Arquitecturas de Alto Desempenho

DETI

Performance Analysis

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Factors affecting program execution

Program execution is affected by multiple factors. Some of them are controlled by the programmer, but some are not.

Among the most important, one may highlight

- at hardware level
  - internal processor organization (instruction scheduling and execution patterns)
  - processor to main memory data path (access times)
- at software level
  - code organization (algorithmic design)
  - match of code generation to processor architecture (compilation procedure)
  - operating system (scheduling policy / power management)

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Quad-core processor characterization

```
[ruib@ruib-laptop ~]$ lscpu
Architecture:                    x86_64
CPU op-mode(s):                  32-bit, 64-bit
Byte Order:                      Little Endian
Address sizes:                   39 bits physical, 48 bits virtual
CPU(s):                          8
On-line CPU(s) list:             0-7
Thread(s) per core:              2
Core(s) per socket:              4
Socket(s):                       1
NUMA node(s):                    1
Vendor ID:                       GenuineIntel
CPU family:                      6
Model:                           142
Model name:                      Intel(R) Core(TM) i7-8565U CPU @ 1.80GHz
Stepping:                        11
CPU MHz:                         900.002
CPU max MHz:                     4600,0000
CPU min MHz:                     400,0000
BogoMIPS:                        3999.93
Virtualization:                  VT-x
L1d cache:                       128 KiB
L1i cache:                       128 KiB
L2 cache:                        1 MiB
L3 cache:                        8 MiB
NUMA node0 CPU(s):               0-7
```

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Dual-core processor characterization

```
[ruib@ruib-laptop2 ~]$ lscpu
Architecture:          x86_64
CPU op-mode(s):        32-bit, 64-bit
Byte Order:            Little Endian
CPU(s):                4
On-line CPU(s) list:   0-3
Thread(s) per core:    2
Core(s) per socket:    2
Socket(s):             1
NUMA node(s):          1
Vendor ID:             GenuineIntel
CPU family:            6
Model:                 78
Model name:            Intel(R) Core(TM) i5-6200U CPU @ 2.30GHz
Stepping:              3
CPU MHz:               2787.223
CPU max MHz:           2800,0000
CPU min MHz:           400,0000
BogoMIPS:              4800.00
Virtualization:        VT-x
L1d cache:             32K
L1i cache:             32K
L2 cache:              256K
L3 cache:              3072K
NUMA node0 CPU(s):     0-3
```

...

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Compiler optimization

- without optimization
  - to reduce the compilation cost
  - to make debugging produce the expected results
- with optimization
  - to improve performance and/or code size at the expense of compilation time and the ability to debug the program
- options (GNU)
  - `[-O0]` almost no code optimization takes place (default situation)
  - `[-O1 … -O3]` performance optimization (degree increases with the number used)
  - `[-Os]` code size optimization
  - `[-Og]` debugging optimization

