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| Z:\Meu Drive\03. Doutorado\30. Doutorado IC-Unicamp\2022-2\Technical Report Template\logo-unicamp-name-line-blk-red-0120.png | **Universidade Estadual de Campinas**  **Instituto de Computação**  **Arquitetura de Computadores II – MO601**  **Prof. Rodolfo Jardim de Azevedo** | Z:\Meu Drive\03. Doutorado\30. Doutorado IC-Unicamp\2022-2\Technical Report Template\logo-ic-unicamp-slant-tint-beg-sky-ora-0120.png |

**Projeto 3**

**Experimentar ferramentas e coletar dados**

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Maio de 2023

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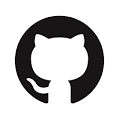
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# Introdução

Repositório Github <https://github.com/rubenscp/RCP-MO601-Project-03>



# Ambiente de Experimentação

O computador utilizado em todos os experimentos está descrito conforme segue e será denominado “Laptop Rubens”:

* Notebook HP Pavilion dm4
* Memória RAM: 16 Gbytes
* SSD: 1 TBytes
* Sistema Operacional
  + Ubuntu 22.04.2 LTS (GNU/Linux 5.15.90.1-microsoft-standard-WSL2 x86\_64)
* CPU:
  + Model name: Intel(R) Core(TM) i7-2620M CPU @ 2.70GHz
  + Architecture: x86\_64
  + CPU op-mode(s): 32-bit, 64-bit
  + Address sizes: 36 bits physical, 48 bits virtual
  + Byte Order: Little Endian
  + CPU(s): 4
  + Vendor ID: GenuineIntel
  + CPU family: 6
  + Thread(s) per core: 2
  + Core(s) per socket: 2
  + L1d cache: 64 KiB (2 instances)
  + L1i cache: 64 KiB (2 instances)
  + L2 cache: 512 KiB (2 instances)
  + L3 cache: 4 MiB (1 instance)

# Ferramentas experimentadas

As ferramentas utilizadas para avaliações em arquitetura de computadores foram SPEC CPU 2017, Simulador multi-core Sniper, Perf profiler, Parsec benchmark, Rodinia benchmark, Intel Pin e Dinero cache simulator. Os dados coletados para cada uma das ferramentas são apresentados nas próximas seções.

## SPEC CPU 2017 benchmark \*

O SPEC CPU 2017 é um pacote de benchmark que contém a próxima geração de SPECs (*Standard Performance Evaluation Corporation*), pacotes de processamento intensivo de CPU para medição e comparação de desempenho computacional, sobrecarregando o processador do sistema, memória e compilador. Esta ferramenta oferece 4 suites para benchmark considerando velocidade (*speed*) e throughput (*rate*) para números inteiros e em ponto flutuante: intspeed, fpspeed, intrate e fprate.

A Tabela 1 apresenta o resumo da experimentação do SPEC CPU 2017 no laptop Rubens com os parâmetros de execução como número de cópias, *threads*, número de iterações, tempo de execução e métrica final da execução (base).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Resultados da execução do SPEC CPU 2017** | | | | | | |
| **Suíte** | **Cópias** | **Threads** | **Nº Iterações** | **Qtde de Benchmarks** | **Tempo de execução** | **Métrica Final (base)** |
| intspeed | 4 | 4 | 3 | 9 | 17993 s - 4,99 hs | **3,42** |
| intspeed | 8 | 8 | 3 | 10 | 18438 s – 5,12 hs | **3,35** |
| intspeed | 16 | 16 | 3 | 10 | 32523 s - 9,03 hs | **1,96** |
| intrate | 4 | 4 | 3 | 10 | 38073 s - 10,57 hs | **5,32** |
| intrate | 8 | 8 | 3 | 9 | 65121 s – 18,08 hs | **5,03** |
| fpspeed | 4 | 4 | 3 | 9 | 79708 s - 22,14 hs | **3,11** |
| fprate | 4 | 4 | 3 | 13 | 58396 s - 16,22 hs | **6,25** |
| fprate | 8 | 1 | 3 | 14 |  |  |
| Duração total das execuções | | | | | ~~310252 s - 86.18 hs~~ |  |

Tabela 1. Suites executadas na ferramenta SPEC CPU 2017 com seus parâmetros da execução, o tempo de execução e a métrica final da execução.

A Tabela 2 apresenta a comparação do computador utilizado no experimento (Laptop Rubens) e outros computadores selecionados da lista de resultados disponível no site do SPEC CPU 2017 (<https://www.spec.org/cpu2017/results/cpu2017.html>). Os computadores selecionados são aqueles que mais se aproximam das características do computador “Laptop Rubens” a fim de que as comparações das métricas finais possam ser equilibradas e justas.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Suite** | **Threads** | **Métrica obtida do Laptop Rubens** | **Outros computadores** | **Métrica** |
| intspeed | 4 | int\_base: 3,42 | SuperWorkstation 5039C-T (X11SCA , Intel Core i3-8100) | int\_base: 7,58 |
| intspeed | 8 | Int\_base: 3,35 | SuperWorkstation 5039C-T (X11SCA , Intel Core i7-9700K) | int\_base: 10,6 |
| intspeed | 16 | int\_base: 1,96 | Não localizado computador equivalente com thread = 16 | --- |
| intrate | 4 | int\_base: 5,32 | ASUS Z170M-PLUS Motherboard (Intel Core i7-6700K) | int\_base: 23,5 |
| intrate | 8 | int\_base: 5,03 | SuperWorkstation 5039C-T (X11SCA , Intel Core i7-9700K) | int\_base: 44,8 |
| fpspeed | 4 | fp\_base: 3,11 | SuperWorkstation 5039C-T (X11SCA , Intel Core i7-9700K) | fp\_base: 32,2 |
| fprate | 4 | fp\_base: 6,25 | SuperWorkstation 5039C-T (X11SCA , Intel Core i7-9700K) | fp\_base: 42,6 |
| fprate | 8 | fp\_base: ??,?? | SuperWorkstation 5039C-T (X11SCA , Intel Core i7-9700K) | fp\_base: 42,6 |

Tabela 2. Comparação das métricas dos benchmarks executados no laptop Rubens e outros computadores.

