How to use Open|SpeedShop to Analyze the Performance of Parallel Codes.

Tutorial @ SC ‘11

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LLNL-PRES-508651

Motivation

- Performance Analysis is becoming more important
  - Complex architectures
  - Complex applications
  - Mapping applications onto architectures
- Often hard to know where to start
  - Which experiments to run first?
  - How to plan follow-on experiments?
  - What kind of problems can be explored?
  - How to interpret the data?

Outline

- Basics on Open|SpeedShop
  - Introduction into one possible tool solution
  - Basic usage instructions
  - Pointers to additional documentation
- Provide you with the ability to …
  - Run these experiments on your own code
  - Provide starting point for performance optimizations
- Some useful pointers
  - http://www.openspeedshop.org
    - Has SC 10 tutorial, quick start guide, OSS download, etc.,
  - http://www.openspeedshop.org/forums
    - Has question/answer on OpenSpeedShop topics

OSS Development

- Jim Galarowicz, Krell
- Don Maghrak, Krell

- Tri-Lab ASC CCE Management
  - Martin Schulz, LLNL
  - David Montoya, LANL
  - Mahesh Rajan, SNLs

- Larger team
  - William Hachfeld and Dave Whitney, Krell
  - Dane Gardner, LANL
  - Scott Cranford and Joseph Kenny, SNLs
  - Chris Chambreau and Matt Legendre, LLNL
  - Dyninst group (Bart Miller, UW & Jeff Hollingsworth, UMD)
  - Phil Roth, ORNL
  - Ciera Jaspan, CMU

Why Open | SpeedShop?

- Various alternatives – vendor tools, other open source tools
  - OSS - Powerful, relatively easy to use
  - OSS - Available for both Blue Gene and Cray XT
  - Open source

What to Look For: Sequential Runs

Step 1: Identify computational intensive parts

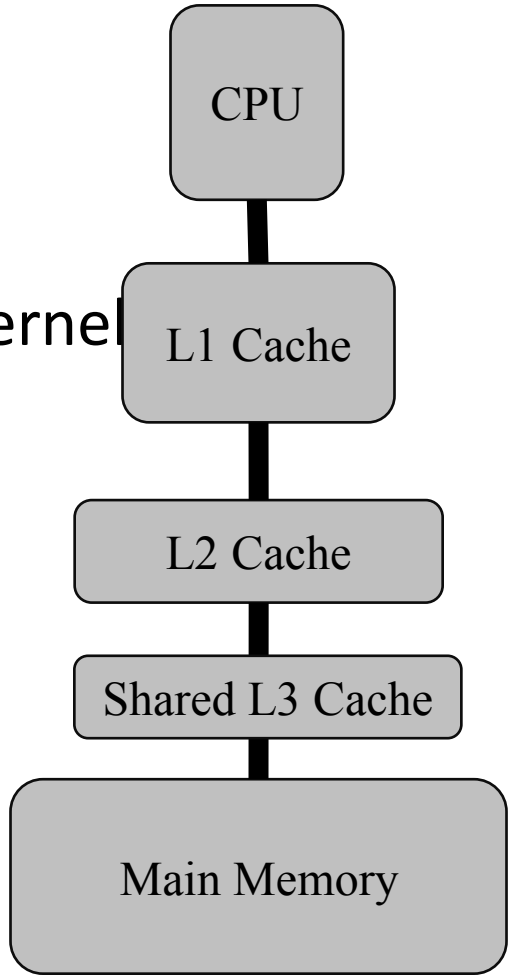
- Where am I spending my time?
  - Modules/Libraries
  - Statements
  - Functions
- Is the time spent in the computational kernel
- Does this match my intuition?

Impact of memory hierarchy

- Do I have excessive cache misses?
- How is my data locality?
- Impact of TLB misses?

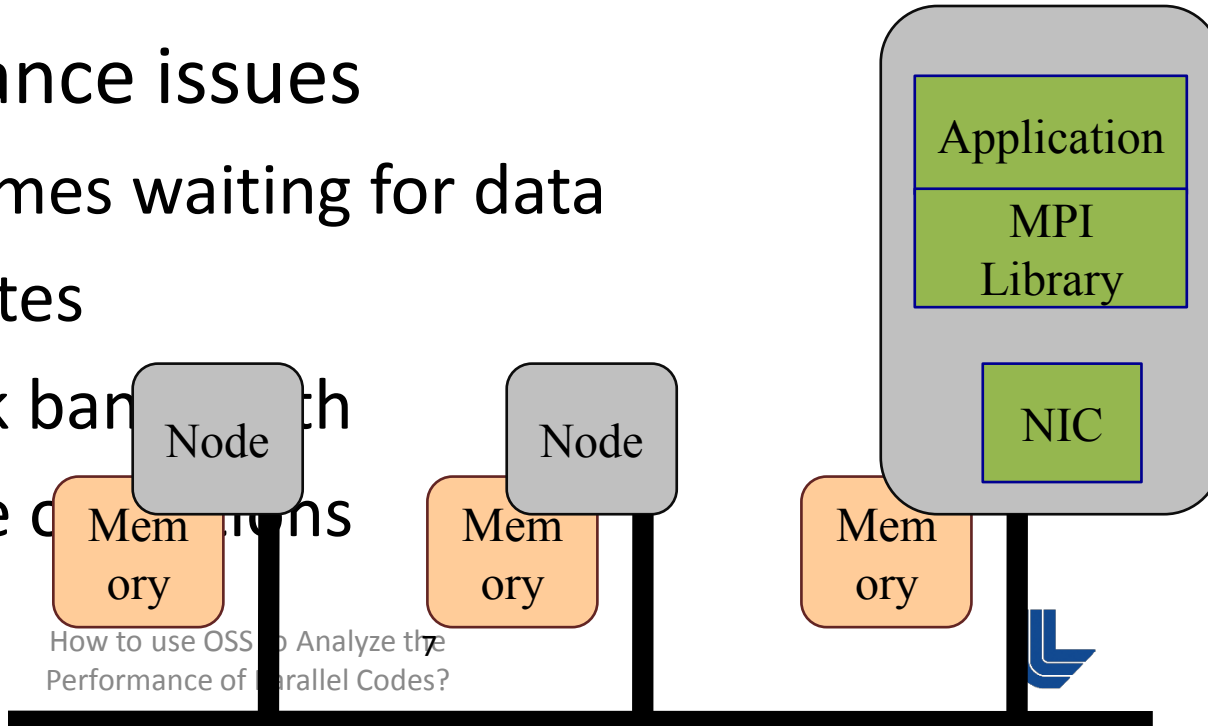
External resources

- Is my I/O efficient?
- Time spent in system libraries?



What to Look For: Message Passing

- Distributed Memory Model
  - Sequential/shared memory nodes coupled by a network
  - Only local memory access
  - Data exchange using message passing (e.g., MPI)
- Typical performance issues
  - Long blocking times waiting for data
  - Low message rates
  - Limited network bandwidth
  - Global collective operations



Performance Tool Terminology

- Statistical Sampling
  - Periodically interrupt execution and record location
  - Report statistical distribution across all reported locations
  - Data typically aggregated over time
  - Most common metric is time, but other metrics possible
  - Useful to get an overview
  - Low and uniform overhead
- Event Tracing
  - Gather and store individual application events
  - Examples: function invocations, MPI messages, I/O calls
  - Events are typically time stamped
  - Provides detailed per event information
  - Can lead to huge data volumes
  - Higher overhead, potentially in bursts

Section 2
Introduction into Open|SpeedShop

Tutorial @ SC ‘11
November, 2011

How to use Open|SpeedShop to Analyze the Performance of Parallel Codes.

