مركز تقنية المعلومات
INFORMATION TECHNOLOGY CENTER

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PARALLEL COMPUTING WITH MATLAB

Parallel Processing Tool-box

- Start up MATLAB in the regular way. This copy of MATLAB that you start with is called the "**client**" copy; the copies of MATLAB that will be created to assist in the computation are known as "**workers**".

- The process of running your program in parallel now requires three steps:
  1. Request a number of workers;
  2. Issue the normal command to run the program. The client program will call on the workers as needed;
  3. Release the workers;

- For e.g. Supposing that your compute node has 8 cores, and that your M file is named “mainprogram.m", the command you might actually issue could look like this:

```
>> matlabpool open local 4
Starting matlabpool using the parallel configuration 'local'.
Waiting for parallel job to start...
Connected to a matlabpool session with 4 labs.
>> mainprogram.m
>> matlabpool close
Sending a stop signal to all the labs...
Waiting for parallel job to finish...
Performing parallel job cleanup...
Done.
```

- The number of workers you request can be any value from 0 up to 4

'matlabpool' & *'pctRunOnAll'* functions

matlabpool

- Open or close pool of MATLAB sessions for parallel computation, enables the parallel language features in the MATLAB language (e.g., parfor) by starting a parallel job that connects this MATLAB client with a number of labs.

Ex: Start a pool of 4 labs using a configuration called myConf:

matlabpool open myConf 4

pctRunOnAll

- Run command on client and all workers in matlabpool

Ex:

- Clear all loaded functions on all labs:

pctRunOnAll clear functions

- Change the directory on all workers to the project directory:

pctRunOnAll cd /opt/projects/new_scheme

- Add some directories to the paths of all the labs:

pctRunOnAll ('addpath /usr/share/path1');

Using '*parfor*' for Parallel Programs

- The simplest way of parallelizing a MATLAB program focuses on the **for** loops in the program.

- **Q:** Can the iterations of the loop be performed in any order without affecting the results?

  If the answer is "**yes**", then generally the loop can be parallelized.

- If you have nested **for** loops, then generally it is not useful to replace these by nested **parfor** loops.
  - If the outer loop can be parallelized, then that is the one that should be controlled by a parfor.
  - If the outer loop cannot be parallelized, then you are free to try to parallelize some of the inner for loops.

- **The safest assumption about a parfor-loop is that each iteration of the loop is evaluated by a different MATLAB worker. If you have a for-loop in which all iterations are completely independent of each other, this loop is a good candidate for a parfor-loop**.

Using '*parfor*' for Parallel Programs

- The next example, which attempts to compute Fibonacci numbers, is not a valid ***parfor***-loop because the value of an element of ***f*** in one iteration depends on the values of other elements of ***f*** calculated in other iterations.

```
>> matlabpool open local 4
Destroying 1 pre-existing parallel job(s) created by matlabpool that were in the
finished or failed state.

Starting matlabpool using the parallel configuration 'local'.
Waiting for parallel job to start...
Connected to a matlabpool session with 4 labs.
>> f=zeros(1,50);
>> f(1)=1;f(2)=2;
>> parfor n=3:50
   f(n) = f(n-1) + f(n-2);
   end
??? Error: The variable f in a parfor cannot be classified.
 See Parallel for Loops in MATLAB, "Overview".
```

- The body of a parfor-loop must be transparent, meaning that all references to variables must be "visible" (i.e., they occur in the text of the program).
  - In the following example, because X is not visible as an input variable in the parfor body (only the string 'X' is passed to **eval**), it does not get transferred to the workers. As a result, MATLAB issues an error at run time:

'parfor' Limitations

Nested spmd Statements

- The body of a parfor-loop cannot contain an spmd statement, and an spmd statement cannot contain a parfor-loop.

Break and Return Statements

- The body of a parfor-loop cannot contain break or return statements.

Global and Persistent Variables

- The body of a parfor-loop cannot contain global or persistent variable declarations.

Handle Classes

- Changes made to handle classes on the workers during loop iterations are not automatically propagated to the client.

P-Code Scripts

- You can call P-code script files from within a parfor-loop, but P-code script cannot contain a parfor-loop.

