Cray Performance Measurement, Analysis and Porting Tools

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Safe Harbor Statement

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Agenda

- 10:20 – 10:30 Overview of Cray PE topics for the day
- 10:30 – 11:15 Cray Performance Tools refresher
- 11:15 – 12:00 lab (CrayPat-lite, loop stats, Rank reorder)
- 12:00 – 13:00 Lunch
- 13:00 – 14:00 Reveal
- 14:00 – 14:30 CCE and OpenACC update
- 14:30 – 15:00 lab with Reveal
- 15:00 – 15:20 Break
- 15:20 – 16:00 CCDB
- 16:00 – 17:00 find a bug using CCDB, general lab time
The Programming Environment Mission

- It is the role of the Programming Environment to **close the gap** between observed performance and achievable performance.

- Support the **application development life cycle** by providing a **tightly coupled** environment with compilers, libraries, and tools that will **hide the complexity** of the system.

  - Address issues of scale and complexity of HPC systems.
  - Target **ease of use** with extended **functionality** and increased **automation**.
  - Close **interaction with users**:
    - For feedback targeting **functionality enhancements**.

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Cray Programming Environment Focus

● **Performance**
  ● Help users maximize the cycles to the application
    ● Address issues of scale and complexity of HPC systems

● **Programmability**
  ● How do you get intuitive behavior and best performance with the least amount of effort
    ● Provide the best environment to develop, debug, analyze, and optimize applications for production supercomputing
    ● Provide programming environment consistency across Cray platforms
Recent Enhancements

- Cray Apprentice2 available for Linux, Mac and Windows with .dmg and .exe installers
  - Available in $CRAYPAT_ROOT/share/desktop_installers

- Router-aware MPI rank placement

- Simplified Interface to performance counters

- Program timeline

- I/O statistics in CrayPat-lite

- pat_build default is now pat_build –O apa
Two Interfaces to the Performance Tools

- **CrayPat** offers a wealth of performance measurement, analysis and presentation options for in-depth performance investigation and tuning assistance.

- **CrayPat-lite** offers easy access to an application performance summary for users not familiar with the Cray performance tools or who may not be familiar with performance analysis.

- **CrayPat classic** and **CrayPat-lite** are designed to compliment each other:
  - Produce files with same format
  - Users familiar with CrayPat can easily switch back and forth between the two interfaces
  - CrayPat-lite users become familiar with reporting style also used with CrayPat
CrayPat-lite

● Produces application performance statistics at the end of a job
  ● Focus is to offer a simplified interface to basic application performance information for users not familiar with the Cray performance tools and perhaps new to application performance analysis
  ● Gives sites the option to enable/disable application performance data collection for all users for a period of time

● Compliments “classic” perftools

● Provides a simple way to transition from perftools-lite to perftools to encourage further tool use for more in-depth performance analysis
Using CrayPat-lite

Access light version of performance tools software

> module load perftools-lite

Build program

> make

a.out (instrumented program)

Run program (no modification to batch script)

aprun a.out

Condensed report to stdout
a.out*.rpt (same as stdout)
a.out*.ap2
MPICH_RANK_XXX files
Performance Statistics Available

● Set of predefined experiments, enabled with the CRAYPAT_LITE environment variable
  ● Sample_profile
  ● Event_profile
  ● GPU

● Job information
  ● Number of MPI ranks, ranks per node, number of threads
  ● Wallclock
  ● High memory water mark
  ● Aggregate MFLOPS (CPU only)
  ● I/O

● Profile of top time consuming routines with load balance
● Observations
● Instructions on how to get more information
CrayPat-lite Output Example

CrayPat/X: Version 6.1.4.12457 Revision 12457 (xf 12277) 02/26/14 13:58:24
Experiment: lite lite/sample_profile
Number of PEs (MPI ranks): 8164
Numbers of PEs per Node: 16 PEs on each of 510 Nodes
4 PEs on 1 Node
Numbers of Threads per PE: 1
Number of Cores per Socket: 8
Execution start time: Fri Feb 28 23:06:31 2014
System name and speed: hera2 2100 MHz

Wall Clock Time: 999.595275 secs
High Memory: 475.52 MBytes
MFLOPS (aggregate): 806112.33 M/sec
I/O Read Rate: 33.57 MBytes/Sec
I/O Write Rate: 215.40 MBytes/Sec

