Debugging and Optimization Tools

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Outline

- Introduction
- Debugging
- Performance / Optimization

Introduction

- **Scope of Today's Talks**
  - Debugging and optimization tools
  - Some basic strategies
- **Take Aways**
  - Common problems and strategies
  - How tools work in general
  - A few specific tools you can try

Debugging

- **Types of problems**
  - "Serial"
    - Invalid memory references
    - Array reference out of bounds
    - Divide by zero
    - Uninitialized variables
  - Parallel
    - Unmatched sends/receives
    - Blocking receive before corresponding send
    - Out of order collectives

Tools

- **printf(), print, write**
  - Versatile, sometimes useful
  - Doesn't scale well, have to recompile
- **Compilers**
  - Turn on bounds checking, exception handling
  - Check dereferencing of NULL pointers
- **Serial gdb**
  - GNU debugger, serial, command-line interface
  - See "man gdb"
- **Parallel GUI debuggers**
  - DDT
  - Totalview

Compiler runtime bounds checking

Out of bounds reference in source code for program “flip”

```
…

allocate(put_seed(random_size))
…

bad_index = random_size+1
put_seed(bad_index) = 67
```

```
ftn  -c -g -Ktrap=fp –Mbounds flip.f90
ftn  -c -g -Ktrap=fp –Mbounds printit.f90
ftn  -o flip flip.o printit.o -g


% qsub –I –qdebug –lmppwidth=48
% cd $PBS_O_WORKDIR
%
% aprun –n 48 ./flip
0: Subscript out of range for array
   put_seed (flip.f90: 50)
    subscript=35, lower bound=1, upper
   bound=34, dimension=1
0: Subscript out of range for array
   put_seed (flip.f90: 50)
    subscript=35, lower bound=1, upper
   bound=34, dimension=1
```

Ddt video

Performance Questions

- How can we tell if a program is performing well?
- Or isn't?
- If performance is not "good," how can we pinpoint why?
- How can we identify the causes?
- What can we do about it?

Performance Metrics

- **Primary metric: application time**
  - but gives little indication of efficiency
- **Derived measures:**
  - rate (Ex.: messages per unit time, Flops per Second, clocks per instruction), cache utilization
- **Indirect measures:**
  - speedup, parallel efficiency, scalability

Optimization

- **Serial**
  - Leverage ILP on the processor
  - Feed the pipelines
  - Exploit data locality
  - Reuse data in cache
- **Parallel**
  - Minimizing latency
  - Maximizing work vs. communication

Identifying Targets for Optimization

- **Sampling**
  - Regularly interrupt the program and record where it is
  - Build up a statistical profile
- **Tracing / Instrumenting**
  - Insert hooks into program to time events
- **Use Hardware Event Counters**
  - Special registers count events on processor
  - E.g. floating point instructions
  - Many possible events
  - Only a few (~4 counters)

Performance Instrumentation

- **Use a tool to "instrument" the code**
  1. Transform a binary executable before executing
  2. Include "hooks" for important events
  3. Run the instrumented executable to capture those events, write out raw data file
  4. Use some tool(s) to interpret the data

Performance Tools @ NERSC

- **IPM: Integrated Performance Monitor**
- **Vendor Tools:**
  - CrayPat
- **Community Tools (Not all fully supported):**
  - TAU (U. Oregon via ACTS)
  - OpenSpeedShop (DOE/Krell)
  - HPCToolKit (Rice U)
  - PAPI (Performance Application Programming Interface)

Types of Counters

- Cycles
- Instruction count
- Memory references, cache hits/ misses
- Floating-point instructions
- Resource utilization

PAPI Event Counters

- PAPI (Performance API) provides a standard interface for use of the performance counters in major microprocessors

- Predefined actual and derived counters supported on the system
  - To see the list, run 'papi_avail' on compute node via aprun:

```
module load perftools
aprun –n 1 papi_avail
```

- AMD native events also provided; use 'papi_native_avail':

```
aprun –n 1 papi_native_avail
```

Introduction to CrayPat

- **Suite of tools to provide a wide range of performance-related information**

- **Can be used for both sampling and tracing user codes**
  - with or without hardware or network performance counters
  - Built on PAPI

- **Supports Fortran, C, C++, UPC, MPI, Coarray Fortran, OpenMP, Pthreads, SHMEM**
- **intro_craypat(1), intro_app2(1), intro_papi(1)**

Using CrayPat

1. **Access the tools**
   – `module load perftools`
2. **Build your application; keep .o files**
   – `make clean`
   – `make`
3. **Instrument application**
   – `pat_build ... a.out`
   – Result is a new file, `a.out+pat`
4. **Run instrumented application to get top time consuming routines**
   – `aprun ... a.out+pat`
   – Result is a new file XXXXX.xf (or a directory containing .xf files)