- **For more details about parfor limitation please refer:**

http://www.mathworks.com/help/toolbox/distcomp/bq9u0a2.html

Sample '*parfor*' Program in MATLAB

```
1
2     matlabpool open local 4;
3
4     ms.UseParallel='always';
5
6     pctRunOnAll ('addpath /home/Proposed');
7
8     N = 100;                % number of iterations
9
10    parfor i=1:1:N
11
12
13        fprintf('=================================================\n');
14        fprintf('=================================================\n');
15
16        fprintf('Iteration Order no = %2d\n',i);
17
18        fprintf('=================================================\n');
19        fprintf('=================================================\n');
20
21
22    end
23
24     matlabpool close
25
```

SPMD (Single Program/Multiple Data)

- The *SPMD* command allows a programmer to set up parallel computations that require more user control than the simple parfor command.

- MATLAB executes the spmd body denoted by statements on several MATLAB workers simultaneously.

- Inside the body of the spmd statement, each MATLAB worker has a unique value of labindex, while numlabs denotes the total number of workers executing the block in parallel.

- Within the body of the spmd statement, communication functions for parallel jobs (such as labSend and labReceive) can transfer data between the workers.

- Values returning from the body of an spmd statement are converted to Composite objects on the MATLAB client.

- A Composite object contains references to the values stored on the remote MATLAB workers, and those values can be retrieved using cell-array indexing. The actual data on the workers remains available on the workers for subsequent spmd execution, so long as the Composite exists on the client and the MATLAB pool remains open.

Using '*spmd*' for Parallel Programs

- Parallel sections of the code begin with the *spmd* statement, and end with an *end* statement. The computations in these blocks occur on the MATLAB workers. The client sits idly and "watches".

- Each worker has access to the variable numlabs, which contains the number of workers. Each worker has a unique value of the variable labindex, between **1** and **numlabs**.

- Any variable defined by the client is "visible" to the workers and can be used on the RHS of eqns within the spmd blocks.

- Any variable defined by the workers is a "*composite*" variable. If a variable called X is defined by the workers, then each worker has its own value, and the set of values is accessible by the client, using the worker's index. Thus X{1} is the value of X computed by worker 1.

- A program can have several spmd blocks. If the program completes an spmd block, carries out some commands in the client program, and then enters another spmd block, then all the variables defined during the previous spmd block still exist.

Using '*spmd*' for Parallel Programs

- Workers cannot directly see each other's variables. Communication from one worker to another can be done through the client.

- However, a limited number of special operators are available, that can be used within spmd blocks, which combine variables. In particular, the command *gplus* sums the values of a variable that exists on all the workers, and returns to each worker the value of that sum.

When to Use spmd

- The "**single program**" aspect of spmd means that the identical code runs on multiple labs. When the spmd block is complete, your program continues running in the client.

- The "multiple data" aspect means that even though the spmd statement runs identical code on all labs, each lab can have different, unique data for that code. So multiple data sets can be accommodated by multiple labs.

- Typical applications appropriate for spmd are those that require running simultaneous execution of a program on multiple data sets, when communication or synchronization is required between the labs. Some common cases are:
  - **Programs that take a long time to execute — spmd lets several labs compute solutions simultaneously.**
  - **Programs operating on large data sets — spmd lets the data be distributed to multiple labs.**

Using '*spmd*' for Parallel Programs

Displaying Output

- When running an spmd statement on a MATLAB pool, all command-line output from the workers displays in the client Command Window. Because the workers are MATLAB sessions without displays, any graphical output (for example, figure windows) from the pool does not display at all.

Creating Composites Outside spmd Statements

- The Composite function creates Composite objects without using an spmd statement. This might be useful to prepopulate values of variables on labs before an spmd statement begins executing on those labs. Assume a MATLAB pool is already open:

```
PP = Composite( ) ;
```

- By default, this creates a Composite with an element for each lab in the MATLAB pool. You can also create Composites on only a subset of the labs in the pool. The elements of the Composite can now be set as usual on the client, or as variables inside an spmd statement.