A Tabela 3 apresenta os comandos com os parâmetros utilizados na execução de cada uma das suítes.

|  |  |
| --- | --- |
| **Suíte** | **Comando para execução do SPEC CPU 2017** |
| intspeed | runcpu --config=rubens-try1 --noreportable --iterations=3 600.perlbench\_s 602.gcc\_s 605.mcf\_s 620.omnetpp\_s 623.xalancbmk\_s 625.x264\_s 631.deepsjeng\_s 641.leela\_s 648.exchange2\_s 998.specrand\_is |
| intrate | runcpu --config=rubens-try1 --reportable --iterations=3 intrate |
| fpspeed | runcpu --config=rubens-try1 --noreportable --iterations=3 603.bwaves\_s 607.cactuBSSN\_s 619.lbm\_s 621.wrf\_s 628.pop2\_s 638.imagick\_s 644.nab\_s 649.fotonik3d\_s 654.roms\_s 996.specrand\_fs |
| fprate | runcpu --config=rubens-try1 --reportable --iterations=3 fprate |

Tabela 3. Comandos SPEC CPU 2017 executados para as suites inspeed, intrate, fpspeed e fprate.

## Simulador multi-core Sniper \*

……

A Tabela 4 apresenta os comandos utilizados na execução dos programas bem como a indicação dos arquivos de resultados.

|  |  |  |
| --- | --- | --- |
| **Comando para execução do programa** | **Resultado** | **Arquivo com o resultado da execução** |
| make run > sniper-result-api.txt | sucesso | sniper-result-api.txt |
| make run > sniper-result-dvfs.txt | sucesso | sniper-result-dvfs.txt |
| make run > sniper-result-fft.txt | sucesso | sniper-result-fft.txt |
| make run > sniper-result-fft-dvfs.txt | sucesso | sniper-result-fft-dvfs.txt |
| make run > sniper-result-fft-hetero.txt | sucesso | sniper-result-fft-hetero.txt |
| make run > sniper-result-fft-hetero-cfg.txt | erro | sniper-result-fft-hetero-cfg.txt |
| make run > sniper-result-fft-marker.txt | erro | sniper-result-fft-marker.txt |
| make run > sniper-result-fork.txt | sucesso | sniper-result-fork.txt |
| make run > sniper-result-shared.txt | sem programa fonte | sniper-result-shared.txt |
| make run > sniper-result-signal.txt | erro | sniper-result-signal.txt |
| make run > sniper-result-smc.txt | erro | sniper-result-smc.txt |
| make run > sniper-result-sniper-in-sniper.txt | erro | sniper-result-sniper-in-sniper.txt |
| make run > sniper-result-spinloop.txt | sucesso | sniper-result-spinloop.txt |
| make run > sniper-result-true.txt | sucesso | sniper-result-true.txt |
|  |  |  |
| **Programas adicionais na pasta "extra\_programs"** | | |
| ../../run-sniper ./RADIX > sniper-result-radix.txt | sucesso | sniper-result-RADIX |
| ../../run-sniper ./CHOLESKY tk14.0 > sniper-result-cholesky.txt | sucesso | sniper-result-CHOLESKY |

Tabela 4. Comandos Sniper executados nos benchmarks do experimento.

Programas selecionados para uso avaliação mais detalhada.

|  |  |  |  |
| --- | --- | --- | --- |
| **Programas selecionados** | **Tempo de execução no simulador Snipe “Total Time”**  **(TSni)** | **Tempo de execução nativo “Total Time”**  **(TNat)** | **Slowndown de simulação**  **(TSni / TNat)** |
| radix | 2430 ms | 2585 ms | 0,940 |
| cholesky | 2946 ms | 5084 ms | 0,579 |
| fft | 248 ms | 376 ms | 0,659 |

* Apresentar algumas métricas de desempenho coletadas pelo simulador Sniper.
  + Start time : -1844408187
  + Initialization finish time : -1844371499
  + Overall finish time : -1844369069
  + Total time with initialization : 39118
  + Total time without initialization : 2430

|  |  |
| --- | --- |
| **Programas selecionados** | **Sniper** |
| Radix – Sniper | PROCESS STATISTICS  Total Rank Sort  Proc Time Time Time  0 2430 1115 1315  TIMING INFORMATION  Start time : -1844408187  Initialization finish time : -1844371499  Overall finish time : -1844369069  Total time with initialization : 39118  Total time without initialization : 2430 |
| Radix – Native | PROCESS STATISTICS  Total Rank Sort  Proc Time Time Time  0 2585 742 1840  TIMING INFORMATION  Start time : 1102732390  Initialization finish time : 1102761743  Overall finish time : 1102764328  Total time with initialization : 31938  Total time without initialization : 2585 |
| cholesky |  |
| cholesky |  |
| Fft – Sniper | PROCESS STATISTICS  Computation Transpose Transpose  Proc Time Time Fraction  0 248 28 0.11290  TIMING INFORMATION  Start time : -1844408306  Initialization finish time : -1844407925  Overall finish time : -1844407677  Total time with initialization : 629  Total time without initialization : 248  Overall transpose time : 28  Overall transpose fraction : 0.11290 |
| Fft – Native | PROCESS STATISTICS  Computation Transpose Transpose  Proc Time Time Fraction  0 376 61 0.16223  TIMING INFORMATION  Start time : -1988961673  Initialization finish time : -1988961469  Overall finish time : -1988961093  Total time with initialization : 580  Total time without initialization : 376  Overall transpose time : 61  Overall transpose fraction : 0.16223 |

## Perf profiler \*

Perf profiler é uma ferramenta Linux que coleta e analisa dados de desempenho de programas ou do sistema operacional.

Os programas selecionados para avaliação são: fft, fork, signal, smc e true.

