	11.22	179.50
67,108,864	8,724,152,320	48.19	181.04

(`N` gigaflops = `Nx10`^{9} operations per second)



CPU results

GPU Performance Details: Intel(R) Core(TM) i7-7700HQ CPU @ 2.80GHz

Contents:

System Configuration

MATLAB Release: R2019b

Host

Name	Intel(R) Core(TM) i7-7700HQ CPU @ 2.80GHz
Clock	900.349 MHz
Cache	6144 KB
NumProcessors	4
OSType	Linux
OSVersion	buildd@lgw01-amd64-031

Results for Backslash (double)

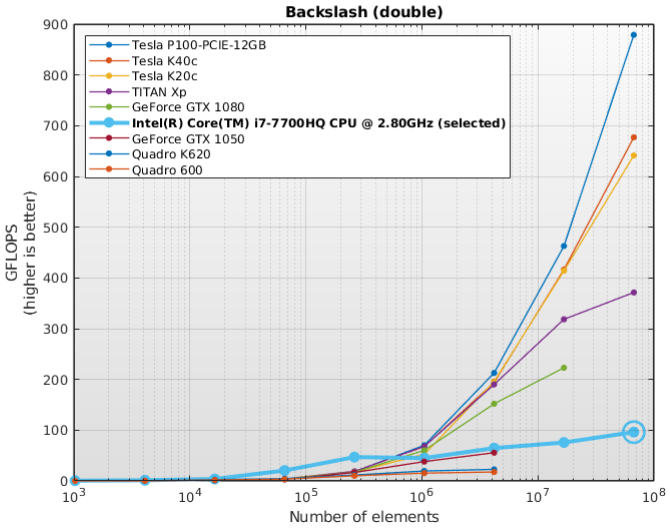
These results show the performance of the GPU or host PC when calculating the matrix left division of an `NxN` matrix with an `Nx1` vector. The number of operations is assumed to be `2/3*N^3 + 3/2*N^2`.

This calculation is usually compute-bound, i.e. the performance depends mainly on how fast the GPU or host PC can perform floating-point operations.

Raw data for Intel(R) Core(TM) i7-7700HQ CPU @ 2.80GHz - Backslash (double)

Array size (elements)	Num Operations	Time (ms)	GigaFLOPS
1,024	23,381	0.05	0.45
4,096	180,907	0.14	1.30
16,384	1,422,677	0.37	3.81
65,536	11,283,115	0.55	20.47
262,144	89,871,701	1.91	46.94
1,048,576	717,400,747	15.93	45.02
4,194,304	5,732,914,517	88.67	64.65
16,777,216	45,838,150,315	605.55	75.70
67,108,864	366,604,539,221	3812.38	96.16

(N gigaflops = $Nx10^9$ operations per second)



MatlabMPI and pMatlab

Parallel Matlab (Octave) using MatlabMPI

Files location: vdwarf - /usr/local/PP/MatlabMPI

Read the README there!

cd to the **examples** directory

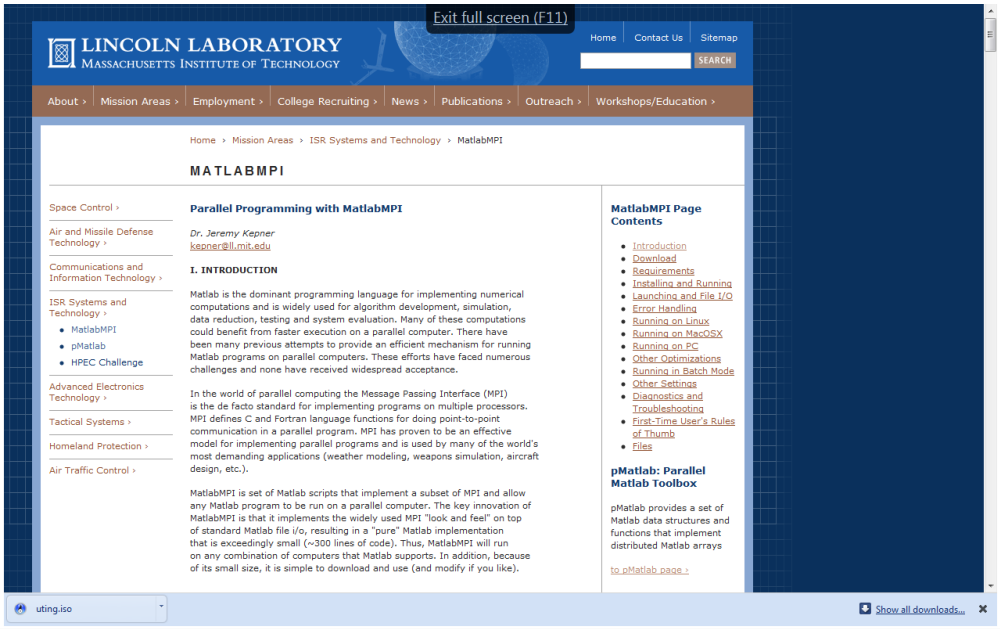
```
eval( MPI_Run('basic', 3,machines) );
```