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Experiment Workflow

Open|SpeedShop Workflow

Application

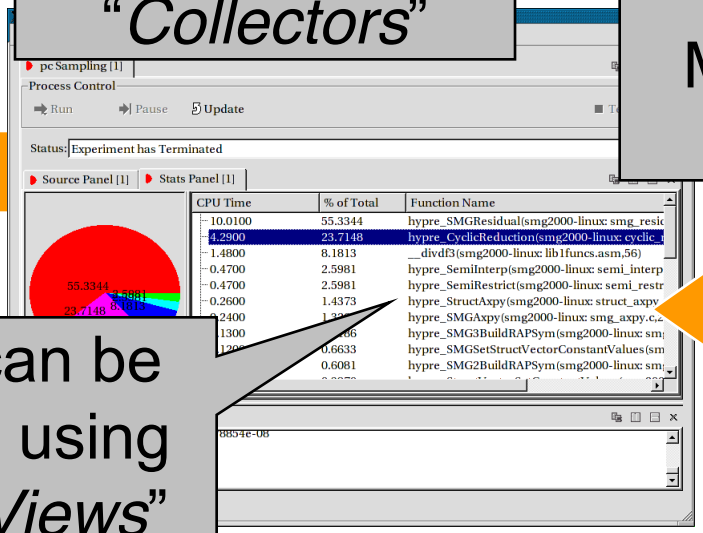
"Experiment"

Open | SpeedShop™

Run

Consists of one or more data "*Collectors*"

Process Management Panel

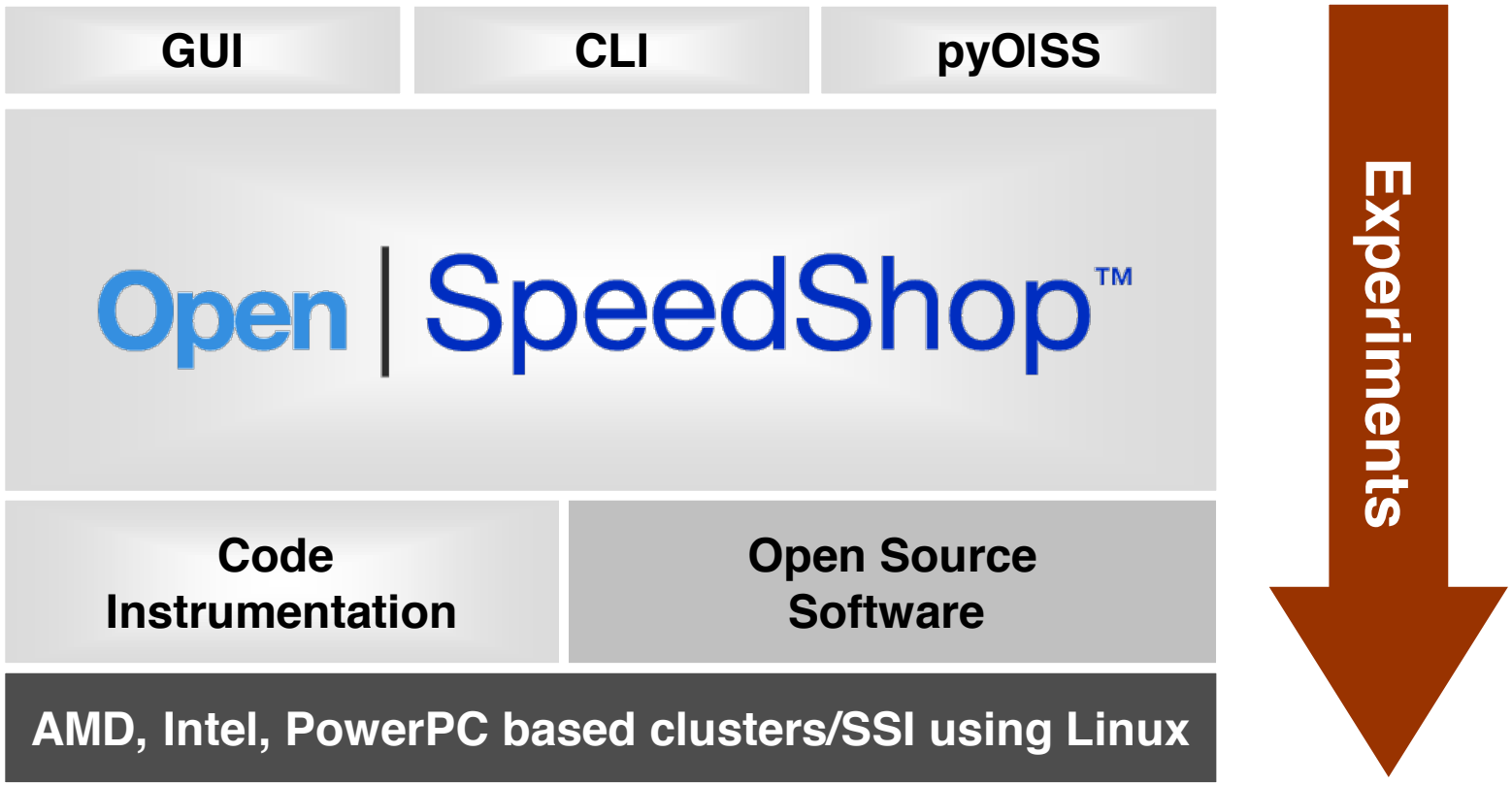


Results

Results can be displayed using several "*Views*"

Stored in SQL database

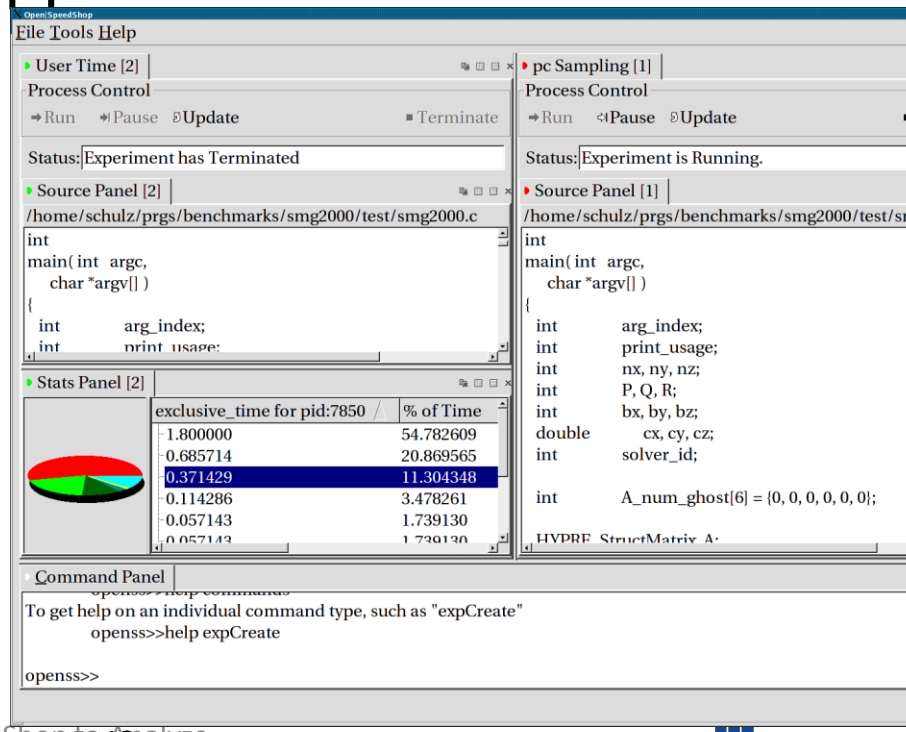
High-level Architecture



Open Source: PAPI, libmonitor, sqlite, Dyninst, MRNet, libdwarf, libelf, python, etc..

Basic Interface Usage

- Step 1
  - Gather data from command line
  - Example: osspcsamp “<application>”
  - Create database
- Step 2
  - Analyze data in GUI
  - Simple graphics
  - Relate data to source
  - openss –f <db file>



Performance Experiments

- Concept of an Experiment
  - What to measure and what to analyze?
  - Experiment type is chosen by user
  - Any experiment can be applied to any application
- Consists of Collectors and Views
  - Collectors define specific performance data sources
    - Program counter samples
    - Call stack samples
    - Hardware counters
    - Tracing of library routines
  - Views specify performance data aggregation and presentation
  - Multiple collectors per experiment possible

Sampling Experiments

- PC Sampling (pcsamp)
  - Record PC in user defined time intervals
  - Low overhead overview of time distribution
  - Good first step, lightweight overview
- Call Path Profiling (usertime)
  - PC Sampling and Call stacks for each sample
  - Provides inclusive and exclusive timing data
  - Use to find hot call paths, whom is calling who
- Hardware Counters (hwc, hwctime, hwcsamp)
  - Access to data like cache and TLB misses
  - hwc, hwctime:
    - Sample a HWC event based on an event threshold
    - Default event is PAPI_TOT_CYC overflows
  - hwcsamp:
    - Sample up to six events based on a sample time (hwcsamp)
    - Default events are PAPI_FP_OPS and PAPI_TOT_CYC

Tracing Experiments

- Input/Output Tracing (io, iot)
  - Record invocation of all POSIX I/O events
  - Provides aggregate and individual timings
  - Provide argument information for each call (iot)
- MPI Tracing (mpi, mpit, mpiotf)
  - Record invocation of all MPI routines
  - Provides aggregate and individual timings
  - Provide argument information for each call (mpit)
  - Create Open Trace Format (OTF) output (mpiotf)
- Floating Point Exception Tracing (fpe)
  - Triggered by any FPE caused by the application
  - Helps pinpoint numerical problem areas

