Using Craypat & Reveal on Cori

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Outline

I. Profiling with Craypat
II. Using Reveal for OpenMP
I. PROFILING WITH CRAYPAT

Profile of Cochise in the Chiricahua Mountains by Ken Bosma, http://www.flickr.com/photos/kretyen/2879059366/
I. Profiling with Craypat

- Introduction
- Simple profiling
- Full-service profiling
• Craypat is Cray’s Performance Analysis Tool
• Evaluate program behavior on Cray supercomputer
  – Under any PrgEnv
• Find hotspots, load imbalance, inefficiencies
  – I/O, memory usage
  – MPI communications
  – Flops
  – Recommendation for rank reordering (sometimes)
• Profiler with limited tracing abilities
  – Tracing tools with better performance: MAP, VampirTrace
Simple Profiling with CrayPat

- `perftools-lite` module easier to use & does (almost) everything in `perftools`
- Compile code with `perftools-lite` module loaded
- Run code as normal
- Output:
  - Stdout & `*.rpt` file: report with execution time, memory high-water mark, aggregate FLOPS rate, top time-consuming user functions, MPI info, etc.
  - `*.ap2` file: can be viewed with Apprentice 2
  - (Possibly) `MPICH_RANK_REORDER` file
Example Output (Preamble)

CrayPat/X: Version 6.4.0 Revision bc8f5bd 05/24/16 17:52:13
Experiment: lite lite/sample_profile
Number of PEs (MPI ranks): 64
Numbers of PEs per Node: 64
Numbers of Threads per PE: 1
Number of Cores per Socket: 68
Execution start time: Thu Oct 13 09:30:31 2016
System name and speed: nid04403 1401 MHz (approx)
Intel knl CPU Family: 6 Model: 87 Stepping: 1
MCDRAM: 7.2 GHz, 16 GiB available as quad, flat (0% cache)

Avg Process Time: 558.16 secs
High Memory: 1,899.7 MBytes 29.7 MBytes per PE
I/O Read Rate: 4.032070 MBytes/sec
I/O Write Rate: 3.618872 MBytes/sec
Table 1: Profile by Function Group and Function (top 10 functions shown)

<table>
<thead>
<tr>
<th>Samp%</th>
<th>Samp</th>
<th>Imb.</th>
<th>Imb.</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>100.0%</td>
<td>55,700.3</td>
<td>--</td>
<td>--</td>
<td>Total</td>
</tr>
<tr>
<td>49.3%</td>
<td>27,466.0</td>
<td>--</td>
<td>--</td>
<td>ETC</td>
</tr>
<tr>
<td>15.6%</td>
<td>8,679.3</td>
<td>1,276.7</td>
<td>13.0%</td>
<td>_cray_HCQSS_01</td>
</tr>
<tr>
<td>12.2%</td>
<td>6,821.2</td>
<td>1,167.8</td>
<td>14.8%</td>
<td>_cray_COS_V_01</td>
</tr>
<tr>
<td>8.9%</td>
<td>4,948.8</td>
<td>581.2</td>
<td>10.7%</td>
<td>_COS_Z</td>
</tr>
<tr>
<td>2.3%</td>
<td>1,285.3</td>
<td>335.7</td>
<td>21.0%</td>
<td>gotoblas_daxpy_k_knl</td>
</tr>
<tr>
<td>1.9%</td>
<td>1,071.1</td>
<td>235.9</td>
<td>18.3%</td>
<td>gotoblas_blas_memory_alloc_knl</td>
</tr>
<tr>
<td>1.9%</td>
<td>1,039.9</td>
<td>185.1</td>
<td>15.3%</td>
<td>gotoblas_dger_k_knl</td>
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<tr>
<td>35.5%</td>
<td>19,747.6</td>
<td>--</td>
<td>--</td>
<td>USER</td>
</tr>
<tr>
<td>23.0%</td>
<td>12,803.4</td>
<td>1,592.6</td>
<td>11.2%</td>
<td>intgrd_</td>
</tr>
<tr>
<td>7.6%</td>
<td>4,229.4</td>
<td>1,033.6</td>
<td>20.0%</td>
<td>dfshre_</td>
</tr>
<tr>
<td>3.1%</td>
<td>1,707.7</td>
<td>501.3</td>
<td>23.1%</td>
<td>drlhrre_</td>
</tr>
<tr>
<td>14.7%</td>
<td>8,169.4</td>
<td>21,597.6</td>
<td>73.7%</td>
<td>MPI</td>
</tr>
<tr>
<td>14.7%</td>
<td>8,169.4</td>
<td>21,597.6</td>
<td>73.7%</td>
<td>MPI_Recv</td>
</tr>
</tbody>
</table>
Simple Profiling Recipe