where:

```
machines = {‘vdwarf1'  ‘vdwarf2‘ ‘vdwrf3’}
```

MatlabMPI

http://www.ll.mit.edu/mission/isr/matlabmpi/matlabmpi.html#introduction

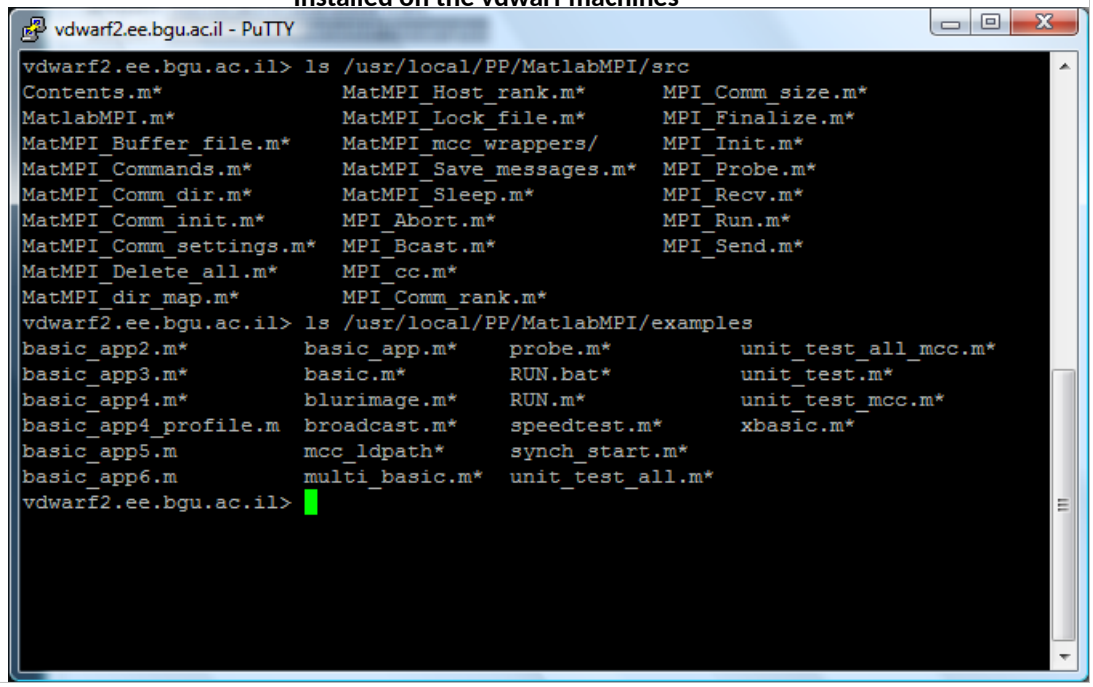


Available examples:

