Debugging with Totalview and DDT

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Three Steps of Code Development

- Debugging
  - Make sure the code runs and yields correct results
- Profiling
  - Analyze the code to identify performance bottlenecks
- Optimization
  - Make the code run faster and/or consume less resources

Debugging Essentials

- Reproducibility
  - Find the scenario where the error is reproducible
- Reduction
  - Reduce the problem to its essence
- Deduction
  - For hypotheses on what the problem might be
- Experimentation
  - Filter out invalid hypotheses

Debugging Methods

- Write/print/printf
- Compiler flags
  - Array bound check, floating point exception etc.
- Debuggers
  - Command line: gdb
  - Graphic: Totalview, DDT, Valgrind, Eclipse

Validation Is Very Important

- Debuggers can tell you where the program crashes and help you to gain better understanding of the context, but
- They cannot detect a correctness problem
- So, it is always a good idea to have test cases with known solutions against which you can validate your program

TotalView & DDT

- Powerful debuggers
  - Can be used to debug both serial and parallel programs
  - Support multiple languages
    - Both supports CUDA
  - Supported on most architecture/platforms
  - Graphic user interface
    - Totalview also has a command line interface
  - Numerous other features
    - Array visualization
    - Memory debugging
    - …

Availability

- TotalView
  - 8.8.0 on Queen Bee (+totalview-8.8.0)
  - 8.3.0 on Queen Bee, Tezpur, Philip and Eric (+totalview-8.3.0.1)
- DDT
  - 2.6 on all LONI and LSU HPC Linux clusters (+ddt-2.6)

Preparing for a Debugging Session

- Compile the program with debugging turned on and optimization turned off (-O0 –g)
- Add softenv keys and resoft
- Make sure X Windows works
- Submit an interactive job session

Working with Debuggers

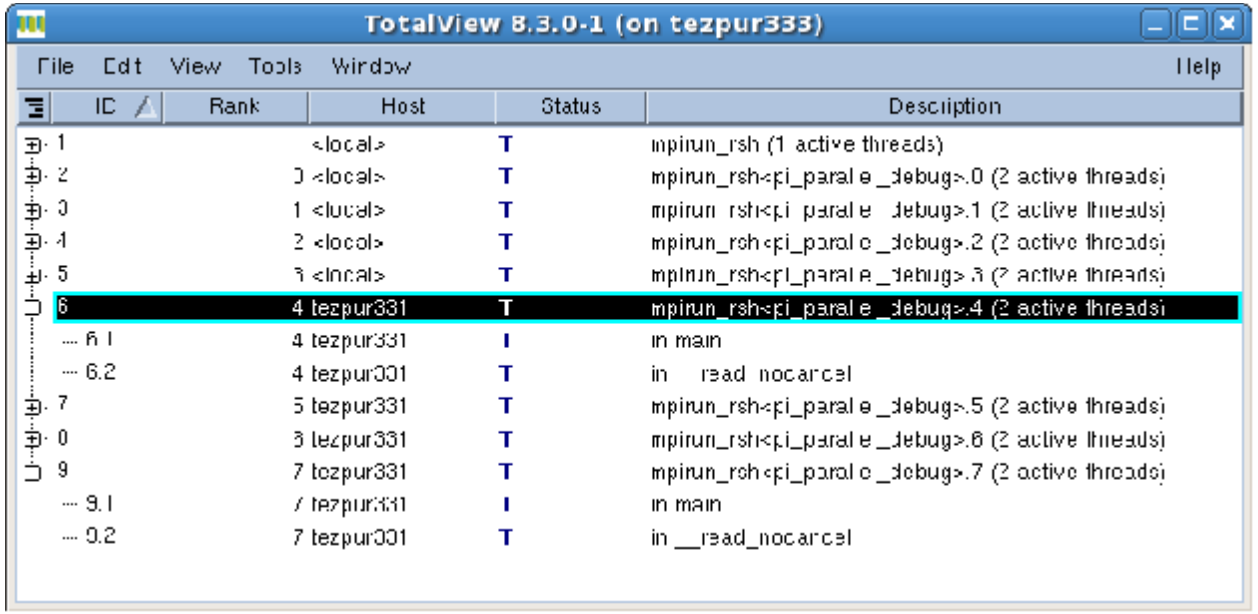
- One can start debugging by
  - Starting the debugger with the executable
  - Debugging a core dump
  - Attaching to a running (or hanging) process
- Common debugging operations
  - Setting up action points
  - Controlling the execution
  - Examining the value of variables
  - …

Launching a Debugging Session

- Serial program
  - Totalview
    - `totalview <executable> -a <program options>`
  - DDT
    - `ddt –start <executable> <program options>`
- Parallel program
  - Totalview
    - `mpirun_rsh –tv –np <num_procs> <host list> <executable> <program options>`
    - `mpirun_rsh –tv –np <num_procs> -hostfile <path_to_hostfile> <executable> <program options>`
  - DDT
    - `ddt –start –np <num_procs> <executable> <program options>`

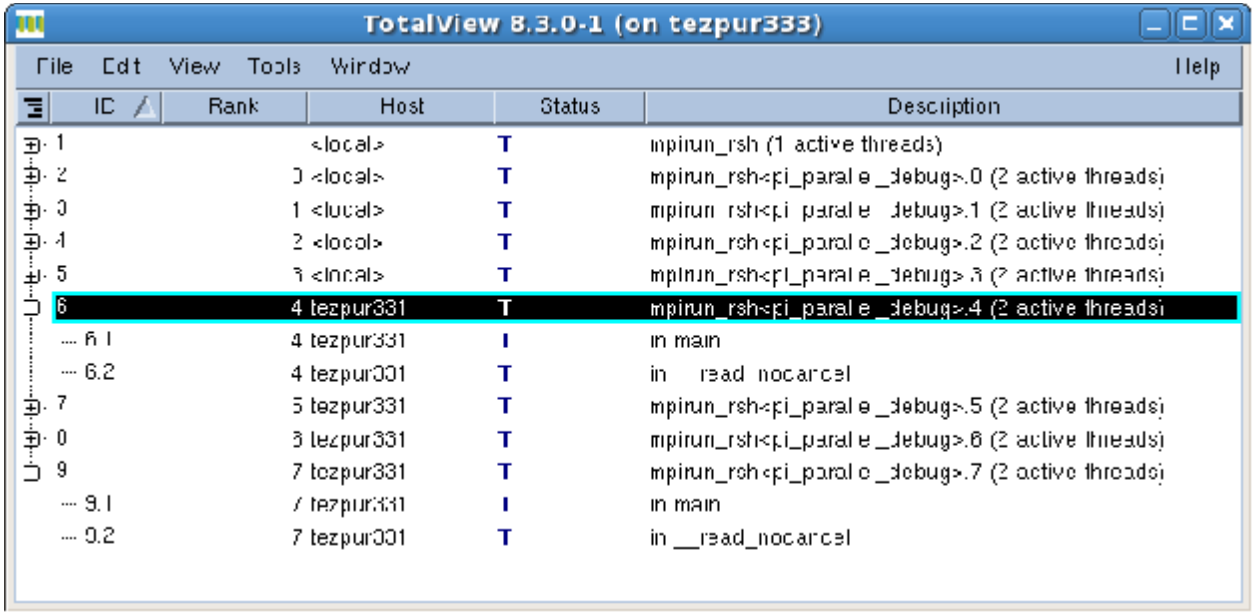
TotalView GUI – Root Window

- Always appears when TotalView is started
- Provides an overview of all processes and threads