<table>
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<th>Time</th>
<th>Imb.</th>
<th>Imb.</th>
<th>Calls</th>
<th>Group</th>
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<td>101.961423</td>
<td>--</td>
<td>--</td>
<td>5315211.9</td>
<td>Total</td>
</tr>
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<td>94.267451</td>
<td>--</td>
<td>--</td>
<td>5272245.9</td>
<td>USER</td>
</tr>
<tr>
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<td>77.248585</td>
<td>2.356249</td>
<td>3.0%</td>
<td>1001.0</td>
<td>LAMMPS_NS::PairLJCut::compute</td>
</tr>
<tr>
<td>6.5%</td>
<td>6.644545</td>
<td>0.105246</td>
<td>1.6%</td>
<td>51.0</td>
<td>LAMMPS_NS::Neighbor::half_bin_newton</td>
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<td>4.131842</td>
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<td>1.0</td>
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<tr>
<td>1.3%</td>
<td>1.288463</td>
<td>0.181268</td>
<td>12.5%</td>
<td>1000.0</td>
<td>LAMMPS_NS::FixNVE::final_integrate</td>
</tr>
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<td>7.0%</td>
<td>7.110931</td>
<td>--</td>
<td>--</td>
<td>42637.0</td>
<td>MPI</td>
</tr>
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<td>4.8%</td>
<td>4.851309</td>
<td>3.371093</td>
<td>41.6%</td>
<td>12267.0</td>
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</tr>
<tr>
<td>1.5%</td>
<td>1.536106</td>
<td>2.592504</td>
<td>63.8%</td>
<td>12267.0</td>
<td>MPI_Wait</td>
</tr>
</tbody>
</table>
The Cray Performance Analysis Framework

- **Supports traditional post-mortem performance analysis**
  - Automatic identification of performance problems
    - Indication of causes of problems
    - Suggestions of modifications for performance improvement
  - `pat_build`: provides automatic instrumentation
  - CrayPat run-time library collects measurements (transparent to the user)
  - `pat_report` performs analysis and generates text reports
  - `pat_help`: online help utility
  - Cray Apprentice2: graphical visualization tool
Steps to Using CrayPat “classic”

Access performance tools software

> module load perftools

Build program, retaining .o files

> make

Instrument binary

> pat_build –O apa a.out

Modify batch script and run program

aprun a.out+pat

Process raw performance data and create report

> pat_report a.out+pat*.xf

> make

a.out

> pat_build –O apa a.out

a.out+pat

aprun a.out+pat

a.out+pat*.xf

> pat_report a.out+pat*.xf

a.out+pat*.ap2
Text report to stdout
a.out+pat*.apa
MPICH_RANK_XXX
Sampling with Line Number information

<table>
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<tr>
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<th>Samp</th>
<th>Imb.</th>
<th>Imb.</th>
<th>Group</th>
<th>Source</th>
<th>Line</th>
<th>PE-HIDE</th>
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<td>93.2%</td>
<td>7804.0</td>
<td>--</td>
<td>--</td>
<td>USER</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>51.7%</td>
<td>4328.7</td>
<td>--</td>
<td>--</td>
<td>calc3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>heidi/DARPA/cache_util/calc3.do300-ijswap.F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.7%</td>
<td>1314.4</td>
<td>93.6</td>
<td>6.8%</td>
<td>line.78</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>13.9%</td>
<td>1167.7</td>
<td>98.3</td>
<td>7.9%</td>
<td>line.79</td>
<td></td>
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<tr>
<td>14.5%</td>
<td>1211.6</td>
<td>97.4</td>
<td>7.6%</td>
<td>line.80</td>
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<td></td>
<td></td>
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<tr>
<td>1.2%</td>
<td>103.1</td>
<td>26.9</td>
<td>21.2%</td>
<td>line.93</td>
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<td></td>
<td></td>
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<tr>
<td>1.1%</td>
<td>88.4</td>
<td>22.6</td>
<td>20.8%</td>
<td>line.94</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0%</td>
<td>84.5</td>
<td>17.5</td>
<td>17.6%</td>
<td>line.95</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>86.8</td>
<td>33.2</td>
<td>28.2%</td>
<td>line.96</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1.3%</td>
<td>105.0</td>
<td>23.0</td>
<td>18.4%</td>
<td>line.97</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4%</td>
<td>116.5</td>
<td>24.5</td>
<td>17.7%</td>
<td>line.98</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