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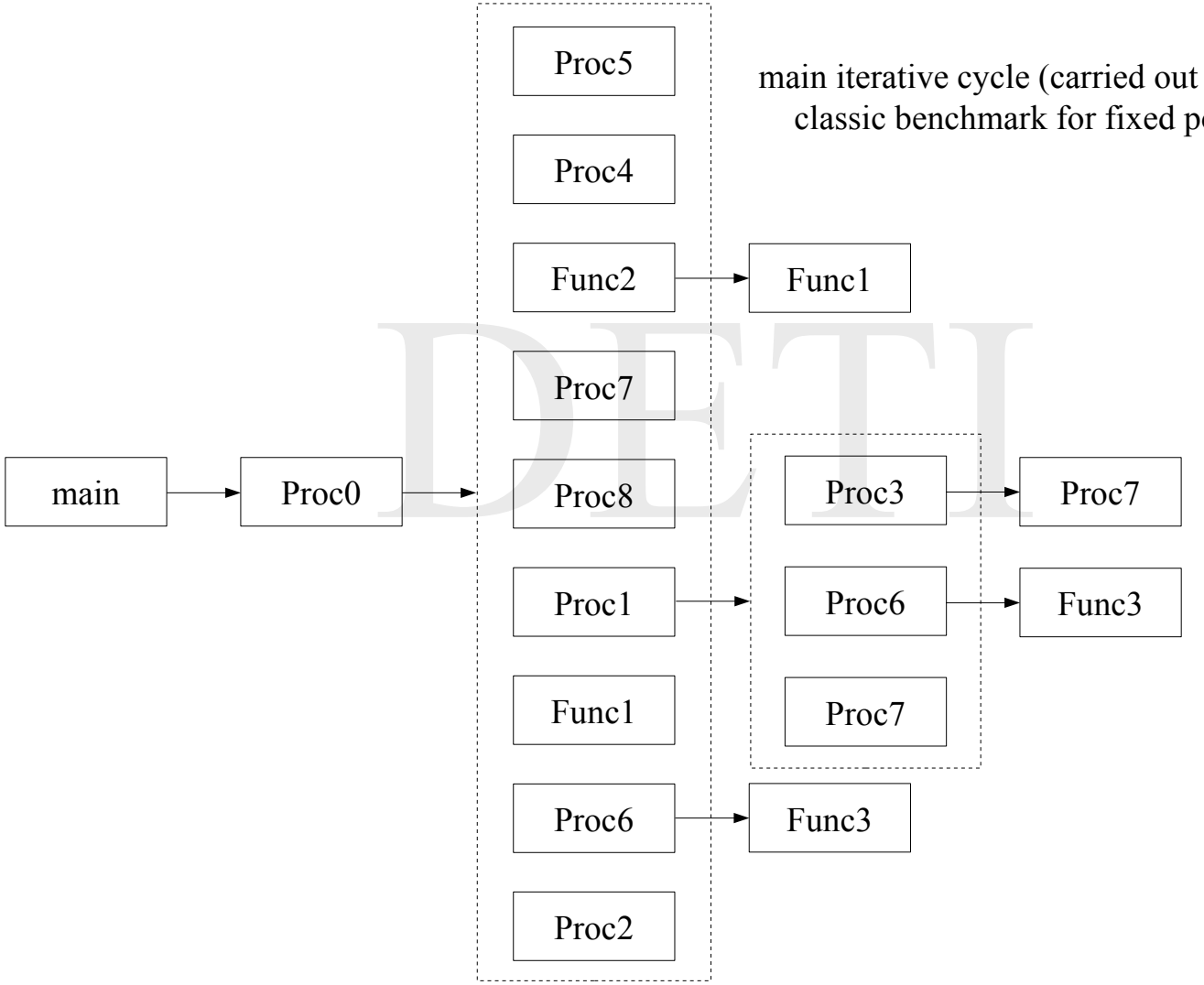
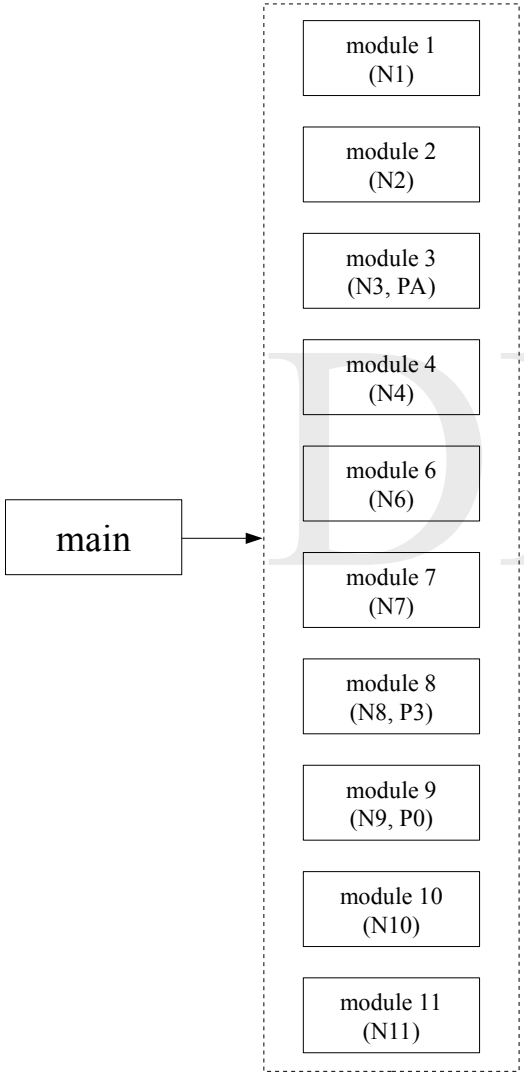
Dhrystone



main iterative cycle (carried out 10 000 000 times)
classic benchmark for fixed point processing

DETI

Whetstone



main iterative cycle (carried out 100 000 times)
classic benchmark for floating point processing

DETI

Prime (*v1 and v2*)

- computation of the number of primes up to a given limit
- version 1 (limit = 10^7)
  - each odd number *n* in the range from 3 to limit is selected in turn to check if it is a multiple of an odd number in the range from 3 to *n*
  - computational intensive with small memory use
- version 2 (limit = 10^9)
  - modified Eratosthenes algorithm
  - large memory use

DEI

Crypt - 1

- sector encryption
  - each sector is encrypted with a different seed
  - there are 2^{21} sectors, each 512 bytes long
  - sectors are encrypted sequentially, 4 bytes at a time
  - each sector occupies a contiguous portion of memory

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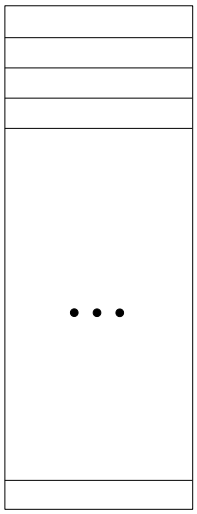
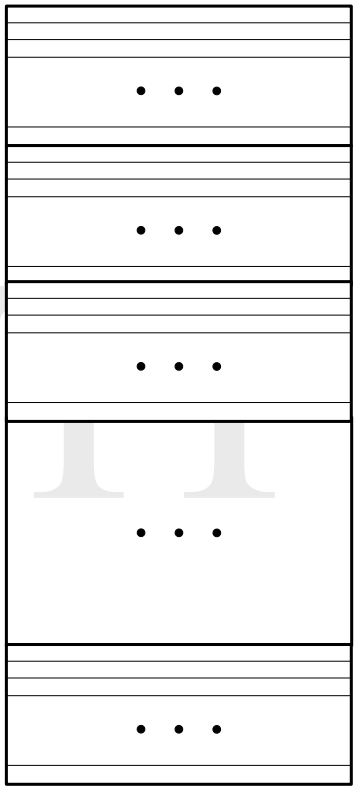
Crypt - 2



host_sector_number
(seed value for sector encrypting)



host_sector_data
(data to be encrypted)