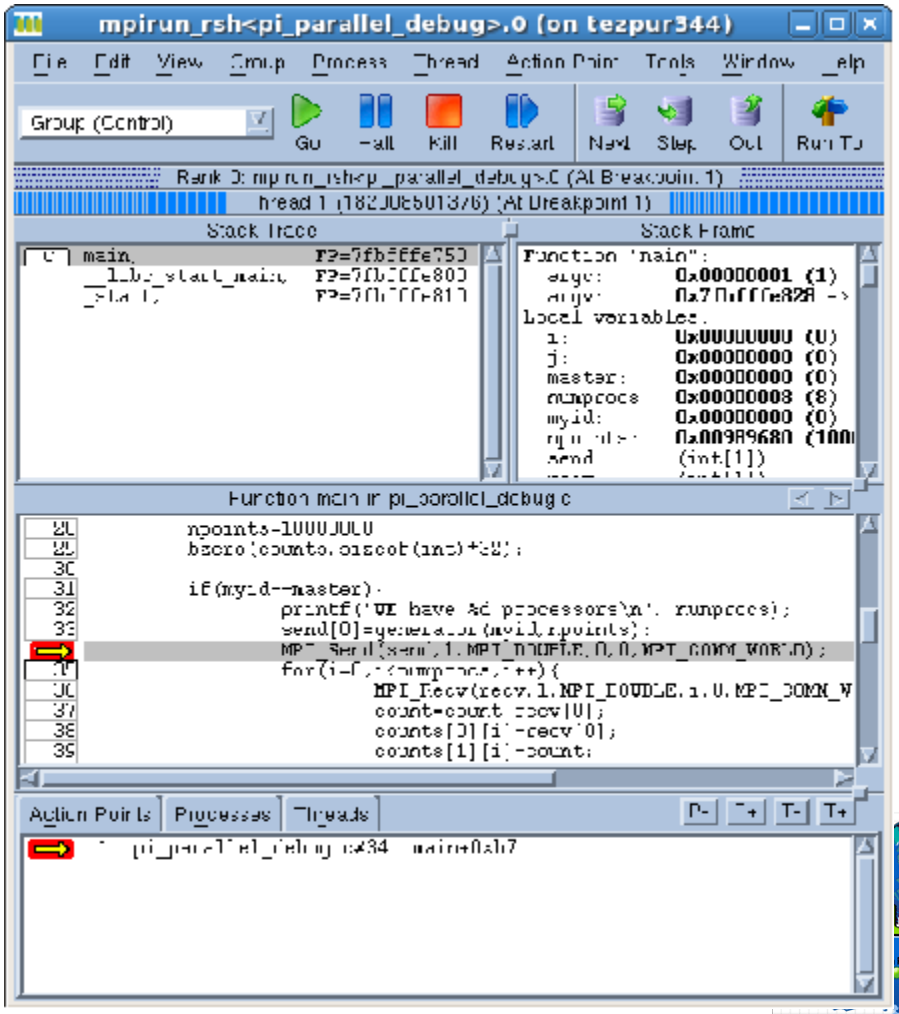
TotalView GUI – Root Window

Status code	Description
Blank	Exited
B	At breakpoint
E	Error
H	Held
K	In kernel
M	Mixed
R	Running
T	Stopped
W	At watchpoint



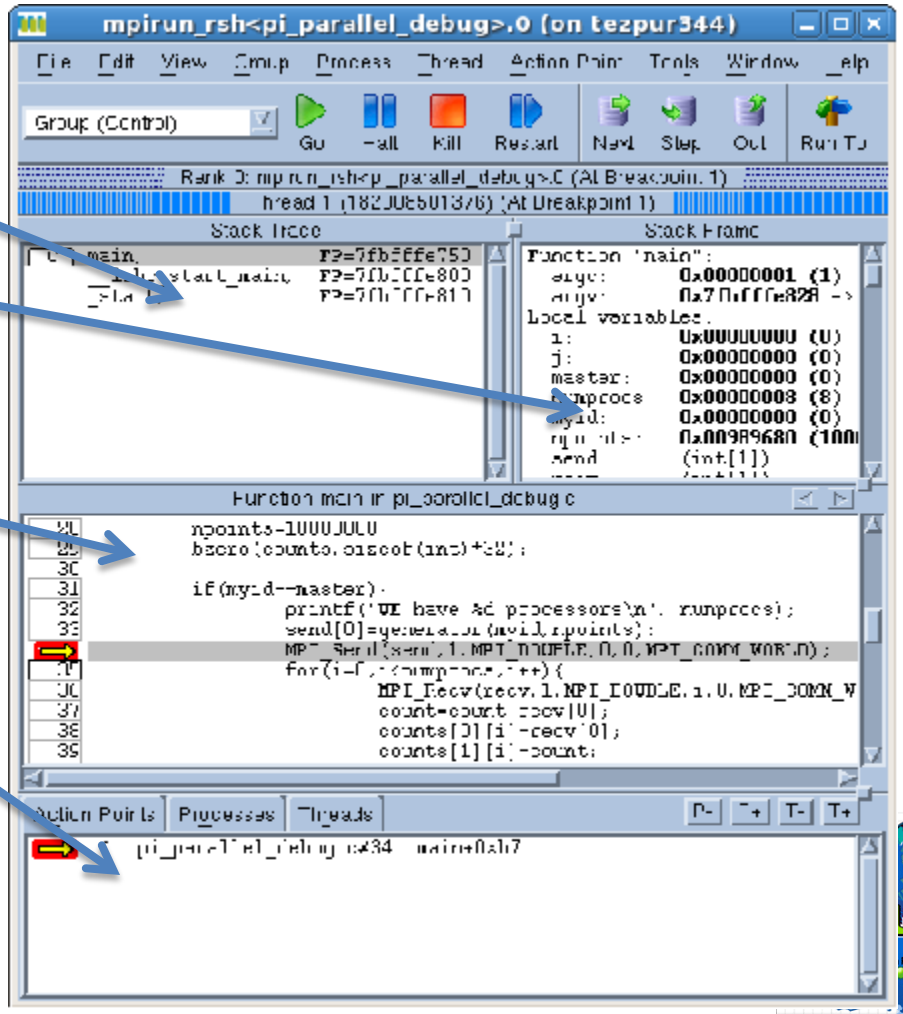
TotalView GUI – Process Window

- Appears when TotalView is started
- For parallel programs each process/thread may have its own process window



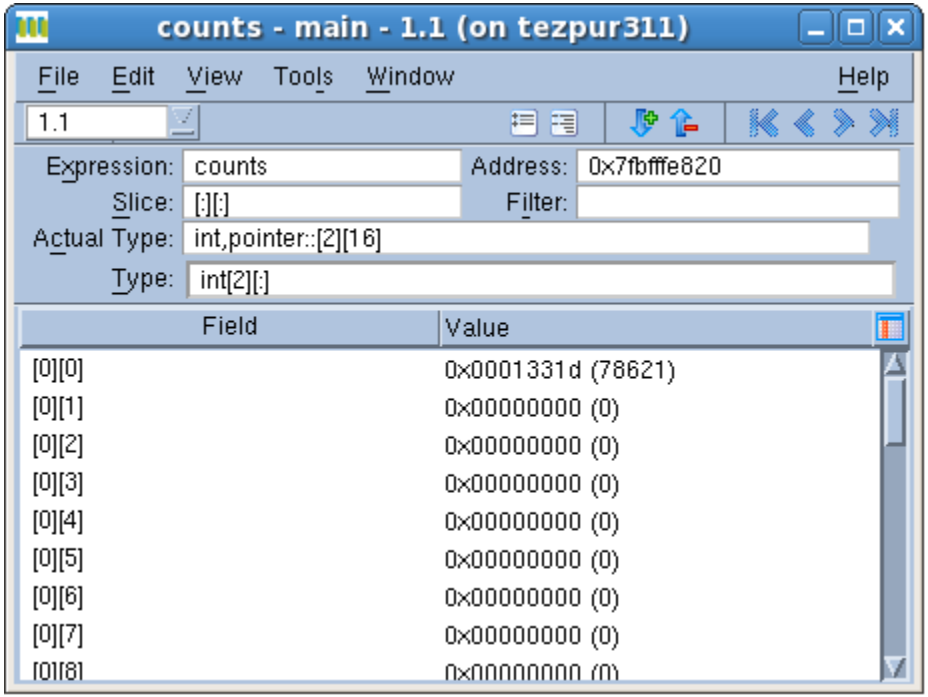
TotalView GUI – Process Window

- Stack trace pane
  - Call stack of routines
- Stack frame pane
  - Local variables, registers and function parameters
- Source pane
  - Source code
- Action points, processes, threads pane
  - Lists of action points
  - Lists of processes
  - List of threads

