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PATC training, Barcelona, May 2012 ‹#›

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Performance analysis with BSC-Tools

Judit Gimenez (judit@bsc.es)
BSC

Outline

Advanced Analysis
- Scaling model
- Structure detection: Clustering
- Folding: Instrumentation + sampling

Scaling model

Presenting application performance

Factors modeling parallel efficiency

- **Load balance** (LB)
- **Micro load balance** (μLB) or **serialization**
- **Transfer**

$$\eta = LB * \mu LB * Transfer$$

Factors describing serial behavior

- Performance: **IPC**

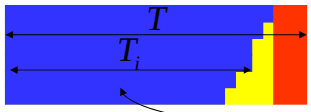
Scaling model

$$Sup = \frac{P}{P_0} * \frac{\eta}{\eta_0} * \frac{IPC}{IPC_0} * \frac{\#instr_0}{\#instr}$$

Scaling model

$$Sup = \frac{P}{P_0} * \frac{LB}{LB_0} * \frac{CommEff}{CommEff_0} * \frac{IPC}{IPC_0} * \frac{\#instr_0}{\#instr}$$

Directly from real execution metrics



$$eff_i = \frac{T_i}{T}$$

$$CommEff = \max(eff_i)$$

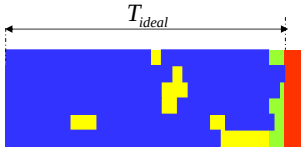
$$LB = \frac{\sum_{i=1}^{P} eff_i}{P * \max(eff_i)}$$

$$\frac{IPC}{\#instr}$$

$$microLB = \frac{\max(T_i)}{T_{ideal}} \qquad Transfer = \frac{T_{ideal}}{T}$$

$$Sup = \frac{P}{P_0} * \frac{macroLB}{macroLB_0} * \frac{microLB}{microLB_0} * \frac{Transfer}{Transfer_0} * \frac{IPC}{IPC_0} * \frac{\#instr_0}{\#instr}$$

Requires Dimemas simulation



Migrating/local load imbalance
Serialization

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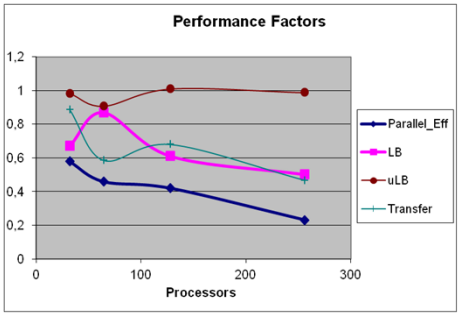
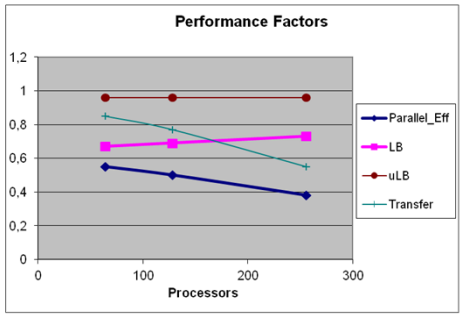
Parallel Performance Models

GROMACS

Original Version



v4.5



Old → new version: -43% instr, -52% time

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Structure detection: Clustering

Performance @ serial computation bursts

Burst = continuous computation region

between exit of an MPI call and entry to the next

Scatter plot representation of bursts

Collapse time dimension

N dimensional space of HWC derived relevant metrics

- Instructions: idea of computational complexity, computational load imbalance,…
- IPC: Idea of absolute performance and performance imbalance

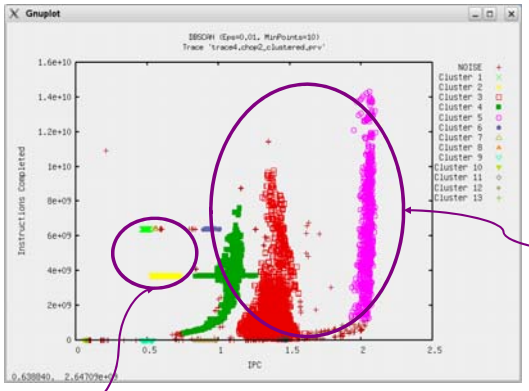
Structure

Clouds, clusters: Burst of “similar” characteristics

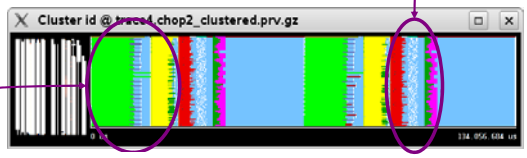
How those similarities spread in the timeline?

