Debugging with TotalView

Le Yan

HPC Consultant
User Services
Goals

- Learn how to start TotalView on Linux clusters
- Get familiar with TotalView graphic user interface
- Learn basic debugging functions of TotalView
Outline

- Overview
- Getting Started
- Debugging with TotalView
  - TotalView GUI
  - Basic debugging techniques
  - Features for parallel programs
Outline

• Overview
• Getting Started
• Debugging with TotalView
  • TotalView GUI
  • Basic debugging techniques
  • Features for parallel programs
Debugging Essentials

● Reproducibility
  • Find the scenario where the error is reproducible

● Reduction
  • Reduce the problem to its essence

● Deduction
  • Form hypotheses on what the problem might be

● Experimentation
  • Filter out invalid hypotheses
Debugging Methods

- Write/Print/Printf
- Compiler flags
- Symbolic debugger
  - GDB - GNU debugger
  - IDB - Intel debugger
- Graphic debugger
  - Totalview
  - DDT
  - Valgrind
  - Eclipse
What A Debugger Can and Cannot Do

- **What a debugger can do**
  - Tell you where the program crashes
  - Help you to gain a better understanding of the context under which it crashes

- **What a debugger cannot do**
  - Tell you how to solve the problem
  - Detect a correctness problem
    - Validation is very important
What Is TotalView

• A very powerful debugger
  • Can be used to debug both serial and parallel programs (especially good for parallel programs)
  • Supports multiple languages
  • Supported on most architecture/platforms
  • Both graphic and command line interfaces
• Numerous features
  • Common functionalities such as controlled execution and breakpoints
  • Array visualization
  • Memory debugging
  • ...
Outline

- Overview
- Getting Started
- Debugging with TotalView
  - TotalView GUI
  - Basic debugging techniques
  - Features for parallel programs
Availability

- TotalView is only available on Queen Bee and Eric for LONI users (due to license restriction)
  - Queen Bee and Eric
    - Key: +totalview-8.3.0.1
  - Add the key to your .soft file and resoft
Getting X Window To Work

- **Linux**
  - `ssh -X -Y username@hostname`

- **Mac Os X**
  - Use X11

- **Windows**
  - Install Xming and Putty
  - Enable X11 Forwarding in Putty

https://docs.loni.org/wiki/X11_Forwarding
Compile Your Program

• Serial program
  • Compile with no optimization and debugging flag turned on:
    • `icc -g -O0 -o myexec myprogram.c`

• Parallel program
  • Use the proper MPI implementation
    • Queen Bee: `+mvapich-1.0-intel10.1-tvdbg`
    • Compile with no optimization and debugging flag turned on:
      • `mpicc -g -O0 -o myexec myprogram.c`
Getting An Interactive Session

- We need to get an interactive debugging session

  - `qsub -I -x -V -l walltime=hh:mm:ss, nodes=1:ppn=x -A <alloc> -q checkpt`

  
 PBS has allocated the following nodes:
  
etzpur333
  
etzpur331
  

- "-X" for X window tunneling

- Run TotalView in the interactive session
Start Totalview

• Serial program
  - totalview <options> <executable>
  - Example: totalview myexec

• Parallel program
  - mpirun_rsh -tv -np <num_procs> <host list> <executable>
    - Example: mpirun_rsh -tv -np 2 tezpur333 tezpur333 myexec
  - mpirun_rsh -tv -np <num_procs> -hostfile <path_to_hostfile> <executable>
    - Example: mpirun_rsh -tv -np 8 -hostfile $PBS_NODEFILE myexec
Outline

- Overview
- Getting Started
- Debugging with TotalView
  - TotalView GUI
  - Basic debugging techniques
  - Features for parallel programs
TotalView GUI – Root Window

- Always appears when TotalView is started
- Provides an overview of all processes and threads
**TotalView GUI – Root Window**

<table>
<thead>
<tr>
<th>Status Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blank</td>
<td>Exited</td>
</tr>
<tr>
<td>B</td>
<td>At Breakpoint</td>
</tr>
<tr>
<td>E</td>
<td>Error</td>
</tr>
<tr>
<td>H</td>
<td>Held</td>
</tr>
<tr>
<td>K</td>
<td>In kernel</td>
</tr>
<tr>
<td>M</td>
<td>Mixed</td>
</tr>
<tr>
<td>R</td>
<td>Running</td>
</tr>
<tr>
<td>T</td>
<td>Stopped</td>
</tr>
<tr>
<td>W</td>
<td>At Watchpoint</td>
</tr>
</tbody>
</table>

