A Debugger for Computational Grid Applications

Robert Hood rhood@nas.nasa.gov
Gabriele Jost gjost@nas.nasa.gov

CSC/MRJ Technology Solutions
NASA AMES Research Center

NAS Parallel Tools Group (1)

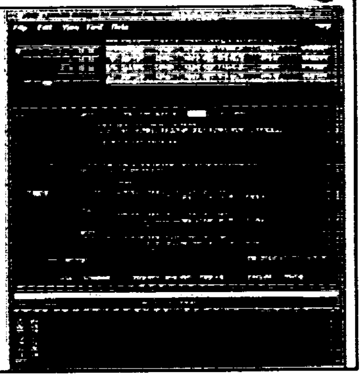
- Parallelization support Tools
  - CAPTools: Transforms serial Fortran code into MPI code with user guidance
  - CAPO: Transforms serial Fortran code into OpenMP code with user guidance
  - Charon: library tool for data distribution and message passing on top of MPI.
  - Adapt: tool for data placement in data parallel programming models
  - Current work: support of multi-level parallelization and hybrid MPI-OpenMP parallelization

NAS Parallel Tools Group (2)

- P2d2 parallel/distributed debugger
- Evaluation of various parallelization strategies:
  - performance, type of application, type of hardware architecture, portability
- Distributed and aggregated computing:
  - large applications running under Globus
- Jobs scheduling and resource allocation under Globus

Historical Background

- ~~Goal in 1994~~: Develop a distributed debugger
  - with a user interface that scales to "many" processes
  - portable across a large variety of machines
- Result in 1996: p2d2 (portable parallel/ distributed debugger)
  - scalable UI
  - highly portable
  - facilitates further research



Debugging Challenge 1998

- ~~Need a~~ debugger for computational grids

- Rest of talk:
  - Debugger architecture
    - support of heterogeneity
    - support of scalability
  - Attaching to grid computations
  - Quick discourse on running jobs under Globus

Debugger Dependencies

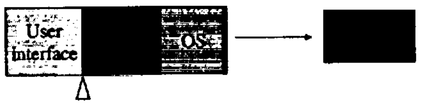
- Function of the Debugger:
  - Mapping between user view of a program at source code level onto the machine version at object level.
- Dependencies:

– Target architecture	⟶	Breakpoint implementation
– Operating system	⟶	Process control
– Compiler	⟶	Symbol table information

Additional dependencies for **parallel processing**, e.g.:
- thread abstraction,
- synchronization method,
- message passing format,
- process creation

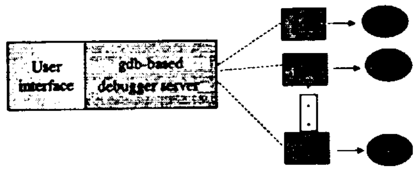
Accomodating Heterogeneity

- P2d2 approach to heterogeneity:
  - Isolate the dependencies of the debugger from the user interface through the use of a client-server model.
- Debugger server :
  - Architecture-, OS-, and compiler-dependent code.
  - Implemented by vendor.
- User interface (UI) client:
  - portable code



Initial Implementation

- Use *gdb* from the Free Software Foundation as debugger server
  - Advantages:
    - freely available
    - portable
  - Disadvantages:
    - Fortran support minimal
- Replication of gdb's permits heterogeneity.

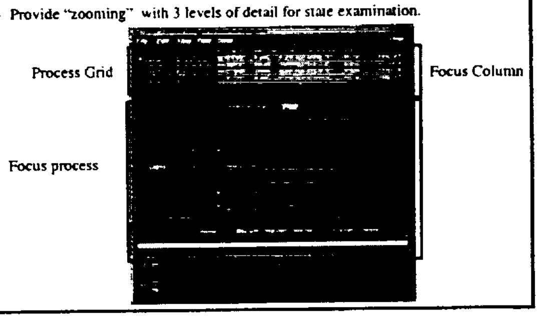


Scalability

- Main debugger operations that need to scale:
  - process control operations
    - setting/deleting breakpoints, continue, single step
  - state examination
    - print, display, stack trace
- Debugging N processes:
  - indicate on which processes control operations are performed
  - extract state information across a set of processes
- p2d2 *process navigation paradigm*:
  - process control operations to processes in control set
  - overview of global state in process grid
  - more information about processes in focus group
  - detailed information about focus process.

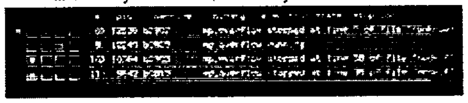
Scaling the User Interface

- Allow collective control of processes
- Provide "zooming" with 3 levels of detail for state examination.



The Process Grid:

- Overview of all processes in the computation
- Used for "zooming in" on processes for closer examination:
  - the focus group
    - one line of text about each process in group
  - the focus process:
    - detailed information about a single process
  - the control set:
    - processes that receive control operations (breakpts, continue)
    - indicated by white frame, selected by mouse click

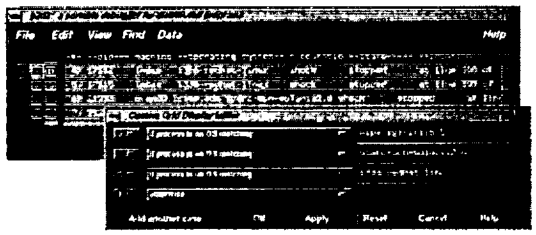


Brief Discourse on Globus (1)

- What are Grids?
  - Super Internets for high-performance computing
  - Worldwide collection of high-end resources:
    - supercomputers, storage, advanced instruments, immersive environments
  - Enable the development of applications that require geographically distributed high-end resources
- What is Globus?
  - Software toolkit to facilitate the creation of Grids
  - Allows:
    - uniform access to distributed resources
    - information services about available resources
    - tools for remote file management, staging of executables and data

Heterogeneity &the UI-Customizing the Display

- Process grid view can be programmed:
  - a list of directives of the form: <icon> if <predicate>
- Samples for <predicate>:
  - running(), eval(expr), systemMatches (string)



Heterogeneity and the UI: Consistent Data View

- Comparing expression values across processes:
  - gdb evaluates to text
  - question: In what context should gdb do the evaluation?
- P2d2 tries to do evaluation in equivalent stack frame:

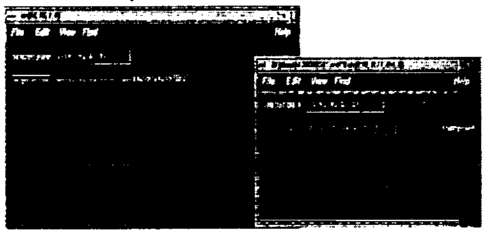
```
Process 1:          Process 2:
#0 in subl          #0 in sub2()
#1 in toto()        #1 in sub3()
#2 in main()        #2 in toto ()
                    #3 in main()
```

In heterogeneous environment:

- function names don't match, e.g.,
  `toto` vs. `toto_` vs. `toto__`
  convert function names to canonical form

Heterogeneity & the UI-Abstract Data View

- Distributed array view



Global Array View　　Local Array View

Status and Future Work

- Status of p2d2 debugging Globus jobs:
  - debugged a Globus job running on 3 machines
    - SGI Origin in California
    - PC/Linux in Ohio
    - Sun Sparc Workstation in Virgina
  - debugged a 128-process Globus job running on 3 Origins
  - not yet there :
    - record contact information in MDS
    - security for Globus initiated jobs
- Distribution Status:
  - plan to distribute under an "OpenSource" copyright.
- Current work:
  - relative debugging of tool-parallelized programs