A Tabela 5 apresenta os comandos com os parâmetros utilizados na execução de cada um dos programas selecionados.

|  |  |
| --- | --- |
| **Programa** | **Comando de execução** |
| fft | perf stat -B ./fft |
| **Resultado da Execução** | |
| FFT with Blocking Transpose  1024 Complex Doubles  1 Processors  65536 Cache lines  16 Byte line size  4096 Bytes per page  PROCESS STATISTICS  Computation Transpose Transpose  Proc Time Time Fraction  0 303 61 0.20132  TIMING INFORMATION  Start time : 695908542  Initialization finish time : 695908777  Overall finish time : 695909080  Total time with initialization : 538  Total time without initialization : 303  Overall transpose time : 61  Overall transpose fraction : 0.20132  Performance counter stats for './fft':  1.06 msec task-clock # 0.746 CPUs utilized  0 context-switches # 0.000 /sec  0 cpu-migrations # 0.000 /sec  62 page-faults # 58.701 K/sec  2540158 cycles # 2.405 GHz  1814472 stalled-cycles-frontend # 71.43% frontend cycles idle  1042654 stalled-cycles-backend # 41.05% backend cycles idle  2132716 instructions # 0.84 insn per cycle  # 0.85 stalled cycles per insn  195210 branches # 184.823 M/sec  6000 branch-misses # 3.07% of all branches  0.001415500 seconds time elapsed  0.001717000 seconds user  0.000000000 seconds sys | |
| **Programa** | **Comando de execução** |
| fft | perf stat -B ./fft if=/dev/zero of=/dev/null count=1000000 |
| **Resultado da Execução** | |
| FFT with Blocking Transpose  1024 Complex Doubles  1 Processors  65536 Cache lines  16 Byte line size  4096 Bytes per page  PROCESS STATISTICS  Computation Transpose Transpose  Proc Time Time Fraction  0 335 59 0.17612  TIMING INFORMATION  Start time : 760328360  Initialization finish time : 760328587  Overall finish time : 760328922  Total time with initialization : 562  Total time without initialization : 335  Overall transpose time : 59  Overall transpose fraction : 0.17612  Performance counter stats for './fft if=/dev/zero of=/dev/null count=1000000':  1.01 msec task-clock # 0.731 CPUs utilized  0 context-switches # 0.000 /sec  0 cpu-migrations # 0.000 /sec  62 page-faults # 61.198 K/sec  2561675 cycles # 2.529 GHz  1839401 stalled-cycles-frontend # 71.80% frontend cycles idle  1031193 stalled-cycles-backend # 40.25% backend cycles idle  2135867 instructions # 0.83 insn per cycle  # 0.86 stalled cycles per insn  195848 branches # 193.316 M/sec  5650 branch-misses # 2.88% of all branches  0.001386500 seconds time elapsed  0.001920000 seconds user  0.000000000 seconds sys | |
| **Programa** | **Comando de execução** |
| fork | perf stat -B ./fork |
| **Resultado da Execução** | |
| Hello world from parent  Hello world from child  Performance counter stats for './fork':  0.94 msec task-clock # 0.045 CPUs utilized  2 context-switches # 2.139 K/sec  0 cpu-migrations # 0.000 /sec  55 page-faults # 58.811 K/sec  1820753 cycles # 1.947 GHz  1528003 stalled-cycles-frontend # 83.92% frontend cycles idle  1222034 stalled-cycles-backend # 67.12% backend cycles idle  578101 instructions # 0.32 insn per cycle  # 2.64 stalled cycles per insn  118406 branches # 126.610 M/sec  6079 branch-misses # 5.13% of all branches  0.020806800 seconds time elapsed  0.001550000 seconds user  0.000000000 seconds sys | |
| **Programa** | **Comando de execução** |
| signal | perf stat -B ./signal |
| **Resultado da Execução** | |
| Installing signal handler  Dereferencing NULL pointer  Received signal 11  Performance counter stats for './signal':  0.45 msec task-clock # 0.545 CPUs utilized  0 context-switches # 0.000 /sec  0 cpu-migrations # 0.000 /sec  30 page-faults # 66.800 K/sec  978289 cycles # 2.178 GHz  798099 stalled-cycles-frontend # 81.58% frontend cycles idle  634507 stalled-cycles-backend # 64.86% backend cycles idle  350129 instructions # 0.36 insn per cycle  # 2.28 stalled cycles per insn  70957 branches # 157.998 M/sec  3626 branch-misses # 5.11% of all branches  0.000824699 seconds time elapsed  0.000910000 seconds user  0.000000000 seconds sys | |
| **Programa** | **Comando de execução** |
| smc | perf stat -B ./smc |
| **Resultado da Execução** | |
| Good morning!  Performance counter stats for './smc':  0.47 msec task-clock # 0.588 CPUs utilized  0 context-switches # 0.000 /sec  0 cpu-migrations # 0.000 /sec  29 page-faults # 61.259 K/sec  1070708 cycles # 2.262 GHz  842947 stalled-cycles-frontend # 78.73% frontend cycles idle  621900 stalled-cycles-backend # 58.08% backend cycles idle  493319 instructions # 0.46 insn per cycle  # 1.71 stalled cycles per insn  92454 branches # 195.298 M/sec  3768 branch-misses # 4.08% of all branches  0.000805700 seconds time elapsed  0.000894000 seconds user  0.000000000 seconds sys | |
| **Programa** | **Comando de execução** |
| true | perf stat -B ./true |
| **Resultado da Execução** | |
| Performance counter stats for './true':  0.48 msec task-clock # 0.548 CPUs utilized  0 context-switches # 0.000 /sec  0 cpu-migrations # 0.000 /sec  28 page-faults # 58.700 K/sec  855835 cycles # 1.794 GHz  697077 stalled-cycles-frontend # 81.45% frontend cycles idle  536036 stalled-cycles-backend # 62.63% backend cycles idle  323449 instructions # 0.38 insn per cycle  # 2.16 stalled cycles per insn  64571 branches # 135.369 M/sec  3028 branch-misses # 4.69% of all branches  0.000870500 seconds time elapsed  0.000992000 seconds user  0.000000000 seconds sys | |

Tabela 5. Comandos Perf profiler executados nos programas selecionados no experimento.

* Incluir os programas RADIX e
* perf stat -B ./RADIX
* perf stat -B ./CHOLESKY tk14.O
* Extrair as mesmas métricas do Sniper de forma nativa
* Comparar as métricas do Perf com as do Sniper
* Justificar as diferenças

## PARSEC Benchmark Suite 3.0 \*

O PARSEC (*Princeton Application Repository for Shared-Memory Computers*) é um conjunto de benchmark composto por programas *multithread* com o propósito de possibilitar estudos de desempenho em computadores com múltiplos processadores.