144.1 38%
APA File Example

# You can edit this file, if desired, and use it
to reinstrument the program for tracing like this:

```
pat_build -O standard.cray-xt.PE-2.1.56HD.pgi-8.0.amd64.pat-5.0.0.2-Oapa.512.quad.cores.seal.090405.1154 mpi.pat_rt_exp=default.pat_rt_hwpc=none.14999.xf.xf.apa
```

# These suggested trace options are based on data from:
```
/home/users/malice/pat/Runs/Runs.seal.pat5001.2009Apr04/.pat.quad/homme/standard.cray-xt.PE-2.1.56HD.pgi-8.0.amd64.pat-5.0.0.2-Oapa.512.quad.cores.seal.090405.1154 mpi.pat_rt_exp=default.pat_rt_hwpc=none.14999.xf.xf.cdb
```

# HWPC group to collect by default.
```
-Drtenv=PAT_RT_HWPC=1 # Summary with TLB metrics.
```

# Libraries to trace.
```
-g mpi
```

User-defined functions to trace, sorted by % of samples.
```
The way these functions are filtered can be controlled with
pat_report options (values used for this file are shown):
```
-s apa_max_count=200    No more than 200 functions are listed.
-s apa_min_size=800     Commented out if text size < 800 bytes.
-s apa_min_pct=1        Commented out if it had < 1% of samples.
-s apa_max_cum_pct=90   Commented out after cumulative 90%.
```

Local functions are listed for completeness, but cannot be traced.
```
-w # Enable tracing of user-defined functions.
Note: -u should NOT be specified as an additional option.
```

```
# 31.29% 38517 bytes
-T prim_advance_mod_preq_advance_exp_
```

```
# 15.07% 14158 bytes
-T prim_si_mod_prim_diffusion_
```

```
# 9.76% 5474 bytes
-T derivative_mod_gradient_str_nonstag_
```

```
# 2.95% 3067 bytes
-T forcing_mod_apply_forcing_
```

```
# 2.93% 118585 bytes
-T column_model_mod_applycolumnmodel_
```

```
# Functions below this point account for less than 10% of samples.
```

```
# 0.66% 4575 bytes
-T bndry_mod_bndry_exchangev_thsave_time_
```

```
# 0.10% 46797 bytes
-T baroclinic_inst_mod_binst_init_state_
```

```
# 0.04% 62214 bytes
-T prim_state_mod_prim_printstate_
```

```
# 0.00% 118 bytes
-T time_mod_timelevel_update_
```

```
-o preqx.cray-xt.PE-2.1.56HD.pgi-8.0.amd64.pat-5.0.0.2.x+apa
```

# New instrumented program.

