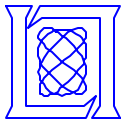

300x Matlab

Dr. Jeremy Kepner
MIT Lincoln Laboratory

September 25, 2002
HPEC Workshop
Lexington, MA

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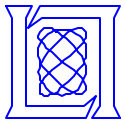


Outline

- **Introduction**
  - *Motivation*
  - *Challenges*
- Approach
- Performance Results
- Future Work and Summary

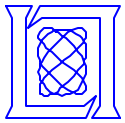
Motivation: DoD Need

- **Cost**

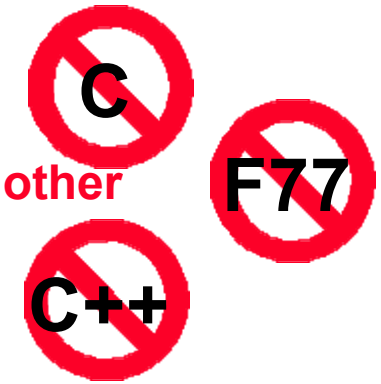
= 4 lines of DoD code

- **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**

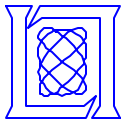
- **MatlabMPI allows any Matlab program to become a high performance parallel program**



Challenges: Why Has This Been Hard?



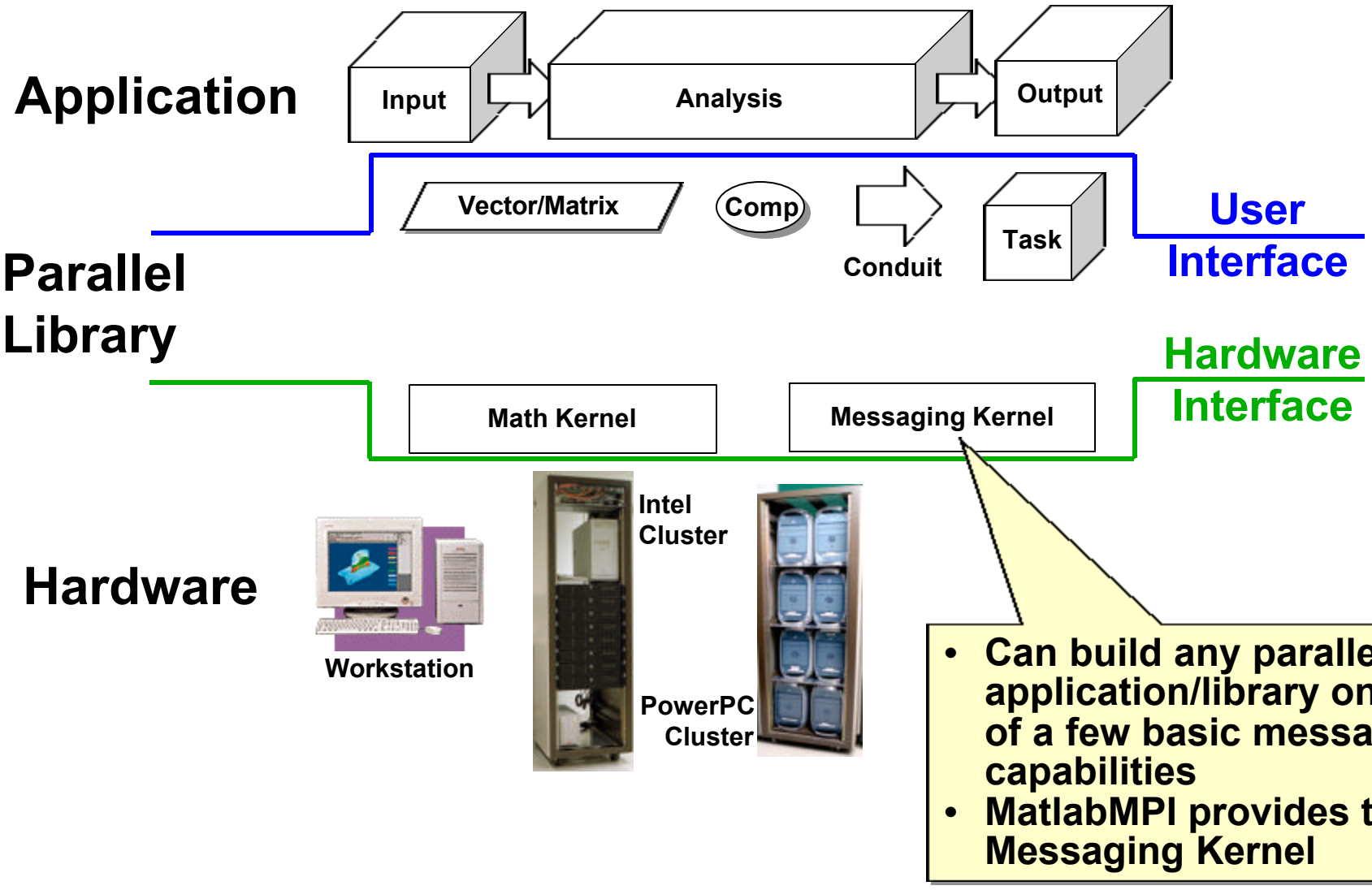
- **Productivity**
  - **Most users will not touch any solution that requires other languages (even cmex)**
- **Portability**
  - **Most users will not use a solution that could potentially make their code non-portable in the future**
- **Performance**
  - **Most users want to do very simple parallelism**
  - **Most programs have long latencies (do not require low latency solutions)**

