300x Matlab

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September 25, 2002
HPEC Workshop
Lexington, MA

This work is sponsored by the High Performance Computing Modernization Office under Air Force Contract F19628-00-C-0002. Opinions, interpretations, conclusions, and recommendations are those of the author and are not necessarily endorsed by the Department of Defense.
Outline

- Introduction
- Motivation
- Challenges
- Approach
- Performance Results
- Future Work and Summary
Motivation: DoD Need

• Cost

\[ \text{Cost} = 4 \text{ lines of DoD code} \]

• DoD has a clear need to rapidly develop, test and deploy new techniques for analyzing sensor data
  – Most DoD algorithm development and simulations are done in Matlab
  – Sensor analysis systems are implemented in other languages
  – Transformation involves years of software development, testing and system integration

• MatlabMPI allows any Matlab program to become a high performance parallel program
Challenges: Why Has This Been Hard?

- **Productivity**
  - Most users will not touch any solution that requires other languages (even cmex)

- **Portability**
  - Most users will not use a solution that could potentially make their code non-portable in the future

- **Performance**
  - Most users want to do very simple parallelism
  - Most programs have long latencies (do not require low latency solutions)
Outline

- Introduction
- Approach
  - Basic Requirements
  - File I/O based messaging
- Performance Results
- Future Work and Summary
Modern Parallel Software Layers

Application
- Input
- Analysis
- Output

Parallel Library
- Vector/Matrix
- Comp
- Conduit
- Task

Hardware Interface
- Math Kernel
- Messaging Kernel

Hardware
- Workstation
- PowerPC Cluster
- Intel Cluster

User Interface

• Can build any parallel application/library on top of a few basic messaging capabilities
• MatlabMPI provides this Messaging Kernel
Parallel computing requires eight capabilities

- `MPI_Run` launches a Matlab script on multiple processors
- `MPI_Comm_size` returns the number of processors
- `MPI_Comm_rank` returns the id of each processor
- `MPI_Send` sends Matlab variable(s) to another processor
- `MPI_Recv` receives Matlab variable(s) from another processor
- `MPI_Init` called at beginning of program
- `MPI_Finalize` called at end of program
Key Insight: File I/O based messaging

- Any messaging system can be implemented using file I/O

- File I/O provided by Matlab via load and save functions
  - Takes care of complicated buffer packing/unpacking problem
  - Allows basic functions to be implemented in ~250 lines of Matlab code
MatlabMPI:
Point-to-point Communication

MPI_Send (dest, tag, comm, variable);

• **Sender** saves variable in Data file, then creates Lock file
• **Receiver** detects Lock file, then loads Data file
Example: Basic Send and Receive

- Initialize
  - Get processor ranks

- Execute send
  - Execute receive

- Finalize
  - Exit

```matlab
MPI_Init; % Initialize MPI.
comm = MPI_COMM_WORLD; % Create communicator.
comm_size = MPI_Comm_size(comm); % Get size.
my_rank = MPI_Comm_rank(comm); % Get rank.
source = 0; % Set source.
dest = 1; % Set destination.
tag = 1; % Set message tag.

if(comm_size == 2) % Check size.
  if (my_rank == source) % If source.
    data = 1:10; % Create data.
    MPI_Send(dest,tag,comm,data); % Send data.
  end
  if (my_rank == dest) % If destination.
    data = MPI_Recv(source,tag,comm); % Receive data.
  end
end

MPI_Finalize; % Finalize Matlab MPI.
exit; % Exit Matlab
```

- Uses standard message passing techniques
- Will run anywhere Matlab runs
- Only requires a common file system
MatlabMPI Additional Functionality

- **Important MPI conveniences functions**
  - `MPI_Abort` kills all jobs
  - `MPI_Bcast` broadcasts a message
    exploits symbolic links to allow for true multi-cast
  - `MPI_Probe` returns a list of all incoming messages
    allows more dynamic message reading

- **MatlabMPI specific functions**
  - `MatMPI_Delete_all` cleans up all files after a run
  - `MatMPI_Save_messages` toggles deletion of messages
    individual messages can be inspected for debugging
  - `MatMPI_Comm_settings` user can set MatlabMPI internals
    rsh or ssh, location of Matlab, unix or windows, ...