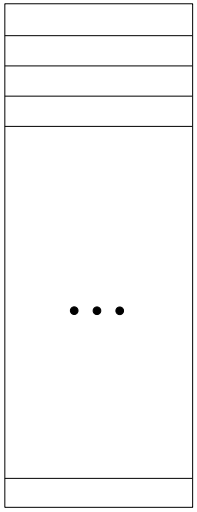
DETI

NewCrypt - 1

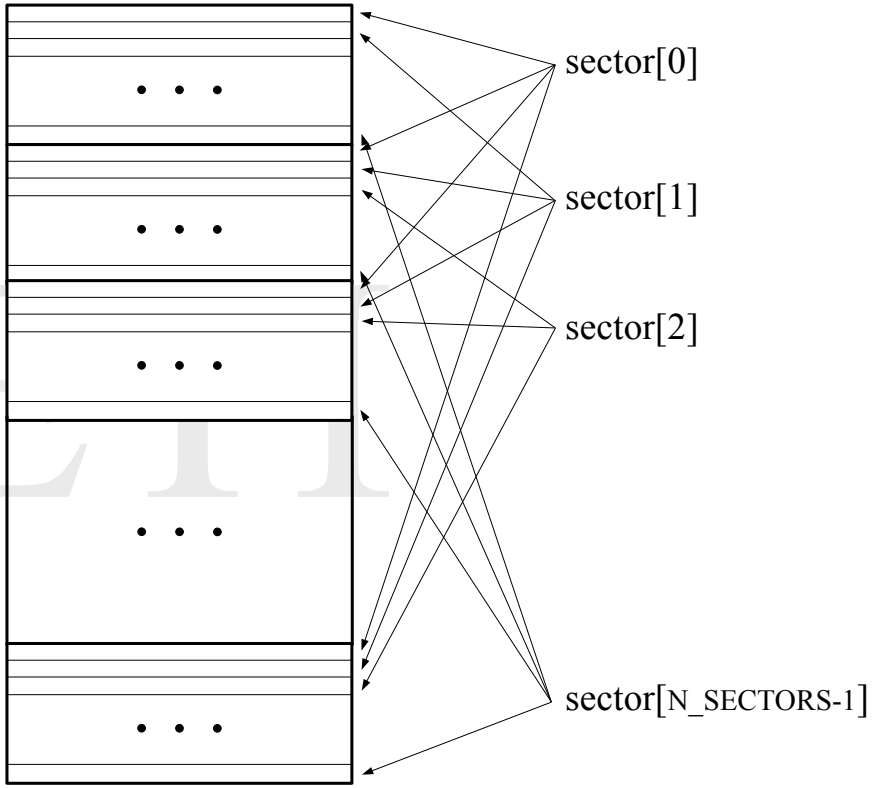
- sector encryption
  - each sector is encrypted with a different seed
  - there are 2^{21} sectors, each 512 bytes long
  - sectors are encrypted sequentially, 4 bytes at a time
  - each sector is scattered in memory
  - each 4 bytes group is separated from any other by a 2^{21} byte distance

DETI

NewCrypt - 2



host_sector_number
(seed value for sector encrypting)



host_sector_data
(data to be encrypted)

DEEI

Collected data - 1

Comp Config		Intel(R) Core(TM) i7-8565U CPU @ 1.80GHz												
Operating System	**Gcc version**	*dhrystone*												
		no opt						**opt**						
		run 1	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*run 1*	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*speed up*
linux 5.8.11	10.2.1	0,503	0,499	0,507	0,507	0,514	**0,506**	0,158	0,159	0,157	0,158	0,157	**0,158**	***3,2***
Operating System	**Gcc version**	*whetstone*												
		no opt						**opt**						
		run 1	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*run 1*	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*speed up*
linux 5.8.11	10.2.1	1,306	1,309	1,319	1,314	1,305	**1,311**	0,382	0,381	0,384	0,387	0,389	**0,385**	***3,4***
Operating System	**Gcc version**	*primev1*												
		no opt						opt						
		run 1	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*run 1*	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*speed up*
linux 5.8.11	10.2.1	1,974	1,995	2,002	2,085	1,989	**2,009**	1,611	1,610	1,653	1,611	1,608	**1,619**	***1,2***
Operating System	**Gcc version**	*primev2*												
		no opt						opt						
		run 1	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*run 1*	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*speed up*
linux 5.8.11	10.2.1	5,759	5,779	5,783	5,796	5,799	**5,783**	4,093	4,101	4,088	4,099	4,083	**4,093**	***1,4***
Operating System	**Gcc version**	*crypt*												
		no opt						opt						
		run 1	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*run 1*	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*speed up*
linux 5.8.11	10.2.1	0,563	0,558	0,574	0,576	0,577	**0,570**	0,293	0,286	0,274	0,287	0,291	**0,286**	***2,0***
Operating System	**Gcc version**	*newCript*												
		no opt						opt						
		run 1	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*run 1*	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*speed up*
linux 5.8.11	10.2.1	2,307	2,324	2,275	2,301	2,329	**2,307**	1,724	1,732	1,755	1,794	1,706	**1,742**	***1,3***