Running a First Experiment

1. Picking the experiment
   - What do I want to measure?
   - We will start with pcsamp to get a first overview
2. Launching the application
   - How do I control my application under O|SS?
   - Enclose how you normally run your application in quotes
   - **osspcsamp** “mpirun –np 256 smg2000 –n 65 65 65”
3. Storing the results
   - O|SS will create a database
   - Name: smg2000-pcsamp.openss
4. Exploring the gathered data
   - O|SS will print a default report
   - Open the GUI to analyze data in detail (run: “**openss**”)

Example Run with Output

```
osspcsamp "mpirun -np 2 ./smg2000 -n 65 65 65"
[openss]: pcsamp experiment using the pcsamp experiment default sampling rate: "100".
[offline pcsamp experiment using the command:
"mpirun -np 2 /opt/OSS-mrnet/bin/ossrun "./smg2000 -n 65 65 65" pcsamp"
openss]: Using OPENSS_PREFIX installed in /opt/OSS-mrnet
[openss]: Setting up offline raw data directory in /tmp/jeg/offline-oss
[openss]: Running
Running with these driver parameters:
 (nx, ny, nz)    = (65, 65, 65)
 (Px, Py, Pz)    = (2, 1, 1)
 (bx, by, bz)    = (1, 1, 1)
 (cx, cy, cz)    = (1.000000, 1.000000, 1.000000)
 (n_pre, n_post) = (1, 1)
 dim             = 3
 solver ID       = 0
=============================================
Struct Interface:
=============================================
Struct Interface:
 wall clock time = 0.049847 seconds
 cpu clock time  = 0.050000 seconds
```

Example Run with Output

- ~~osspcsamp "mpirun –np 2~~ smg2000 –n 65 65 ~~65"~~

```
==========================================
Setup phase times:
==========================================
SMG Setup:
 wall clock time = 0.635208 seconds
 cpu clock time  = 0.630000 seconds
==========================================
Solve phase times:
==========================================
SMG Solve:
 wall clock time = 3.987212 seconds
 cpu clock time  = 3.970000 seconds
Iterations = 7
Final Relative Residual Norm = 1.774415e-07
[openss]: Converting raw data from /tmp/jeg/offline-oss into temp file X.0.openss

Processing raw data for smg2000
Processing processes and threads ...
Processing performance data ...
Processing functions and statements ...
```

Example Run with Output

- osspcsamp "mpirun –np 2 smg2000 –n 65 65 65"

```
[openss]: Restoring and displaying default view for:
/home/jeg/DEMOS/demos/mpi/openmpi-1.4.2/smg2000/test/smg2000-pcsamp-1.openss
[openss]: The restored experiment identifier is:  -x 1

Exclusive CPU time      % of CPU Time  Function (defining location)
    in seconds.
    3.630000000        43.060498221  hypre_SMGResidual (smg2000: smg_residual.c,152)
    2.860000000        33.926453144  hypre_CyclicReduction (smg2000: cyclic_reduction.c,757)
    0.280000000         3.321470937  hypre_SemiRestrict (smg2000: semi_restrict.c,125)
    0.210000000         2.491103203  hypre_SemiInterp (smg2000: semi_interp.c,126)
    0.150000000         1.779359431  opal_progress (libopen-pal.so.0.0.0)
    0.100000000         1.186239620 mca_btl_sm_component_progress (libmpi.so.0.0.2)
    0.090000000         1.067615658  hypre_SMGAxpy (smg2000: smg_axpy.c,27)
    0.080000000         0.948991696  ompi_generic_simple_pack (libmpi.so.0.0.2)
    0.070000000         0.830367734  __GI_memcpy (libc-2.10.2.so)
    0.070000000         0.830367734 hypre_StructVectorSetConstantValues (smg2000:
struct_vector.c,537)
    0.060000000         0.711743772  hypre_SMG3BuildRAPSym (smg2000: smg3_setup_rap.c,233)
```

❖ View with GUI: openss –f smg2000-pcsamp-1.openss

Default Output R

Toolbar to switch Views

Performance Data Default view: by Function (Data is sum from all processes and threads)
Select "Functions", click D-icon

File Tools

pc Sampling [1]

Process Control

Run Cont Pau Update Terminate

Status: Process Loaded. Click on the "Run" button to begin the experiment.

Stats Panel [1] ManageProcessesPanel [1]

I U CL D S OV LB CA CC Showing Functions Report:

View/Display Choice: Functions Statements Linked Objects

Executables: smg2000 Host: localhost.localdomain Processes/Ranks/Threads:(2) 0 ...

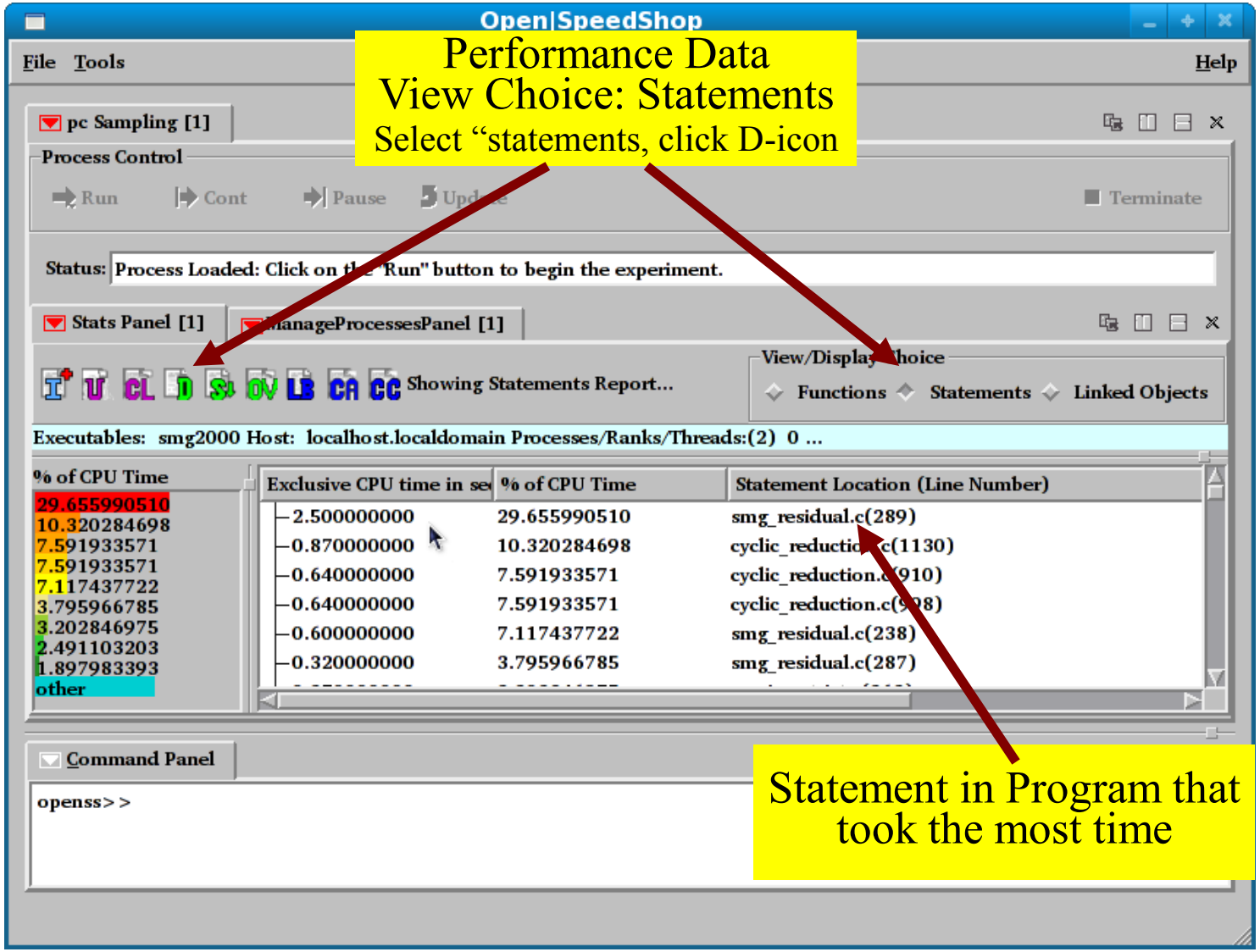
% of CPU Time	Exclusive CPU time in se	% of CPU Time	Function (defining location)
43.060498221	3.630000000	43.060498221	hypre_SMGResidual (smg2000: smg_residual.c,152)
33.926453144	2.8[illegible]0000000	33.926453144	hypre_CyclicReduction (smg2000: cyclic_reduction.c,757)
3.321470937	0.280000000	3.321470937	hypre_SemiRestrict (smg2000: semi_restrict.c,125)
2.491103203	0.210000000	2.491103203	hypre_SemiInterp (smg2000: semi_interp.c,126)
1.779359431	0.150000000	1.779359431	opal_progress (libopen-pal.so.0.0.0)
1.186239620	0.100000000	1.186239620	mca_btl_sm_component_progress (libmpi.so.0.0.2)
1.067615658			
other			

Graphical Representation

Command Panel

openss>>

Statement Report Output View



Associate Source & Performance Data

Open|SpeedShop

File Tools Help

Double click to open source window

Use window controls to split/arrange windows

Terminate

Status: Process Loaded: Click on the "Run" button to begin the experiment.