- **Other**
  - Processor specific directories
Outline

• Introduction

• Approach

• **Performance Results**
  • Bandwidth
  • Parallel Speedup

• Future Work and Summary
MatlabMPI vs MPI bandwidth

- Bandwidth matches native C MPI at large message size
- Primary difference is latency (35 milliseconds vs. 30 microseconds)
MatlabMPI bandwidth scalability

Linux w/Gigabit Ethernet

- Bandwidth scales to multiple processors
- Cross mounting eliminates bottlenecks
• Achieved “classic” super-linear speedup on fixed problem
• Achieved speedup of ~300 on 304 processors on scaled problem
Productivity vs. Performance

- Programmed image filtering several ways
  - Matlab
  - VSIPL
  - VSIPL/OpenMPI
  - VSIPL/MPI
  - PVL
  - MatlabMPI

- MatlabMPI provides
  - high productivity
  - high performance
Current MatlabMPI deployment

- Lincoln Signal processing (7.8 on 8 cpus, 9.4 on 8 duals)
- Lincoln Radar simulation (7.5 on 8 cpus, 11.5 on 8 duals)
- Lincoln Hyperspectral Imaging (~3 on 3 cpus)
- MIT LCS Beowulf (11 Gflops on 9 duals)
- MIT AI Lab Machine Vision
- OSU EM Simulations
- ARL SAR Image Enhancement
- Wash U Hearing Aid Simulations
- So. Ill. Benchmarking
- JHU Digital Beamforming
- ISL Radar simulation
- URI Heart modelling

- Rapidly growing MatlabMPI user base
- Web release may create hundreds of users
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Future Work: Parallel Matlab Toolbox

- Parallel Matlab need has been identified
  - HPCMO (OSU)

- Required user interface has been demonstrated
  - MatlabP (MIT/LCS)
  - PVL (MIT/LL)

- Required hardware interface has been demonstrated
  - MatlabMPI (MIT/LL)

High Performance Matlab Applications

- DoD Sensor Processing
- DoD Mission Planning
- Scientific Simulation
- Commercial Applications

Parallel Matlab Toolbox

- Allows parallel programs with no additional lines of code

Parallel Computing Hardware
Future Work: Scalable Perception

• Data explosion
  – Advanced perception techniques must process vast (and rapidly growing) amounts of sensor data
• Component scaling
  – Research has given us high-performance algorithms and architectures for sensor data processing,
  – But these systems are not modular, reflective, or radically reconfigurable to meet new goals in real time
• Scalable perception
  – will require a framework that couples the computationally daunting problems of real-time multimodal perception to the infrastructure of modern high-performance computing, algorithms, and systems.
• Such a framework must exploit:
  – High-level languages
  – Graphical / linear algebra duality
  – Scalable architectures and networks
Summary

• MatlabMPI has the basic functions necessary for parallel programming
  – Size, rank, send, receive, launch
  – Enables complex applications or libraries

• Performance can match native MPI at large message sizes

• Demonstrated scaling into hundreds of processors

• Demonstrated productivity

• Available on HPCMO systems

• Available on Web
Acknowledgements

• Support
  – Charlie Holland DUSD(S&T) and John Grosh OSD
  – Bob Bond and Ken Senne (Lincoln)

• Collaborators
  – Stan Ahalt and John Nehrbass (Ohio St.)
  – Alan Edelman, John Gilbert and Ron Choy (MIT LCS)

• Lincoln Applications
  – Gil Raz, Ryan Haney and Dan Drake
  – Nick Pulsone and Andy Heckerling
  – David Stein

• Centers
  – Maui High Performance Computing Center
  – Boston University
http://www.ll.mit.edu/MatlabMPI