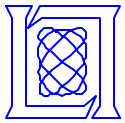


Outline

- Introduction
- **Approach**
  - ***Basic Requirements***
  - ***File I/O based messaging***
- Performance Results
- Future Work and Summary

Modern Parallel Software Layers



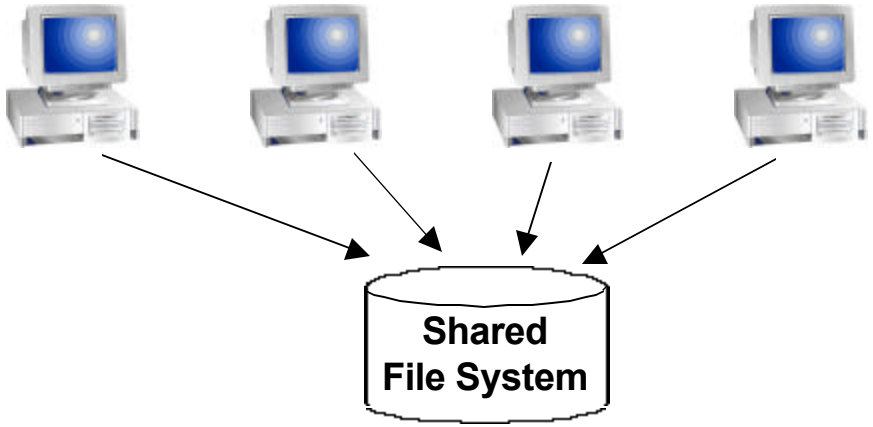


MatlabMPI "Core Lite"