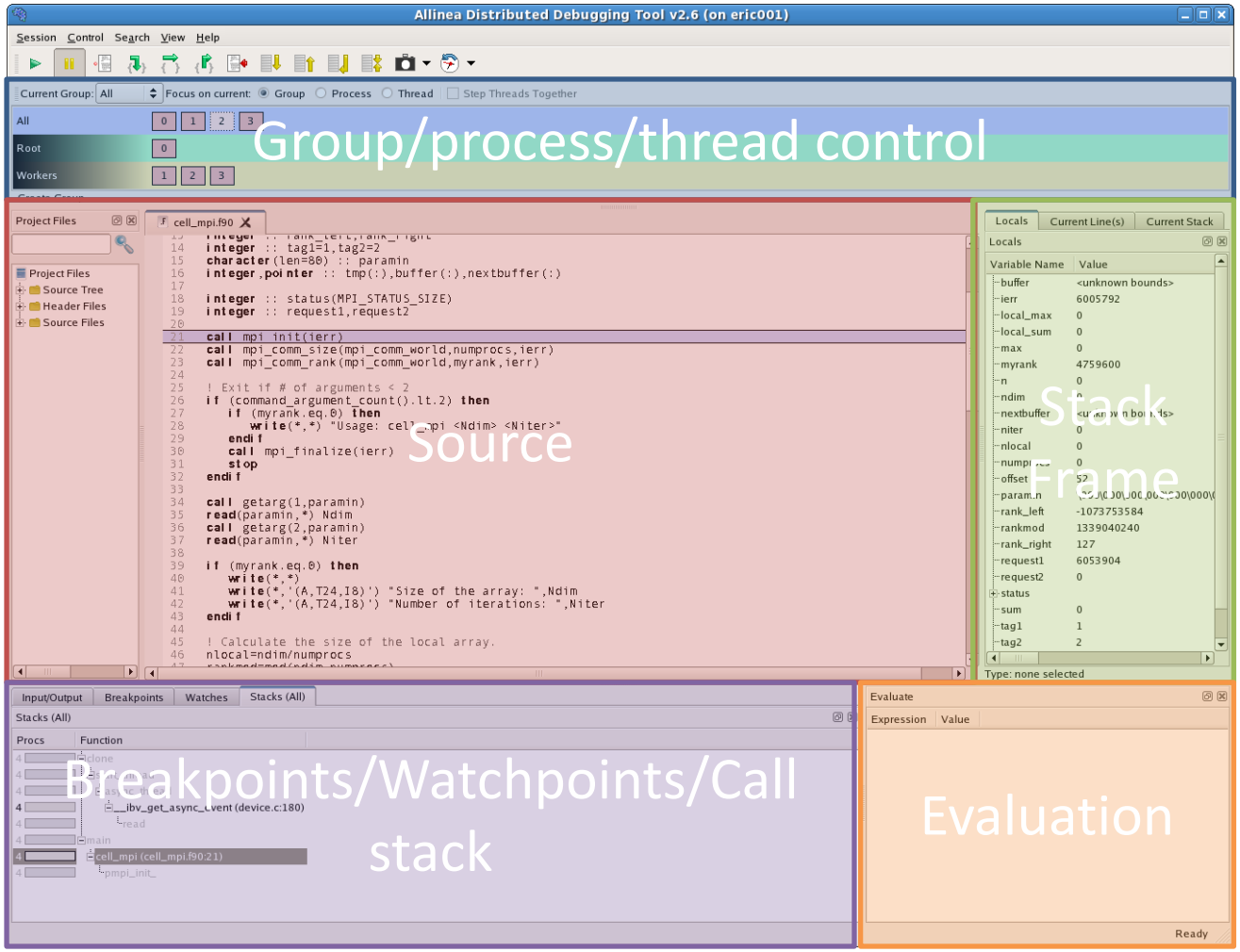


TotalView GUI – Variable Window

- Can be opend by double-clicking on a variable name
  - Called “dive” in Totalview terminology
- Display detailed information of a variable
- One can also edit the data here



DDT GUI

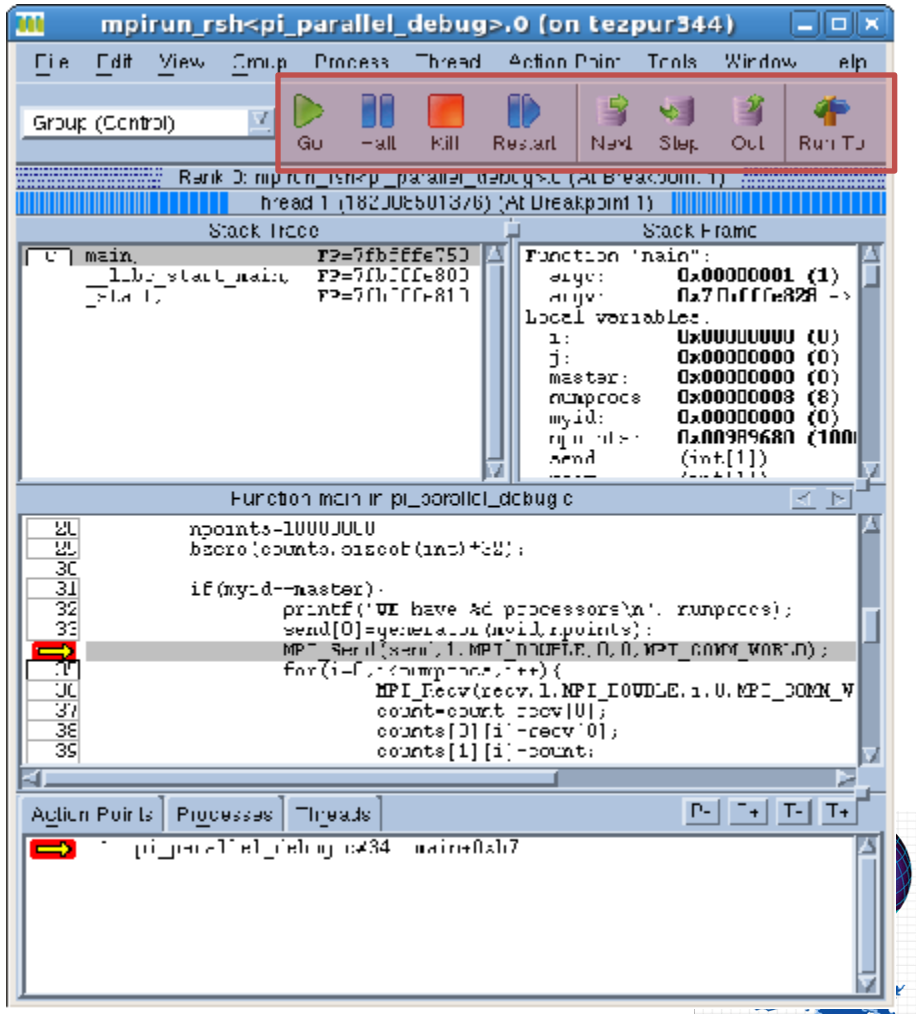

Allinea Distributed Debugging Tool v2.6 (on eric001)
Session Control Search View Help
Current Group: All
Focus on current: Group Process Thread
Step Threads Together
All
Root
Workers
Group/process/thread control
Project Files
cell_mpi.f90
Source
Locals
Current Line(s)
Current Stack
Variable Name
Value
Stack Frame
Input/Output
Breakpoints
Watches
Stacks (All)
Procs
Function
Breakpoints/Watchpoints/Call stack
Evaluate
Expression
Value
Evaluation
Ready

Other Ways of Starting a Debugging Session

- Open a core file
  - Need to select an executable
  - Can only browse variables and evaluate expressions since there is no active process
- Attach to one or more running (or hanging) processes

TotalView: Controlling Execution

- Commonly used commands
  - Go: start/resume execution
  - Halt: stop execution
  - Kill: terminate debugging session
  - Restart: restart a running program
  - Next: run to next source line WITHOUT stepping into another function or subroutine
  - Step: run to next source line
  - Out: run to the completion of a function or subroutine