- For details about accessing data with composites for spmd please see:

  http://www.mathworks.com/help/toolbox/distcomp/brukctb-1.html

- For details about Distributing arrays, co-distributed arrays and distributed arrays please refer: http://www.mathworks.com/help/toolbox/distcomp/br9_n7w-1.html

Composite

- Creates Composite object
- **Syntax:** *C = Composite()* *C = Composite(nlabs)*
- C = Composite() creates a Composite object on the client using labs from the MATLAB pool. Generally, you should construct Composite objects outside any spmd statement.
- C = Composite(nlabs) creates a Composite object on the parallel resource set that matches the specified constraint. nlabs must be a vector of length 1 or 2, containing integers or Inf.
- A Composite object has one entry for each lab; initially each entry contains no data. Use either indexing or an spmd block to define values for the entries.

Examples

- Create a Composite object with no defined entries, then assign its values:

```
c = Composite();        % One element per lab in the pool
for ii = 1:length(c)    % Set the entry for each lab to zero
    c{ii} = 0;          % Value stored on each lab
end
```

Distributed

- Create distributed array from data in client workspace

- **Syntax:** *D = distributed(X)*

- D = distributed(X) creates a distributed array from X. X is an array stored on the MATLAB client, and D is a distributed array stored in parts on the workers of the open MATLAB pool.

Examples

- Create a small array and distribute it:

```
Nsmall = 50;
D1 = distributed(magic(Nsmall));
```

- Create a large distributed array using a static build method:

```
Nlarge = 1000;
D2 = distributed.rand(Nlarge);
```

USING '*spmd*' FOR PARALLEL PROGRAMS

```
1
2 -    matlabpool open local 4;
3
4 -    ms.UseParallel='always';
5
6 -    pctRunOnAll('addpath /home/aliakber');
7
8 -    spmd
9
10 -       if labindex==1
11
12 -           R=rand(3,3);
13
14 -       else
15
16 -           R=rand(4,4);
17
18 -       end
19
20 -   end
21
22 -   matlabpool close
```

```
Command Window
Starting matlabpool using the parallel configuration 'local'.
Waiting for parallel job to start...
Connected to a matlabpool session with 4 labs.
  1
    R =

        0.8147    0.9134    0.2785
        0.9058    0.6324    0.5469
        0.1270    0.0975    0.9575

  2
    R =

        0.9173    0.4612    0.2155    0.4621
        0.6839    0.1562    0.4978    0.9846
        0.8661    0.4626    0.2904    0.9587
        0.4809    0.8009    0.9071    0.5795

  3
    R =

        0.2951    0.7010    0.9143    0.7375
        0.0990    0.3821    0.2740    0.5407
        0.3277    0.9602    0.6484    0.6348
        0.6902    0.7780    0.2781    0.0948

  4
    R =

        0.3527    0.5647    0.0360    0.8565
        0.9411    0.0864    0.4363    0.6978
        0.3007    0.9689    0.7699    0.7676
        0.4783    0.4288    0.3194    0.3136

Sending a stop signal to all the labs...
Waiting for parallel job to finish...
Performing parallel job cleanup...
Done.
```

How to Measure and Report Elapsed Time

- You can use the *tic* and *toc* functions to begin and end timing.
- The call to *toc* returns the number of seconds elapsed since *tic* was called.
- Here is an example of the use of both *tic* and *toc* when measuring performance of a parallel computation.

```
>> tic;
>>  parfor n=3:50
   f(n) = f(n) + 2;
   end
>> toc
Elapsed time is 16.239578 seconds.
```

Parallel Tool Box - Function Reference

The MathWorks MATLAB&SIMULINK®

One MATLABPOOL, Many Uses

- `spmd ... end`
  - A MATLAB block
  - Data Parallel (Worker communication)
- `parfor ... end`
  - A MATLAB block
  - Task Parallel (No worker communication)
- Built-in parallelism in some toolboxes
- MATLAB manages data transfer between workers and desktop
- Use the same pool of MATLAB workers
- Can exist along with serial code in the same program
  - Execute interactively from MATLAB command line
  - Execute off-line using `batch` (scripts) or `createMATLABpooljob` (functions)
- All run serially if no workers are available