A Tabela 6 apresenta a compilação dos pacotes de benchmark oferecidos no PARSEC com o resultado indicando sucesso ou os erros apresentados no processo de compilação (build).

|  |  |  |
| --- | --- | --- |
| **Pacote** | **Comando para compilação** | **Resultado** |
| blackscholes | parsecmgmt -a build -p blackscholes | Compilou com sucesso. |
| bodytrack | parsecmgmt -a build -p bodytrack | Compilou com sucesso. |
| facesim | parsecmgmt -a build -p facesim | make[2]: \*\*\* [/usr/local/parsec-3.0/pkgs/apps/facesim/obj/amd64-linux.gcc/Public\_Library/Makefile.common:407: obj/Collisions\_And\_Interactions/COLLISION\_BODY\_LIST\_3D.o] Error 1  make[2]: Leaving directory '/usr/local/parsec-3.0/pkgs/apps/facesim/obj/amd64-linux.gcc/Public\_Library'  make[1]: \*\*\* No rule to make target '/usr/local/parsec-3.0/pkgs/apps/facesim/obj/amd64-linux.gcc/lib/libPhysBAM.a', needed by 'facesim'. Stop.  make[1]: Leaving directory '/usr/local/parsec-3.0/pkgs/apps/facesim/obj/amd64-linux.gcc/Benchmarks/facesim'  make: \*\*\* [Makefile:16: all] Error 2  [PARSEC] Error: 'env version=pthreads PHYSBAM=/usr/local/parsec-3.0/pkgs/apps/facesim/obj/amd64-linux.gcc CXXFLAGS=-O3 -g -funroll-loops -fprefetch-loop-arrays -fpermissive -fno-exceptions -std=c++11 -static-libgcc -Wl,--hash-style=both,--as-needed -DPARSEC\_VERSION=3.0-beta-20150206 -fexceptions /usr/bin/make' failed. |
| ferret | parsecmgmt -a build -p ferret | make: \*\*\* [Makefile:108: /usr/local/parsec-3.0/pkgs/apps/ferret/obj/amd64-linux.gcc/parsec/obj/LSH\_query.o] Error 1  [PARSEC] Error: 'env version=pthreads CFLAGS=-I/usr/local/parsec-3.0/pkgs/libs/gsl/inst/amd64-linux.gcc/include -I/usr/local/parsec-3.0/pkgs/libs/libjpeg/inst/amd64-linux.gcc/include -O3 -g -funroll-loops -fprefetch-loop-arrays -static-libgcc -Wl,--hash-style=both,--as-needed -DPARSEC\_VERSION=3.0-beta-20150206 LDFLAGS=-L/usr/local/parsec-3.0/pkgs/libs/gsl/inst/amd64-linux.gcc/lib -L/usr/local/parsec-3.0/pkgs/libs/libjpeg/inst/amd64-linux.gcc/lib -L/usr/lib64 -L/usr/lib /usr/bin/make' failed. |
| fluidanimate | parsecmgmt -a build -p fluidanimate | Compilou com sucesso. |
| freqmine | parsecmgmt -a build -p freqmine | Compilou com sucesso. |
| raytrace | parsecmgmt -a build -p raytrace | No package 'xext' found  Consider adjusting the PKG\_CONFIG\_PATH environment variable if you  installed software in a non-standard prefix.  Alternatively, you may set the environment variables XLIBGL\_CFLAGS  and XLIBGL\_LIBS to avoid the need to call pkg-config.  See the pkg-config man page for more details.  [PARSEC] Error: 'env ./configure --with-driver=xlib --enable-glut --enable-static --disable-shared --prefix=/usr/local/parsec-3.0/pkgs/libs/mesa/inst/amd64-linux.gcc' failed. |
| swaptions | parsecmgmt -a build -p swaptions | | ^~~~~~  make[1]: \*\*\* [../../build/Makefile.tbbmalloc:70: proxy.o] Error 1  make[1]: Leaving directory '/usr/local/parsec-3.0/pkgs/libs/tbblib/obj/amd64-linux.gcc/build/linux\_intel64\_gcc\_cc11.3.0\_libc2.35\_kernel5.15.90.1\_debug'  make: \*\*\* [Makefile:49: tbbmalloc] Error 2  [PARSEC] Error: 'env compiler=gcc PATH=/usr/bin:/usr/local/parsec-3.0/bin:/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin:/snap/bin:/usr/local/parsec-3.0/bin CXXFLAGS=-O3 -g -funroll-loops -fprefetch-loop-arrays -fpermissive -fno-exceptions -static-libgcc -Wl,--hash-style=both,--as-needed -DPARSEC\_VERSION=3.0-beta-20150206 -fexceptions /usr/bin/make' failed. |
| vips | parsecmgmt -a build -p vips | Compilou com sucesso. |

Tabela 6. Resultado da compilação dos pacotes do PARSEC.

O PARSEC possibilita definir a região de interesse (ROI – *Region Of Interest*) baseada em seis tipos de entrada possíveis na execução dos benchmarks. As entradas são: test, simdev, simsmall, simmedium, simlarge e native.

Os testes realizados no experimento utilizaram todas as entradas nos benchmarks executados, cujos comandos de execução a indicação dos resultados são apresentados na Tabela 7 que segue. As saídas da execução estão armazenadas nos arquivos com extensão “txt”.