DEI

Collected data - 2

Comp Config		Intel(R) Core(TM) 4 x i5-6200U CPU @ 2.30GHz / 8GB												
Operating System	**Gcc version**	*dhrystone*												
		no opt						**opt**						
		run 1	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*run 1*	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*speed up*
windows 10	6.4.0	0,843	0,798	0,812	0,798	0,798	**0,810**	0,140	0,140	0,140	0,140	0,140	**0,140**	***5,8***
linux 4.12.9	6.4.1	0,821	0,817	0,826	0,824	0,822	**0,822**	0,252	0,249	0,259	0,252	0,252	**0,253**	***3,3***
linux 4.18.5	8.1.1	0,844	0,838	0,859	0,836	0,853	**0,846**	0,284	0,288	0,289	0,290	0,285	**0,287**	***2,9***
linux 4.18.8	8.1.1	0,920	1,047	0,992	0,926	0,931	**0,963**	0,274	0,264	0,264	0,265	0,264	**0,266**	***3,6***
linux 5.0.16	8.3.1	0,842	0,966	0,958	0,955	0,868	**0,918**	0,256	0,254	0,259	0,254	0,274	**0,259**	***3,5***
Operating System	**Gcc version**	*whetstone*												
		no opt						**opt**						
		run 1	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*run 1*	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*speed up*
windows 10	6.4.0	3,218	3,187	3,156	3,203	3,187	**3,190**	0,578	0,562	0,562	0,578	0,578	**0,572**	***5,6***
linux 4.12.9	6.4.1	2,359	2,346	2,348	2,339	2,337	**2,346**	0,902	0,918	0,902	0,900	0,898	**0,904**	***2,6***
linux 4.18.5	8.1.1	2,190	2,173	2,182	2,171	2,197	**2,183**	0,738	0,730	0,739	0,716	0,737	**0,732**	***3,0***
linux 4.18.8	8.1.1	2,217	2,225	2,253	2,217	2,222	**2,227**	0,730	0,772	0,774	0,766	0,768	**0,762**	***2,9***
linux 5.0.16	8.3.1	2,272	2,297	2,462	2,463	2,271	**2,353**	0,744	0,717	0,717	0,741	0,744	**0,733**	***3,2***

DEIT

Collected data - 3

Operating System	**Gcc version**	*primev1*												
		no opt						opt						
		run 1	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*run 1*	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*speed up*
windows 10	6.4.0	3,406	3,406	3,406	3,406	3,406	**3,406**	3,031	3,031	3,031	3,015	3,031	**3,028**	***1,1***
linux 4.12.9	6.4.1	3,253	3,287	3,291	3,283	3,260	**3,275**	2,929	2,941	2,932	2,930	2,928	**2,932**	***1,1***
linux 4.18.5	8.1.1	3,277	3,307	3,264	3,254	3,277	**3,276**	2,621	2,628	2,632	2,621	2,624	**2,625**	***1,2***
linux 4.18.8	8.1.1	3,899	3,343	3,914	3,352	3,334	**3,568**	2,681	2,679	2,954	2,678	2,922	**2,783**	***1,3***
linux 5.0.16	8.3.1	3,322	3,292	3,309	3,311	3,386	**3,324**	2,664	2,640	2,714	2,647	2,658	**2,665**	***1,2***
Operating System	**Gcc version**	*primev2*												
		no opt						opt						
		run 1	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*run 1*	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*speed up*
windows 10	6.4.0	9,187	9,187	9,124	9,203	9,375	**9,215**	6,374	6,328	6,327	6,358	6,375	**6,352**	***1,5***
linux 4.12.9	6.4.1	8,098	8,153	8,093	8,089	8,124	**8,111**	5,488	5,488	5,484	5,489	5,488	**5,487**	***1,5***
linux 4.18.5	8.1.1	10,992	11,059	11,088	11,158	11,161	**11,092**	5,358	5,404	5,356	5,416	5,361	**5,379**	***2,1***
linux 4.18.8	8.1.1	11,636	11,694	11,571	12,113	11,980	**11,799**	5,696	5,593	5,660	5,623	5,611	**5,637**	***2,1***
linux 5.0.16	8.3.1	11,244	11,253	11,349	11,160	11,278	**11,257**	5,375	5,334	5,317	5,338	5,316	**5,336**	***2,1***

DETI

Collected data - 4

Operating System	**Gcc version**	*crypt*												
		no opt						opt						
		run 1	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*run 1*	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*speed up*
linux 4.18.5	8.1.1	0,889	0,890	0,889	0,895	0,888	**0,890**	0,388	0,397	0,386	0,398	0,393	**0,392**	***2,3***
linux 4.18.8	8.1.1	1,100	0,975	0,998	0,918	0,928	**0,984**	0,433	0,415	0,427	0,442	0,421	**0,428**	***2,3***
linux 5.0.16	8.3.1	0,904	0,899	0,896	0,899	0,900	**0,900**	0,402	0,388	0,394	0,399	0,385	**0,394**	***2,3***
Operating System	**Gcc version**	*newCrypt*												
		no opt						opt						
		run 1	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*run 1*	*run 2*	*run 3*	*run 4*	*run 5*	*aver*	*speed up*
linux 4.18.5	8.1.1	8,817	7,950	7,611	5,247	5,443	**7,014**	17,560	5,577	11,660	4,518	11,700	**10,203**	***0,7***
linux 4.18.8	8.1.1	4,981	9,318	5,628	3,772	4,582	**5,656**	6,739	8,343	4,286	8,586	7,829	**7,157**	***0,8***
linux 5.0.16	8.3.1	7,962	9,647	6,329	5,124	7,178	**7,248**	5,924	8,515	6,032	8,514	8,312	**7,459**	***1,0***

DETI

gprof profile processing

- generation of extra code to write profile information suitable for analysis by `gprof`
  - `gcc -pg <other options> <source files> -o <exec file>_gprof`
- run the program to collect profile information
  - `./<exec file>_gprof`
- produce the summarized results
  - `gprof <exec file>_gprof > <exec file>_gprof.out`

DETI

Dhrystone execution profile - 1

Execution profile of non-optimized version

Flat profile:

Each sample counts as 0.01 seconds.