- 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

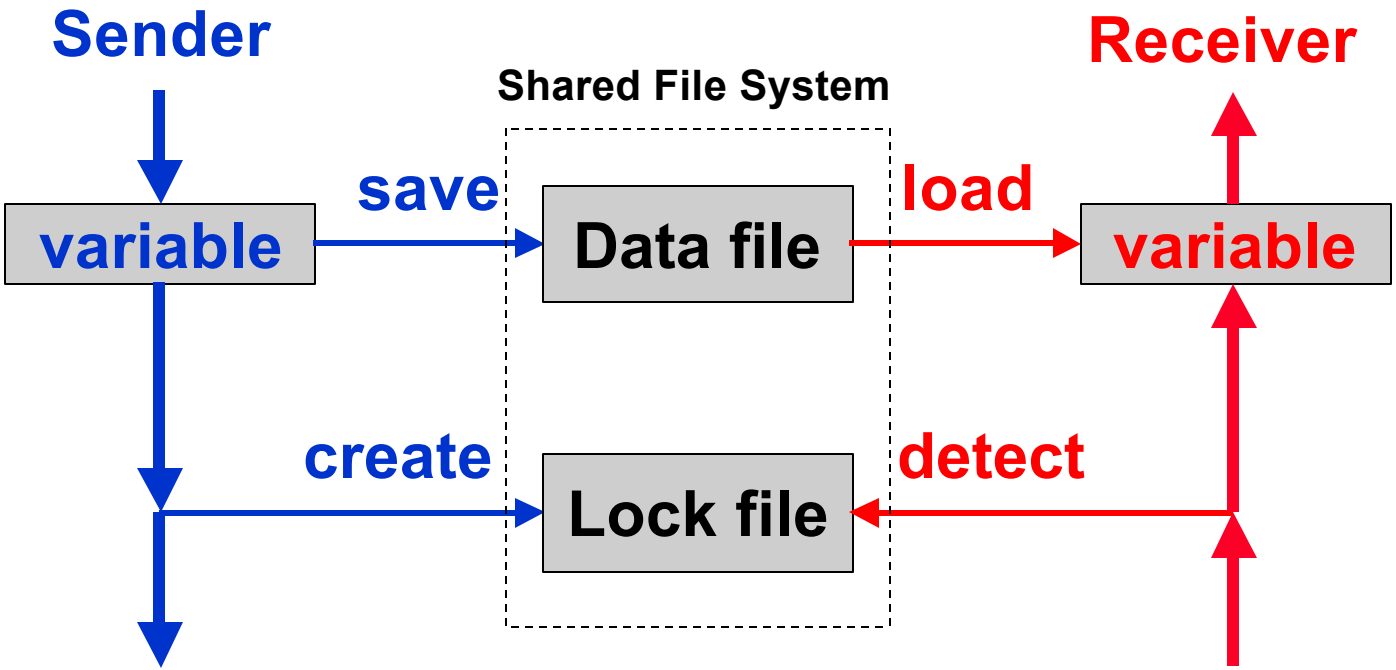
- Any messaging system can be implemented using file I/O



- 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

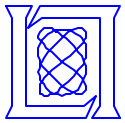
MatlabMPI: Point-to-point Communication

MPI_Send (dest, tag, comm, variable);



variable = MPI_Recv (source, tag, comm);

- Sender saves variable in Data file, then creates Lock file
- Receiver detects Lock file, then loads Data file