How does it relate to source code?

Clustering module – detecting structure



Huge variability on instructions



Most relevant computing regions obtain poor IPC

Unbalance due to different number of chunks

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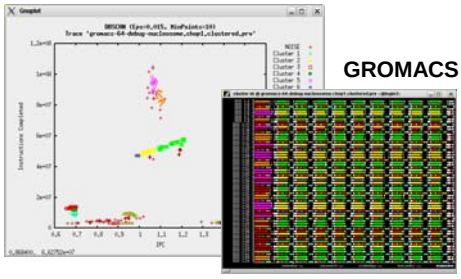
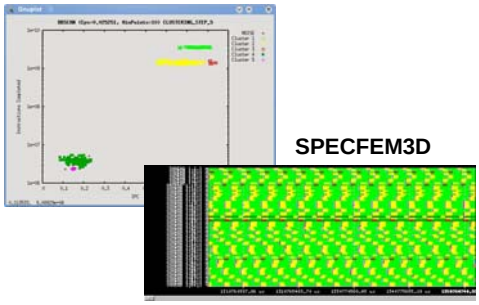
Clustering module – detecting structure

Highlight structure

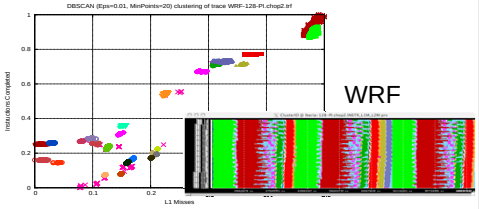
- Clusters injected in trace
- Phases vs. routines



GROMACS



SPECFEM3D



WRF

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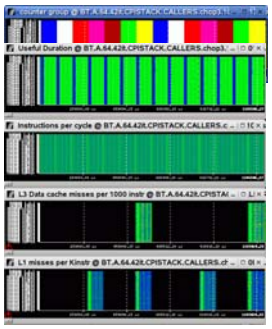
HWC projection

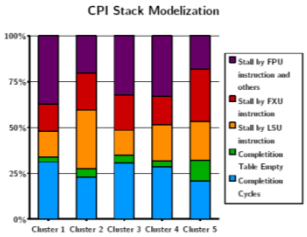
Full characterization

All HWCs and ratios between them
CPI stack model

From a single run



Cluster	1	2	3	4	5
%Time	54.88	17.96	16.90	6.44	1.42
Avg. Burst Dur. (ms)	1.02	0.78	13.14	2.50	1.11
IPC	1.02	0.65	0.89	0.91	0.53
MIPS	2231.8	1423.3	1966.5	2001.8	1163.0
MFLOPS	339.2	46.3	191.6	269.2	23.6
L1M/KInstr	0.92	1.53	1.19	1.17	2.88
L2M/KInstr	0.06	1.26	0.06	0.35	0.21
Mem.BW (MB/s)	16.79	218.47	13.87	85.77	29.76



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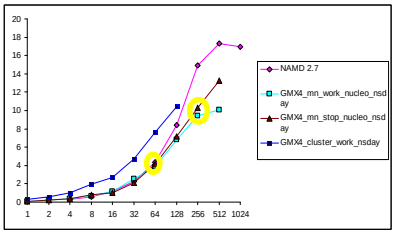
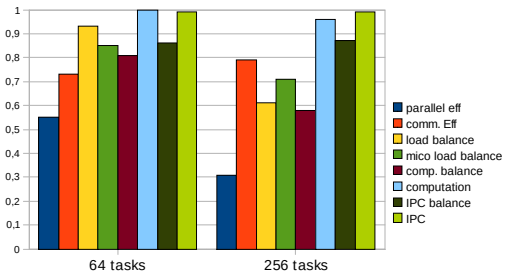
Example: From quick analysis...