% time	cumulative seconds	self seconds	calls	self ms/call	total ms/call	name
30.14	0.14	0.14	1	135.62	452.07	Proc0
23.44	0.24	0.11	10000000	0.00	0.00	Proc1
13.39	0.30	0.06	10000000	0.00	0.00	Proc8
8.93	0.34	0.04	30000000	0.00	0.00	Func1
8.93	0.38	0.04	30000000	0.00	0.00	Proc7
8.93	0.42	0.04	10000000	0.00	0.00	Func2
4.46	0.44	0.02	10000000	0.00	0.00	Proc3
2.23	0.45	0.01	10000000	0.00	0.00	Proc5
0.00	0.45	0.00	10000000	0.00	0.00	Func3
0.00	0.45	0.00	10000000	0.00	0.00	Proc2
0.00	0.45	0.00	10000000	0.00	0.00	Proc4
0.00	0.45	0.00	10000000	0.00	0.00	Proc6

DETI

Dhrystone execution profile - 2

Execution profile of optimized version

Flat profile:

Each sample counts as 0.01 seconds.

% time	cumulative seconds	self seconds	calls	self ms/call	total ms/call	name
67.10	0.04	0.04				Proc0
33.55	0.06	0.02	10000000	2.01	2.01	Proc1

DETI

Whetstone execution profile - 1

Execution profile of non-optimized version

Flat profile:

Each sample counts as 0.01 seconds.

% time	cumulative seconds	self seconds	calls	self ms/call	total ms/call	name
47.70	0.39	0.39				main
22.02	0.57	0.18	89900000	2.01	2.01	P3
22.02	0.75	0.18	1400000	128.96	128.96	PA
8.56	0.82	0.07	61600000	1.14	1.14	P0

DETI

Whetstone execution profile - 2

Execution profile of optimized version

Flat profile:

Each sample counts as 0.01 seconds.

% time	cumulative seconds	self seconds	calls	self ms/call	total ms/call	name

DETI

Crypt execution profile - 1

Execution profile of non-optimized version

Flat profile:

Each sample counts as 0.01 seconds.

% time	cumulative seconds	self seconds	calls	self ms/call	total ms/call	name
60.10	1.27	1.27				main
40.22	2.13	0.85	2097152	406.63	406.63	modify_sector_cpu_kernel
0.00	2.13	0.00	4	0.00	0.00	get_delta_time

DETI

Crypt execution profile - 2

Execution profile of optimized version

Flat profile:

Each sample counts as 0.01 seconds.

% time	cumulative seconds	self seconds	calls	self ms/call	total ms/call	name

DETI

NewCrypt execution profile - 1

Execution profile of non-optimized version

Flat profile:

Each sample counts as 0.01 seconds.

% time	cumulative seconds	self seconds	calls	self ms/call	total ms/call	name
74.92	2.35	2.35	2097152	1.12	1.12	modify_sector_cpu_kernel
26.04	3.17	0.82				main
0.00	3.17	0.00	4	0.00	0.00	get_delta_time

DETI

NewCrypt execution profile - 2

Execution profile of optimized version

Flat profile:

Each sample counts as 0.01 seconds.

% time	cumulative seconds	self seconds	calls	self ms/call	total ms/call	name

DETI

`perf` profile and event processing

- run the program to collect profile information and store it in `perf.data`
  - `perf record <exec file>`
- display profile information collected by `perf record`
  - `perf report`
- run the program to collect performance statistics
  - `perf stat -d <exec file>`

DETI

Dhrystone execution profile and event processing - 1

Execution profile of non-optimized version

```
Samples: 2K of event 'cycles:u', Event count (approx.): 2222560500
Overhead  Command  Shared Object      Symbol
  26,81%  dhry     dhry               [.] Proc0
  12,98%  dhry     dhry               [.] Proc8
  10,48%  dhry     dhry               [.] Func1
  10,35%  dhry     dhry               [.] Proc1
   9,68%  dhry     libc-2.31.so       [.] __strcmp_avx2
   7,75%  dhry     dhry               [.] Proc7
   6,86%  dhry     dhry               [.] Func2
   3,40%  dhry     dhry               [.] Proc6
   3,21%  dhry     dhry               [.] Proc2
   3,18%  dhry     dhry               [.] Proc3
   2,19%  dhry     dhry               [.] Func3
   1,84%  dhry     dhry               [.] Proc4
   0,82%  dhry     dhry               [.] Proc5
   0,44%  dhry     dhry               [.] strcmp@plt
   0,01%  dhry     [unknown]          [k] 0xffffffff82c00fe7
   0,00%  dhry     ld-2.31.so         [.] _dl_sysdep_start
```

