Interactive Supercomputing’s Star-P Platform: Parallel MATLAB & MPI Classroom Study

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Company

• Background:
  – Founded in 2004, venture-backed
  – M.I.T. spin-off
  – Exclusive technology license
  – Parallel Computing Harder than most realize:
    – Technology: Star-P software platform supporting automatic parallelization and interactive execution of desktop technical applications on parallel servers
    – Not just a parallel MATLAB

• Market:
  – Value prop: reduction in time-to-solution for large and complex problems
  – Can plug in existing parallel and serial software seamlessly
Star-P™ Enables Easy Parallel Computing on Multi-core Servers and Clusters.

Today, with MATLAB® environment.
Easiest Parallel use of MATLAB

- Run MATLAB on each machine
# The Parallel MATLABs
(no one such beast)

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<th>multiMATLAB</th>
<th>Netsolve</th>
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<td>Toolbox</td>
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<td>MATHWORKS Cleve Moler’s Vision</td>
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**Star-P with the MATLAB client environment!**
The Client (a math lab) is the browser!
Client-Server Parallel Computing

- Your bank & financial data
- Your email
- Your travel
- Your photos
- 2006: MIT students hw grades
- Your parallel computing
Client-Server Parallel Computing

Platform for automatic parallelization and interactive execution of desktop apps on HPCs
The Key to Star-P™ Value: Architecture

**Client-Server Software**
- Client interacts with HLL environments
- Distributed server for SMP and cluster systems

**Computing Modes**
- Serial & parallel computing
- Data- and Task-parallel
- Extensions via API/SDK

**Ease of Use**
- Simple Star-P commands

**Software Platform**
- Multiple HLLs and applications *(future)*
Plug into Star-P through Server API

- Through MATLAB, access:
  - Your own library functions
  - Specialized hardware (FPGA’s)
- Serial and parallel codes
  - Coarse-grained “multiply effect”
  - Parallel codes
- Started in MPI?
  - Not too late. Just plug it in and keep moving forward. Access from MATLAB
- Have an old serial fortran code?
  - Run it with multiple parameters on different processors. Access from MATLAB
Video

To get started, select MATLAB Help or Demos from the Help menu.

```
>> path(path, '.\matlab'); ppstart('kong.isc-dev.com', 34323);
Connecting to Star-P Server with 8 processes

Star-P Client.
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(C) Interactive Supercomputing, Inc 2004-2006.
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>> 1+1
ans =

2

>> a=rand(200*p)
a =

dense object: 200p-by-200p

>> b=inv(a)
b =

dense object: 200p-by-200p

>> c=a*b
```
Brings It All Together!
Serial Computing in Star-P™

- Use MATLAB
  - File Editor
  - Profiler
  - Debugger
  - Array Editor
  - Desktop
  - Visualization
  - Small Calculations

- Computations taking less than .5 seconds
Task Parallel Computing in Star-P™

- Data size < 100MB
- Execution time > .5 second
- Code separable in time
- Embarrassingly parallel apps
- Incorporate Star-P’s `ppeval`

```matlab
1  %Generate the Fourier Transform on 10 degree spacing
2  angles = linspace(0,360,37);
3  %Serial Version
4  load('brain.mat','A');
5  for i = 1:length(angles);
6      FFTangles(:,:,i) = genFFTangles(angles(i),A);
7  end
```

INTERACTIVE supercomputing
Task Parallel Computing in Star-P™

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4  load('brain.mat','A');
5  for i = 1:length(angles);
6      FFTangles(:,:,i) = genFFTangles(angles(i),A);
7  end
8  %Parallel Version
9  ppload('brain.mat','A');
10  FFTangles = ppeval('genFFTangles',split(angles),bcast(A));
```
ppeval syntax (parallel function)

- \( a = \text{rand}(500,500,200*p) \);
- \([u, s, v] = \text{ppeval('svd',a)}; \) % default svd on z-dim

- \( a = \text{rand}(500,500*p,200) \);
- \([u, s, v] = \text{ppeval('svd',a)}; \) % default svd on z-dim anyway

Answer does not depend on distribution: Parallel computers need shapes to enter from all sides.
Pi Recipe

```
>> n=8;  k=1:n;
>> sum(ppeval('quad','4./(1+x.^2)', (k-1)/n, k/n))
```

Parallel Evaluate **Pieces of pi:**
\[
\int \frac{4}{1+x^2} \, dx \text{ on } [0,1/8],[1/8,2/8],\ldots,[7/8,1] \text{ and sum.}
\]

ans =
3.14159265358979

**Abstraction:** Independent of number of processors or processes!
**Abstraction:** Parameters automatically moved to server!
Data Parallel Computing in Star-P™

- Data sizes >100MB
- Execution time > .5 second
- Data not separable
- Operations on vectors and matrices
- Incorporate \( *p \)
  - Global parallelism
  - Variables become parallel
  - Propagation occurs
    - Results are parallel
    - Functions performed on parallel data