Stats Panel [1]

Showing Statement: »

Executables: smg2000 Host: localhost.localdomain Processes/

Exclusive CPU time i	% of CPU Time	Statement Location (I
2.500000000	29.655990510	smg_residual.c(289)
0.870000000	10.320284698	cyclic_reduction.c(113
0.640000000	7.591933571	cyclic_reduction.c(910
0.640000000	7.591933571	cyclic_reduction.c(998
0.600000000	7.117437722	smg_residual.c(238)
0.320000000	3.795966785	smg_residual.c(287)
0.270000000	3.202846975	semi_restrict.c(262)
0.210000000	2.491103203	topo_unity_componer

Source Panel [1]

Exclusive C /home/jeg/DEMOS/demos/mpi/openmpi-1.4.2/smg2000/struct_ls/smg_residual.c

```
281                 hypre_BoxLoop3Begin(loop_size,
282                                     A_data_box, start, base_stride, Ai,
283                                     x_data_box, start, base_stride, xi,
284                                     r_data_box, start, base_stride, ri);
285 #define HYPRE_BOX_SMP_PRIVATE loopk,loopi,loopj,Ai,xi,ri
286 #include "hypre_box_smp_forloop.h"
287                 hypre_BoxLoop3For(loopi, loopj, loopk, Ai, xi, ri)
288                 {
289                    rp[ri] -= Ap[Ai] * xp[xi];
290                 }
291                 hypre_BoxLoop3End(Ai, xi, ri);
292              }
293           }
```

0.320000

>> 2.500

0.010000

Command Panel

ManageProcessesPanel [1]

Processes:	Rank
30947	0
30948	1

Process Sets	PID	Rank	Thread
Dynamic Process Set			
All	All		
Disconnected	Disconnected		

Selected performance data point

Section Summary

- Place the way you **run** your application **normally** in quotes and pass it as an argument to osspcsamp, or any of the other experiment convenience scripts: ossio, ossmpi, etc.
  - osspcsamp “srun –N 8 –n 64 ./mpi_application app_args”
- Open|SpeedShop creates default view to stdout
- Open|SpeedShop creates a database file
- Display alternative views of the data with the GUI via:
  - openss –f <database file>
- Display alternative views of the data with the CLI via:
  - openss –cli –f <database file>
- On clusters, need to set OPENSS_RAWDATA_DIR
  - Need a shared file system across all nodes of a cluster
- Start with pcsamp for overview of performance
- Then “home” into performance issues with other experiments, if necessary

Section 3
Sampling Experiments

Tutorial @ SC '11
November, 2011

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Sampling Experiments in O|SS

- PC Sampling
  - Approximates CPU Time for Line and Function
  - No Call Stacks
  - Convenience Script: osspcsamp
- User Time
  - Inclusive vs. Exclusive CPU Time
  - Includes Call Stacks
  - Convenience Script: ossusertime
- HW Counters
  - Samples Hardware Counter Overflows (hwc, hwctime)
  - Periodically samples up to six (6) Hardware Counter Events (hwcsamp)
  - Convenience Scripts: osshwc, osshwctime, osshwcsamp

Running Program Counter Sampling

Offline pcsamp experiment on smg2000 application

<u>Option 1: Convenience script basic syntax</u>

osspcsamp “smg2000 –n 50 50 50”

osspcsamp “smg2000 –n 50 50 50” high

- Optional Parameter:
  - Sampling frequency (samples per second)
  - Alternative parameter: high (200) | low (50) | default (100)

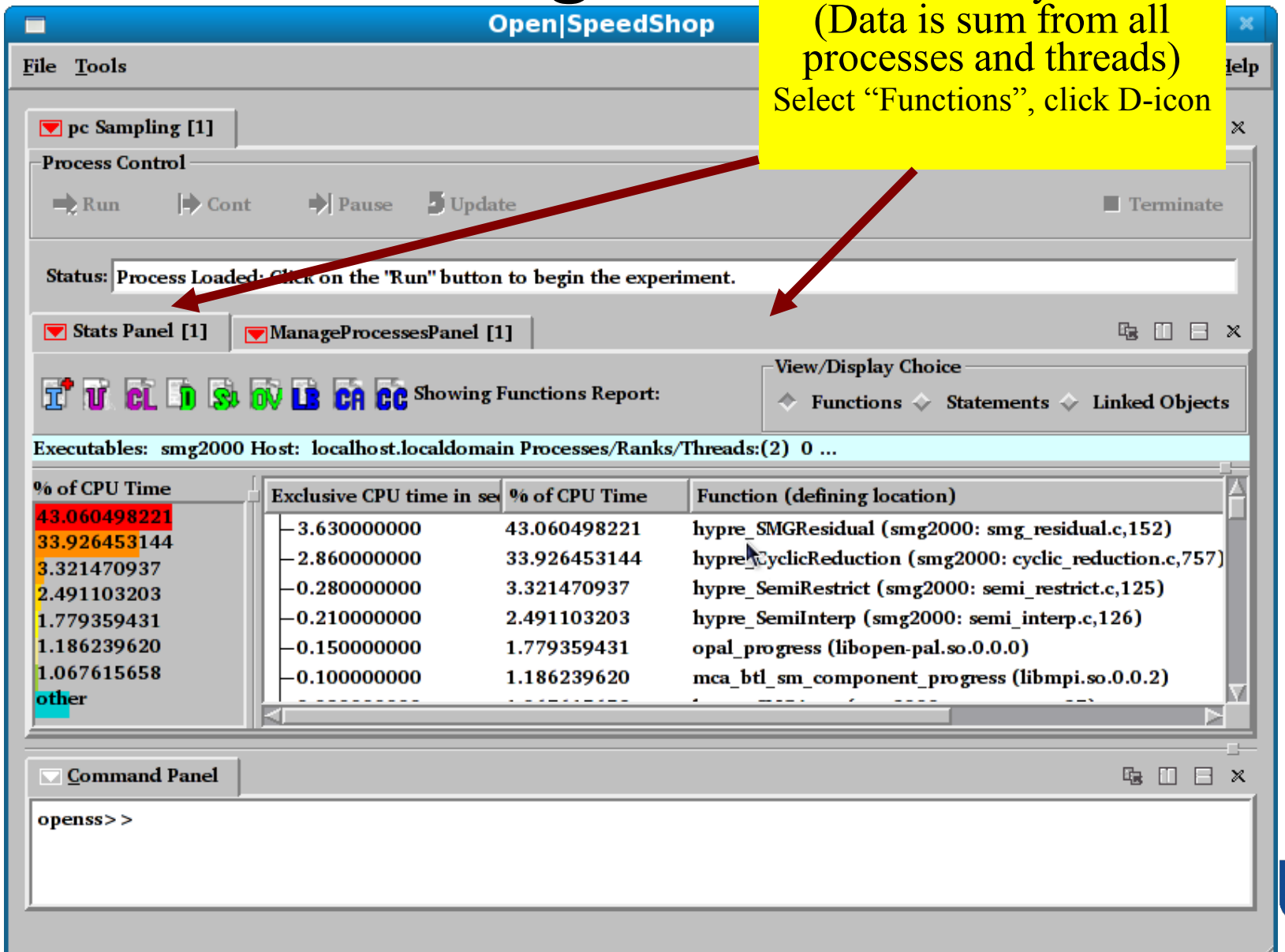
<u>Option 2: Explicit openss syntax</u>

openss –offline –f “smg2000 –n 50 50 50” pcsamp

Recommendation: compile code with –g to get statements!

