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**Projeto 3**

**Experimentar ferramentas e coletar dados**

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# Introdução

Esse trabalho tem o propósito de utilizar algumas ferramentas de avaliação de arquitetura de computadores com a coleta de dados da execução de *benchmarks* e programas que exploram aspectos como tempo de processamento, número de instruções executadas e uso de memória RAM e cache. As ferramentas utilizadas foram SPEC CPU 2017, simulador multi-core Sniper, Perf profiler, Parsec benchmark, Rodinia benchmark, Intel Pin e Dinero cache simulator.

Os resultados obtidos na execução das ferramentas estão organizados no repositório Github por meio do link <https://github.com/rubenscp/RCP-MO601-Project-03>.

A Seção 2 apresenta o ambiente de experimentação, a Seção 3 detalhada a execução e resultados alcançados em cada ferramenta, a Seção 4 descreve considerações sobre o aprendizado neste projeto e a Seção 5 apresentas as conclusões do trabalho.

# Ambiente de Experimentação

O computador utilizado nesse trabalho será denominado como “Laptop Rubens” e o sistema operacional base é o Windows 10 Pro 22H2, contudo para a execução de todas as ferramentas foi utilizado o Windows Subsystem for Linux (WSL).

Os detalhes da configuração do Laptop Rubens são descritos a seguir:

* Notebook HP Pavilion dm4
* Memória RAM: 16 Gbytes
* SSD: 1 TBytes
* Sistema Operacional utilizado no Windows Subsystem for Linux:
  + 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 definidas previamente na especificação do projeto cujos detalhes de cada execução são apresentados nas próximas subseções.

## 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 indicando os parâmetros da execução, a duração da execução e a métrica final de execução produzida pela ferramenta. Os resultados detalhados desse experimento podem ser consultados na seção [SPEC CPPU 2017 do repositório Github](https://github.com/rubenscp/RCP-MO601-Project-03/tree/main/spec_cpu_2017/results%20laptop%20Rubens).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **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** |
| fpspeed | 4 | 8 | 3 | 9 | ???????????? | **??????** |
| fprate | 4 | 4 | 3 | 13 | 58396 s - 16,22 hs | **6,25** |
| fprate | 8 | 1 | 3 | 14 | 124885 s - 34,69 hs | **5,82** |
| Duração total das execuções | | | | | ~~435137 s – 120.87 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 das métricas produzidas no Laptop Rubens e de outros computadores selecionados a partir da lista de resultados disponíveis no site oficial da ferramenta 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 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 |
| fpspeed | 8 | fp\_base: ??? | 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: 5,82 | 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.

|  |  |
| --- | --- |
| **Suite** | **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 intspeed, intrate, fpspeed e fprate.

## Simulador multi-core Sniper \*

Sniper é uma ferramenta de simulação de código voltada para a modelagem e análise do desempenho de sistemas multi-core explorando o comportamento do sistema para sua otimização. Os experimentos exploraram os programas

A Tabela 4 apresenta os comandos utilizados na execução dos programas de teste que acompanham a ferramenta Sniper e o resultado da execução.

|  |  |  |
| --- | --- | --- |
| **Comando para execução do programa** | **Resultado da execução do programa** | **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 testados** | | |
| ../../run-sniper ./RADIX > sniper-result-radix.txt | sucesso | sniper-result-RADIX |
| ../../run-sniper ./CHOLESKY tk14.0 > sniper-result-cholesky.txt  **Como executar CHOLESKY no Sniper passando o parâmetro tk14.0?** | ???? | sniper-result-CHOLESKY |

Tabela 4. Comandos Sniper executados nos benchmarks do experimento.

Os resultados detalhados desse experimento podem ser consultados na seção [Sniper do repositório Github](https://github.com/rubenscp/RCP-MO601-Project-03/tree/main/sniper).