TotalView ID

**Host name**

**Status**

---

**File** | **Edit** | **View** | **Tools** | **Window**
---|---|---|---|---

<table>
<thead>
<tr>
<th>ID</th>
<th>Rank</th>
<th>Host</th>
<th>Status</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>T</td>
<td>mpirun_rsh (1 active threads)</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>&lt;local&gt;</td>
<td>T</td>
<td>mpirun_rsh&lt;pi_parallel_debug&gt;.0 (2 active threads)</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>&lt;local&gt;</td>
<td>T</td>
<td>mpirun_rsh&lt;pi_parallel_debug&gt;.1 (2 active threads)</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>&lt;local&gt;</td>
<td>T</td>
<td>mpirun_rsh&lt;pi_parallel_debug&gt;.2 (2 active threads)</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>&lt;local&gt;</td>
<td>T</td>
<td>mpirun_rsh&lt;pi_parallel_debug&gt;.3 (2 active threads)</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>tezpur331</td>
<td>T</td>
<td>mpirun_rsh&lt;pi_parallel_debug&gt;.4 (2 active threads)</td>
</tr>
<tr>
<td></td>
<td>6.1</td>
<td></td>
<td></td>
<td>in main</td>
</tr>
<tr>
<td></td>
<td>6.2</td>
<td></td>
<td></td>
<td>in __read_nocancel</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>tezpur331</td>
<td>T</td>
<td>mpirun_rsh&lt;pi_parallel_debug&gt;.5 (2 active threads)</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>tezpur331</td>
<td>T</td>
<td>mpirun_rsh&lt;pi_parallel_debug&gt;.6 (2 active threads)</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>tezpur331</td>
<td>T</td>
<td>mpirun_rsh&lt;pi_parallel_debug&gt;.7 (2 active threads)</td>
</tr>
<tr>
<td></td>
<td>9.1</td>
<td></td>
<td></td>
<td>in main</td>
</tr>
<tr>
<td></td>
<td>9.2</td>
<td></td>
<td></td>
<td>in __read_nocancel</td>
</tr>
</tbody>
</table>
TotalView GUI – Process Window

- Appears when TotalView is started (if a program is specified)
- 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
TotalView GUI – Variable Window

- Can be opened by double-clicking on a variable name (dive)
- Display detailed information of a variable
- One can also edit the data here
Outline

- Overview
- Getting Started
- Debugging with TotalView
  - TotalView GUI
  - Basic debugging techniques
  - Features for parallel programs
Working With TotalView

- One can start debugging with Totalview by
  - Starting TotalView with the executable
  - Debugging a core file
  - Attaching to a running (or hung) process

- We usually debug a code by
  - Setting up action points
  - Controlling the execution
  - Examining the value of variables
  - Editing the source code
  - ...
Debugging A Core File

- Start TotalView without specifying the name of the program
- Open the program and core file through the 'New Program' window
Attaching To A Running Process

- Again, start TotalView without specifying the name of the program
- Attach to a running process through the 'New Program' window
Controlling Execution

- Control commands
  - Go – start/resume execution
  - Halt – stop execution
  - Kill – terminate the job
  - Restart – Restarts a running program
  - Next – run to next source line without stepping in to another subroutine/function
  - Step – run to next source line
  - Out – run to the completion of a function
  - ...

![Image of debugging interface](http://www.loni.org)
Action Points in TotalView

- **Breakpoints** stop the execution of the processes and threads that reach it
  - Can be conditional or unconditional
- **Process barrier points** synchronize a set of processes or threads
- **Evaluation points** cause a code fragment to be executed when reached
- **Watchpoints** let the programmer monitor a location in memory, and stop execution or evaluate an expression when its value changes
Breakpoints

- The most basic action point
- To add a breakpoint
  - Click on the line number
  - Right click on a source line -> Set breakpoint
Evaluation Points

- Stop and execute a code fragments when reached
  - Useful when testing small patches
- To add a code fragment
  - Tools > Evaluate
Watchpoints

- Two types of watchpoints
  - Unconditional
  - Conditional
    - Example: stop the execution after 50k iterations

- To add a watchpoint
  - Right click on a variable -> Create watchpoint
Diving On An Object

• “Diving” means “showing more details on an object”

• By double clicking, one can dive on
  • Variables
  • Processes/threads
  • Subroutines
  • ...

• Use the 'undive' button to go back
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
Handling Arrays (1)

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

![Filtering example](image)
Handling Arrays (3)

- Visualization
  - Variable window -> Tools -> Visualization

- Statistics
  - Variable window -> Tools -> Statistics
Viewing Dynamic Arrays in C/C++

- Edit “type” in the variable window
- Tell TotalView how to interpret the memory from a starting location
- Example
  - To view an array of 100 integers
    - int * -> int[100]*
Outline

● Overview
● Getting Started
● Debugging with TotalView
  ● TotalView GUI
  ● Basic debugging techniques
  ● Features for parallel programs
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 with TotalView

- 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 “t+/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
Displaying Call Graph

- Quick view of program state
  - Nodes are functions
  - Edges are calls
  - Look for outliers

- To access
  - Tools -> Call Graph
Not Covered

- Memory debugging
  - Leak detection
  - Heap status
  - Memory usage
  - Memory comparison
  - ...
- Command line interface
- Command line options
References and Additional Resources

- TotalView user manual
  - http://www.totalviewtech.com/support/documentation/totalview/

- LLNL Total View tutorial
  - https://computing.llnl.gov/tutorials/totalview/

- HPCBugBase
  - http://www.hpcbugbase.org/index.php/Main_Page
Exercise

- Files and instructions

- Use the serial program to get familiar with the features of TotalView
  - It is bug-free

- Debug the parallel program
  - Check the result by comparing to that of the serial program