DDT: Controlling Execution

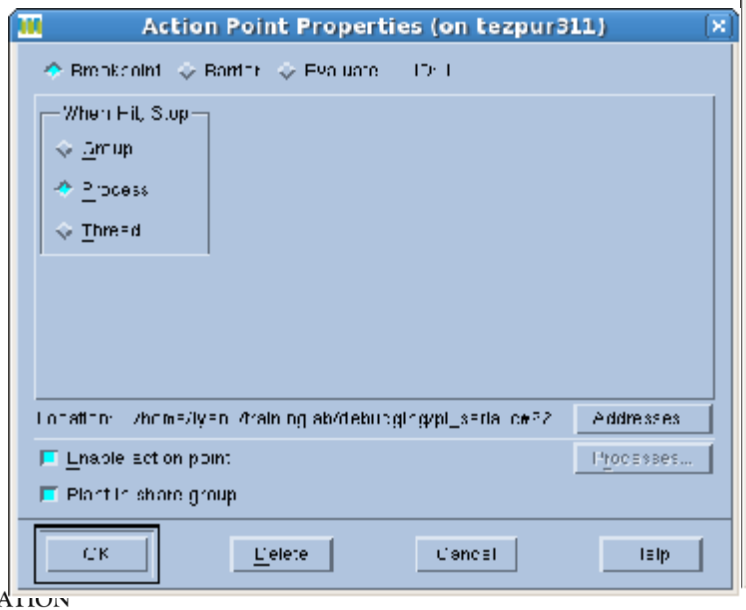
- Similar commands to TotalView
- A few more commands to move up and down stack frame
  - The “align stack frames” command is useful to bring paused processes to the same place in the program

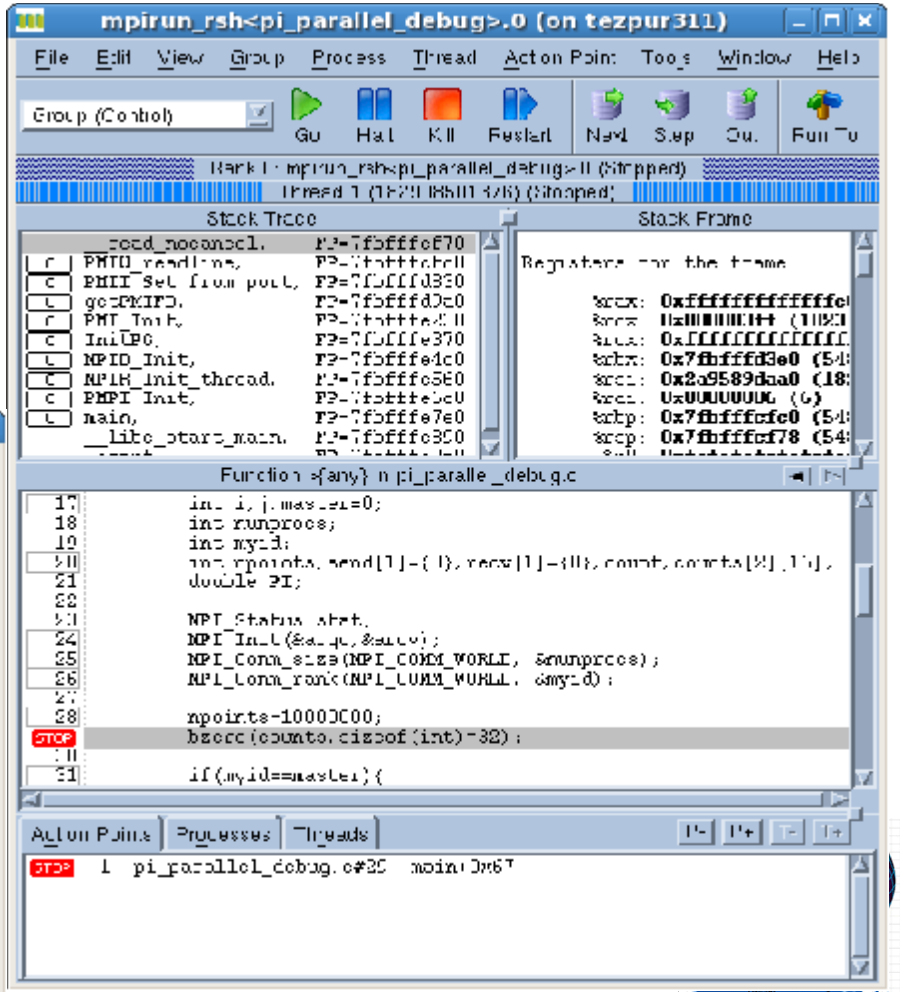
Action Points

- Break points stop the execution when reached
  - Can be conditional
- Barrier points synchronize a set of processes of threads
- Evaluation points cause a code segment to be executed when reached
- Watch points allow the programmer monitor a location in memory
  - Can stop execution or evaluate an expression when its value changes

TotalView: Break points

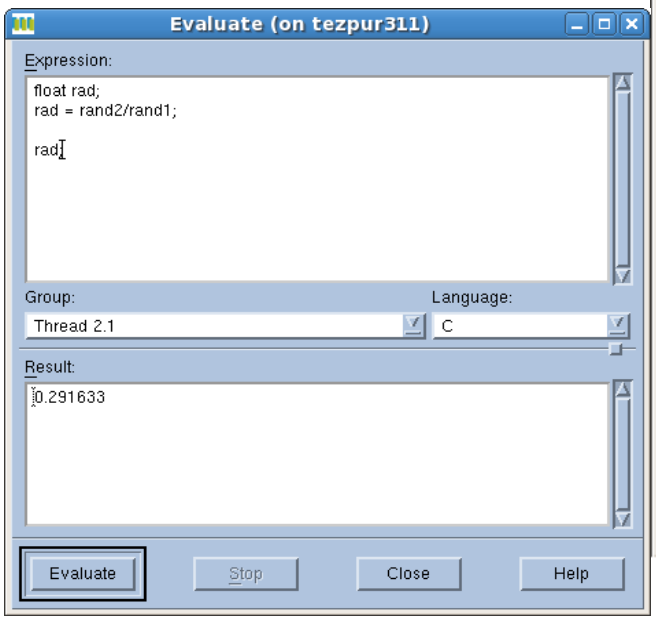
- How to set
  - Left click on the line number
  - Right click on a line -> “set breakpoint”
- Will appear in the action point list