EXPLORAR O PARALELISMO –N

parsecmgmt -a run -p fluidanimate -i native -n 16

parsecmgmt -a run -p blackscholes -i native -n 16

parsecmgmt -a run -p freqmine -i native -n 16

parsecmgmt -a run -p vips -i native -n 16

parsecmgmt -a run -p fluidanimate -i native -n 8

parsecmgmt -a run -p blackscholes -i native -n 8

parsecmgmt -a run -p freqmine -i native -n 8

parsecmgmt -a run -p vips -i native -n 8

parsecmgmt -a run -p fluidanimate -i native -n 4

parsecmgmt -a run -p blackscholes -i native -n 4

parsecmgmt -a run -p freqmine -i native -n 4

parsecmgmt -a run -p vips -i native -n 4

parsecmgmt -a run -p fluidanimate -i native -n 2

parsecmgmt -a run -p blackscholes -i native -n 2

parsecmgmt -a run -p freqmine -i native -n 2

parsecmgmt -a run -p vips -i native -n 2

parsecmgmt -a run -p fluidanimate -i native

parsecmgmt -a run -p blackscholes -i native

parsecmgmt -a run -p freqmine -i native

parsecmgmt -a run -p vips -i native

|  |  |  |  |
| --- | --- | --- | --- |
| **Núm. da Execução** | **Pacote** | **Entrada** | **Comando de execução do pacote de Benchmark** |
| 001 | blackscholes | test | parsecmgmt -a run -p blackscholes -i test > result/exec-001-blackscholes-test.txt |
| 002 | blackscholes | simdev | parsecmgmt -a run -p blackscholes -i simdev > result/exec-002-blackscholes-simdev.txt |
| 003 | blackscholes | simsmall | parsecmgmt -a run -p blackscholes -i simsmall > result/exec-003-blackscholes-simsmall.txt |
| 004 | blackscholes | simlarge | parsecmgmt -a run -p blackscholes -i simlarge > result/exec-004-blackscholes-simlarge.txt |
| 005 | blackscholes | native | parsecmgmt -a run -p blackscholes -i native > result/exec-005-blackscholes-native.txt |
| 006 | vips | test | parsecmgmt -a run -p vips -i test > result/exec-006-vips-test.txt |
| 007 | vips | simdev | parsecmgmt -a run -p vips -i simdev > result/exec-007-vips-simdev.txt |
| 008 | vips | simsmall | parsecmgmt -a run -p vips -i simsmall > result/exec-008-vips-simsmall.txt |
| 009 | vips | simlarge | parsecmgmt -a run -p vips -i simlarge > result/exec-009-vips-simlarge.txt |
| 010 | vips | native | parsecmgmt -a run -p vips -i native > result/exec-010-vips-native.txt |
| 011 | bodytrack | test | parsecmgmt -a run -p bodytrack -i test > result/exec-011-bodytrack-test.txt |
| 012 | bodytrack | simdev | parsecmgmt -a run -p bodytrack -i simdev > result/exec-012-bodytrack-simdev.txt |
| 013 | bodytrack | simsmall | parsecmgmt -a run -p bodytrack -i simsmall > result/exec-013-bodytrack-simsmall.txt |
| 014 | bodytrack | simlarge | parsecmgmt -a run -p bodytrack -i simlarge > result/exec-014-bodytrack-simlarge.txt |
| 015 | bodytrack | native | parsecmgmt -a run -p bodytrack -i native > result/exec-015-bodytrack-native.txt |
| 016 | fluidanimate | test | parsecmgmt -a run -p fluidanimate -i test > result/exec-016-fluidanimate-test.txt |
| 017 | fluidanimate | simdev | parsecmgmt -a run -p fluidanimate -i simdev > result/exec-017-fluidanimate-simdev.txt |
| 018 | fluidanimate | simsmall | parsecmgmt -a run -p fluidanimate -i simsmall > result/exec-018-fluidanimate-simsmall.txt |
| 019 | fluidanimate | simlarge | parsecmgmt -a run -p fluidanimate -i simlarge > result/exec-019-fluidanimate-simlarge.txt |
| 020 | fluidanimate | native | parsecmgmt -a run -p fluidanimate -i native > result/exec-020-fluidanimate-native.txt |
| 021 | freqmine | test | parsecmgmt -a run -p freqmine -i test > result/exec-021-freqmine-test.txt |
| 022 | freqmine | simdev | parsecmgmt -a run -p freqmine -i simdev > result/exec-022-freqmine-simdev.txt |
| 023 | freqmine | simsmall | parsecmgmt -a run -p freqmine -i simsmall > result/exec-023-freqmine-simsmall.txt |
| 024 | freqmine | simlarge | parsecmgmt -a run -p freqmine -i simlarge > result/exec-024-freqmine-simlarge.txt |
| 025 | freqmine | native | parsecmgmt -a run -p freqmine -i native > result/exec-025-freqmine-native.txt |
| 026 | splash2 | test | parsecmgmt -a run -p splash2 -i test > result/exec-026-splash2-test.txt |
| 027 | splash2 | simdev | parsecmgmt -a run -p splash2 -i simdev > result/exec-027-splash2-simdev.txt |
| 028 | splash2 | simsmall | parsecmgmt -a run -p splash2 -i simsmall > result/exec-028-splash2-simsmall.txt |
| 029 | splash2 | simlarge | parsecmgmt -a run -p splash2 -i simlarge > result/exec-029-splash2-simlarge.txt |
| 030 | splash2 | native | parsecmgmt -a run -p splash2 -i native > result/exec-030-splash2-native.txt |
| 031 | splash2x | test | parsecmgmt -a run -p splash2x -i test > result/exec-031-splash2x-test.txt |
| 032 | splash2x | simdev | parsecmgmt -a run -p splash2x -i simdev > result/exec-032-splash2x-simdev.txt |
| 033 | splash2x | simsmall | parsecmgmt -a run -p splash2x -i simsmall > result/exec-033-splash2x-simsmall.txt |
| 034 | splash2x | simlarge | parsecmgmt -a run -p splash2x -i simlarge > result/exec-034-splash2x-simlarge.txt |
| 035 | splash2x | native | parsecmgmt -a run -p splash2x -i native > result/exec-035-splash2x-native.txt |

Tabela 7. Comandos PARSEC para execução dos benchmarks com as entradas possíveis.

Fazer um gráfico quatro aplicações, variando o valor de N no eixo X e o tempo real no Y. Usar N=1 a referencia (baseline)

## Rodinia benchmark \*

O Rodinia Benchmark é uma ferramenta destinada a infraestrutura de computação heterogênea com implementações com OpenMP, OpenCL e CUDA.

A Tabela 8 apresenta a lista dos programas que foram compilados com sucesso em cada implementação.

|  |  |  |
| --- | --- | --- |
| **CUDA (make CUDA)** | **OPENMP (make OMP)** | **OPENCL (make OPENCL)** |
| backprop | backprop | OCL\_particlefilter\_double |
| bfs | bfs | OCL\_particlefilter\_naive |
| dwt2d | euler3d\_cpu | OCL\_particlefilter\_single |
| gaussian | euler3d\_cpu\_double | backprop |
| heartwall | heartwall | gaussian |
| hotspot | hotspot | heartwall |
| kmeans | kmeans | hotspot |
| leukocyte | lavaMD | kmeans |
| needle | leukocyte | lavaMD |
| nn | lud\_omp | leukocyte |
| pathfinder | needle | lud |
| sc\_gpu | nn | nn |
| srad\_v1 | particle\_filter | nw |
| srad\_v2 | pathfinder | srad |
|  | pre\_euler3d\_cpu |  |
|  | pre\_euler3d\_cpu\_double |  |
|  | sc\_omp |  |
|  | srad\_v1 |  |
|  | srad\_v2 |  |

Tabela 8. Lista de programas que foram compilados com sucesso no ambiente da ferramenta Rodinia Benchmark.