Viewing Flat

Performance Data
Default view: by Function
(Data is sum from all processes and threads)
Select "Functions", click D-icon



Identifying Critical Regions

- Profiles show computationally intensive code regions
  - First views: Time spent per functions or per statements
    - Default view reports statistics based on functions
    - For statements, choose Statements View option
- Questions:
  - Are those functions/statements expected?
  - Do they match the computational kernels?
  - Any runtime functions taking a lot of time?
- Identify bottleneck components
  - View the profile aggregated by shared objects
    - Linked Object View option
  - Correct/expected modules?
  - Impact of support and runtime libraries

Adding Context (usertime experiment)

- Missing information in flat profiles
  - Distinguish routines called from multiple callers
  - Understand the call invocation history
  - Context for performance data
- Critical technique: Stack traces
  - Gather stack trace for each performance sample
  - Aggregate only samples with equal trace
- User perspective:
  - Butterfly views (shows caller/callee relationships)
  - Hot call paths
    - Paths through application that take most time

The Usertime Experiment

- Provides inclusive/exclusive time
  - Time spent inside a function only (exclusive)
  - Time spent inside a function and its children (inclusive)
- Similar to the pcsamp experiment
  - Collect program counter information
  - But also: collect call stack information at every sample
- Tradeoffs
  - Obtain additional context information
  - Have higher overhead/lower sampling rate

Running Usertime Experiments

Offline usertime experiment on smg2000 application

<u>Option 1: Convenience script basic syntax</u>

ossusertime “smg2000 –n 50 50 50”

ossusertime “smg2000 –n 50 50 50” low

- Parameters
  - Sampling frequency (samples per second)
  - Alternative parameter: high (70) | low (18) | default (35)

<u>Option 2: Explicit openss syntax:</u>

openss –offline –f “smg2000 –n 50 50 50” usertime

Recommendation: compile code with –g to get statements!

Stack Trace Views: Hot Call Path

Open|SpeedShop

File Tools Help

User Time [1]

Process Control

Run Cont Pause Update Terminate

Status: Process Loaded: Click on the "Run" button to begin the experiment.

Stats Panel [1] ManageProcessesPanel [1]

I U CL D S G GI HC B TS OV LB CA CC Showing Hot Callpath Report:

Executables: smg2000 Host: localhost Processes/Ranks/Threads:(2) 0 ...

Exclusive CPU time in second	Inclusive CPU time in seconds	% of Total Exclusive CPU Tim	Call Stack Function (defining location)
			main (smg2000: smg2000.c,21)
			@ 65 in HYPRE_StructSMGSolve (smg2000: HYPRE_struct_smg.c,64)
			@ 168 in hypre_SMGSolve (smg2000: smg_solve.c,57)
0.114286	0.114286	1.632653	@ 289 in hypre_SMGResidual (smg2000: smg_residual.c,152)

Command Panel

openss>>

Hot Call Path
Click HC-icon

The O|SS HWC Experiments

- Provides access to hardware counters
  - Implemented on top of PAPI
  - Access to PAPI and native counters
  - Examples: cache misses, TLB misses, bus accesses
- Basic model 1: Thresholding
  - User selects counter
  - Run until a fixed number of events have been reached
  - Take PC sample at that location
  - Reset number of events
  - Ideal number of events (threshold) depends on application
- Basic model 2: Sampling
- Three versions
  - HWC = flat hardware counter profile
  - HWCtime = profiles with context / stacktraces
  - HWCsamp = PC sampling with multiple HWCs

Running hwc and hwctime

Example: Offline hwc[time] experiment on SMG2000

Option 1: Basic Syntax

```
osshwc[time] “smg2000” <counter> <threshold>
```

Option 2: Explicit Syntax

```
setenv OPENSS_HWC_EVENT <counter>
setenv OPENSS_HWC_TRHESHOLD <threshold>
openss –offline –f “smg2000” hwc[time]
```

Available counter

- Any counter reported by “papi_avail –a” and not derived
- Native counters listed in the PAPI documentation

Examples of Typical Counters

PAPI Name	Description	Threshold
PAPI_L1_DCM	L1 data cache misses	high
PAPI_L2_DCM	L2 data cache misses	high/medium
PAPI_L1_DCA	L1 data cache accesses	high
PAPI_FPU_IDL	Cycles in which FPUs are idle	high/medium
PAPI_STL_ICY	Cycles with no instruction issue	high/medium
PAPI_BR_MSP	Miss-predicted branches	medium/low
PAPI_FP_INS	Number of floating point instructions	high
PAPI_LD_INS	Number of load instructions	high
PAPI_VEC_INS	Number of vector/SIMD instructions	high/medium
PAPI_HW_INT	Number of hardware interrupts	low
PAPI_TLB_TL	Number of TLB misses	low

Note: Threshold indications are just rough guidance and depend on the application.

Note: Not all counters exist on all platforms (check with papi_avail)

Running hwcsamp

Example: Offline hwcsamp experiment on SMG2000

Option 1: Basic Syntax

```
osshwcsamp "smg2000" <event list> <sampling rate>
```

Option 2: Explicit Syntax

```
setenv OPENSS_HWCSAMP_EVENTS <event list>
setenv OPENSS_HWCSAMP_RATE <sampling rate>
openss –offline –f "smg2000" hwcsamp
```

Available counter

- Any counters reported by "papi_avail"
- Native counters listed in the PAPI documentation
  - Native counters also reported by "papi_native_avail"

Viewing hwcsamp Data

Open|SpeedShop

File Tools Help

HWCSamp Panel [1]

Process Control

Run Cont Terminate

Exclusive Time

Multiple HWC Event Counts

Status: Process Loaded: Click on the "Run" button to begin the experiment.

Stats Panel [1] ManageProcessesPanel [1]

I U CL D S OV LB CA CC Showing Functions Report:

View/Display Choice

Functions Statements Linked Objects

Executables: smg2000 Host: localhost.localdomain Processes/Ranks/Threads:(2) ...

% of CPU Time

44.697833523
28.620296465
3.534777651
3.420752566
3.306727480
2.964652223
other

Exclusive CPU time in sec	% of CPU Time	PAPI_TOT_CYC	PAPI_FP_OPS	Function (defining location)
3.920000000	44.697833523	11772604888	1198486900	hypre_SMGResidual (smg2000: smg_
2.510000000	28.620296465	7478131309	812850606	hypre_CyclicReduction (smg2000: cy
0.310000000	3.534777651	915610917	48863259	opal_progress (libopen-pal.so.0.0.0)
0.300000000	3.420752566	910260309	100529525	hypre_SemiRestrict (smg2000: semi_
0.290000000	3.306727480	874155835	48509938	mca_btl_sm_component_progress (li
0.260000000	2.964652223	781833036	98664505	hypre_SemiInterp (smg2000: semi_i

Command Panel

openss>>

Viewing hwcsamp data in CLI

openss -cli -f smg2000-hwcsamp-1.openss

openss>>[openss]: The restored experiment identifier is: -x 1

openss>>expview

Exclusive CPU time in seconds.	% of CPU Time	PAPI_TOT_CYC	PAPI_FP_OPS	Function (defining location)
3.920000000	44.697833523	11772604888	1198486900	hypre_SMGResidual (smg2000: smg_residual.c,152)
2.510000000	28.620296465	7478131309	812850606	hypre_CyclicReduction (smg2000: cyclic_reduction.c,757)
0.310000000	3.534777651	915610917	48863259	opal_progress (libopen-pal.so.0.0.0)
0.300000000	3.420752566	910260309	100529525	hypre_SemiRestrict (smg2000: semi_restrict.c,125)
0.290000000	3.306727480	874155835	48509938	mca_btl_sm_component_progress (libmpi.so.0.0.2)

Viewing hwcsamp data in CLI

openss>>expview -v linkedobjects

Exclusive CPU time in seconds.	% of CPU Time	PAPI_TOT_CYC	PAPI_FP_OPS	LinkedObject
7.710000000	87.315968290	22748513124	2396367480	smg2000
0.610000000	6.908267271	1789631493	126423208	libmpi.so.0.0.2
0.310000000	3.510758777	915610917	48863259	libopen-pal.so.0.0.0
0.200000000	2.265005663	521249939	46127342	libc-2.10.2.so
8.830000000	100.000000000	25975005473	2617781289	Report Summary

openss>>expview -m flops

Mflops	Function (defining location)
478.639000000	hypre_ExchangeLocalData (smg2000: communication.c,708)
456.405900000	hypre_StructAxpy (smg2000: struct_axpy.c,25)
452.758600000	mca_pml_ob1_isend (libmpi.so.0.0.2)
447.734300000	MPI_Irecv (libmpi.so.0.0.2)

Section 4
I/O Tracing

Tutorial @ SC '11

November, 2011

How to use Open|SpeedShop to Analyze the Performance of Parallel Codes.

