

BSC Tools Hands-On

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Getting a trace with Extrae



Extrae features

Platforms

- Intel, Cray, BlueGene, MIC, ARM, Android, Fujitsu Sparc ...
- Parallel programming models
 - MPI, OpenMP, pthreads, OmpSs, CUDA, OpenCL, Java, Python ...
- Performance Counters
 - Using PAPI interface
- Link to source code
 - Callstack at MPI routines
 - OpenMP outlined routines
 - Selected user functions (Dyninst)
- Periodic sampling
- User events (Extrae API)



How does Extrae work?

- Symbol substitution through LD_PRELOAD
 - Specific libraries for each combination of runtimes
 - MPI
 - OpenMP
 - OpenMP+MPI
 - ...

Dynamic instrumentation

- Based on Dyninst (developed by U.Wisconsin / U.Maryland)
 - Instrumentation in memory
 - Binary rewriting
- Alternatives
 - Static link (i.e., PMPI, Extrae API)



Getting your first trace

Provided folder tools-material in /work/ta002/shared/bsctools contains:

- Application compiled for the GNU PrgEnv (lulesh2.0-gnu)
- Jobscripts to execute and trace (job.pbs, trace.sh)
- Configuration of the tracing tool (extrae.xml)
- Already generated tracefiles (traces/*.{pcf,prv,row})
- Clustering analysis configuration file (cluster.xml)
- Copy this folder to your \$HOME and you are ready to follow this hands-on tutorial

Using Extrae in 3 steps

1. Adapt your job submission scripts

2. Configure what to trace

- XML configuration file
- **Example configurations at** \$EXTRAE_HOME/share/example

3. Run it!

• For further reference check the **Extrae User Guide**:

- <u>https://tools.bsc.es/doc/html/extrae</u>
- Also distributed with Extrae at SEXTRAE_HOME/share/doc

Step 1: Adapt the job script to load Extrae

Example of a standard jobscript (without tracing)



Step 1: Adapt the job script to load Extrae

Jobscript modified to load Extrae (extrae/job.pbs)



Step 1: Adapt the job script to load Extrae

Tracing launcher helper script (extrae/trace.sh)



Step 1: Which tracing library?

Choose depending on the application type

Library	Serial	MPI	OpenMP	pthread	CUDA
libseqtrace	\checkmark				
libmpitrace[f] ¹		\checkmark			
libomptrace			\checkmark		
libpttrace				\checkmark	
libcudatrace					\checkmark
libompitrace[f] ¹		\checkmark	\checkmark		
libptmpitrace[f] ¹		\checkmark		\checkmark	
libcudampitrace[f] 1		\checkmark			\checkmark

¹ add suffix "f" in Fortran codes

Step 2: Extrae XML configuration



Step 2: Extrae XML configuration (II)



Step 3: Run it!

Submit your job as usual

archer\$ qsub -q R7133965 job.pbs

• **REMEMBER!** Run job from your /work folder (NOT IN HOME!)

All done! Check your resulting trace

• Once finished (check with "qstat -u \$USER") you will have the trace (3 files):

```
archer$ ls -1
...
lulesh2.0-gnu-27p.pcf
lulesh2.0-gnu-27p.prv
lulesh2.0-gnu-27p.row
```

- Any trouble? There's a trace already generated under the "traces" folder
- Now let's look into it!



Analysing a trace with Extrae



First steps of analysis

- Copy the trace to your computer
- Load the trace with Paraver



First steps of analysis

- Follow Tutorial #3
 - Introduction to Paraver and Dimemas methodology



Measure the parallel efficiency

Click on "mpi_stats.cfg"

Check the Average for the column labelled "Outside MPI"

