Overview of MPI

Overview of ISP's Handling of MPI

About 30 minutes – by Mike

The Continued and Foreseen Ubiquity of MPI

IBM Blue Gene
(Picture Courtesy IBM)

LANL's Petascale machine
"Roadrunner"
(AMD Opteron CPUs and
IBM PowerX Cell)

- The choice for large-scale parallel simulations (earthquake, weather..)
- Runs "everywhere" – esp on expensive state-of-the-art supercomputers
- Very mature codes exist in MPI – cannot easily be re-implemented
- Performs critical simulations in science and engineering
- ISP supports dynamic verification of MPI C applications

Overview of Message Passing Interface (MPI) API

- One of the Stunning Standardization Successes
- Lingua franca of Parallel Computing
- Runs on parallel machines of a WIDE range of sizes
- Standard is published at www.mpi-forum.org
- MPI 2.0 includes over 300 functions

Overview of ISP's Handling of MPI Calls

- MPI 2.0 includes over 300 functions
- ISP works by Hijacking the MPI Calls
- ISP currently handles over 60 Calls
  - Includes very popular ones
  - ISP has FULLY handled MANY applications (next slide)
  - We are continually extending the range
  - Calls not handled can often be directly issued (no hijack)
- Creating a tool such as ISP is a non-trivial venture
  - Ongoing research extends ISP's range

ISP’s Score-Card of handling MPI / C Applications

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- ADLB
  - Initial experiments have been successful

Crash course on MPI

If you don't know MPI, you'll like our brevity

If you know MPI, then too you'll like the brevity

☺

We will introduce four MPI functions

Namely S, R, W, and B

(out of the > 300)

Non-blocking send, MPI_Isend

- MPI_Isend(destination, msg_buf, req_struct)
- This is a non-blocking call

- Start copying out msg_buf
- Starts a memory-to-memory copy from issuing process to destination process
  - May benefit from runtime buffering

- MPI_Wait(req_struct) awaits completion
  - When Wait unblocks, **sending proc can reuse msg_buf**

We often abbreviate MPI_Isend

as Isend or simply **S**

We often abbreviate MPI_Wait

as Wait or simply **W**

Non-blocking receive, MPI_Irecv

- MPI_Irecv(source, msg_bug, req_struct, ..)
- This is a non-blocking receive call

- Starts a memory-to-memory copy from source process
- Source can be specified as ANY-SRC or ‘wildcard’ or ‘*’

- MPI_Wait(req_struct) awaits completion
  - When Wait unblocks, msg_buff is ready for consumption

- Source can be
  - “wildcard” or * or ANY_SOURCE
  - Receive from any eligible (matching) sender

We abbreviate MPI_Irecv

as Irecv, or simply R

Illustration of S and R in action

in ‘lucky.c’ and ‘unlucky.c’

Example MPI program 'lucky.c'

Process P0	Process P1	Process P2
R(from:*, r1) ;	Sleep(3);	//Sleep(3);
R(from:2, r2);	S(to:0, r1);	S(to:0, r1);
S(to:2, r3);	All the Ws…	R(from:0, r2);
R(from:*, r4);		S(to:0, r3);
All the Ws…		All the Ws…

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Example MPI program ‘lucky.c’ (lucky for tester)

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S(to:2, r3);	All the Ws…	R(from:0, r2);
R(from:*, r4);		S(to:0, r3);
All the Ws…		All the Ws…

deadlock

MPI program ‘unlucky.c’

Process P0	Process P1	Process P2
R(from:*, r1) ;	// Sleep(3);	Sleep(3);
R(from:2, r2);	S(to:0, r1);	S(to:0, r1);
S(to:2, r3);	All the Ws…	R(from:0, r2);
R(from:*, r4);		S(to:0, r3);
All the Ws…		All the Ws…

‘unlucky.c’

Process P0	Process P1	Process P2
R(from:*, r1) ;	// Sleep(3);	Sleep(3);
R(from:2, r2);	S(to:0, r1);	S(to:0, r1);
S(to:2, r3);	All the Ws…	R(from:0, r2);
R(from:*, r4);		S(to:0, r3);
All the Ws…		All the Ws…

No deadlock

More MPI Commands

– MPI_Barrier(…) is abbreviated as Barrier() or **B**

– All processes must invoke Barrier
before any process can return from Barrier call

– Useful high-performance global sync. operation

– Sometimes used 'for fear of the unforeseen'
  - ISP's algorithm for removing the Functionally Irrelevant Bs, or F.I.B. (see EuroPVM/MPI 2008)

So you think you really understand

S, R, W, and B ?