```
./AUTO/cray/css_pe_tools/malice/craypat/build/pat/2009Apr03/2.1.56HD/amd64/homme/pgi7pat-5.0.0.2/homme/2005Dec08/build.Linux/preqx.cray-xt.PE-2.1.56HD.pgi-8.0.amd64.pat-5.0.0.2.x # Original program.
```

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CrayPat Runtime Options

- Runtime controlled through PAT_RT_XXX environment variables

- See `intro_craypat(1)` man page

**Examples of control**
- Enable full trace
- Change number of data files created
- Enable collection of HW counters
- Enable collection of network counters
- Enable tracing filters to control trace file size (max threads, max call stack depth, etc.)
Example Runtime Environment Variables

● Optional timeline view of program available
  ● export PAT_RT_SUMMARY=0
  ● View trace file with Cray Apprentice

● Write 1 file per node:
  ● export PAT_RT_EXPFILE_MAX=0

● Request hardware performance counter information:
  ● export PAT_RT_PERFCTR=<HW counter group or event(s)>
  ● Can specify individual events or predefined groups
Generating Profile from APA

- Instrument application for further analysis (a.out+apa)

  % pat_build -O <apafilename>.apa

- Run application

  % aprun ... a.out+apa  (or qsub <apa script>)

- Generate text report and visualization file (.ap2)

  % pat_report -o my_text_report.txt [<datafile>.xf | <datadir>]

- View report in text and/or with Cray Apprentice^2

  % app2 <datafile>.ap2
## Files Generated and the Naming Convention

<table>
<thead>
<tr>
<th>File Suffix</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.out+pat</td>
<td>Program instrumented for data collection</td>
</tr>
<tr>
<td>a.out...s.xf</td>
<td>Raw data for sampling experiment, available after application execution</td>
</tr>
<tr>
<td>a.out...t.xf</td>
<td>Raw data for trace (summarized or full) experiment, available after application execution</td>
</tr>
<tr>
<td>a.out...st.ap2</td>
<td>Processed data, generated by pat_report, contains application symbol information</td>
</tr>
<tr>
<td>a.out...s.apa</td>
<td>Automatic profiling panalysis template, generated by pat_report (based on pat_build –O apa experiment)</td>
</tr>
<tr>
<td>a.out+apa</td>
<td>Program instrumented using .apa file</td>
</tr>
<tr>
<td>MPICH_RANK_ORDER.Custom</td>
<td>Rank reorder file generated by pat_report from automatic grid detection an reorder suggestions</td>
</tr>
</tbody>
</table>
Performance Counters

● Cray supports raw counters, derived metrics and thresholds for:
  ● Processor
  ● Network
  ● Accelerator
  ● Power

● Predefined groups
  ● Groups together suggested counters for experiments

● Single interface to access counters (PAT_RT_PERFCTR environment variable)

● PAPI with Cray custom components for network, uncore, power (available to 3rd party tool developers)
Example: HW counter data and Derived Metrics

PAT_RT_HWPC=1
Flat profile data
Raw counts
Derived metrics

PAPI_TLB_DM  Data translation lookaside buffer misses
PAPI_L1_DCA  Level 1 data cache accesses
PAPI_FP_OPS  Floating point operations
DC_MISS     Data Cache Miss
User_Cycles  Virtual Cycles

USER

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time%</td>
<td>98.3%</td>
</tr>
<tr>
<td>Time</td>
<td>4.434402 secs</td>
</tr>
<tr>
<td>Imb. Time</td>
<td>-- secs</td>
</tr>
<tr>
<td>Imb. Time%</td>
<td>--</td>
</tr>
<tr>
<td>Calls</td>
<td>0.001M/sec</td>
</tr>
<tr>
<td>PAPI_L1_DCM</td>
<td>14.820M/sec</td>
</tr>
<tr>
<td>PAPI_TLB_DM</td>
<td>0.902M/sec</td>
</tr>
<tr>
<td>PAPI_L1_DCA</td>
<td>333.331M/sec</td>
</tr>
<tr>
<td>PAPI_FP_OPS</td>
<td>445.571M/sec</td>
</tr>
<tr>
<td>User time (approx)</td>
<td>4.434 secs</td>
</tr>
<tr>
<td>Average Time per Call</td>
<td>0.000985 sec</td>
</tr>
<tr>
<td>CrayPat Overhead : Time</td>
<td>0.1%</td>
</tr>
<tr>
<td>HW FP Ops / User time</td>
<td>445.571M/sec</td>
</tr>
<tr>
<td>HW FP Ops / WCT</td>
<td>445.533M/sec</td>