Tutoriais									
The first question to answer when analyzing a parallel code is "how efficient does it				MPI call	profile @ l	ulesh2.0-gr	u-27p.prv		
run?". The efficiency of a parallel program can be defined based on two aspects: the parallelization efficiency and the efficiency obtained in the execution of the serial regions. These two metrics would be the first checks on the proposed methodology.			🔍 🔳 н)	• • *	Σ %				
		THREAD 1.18.1	88.07 %	0.26 %	0.12 %	0.13 %	1.70 %	0.01 %	0.00 %
<u>cfgs/mpi/mpi_stats.cfg</u> Th s configuration pops up a table with %time that		THREAD 1.19.1	89.85 %	0.24 %	0.08 %	0.13 %	1.89 %	0.01 %	0.00 %
eveny thread spends in every MI I call. Look at the global statistics at the bottom of		THREAD 1.20.1	86.80 %	0.24 %	0.12 %	0.29 %	1.25 %	0.01 %	0.00 %
efficiency, entry Avg/Max represents the global load balance and entry Maximum		THREAD 1.21.1	86.19 %	0.25 %	0.08 %	0.06 %	1.71 %	0.01 %	0.00 %
represents the communication efficiency. If any of those values are lower than		THREAD 1.22.1	86.40 %	0.27 %	0.11 %	0.12 %	1.15 %	0.01 %	0.00 %
control window to identify the phases and iterations of the code.		THREAD 1.23.1	93.71 %	0.34 %	0.16 %	0.27 %	1.09 %	0.01 %	0.00 %
To many the computation time distribution land the configuration file		THREAD 1.24.1	91.36 %	0.13 %	0.12 %	0.37 %	1.22 %	0.01 %	0.00 %
• To measure the computation time distribution load the conliguration life <u>ofgs/general/2dh_usefulduration.ofg</u> This configuration pops up a		THREAD 1.25.1	92.49 %	0.11 %	0.08 %	0.22 %	0.95 %	0.01 %	0.00 %
histogram of the duration for the computation regions. The computation regions		THREAD 1.26.1	90.97 %	0.13 %	0.11 %	0.25 %	1.10 %	0.01 %	0.00 %
histogram does not show vertical lines, it indicates the computation time may be		THREAD 1.27.1	90.26 %	0.12 %	0.08 %	0.16 %	1.48 %	0.01 %	0.00 %
not balanced. Open the control window to look at the time distribution and visually									H
	Parallel efficiency (Avg)	Total	2,447.87 %	5.87 %	3.16 %	4.91 %	26.98 %	0.58 %	1.77 %
 To measure the computational load (instructions) distribution load the configuration file of an (non-instruction) is not must imperformed in the second secon		Average	90.66 %	0.22 %	0.12 %	0.18 %	1.00 %	0.02 %	0.07 %
configuration pops up a histogram of the instructions for the computation regions.		Maximu	97.93 %	0.36 %	0.20 %	0.37 %	1.89 %	0.05 %	0.70 %
The computation regions are delimited by the exit from an MPI call and the entry	Comm efficiency (Max)	minimum	86.19 %	0.07 %	0.06 %	0.06 %	0.26 %	0.01 %	0.00 %
distribution of the instructions may be not balanced. Open the control window to		StDev	2.79 %	0.09 %	0.03 %	0.08 %	0.46 %	0.01 %	0.17 %
look at the time distribution and correlate both views.		Avg/Ma	0.93	0.60	0.59	0.49	0.53	0.45	0.0
• To measure the serial regions performance look at the IPC timeline loaded	Load balance (Avg/Ivlax)								

Focus on the iterative part



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	THREAD 1.18.1	88.07 %	0.26 %	0.12 %	0.13 %	1.70 %	0.01 %	0.00
	THREAD 1.19.1	89.85 %	0.24 %	0.08 %	0.13 %	1.89 %	0.01 %	0.00
	THREAD 1.20.1	86.80 %	0.24 %	0.12 %	0.29 %	1.25 %	0.01 %	0.00
	THREAD 1.21.1	86.19 %	0.25 %	0.08 %	0.06 %	1.71 %	0.01 %	0.00
	THREAD 1.22.1	86.40 %	0.27 %	0.11 %	0.12 %	1.15 %	0.01 %	0.00
	THREAD 1.23.1	93.71 %	0.34 %	0.16 %	0.27 %	1.09 %	0.01 %	0.00
	THREAD 1.24.1	91.36 %	0.13 %	0.12 %	0.37 %	1.22 %	0.01 %	0.00
	THREAD 1.25.1	92.49 %	0.11 %	0.08 %	0.22 %	0.95 %	0.01 %	0.00
	THREAD 1.26.1	90.97 %	0.13 %	0.11 %	0.25 %	1.10 %	0.01 %	0.00
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	Total	2,447.87 %	5.87 %	3.16 %	4.91 %	26.98 %	0.58 %	1.77
	Average	90.66 %	0.22 %	0.12 %	0.18 %	1.00 %	0.02 %	0.07
	Maximum	97.93 %	0.36 %	0.20 %	0.37 %	1.89 %	0.05 %	0.70
	Minimum	86.19 %	0.07 %	0.06 %	0.06 %	0.26 %	0.01 %	0.00
	StDev	2.79 %	0.09 %	0.03 %	0.08 %	0.46 %	0.01 %	0.17
	Avg/Max	0.93	0.60	0.59	0.49	0.53	0.45	0.