A Tabela 5 indica os três programas selecionados com os tempos de execução nativo e pelo simulador Sniper e o cálculo do slowdown de simulação. A Tabela 6 apresenta outras métricas produzidas pelo Sniper.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Programas selecionados** | **Número de instruções** | **Tempo de execução no simulador Sniper “Total Time”**  **(TSni)** | **Tempo de execução nativo “Total Time”**  **(TNat)** | **Slowdown de simulação**  **(TSni / TNat)** |
| radix | 49038672 | 2430 ms | 2585 ms | **0,940** |
| cholesky | 47292015 | **Verificar a execução simulado pelo Sniper**  2946 ms | 5084 ms | **0,579** |
| fft | 2235018 | 248 ms | 376 ms | **0,659** |
| dvfs | 548826 | Elapsed time: 4.51 seconds | real 0m0.012s | **?????** |
| fork | 570815 | Elapsed time: 4.23 seconds | real 0m0.037s | **?????** |
| spinloop | 529774 | Elapsed time: 4.42 seconds | real 0m0.046s |  |

Tabela 5. Programas selecionados com detalhamento dos tempos de execução nativo e pelo simulador acompanhados do cálculo do slowdown.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Programas selecionados** | **Elapsed time**  **(s)** | **Total time with initialization**  **(ms)** | **Leaving ROI Time**  **(s)** | **Simulation Speed**  **(KIPS)** | **Instructions Per Cycle**  **IPC** |
| radix | 101,11 | 39118 | 101,01 | 461,8 | 0,45 |
| cholesky | **Verificar a execução simulado pelo Sniper** | **Verificar a execução simulado pelo Sniper** | **Verificar a execução simulado pelo Sniper** | **Verificar a execução simulado pelo Sniper** | **Verificar a execução simulado pelo Sniper** |
| fft | 6,21 | 629 | 2,92 | 404.9 | 0,69 |
| spinloop | 4,42 | --- | 4,20 | 25,6 | 0,47 |
| fork | 4,23 | --- | 4,06 | 11,0 | 0,35 |

Tabela 6. Outras métricas de desempenho coletadas pelo Sniper.

* 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 – Sniper |  |
| Cholesky – Native | PROCESS STATISTICS  Total  Proc Time  0 5893  TIMING INFORMATION  Start time : -1313426210  Initialization finish time : -1313377396  Overall finish time : -1313371503  Total time with initialization : 54707  Total time without initialization : 5893 |
| 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 |

Tabela 7. Métricas de desempenho para os programas radix, cholesky e fft.

## 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 8 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 8. 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

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Programs** | **Elapsed Time**  **(s)** |  | **User Time**  **(s)** |  | **Sys Time**  **(s)** |  | **Total Time (ms)** |  |
|  | **Perf** | **Native** | **Perf** | **Native** | **Perf** | **Native** | **Perf** | **Native** |
| radix | 0.109805213 | 0.126 | 0. 048477000 | 0.45 | 0.009695000 | 0.0 | 17.962 | 14.718 |
| cholesky | 0.059534599 | 0.085 | 0.029256000 | 0.014 | 0.0 | 0.0 | 21089 | 38072 |
| fft | 0.002227599 | 0.019 | 0.002269000 | 0.002 | 0.0 | 0.0 | 400 | 352 |
| spinloop | 0.020184399 | 0.047 | 0.002096000 | 0.002 | 0.0 | 0.0 | --- | --- |
| fork | 0.011937503 | 0.052 | 0.003388000 | 0.003 | 0.0 | 0.0 | --- | --- |

## 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 9 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 9. 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 10 que segue. As saídas da execução estão armazenadas nos arquivos com extensão “txt”.

Os resultados detalhados desse experimento podem ser consultados na seção [Parsec do repositório Github](https://github.com/rubenscp/RCP-MO601-Project-03/tree/main/parsec/result).