Example: Basic Send and Receive

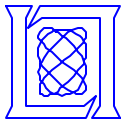
- Initialize
- Get processor ranks

- Execute send
- Execute recieve

- Finalize
- Exit

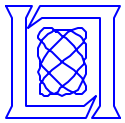
```
MPI_Init;                              % Initialize MPI.
comm = MPI_COMM_WORLD;                 % Create communicator.
comm_size = MPI_Comm_size(comm);       % Get size.
my_rank = MPI_Comm_rank(comm);         % Get rank.
source = 0;                            % Set source.
dest = 1;             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

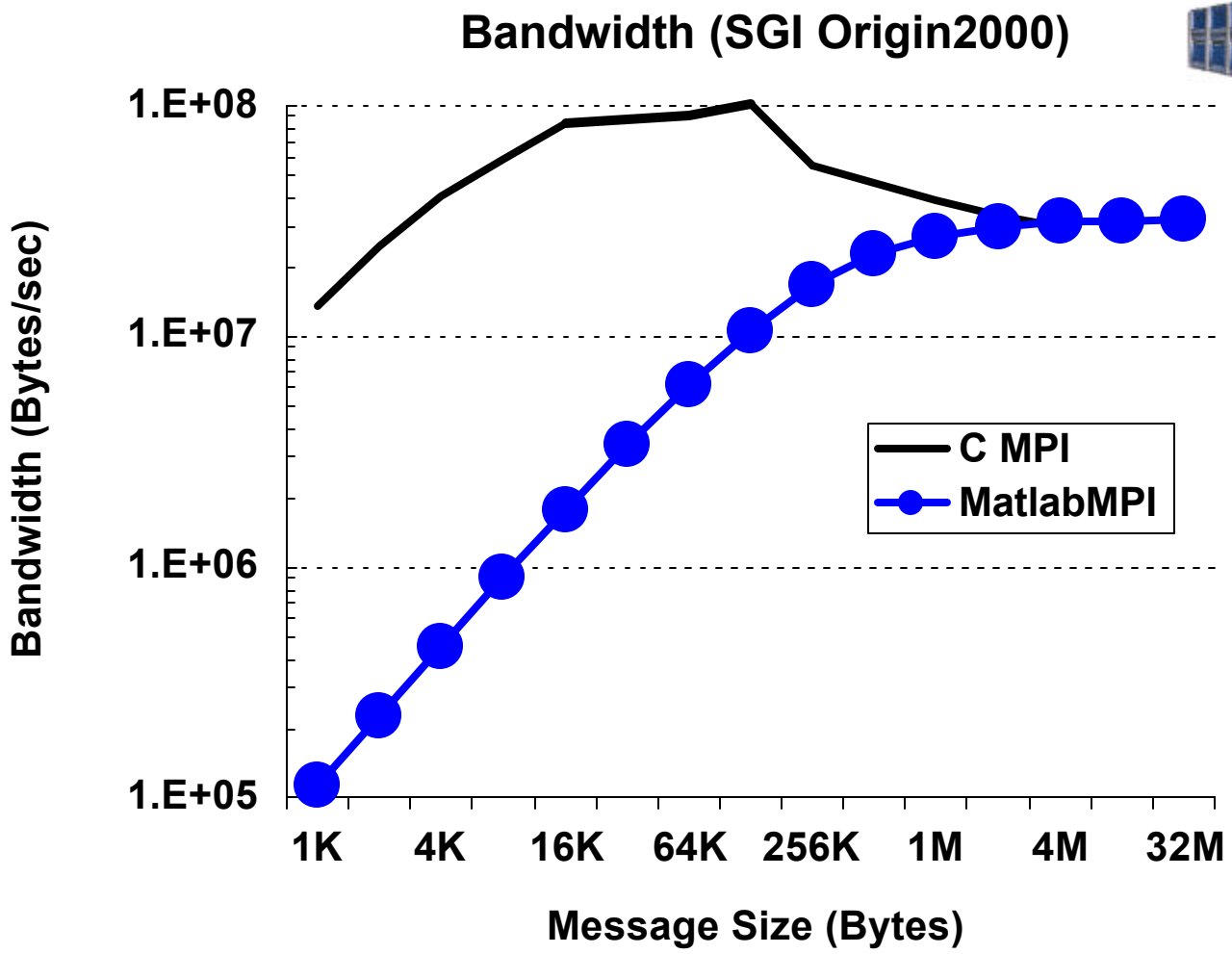