MPI call profile @ lulesh2.0-gnu-27p.prv

Click on Open Control Window

Focus on the iterative part



Image: Point Poi			MPI cal	profile @	lulesh2.0-	gnu-27p.prv		
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StDev 2.79 % 0.09 % 0.03 % 0.08 % 0.46 % 0.01 %	Minimum	86.19 %	0.07 %	0.06 %	0.06 %	0.26 %	0.01 %	0.00
	StDev	2.79 %	0.09 %	0.03 %	0.08 %	0.46 %	0.01 %	0.17
Avg/Max 0.93 0.60 0.59 0.49 0.53 0.45	Avg/Max	0.93	0.60	0.59	0.49	0.53	0.45	0.0
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Recalculate efficiency of iterative region



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HREAD 1.18.1	88.07 %	0.26 %	0.12 %	0.13 %	1.70 %	0.01 %	0.00 9
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HREAD 1.20.1	86.80 %	0.24 %	0.12 %	0.29 %	1.25 %	0.01 %	0.00 9
HREAD 1.21.1	86.19 %	0.25 %	0.08 %	0.06 %	1.71 %	0.01 %	0.00 9
HREAD 1.22.1	86.40 %	0.27 %	0.11 %	0.12 %	1.15 %	0.01 %	0.00 9
HREAD 1.23.1	93.71 %	0.34 %	0.16 %	0.27 %	1.09 %	0.01 %	0.00 9
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HREAD 1.25.1	92.49 %	0.11 %	0.08 %	0.22 %	0.95 %	0.01 %	0.00 9
HREAD 1.26.1	90.97 %	0.13 %	0.11 %	0.25 %	1.10 %	0.01 %	0.00 9
HREAD 1.27.1	90.26 %	0.12 %	0.08 %	0.16 %	1.48 %	0.01 %	0.00 9
Total	2,447.87 %	5.87 %	3.16 %	4.91 %	26.98 %	0.58 %	1.77 9
Average	90.66 %	0.22 %	0.12 %	0.18 %	1.00 %	0.02 %	0.07 9
Maximum	97.93 %	0.36 %	0.20 %	0.37 %	1.89 %	0.05 %	0.70 9
Minimum	86.19 %	0.07 %	0.06 %	0.06 %	0.26 %	0.01 %	0.00 9
StDev	2.79 %	0.09 %	0.03 %	0.08 %	0.46 %	0.01 %	0.17 9
Avg/Max	0.93	0.60	0.59	0.49	0.53	0.45	0.0

Recalculate efficiency of iterative region



Right click \rightarrow Paste \rightarrow Time

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THREAD 1.18.1	86.41 %	0.13 %	0.09 %	0.13 %	2.04 %	11.12 %
THREAD 1.19.1	88.89 %	0.09 %	0.07 %	0.14 %	2.16 %	8.58 %
THREAD 1.20.1	84.75 %	0.13 %	0.09 %	0.33 %	1.41 %	13.22 %
THREAD 1.21.1	83.99 %	0.10 %	0.06 %	0.06 %	1.96 %	13.77 %
THREAD 1.22.1	84.20 %	0.13 %	0.09 %	0.13 %	1.33 %	14.05 %
THREAD 1.23.1	93.98 %	0.21 %	0.14 %	0.30 %	1.18 %	4.13 %
THREAD 1.24.1	90.87 %	0.15 %	0.09 %	0.35 %	1.22 %	7.24 %
THREAD 1.25.1	92.20 %	0.10 %	0.06 %	0.22 %	0.98 %	6.37 %
THREAD 1.26.1	90.32 %	0.15 %	0.09 %	0.24 %	1.06 %	8.08 %
THREAD 1.27.1	89.41 %	0.11 %	0.05 %	0.13 %	1.53 %	8.66 %
Total	2,424.98 %	3.51 %	3.07 %	5.25 %	29.42 %	231.93 %
Average	89.81 %	0.13 %	0.11 %	0.19 %	1.09 %	8.59 %
Maximum	98.88 %	0.25 %	0.22 %	0.45 %	2.16 %	14.12 %
Minimum	83.99 %	0.06 %	0.05 %	0.06 %	0.30 %	0.03 %
StDev	3.62 %	0.04 %	0.04 %	0.09 %	0.56 %	3.49 %
Avg/Max	0.91	0.52	0.51	0.43	0.50	0.61

Efficiency of iterative region

3 numbers to quickly describe the efficiency

of your code

- Parallel efficiency → % of time my program is computing (100% is perfect)
- Comm efficiency → At least 1 process can finish all communications in 100 - Maximum % of the program's time (100% is perfect)
- Load balance → Ratio of slow/fast processes (1 is perfectly balanced)