GROMACS analysis





Main scalability problems:
. Load balance
. Computation balance

4% of code replication

64 tasks already poor efficiency!
. Communication problem

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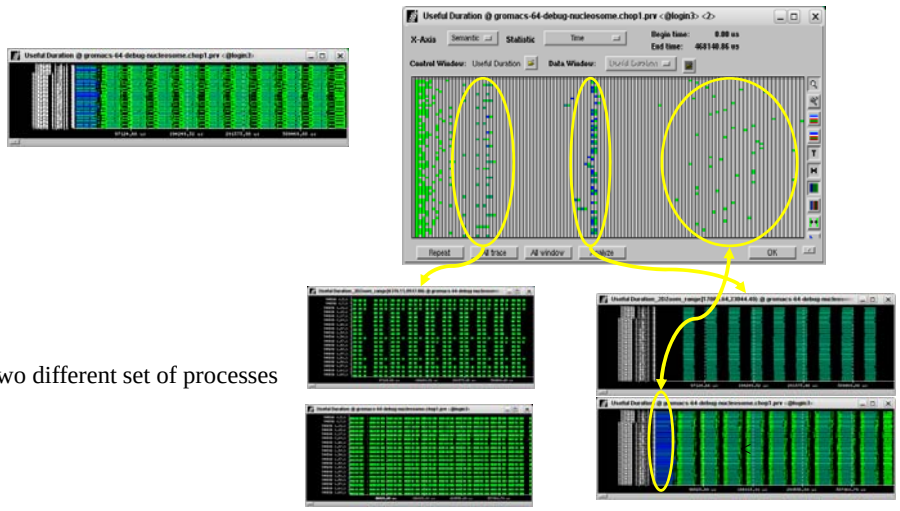
Example: ... to details

64 tasks computation duration analysis



Two different set of processes

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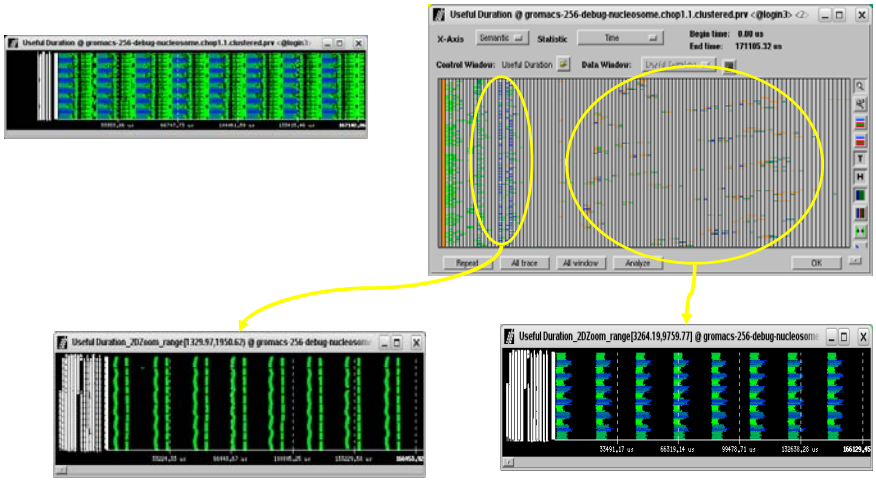
Example: ... to details

256 tasks computation duration analysis



Two different set of processes unbalance increases

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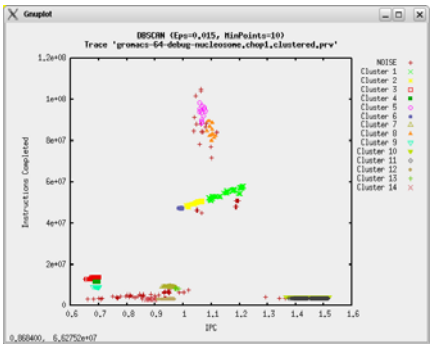
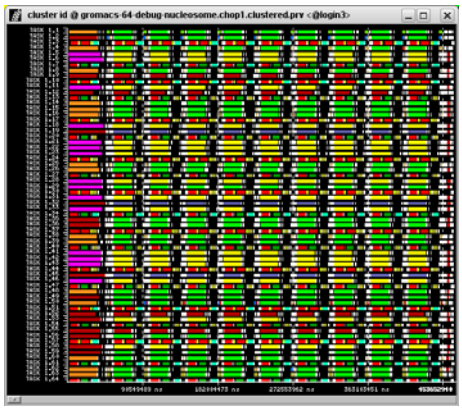
Example: ... to details