LLNL-PRES-508651

Need for Understanding I/O

- I/O could be significant percentage of execution time dependent upon:
  - Checkpoint, analysis output, and visualization & I/O frequencies
  - I/O pattern in the application:
    N-to-1, N-to-N; simultaneous writes or requests
  - Nature of application:
    data intensive, traditional HPC, out-of-core
  - File system and Striping: NFS, Lustre, Panasas, and #of OSTs
  - I/O libraries: MPI-IO, hdf5, PLFS,…
  - Other jobs stressing the I/O sub-systems
- Obvious candidates to explore first while tuning:
  - Use parallel file system
  - Optimize for I/O pattern
  - Match checkpoint I/O frequency to MTBI of the system
  - Use appropriate libraries

Running I/O Experiments

Offline io/iot experiment on smg2000 application

<u>Option 1: Convenience script basic syntax</u>

ossio[t] “smg2000 –n 50 50 50” [default | <list of I/O func>]

- Parameters

  I/O Function list to trace (default is all)

<u>Option 2: Explicit openss syntax:</u>

setenv OPENSS_IO_TRACED read,write,dup (only needed to change default)

openss –offline –f “smg2000 –n 50 50 50” io

setenv OPENSS_IOT_TRACED read,write,dup (only needed to change default)

openss –offline –f “smg2000 –n 50 50 50” iot

Additional I/O analysis with O|SS

- Extended I/O Tracing (iot experiment)
  - Records each event in chronological order
  - Collects Additional Information
    - Function Parameters
    - Function Return Value
- When to use extended I/O tracing?
  - When you want to trace the exact order of events
  - When you want to see the return values or bytes read or written.

Additional I/O analysis with O|SS

```
openss>>expview
  I/O Call Time(ms)      % of Total Time      Number of Calls Function (defining location)
      17.906473000        96.239580457                2 __libc_read (libpthread-2.10.2.so)
       0.394533000         2.120444958               36 __libc_write (libpthread-2.10.2.so)
       0.265676000         1.427894079               72 llseek (libpthread-2.10.2.so)
       0.024794000         0.133257072                2 __libc_close (libpthread-2.10.2.so)
       0.014666000         0.078823434                2 __libc_open (libpthread-2.10.2.so)

openss>>expview -vtrace
       Start Time     I/O Call Time(ms)      % of Total Time Function Dependent       File/Path Name  Call Stack Function (defining location)
  Return Value
2011/04/22 15:28:49        0.009847000        0.052923384          10             input  >>>>>>>>>>>__libc_open (libpthread-2.10.2.so)
2011/04/22 15:28:49        0.003003000        0.016139832           0  /home/jeg/DEMOS/demos/mpi/openmpi-
1.4.2/sweep3d/input  >>>>>>>>>>llseek (libpthread-2.10.2.so)
2011/04/22 15:28:49       17.902981000       96.220812461          53  /home/jeg/DEMOS/demos/mpi/openmpi-
1.4.2/sweep3d/input  >>>>>>>>>>>>>>>__libc_read (libpthread-2.10.2.so)
2011/04/22 15:28:49        0.013479000        0.072443820           0  /home/jeg/DEMOS/demos/mpi/openmpi-
1.4.2/sweep3d/input  >>>>>>>>>__libc_close (libpthread-2.10.2.so)
2011/04/22 15:28:49        0.004819000        0.025900050          10             input  >>>>>>>>>>>__libc_open (libpthread-2.10.2.so)
2011/04/22 15:28:49        0.002095000        0.011259723           0  /home/jeg/DEMOS/demos/mpi/openmpi-
1.4.2/sweep3d/input  >>>>>>>>>>llseek (libpthread-2.10.2.so)
```

I/O output via CLI (equivalent of HC in GUI)

```
openss>>expview -vcalltrees,fullstack iot1
 I/O Call Time(ms)      % of Total Time      Number of Calls  Call Stack Function (defining location)
                                    _start (sweep3d.mpi)
                                      > @ 470 in __libc_start_main (libmonitor.so.0.0.0: main.c,450)
                                       >>__libc_start_main (libc-2.10.2.so)
                                        >>> @ 428 in monitor_main (libmonitor.so.0.0.0: main.c,412)
                                         >>>>main (sweep3d.mpi)
                                          >>>>> @ 58 in MAIN__ (sweep3d.mpi: driver.f,1)
                                           >>>>>> @ 25 in task_init_ (sweep3d.mpi: mpi_stuff.f,1)
                                             >>>>>>>_gfortran_ftell_i2_sub (libgfortran.so.3.0.0)
                                              >>>>>>>>_gfortran_ftell_i2_sub (libgfortran.so.3.0.0)
                                               ....
                                                  >>>>>>>>>>>>>>_gfortran_st_read (libgfortran.so.3.0.0)
   17.902981000        96.220812461                1 >>>>>>>>>>>>>>>__libc_read (libpthread-2.10.2.so)
```

Section 5
How to Detect Bottlenecks in Parallel Codes?

Tutorial @ SC '11
November, 2011

How to use Open|SpeedShop to Analyze the Performance of Parallel Codes.

LLNL-PRES-508651

Integration with MPI

- O|SS has been tested with a variety of MPIs
  - Including: Open MPI, MVAPICH, and MPICH2 (Intel, Cray)
- Running O|SS experiments on MPI codes
  - Add MPI starter/driver phrase as part of executable name, just as you would when running outside of the O|SS tool
  - ossmpi “mpirun –np 128 sweep3d.mpi”
  - osspcsamp “mpirun –np 32 sweep3d.mpi”
  - ossio “srun –N 4 –n 16 sweep3d.mpi”
  - openss –offline –f “mpirun –np 128 sweep3d.mpi” hwctime
  - openss –online –f “srun –N 8 –n 128 sweep3d.mpi” usertime

Parallel Result Analysis

- Default views
  - Values aggregated across all ranks
  - Manually include/exclude individual ranks/processes/threads
- Comparing ranks
  - Use the Customize Stats Panel View
  - Create compare columns for process groups or individual ranks
- Load Balance View
  - Calculates min, max, average across ranks, processes, or threads
- Comparative Analysis View (finding outliers)
  - Uses “cluster analysis” algorithm to group similar performing ranks, processes, or threads

Running MPI Experiments

Offline mpi/mpit/mpiotf experiment on smg2000 appl.

<u>Option 1: Convenience script basic syntax</u>

ossmpi[t] “srun –N 4 –n 32 smg2000 –n 50 50 50” [default | <list MPI func> | mpi category]

- Parameters

  MPI Function list to trace (default is all)

<u>Option 2: Explicit openss syntax:</u>

setenv OPENSS_MPI_TRACED collective_com

openss –offline –f “srun –N 4 –n 32 smg2000 –n 50 50 50” mpi

setenv OPENSS_MPIT_TRACED MPI_Allgather,MPI_Send

openss –offline –f “srun –N 4 –n 32 smg2000 –n 50 50 50” mpit

MPI Tracing Results: Default View

Open|SpeedShop

File Tools Help

MPI [1]

Process Control

Run Cont Pause Terminate

Status: Process Loaded. Click on the "Run" button to begin the experiment.

Stats Panel [1] ManageProcessesPanel [1]

Showing Functions Report

Executables: smg2000 Hosts:(64) hyperion583.llnl.gov ... Processes/Ranks/Threads:(512) 0 ...

Metadata for Experiment 1:
Application command:
Executables: smg2000
Experiment type: mpi
Host(s): hyperion583.llnl.gov hyperion584.llnl.gov hyperion585.llnl.gov hyperion586.llnl.gov hyperion587.llnl.gov hyperion588.llnl.gov hyperion589.llnl.gov h
Processes, Ranks or Threads: 0-511

Minimum MPI Call Time(ms)	Maximum MPI Call Time(ms)	Average Time(ms)	Number of Calls	Function (defining location)
555.306000	1276.275000	755.289027	512	PMPI_Init (libmonitor.so.0.0.0: pmpi.c,94)
151.147000	167.504000	163.231094	512	PMPI_Finalize (libmonitor.so.0.0.0: pmpi.c,223)
0.152000	0.474000	0.334205	512	MPI_Allgatherv (libmpich.so.1.0: allgatherv.c,73)
0.043000	0.212000	0.133098	512	MPI_Allgather (libmpich.so.1.0: allgather.c,70)
0.031000	2.034000	1.312102	512	MPI_Barrier (libmpich.so.1.0: barrier.c,56)
0.013000	10.322000	0.717578	6144	MPI_Allreduce (libmpich.so.1.0: allreduce.c,59)
0.000001	611.617000	0.977852	4667648	MPI_Waitall (libmpich.so.1.0: waitall.c,57)
0.000001	0.600000	0.001156	5403936	MPI_Isend (libmpich.so.1.0: isend.c,58)
0.000001	0.069000	0.000665	5403936	MPI_Irecv (libmpich.so.1.0: irecv.c,48)

Information Icon Displays Experiment Metadata

Aggregated Results

View Results: Show MPI Callstacks

Open|SpeedShop

File Tools Help

MPI [1]

Process Control

Run

Unique Call Paths View: Click C+ Icon

Unique Call Paths to MPI_Waitall and other MPI functions

Status: Process Loaded: Click on the "Run" button to begin the experiment.