A Tabela 9 apresenta a execução de benchmarks com alguns resultados detalhados ou o nome do arquivo de resultado devido ao seu tamanho excessivo.

|  |  |  |
| --- | --- | --- |
| **Implementação** | **Benchmark** | **Resultado** |
| OPENMP | bfs | result.txt |
| OPENMP | cfd (euler3d) | 409.637 segundos  root@NotebookRubens:/usr/local/rodinia\_3.1/openmp/cfd# ./run  Starting...  Compute time: 409.637  Saving solution...  Saved solution...  Cleaning up...  Done... |
| OPENMP | heartwall | result.txt |
| OPENMP | hotspot | output.out |
| OPENMP | kmeans | root@NotebookRubens:/usr/local/rodinia\_3.1/openmp/kmeans# ./run  ./run: line 1: ./kmeans\_serial/kmeans: No such file or directory  I/O completed  num of threads = 4  number of Clusters 5  number of Attributes 34  Time for process: 4.266001 |
| OPENMP | lavaMD | root@NotebookRubens:/usr/local/rodinia\_3.1/openmp/lavaMD# ./run  Configuration used: cores = 4, boxes1d = 10  Time spent in different stages of CPU/MCPU KERNEL:  0.000000000000 s, 0.000000000000 % : CPU/MCPU: VARIABLES  0.000014000000 s, 0.000279933040 % : MCPU: SET DEVICE  0.000000000000 s, 0.000000000000 % : CPU/MCPU: INPUTS  5.001182079315 s, 99.999717712402 % : CPU/MCPU: KERNEL  Total time:  5.001195907593 s |
| OPENMP | leukocyte | root@NotebookRubens:/usr/local/rodinia\_3.1/openmp/leukocyte# ./run  Num of threads: 4  Detecting cells in frame 0  Cells detected: 36  Detection runtime  -----------------  GICOV computation: 0.52551 seconds  GICOV dilation: 0.21413 seconds  Total: 0.79247 seconds  Tracking cells across 5 frames  Processing frame 5 / 5  Tracking runtime (average per frame):  ------------------------------------  MGVF computation: 14.68158 seconds  Snake evolution: 0.02456 seconds  Total: 4.09308 seconds  Total application run time: 21.25787 seconds |
| OPENMP | nn | root@NotebookRubens:/usr/local/rodinia\_3.1/openmp/nn# ./run  The 5 nearest neighbors are:  1974 12 22 18 24 JOYCE 30.6 89.9 80 593 --> 0.608276  2003 8 27 12 10 TONY 29.9 89.4 160 286 --> 0.608275  1997 11 14 12 24 HELENE 30.5 89.8 134 529 --> 0.538515  1980 10 22 18 3 ISAAC 30.1 90.4 110 778 --> 0.412312  1988 12 27 0 18 TONY 30.0 89.8 113 39 --> 0.199997  total time : 0.527607023716 s |
| OPENMP | particle\_filter | Result.txt |
| OPENMP | pathfinder | o.out |
| OPENMP | srad\_v1 | root@NotebookRubens:/usr/local/rodinia\_3.1/openmp/srad/srad\_v1# ./run  Time spent in different stages of the application:  0.000000000000 s, 0.000000000000 % : SETUP VARIABLES  0.000021000000 s, 0.001276622177 % : READ COMMAND LINE PARAMETERS  0.131821006536 s, 8.013600349426 % : READ IMAGE FROM FILE  0.002430000110 s, 0.147723421454 % : RESIZE IMAGE  0.000082999999 s, 0.005045697093 % : SETUP, MEMORY ALLOCATION  0.016366999596 s, 0.994974911213 % : EXTRACT IMAGE  1.328287959099 s, 80.748657226562 % : COMPUTE  0.005131000187 s, 0.311921358109 % : COMPRESS IMAGE  0.160110995173 s, 9.733392715454 % : SAVE IMAGE INTO FILE  0.000714000023 s, 0.043405152857 % : FREE MEMORY  Total time: 1.644966006279 s |
| OPENMP | srad\_v2 | root@NotebookRubens:/usr/local/rodinia\_3.1/openmp/srad/srad\_v2# ./run  Randomizing the input matrix  Start the SRAD main loop  Computation Done |

Tabela 9. Benchmarks executados com os resultados.

A Tabela 10 apresenta comparações de alguns benchmarks que foram executados nas três implementações CUDA, OpenMP e OpenCL.

