Workload Explanation

CPU-bound Program

This program performs intensive computational tasks, stressing the CPU. It includes operations such as matrix multiplications or prime number calculations.

Memory-bound Program

This program heavily relies on memory operations, causing frequent cache misses and memory accesses. It involves tasks such as linked list traversal or large array manipulations.

I/O-bound Program

This program predominantly interacts with storage devices, leading to delays due to disk read/write operations. Examples include file processing or database queries.

Mixed Workload Program

This program combines CPU, memory, and I/O operations to evaluate overall system performance under diverse workload conditions.

Performance Analysis

Key Performance Metrics Observed

- **CPU Usage**: Measured the percentage of CPU cycles utilized by each program.
- **Cache Misses**: Observed how efficiently memory accesses were handled.
- **Branch Misses**: Identified inefficiencies in branch prediction.
- **I/O Wait Time**: Evaluated disk-related delays for the I/O-bound workload.
- **Execution Time**: Measured time taken for completion of each workload.

Performance Graphs

Cache Misses vs Threads

Cache References vs Threads

Execution Time vs Threads

perf Tool Output Screenshots

CPU-bound Program

```
Execution Time: 0.100156 seconds
jibankrishna@jibankrishna-HP-ENVY-Laptop-13-aq1xxx:~/Desktop/MT24121_PA02$ perf stat -e cycles,instructions,cache-references,cache-misses,branch-misses,context-switches,cpu-migrations
./cpu_bound
Execution Time: 0.091702 seconds

 Performance counter stats for './cpu_bound':

       371,902,474      cycles
       585,513,282      instructions              #    1.57  insn per cycle
        24,570,146      cache-references
           280,353      cache-misses              #    1.14% of all cache refs
           157,766      branch-misses
                18      context-switches
                 2      cpu-migrations

       0.044505069 seconds time elapsed

       0.100951000 seconds user
       0.003809000 seconds sys
```

Memory-bound Program

```
Execution Time: 13.679355 seconds
jibankrishna@jibankrishna-HP-ENVY-Laptop-13-aq1xxx:~/Desktop/MT24121_PA02$ perf stat -e cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses ./memory_bound
Execution Time: 13.679355 seconds

 Performance counter stats for './memory_bound':

       869,377,139      cache-references
       814,632,678      cache-misses              #   93.70% of all cache refs
     4,772,138,868      L1-dcache-loads
       641,197,530      L1-dcache-load-misses     #   13.44% of all L1-dcache accesses

       5.068892797 seconds time elapsed

      15.150984000 seconds user
       0.124991000 seconds sys
```

I/O-bound Program

```
Execution Time: 0.007445 seconds
jibankrishna@jibankrishna-HP-ENVY-Laptop-13-aq1xxx:~/Desktop/MT24121_PA02$ perf stat -e context-switches,cpu-migrations,page-faults ./io_bound
Execution Time: 0.010001 seconds

 Performance counter stats for './io_bound':

                 4      context-switches
                 3      cpu-migrations
                89      page-faults

       0.004005328 seconds time elapsed

       0.007571000 seconds user
       0.003365000 seconds sys
```

Mixed Workload Program

```
Execution Time: 0.016007 seconds
jibankrishna@jibankrishna-HP-ENVY-Laptop-13-aq1xxx:~/Desktop/MT24121_PA02$ perf stat -e cycles,instructions,cache-references,cache-misses,branch-misses,context-switches,cpu-migrations,
page-faults ./mixed_workload
Execution Time: 0.016218 seconds

 Performance counter stats for './mixed_workload':

       142,012,808      cycles
       151,800,891      instructions              #    1.07  insn per cycle
         1,251,701      cache-references
           323,403      cache-misses              #   25.84% of all cache refs
           133,766      branch-misses
                17      context-switches
                 6      cpu-migrations
             1,093      page-faults

       0.026920066 seconds time elapsed

       0.027180000 seconds user
       0.010310000 seconds sys
```

Discussion of Results

Bottlenecks and Observations

- **CPU-bound Program**: Observed high CPU utilization with minimal I/O wait time.
- **Memory-bound Program**: Significant cache misses indicate poor cache locality.
- **I/O-bound Program**: High I/O wait time observed, leading to slower execution.
- **Mixed Workload Program**: A balanced mix of CPU, memory, and I/O usage, revealing insights on overall system efficiency.

Optimization Opportunities

- **CPU-bound**: Parallelization and SIMD optimizations could enhance performance.
- **Memory-bound**: Optimizing data structures and prefetching could reduce cache misses.
- **I/O-bound**: Using asynchronous I/O and SSDs could help mitigate delays.
- **Mixed Workload**: Fine-tuning resource allocation strategies can optimize execution.

Conclusion Each workload stresses different system components, offering valuable insights into hardware capabilities and optimization strategies. Further profiling with different input sizes and optimization techniques can yield additional performance gains.

Perf Ananlysis of four programs:-

==== Profiling cpu_bound ====

Running cpu_bound with 2 threads...

Execution Time: 0.193760 seconds with 2 threads

Execution Time: 0.170967 seconds with 2 threads

Execution Time: 0.165894 seconds with 2 threads

Execution Time: 0.177926 seconds with 2 threads

Execution Time: 0.174952 seconds with 2 threads

Performance counter stats for './cpu_bound 2' (5 runs):

474,059,325   cycles   (+- 2.65%)

1,087,950,163   instructions   # 2.29 insn per cycle   (+- 0.01%)

```
    13,868,908    cache-references                                    ( +- 1.43% )

       313,465    cache-misses              #  2.26% of all cache refs      ( +-
15.54% )

             6    context-switches                                    ( +- 9.72% )

             1    cpu-migrations                                      ( +- 87.18% )


     0.10793 +- 0.00390 seconds time elapsed  ( +-  3.61% )
```

Running cpu_bound with 4 threads...