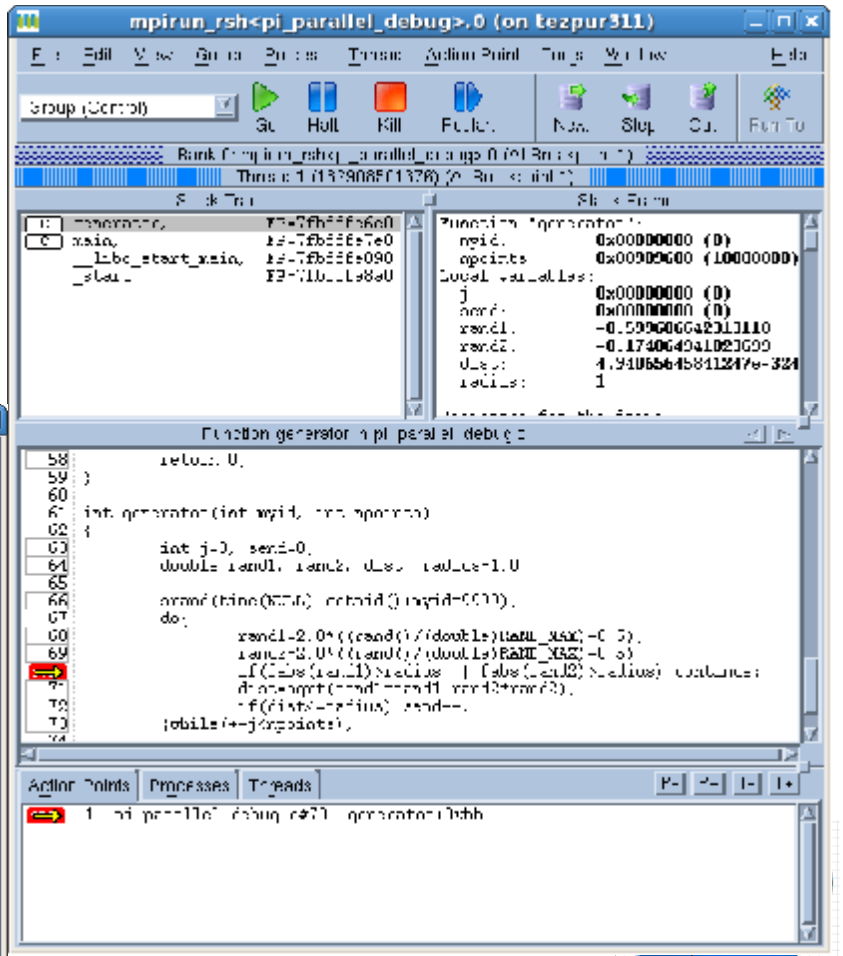




TotalView: Evaluation Points

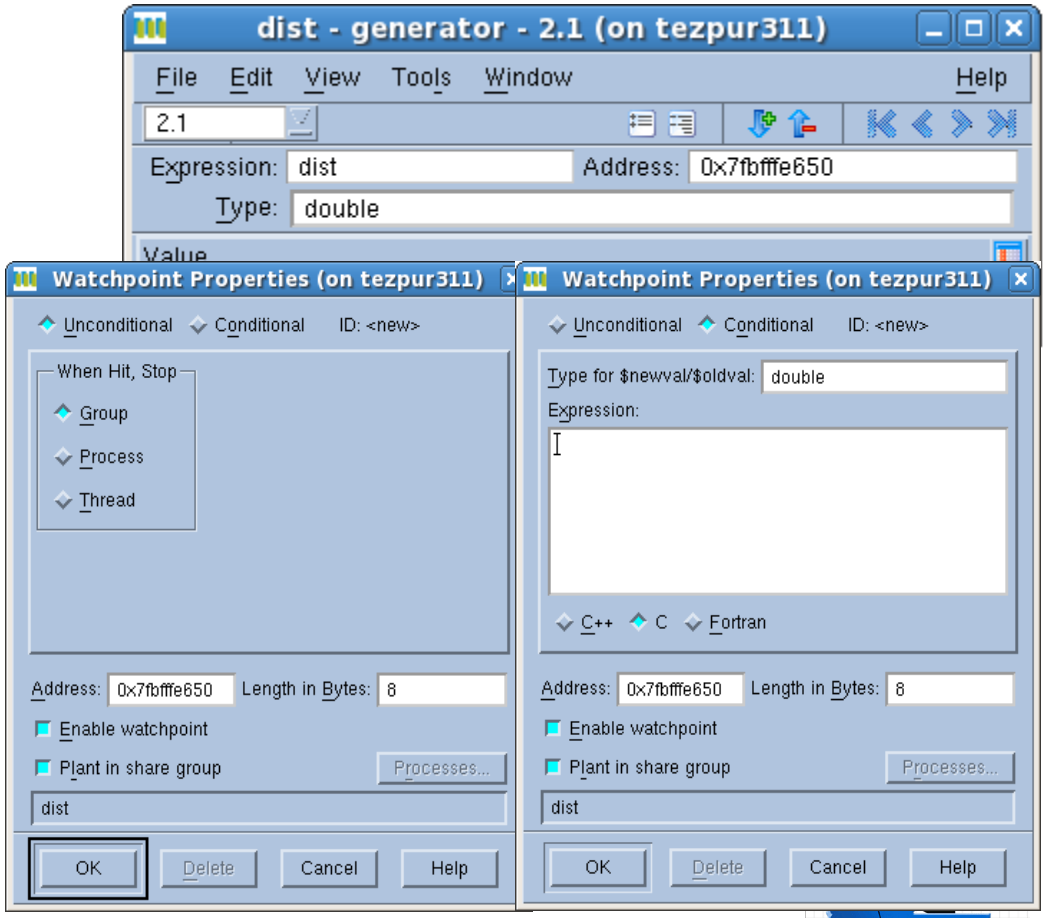
- How to set
  - "Tools" -> "Evaluate"
- Execute a small segment of code at specified location
  - Useful when testing on-the-fly fixes





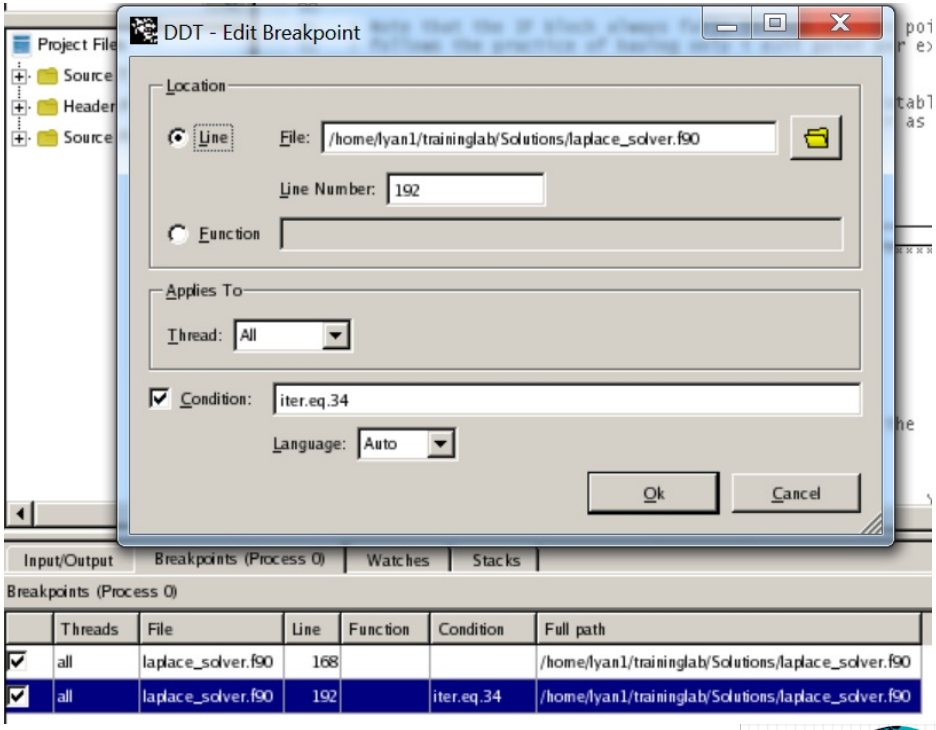
TotalView: Watch Points

- Monitor a memory location and stop execution when it is overwritten
- How to set
  - Right click on a variable -> "Create watchpoint"
- Can be conditional
  - Example: only watch this memory location after a certain number of iterations



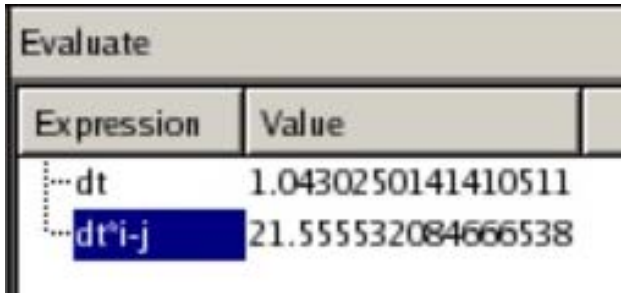
DDT: Breakpoints

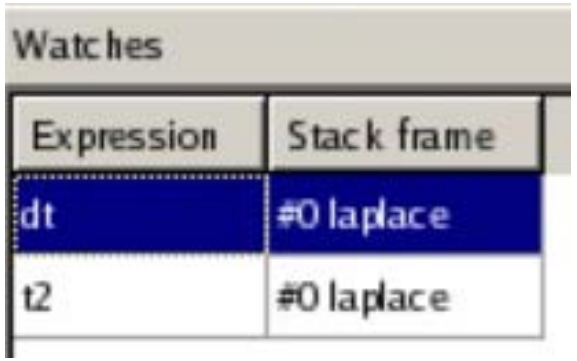
- How to set
  - Double click on a line
  - Right click on a line -> "Add breakpoint"
- Will appear in the breakpoint list