- Important MPI conveniences functions
  - MPI_Abort kills all jobs
  - MPI_Bcast broadcasts a message
    exploits symbolic links to allow for true multi-cast
  - MPI_Probe returns a list of all incoming messages
    allows more dynamic message reading
- MatlabMPI specific functions
  - MatMPI_Delete_all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

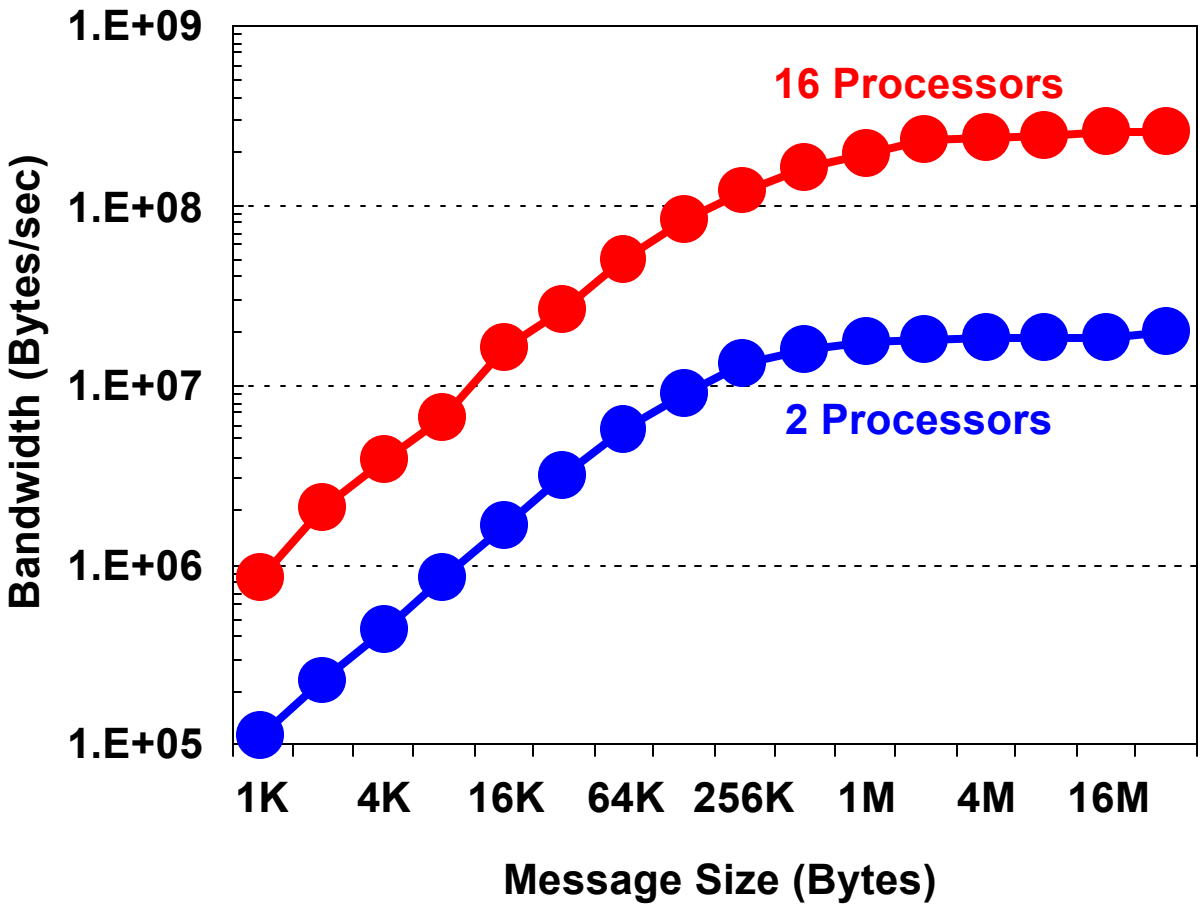
MatlabMPI vs MPI bandwidth



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

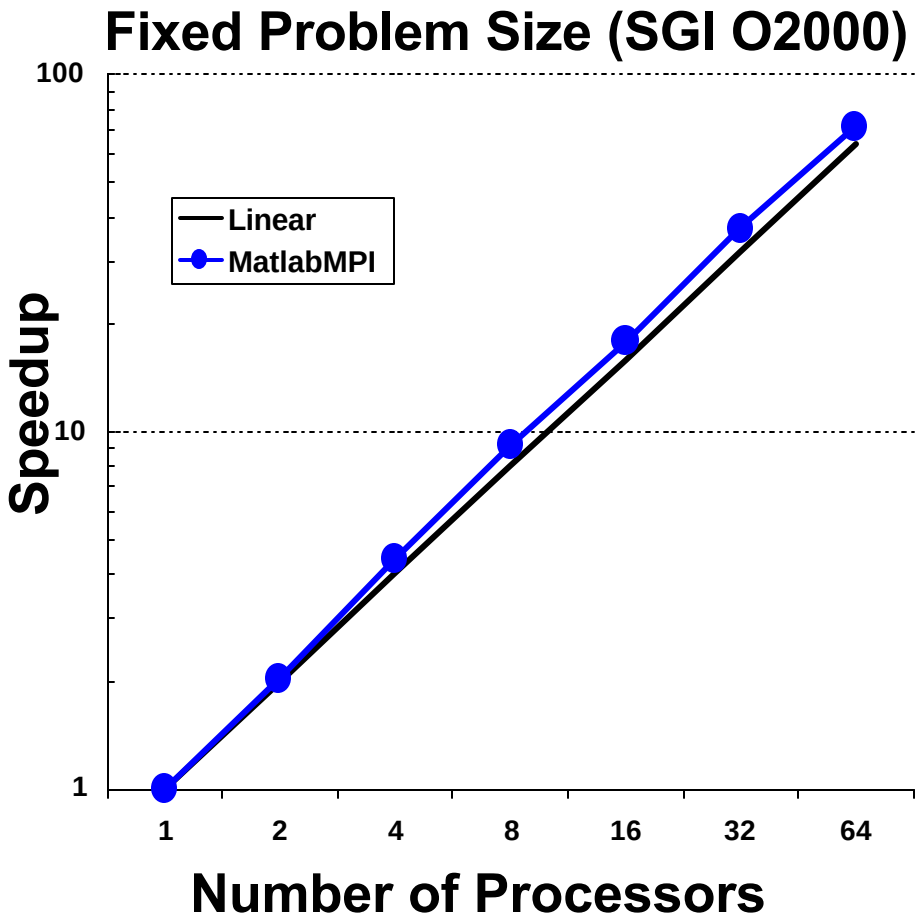
MatlabMPI bandwidth scalability