• Load/unload modules:
  - module unload darshan
  - module load perftools-base perftools-lite

• Compile and run your code as usual
Full-Service Profiling

• Motivation:
  – Need more info than perftools-lite provides
  – Want to ignore certain subroutines
  – Focus on particular class of functions
  – Tracing rather than profiling

• Super-deluxe profiling recipe
• pat_build options
Super-Deluxe Profiling Recipe (1)

• **Load/unload modules:**
  - `module unload darshan`
  - `module load perftools-base perftools`

• **Compile code as usual, making sure to preserve object files**

• **`pat_build -O apa myapp`**
  - Generates executable called `myapp+pat`

• **Run `myapp+pat`**
  - Results in output file with name like `myapp+pat+######.xf` or directory called `myapp+pat+######`
Super-Deluxe Profiling Recipe (2)

• `pat_report myapp+pat+*.xf`
  – Generates `myapp+pat+*.apa`

• `pat_build -O myapp+pat+*.apa`
  – Generates executable called `myapp+apa`

• Run `myapp+apa`

• `pat_report myapp+apa+*.xf`
pat_build Options

• **pat_build -O apa myapp**
  - Craypat output for `myapp+pat` will be sampling to determine which subroutines can be ignored in full run. Additional file, 
    `*.apa`, produced from `pat_report`
  - After this run, execute `pat_build -O *.apa file` to re-instrument `myapp+pat` into `myapp+apa` and run `myapp+apa` to get performance info

• **pat_build -g tracegroup myapp**
  - `tracegroup` is group of functions that can be automatically traced by CrayPat. Options include: `blas, fftw, mpi, netcdf, petsc`

• **pat_build -w myapp**
  - Do tracing experiment instead of profiling
II. PARALLELIZATION WITH CRAY REVEAL

“Happiness Revealed,” by Leonard Farshore, https://flic.kr/p/9z7isd
Cray Reveal

• Tool for porting to shared-memory or offload programming models
• Combine profiling info from Craypat and Cray compiler annotation to determine where to place OpenMP directives (generated automatically)
• Works ONLY with Cray programming environment
Using Cray Reveal

1. Compile code with Craypat instrumentation and create program library
2. Run representative job
3. Run Reveal
4. Insert directives, consider loop reordering, and analyze performance from optimizations
Cray Reveal Recipe (1)

• Load/unload modules:
  – module unload darshan
  – module swap PrgEnv-intel PrgEnv-cray
  – module load perftools-base perftools

• Compile & link with
  – -h profile_generate (to instrument), and
  – -h pl=/directory/path/myapp.pl (for compiler feedback)

• Instrument binary for tracing:
  – pat_build -w ./myapp
  – Creates instrumented application: myapp+pat
Run instrumented application (myapp+pat) as normal

- Ideally this is job requiring 5-15 mins runtime, performing important subroutines in similar proportions to typical run

This creates file called myapp+pat+#####-####t.xf (or directory myapp+pat+#####-####t/ for large runs)

Create report with loop statistics

- pat_report myapp+pat+* > loops_report.txt

- Generates .ap2 file & generates text report in output file
Cray Reveal Recipe (3)

• Run Reveal
  - `reveal /directory/path/myapp.pl` (compiler info only)
  - `reveal /directory/path/myapp.pl myapp +#####+++t.ap2` (compiler + profiler info)
Opening Screen