DDT: Evaluation and Watch Points

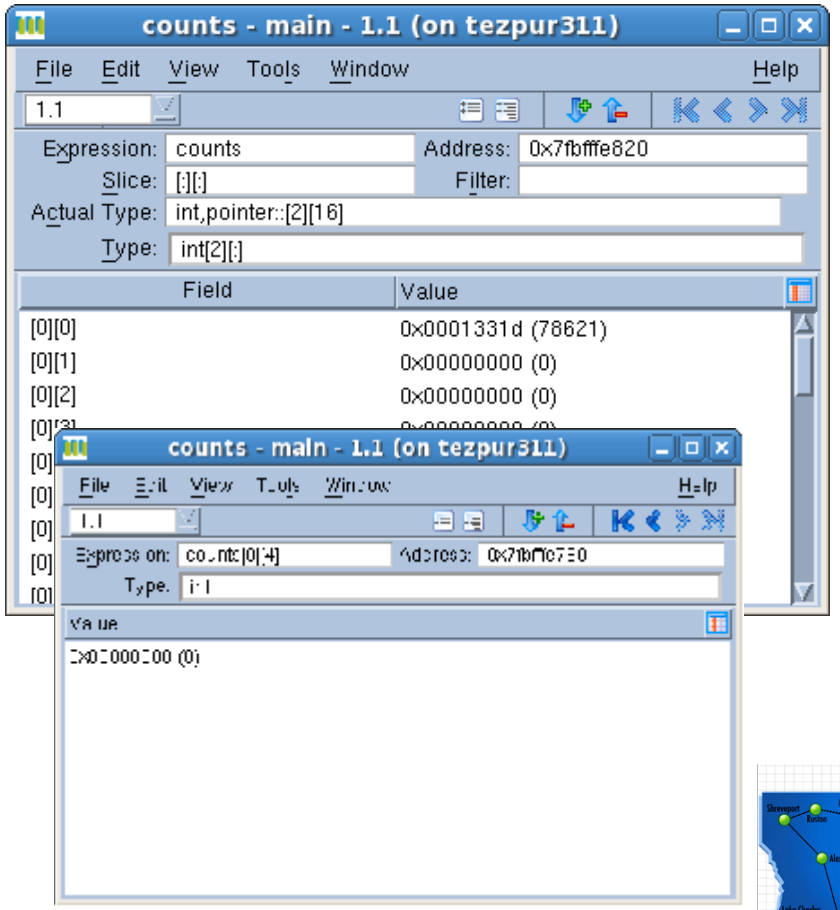
- How to set
  - Right click on variable -> "Add to Evaluations" or "Add to Watchs"
- DDT does not provide as many options for evaluation and watch points





TotalView: Diving On An Object

- "Diving" means "showing more details on an object"
- One can dive on
  - Variables
  - Processes/threads
  - Subroutines
- Use "undive" to go back

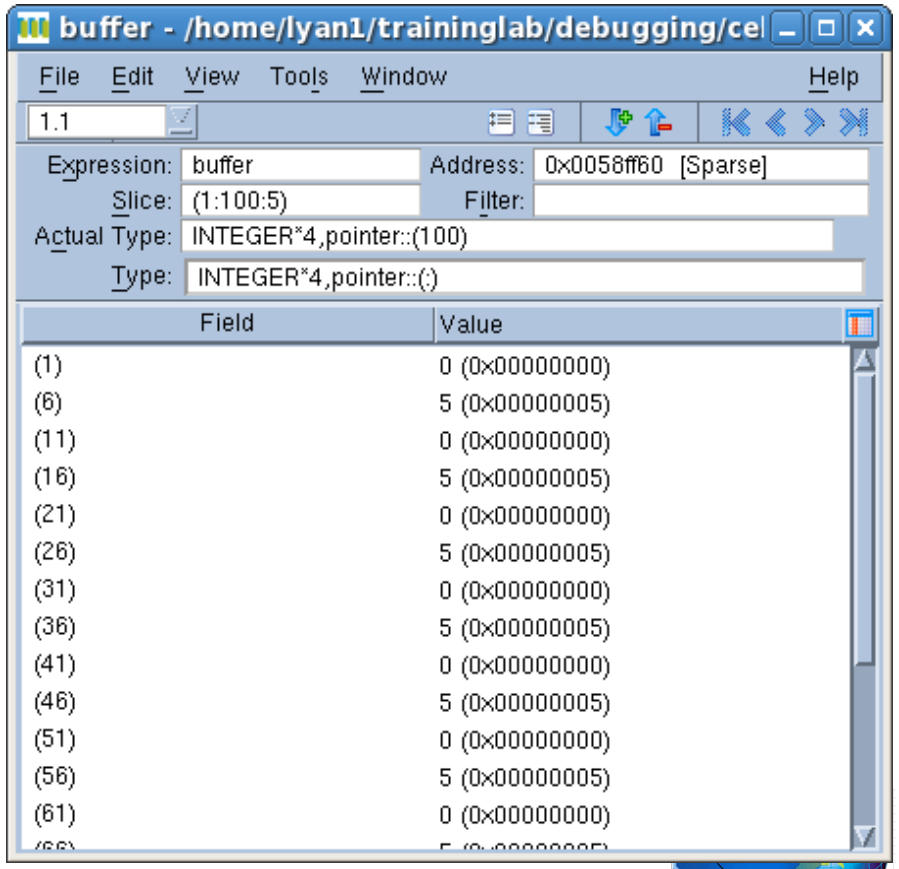


TotalView: Viewing/Editing Data

- View values and types of variables
  - By hovering mouse over the variable
  - In stack frame
  - In variable window
- Edit variable value and type
  - In stack frame
  - In variable window

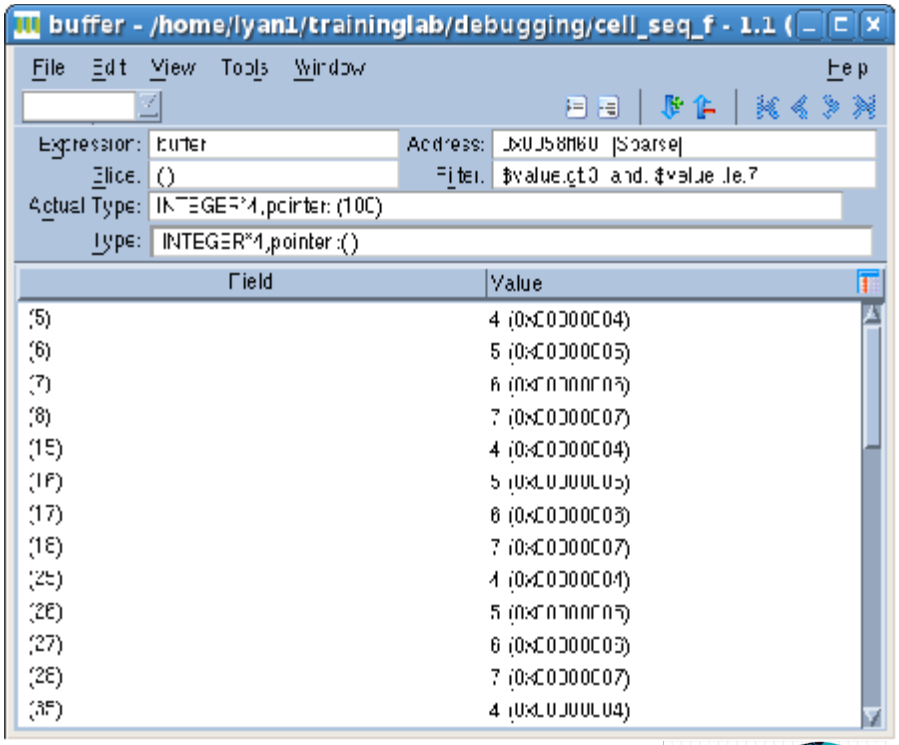
TotalView: Handling Arrays (1)

- Slicing
  - Display array subsection by editing the slice field in the variable window
  - Form
    - [upper bound:lower bound:stride]