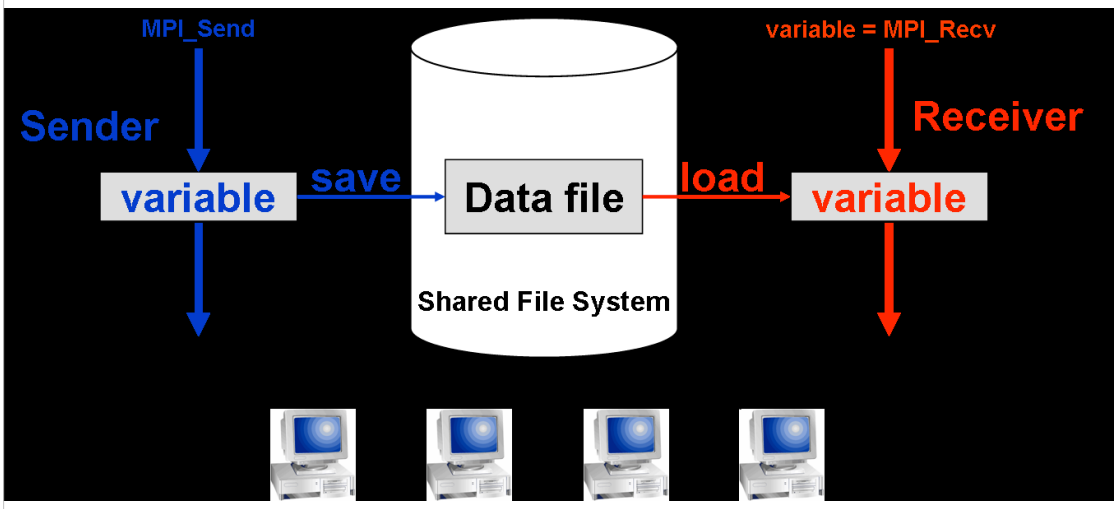
```
   xbasic.m       Extremely simple MatlabMPI program that prints out the rank
of                      each processor.
   basic.m        Simple MatlabMPI program that sends data from processor 1
to             processor 0.
   multi_basic.m   Simple MatlabMPI program that sends data from
                   processor 1 to processor 0 a few times.
   probe.m        Simple MatlabMPI program that demonstrates the
                   using MPI_Probe to check for incoming messages.
   broadcast.m     Tests MatlabMPI broadcast command.
   basic_app.m     Examples of the most common usages of MatlabMPI.
   basic_app2.m    Examples of the most common usages of MatlabMPI.
   basic_app3.m    Examples of the most common usages of MatlabMPI.
   basic_app4.m    Examples of the most common usages of MatlabMPI.
   blurimage.m     MatlabMPI test parallel image processing application.
   speedtest.m     Times MatlabMPI for a variety of messages.
   synch_start.m   Function for synchronizing starts.
   machines.m      Example script for creating a machine description.
   unit_test.m     Wrapper for using an example as a unit test.
   unit_test_all.m Calls all of the examples as way of testing the
                entire library.
   unit_test_mcc.m Wrapper for using an example as a mcc unit test.
   unit_test_all_mcc.m Calls all of the examples using MPI_cc
                as way of testing the entire library.
```

MatlabMPI Demo

Installed on the vdwarf machines

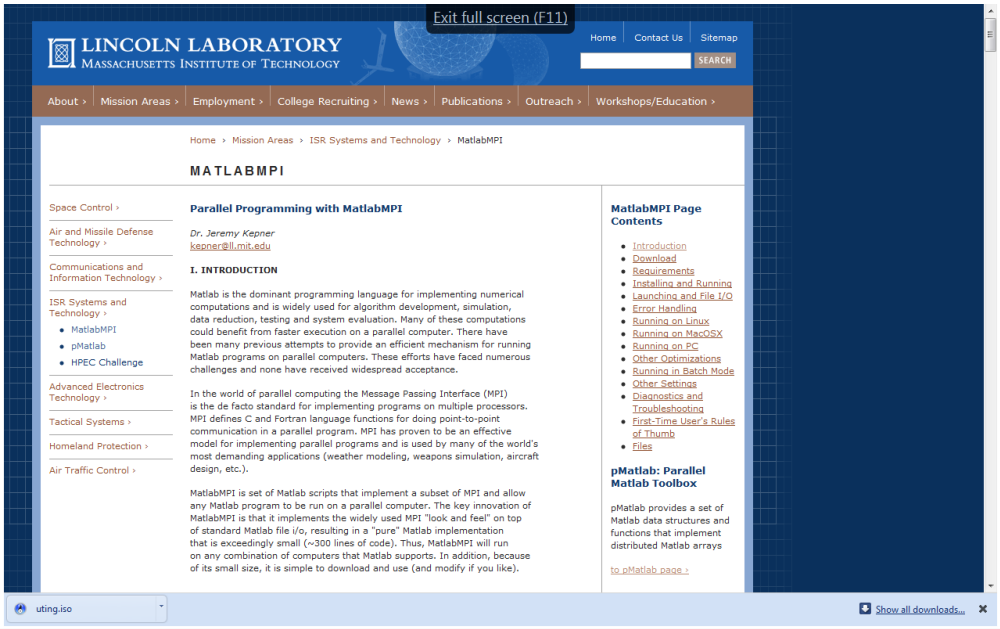


MatlabMPI implements the fundamental communication operations in MPI using MATLAB's file I/O functions.



