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MATLAB on Multi-core Clusters

Yes, there is a parallel MATLAB

Is There Parallel MATLAB?

- Cleve's Corner by Cleve Moler
  - Title: *Why there isn't a parallel MATLAB*
    - Memory model
      - Distribution of data takes longer than computation
    - Granularity
      - Not much MATLAB's internal functionality can be made in paralell
    - Business situation
      - No customers with parallel computers
  - Year of publication: 1995
  - Machines of the time:
    - Ardent Titan
    - Intel iPSC (128 nodes)
- 2008: parallel MATLAB is a must
  - Clusters are everywhere
  - I cannot buy a single-core processors

Parallel MATLAB? Really?

- Programming environment for matrices
  - Programming language with \ as an operator
- Shell environment
  - System command shell
    - ! ls
  - GUI shell
    - fig = figure()
  - Java shell
    - str = java.lang.String('Hello world!')
- Set of toolboxes (80+)
  - SymBio, ...
- Parallel RAD IDE?
  - pafor, spmd, parallel job management, multi-cores, clusters

Overview

- Multithreading
- parfor keyword
- spmd keyword
- Parallel jobs
- Distributed arrays

Multithreading

- No changes to the code
- Control of parallelism
  - GUI menu
  - oldThreadCount = maxNumCompThreads(new)
- Functional scope
  - BLAS
  - LAPACK
  - Built-in operators
  - Built-in functions

- Test
  - for n = 1:1000
    - max(svd(randn(n)))
  - end
- Efficiency (lack of it)
  - 1 core 100%
  - 2 cores 52%
  - 3 cores 35%
  - 4 cores 26%
- Questions:
  - Why multithreading didn't work?
  - No multithreading in MATLAB?
  - Multithreading no good?

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for → parfor

- for n = 1:1000
  - max(svd(randn(n)))
- end
-
- Efficiency (complete lack of it)
  - 1 100%
  - 2 50%
  - 3 33%
  - 4 25%

- parfor n = 1:1000
  - max(svd(randn(n)))
- end
-
- Efficiency
  - 1 core 100%
  - 2 cores 89%
  - 3 cores 83%
  - 4 cores 79%

Example parfor Loop

- for j = 1:N
  -
  - total1 = total1 + j
  -
  -
  - total2 = max(total2, foo(j))
  -
  -
  - total3 = bar(total3, j)
- end

- parfor j = 1:N
  - % operator as a reduction
  - total1 = total1 + j
  -
  - % intrinsic as a reduction
  - total2 = max(total2, foo(j))
  -
  - % user function as a reduction
  - total3 = bar(total3, j)
- end

Parallel for Loops with parfor

- Minimal changes to code for → parfor
- Control of parallelism
  - matlabpool()
- Random order of iterations
  - Helps load balancing
- Built-in and custom reductions
  - Heavy code analysis
- Requirements
  - Iteration independence
  - Code transparency
- Different than OpenMP
  - No need for shared memory
  - No need for special syntax/pragmas

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parfor → spmd

- parfor n = 1:1000
  - max(svd(randn(n)))
- end

- spmd
  - for n = 1000:100000
    - cdstr = codistributor
    - A = randn(n, cdstr)
    - max(svd(A))
  - end
- end

spmd: Remoteness and Persistence

- Automatic variable classification
  - In = 1
  - InOut = 3
  - spmd
    - Out = 2
    - InOut = In + Out
  - end
- Automatic data transfer
- Persistence
  - spmd
    - x = 1
  - end
  - z = 2
  - spmd
    - y = x + z
  - end

spmd and Composites

- Composites
  - A = rand(1000)
  - class(A) % 'double'
  - spmd
    - svd(A)
  - end
  - class(A) % 'Composite'
- Remote reference
  - No data transfer unless explicitly dereferenced
- Cell-like interface
  - clientA = A{1}

spmd Varieties

- spmd — same as spmd(0, Inf)
  - x = numlabs;
- end
- spmd(3) — same as spmd(3, 3)
  - x = numlabs;
- end
- spmd(3, 6)
  - x = numlabs;
- end
- spmd(0, Inf) — same as spmd
  - x = numlabs;
- end

Controlling Resources with Matlabpool

- Matlabpool syntax – quick reference
  - matlabpool open
  - matlabpool close
  - matlabpool size
  - matlab open local 3
  - matlab open MyCluster 127
- Controls toolboxes that already use parfor

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Parallel Jobs: Syntax

- mpirun -machine MyCluster
-
- -np 127
- ModelSimulation.exe inputDataFile outputDataFile
- qsub ModelSimulation.pbs
- while [true]
  - If [qstat] break
- end while

- sched = findResource('Conf', 'MyCluster')
- job = createParallelJob(sched)
- set(job, MinimumNumberNumberOfWorkers, 127)
- task = createTask(job, @ModelSimulation, 1 inputData)
- submit(job)
- waitForState(job, 'finished')
- oargs = getAllOutputArguments(job)

Parallel Jobs: Overview

- Schedulers and batch systems
  - local
    - For a laptop, desktop, single multi-core node
  - Job Manager
    - Allows callbacks from cluster
  - PBS Pro, Torque
  - Platform LSF
  - Sun Grid Engine
  - Windows CCE: CCS1, CCS2
  - mpiexec
    - Shell command: mpirun. mpiexec, ...
  - <generic>
    - Condor, ...
- Debugging
  - Deadlock detection
- Profiling
  - mpiprofile() function
    - Switch on or off
  - Not based on PMPI layer
- Swappable MPI implementation
  - Must be MPICH2 binary compatible
    - HP
    - Intel
    - Microsoft
    - MVAPICH2
    - Myricom
  - MPI 3.0 request: ABI for MPI