</tr>
<tr>
<td>Computational intensity</td>
<td>0.17 ops/cycle</td>
</tr>
<tr>
<td>MFLOPS (aggregate)</td>
<td>1782.28M/sec</td>
</tr>
<tr>
<td>TLB utilization</td>
<td>369.60 refs/miss</td>
</tr>
<tr>
<td>D1 cache hit,miss ratios</td>
<td>95.6% hits</td>
</tr>
<tr>
<td>D1 cache utilization (misses)</td>
<td>22.49 refs/miss</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example: HW counter data and Derived Metrics

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MPI Rank Reorder

- MPI rank placement with environment variable

- Distributed placement
- SMP style placement
- Folded rank placement
- User provided rank file
MPI Rank Reorder (cont’d)

- Non-default MPI rank placements are useful when point-to-point communication consumes significant fraction of the program time, and there is a significant load imbalance.

- Performance report contains a prioritized list of placement scenarios and includes instructions on how to choose one of the placements for subsequent program execution.

- Custom placement files automatically generated, user just chooses one.

- Utilities available to create MPI rank placements for applications with grid or lattice topologies.
Automatic Communication Grid Detection

- Cray performance tools produce a custom rank order if it’s beneficial based on grid size, grid order and cost metric.

- **Heuristics available for:**
  - MPI sent message statistics
  - User time (time spent in user functions) – can be used for PGAS codes
  - Hybrid of sent message and user time

- **Summarized findings in report**

- **Available with sampling or tracing**

- **Describe how to re-run with custom rank order**
## MPI Rank Order Observations

### Table 1: Profile by Function Group and Function

<table>
<thead>
<tr>
<th>Time%</th>
<th>Time</th>
<th>Imb. Time</th>
<th>Imb. Time%</th>
<th>Calls</th>
<th>Group Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>100.0%</td>
<td>463.147240</td>
<td>--</td>
<td>--</td>
<td>21621.0</td>
<td>Total</td>
</tr>
<tr>
<td>52.0%</td>
<td>240.974379</td>
<td>--</td>
<td>--</td>
<td>21523.0</td>
<td>MPI</td>
</tr>
<tr>
<td>47.7%</td>
<td>221.142266</td>
<td>36.214468</td>
<td>14.1%</td>
<td>10740.0</td>
<td>mpi_recv</td>
</tr>
<tr>
<td>4.3%</td>
<td>19.829001</td>
<td>25.849906</td>
<td>56.7%</td>
<td>10740.0</td>
<td>MPI_SEND</td>
</tr>
<tr>
<td>43.3%</td>
<td>200.474690</td>
<td>--</td>
<td>--</td>
<td>32.0</td>
<td>USER</td>
</tr>
<tr>
<td>41.0%</td>
<td>189.897060</td>
<td>58.716197</td>
<td>23.6%</td>
<td>12.0</td>
<td>sweep_</td>
</tr>
<tr>
<td>1.6%</td>
<td>7.579876</td>
<td>1.899097</td>
<td>20.1%</td>
<td>12.0</td>
<td>source_</td>
</tr>
<tr>
<td>4.7%</td>
<td>21.698147</td>
<td>--</td>
<td>--</td>
<td>39.0</td>
<td>MPI_SYNC</td>
</tr>
<tr>
<td>4.3%</td>
<td>20.091165</td>
<td>20.005424</td>
<td>99.6%</td>
<td>32.0</td>
<td>mpi_allreduce_(sync)</td>
</tr>
<tr>
<td>0.0%</td>
<td>0.000024</td>
<td>--</td>
<td>--</td>
<td>27.0</td>
<td>SYSCALL</td>
</tr>
</tbody>
</table>
MPI Grid Detection:

There appears to be point-to-point MPI communication in a 96 X 8 grid pattern. The 52% of the total execution time spent in MPI functions might be reduced with a rank order that maximizes communication between ranks on the same node. The effect of several rank orders is estimated below.

A file named MPICH_RANK_ORDER.Grid was generated along with this report and contains usage instructions and the Custom rank order from the following table.

<table>
<thead>
<tr>
<th>Rank Order</th>
<th>On-Node Bytes/PE</th>
<th>On-Node Bytes/PE% of Total Bytes/PE</th>
<th>MPICH_RANK_REORDER_METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Custom</td>
<td>2.385e+09</td>
<td>95.55%</td>
<td>3</td>
</tr>
<tr>
<td>SMP</td>
<td>1.880e+09</td>
<td>75.30%</td>
<td>1</td>
</tr>
<tr>
<td>Fold</td>
<td>1.373e+06</td>
<td>0.06%</td>
<td>2</td>