MatlabMPI

http://www.ll.mit.edu/mission/isr/matlabmpi/matlabmpi.html#introduction



Add to Matlab path:

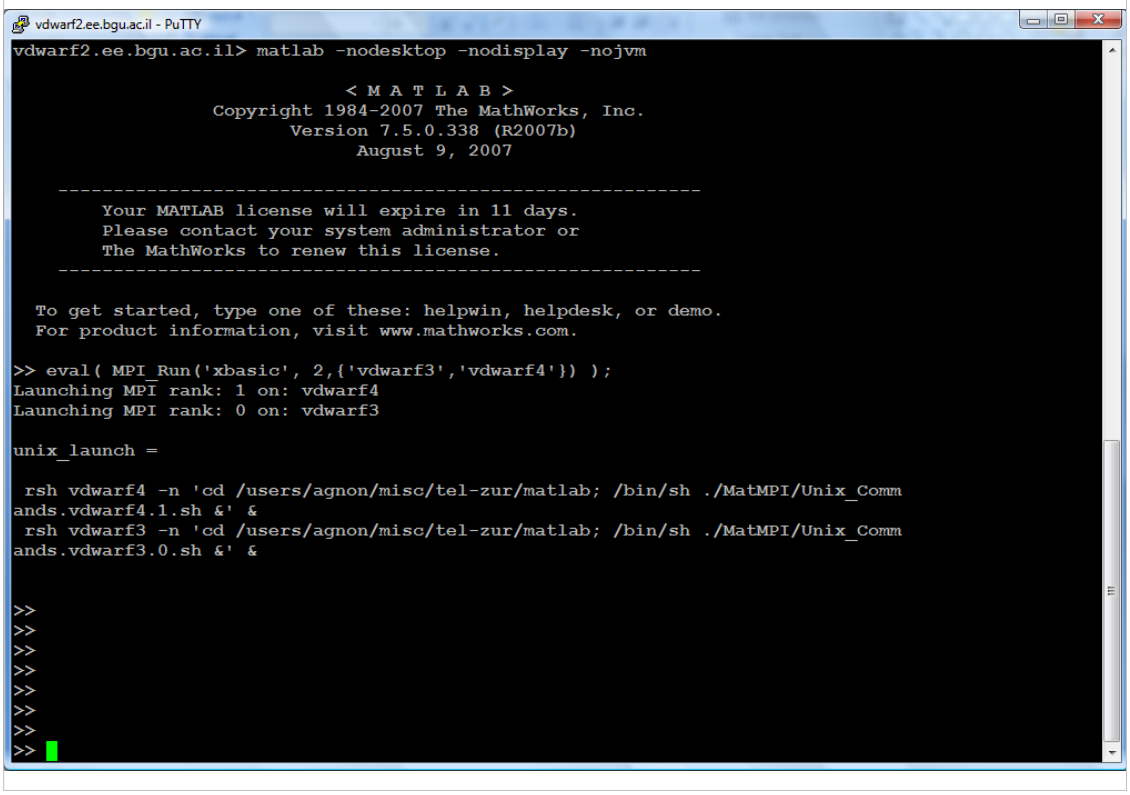
```
vdwarf2.ee.bgu.ac.il> cat startup.m
addpath /usr/local/PP/MatlabMPI/src
addpath /usr/local/PP/MatlabMPI/examples
Addpath ./MatMPI
```

xbasic

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Basic Matlab MPI script that
% prints out a rank.
%
% To run, start Matlab and type:
%
%   eval( MPI_Run('xbasic',2,{}) );
%
% Or, to run a different machine type:
%
%   eval( MPI_Run('xbasic',2,{'machine1' 'machine2'}) );
%
% Output will be piped into two files:
%
%   MatMPI/xbasic.0.out
%   MatMPI/xbasic.1.out
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% MatlabMPI
% Dr. Jeremy Kepner
% MIT Lincoln Laboratory
% kepner@ll.mit.edu
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
% Initialize MPI.
MPI_Init;

% Create communicator.
comm = MPI_COMM_WORLD;