DETI

Dhrystone execution profile and event processing - 2

Event processing of non-optimized version

```
Performance counter stats for './dhry':

     514,41 msec task-clock:u                     #    0,998 CPUs utilized
          0      context-switches:u               #    0,000 K/sec
          0      cpu-migrations:u                 #    0,000 K/sec
         54      page-faults:u                    #    0,105 K/sec
 2229040253      cycles:u                         #    4,333 GHz                      (49,82%)
 5573361662      instructions:u                   #    2,50  insn per cycle           (62,46%)
  749450190      branches:u                       # 1456,912 M/sec                    (62,65%)
       3593      branch-misses:u                  #    0,00% of all branches          (62,69%)
 2084810266      L1-dcache-loads:u                # 4052,817 M/sec                    (62,71%)
       4789      L1-dcache-load-misses:u          #    0,00% of all L1-dcache hits    (62,62%)
       1442      LLC-loads:u                      #    0,003 M/sec                    (49,79%)
        667      LLC-load-misses:u                #   46,26% of all LL-cache hits     (49,72%)

      0,515189804 seconds time elapsed

      0,510955000 seconds user
      0,000989000 seconds sys
```

DETI

Dhrystone execution profile and event processing - 3

Execution profile of optimized version

```
Samples: 584  of event 'cycles:u', Event count (approx.): 632019100
Overhead  Command  Shared Object      Symbol
  66,42%  dhry_O3  libc-2.31.so       [.] __strcmp_avx2
  16,07%  dhry_O3  dhry_O3            [.] Proc0
  15,70%  dhry_O3  dhry_O3            [.] Proc1
   1,75%  dhry_O3  dhry_O3            [.] strcmp@plt
   0,05%  dhry_O3  ld-2.31.so         [.] _dl_load_cache_lookup
   0,01%  dhry_O3  [unknown]          [k] 0xffffffff82c00fe7
```

DETI

Dhrystone execution profile and event processing - 4

Event processing of optimized version

```
Performance counter stats for './dhry_O3':

     149,91 msec task-clock:u                     #    0,994 CPUs utilized
          0      context-switches:u               #    0,000 K/sec
          0      cpu-migrations:u                 #    0,000 K/sec
         54      page-faults:u                    #    0,360 K/sec
  631177895      cycles:u                         #    4,210 GHz                      (49,32%)
  959183555      instructions:u                   #    1,52  insn per cycle           (61,99%)
  139789059      branches:u                       #  932,469 M/sec                    (61,99%)
       5405      branch-misses:u                  #    0,00% of all branches          (62,60%)
  269186917      L1-dcache-loads:u                # 1795,623 M/sec                    (63,30%)
        560      L1-dcache-load-misses:u          #    0,00% of all L1-dcache hits    (63,35%)
        345      LLC-loads:u                      #    0,002 M/sec                    (50,06%)
        277      LLC-load-misses:u                #   80,29% of all LL-cache hits     (49,38%)

      0,150866342 seconds time elapsed

      0,149167000 seconds user
      0,000965000 seconds sys
```

DETI

Whetstone execution profile and event processing - 1

Execution profile of non-optimized version

```
Samples: 5K of event 'cycles:u', Event count (approx.): 5780646128
Overhead  Command  Shared Object     Symbol
  34,23%  whet     whet              [.] main
  22,74%  whet     whet              [.] P3
  11,79%  whet     whet              [.] PA
   7,51%  whet     whet              [.] P0
   6,90%  whet     libm-2.31.so      [.] __ieee754_log_fma
   5,32%  whet     libm-2.31.so      [.] __ieee754_exp_fma
   2,66%  whet     libm-2.31.so      [.] __cos_fma
   2,47%  whet     libm-2.31.so      [.] __atan_fma
   2,02%  whet     libm-2.31.so      [.] __sqrt_finite@GLIBC_2.15
   1,10%  whet     libm-2.31.so      [.] exp@@GLIBC_2.29
   1,01%  whet     libm-2.31.so      [.] __sin_fma
   0,39%  whet     libm-2.31.so      [.] __sqrt
   0,39%  whet     libm-2.31.so      [.] log@@GLIBC_2.29
   0,31%  whet     whet              [.] cos@plt
   0,25%  whet     whet              [.] log@plt
   0,19%  whet     whet              [.] sqrt@plt
   0,18%  whet     whet              [.] atan@plt
   0,15%  whet     whet              [.] exp@plt
   0,15%  whet     libm-2.31.so      [.] 0x000000000000f3a4
   0,13%  whet     whet              [.] sin@plt
   0,12%  whet     libm-2.31.so      [.] 0x000000000000f2f4
   0,01%  whet     ld-2.31.so        [.] _dl_setup_hash
   0,00%  whet     ld-2.31.so        [.] _dl_sysdep_start
   0,00%  whet     [unknown]         [k] 0xffffffff82c00fe7
```

DEEI

Whetstone execution profile and event processing - 2

Event processing of non-optimized version

Performance counter stats for './whet':

```
    1309,12 msec task-clock:u                     #    0,999 CPUs utilized
          0      context-switches:u               #    0,000 K/sec
          0      cpu-migrations:u                 #    0,000 K/sec
         70      page-faults:u                    #    0,053 K/sec
 5757284243      cycles:u                         #    4,398 GHz                      (49,89%)
10580098798      instructions:u                   #    1,84  insn per cycle           (62,42%)
 1167798406      branches:u                       #  892,050 M/sec                    (62,47%)
      38659      branch-misses:u                  #    0,00% of all branches          (62,55%)
 4491468135      L1-dcache-loads:u                # 3430,912 M/sec                    (62,63%)
       7086      L1-dcache-load-misses:u          #    0,00% of all L1-dcache hits    (62,58%)
       1078      LLC-loads:u                      #    0,823 K/sec                    (49,98%)
        901      LLC-load-misses:u                #   83,58% of all LL-cache hits     (49,90%)

      1,310054073 seconds time elapsed

      1,302868000 seconds user
      0,000981000 seconds sys
```