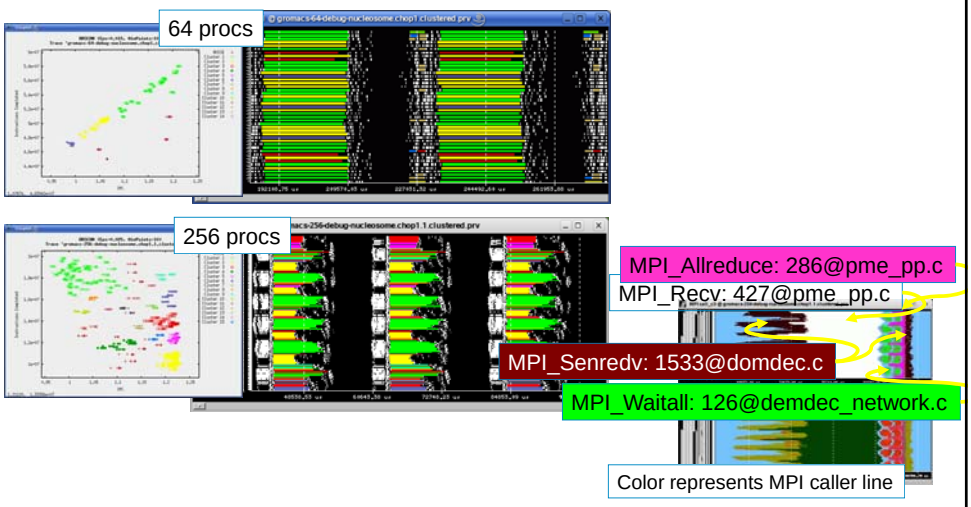
GROMACS structure, 64 tasks





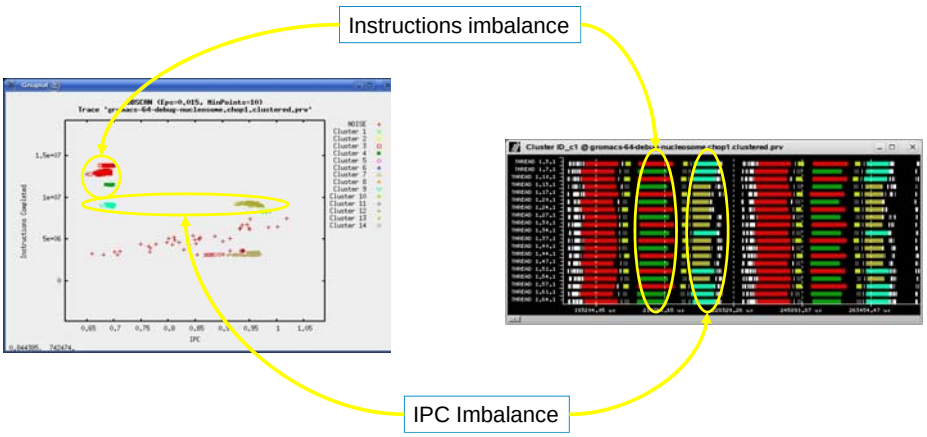
Example: ... to details

GROMACS PMEs balance / scalability



Example: ... to details

GROMACS FFTs balance

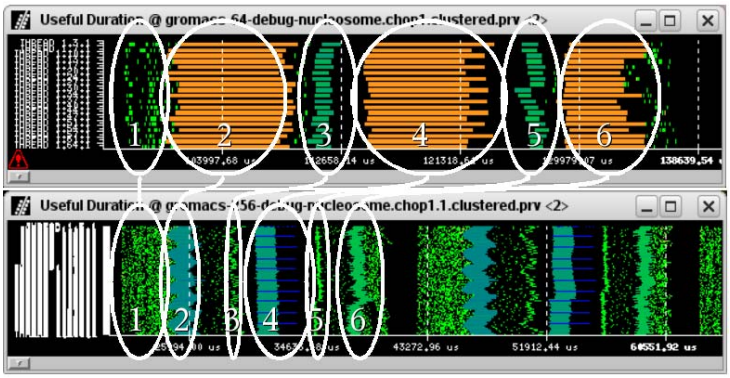


Example: ... to details

GROMACS: Comparing computation time for FFTs

64 tasks
(one iteration)