```
n=10000
A = rand(n, n);
x = randn(n, 1);
y = zeros(size(x));

while norm(x-y) / norm(x) > 1e-11
    y = x;
x = A*x;
x = x / norm(x);
end;
```
Data Parallel Computing in Star-P™

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    - Results are parallel
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```matlab
% explicitly parallel with *p
n=10000*p

% implicitly parallel
A = rand(n, n);

% implicitly parallel
x = randn(n, 1);

% implicitly parallel
y = zeros(size(x));

while norm(x-y) / norm(x) > 1e-11
    y = x;
    x = A*x;
    x = x / norm(x);
end;
```
Programming for Best Performance - 1

- *p tag triggers automatic Data Parallel computation
- ppeval triggers automatic Task Parallel computation

But, for high performance:
- Some program segments are best run in Serial mode
- Some in Task Parallel mode
- Some in Data Parallel mode
Classroom Homework

• The Buffon Needle Problem

\[ \text{Buffon}(1,1,.5,1000*p) \]

function \( z = \text{Buffon}(a,b,l, \text{trials}) \)

\[
\begin{align*}
    r &= \text{rand}(\text{trials},3); \\
    x &= a*r(:,1) + l*cos(2*pi*r(:,3)); \\
    y &= b*r(:,2) + l*sin(2*pi*r(:,3)); \\
    \text{inside} &= (x \geq 0) \& (y \geq 0) \& (x \leq a) \& (y \leq b); \\
    \text{buffonpi} &= (2*l*(a+b) - l^2)/ (a*b*(1-\text{sum(inside)/trials}));
\end{align*}
\]
Classroom Experiment

• A data collector’s dream:
  – 29 students, each code run in MPI and three versions of Star-P. Some students more skilled with MPI than others.
Classroom Experiment

• A data collector’s dream:
  – 29 students, each code run in MPI and three versions of Star-P. Some students more skilled with MPI than others.
Productivity Study – Kepner diagram

- Star-P internal
- Star-P 2.3
- Star-P 2.1

Development Time

Performance

small ----> large

best ----> bad

MPI Best

MPI Typical
Desktop Applications You Love
The High Performance You Crave

INTERACTIVE SUPERCOMPUTING
“Parallel Computing done right”
Information

www.interactivesupercomputing.com
edelman@mit.edu
Star-P™ System Configurations - 1

Multi-core SMP Servers

Example:
Client – Linux/Windows desktop/laptop
Server – Sun Fire X4600, 8 dual-core Opterons (16 cores), SUSE Linux
Star-P Server – 8-socket license
Star-P Client – unlimited number of users
Local or remote access

Multi-core Clusters

Example:
Client – Linux/Windows desktop/laptop
Servers – 4x HP ProLiant BL25p (16 Opteron cores), SUSE
2x SGI Altix XE (8 Xeon 5100 cores), Redhat
Star-P Server – 12-socket license
Star-P Client – unlimited number of users
Local or remote access

Example Systems (SMP Servers and Clusters)

<table>
<thead>
<tr>
<th>Opteron</th>
<th>Xeon 5100</th>
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</thead>
<tbody>
<tr>
<td>Sun: SunFire x4100, x4200, x4600</td>
<td>HP: ProLiant BL20p G4, DL140 G3, DL360 G5, DL380 G5</td>
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<tr>
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<td>Penguin: Relion 1600, 2600</td>
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<td></td>
<td>Verari: RM2220, VB1220</td>
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</tbody>
</table>

x86/64 Architectures: Opteron and/or Xeon 5100
Star-P™ System Configurations - 2

IA64 (Itanium) Architecture

Traditional HPC Servers / SMP

Example:
Client – Linux/Windows desktop/laptop
Server – SGI Altix 32 CPUs, NUMAflex Architecture, SGI ProPak 4 (SUSE SLES9 Linux)
Star-P Server – 32-CPU license
Star-P Client – unlimited number of users,
Star-P Admin Server software for managed access and resource allocation

Example IA64 Systems:
SGI Altix 350, SGI Altix 450
Star-P Architecture - Logical

- Client
- Workgroup server(s)
- Master Control Module
- User & Admin database
- Data Storage
Applications by Industries
Radar Signal Processing

- Air Force Labs in Rome, NY
- Application: Radar Analysis & System Design
- Challenge: analysis of growing data sets
  - Satellite-based
  - Real time
- Star-P Solution:
  - Reuse existing MATLAB codes
  - Solve larger problems (TB’s)
  - Interactive “what if” scenarios
Econometric Modeling

- Columbia University’s Earth Institute
- Application:
  - Understanding interactions of climate, crop selection, and impact on local populations
  - Development of public policy, insurance, relief programs
- Star-P Solution:
  - Interactive development of complex statistical model
  - Scale to enormous data sets
Molecular Simulation

- Department of Chemistry, M.I.T.
- Application:
  - molecular modeling of thermodynamic properties from first principles
  - Impacts smog, weather patterns
- Star-P Solution:
  - Transparent parallelization of existing MATLAB models
  - Global array syntax to solve large systems of equations with 16-P Altix