|  |  |  |
| --- | --- | --- |
| **Comparação de Benchmarks entre as Implementações CUDA, OpenMP e OpenCL** | | |
| **Hotspot** | | |
| **CUDA** | **OpenMP** | **OpenCL** |
| root@NotebookRubens:/usr/local/rodinia\_3.1/cuda/hotspot# ./run  WG size of kernel = 16 X 16  pyramidHeight: 2  gridSize: [512, 512]  border:[2, 2]  blockGrid:[43, 43]  targetBlock:[12, 12]  Start computing the transient temperature  Ending simulation | root@NotebookRubens:/usr/local/rodinia\_3.1/openmp/hotspot# ./run  Start computing the transient temperature  Ending simulation  Total time: 0.045 seconds | Erro de execução |
| **BFS** | | |
| **CUDA** | **OpenMP** | **OpenCL** |
| root@NotebookRubens:/usr/local/rodinia\_3.1/cuda/bfs# ./run  Reading File  Read File  Copied Everything to GPU memory  Start traversing the tree  Kernel Executed 1 times  Result stored in result.txt >> 1.000.000 lines | root@NotebookRubens:/usr/local/rodinia\_3.1/openmp/bfs# ./run  Reading File  Start traversing the tree  Compute time: 0.633491  Result stored in result.txt >> 1.000.000 lines | Erro de compilação |
| **HeartWall** | | |
| **CUDA** | **OpenMP** | **OpenCL** |
| root@NotebookRubens:/usr/local/rodinia\_3.1/cuda/heartwall# ./run  WG size of kernel = 256  frame progress: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19  Resultados no arquivo result.txt | root@NotebookRubens:/usr/local/rodinia\_3.1/openmp/heartwall# ./run  num of threads: 4  frame progress: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19  Resultados no arquivo result.txt | Erro de execução |
| **particlefilter** | | |
| **CUDA** | **OpenMP** | **OpenCL** |
| Erro de compilação | video sequence took 0.043539  time to get neighbors took: 0.000005  time to get weightstook: 0.014813  time to set arrays took: 0.000106  time to set error took: 0.000682  time to get likelihoods took: 0.002394  time to get exp took: 0.000109  time to sum weights took: 0.000008  time to normalize weights took: 0.000004  time to move object took: 0.000008  xe: 64.523185  ye: 64.469547  0.702991  ...  time to calc cum sum took: 0.000033  time to calc u took: 0.011697  time to calc new array x and y took: 0.061382  time to reset weights took: 0.000047  time to set error took: 0.006374  time to get likelihoods took: 0.008245  time to get exp took: 0.011114  time to sum weights took: 0.011051  time to normalize weights took: 0.008430  time to move object took: 0.016451  xe: 48.546698  ye: 72.385056  17.581630  time to calc cum sum took: 0.000034  time to calc u took: 0.013806  time to calc new array x and y took: 0.053608  time to reset weights took: 0.000045  particle filter took 0.937339  entire program took 0.980878 | root@notebookrubens:/usr/local/rodinia\_3.1/opencl/particlefilter# ./run  video sequence took 0.063222  error: clgetplatformids(1,\*,0) failed  particle filter took 0.694592  entire program took 0.757814  video sequence took 0.031961  error: clgetplatformids(1,\*,0) failed  particle filter took 0.632983  entire program took 0.664944 |

Tabela 10. Comparação de benchmarks nas três implementações CUDA, OpenMP e OpenCL.

* Se tiver hardware suficiente, rodar as múltiplas versões do programa e comparar o desempenho no mesmo computador.
* Para múltiplas configurações do mesmo programa, indicar as diferenças de desempenho.
* Executar o Rodínia nos três programas abaixo e comparar o desempenho:
  + RADIX
  + CHOLESKY
  + FFT

## Intel Pin

* Aguardando definição dos 3 programas para experimentos posteriores
* Executar o Pin nos três programas abaixo e comparar o desempenho utilizando a ferramenta do “PinTools” (opcodemix) aplicado aos três programas abaixo
  + RADIX
  + CHOLESKY
  + FFT

## Dinero cache simulator

A ferramenta Dinero é um simulador de cache de 4ª geração de simuladores.

Os programas utilizados nessa ferramenta foram o RADIX e o fft. Vários parâmetros foram avaliados considerando valores distintos para cache L1 (instrução e data), combinados com cache L2 e L3 (unificadas).

A Tabela 11 apresenta os comandos utilizados na execução dos programas RADIX e fft com os diversos parâmetros de execução relacionados às caches L1, L2 e L3.