|  |  |  |  |
| --- | --- | --- | --- |
| **Núm. da Execução** | **Pacote** | **Entrada** | **Comando de execução do pacote de Benchmark** |
| 001 | blackscholes | test | parsecmgmt -a run -p blackscholes -i test > results/exec-001-blackscholes-test.txt |
| 002 | blackscholes | simdev | parsecmgmt -a run -p blackscholes -i simdev > results/exec-002-blackscholes-simdev.txt |
| 003 | blackscholes | simsmall | parsecmgmt -a run -p blackscholes -i simsmall > results/exec-003-blackscholes-simsmall.txt |
| 004 | blackscholes | simlarge | parsecmgmt -a run -p blackscholes -i simlarge > results/exec-004-blackscholes-simlarge.txt |
| 005 | blackscholes | native | parsecmgmt -a run -p blackscholes -i native > results/exec-005-blackscholes-native.txt |
| 006 | vips | test | parsecmgmt -a run -p vips -i test > results/exec-006-vips-test.txt |
| 007 | vips | simdev | parsecmgmt -a run -p vips -i simdev > results/exec-007-vips-simdev.txt |
| 008 | vips | simsmall | parsecmgmt -a run -p vips -i simsmall > results/exec-008-vips-simsmall.txt |
| 009 | vips | simlarge | parsecmgmt -a run -p vips -i simlarge > results/exec-009-vips-simlarge.txt |
| 010 | vips | native | parsecmgmt -a run -p vips -i native > results/exec-010-vips-native.txt |
| 011 | bodytrack | test | parsecmgmt -a run -p bodytrack -i test > results/exec-011-bodytrack-test.txt |
| 012 | bodytrack | simdev | parsecmgmt -a run -p bodytrack -i simdev > results/exec-012-bodytrack-simdev.txt |
| 013 | bodytrack | simsmall | parsecmgmt -a run -p bodytrack -i simsmall > results/exec-013-bodytrack-simsmall.txt |
| 014 | bodytrack | simlarge | parsecmgmt -a run -p bodytrack -i simlarge > results/exec-014-bodytrack-simlarge.txt |
| 015 | bodytrack | native | parsecmgmt -a run -p bodytrack -i native > results/exec-015-bodytrack-native.txt |
| 016 | fluidanimate | test | parsecmgmt -a run -p fluidanimate -i test > results/exec-016-fluidanimate-test.txt |
| 017 | fluidanimate | simdev | parsecmgmt -a run -p fluidanimate -i simdev > results/exec-017-fluidanimate-simdev.txt |
| 018 | fluidanimate | simsmall | parsecmgmt -a run -p fluidanimate -i simsmall > results/exec-018-fluidanimate-simsmall.txt |
| 019 | fluidanimate | simlarge | parsecmgmt -a run -p fluidanimate -i simlarge > results/exec-019-fluidanimate-simlarge.txt |
| 020 | fluidanimate | native | parsecmgmt -a run -p fluidanimate -i native > results/exec-020-fluidanimate-native.txt |
| 021 | freqmine | test | parsecmgmt -a run -p freqmine -i test > results/exec-021-freqmine-test.txt |
| 022 | freqmine | simdev | parsecmgmt -a run -p freqmine -i simdev > results/exec-022-freqmine-simdev.txt |
| 023 | freqmine | simsmall | parsecmgmt -a run -p freqmine -i simsmall > results/exec-023-freqmine-simsmall.txt |
| 024 | freqmine | simlarge | parsecmgmt -a run -p freqmine -i simlarge > results/exec-024-freqmine-simlarge.txt |
| 025 | freqmine | native | parsecmgmt -a run -p freqmine -i native > results/exec-025-freqmine-native.txt |
| 026 | splash2 | test | parsecmgmt -a run -p splash2 -i test > results/exec-026-splash2-test.txt |
| 027 | splash2 | simdev | parsecmgmt -a run -p splash2 -i simdev > results/exec-027-splash2-simdev.txt |
| 028 | splash2 | simsmall | parsecmgmt -a run -p splash2 -i simsmall > results/exec-028-splash2-simsmall.txt |
| 029 | splash2 | simlarge | parsecmgmt -a run -p splash2 -i simlarge > results/exec-029-splash2-simlarge.txt |
| 030 | splash2 | native | parsecmgmt -a run -p splash2 -i native > results/exec-030-splash2-native.txt |
| 031 | splash2x | test | parsecmgmt -a run -p splash2x -i test > results/exec-031-splash2x-test.txt |
| 032 | splash2x | simdev | parsecmgmt -a run -p splash2x -i simdev > results/exec-032-splash2x-simdev.txt |
| 033 | splash2x | simsmall | parsecmgmt -a run -p splash2x -i simsmall > results/exec-033-splash2x-simsmall.txt |
| 034 | splash2x | simlarge | parsecmgmt -a run -p splash2x -i simlarge > results/exec-034-splash2x-simlarge.txt |
| 035 | splash2x | native | parsecmgmt -a run -p splash2x -i native > results/exec-035-splash2x-native.txt |
| 051 | blackscholes | native | parsecmgmt -a run -p blackscholes -i native -n 2 > results/exec-051-blackscholes-native-n2.txt |
| 052 | blackscholes | native | parsecmgmt -a run -p blackscholes -i native -n 4 > results/exec-052-blackscholes-native-n4.txt |