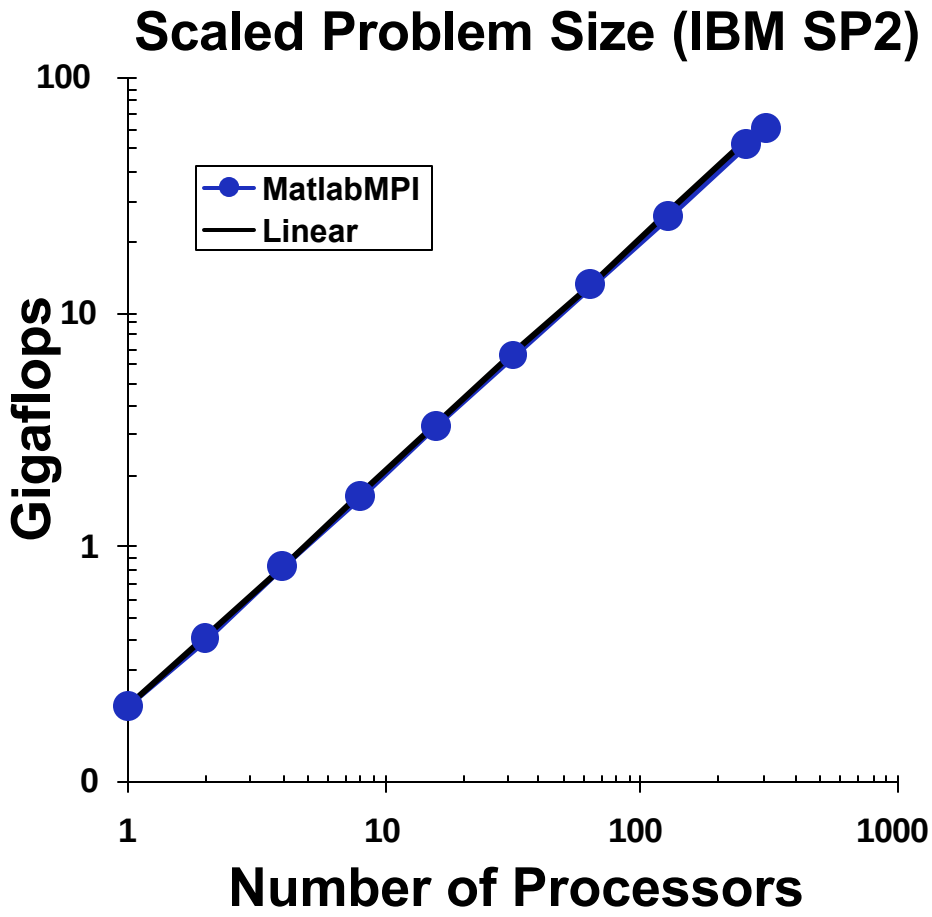
Linux w/Gigabit Ethernet



- Bandwidth scales to multiple processors
- Cross mounting eliminates bottlenecks

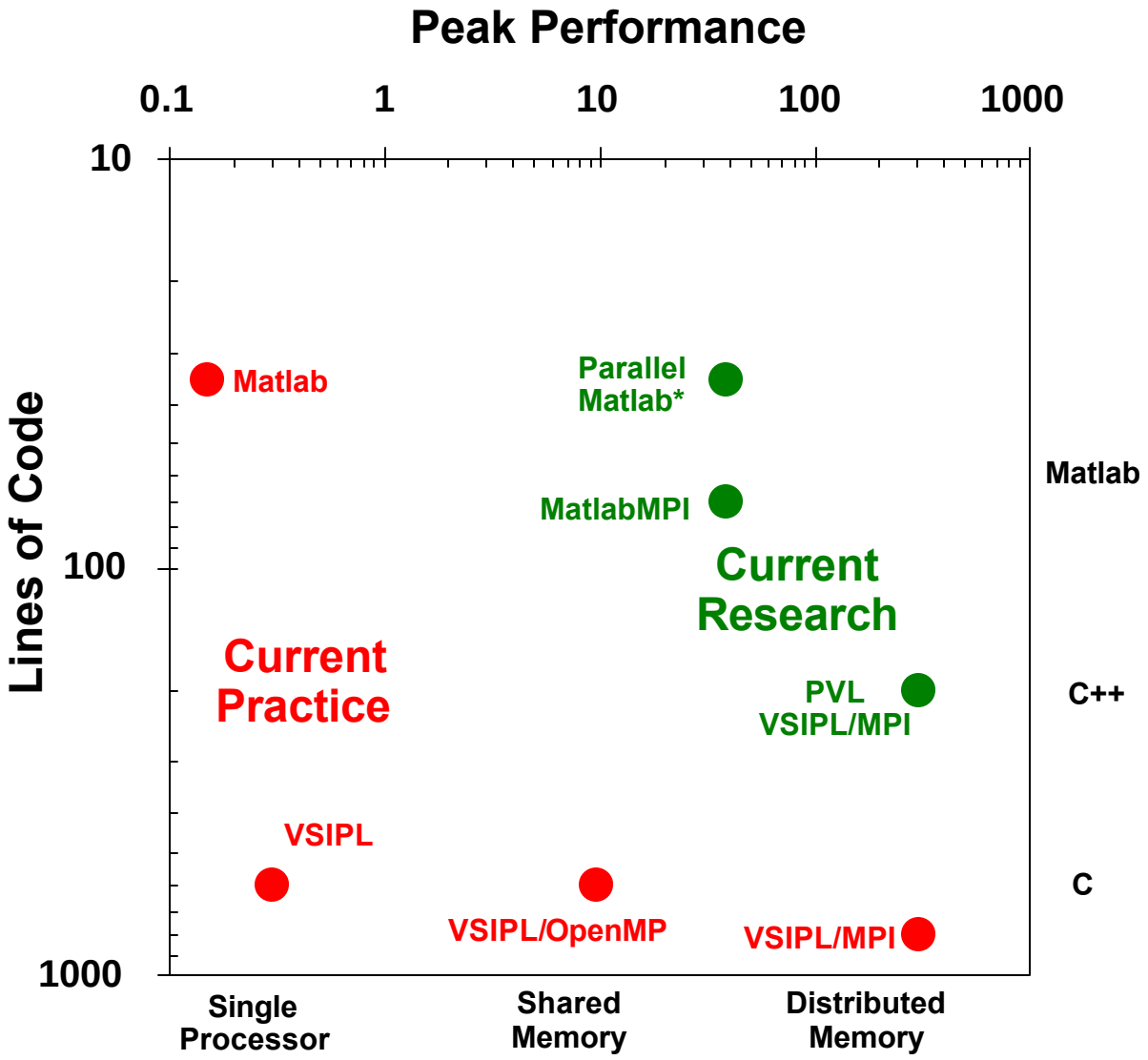
Image Filtering Parallel Performance



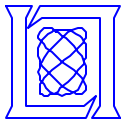


- Achieved "classic" super-linear speedup on fixed problem
- Achieved speedup of ~300 on 304 processors on scaled problem

Productivity vs. Performance



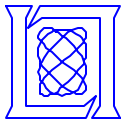
- Programmed image filtering several ways
  - Matlab
  - VSIPL
  - VSIPL/OpenMPI
  - VSIPL/MPI
  - PVL
  - MatlabMPI
- MatlabMPI provides