Let us find out!

MPI Quiz involving S, R, W, and B

Will this single-process example called "Auto-send" deadlock ?

P0 : R(from:0, h1); B; S(to:0, h2); W(h1); W(h2);

Types of bugs detected by ISP

- Deadlocks
  - Quite common
    - Due to mismatched sends / receives
      - Unequal source / destination field
      - Unequal tags
      - Different communicators
    - Mismatched collectives
      - Flags many that are 'glibly handled' by real MPI runtimes
        - » Example : MPI_Allreduce : root must participate too
          - **Or else, we must deadlock – yet MPI libraries often don't**
  - Yet easily missed in the exploding number of schedules!
  - ISP GUI allows users to identify onset of deadlock in replay trace
  - ISP finds deadlocks by
    - Generating only the relevant interleavings
    - Ensuring that ALL the above sources will be detected!

Types of bugs detected by ISP

- MPI Object Leaks
  - Quite common
    - Due to forgotten deallocations of one or more of these :
      - Communicators
      - Request Structures
      - Types
      - …
    - Causes ‘slow death’ of important programs!
      - **Nightmarish to debug !**
  - Yet easily missed in the exploding number of schedules!
  - ISP GUI takes you to the allocation that was leaked
  - ISP finds leaks
    - Generating only the relevant interleavings
    - Instrumenting uses

Types of bugs detected by ISP

- Assertion Violations
  - Programmers MUST use C ‘assert’ statements
  - ISP GUI takes you to failing assert
  - Guaranteed checking
    - Generating only the relevant interleavings
    - Checks across ALL these – won’t miss assert checking due to “chancy” speed-dependent scheduling

Types of bugs detected by ISP

- Default Safety Properties
  - Many MPI usage-checking rules are yet to be built
  - Will make ISP all the more powerful