256 tasks
(2,2 iterations in the same time interval, 4 times more resources)



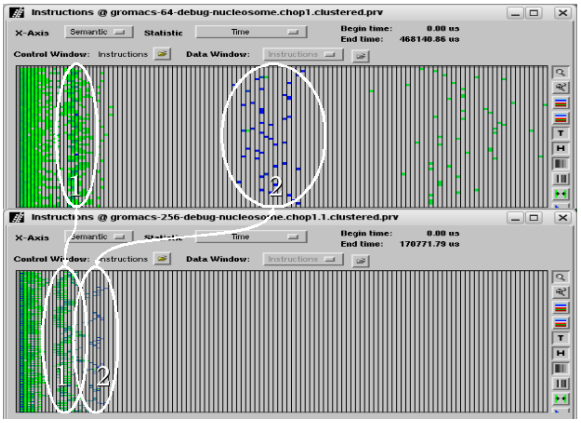
Zone 4 has a potentially structured imbalance with scalability problems (MPI_Alltoallv: 241@fftgrid.c)

Example: ... to details

GROMACS Computational load balance

64 tasks

256 tasks



Zone 1 does not scale and increases imbalance!

Folding: Combining instrumentation and sampling

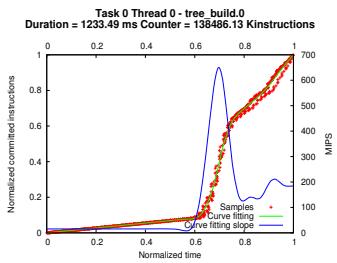
Folding samples – granularity / overhead

Application granularity vs. detailed granularity

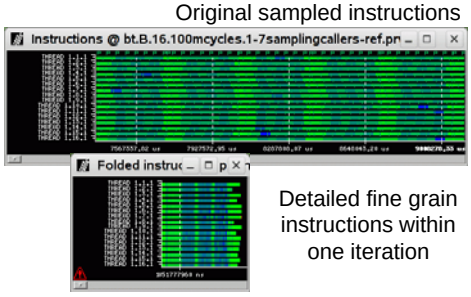
Samples: hardware counters + callstack

Folding: based on known structure: iterations, routines, clusters; project all the samples into one instance

Extremely detailed time evolution of hardware counts, rates and callstack with minimal overhead

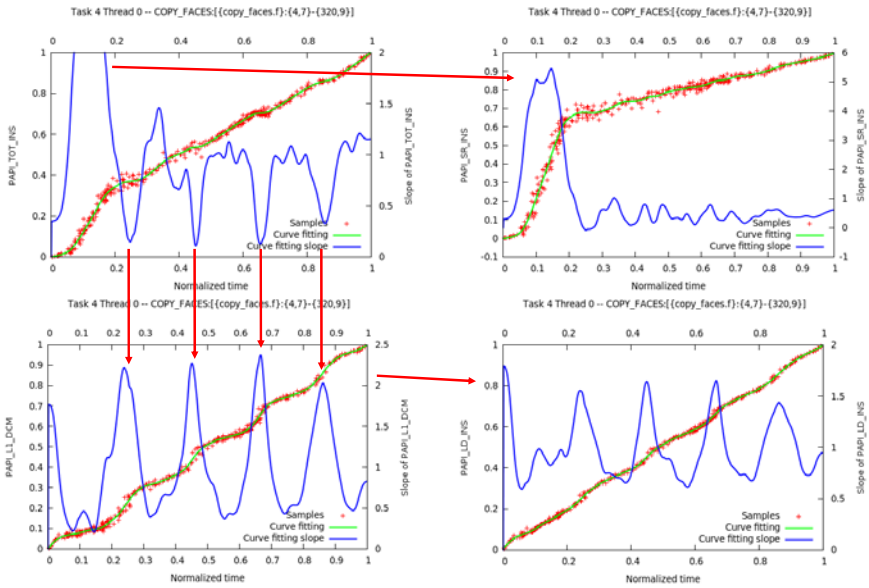


Original sampled instructions



Detailed fine grain instructions within one iteration

Folding samples – granularity / overhead

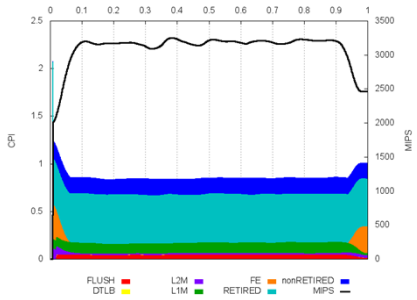


CPI Breakdown: PMEMD (2 tasks)