Parall

Comm

Load b

- Any value below 85% (0.85)?
 - Pay attention there

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ses (1	THREAD 1.21.1	83.99 %	0.10 %	0.06 %	0.06 %	1.96 %	13.77 %			
(-	THREAD 1.22.1	84.20 %	0.13 %	0.09 %	0.13 %	1.33 %	14.05 %			
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	THREAD 1.24.1	90.87 %	0.15 %	0.09 %	0.35 %	1.22 %	7.24 %			
	THREAD 1.25.1	92.20 %	0.10 %	0.06 %	0.22 %	0.98 %	6.37 %			
	THREAD 1.26.1	90.32 %	0.15 %	0.09 %	0.24 %	1.06 %	8.08 %			
	THREAD 1.27.1	89.41 %	0.11 %	0.05 %	0.13 %	1.53 %	8.66 %			
	Total	2.424.98 %	3.51 %	3.07 %	5.25 %	29.42 %	231.93 %			
el efficiency (Avg)	Averagy	89.81 %	0.13 %	0.11 %	0.19 %	1.09 %	8.59 %			
	Maximu	98.88 %	0.25 %	0.22 %	0.45 %	2.16 %	14.12 %			
efficiency (Max)	minimum	83.99 %	0.06 %	0.05 %	0.06 %	0.30 %	0.03 %			
	StDev	3.62 %	0.04 %	0.04 %	0.09 %	0.56 %	3.49 %			
		0.01	0.52	0.51	0.42	0.50	0.61			

Computation time distribution

Click on "2dh_usefulduration.cfg" (2nd link) → Shows time computing





Focus on the iterative part

■ Click on "2dh_usefulduration.cfg" (2nd link) → Shows time computing



Computation time distribution

Click on "2dh_usefulduration.cfg" (2nd link) → Shows time computing



Computation load distribution

■ Click on "2dh_useful_instructions.cfg" (3rd link) → Shows amount of work





Computation load distribution

• Comparing the two histograms \rightarrow Similar shapes \rightarrow Work distribution determines time computing



Where does this happen?

• Go from the table to the timeline



Where does this happen?

Go from the table to the timeline



Where does this happen?



Where does this happen?



Hints → Call stack references → Caller function



Where does this happen?



Hints → Call stack references → Caller function



Save CFG's (method 1)



Save CFG's (method 2)





CFG's distribution

■ Paraver comes with many included CFG's → Apply any CFG to any trace!

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CFG's distribution

■ Paraver comes with many included CFG's → Apply any CFG to any trace!

😣 🖻 🗊 Paraver		
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Load Session	Ctrl+L	/home/gllort/Apps/wxparaver/4.6.2/cfgs/mpi/analysis/mpi_stats.cfg
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		/home/gllort/Apps/wxparaver/4.6.2/cfgs/General/sanity_checks/flushing.cfg
		/home/gllort/Apps/wxparaver/4.6.2/cfgs/counters_PAPI/performance/IPC.cfg
		/home/gllort/Apps/wxparaver/latest/cfgs/General/views/executing_cpu.cfg
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Hints: a good place to start!

Paraver suggests CFG's based on the contents of the trace



Do it on your code!

Follow guidelines from slides 7-16 to your own code to get a trace

• There are more examples of tracing scripts for different programming models under \$EXTRAE_HOME/share/examples

Follow guidelines from slides 17-34 to conduct an initial analysis

- The usual suspects:
 - Parallel Efficiency is low? Load balance issues?
 - Imbalances in the durations of computations?
 - Are these caused by work imbalance?



Cluster-based analysis



Use clustering analysis

Run clustering

archer> cd \$HOME/tools-material/clustering

archer> \$HOME/clustering/bin/BurstClustering \

- -d cluster.xml \
- -i ../extrae/lulesh2.0-gnu-27p.prv \
- -o lulesh2.0-gnu-27p_clustered.prv

If you didn't get your own trace, use a prepared one from:

archer> ls \$HOME/tools-material/traces/lulesh2.0-gnu-27p.prv

Cluster-based analysis

Check the resulting scatter plot

laptop> gnuplot lulesh2.0_27p_clustered.IPC.PAPI_TOT_INS.gnuplot

- Identify main computing trends
- Work (Y) vs. Speed (X)
- Look at the clusters shape
 - Variability in both axes indicate potential imbalances



Correlating scatter plot and time distribution

Open the clustered trace with Paraver and look at it

laptop> \$HOME/paraver/bin/wxparaver clustered.prv

- Display the distribution of clusters over time
 - File → Load configuration → \$HOME/paraver/cfgs/clustering/clusterID_window.cfg





BSC Tools Hands-On

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