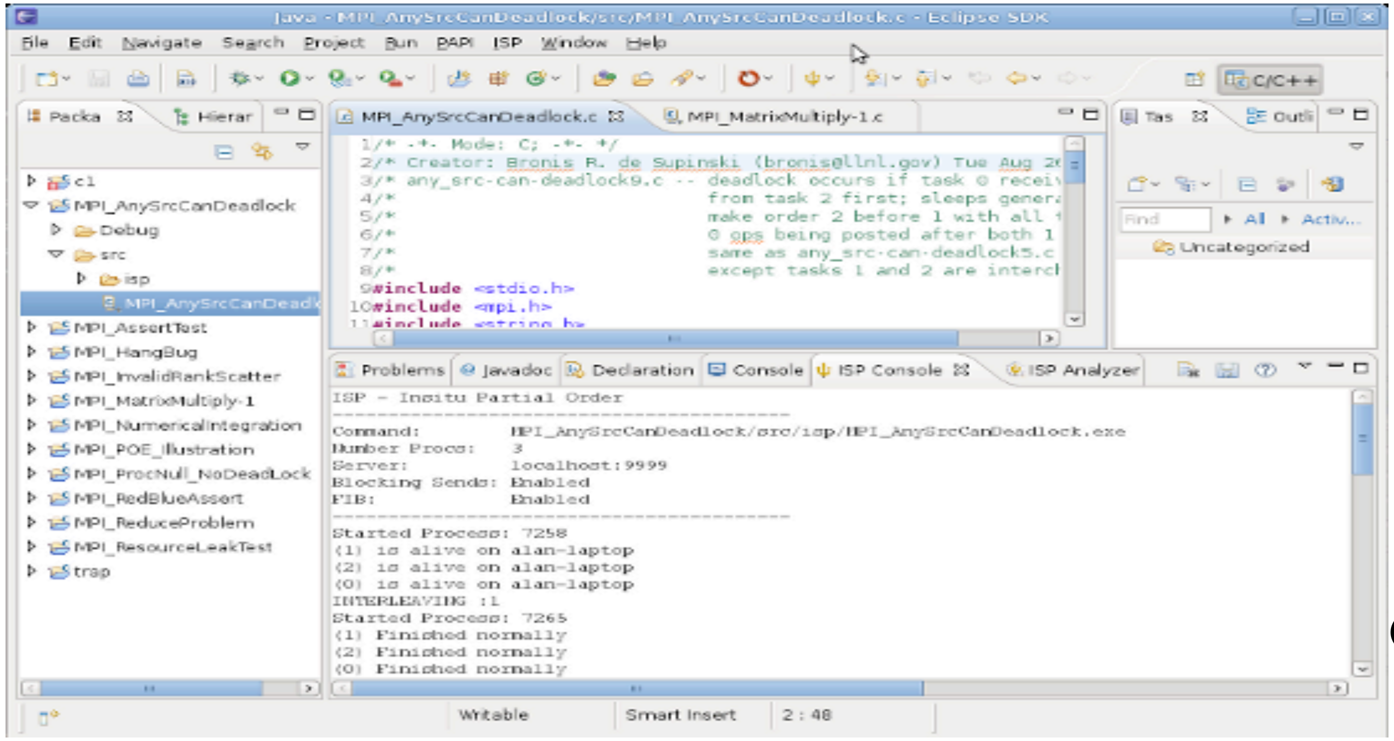
Summary of ISP

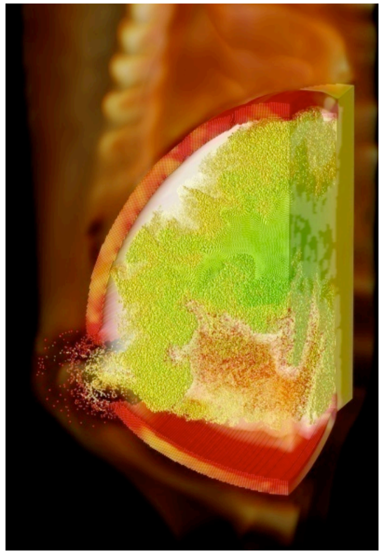
- We have built the only push-button dynamic analysis tool for MPI / C programs called ISP
  - Work on MPI / Fortran in progress
  - Runs on MAC OS/X, Windows, Linux
  - Tested against five state-of-the-art MPI libraries
    - MPICH2, OpenMPI, MSMPI, MVAPICH, IBM MPI (in progress)
  - Visual-Studio and Eclipse Parallel Tools Platform integration
  - 100s of large case studies : tool + these + LiveDVD ISO available !!
  - Guarantees to find assertion violations, deadlocks, MPI leaks (for a given test harness, all RELEVANT interleavings are replayed)
  - Efficiency is decent (getting better)
    - 15K LOC Parmetis Hypergraph Partitioner analyzed for deadlocks, resource leaks, assertion violations for a given test harness in < 5 seconds for 2 MPI processes on a laptop
  - Contribution to the Eclipse Consortium underway (lawyers looking now)
- ISP can dynamically execute and reveal the space of all standard-compliant executions of MPI even when running on **an arbitrary platform**
  - **ISP's internal scheduling decisions are taken in a fairly general way**

Features of ISP, dynamic verifier for MPI apps

(BlueGene/L - Image courtesy of IBM / LLNL)

- Verifies MPI User Applications, generating only the *Relevant Process Interleavings*
- Detects all Deadlocks, Assert Violations, MPI object leaks, and Default Safety Properties
- Works by Instrumenting MPI Calls Computing Relevant Interleavings, Replaying





(Image courtesy of Steve Parker, U of Utah)

End of B