Core2 model

(core2duo t9400 @ 2.533 GHz)

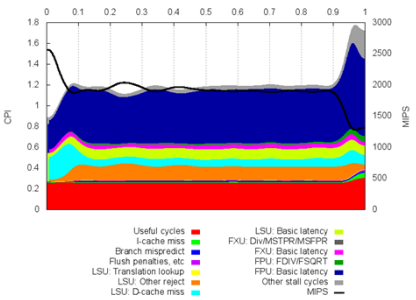
Intel Core2Duo CPI model evolution for pmemd.2tasks.x86.2.chop1.clustered.fused.extract.1.1.Cluster_1.0



Power5 model

(ppc970mp @ 2.3 GHz)

PowerPC model evolution for pmemd.2tasks.ppc.chop1.clustered.fused.extract.1.1.Cluster_1.0



FLUSH: Cycles stalled by branch mispredictions
DTLB: Cycles stalled by TLB misses
L2M: Cycles stalled by L2 misses
L1M: Cycles stalled by L1 misses
FE: Remaining stalled cycles
nonRETIRED: miss-speculated work? Instructions that entered the RS (Reservation Stations) but did not retire – should be counted in CPI?
RETIRED: useful work

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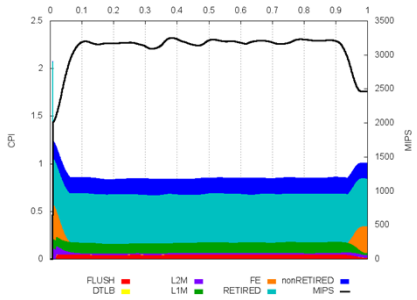
CPI Breakdown: PMEMD (2 tasks)

Core2 model

(core2duo t9400 @ 2.533 GHz)

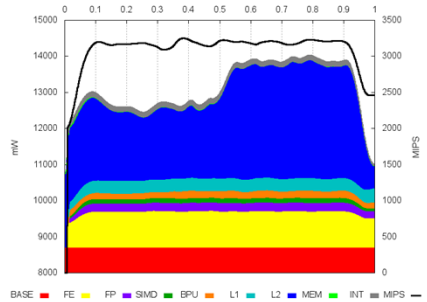
Intel Core2Duo CPI model evolution for pmemd.2tasks.x86.2.chop1.clustered.fused.extract.1.1.Cluster_1.0



Core2 power model

(core2duo t9400 @ 2.533 GHz)

Core2Duo Power consumption model evolution for pmemd.2tasks.x86.2.chop1.clustered.fused.extract.1.1.Cluste



FLUSH: Cycles stalled by branch mispredictions
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FE: Remaining stalled cycles
nonRETIRED: miss-speculated work? Instructions that entered the RS (Reservation Stations) but did not retire – should be counted in CPI?
RETIRED: useful work

BASE: Static consumption
FE: Regular instruction consumption, front-end component
BPU: Branch Prediction Unit consumption
FP/SIMD/INT: Consumption for FP/SIMD/integer instructions
L1: L1 consumption
L2: L2 & Front-Side-Bus consumption
MEM: Memory consumption