  - high productivity
  - high performance



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



Outline

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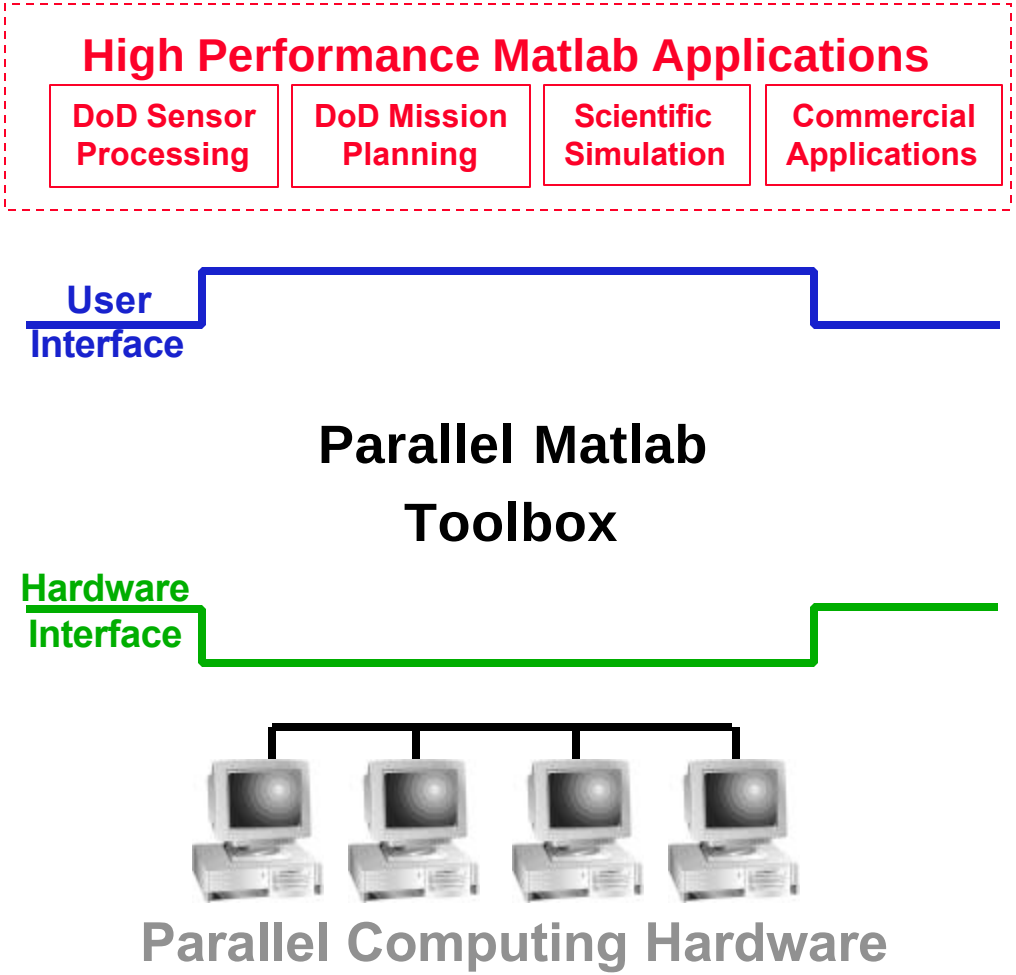
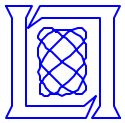
Future Work: Parallel Matlab Toolbox

- **Parallel Matlab need has been identified**
  - HPCMO (OSU)
- **Required user interface has been demonstrated**
  - Matlab*P (MIT/LCS)
  - PVL (MIT/LL)
- **Required hardware interface has been demonstrated**
  - MatlabMPI (MIT/LL)

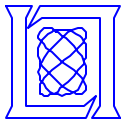


- **Allows parallel programs with no additional lines of code**



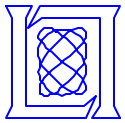
Future Work: Scalable Perception

- **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



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- **Support**
  - Charlie Holland DUSD(S&T) and John Grosh OSD
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- **Collaborators**
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  - Nick Pulsone and Andy Heckerling
  - David Stein

- **Centers**
  - Maui High Performance Computing Center
  - Boston University

http://www.ll.mit.edu/MatlabMPI