Parallel Tool Box - Function Reference

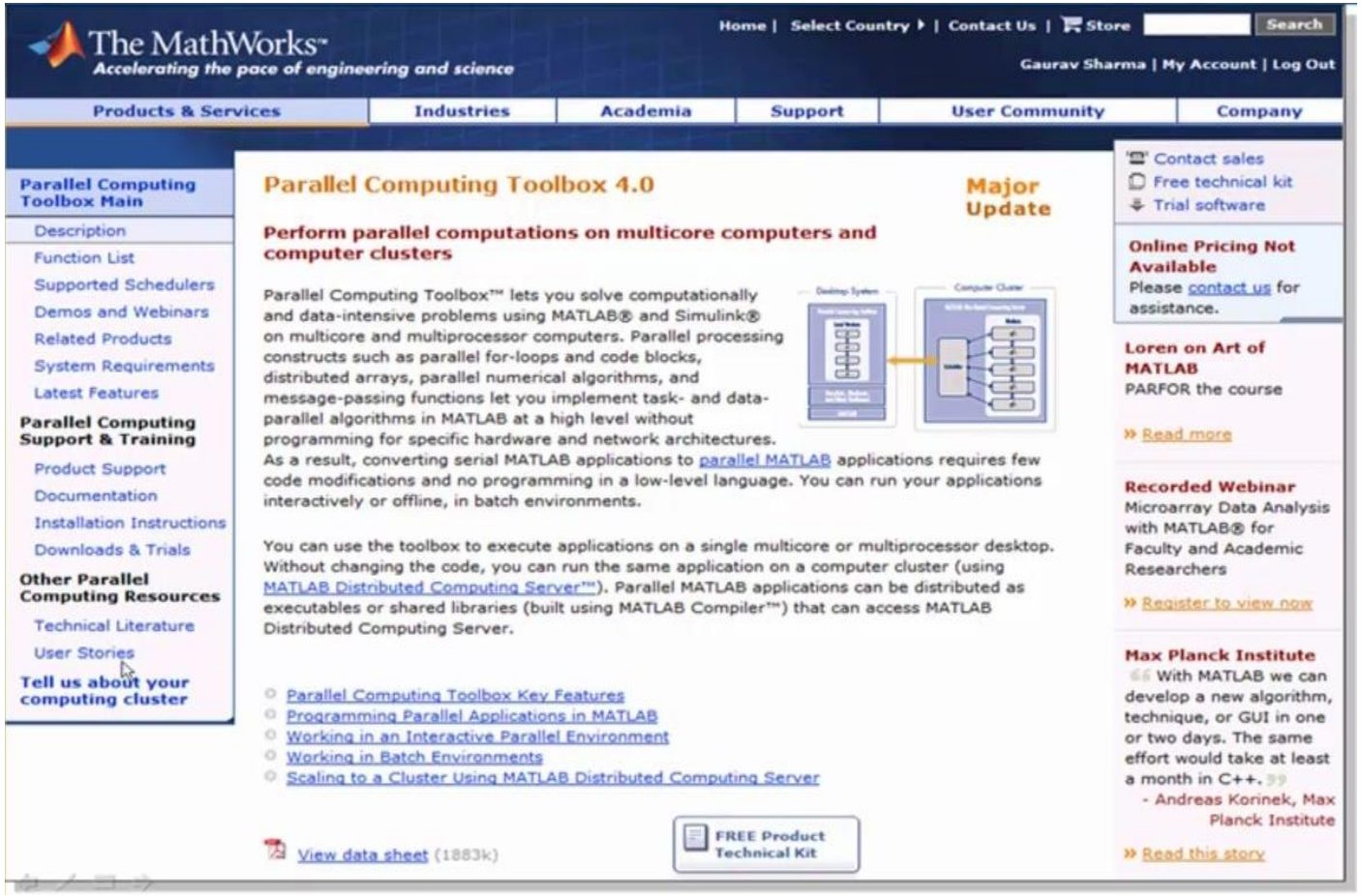
- Following are the types of functions available in parallel tool box

1.	Parallel Code Execution	Constructs for automatically running code in parallel
2.	Distributed and Codistributed Arrays	Data partitioned across multiple MATLAB sessions
3.	Jobs and Tasks	Parallel computation through individual tasks
4.	Interlab Communication Within a Parallel Job	Communications between labs during job execution
5.	Graphics Processing Unit	Transferring data and running code on the GPU
6.	Utilities	Utilities for using Parallel Computing Toolbox

- For more details:

http://www.mathworks.com/help/toolbox/distcomp/f1-6010.html

Parallel Tool Box 4.0 - Webpage



FOR FURTHER ASSISTANCE:

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