Parallel Debugging

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Outline

- Motivation
- Approaches and Tools
- Totalview

Problems of Parallel Programming

- All problems of serial programming
- Additional problems:
  - Increased difficulty to verify correctness of program
  - Increased difficulty to debug N parallel processes
  - New parallel problems:
    - **deadlocks**
    - **race conditions**
    - **irreproducibility**

What is a debugger?

- Common Misconception:
  A debugger is a tool to find and remove bugs
- A debugger does:
  - tell you where the program crashed
  - help to gain a better understanding of the program and what is going on
- Consequence:
  - A debugger does not help much if your program does not crash, e.g. just gives wrong results
  - Avoid using a debugger as far as possible.
  - Use it as last resort.

Avoiding debuggers

- Think about a verbose execution mode of your program
- Use a careful/paranoid programming style
  - check invariants and pre-requisites (assert(m>=0), assert(v<c))
- Use the debugging/assertion techniques of the compiler
  - use debug flags (-g), warnings (-Wall)
  - array bound checks in Fortran
  - use memory debug libraries (-lefence)

Avoiding Debuggers

- Write portable programs
  - it avoids future problems
    - **architectures/platforms have a short life**
    - **all compilers and libraries have bugs**
    - **all languages and standards include implementation defined behavior**
  - running on different platforms and architectures significantly increases the reliability
- Use verification tools for parallel programming like assure

Parallel Debuggers

- Most vendor debuggers have some support
- gdb has basic support for threads
- Debugging MPI programs with a “scalar” debugger is hard but possible
  - mpich supports debugging with gdb attached to one process
  - manual attaching to the processes is possible
- totalview is a good but expensive tool

TOTALVIEW

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What is TotalView?

- Parallel debugger
- Source level debugging for C, C++, F77, F90, HPF
- **MPI, OpenMP**, Pthreads, PVM, shmem
- SMPs, MPPs, PVPs, Clusters
- Available on all major Unix Platforms and most Supercomputers
- GUI (independent of platform, exception Cray T3E)
  - totalview 4.x based on tcl/tk
  - totalview 5.x based on Motif

Availability of TotalView

- Compaq Digital Alpha
  HP-UX
  IBM RS6000 and SP Power
  SGI MIPS
  Sun SPARC SunOS 5
  Linux Intel IA32 (RedHat)
  Linux Alpha (RedHat)
- Cray T3E by Cray
- Hitachi SR2201 by SofTek, SR8000
- NEC SX-4 (V 3.x) by SofTek, SX-5 in beta-test

Availability of TotalView at HWW

Platform	Availability	Remarks
Volvox	Yes	V 5 and V4
Hitachi SR2201	Yes	V 3.7.9
Hitachi SR8000	Yes	V 4.0
Cray T3E	Yes	Cray 3.0.0
NEC SX-4	Yes	V 3.7.9
NEC SX-5	Yes	Betatest
SGI Onyx	No	Use cvd
HP N-Class	Yes	V 4.1 and V5
IBM SP	Yes	V 4.1
Cray SV1	Yes	Cray 3.0.0

Development Platforms

More information:

www.hlrs.de/organization/par/services/tools/debugger/totalview

Availability of TotalView at University Stuttgart

2 user 8 CPU Floating License for University Stuttgart:

1. Download Software from http://www.etnus.com
2. Set environment variable for license.

LM_LICENSE_FILE=7244@servint1.rus.uni-stuttgart.de

More information about campus licenses available at

http://www.hlrs.de/organization/par/services/tools/campus

TotalView usage at HLRS

- set USE_TOTALVIEW in your login scripts
- CRAY T3E: set USE_PROG_ENV
- Compile with -g compiler switch
  CRAY T3E: compiler switch -G
- command name: **totalview**

Starting TotalView

On a new process:

```
% totalview myprog -a arguments to myprog
```

To debug MPI programs:

```
% totalview mpirun -a -nprocs 3 myprog
% mpirun -tv -np 3 myprog
```