Adjust script for +pat

5. **Run pat_report on that new file; view results**
   – `pat_report XXXXX.xf > my_profile`
   – `vi my_profile`
   – Result is also a new file: XXXXX.ap2

Using Apprentice

- Optional visualization tool for Cray's perftools data
- Use it in a X Windows environment
- Uses a data file as input (`XXX.ap2`) that is prepared by `pat_report`

```
1. module load perftools
2. ftn -c mpptest.f
3. ftn -o mpptest mpptest.o
4. pat_build -u -g mpi mpptest
5. aprun -n 16 mpptest+pat
6. pat_report mpptest+pat+PID.xf >
   my_report
7. app2 [--limit_per_pe tags] [XXX.ap2]
```

Apprentice Basic View

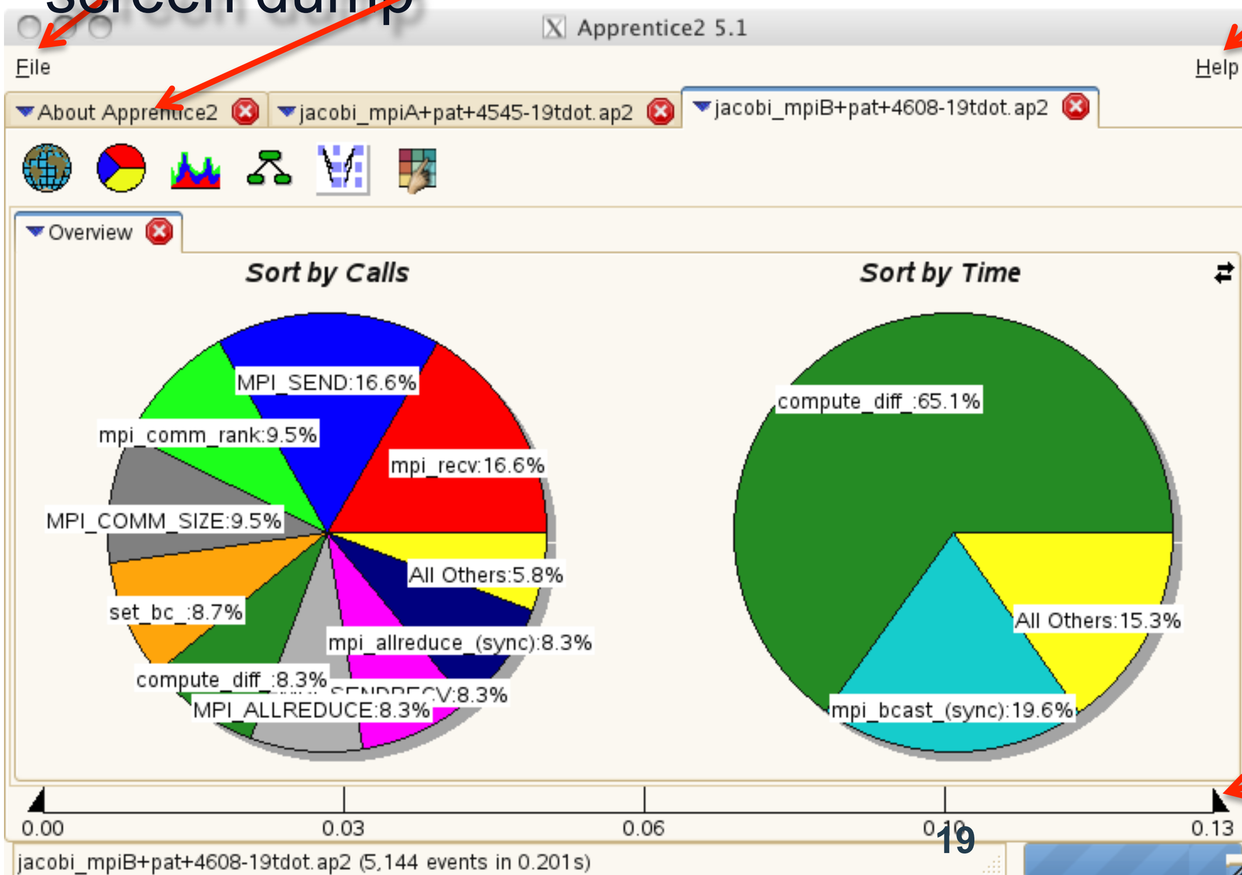
Can select new (additional) data file and do a screen dump

Worthless

Useful

Can select other views of the data

Can drag the "calipers" to focus the view on portions of the run



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