DETI

Whetstone execution profile and event processing - 3

Execution profile of optimized version

```
Samples: 1K of event 'cycles:u', Event count (approx.): 1651177492
Overhead  Command  Shared Object      Symbol
  51,39%  whet_O3  whet_O3            [.] main
  23,19%  whet_O3  libm-2.31.so       [.] __ieee754_log_fma
  18,46%  whet_O3  libm-2.31.so       [.] __ieee754_exp_fma
   3,92%  whet_O3  libm-2.31.so       [.] exp@@GLIBC_2.29
   0,74%  whet_O3  libm-2.31.so       [.] log@@GLIBC_2.29
   0,61%  whet_O3  libm-2.31.so       [.] 0x000000000000f2f4
   0,60%  whet_O3  whet_O3            [.] log@plt
   0,53%  whet_O3  whet_O3            [.] exp@plt
   0,47%  whet_O3  libm-2.31.so       [.] 0x000000000000f3a4
   0,07%  whet_O3  libc-2.31.so       [.] _IO_file_write@@GLIBC_2.2.5
   0,02%  whet_O3  ld-2.31.so         [.] _dl_cache_libcmp
   0,00%  whet_O3  [unknown]          [k] 0xffffffff82c00fe7
```

DEIT

Whetstone execution profile and event processing - 4

Event processing of optimized version

```
Performance counter stats for './whet_O3':

     422,84 msec task-clock:u                     #    0,999 CPUs utilized
          0      context-switches:u               #    0,000 K/sec
          0      cpu-migrations:u                 #    0,000 K/sec
         67      page-faults:u                    #    0,158 K/sec
 1657196158      cycles:u                         #    3,919 GHz                      (49,86%)
 1624717675      instructions:u                   #    0,98  insn per cycle           (62,40%)
  259068224      branches:u                       #  612,683 M/sec                    (62,40%)
       7276      branch-misses:u                  #    0,00% of all branches          (62,41%)
  324836740      L1-dcache-loads:u                #  768,222 M/sec                    (62,59%)
       4659      L1-dcache-load-misses:u          #    0,00% of all L1-dcache hits    (62,66%)
       1781      LLC-loads:u                      #    0,004 M/sec                    (50,13%)
       1595      LLC-load-misses:u                #   89,56% of all LL-cache hits     (49,94%)

       0,423229358 seconds time elapsed

       0,416980000 seconds user
       0,000992000 seconds sys
```

DETI

Crypt execution profile and event processing - 1

Execution profile of non-optimized version

```
Samples: 5K of event 'cycles:u', Event count (approx.): 5143354868
Overhead  Command  Shared Object      Symbol
  47,67%  crypt    crypt              [.] modify_sector_cpu_kernel
  47,29%  crypt    crypt              [.] main
   3,25%  crypt    [unknown]          [k] 0xffffffff82c00fe7
   0,86%  crypt    libc-2.31.so       [.] __random_r
   0,65%  crypt    libc-2.31.so       [.] __random
   0,17%  crypt    libc-2.31.so       [.] rand
   0,11%  crypt    crypt              [.] rand@plt
   0,01%  crypt    libc-2.31.so       [.] _dl_addr
   0,01%  crypt    ld-2.31.so         [.] _dl_cache_libcmp
   0,00%  crypt    ld-2.31.so         [.] _dl_sysdep_start
```

DETI

Crypt execution profile and event processing - 2

Event processing of non-optimized version

Performance counter stats for './crypt':

```
    1484,65 msec task-clock:u                     #    0,999 CPUs utilized
          0      context-switches:u               #    0,000 K/sec
          0      cpu-migrations:u                 #    0,000 K/sec
     264247      page-faults:u                    #    0,178 M/sec
 5108403156      cycles:u                         #    3,441 GHz                      (49,85%)
10308450742      instructions:u                   #    2,02  insn per cycle           (62,38%)
  607779880      branches:u                       #  409,376 M/sec                    (62,51%)
    2235803      branch-misses:u                  #    0,37% of all branches          (62,58%)
 5480293319      L1-dcache-loads:u                # 3691,301 M/sec                    (62,64%)
   17055055      L1-dcache-load-misses:u          #    0,31% of all L1-dcache hits    (62,60%)
     418133      LLC-loads:u                      #    0,282 M/sec                    (49,94%)
     276924      LLC-load-misses:u                #   66,23% of all LL-cache hits     (49,88%)

       1,485962366 seconds time elapsed

       1,206725000 seconds user
       0,266730000 seconds sys
```

DETI

Crypt execution profile and event processing - 3

Execution profile of optimized version

```
Samples: 2K of event 'cycles:u', Event count (approx.): 1552736429
Overhead  Command   Shared Object      Symbol
  82,44%  crypt_O3  crypt_O3           [.] main
  11,11%  crypt_O3  [unknown]          [k] 0xffffffff82c00fe7
   3,00%  crypt_O3  libc-2.31.so       [.] __random_r
   2,05%  crypt_O3  libc-2.31.so       [.] __random
   0,70%  crypt_O3  libc-2.31.so       [.] rand
   0,68%  crypt_O3  crypt_O3           [.] rand@plt
   0,02%  crypt_O3  ld-2.31.so         [.] strdup
```