To debug IBM POE programs:

```
% totalview poe -a myprog [args]
```

To debug CRAY T3E programs:

```
% totalview -X #procs myprog [args]
```

Totalview on Hitachi SR8000

- Compilation:
  - `f90 -g`
  - `cc -g`
  - `KCC -g --backend -tv`
- OpenMP
  - `f90 -g -omp -procnum=8`
  - `cc -g -omp -parallel=1 -O2`
- MPI
  - `mpirun -tv`

Totalview on HPN

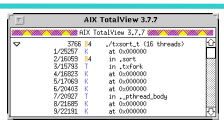
- Compilation:
  - `f90 -g`
  - `cc -g`
  - `KCC -g`
- OpenMP
  - `guidef90 -g`
  - `guidec -g`
  - `guidec++ -g`
- MPI
  - `mpirun -np #procs -tv ./a.out`

Totalview Exercise: Basic Look & Feel

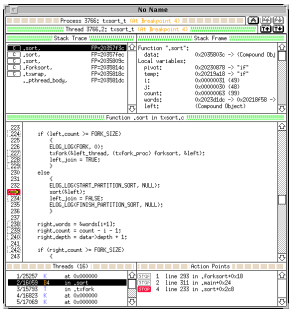
- Log into hwwhpn.hww.de
- use bash as shell
- Change into directory
  `~/TOTALVIEW/#NR/TOTALVIEW/SIMPLE`
- Compile calc_pi_{f90,c,cc}.{f90,c,cc}
- Start totalview with `totalview` *`executable`*

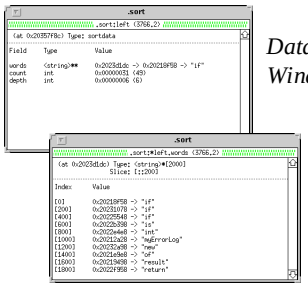
TotalView Windows

Root Window



Process Window

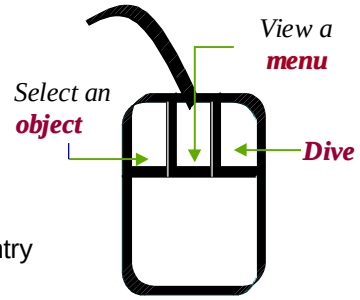




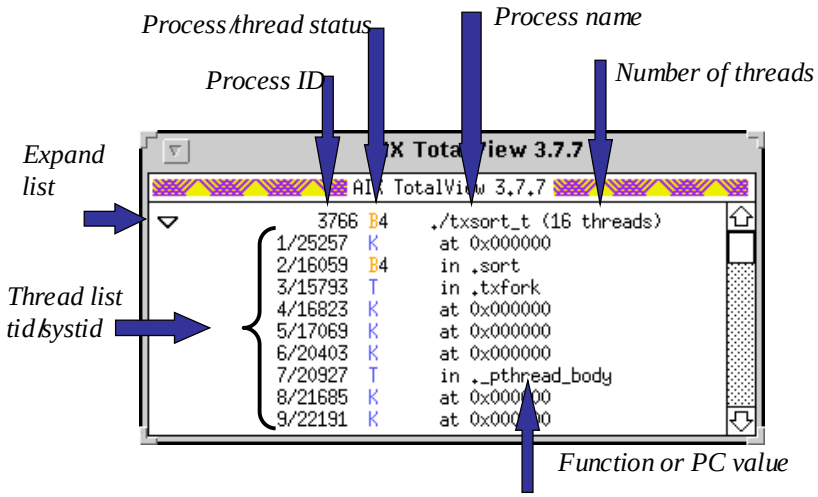
Data Windows

Totalview Mouse Buttons

- **Left** button is **Select**:
  - Chooses an item of interest,
  - Starts editing a item
- **Middle** button is **Menu**:
  - Raises a menu of actions
  - All menus have a **Help** (^?) entry
- **Right** button is **Dive**:
  - Gets more information about an item
  - **Shift+Dive** forces open a new window