% Modify common directory from default for better performance.
% comm = MatMPI_Comm_dir(comm,'/tmp');

% Get size and rank.
comm_size = MPI_Comm_size(comm);
my_rank = MPI_Comm_rank(comm);

% Print rank.
disp(['my_rank: ',num2str(my_rank)]);

% Wait momentarily.
pause(2.0);

% Finalize Matlab MPI.
MPI_Finalize;
disp('SUCCESS');
if (my_rank ~= MatMPI_Host_rank(comm))
  exit;
end
```

Demo folder ~/matlab/, watch top at the other machine



Parallel Matlab (Octave) using pMatlab

Global arrays – "…Communication is hidden from the programmer; arrays are automatically redistributed when necessary, without the knowledge of the programmer…"

"…The ultimate goal of pMatlab is to move beyond basic messaging (and its inherent programming complexity) towards higher level parallel data structures and functions, allowing any MATLAB user to parallelize their existing program by simply changing and adding a few lines,

Source: http://www.ll.mit.edu/mission/isr/pmatlab/pMatlab_intro.pdf

Instead of:

```
if (my_rank==0) | (my_rank==1) | (my_rank==2) | (my_rank==3)
  A_local=rand(M,N/4);
end

if (my_rank==4) | (my_rank==5) | (my_rank==6) | (my_rank==7)
  B_local=zeros(M/4,N);
end

tag = 0;
if (my_rank==0) | (my_rank==1) | (my_rank==2) | (my_rank==3)
   A_local=fft(A_local);
   for ii = 0:3
      MPI_Send(ii+4, tag, comm, A_local(ii*M/4 + 1:(ii+1)*M/4,:));
   end
end

if (my_rank==4) | (my_rank==5) | (my_rank==6) | (my_rank==7)
   for ii = 0:3
      B_local(:, ii*N/4 + 1:(ii+1)*N/4) = MPI_Recv(ii, tag, comm);
   end
end
```

Write using pMatlab:

```
mapA = map([1 4],{},[0:3]);
mapB = map([4 1],{},[4:7]);
A = rand(M,N,mapA);
B = zeros(M,N,mapB);
B(:,:) = fft(A);
```

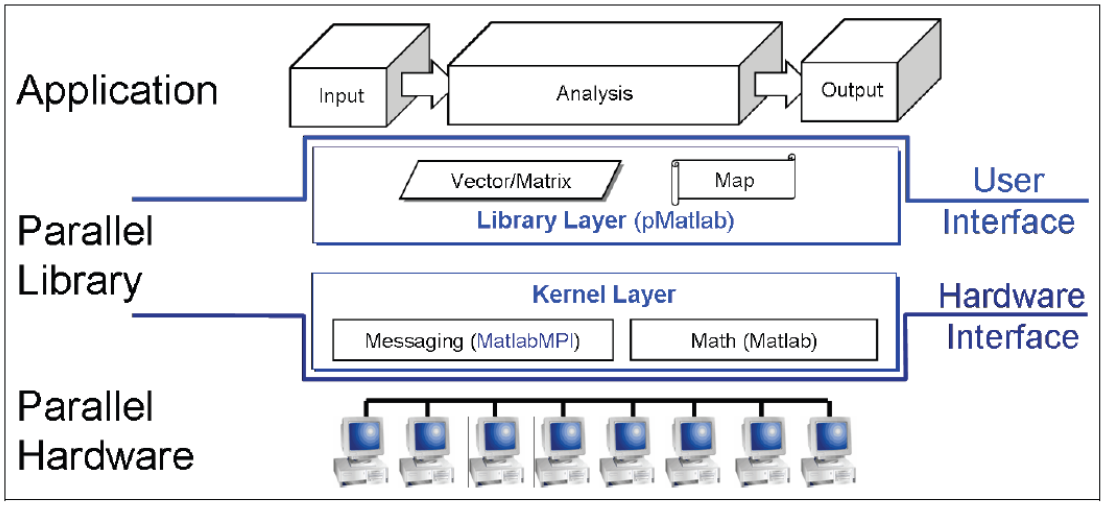
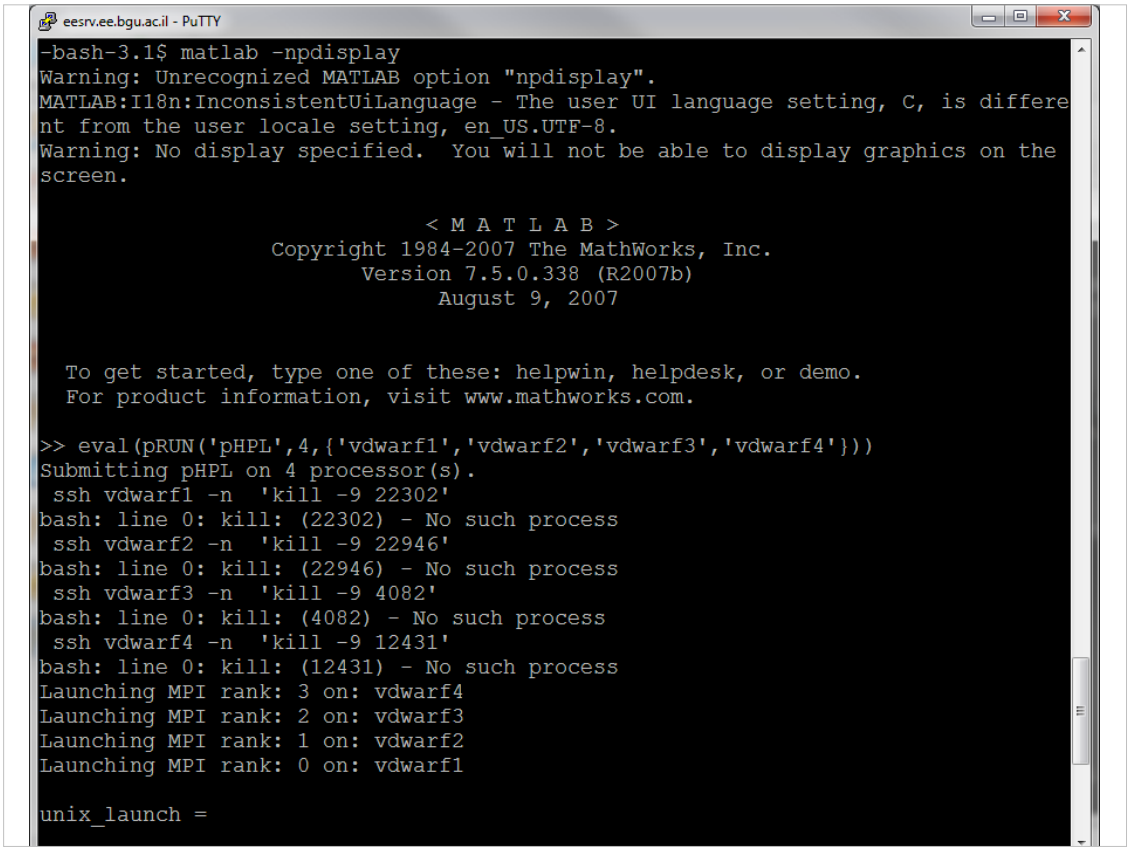


Figure 11 – Parallel MATLAB consists of two layers. pMatlab provides parallel data structures and library functions. MatlabMPI provides messaging capability.


eesrv.ee.bgu.ac.il - PuTTY
-bash-3.1$ matlab -npdisplay
Warning: Unrecognized MATLAB option "npdisplay".
MATLAB:I18n:InconsistentUiLanguage - The user UI language setting, C, is differe
nt from the user locale setting, en_US.UTF-8.
Warning: No display specified. You will not be able to display graphics on the
screen.
< M A T L A B >
Copyright 1984-2007 The MathWorks, Inc.
Version 7.5.0.338 (R2007b)
August 9, 2007
To get started, type one of these: helpwin, helpdesk, or demo.
For product information, visit www.mathworks.com.
>> eval(pRUN('pHPL',4,{'vdwarf1','vdwarf2','vdwarf3','vdwarf4'}))
Submitting pHPL on 4 processor(s).
ssh vdwarf1 -n 'kill -9 22302'
bash: line 0: kill: (22302) - No such process
ssh vdwarf2 -n 'kill -9 22946'
bash: line 0: kill: (22946) - No such process
ssh vdwarf3 -n 'kill -9 4082'
bash: line 0: kill: (4082) - No such process
ssh vdwarf4 -n 'kill -9 12431'
bash: line 0: kill: (12431) - No such process
Launching MPI rank: 3 on: vdwarf4
Launching MPI rank: 2 on: vdwarf3
Launching MPI rank: 1 on: vdwarf2
Launching MPI rank: 0 on: vdwarf1
unix_launch =

Proceed to pMatlab slides...

Matlab (Octave) + Condor

Sample 1:

submit file (cp.sub)