| 053 | blackscholes | native | parsecmgmt -a run -p blackscholes -i native -n 8 > results/exec-053-blackscholes-native-n8.txt |
| 054 | blackscholes | native | parsecmgmt -a run -p blackscholes -i native -n 16 > results/exec-054-blackscholes-native-n16.txt |
| 055 | vips | native | parsecmgmt -a run -p vips -i native -n 2 > results/exec-055-vips-native-n2.txt |
| 056 | vips | native | parsecmgmt -a run -p vips -i native -n 4 > results/exec-056-vips-native-n4.txt |
| 057 | vips | native | parsecmgmt -a run -p vips -i native -n 8 > results/exec-057-vips-native-n8.txt |
| 058 | vips | native | parsecmgmt -a run -p vips -i native -n 16 > results/exec-058-vips-native-n16.txt |
| 059 | bodytrack | native | parsecmgmt -a run -p bodytrack -i native -n 2 > results/exec-059-bodytrack-native-n2.txt |
| 060 | bodytrack | native | parsecmgmt -a run -p bodytrack -i native -n 4 > results/exec-060-bodytrack-native-n4.txt |
| 061 | bodytrack | native | parsecmgmt -a run -p bodytrack -i native -n 8 > results/exec-061-bodytrack-native-n8.txt |
| 062 | bodytrack | native | parsecmgmt -a run -p bodytrack -i native -n 16 > results/exec-062-bodytrack-native-n16.txt |
| 063 | fluidanimate | native | parsecmgmt -a run -p fluidanimate -i native -n 2 > results/exec-063-fluidanimate-native-n2.txt |
| 064 | fluidanimate | native | parsecmgmt -a run -p fluidanimate -i native -n 4 > results/exec-064-fluidanimate-native-n4.txt |
| 065 | fluidanimate | native | parsecmgmt -a run -p fluidanimate -i native -n 8 > results/exec-065-fluidanimate-native-n8.txt |
| 066 | fluidanimate | native | parsecmgmt -a run -p fluidanimate -i native -n 16 > results/exec-066-fluidanimate-native-n16.txt |
| 067 | freqmine | native | parsecmgmt -a run -p freqmine -i native -n 2 > results/exec-067-freqmine-native-n2.txt |
| 068 | freqmine | native | parsecmgmt -a run -p freqmine -i native -n 4 > results/exec-068-freqmine-native-n4.txt |
| 069 | freqmine | native | parsecmgmt -a run -p freqmine -i native -n 8 > results/exec-069-freqmine-native-n8.txt |
| 070 | freqmine | native | parsecmgmt -a run -p freqmine -i native -n 16 > results/exec-070-freqmine-native-n16.txt |
| 071 | splash2 | native | parsecmgmt -a run -p splash2 -i native -n 2 > results/exec-071-splash2-native-n2.txt |
| 072 | splash2 | native | parsecmgmt -a run -p splash2 -i native -n 4 > results/exec-072-splash2-native-n4.txt |
| 073 | splash2 | native | parsecmgmt -a run -p splash2 -i native -n 8 > results/exec-073-splash2-native-n8.txt |
| 074 | splash2 | native | parsecmgmt -a run -p splash2 -i native -n 16 > results/exec-074-splash2-native-n16.txt |
| 075 | splash2x | native | parsecmgmt -a run -p splash2x -i native -n 2 > results/exec-075-splash2x-native-n2.txt |
| 076 | splash2x | native | parsecmgmt -a run -p splash2x -i native -n 4 > results/exec-076-splash2x-native-n4.txt |
| 077 | splash2x | native | parsecmgmt -a run -p splash2x -i native -n 8 > results/exec-077-splash2x-native-n8.txt |
| 078 | splash2x | native | parsecmgmt -a run -p splash2x -i native -n 16 > results/exec-078-splash2x-native-n16.txt |

Tabela 10. Comandos PARSEC para execução dos benchmarks com as entradas possíveis.

APRESENTAR OS PARAMETROS TESADOS COMBINADOS NATIVE E –N

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Pacote** | **Entrada** |  |
| 001 | blackscholes | test |  |
| 002 | blackscholes | simdev |  |
| 003 | blackscholes | simsmall |  |

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

A Tabela 12 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 12. Benchmarks executados com os resultados.

A Tabela 13 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 13. 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 14 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 14. Comandos Dinero para execução dos programas RADIX e FFT com variados parâmetros de execução relacionados às caches L1, L2 e L3.

Os resultados detalhados desse experimento podem ser consultados na seção [Dinero do repositório Github](https://github.com/rubenscp/RCP-MO601-Project-03/tree/main/dinero/results).

**decisão sobre a melhor configuração de cache entre as testadas**

# Considerações sobre o aprendizado nesse projeto

# Conclusões

# Apêndice