|  |  |
| --- | --- |
| **Programa RADIX** | |
| **Comando de execução** | **Arquivo com o resultado da execução** |
| ./dineroIV-tar -l1-isize 1k -l1-dsize 1k -l1-ibsize 32 -l1-dbsize 32 -informat p < RADIX > dinero-result-RADIX-001.txt | dinero-result-RADIX-001.txt |
| ./dineroIV-tar -l1-isize 2k -l1-dsize 2k -l1-ibsize 16 -l1-dbsize 16 -informat p < RADIX > dinero-result-RADIX-002.txt | dinero-result-RADIX-002.txt |
| ./dineroIV-tar -l1-isize 4k -l1-dsize 4k -l1-ibsize 8 -l1-dbsize 8 -informat p < RADIX > dinero-result-RADIX-003.txt | dinero-result-RADIX-003.txt |
| ./dineroIV-tar -l1-isize 8k -l1-dsize 8k -l1-ibsize 4 -l1-dbsize 4 -informat p < RADIX > dinero-result-RADIX-004.txt | dinero-result-RADIX-004.txt |
| ./dineroIV-tar -l1-isize 16k -l1-dsize 16k -l1-ibsize 2 -l1-dbsize 2 -informat p < RADIX > dinero-result-RADIX-005.txt | dinero-result-RADIX-005.txt |
| ./dineroIV-tar -l1-isize 32k -l1-dsize 32k -l1-ibsize 1 -l1-dbsize 1 -informat p < RADIX > dinero-result-RADIX-006.txt | dinero-result-RADIX-006.txt |
| ./dineroIV-tar -l1-isize 1k -l1-dsize 1k -l1-ibsize 32 -l1-dbsize 32 -l1-iassoc 8 -l1-dassoc 8 -informat p < RADIX > dinero-result-RADIX-007.txt | dinero-result-RADIX-007.txt |
| ./dineroIV-tar -l1-isize 16k -l1-dsize 16k -l1-ibsize 2 -l1-dbsize 2 -l1-iassoc 8 -l1-dassoc 8 -informat p < RADIX > dinero-result-RADIX-008.txt | dinero-result-RADIX-008.txt |
| ./dineroIV-tar -l1-isize 32k -l1-dsize 32k -l1-ibsize 1 -l1-dbsize 1 -l1-iassoc 8 -l1-dassoc 8 -informat p < RADIX > dinero-result-RADIX-009.txt | dinero-result-RADIX-009.txt |
| ./dineroIV-tar -l1-isize 16k -l1-dsize 16k -l1-ibsize 2 -l1-dbsize 2 -l1-iassoc 8 -l1-dassoc 8 -l2-usize 512k -l2-ubsize 1 -informat p < RADIX > dinero-result-RADIX-010.txt | dinero-result-RADIX-010.txt |
| ./dineroIV-tar -l1-isize 16k -l1-dsize 16k -l1-ibsize 2 -l1-dbsize 2 -l1-iassoc 8 -l1-dassoc 8 -l2-usize 256k -l2-ubsize 2 -informat p < RADIX > dinero-result-RADIX-011.txt | dinero-result-RADIX-011.txt |
| ./dineroIV-tar -l1-isize 16k -l1-dsize 16k -l1-ibsize 2 -l1-dbsize 2 -l1-iassoc 8 -l1-dassoc 8 -l2-usize 128k -l2-ubsize 4 -informat p < RADIX > dinero-result-RADIX-012.txt | dinero-result-RADIX-012.txt |
| ./dineroIV-tar -l1-isize 16k -l1-dsize 16k -l1-ibsize 2 -l1-dbsize 2 -l1-iassoc 8 -l1-dassoc 8 -l2-usize 128k -l2-ubsize 4 -l2-uassoc 8 -l3-usize 1m -l3-ubsize 4 -l3-uassoc 8 -informat p < RADIX > dinero-result-RADIX-013.txt | dinero-result-RADIX-013.txt |
| ./dineroIV-tar -l1-isize 16k -l1-dsize 16k -l1-ibsize 2 -l1-dbsize 2 -l1-iassoc 8 -l1-dassoc 8 -l2-usize 128k -l2-ubsize 4 -l2-uassoc 8 -l3-usize 2m -l3-ubsize 4 -l3-uassoc 8 -informat p < RADIX > dinero-result-RADIX-014.txt | dinero-result-RADIX-014.txt |
| ./dineroIV-tar -l1-isize 16k -l1-dsize 16k -l1-ibsize 2 -l1-dbsize 2 -l1-iassoc 8 -l1-dassoc 8 -l2-usize 128k -l2-ubsize 4 -l2-uassoc 8 -l3-usize 4m -l3-ubsize 1 -l3-uassoc 8 -informat p < RADIX > dinero-result-RADIX-015.txt | dinero-result-RADIX-015.txt |
| **Programa FFT** | |
| **Comando de execução** | **Arquivo com o resultado da execução** |
| ./dineroIV-tar -l1-isize 1k -l1-dsize 1k -l1-ibsize 32 -l1-dbsize 32 -informat p < fft > dinero-result-fft-001.txt | dinero-result-fft-001.txt |
| ./dineroIV-tar -l1-isize 2k -l1-dsize 2k -l1-ibsize 16 -l1-dbsize 16 -informat p < fft > dinero-result-fft-002.txt | dinero-result-fft-002.txt |
| ./dineroIV-tar -l1-isize 4k -l1-dsize 4k -l1-ibsize 8 -l1-dbsize 8 -informat p < fft > dinero-result-fft-003.txt | dinero-result-fft-003.txt |
| ./dineroIV-tar -l1-isize 8k -l1-dsize 8k -l1-ibsize 4 -l1-dbsize 4 -informat p < fft > dinero-result-fft-004.txt | dinero-result-fft-004.txt |
| ./dineroIV-tar -l1-isize 16k -l1-dsize 16k -l1-ibsize 2 -l1-dbsize 2 -informat p < fft > dinero-result-fft-005.txt | dinero-result-fft-005.txt |
| ./dineroIV-tar -l1-isize 32k -l1-dsize 32k -l1-ibsize 1 -l1-dbsize 1 -informat p < fft > dinero-result-fft-006.txt | dinero-result-fft-006.txt |
| ./dineroIV-tar -l1-isize 1k -l1-dsize 1k -l1-ibsize 32 -l1-dbsize 32 -l1-iassoc 8 -l1-dassoc 8 -informat p < fft > dinero-result-fft-007.txt | dinero-result-fft-007.txt |
| ./dineroIV-tar -l1-isize 16k -l1-dsize 16k -l1-ibsize 2 -l1-dbsize 2 -l1-iassoc 8 -l1-dassoc 8 -informat p < fft > dinero-result-fft-008.txt | dinero-result-fft-008.txt |
| ./dineroIV-tar -l1-isize 32k -l1-dsize 32k -l1-ibsize 1 -l1-dbsize 1 -l1-iassoc 8 -l1-dassoc 8 -informat p < fft > dinero-result-fft-009.txt | dinero-result-fft-009.txt |
| ./dineroIV-tar -l1-isize 16k -l1-dsize 16k -l1-ibsize 2 -l1-dbsize 2 -l1-iassoc 8 -l1-dassoc 8 -l2-usize 512k -l2-ubsize 1 -informat p < fft > dinero-result-fft-010.txt | dinero-result-fft-010.txt |
| ./dineroIV-tar -l1-isize 16k -l1-dsize 16k -l1-ibsize 2 -l1-dbsize 2 -l1-iassoc 8 -l1-dassoc 8 -l2-usize 256k -l2-ubsize 2 -informat p < fft > dinero-result-fft-011.txt | dinero-result-fft-011.txt |
| ./dineroIV-tar -l1-isize 16k -l1-dsize 16k -l1-ibsize 2 -l1-dbsize 2 -l1-iassoc 8 -l1-dassoc 8 -l2-usize 128k -l2-ubsize 4 -informat p < fft > dinero-result-fft-012.txt | dinero-result-fft-012.txt |
| ./dineroIV-tar -l1-isize 16k -l1-dsize 16k -l1-ibsize 2 -l1-dbsize 2 -l1-iassoc 8 -l1-dassoc 8 -l2-usize 128k -l2-ubsize 4 -l2-uassoc 8 -l3-usize 1m -l3-ubsize 4 -l3-uassoc 8 -informat p < fft > dinero-result-fft-013.txt | dinero-result-fft-013.txt |
| ./dineroIV-tar -l1-isize 16k -l1-dsize 16k -l1-ibsize 2 -l1-dbsize 2 -l1-iassoc 8 -l1-dassoc 8 -l2-usize 128k -l2-ubsize 4 -l2-uassoc 8 -l3-usize 2m -l3-ubsize 4 -l3-uassoc 8 -informat p < fft > dinero-result-fft-014.txt | dinero-result-fft-014.txt |
| ./dineroIV-tar -l1-isize 16k -l1-dsize 16k -l1-ibsize 2 -l1-dbsize 2 -l1-iassoc 8 -l1-dassoc 8 -l2-usize 128k -l2-ubsize 4 -l2-uassoc 8 -l3-usize 4m -l3-ubsize 1 -l3-uassoc 8 -informat p < fft > dinero-result-fft-015.txt | dinero-result-fft-015.txt |

Tabela 11. Comandos Dinero para execução dos programas RADIX e FFT com variados parâmetros de execução relacionados às caches L1, L2 e L3.

# Considerações sobre o aprendizado nesse projeto

# Conclusões