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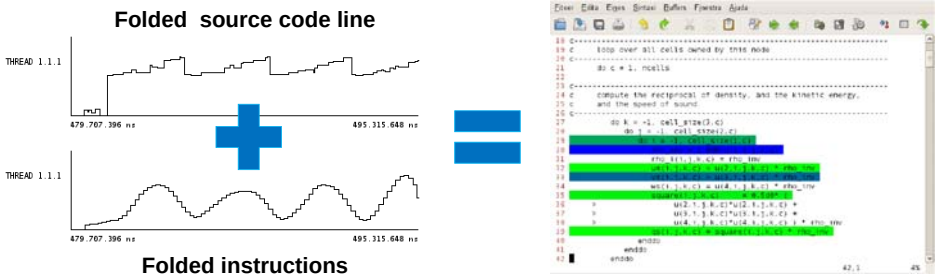
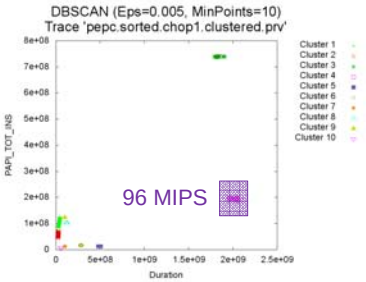
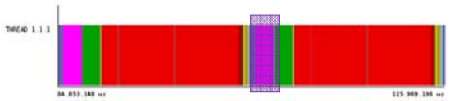
Folding → profiles of rates

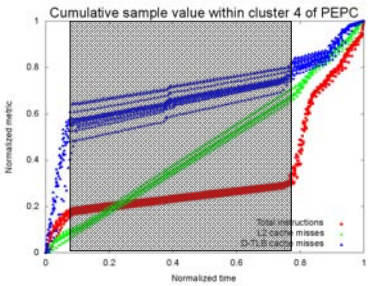


Example: PEPC





Performance metrics
16 MIPS
2.3 M L2 misses/s
0.1 M TLB misses/s



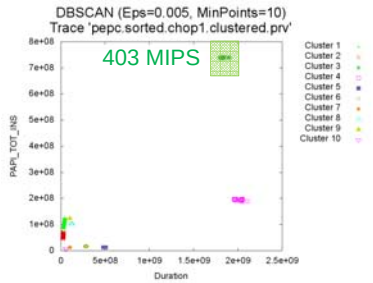

```
htable%node = 0
htable%key = 0
htable%link = -1
htable%leaves = 0
htable%childcode = 0
```

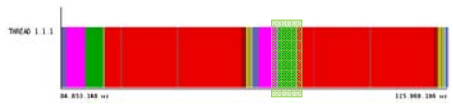
→

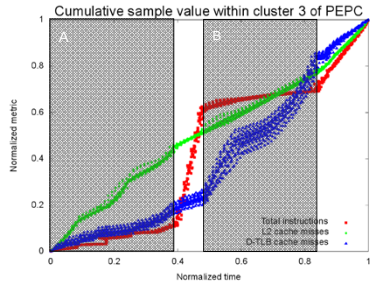
```
do i = 1, n
 htable(i)%node = 0
 htable(i)%key = 0
 htable(i)%link = -1
 htable(i)%leaves = 0
 htable(i)%childcode = 0
End do
```

Changes
-70% time
-18% instructions
-63% L2 misses
-78% TLB misses
253 MIPS (+163%)

Example: PEPC







Performance metrics	
Region A	Region B
100 MIPS	80 MIPS
4 M L2 misses/s	2 M L2 misses/s
0.4 M TLB misses/s	1 M TLB misses/s

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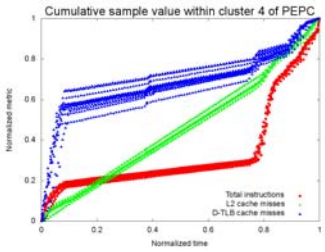
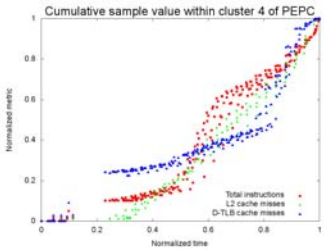
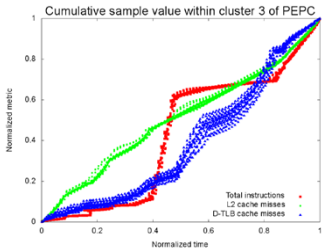
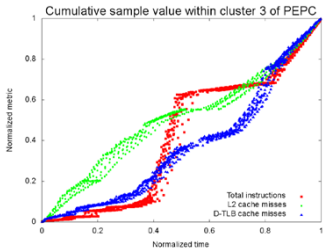
Example: PEPC (optimized)





Changes
-70% time
-18% instructions
-63% L2 misses
-78% TLB misses
253 MIPS (+163%)





Changes
-30% time
-1% instructions
-10% L2 misses
-32% TLB misses
544MIPS (+34%)

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