Totalview Main Window



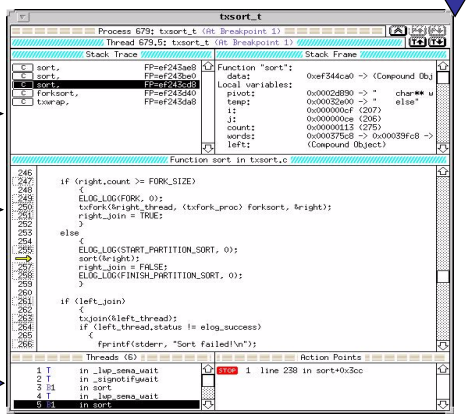
TotalView Process Window

Process/thread motion buttons

Stack Trace pane

Source pane

Thread pane



Local variables for the selected frame

Action Points pane

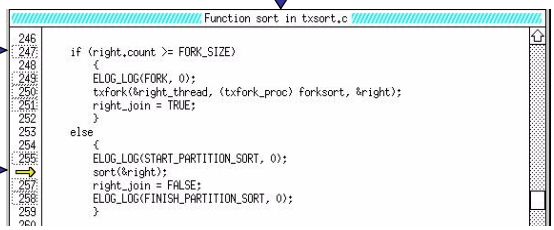
TotalView Source Pane

Gridded box is a possible site for a breakpoint

Current function and source file

***Select** to set one*

Current point of execution



- **Dive** on a source word to get more information
- **Select** a line to use **Run to selection** command
- **Select** or **dive** on a line number to set an action point

Parallel Debugging - Philosophy

- By default, TotalView places processes in groups
  - Program Group - Includes parent and all related processes
  - Share Group - Only processes that share the same source code
- Command can act on single process or share group
  - halt process (h) , halt group (H)
  - next step process (n), next step group (N)
  - go process (g), go group (G)

Totalview Exercise: Debug simple program

- Run calc_pi inside totalview:
  - Check where the program crashes
- analyze core file with totalview
  - run calc_pi
  - execute `totalview calc_pi core`
- for advanced users: choose another programming paradigm:
  - MPI, OpenMP, MPI+OpenMP

Totalview support for debugging MPI

- Special support for MPI is available depending on your MPI library:
  - display message queue state of a process
- Supported MPI implementations:
  - mpich v1.1.0 or later (use -debug in configure)
  - HP MPI v1.6
  - Compaq MPI >v1.7
  - IBM, release >2.2 of Parallel Environment, threaded version of MPI
  - SGI MPI v1.3 or later

TotalView MPI Message Queue Window

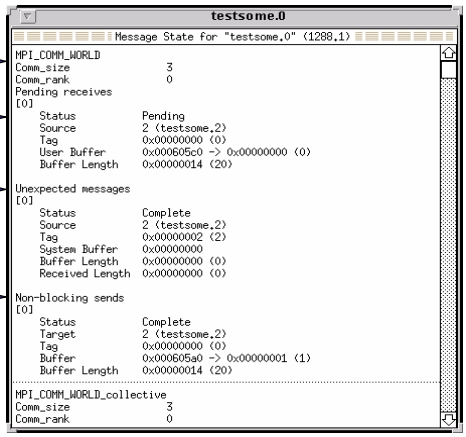
Communicator name and info

Non-blocking receive operations

Unmatched incoming messages

Non-blocking send operations

- Dive on source or target to refocus Process window
- Dive on buffer to see message contents



Totalview Exercise: Parallel program

- Example in TOTALVIEW/MPI:
  - deadlock_{c,cc,f90}.{c,cc,f90}
  - start program with `mpirun -tv -np 2 a.out`
  - interrupt execution after “deadlock”
  - try to find the reason for the deadlock and fix it
- For advanced users:
  - pending_{c,cc,f90}.{c,cc,f90}
  - try to find pending message by setting breakpoint at `MPI_Finalize`

TotalView more information

- http://www.etnus.com/products/totalview/index.html
- http://www.hlrs.de/organization/par/services/tools/debugger/totalview
  - User Guide
  - Installation Guide
  - CLI Guide
  - Powerpoint Tutorial
- CRAY T3E: Online Documentation at http://www.hlrs.de/platforms/crayt3e