Stats Panel [1] | ManageProcessesPanel [1]

I U CL D G G HC B TS OV LB CA CC Showing CallTrees,FullStack Report:

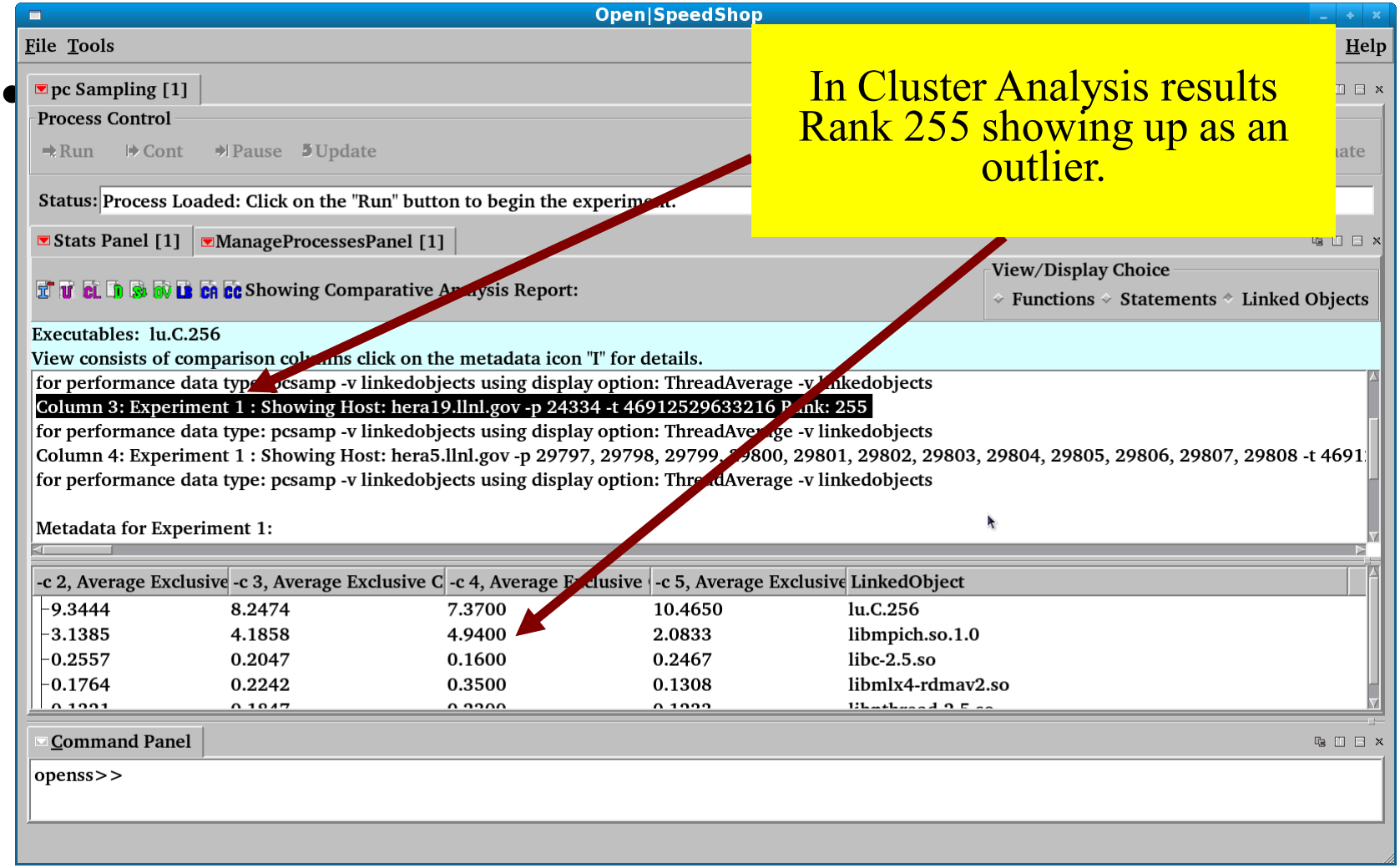
Executables: smg2000 Host: localhost.localdomain Processes/Ranks/Threads:(2) 0 ...

Exclusive MPI Call Time(ms)	% of Total	Number of Calls	Call Stack Function (defining location)
0.000000	0.000000		main (smg2000: smg2000.c,21)
106.082304	12.510346	2	@ 94 in PMPI_Init (libmonitor.so.0.0.0: pmpi.c,94)
0.000000	0.000000		main (smg2000: smg2000.c,21)
0.000000	0.000000		@ 49 in HYPRE_StructSMGSetup (smg2000: HYPRE_struct_smg.c,48)
0.000000	0.000000		@ 335 in hypre_SMGSetup (smg2000: smg_setup.c,28)
0.000000	0.000000		@ 405 in hypre_SMGRelaxSetup (smg2000: smg_relax.c,357)
0.000000	0.000000		@ 613 in hypre_SMGRelaxSetupASol (smg2000: smg_relax.c,540)
0.000000	0.000000		@ 335 in hypre_SMGSetup (smg2000: smg_setup.c,28)
0.000000	0.000000		@ 405 in hypre_SMGRelaxSetup (smg2000: smg_relax.c,357)
0.000000	0.000000		@ 619 in hypre_SMGRelaxSetupASol (smg2000: smg_relax.c,540)
0.000000	0.000000		@ 549 in hypre_CyclicReductionSetup (smg2000: cyclic_reduction.c,4
0.000000	0.000000		@ 491 in hypre_StructCoarsen (smg2000: coarsen.c,139)
24.321377	2.868234	600	@ 39 in MPI_Waitall (libmpi.so.0.0.1: pwaitall.c,39)

Command Panel

openss>>

Finding Outliers: Using NPB: LU



In Cluster Analysis results Rank 255 showing up as an outlier.

Load Balance View: Using NPB: LU

Open|SpeedShop

File Tools Help

pc Sampling [1]

Process Control

Run Cont Pause Update Terminate

Status: Process Loaded: Click on the "Run" button to begin the experiment.

Stats Panel [1] ManageProcessesPanel [1]

Showing Load Balance (min,max,ave) Report:

View/Display Choice: Functions Statements Linked Objects

Executables: lu.C.256 Hosts:(16) hera10.llnl.gov ... Processes/Ranks/Threads:(256) 0 ...

Max Exclusive	Rank of Max	Min Exclusive	Rank of Min	Average Exclus	LinkedObject
10.8800	17	[illegible]	255	9.3078	lu.C.256
4.9400	255	1.7600	17	3.1738	libmpich.so.1.0
0.5400	94	0.1100	0	0.2511	libc-2.5.so
0.3500	255	0.0500	219	0.1785	libmlx4-rdmav2.so
0.3000	190	0.0500	55	0.1359	libpthread-2.5.so

Command Panel

openss>>

Rank 255 has maximum MPI library time value

Section 6
User Interfaces

Tutorial @ SC '11

November, 2011

How to use Open|SpeedShop to Analyze the Performance of Parallel Codes.

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CLI Command Overview

- Experiment creations
  - `expcreate`
  - `expattach*`
- Experiment control
  - `expgo`
  - `expwait*`
  - `expdisable*`
  - `expenable*`
- Experiment storage
  - `expsave`
  - `exprestore`
- Result presentation
  - `expview`
  - `opengui`
- Misc. commands
  - `help`
  - `list`
  - `log`
  - `record`
  - `playback`
  - `history`
  - `quit`

`*online version only`

CLI Command Examples

- Simple usage to create, run, view data
  - **openss –cli** (use cli to run experiment:3 commands)
    - **expcreate –f "mutatuee 2000"** pcsamp (create an experiment with instrumentation added for the particular collector)
    - **expgo** (runs the experiment gathering data into database)
    - **expview** (displays the default view of the performance data)
- Alternative views of the performance data
  - **openss –cli –f <datbase file name>**
    - **expview –v statements** (see the statements that took the most time)
    - **expview –v linkedobjects** (see time attributed to the libraries in appl.)
    - **expview –v calltrees, fullstack** (see all the call paths in application)
    - **expview –m loadbalance** (see the min, max, average across ranks/threads)
    - **list –v metrics** (display the optional performance data metrics)
    - **expview –m <metric from above>** (view the metric specified)

Section 7
Comparing Experiment Results

Tutorial @ SC '11
November, 2011

How to use Open|SpeedShop to Analyze the Performance of Parallel Codes.