</tr>
<tr>
<td>RoundRobin</td>
<td>0.000e+00</td>
<td>0.00%</td>
<td>0</td>
</tr>
</tbody>
</table>
# The 'Custom' rank order in this file targets nodes with multi-core processors, based on Sent Msg Total Bytes collected for:

# Program: /lus/nid00030/heidi/sweep3d/mod/sweep3d.mpi
# Ap2 File: sweep3d.mpi+pat+27054-89t.ap2
# Number PEs: 48
# Max PEs/Node: 4

# To use this file, make a copy named MPICH_RANK_ORDER, and set the environment variable MPICH_RANK_REORDER_METHOD to 3 prior to executing the program.

# The following table lists rank order alternatives and the grid_order command-line options that can be used to generate a new order.
...
# The 'USER_Time_hybrid' rank order in this file targets nodes with multi-core processors, based on
# To use this file, sent msg total bytes collected for:
# Program: /lus/nid00023/malice/craypat/worksho/bh20demo/Rank/sweep3d/src/sweep3d
# Number PEs: 768
# Max PEs/Node: 16
# To use this file, make a copy named MPICH_RANK_ORDER, and set the environment variable MPICH_RANK_ORDER_MET...
grid_order Utility

- Can use grid_order utility without first running the application with the Cray performance tools if you know a program’s data movement pattern

- Originally designed for MPI programs, but since reordering is done by PMI, it can be used by other programming models (since PMI is used by MPI, SHMEM and PGAS programming models)

- Utility available if perftools modulefile is loaded

- See grid_order(1) man page or run grid_order with no arguments to see usage information
Reorder Example for Bisection Bandwidth

- Assume 32 ranks

- Decide on row or column ordering:

  $ \texttt{grid\_order} \ -R \ -g \ 2,16$
  
  $0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15$
  
  $16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31$

  $ \texttt{grid\_order} \ -C \ -g \ 2,16$
  
  $0,2,4,6,8,10,12,14,16,18,20,22,24,26,28,30$
  
  $1,3,5,7,9,11,13,15,17,19,21,23,25,27,29,31$

- Since rank 0 talks to rank 16, and not with rank 1, we choose Row ordering
Reorder Example for Bisection Bandwidth (2)

- Specify cell (or chunk) to make sure rank pairs live on same node (but don’t care how many pairs live on a node)

- `grid_order -R -g 2,16 -c 2,1`
Using New Rank Order

- Save grid_order output to file called MPICH_RANK_ORDER
- Export MPICH_RANK_REORDER_METHOD=3
- Run non-instrumented binary with and without new rank order to check overall wallclock time for improvements
Collecting Loop Work Estimates

- Load PrgEnv-cray module (must use CCE)
- Load perftools module

- Compile **AND** link with –h profile_generate
  - cc –h profile_generate –o my_program my_program.c

- Instrument binary for tracing
  - pat_build –w my_program

- Run application

- Create report with loop statistics
  - pat_report my_program.xf > loops_report

---

**Important Note:**
pat_report produces report plus .ap2 file that can be used with Reveal
Table 2: Loop Stats by Function (from -hprofile_generate)

<table>
<thead>
<tr>
<th>Loop Incl Time</th>
<th>Loop Hit</th>
<th>Loop Trips Avg</th>
<th>Loop Trips Min</th>
<th>Loop Trips Max</th>
<th>Function=/.LOOP[.] PE=HIDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.995914</td>
<td>100</td>
<td>25</td>
<td>0</td>
<td>25</td>
<td>sweepy_.LOOP.1.1i.33</td>
</tr>
<tr>
<td>8.995604</td>
<td>2500</td>
<td>25</td>
<td>0</td>
<td>25</td>
<td>sweepy_.LOOP.2.1i.34</td>
</tr>
<tr>
<td>8.894750</td>
<td>50</td>
<td>25</td>
<td>0</td>
<td>25</td>
<td>sweepz_.LOOP.05.1i.49</td>
</tr>
<tr>
<td>8.894637</td>
<td>1250</td>
<td>25</td>
<td>0</td>
<td>25</td>
<td>sweepz_.LOOP.06.1i.50</td>
</tr>
<tr>
<td>4.420629</td>
<td>50</td>
<td>25</td>
<td>0</td>
<td>25</td>
<td>sweepx2_.LOOP.1.1i.29</td>
</tr>
<tr>
<td>4.420536</td>
<td>1250</td>
<td>25</td>
<td>0</td>
<td>25</td>
<td>sweepx2_.LOOP.2.1i.30</td>
</tr>
<tr>
<td>4.387534</td>