MPI vs. MATLAB

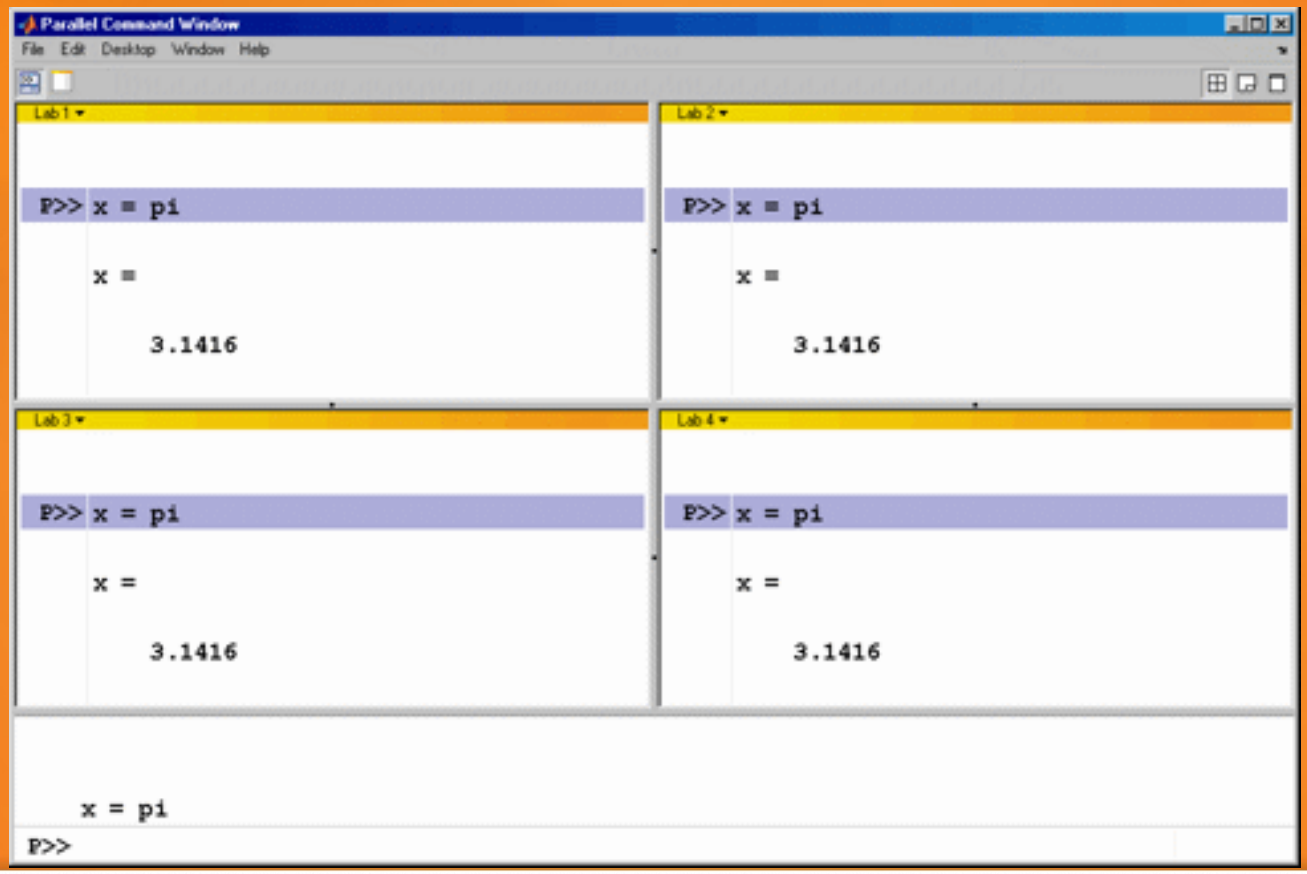
- MPI_Comm_rank
- MPI_Comm_size
- MPI_Send
- MPI_Recv
- MPI_Sendrecv
- MPI_Barrier
- MPI_Broadcast
- MPI_Probe
- MPI_Reduce(..., MPI_SUM)
- MPI_Reduce(..., MyFunction)
- mpirun -machinefile MyCluster xterm -e MySimulation.exe

- labindex
- numlabs
- labSend
- labReceive
- labSendReceive
- labBarrier
- labBroadcast
- labProbe
- gplus
- gop
- pmode start MyCluster

pmode

- Parallel shell
- Think: “inside spmd”
  - spmd
    - <parallel shell>
  - end

- MATLAB look-and-feel
- Ideal for
  - Prototyping
  - Debugging



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Distributed Arrays: Quick Look

- Sequential code
- N = 1000
- A = rand(N)
- b = rand(N, 1)
- t = tic
- x = b \ A
- t = toc(t)
-
- fprintf(1, 'Gflop/s=%g',
  2/3 * N^3 / t)

- Parallel code
- N = 100000
- A = rand(N, codistributor)
- b = rand(N, 1, codistributor)
- t = tic
- x = b \ A
- t = toc(t)
- if (labindex == 1)
- fprintf(1, 'Gflop/s=%g',
  2/3 * N^3 / t)
- end

Distributed Arrays: Functionality

- Many overloaded methods
  - 150+ functions
  - Operators
  - Linear algerbra
  - Indexing
  - Data analysis
- Distribution schemes
  - Variant 1D
    - codistributor('1d',dim, partition)
  - 2D block cyclic
    - codistributor('2d', [labRows labCols], blkSize)

Parting Words Picture