DET

Crypt execution profile and event processing - 4

Event processing of optimized version

```
Performance counter stats for './crypt_O3':

     632,79 msec task-clock:u                     #    0,999 CPUs utilized
          0      context-switches:u               #    0,000 K/sec
          0      cpu-migrations:u                 #    0,000 K/sec
     264247      page-faults:u                    #    0,418 M/sec
 1491017075      cycles:u                         #    2,356 GHz                      (50,02%)
 2126489266      instructions:u                   #    1,43  insn per cycle           (62,55%)
  369167269      branches:u                       #  583,399 M/sec                    (62,54%)
    2227985      branch-misses:u                  #    0,60% of all branches          (62,54%)
  353223989      L1-dcache-loads:u                #  558,203 M/sec                    (62,55%)
   17147696      L1-dcache-load-misses:u          #    4,85% of all L1-dcache hits    (62,47%)
     303176      LLC-loads:u                      #    0,479 M/sec                    (49,94%)
     279632      LLC-load-misses:u                #   92,23% of all LL-cache hits     (49,94%)

       0,633159520 seconds time elapsed

       0,370175000 seconds user
       0,256542000 seconds sys
```

DETI

NewCrypt execution profile and event processing - 1

Execution profile of non-optimized version

```
Samples: 12K of event 'cycles:u', Event count (approx.): 12211478588
Overhead  Command   Shared Object      Symbol
  78,33%  newCrypt  newCrypt           [.] modify_sector_cpu_kernel
  19,48%  newCrypt  newCrypt           [.] main
   1,45%  newCrypt  [unknown]          [k] 0xffffffff82c00fe7
   0,35%  newCrypt  libc-2.31.so       [.] __random_r
   0,32%  newCrypt  libc-2.31.so       [.] __random
   0,04%  newCrypt  libc-2.31.so       [.] rand
   0,02%  newCrypt  newCrypt           [.] rand@plt
   0,00%  newCrypt  ld-2.31.so         [.] _dl_map_object_from_fd
   0,00%  newCrypt  ld-2.31.so         [.] _dl_sysdep_start
```

DETI

NewCrypt execution profile and event processing - 2

Event processing of non-optimized version

```
Performance counter stats for './newCrypt':

    3210,17 msec task-clock:u                     #    1,000 CPUs utilized
          0      context-switches:u               #    0,000 K/sec
          0      cpu-migrations:u                 #    0,000 K/sec
     264247      page-faults:u                    #    0,082 M/sec
12438447384      cycles:u                         #    3,875 GHz                      (49,97%)
10312064290      instructions:u                   #    0,83  insn per cycle           (62,49%)
  613699245      branches:u                       #  191,173 M/sec                    (62,53%)
    2244086      branch-misses:u                  #    0,37% of all branches          (62,54%)
 5492148756      L1-dcache-loads:u                # 1710,857 M/sec                    (62,53%)
  550191577      L1-dcache-load-misses:u          #   10,02% of all L1-dcache hits    (62,51%)
  473432410      LLC-loads:u                      #  147,479 M/sec                    (49,96%)
    6110025      LLC-load-misses:u                #    1,29% of all LL-cache hits     (49,95%)

       3,211376212 seconds time elapsed

       2,934441000 seconds user
       0,255312000 seconds sys
```

DETI

NewCrypt execution profile and event processing - 3

Execution profile of optimized version

```
Samples: 8K of event 'cycles:u', Event count (approx.): 7495550730
Overhead  Command      Shared Object      Symbol
  96,30%  newCrypt_O3  newCrypt_O3        [.] main
   2,38%  newCrypt_O3  [unknown]          [k] 0xffffffff82c00fe7
   0,62%  newCrypt_O3  libc-2.31.so       [.] __random_r
   0,50%  newCrypt_O3  libc-2.31.so       [.] __random
   0,13%  newCrypt_O3  libc-2.31.so       [.] rand
   0,07%  newCrypt_O3  newCrypt_O3        [.] rand@plt
   0,00%  newCrypt_O3  ld-2.31.so         [.] strdup
   0,00%  newCrypt_O3  ld-2.31.so         [.] _dl_sysdep_start
```

DETI

NewCrypt execution profile and event processing - 4

Event processing of optimized version

```
Performance counter stats for './newCrypt_O3':

    2089,64 msec task-clock:u                     #    1,000 CPUs utilized
          0      context-switches:u               #    0,000 K/sec
          0      cpu-migrations:u                 #    0,000 K/sec
     264246      page-faults:u                    #    0,126 M/sec
 7588582815      cycles:u                         #    3,632 GHz                      (50,00%)
 2140828781      instructions:u                   #    0,28  insn per cycle           (62,53%)
  371156019      branches:u                       #  177,617 M/sec                    (62,53%)
    2240063      branch-misses:u                  #    0,60% of all branches          (62,53%)
  354188450      L1-dcache-loads:u                #  169,498 M/sec                    (62,53%)
  833829604      L1-dcache-load-misses:u          #  235,42% of all L1-dcache hits    (62,49%)
  441406756      LLC-loads:u                      #  211,236 M/sec                    (49,96%)
    8964163      LLC-load-misses:u                #    2,03% of all LL-cache hits     (49,96%)

       2,090489392 seconds time elapsed

       1,835238000 seconds user
       0,241205000 seconds sys
```

DETI