<td>50</td>
<td>25</td>
<td>0</td>
<td>25</td>
<td>sweepx1_.LOOP.1.1i.29</td>
</tr>
<tr>
<td>4.387457</td>
<td>1250</td>
<td>25</td>
<td>0</td>
<td>25</td>
<td>sweepx1_.LOOP.2.1i.30</td>
</tr>
<tr>
<td>2.523214</td>
<td>187500</td>
<td>107</td>
<td>0</td>
<td>107</td>
<td>riemann_.LOOP.2.1i.63</td>
</tr>
<tr>
<td>1.541299</td>
<td>20062500</td>
<td>12</td>
<td>0</td>
<td>12</td>
<td>riemann_.LOOP.3.1i.64</td>
</tr>
<tr>
<td>0.863656</td>
<td>1687500</td>
<td>104</td>
<td>0</td>
<td>108</td>
<td>parabola_.LOOP.6.1i.67</td>
</tr>
</tbody>
</table>
Cray Apprentice2 Overview

Profile

Function/Region Profile
- 63.9% = mpi_recv
- 29.2% = sweep_
- 3.2% = mpi_allreduce_(sync)

Load Imbalance
- 24.76s = mpi_recv
- 79.40s = sweep_
- 10.20s = mpi_allreduce_(sync)

CPU

Memory Utilization
- Process HiMem (MBytes) 658.835

Data Movement
- MPI Msg MBytes 2380.775
Call Tree View with Load Imbalance Information

- **Height**: exclusive time
- **Width**: inclusive time

**Hints for performance tuning**

**Load balance overview** (Yellow represents imbalance time)

**Width ⇔ inclusive time**

**Height ⇔ exclusive time**
CPU Program Timeline: 36GB CP2K Full Trace

- CPU call stack: Bar represents CPU function or region. Hover over bar to get function name, start and end time.
- Shows wait time.
- Program histogram showing wait time.
- Program wallclock time line.
- Hover to see what different filters do.
GPU Program Timeline

CPU call stack:
Bar represents CPU function or region: Hover over bar to get function name, start and end time

Bar represents GPU stream event: Hover over bar to get event info

Navigation assistance

Program histogram of wait, copy kernel time

Program wallclock time line
## Example Default Accelerator Statistics

### Table 1: Time and Bytes Transferred for Accelerator Regions

<table>
<thead>
<tr>
<th>Host</th>
<th>Host</th>
<th>Acc</th>
<th>Acc Copy</th>
<th>Calltree</th>
<th>Time%</th>
<th>Time</th>
<th>Time</th>
<th>In</th>
<th>Out</th>
<th>PE=HIDE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100.0%</td>
<td>2.750</td>
<td>2.015</td>
<td>2812.760</td>
<td>13.568</td>
<td>103</td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>100.0%</td>
<td>2.750</td>
<td>2.015</td>
<td>2812.760</td>
<td>13.568</td>
<td>103</td>
<td>lbm3d2p_d_</td>
<td>lbm3d2p_d_ ACC_DATA_REGION@li.104</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>63.5%</td>
<td>1.747</td>
<td>1.747</td>
<td>2799.192</td>
<td>--</td>
<td>1</td>
<td>lbm3d2p_d_ ACC_COPY@li.104</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22.1%</td>
<td>0.609</td>
<td>0.088</td>
<td>12.304</td>
<td>12.304</td>
<td>36</td>
<td>streaming_</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>20.6%</td>
<td>0.566</td>
<td>0.046</td>
<td>12.304</td>
<td>12.304</td>
<td>27</td>
<td>streaming_exchange_</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>18.8%</td>
<td>0.517</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1</td>
<td>streaming_exchange_ ACC_DATA_REGION@li.526(exclusive)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>1.6%</td>
<td>0.043</td>
<td>0.042</td>
<td>--</td>
<td>--</td>
<td>9</td>
<td>streaming_ ACC_DATA_REGION@li.907</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1.1%</td>
<td>0.031</td>
<td>0.031</td>
<td>--</td>
<td>--</td>
<td>4</td>
<td>streaming_ ACC_REGION@li.909</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1%</td>
<td>0.031</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1</td>
<td>streaming_ ACC_REGION@li.909(exclusive)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

...
Lab Time

- **bw.ncsa.illinois.edu:~heidi/scratch/lab/**
  - CrayPat-lite
    - pr01

- Loop statistics
  - pr05

- MPI rank reorder
  - pr03

- Apprentice2
  - pr04

- Reveal
  - pr05, pr01

- **CCDB**
Questions

?
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