```
------------------------
universe        = vanilla
executable      = cp1.bat
initialdir      = C:\user\CondorMatlab
log             = matlabtest.log
error           = matlabtest.err
input           = CondorMatlabTest.m
getenv          = true
requirements    = (NAME == "slot1@remotePC")
queue
---------------------------
```

cp1.bat

```
----------------
cd "C:\PROGRA~1\MATLAB\R2007b\bin\win32"
matlab.exe  -r  "CondorMatlabTest"
```

Condor Demos

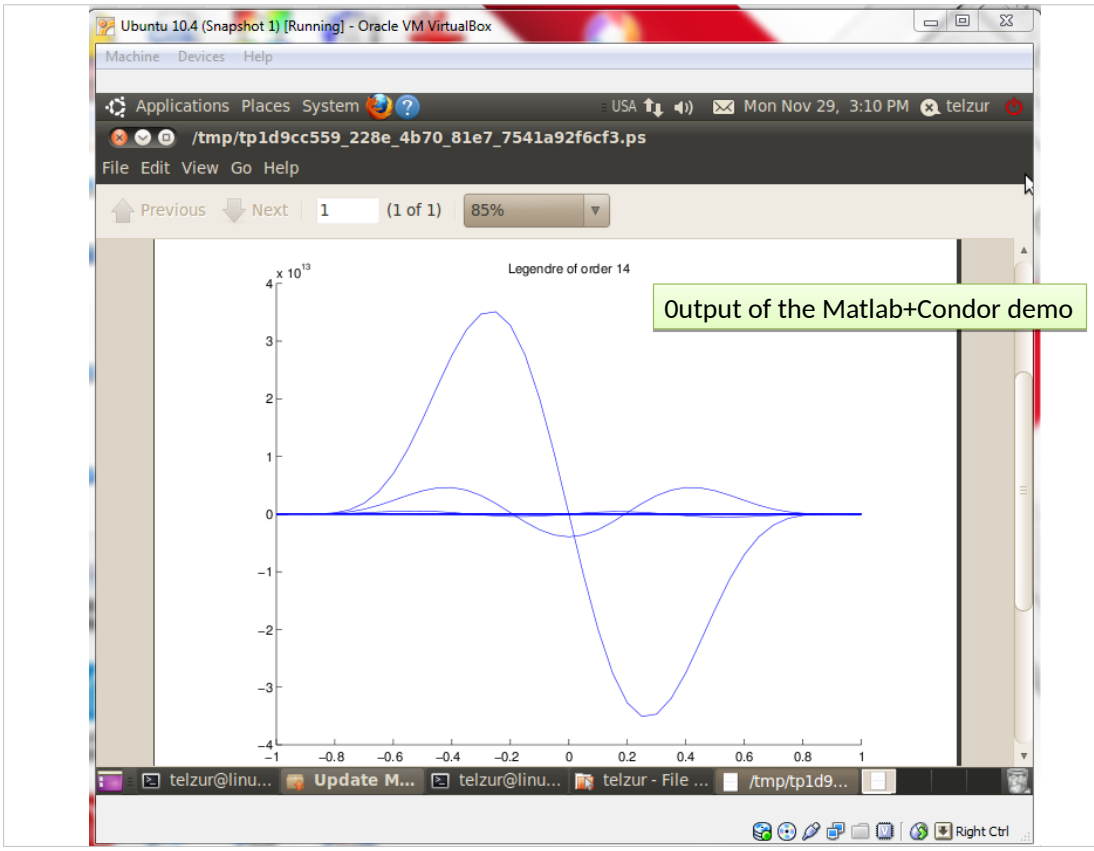
- On my PC: `C:\Users\telzur\Documents\BGU\Teaching\ParallelProcessing\PP2011A\Lectures\06\condor_demo_2010`
- *** has a bug ***

On the Linux vdwarf – Condor + Octave

`/users/agnon/misc/tel-zur/condor/octave`

- On the Linux vdwarf – Condor + Matlab

`/users/agnon/misc/tel-zur/condor/matlab/example_legendre`



0utput of the Matlab+Condor demo