New to Reveal?
Try "Getting Started" in the "Help" Menu
### Scoping Window

#### List of Loops to be Scoped

<table>
<thead>
<tr>
<th>Scope?</th>
<th>Line #</th>
<th>File or Source Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>✔️</td>
<td>0</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/charconv.c</td>
</tr>
<tr>
<td>✔️</td>
<td>1</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/convert.c</td>
</tr>
<tr>
<td>✔️</td>
<td>2</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/d07hw.f</td>
</tr>
<tr>
<td>✔️</td>
<td>3</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/d09hw.f</td>
</tr>
<tr>
<td>✔️</td>
<td>4</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/d13hw.f</td>
</tr>
<tr>
<td>✔️</td>
<td>5</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/d132hw.f</td>
</tr>
<tr>
<td>✔️</td>
<td>6</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/dahhw.f</td>
</tr>
<tr>
<td>✔️</td>
<td>7</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/dchhw.f</td>
</tr>
<tr>
<td>✔️</td>
<td>8</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/dshhw.f</td>
</tr>
<tr>
<td>✔️</td>
<td>9</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/dihhw.f</td>
</tr>
<tr>
<td>✔️</td>
<td>10</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/doincall.c</td>
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<tr>
<td>✔️</td>
<td>11</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/drifhw.f</td>
</tr>
<tr>
<td>✔️</td>
<td>12</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/dthhw.f</td>
</tr>
<tr>
<td>✔️</td>
<td>13</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/fdriver.c</td>
</tr>
<tr>
<td>✔️</td>
<td>14</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/funmaster.c</td>
</tr>
<tr>
<td>✔️</td>
<td>15</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/fuslave.c</td>
</tr>
<tr>
<td>✔️</td>
<td>16</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/gaussian.c</td>
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<tr>
<td>✔️</td>
<td>17</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/integ.T</td>
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<tr>
<td>✔️</td>
<td>18</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/intgrd.f</td>
</tr>
<tr>
<td>✔️</td>
<td>19</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/mypnorms.c</td>
</tr>
<tr>
<td>✔️</td>
<td>20</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/mstrmaster.c</td>
</tr>
<tr>
<td>✔️</td>
<td>21</td>
<td>/global/a2/r/rjhb/cur12/mycode/perf/fam/main.c</td>
</tr>
</tbody>
</table>

**Apply Filter** | **Time:** 0.000s | **Tps:** 2 | **Threads:** 4 | **Speedup:** 0.010 | **20 Loops selected**
Compiler Annotations & Explanations

- A loop starting at line 133 was not vectorized because it contains a call to function "funsph" on line 135.
- A loop starting at line 144 was not vectorized because it contains a call to a subroutine or function on line 152.
- A loop starting at line 152 was partially vectorized with a single vector iteration.
Partial Success in Subroutine

**Source:**
```
SUBROUTINE DFSPHERE(NDIM, CENTER, INGRID, X, W, FNVAL)
  +
  C++BEGIN PROLOGUE DFSPHERE
  C++KEYWORDS fully symmetric sun
  C++PURPOSE To compute fully symmetric basic rule sums
  C++AUTHOR Alan Genz, Computer Science Department, Washington State University, Pullman, WA 99163-1220 USA
  C++LAST MODIFICATION 08-04-90
  C++DESCRIPTION DFSPHERE computes a fully symmetric sum for a vector of integrand values over a hyper-rectangular region.
  C
  The sum is fully symmetric with respect to the center of the region and is taken over all sign changes and permutations of the generators for the sum.
  C
  ON ENTRY
  C
  NDIM Integer.
  19 C Number of variables.
  CENTER Real array of dimension NDIM.
  20 C The coordinates for the center of the region.
  INGRID Real array of dimension NDIM.
  21 C The length of the region.
  X Real array of dimension NDIM.
  A work array.
  G Real array of dimension NDIM.
  25 C The generators for the fully symmetric sum. These MUST BE non-negative and non-increasing.
  NGRID Integer.
  26 C Number of components for the vector integrand.
  FVALFN externally declared subroutine.
  27 C Computes the components of the integrand at a point X.
  It must have parameters (NDIM, X, NGRID, FVALFN).
  Input Parameters:
  X Real array of dimension NDIM.
  Defines the evaluation point.
  NDIM Integer.
```