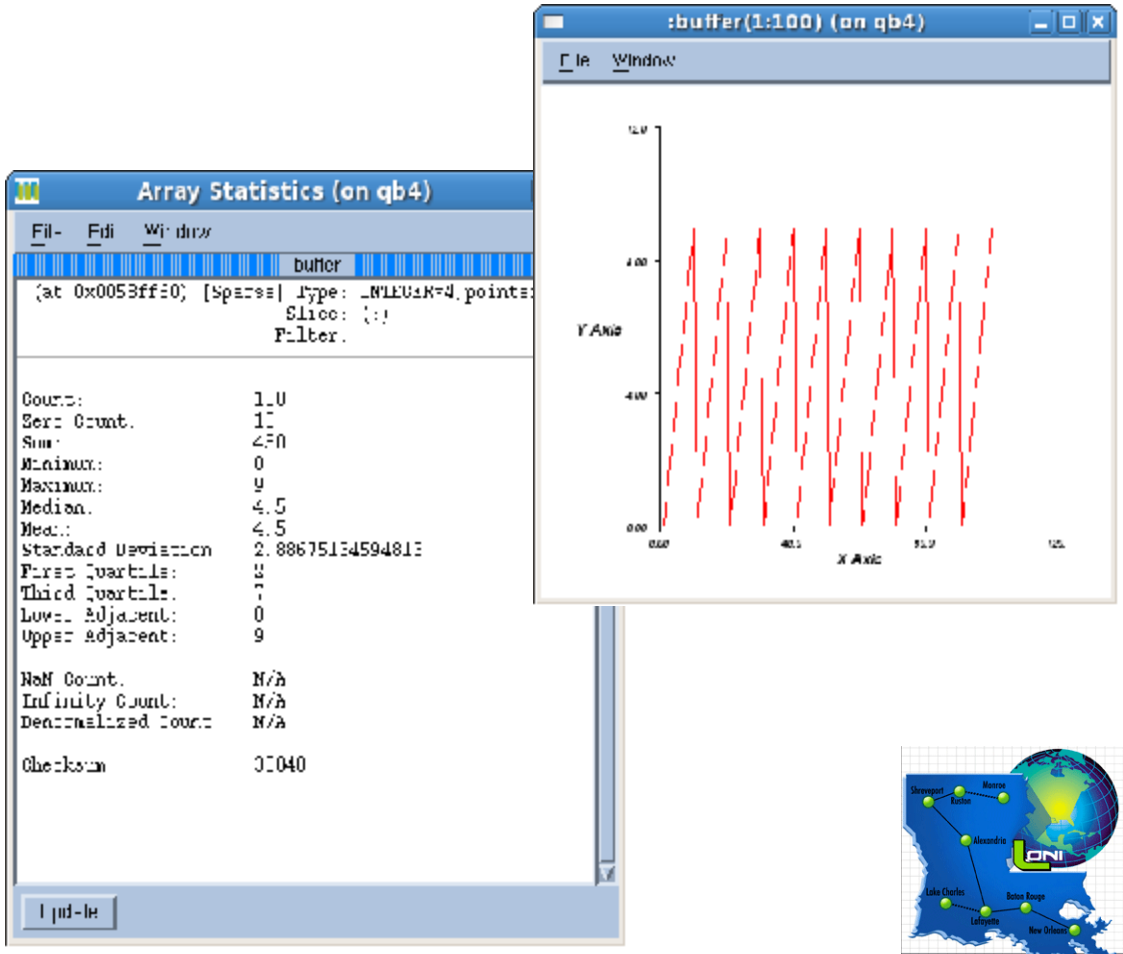
TotalView: Handling Arrays (2)

- Filtering
  - Display array subsection by applying a filter (filter field in the variable window)
  - Available filter options
    - Arithmetic comparison to a constant
    - Comparison to NaNs and Infs
    - Conditions can be combined by using logic operators

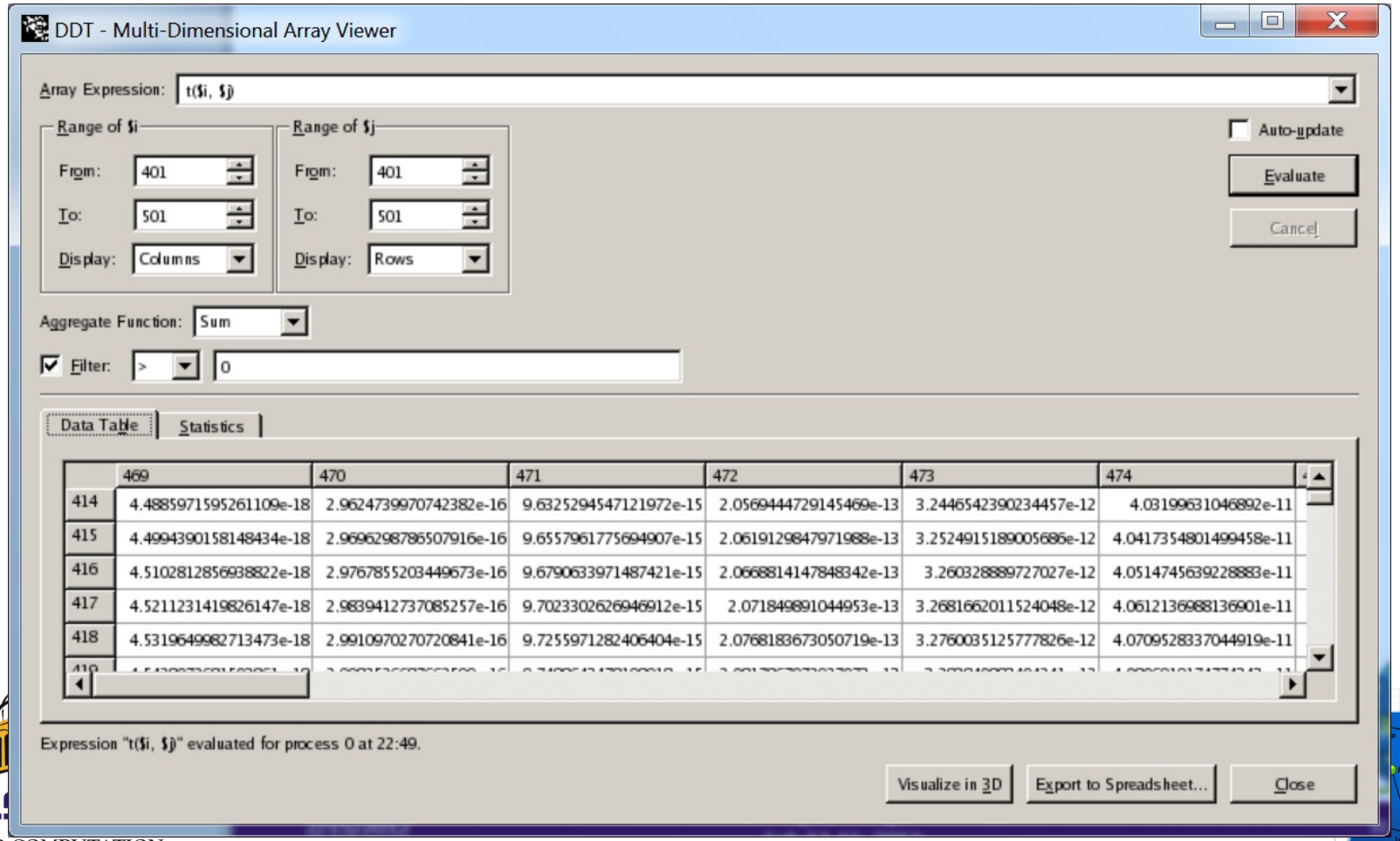


TotalView: Handling Arrays (3)

- Visualization
- Statistics



DDT: Handling Arrays



Bugs in Parallel Programs

- Parallel programs are prone to the usual bugs found in sequential programs, plus
  - Erroneous use of language features
  - Mismatched parameters, missing mandatory calls etc.
  - Defective space decomposition
  - Incorrect/improper synchronization
  - Hidden serialization

Debugging Parallel Programs

- Everything we talked about TotalView still works (well, almost)
  - Exceptions: stepping over a communication call while the other processes are stopped or being held
- Additional features
  - Scope of Control Commands
    - Group/Process/Thread
  - Displaying message queues (MPI programs)