LLNL-PRES-508651

Comparing Performance Data (1)

- GUI Custom Compare Panel (CC icon)
  - See users guide or tutorials for details
- Convenience Script: osscompare
  - Compares Open|SpeedShop databases to each other
  - Compare up to 8 at one time
    - If output file name is too long use:
    - export **OPENSS_USE_INTERNAL_NAMING**=1
    - Causes shortened output file names to be created
  - Produces side-by-side comparison listing
  - Optionally create "csv" output for input into spreadsheet (Excel,..)
    - export **OPENSS_CREATE_CSV**=1
- osscompare syntax:
  - osscompare “db1.openss,db2.openss,…” [options]
  - osscompare man page has more details

Comparing Performance Data (2)

osscompare "smg2000-pcsamp.openss,smg2000-pcsamp-1.openss”

```
openss]: Legend: -c 2 represents smg2000-pcsamp.openss
[openss]: Legend: -c 4 represents smg2000-pcsamp-1.openss
-c 2, Exclusive CPU   -c 4, Exclusive CPU  Function (defining location)
  time in seconds.      time in seconds.
      3.870000000          3.630000000  hypre_SMGResidual (smg2000: smg_residual.c,152)
      2.610000000          2.860000000  hypre_CyclicReduction (smg2000: cyclic_reduction.c,757)
      2.030000000          0.150000000  opal_progress (libopen-pal.so.0.0.0)
      1.330000000          0.100000000 mca_btl_sm_component_progress (libmpi.so.0.0.2:
topo_unity_component.c,0)
      0.280000000          0.210000000  hypre_SemiInterp (smg2000: semi_interp.c,126)
      0.280000000          0.040000000  mca_pml_ob1_progress (libmpi.so.0.0.2:
topo_unity_component.c,0)
```

Section 8
Static Binary Support

Tutorial @ SC '11
November, 2011

How to use Open|SpeedShop to Analyze the Performance of Parallel Codes.

LLNL-PRES-508651

Workflow Differences for Static Binary

- When shared library support is limited
  - Normal manner of running experiments doesn't work
  - Need to link our collectors into the static executable
- Current method (static) of support on Cray and BG/P
- Must relink application to add in OSS collector code.
  - **osslink** command is provided to help
- Have the OpenSpeedShop target NOT host environment module loaded when relinking

Open|SpeedShop & Static Executables

- osslink: A script to help with linking in our collectors
  - **osslink** is a script that hides a lot of the link details
  - Calls to it are usually embedded inside application makefiles
  - Can also be used to compile and link applications
  - Sorts the experiment specific library and collector specification
  - Sorts out some platform differences to do the correct link
- Find Makefile target to add entry for relink with collector
  - The user generally needs find the target that creates the actual static executable and create a collector target that links in the selected collector as shown in the example.
- Example follows ->

Re-linking application using osslink

- Example modification for smg2000 application

```
smg2000: smg2000.o
    @echo  "Linking" $@ "... "
    ${CC} -o smg2000 smg2000.o ${LFLAGS}

smg2000-pcsamp: smg2000.o
    @echo  "Linking" $@ "... "
    osslink  -v -c pcsamp ${CC} -o smg2000-pcsamp smg2000.o ${LFLAGS}

smg2000-usertime: smg2000.o
    @echo  "Linking" $@ "... "
    osslink -v -c usertime ${CC} -o smg2000-usertime smg2000.o ${LFLAGS}

smg2000-hwcsamp: smg2000.o
    @echo  "Linking" $@ "... "
    osslink -v -c hwcsamp ${CC} -o smg2000-hwcsamp smg2000.o ${LFLAGS}

smg2000-io: smg2000.o
    @echo  "Linking" $@ "... "
    osslink -u open -v -c io ${CC} -o smg2000-io smg2000.o ${LFLAGS}

smg2000-iot: smg2000.o
    @echo  "Linking" $@ "... "
    osslink -u open -v -c iot ${CC} -o smg2000-iot smg2000.o ${LFLAGS}

smg2000-mpi: smg2000.o
    @echo  "Linking" $@ "... "
    osslink -v -c mpi ${CC} -o smg2000-mpi smg2000.o ${LFLAGS}
```

Workflow Differences for Static Binary

- Running the re-linked executable causes the application to write the raw data files to the location specified by OPENSS_RAWDATA_DIR
- Converting raw data to an OpenSpeedShop database
  - Normally the convenience scripts or **openss** tool will do this under the hood
  - ossutil command will create the database file.
  - If raw data files are in /home/jgalaro/smg2000/test/raw
  - **Then ossutil** /home/jgalaro/smg2000/test/raw # creates a database file
  - Symbol table information is read and mapped to the raw data application addresses to map source to the performance data.
- The ossutil step may be added to the batch script to eliminate an additional step
- Now normal OpenSpeedShop GUI and CLI viewing of the performance data is possible

Workflow Differences for Static Binary

- Now run executable: (note –bb argument to aprun)

```
PBS -q debug
#PBS -N smg2000-pcsamp
…
# must have a clean raw data directory each run
rm -rf /home/jgalaro/smg2000/test/raw
mkdir /home/jgalaro/smg2000/test/raw

setenv OPENSS_RAWDATA_DIR /home/jgalaro/smg2000/test/raw
setenv OPENSS_DB_DIR /home/jgalaro/smg2000/test/

cd /home/jgalaro/smg2000/test
# needs –bb to have the original executable available when doing ossutil
aprun -bb -n 16 /home/jgalaro/smg2000/test/smg2000-pcsamp

# creates a X.0.openss database file, may need to load module pointing to openspeedshop here
ossutil /home/jgalaro/smg2000/test/raw
```

Open|SpeedShop on Cray/BG Systems

- Changes to shared library support recently
  - Dynamic shared library support now available in newer O/S
  - We are working on providing shared support in addition to static binary support
  - This will allow the normal Open|SpeedShop workflow to be used, for example:
    - osspcsamp “how you run the executable dynamically”
- Hoping to have this shared support in Open|SpeedShop in the next 3 months.

Conclusions

Tutorial @ SC ‘11
November, 2011

How to use Open|SpeedShop to Analyze the Performance of Parallel Codes.

Questions vs. Experiments

- Where do I spend my time?
  - Flat profiles (pcsamp)
  - Getting inclusive/exclusive timings with callstacks (usertime)
  - Identifying hot callpaths (usertime + HC analysis)
- How do I analyze cache performance?
  - Measure memory performance using hardware counters (hwc)
  - Compare to flat profiles (custom comparison)
  - Compare multiple hardware counters (N x hwc, hwcsamp)
- How to identify I/O problems?
  - Study time spent in I/O routines (io)
  - Compare runs under different scenarios (custom comparisons)
- How do I find parallel inefficiencies?
  - Study time spent in MPI routines (mpi)
  - Look for load imbalance (LB view) and outliers (CA view)

Key Environment Variables

- Important runtime environment variables (module file)
  - **OPENSS_RAWDATA_DIR**
    - Shared (across nodes) file system dir where raw data files are written
  - **OPENSS_DB_DIR**
    - Need a file system with locking enabled: directory path for database
    - lustre file system may not have locking enabled
  - **OPENSS_PLUGIN_PATH**
    - Path to directory where plugins are stored
  - **OPENSS_MPI_IMPLEMENATION** (if multiple)
    - If Open|SpeedShop was built with multiple MPI implementations, this points openss at the one you are using in your application
    - Also, only required if using the mpi, mpit, or mpiotf experiments
  - **LD_LIBRARY_PATH, PATH**
    - Linux path variables
  - Example

```
export OPENSS_PREFIX=/home/skg/local
export OPENSS_MPI_IMPLEMENTATION=openmpi
export OPENSS_PLUGIN_PATH=$OPENSS_PREFIX/lib64/openspeedshop
export LD_LIBRARY_PATH=$OPENSS_PREFIX/lib64:$LD_LIBRARY_PATH
export PATH=$OPENSS_PREFIX/bin:$PATH
```

Open|SpeedShop Documentation

- Open|SpeedShop User Guide Documentation
  - http://www.openspeedshop.org/docs/user_guide/
  - …/share/doc/packages/OpenSpeedShop/users_guide
- Python Scripting API Documentation
  - http://www.openspeedshop.org/docs/pyscripting_doc/
  - …/share/doc/packages/OpenSpeedShop/pyscripting_doc
- Command Line Interface Documentation
  - http://www.openspeedshop.org/docs/user_guide/
  - …/share/doc/packages/OpenSpeedShop/users_guide
- Man pages: OpenSpeedShop, osspcsamp, ossmpi, …
- Quick start guide downloadable from web site
  - http://www.openspeedshop.org
  - Click on “Download Quick Start Guide” button

Availability and Contact

- Current version: 2.0.1 about to be released
- Open|SpeedShop Website
  - http://www.openspeedshop.org/
- Open|SpeedShop Forum
  - http://www.openspeedshop.org/forums/
- Download options:
  - Package with install script
  - Source for tool and base libraries
- Feedback
  - Bug tracking available from website
  - Contact information on website
  - Feel free to OSS team directly

How to Learn More about OSS

This short tutorial gives a hint at the full power of OSS

- Sign up for SC ‘11 Monday 1/2-day OSS Tutorial !

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