Successful Scoping
Directives Generated by Reveal

! Directive inserted by Cray Reveal. May be incomplete.
!$OMP parallel do default(none)
!$OMP& private (i)
!$OMP& shared (ndim, center, hwidth, x, g)
### Unsuccessful Scoping

#### Scope Loops

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Scope</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>centr</td>
<td>Array</td>
<td>Unresolved</td>
<td>Possible recurrence involving this object.</td>
</tr>
<tr>
<td>dir</td>
<td>Array</td>
<td>Unresolved</td>
<td>Possible recurrence involving this object.</td>
</tr>
<tr>
<td>error</td>
<td>Scalar</td>
<td>Unresolved</td>
<td>Possible recurrence involving this object.</td>
</tr>
<tr>
<td>errors</td>
<td>Array</td>
<td>Unresolved</td>
<td>Possible recurrence involving this object.</td>
</tr>
<tr>
<td>greate</td>
<td>Array</td>
<td>Unresolved</td>
<td>Possible recurrence involving this object.</td>
</tr>
<tr>
<td>hwidths</td>
<td>Array</td>
<td>Unresolved</td>
<td>Possible recurrence involving this object.</td>
</tr>
<tr>
<td>ndim</td>
<td>Scalar</td>
<td>Unresolved</td>
<td>Possible recurrence involving this object.</td>
</tr>
<tr>
<td>numfun</td>
<td>Scalar</td>
<td>Unresolved</td>
<td>Possible recurrence involving this object.</td>
</tr>
<tr>
<td>subgn@dirre_</td>
<td>Scalar</td>
<td>Unresolved</td>
<td>Possible recurrence involving this object.</td>
</tr>
<tr>
<td>value</td>
<td>Scalar</td>
<td>Unresolved</td>
<td>Possible recurrence involving this object.</td>
</tr>
<tr>
<td>values</td>
<td>Array</td>
<td>Unresolved</td>
<td>Possible recurrence involving this object.</td>
</tr>
<tr>
<td>work</td>
<td>Array</td>
<td>Unresolved</td>
<td>Possible recurrence involving this object.</td>
</tr>
<tr>
<td>center</td>
<td>Array</td>
<td>Private</td>
<td>WARN LastPrivate of array may be very expensive.</td>
</tr>
<tr>
<td>hwidth</td>
<td>Array</td>
<td>Private</td>
<td>WARN LastPrivate of array may be very expensive.</td>
</tr>
<tr>
<td>i</td>
<td>Scalar</td>
<td>Private</td>
<td></td>
</tr>
<tr>
<td>index</td>
<td>Scalar</td>
<td>Private</td>
<td></td>
</tr>
<tr>
<td>ndiv</td>
<td>Scalar</td>
<td>Private</td>
<td></td>
</tr>
<tr>
<td>sbrgns</td>
<td>Scalar</td>
<td>Shared</td>
<td></td>
</tr>
</tbody>
</table>

#### Scoping Results

- **FAIL**: Possible recurrence involving this object.
- **WARN**: Assuming no conflict in scatter.
- **RPC**: Possible recurrence involving this object.
- **ERR**: Possible conflict requirements, unable to scope.
- **FAIL**: Possible conflict requirements, unable to scope.
- **WARN**: Assuming no conflict in scatter.
Unsuccessful Scoping Directive

! Directive inserted by Cray Reveal. May be incomplete.
!$OMP parallel do default(none)
!$OMP& unresolved (ndim, numfun, values, errors, centrs, hwidts, greate, dir,
!$OMP& work, center, hwidth, subrgn@dtrhre_, value, error)
!$OMP& private (i, index)
!$OMP& shared (ndiv, sbrgns)
Cray Reveal Recipe (4)

• Insert directives

• Examine compiler feedback to determine potential loop reordering
  – E.g., row- vs. column-ordered memory access patterns
  – Moving conditionals outside of loops
  – Cray compiler good at loop optimizations but requires some human help at times

• Analyze performance after optimizations
  – (Lather, rinse, repeat)
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