Scope of Control Commands

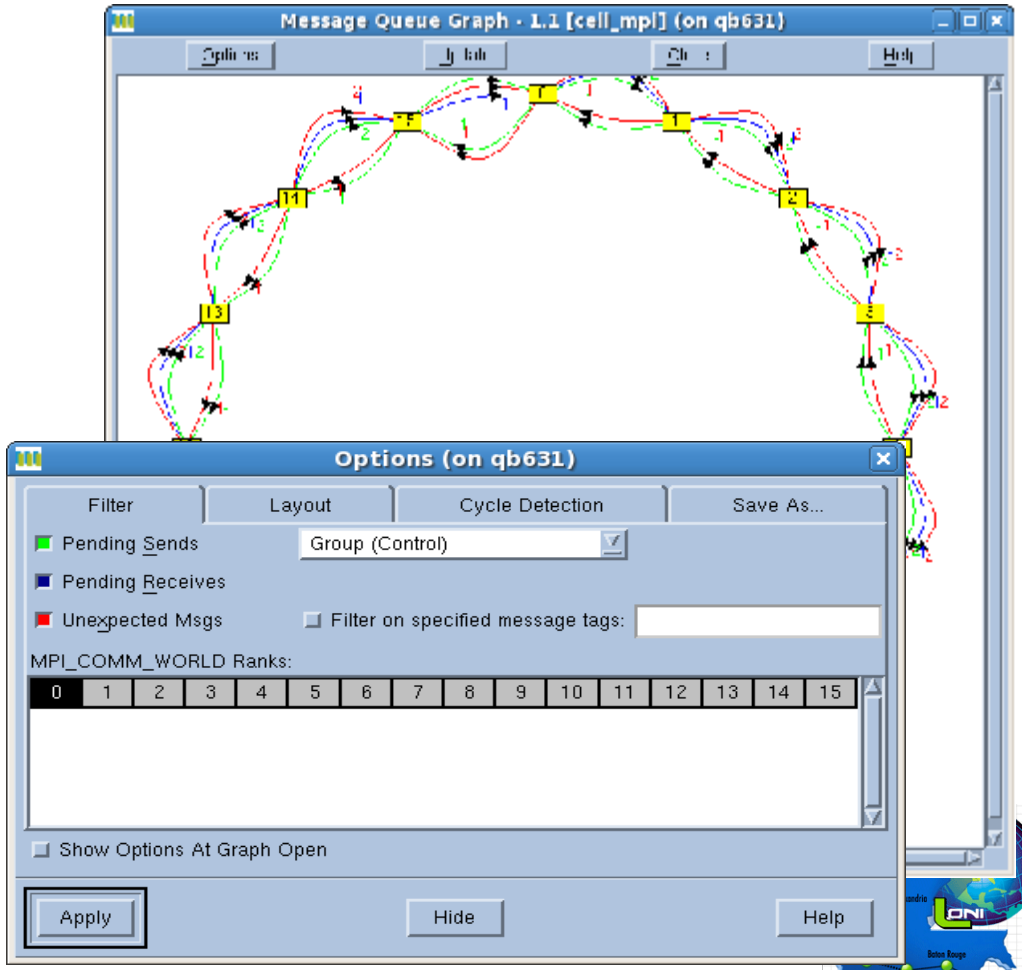
- For serial programs
  - Not an issue because there is only one execution stream
- For parallel programs, we need to decide the scope to which a control command applies
  - The process window always focuses on one process/thread
  - Need to set the appropriate scope when
    - Giving control commands
    - Setting action points
  - Switch between process/threads
    - ?p+/p-?and 搕+/t-?button
    - Through the root window
    - Through the process/thread tab

Process/Thread Groups

- Group (control): all processes and threads
- Group (workers): all threads that are executing user code
- Rank X: current process and its threads
- Process (workers): user threads in the current process
- Thread X.Y: current thread
- User defined group
  - Group -> Custom Groups, or
  - Create in call graph

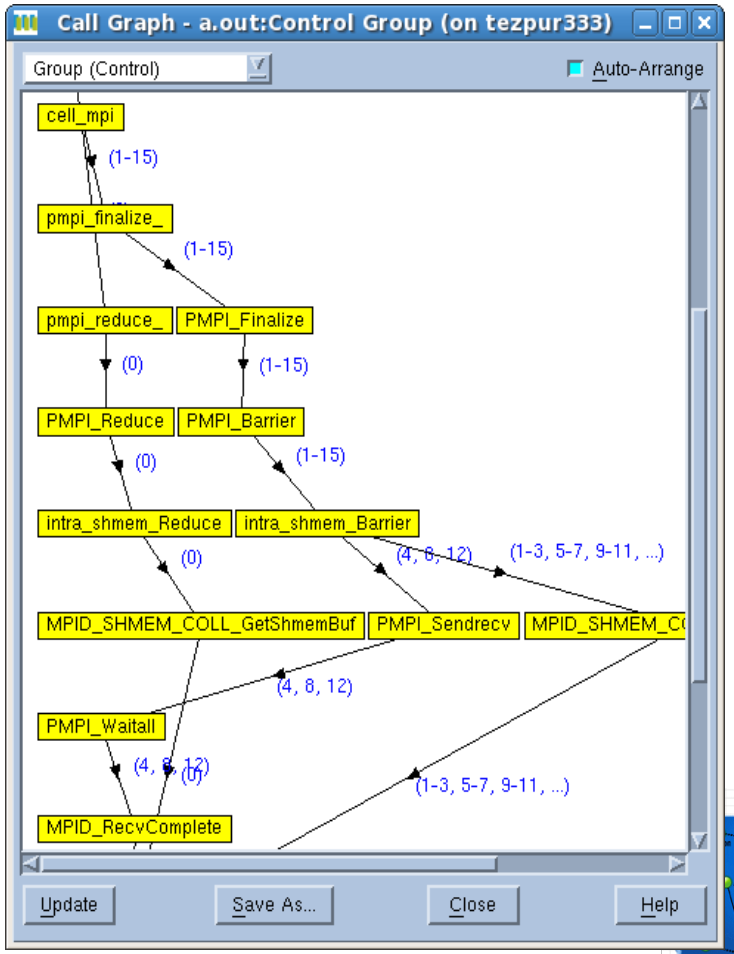
Displaying Message Queues

- Detect
  - Deadlocks
  - Load balancing issues
- To access
  - Tools -> Message Queue Graph



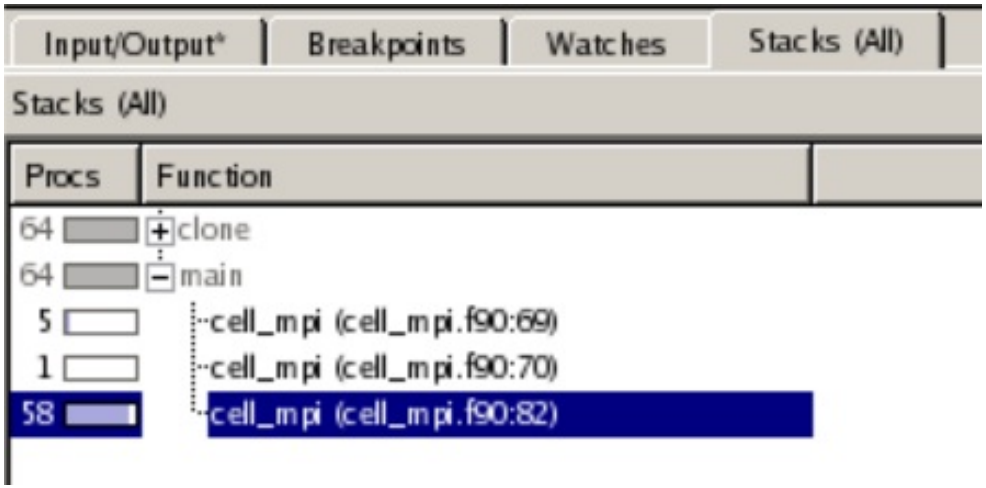
TotalView: Displaying Call Graph

- Quick view of program state
  - Nodes are functions
  - Edges are calls
  - Look for outliers
- To access
  - Tools -> Call Graph



DDT: Parallel Stack View

- Shows a tree of functions merged from every process in a group of processes
- Can create process groups based on their location
- Very helpful when dealing with a large number of processes



Not Covered

- Memory debugging
  - Leak detection
  - Heap status
  - Memory usage
  - Memory comparison
  - …
- Command line interface
- Command line options