Execution Time: 0.221580 seconds with 4 threads

Execution Time: 0.249273 seconds with 4 threads

Execution Time: 0.202831 seconds with 4 threads

Execution Time: 0.227222 seconds with 4 threads

Execution Time: 0.294209 seconds with 4 threads

```
 Performance counter stats for './cpu_bound 4' (5 runs):


   580,860,778    cycles                                          ( +-  5.01% )

 1,089,334,054    instructions            #   1.88  insn per cycle        ( +-
0.01% )

    16,387,504    cache-references                                    ( +- 9.22% )

       451,934    cache-misses            #  2.76% of all cache refs        ( +-
15.62% )

            13    context-switches                                    ( +- 24.08% )

             1    cpu-migrations                                      ( +- 37.42% )
```

0.09358 +- 0.00595 seconds time elapsed (+- 6.36%)

Running cpu_bound with 8 threads...

Execution Time: 0.811722 seconds with 8 threads

Execution Time: 0.395160 seconds with 8 threads

Execution Time: 0.313039 seconds with 8 threads

Execution Time: 0.307350 seconds with 8 threads

Execution Time: 0.317651 seconds with 8 threads

 Performance counter stats for './cpu_bound 8' (5 runs):

    799,391,371   cycles   (+- 0.75%)

  1,085,522,725   instructions   #   1.36 insn per cycle   (+-
0.05%)

     24,329,926   cache-references   (+- 3.81%)

        668,783   cache-misses   #   2.75% of all cache refs   (+-
5.04%)

            105   context-switches   (+- 6.06%)

             11   cpu-migrations   (+- 10.98%)

    0.1104 +- 0.0228 seconds time elapsed (+- 20.61%)

Running cpu_bound with 10 threads...

Execution Time: 0.321014 seconds with 10 threads

Execution Time: 0.323546 seconds with 10 threads

Execution Time: 0.331500 seconds with 10 threads

Execution Time: 0.320024 seconds with 10 threads

Execution Time: 0.320857 seconds with 10 threads

 Performance counter stats for './cpu_bound 10' (5 runs):

    825,651,775   cycles   (+- 0.56%)

  1,094,050,497   instructions   #   1.33 insn per cycle   (+- 0.02%)

     26,437,503   cache-references   (+- 3.20%)

        588,366   cache-misses   #   2.23% of all cache refs   (+- 4.39%)

            135   context-switches   (+- 3.32%)

             22   cpu-migrations   (+- 7.19%)

    0.07050 +- 0.00122 seconds time elapsed (+- 1.72%)

Running cpu_bound with 50 threads...

Execution Time: 0.319623 seconds with 50 threads

Execution Time: 0.325268 seconds with 50 threads

Execution Time: 0.317960 seconds with 50 threads

Execution Time: 0.318218 seconds with 50 threads

Execution Time: 0.326061 seconds with 50 threads

Performance counter stats for './cpu_bound 50' (5 runs):

864,335,025   cycles   (+- 0.54%)

1,105,959,098   instructions   #   1.28 insn per cycle   (+- 0.02%)

29,067,153   cache-references   (+- 3.04%)

608,559   cache-misses   #   2.09% of all cache refs   (+- 5.53%)

175   context-switches   (+- 3.84%)

72   cpu-migrations   (+- 3.87%)

0.06451 +- 0.00131 seconds time elapsed (+- 2.04%)

Running cpu_bound with 100 threads...

Execution Time: 0.300305 seconds with 100 threads

Execution Time: 0.332948 seconds with 100 threads

Execution Time: 0.327241 seconds with 100 threads

Execution Time: 0.319270 seconds with 100 threads

Execution Time: 0.285753 seconds with 100 threads

Performance counter stats for './cpu_bound 100' (5 runs):

```
      875,079,155      cycles                                          ( +-  0.46% )

    1,120,724,988      instructions              #   1.28  insn per cycle          ( +-
0.05% )

       29,916,659      cache-references                                ( +-  2.11% )

          814,209      cache-misses              #   2.72% of all cache refs      ( +-
2.47% )

              203      context-switches                                ( +- 12.75% )

              110      cpu-migrations                                  ( +- 20.39% )


       0.066883 +- 0.000963 seconds time elapsed  ( +-  1.44% )
```

==== Profiling memory_bound ====

Running memory_bound with 2 threads...

Execution Time with 2 threads: 7.889237 seconds

Execution Time with 2 threads: 7.864245 seconds

Execution Time with 2 threads: 6.954425 seconds

Execution Time with 2 threads: 7.473966 seconds

Execution Time with 2 threads: 6.904217 seconds

 Performance counter stats for './memory_bound 2' (5 runs):

```
   18,951,413,036      cycles                                          ( +-  2.55% )

   23,059,484,842      instructions              #   1.22  insn per cycle          ( +-
0.02% )

    1,048,648,221      cache-references                                ( +-  0.21% )
```

```
   807,516,046      cache-misses              #  77.01% of all cache refs      ( +-
0.40% )

          150      context-switches                              ( +- 30.51% )

           17      cpu-migrations                                ( +- 36.71% )


      6.224 +- 0.155 seconds time elapsed  ( +-  2.49% )
```

Running memory_bound with 4 threads...

Execution Time with 4 threads: 15.575453 seconds

Execution Time with 4 threads: 14.904760 seconds

Execution Time with 4 threads: 15.184503 seconds

Execution Time with 4 threads: 14.685241 seconds

Execution Time with 4 threads: 14.519817 seconds

 Performance counter stats for './memory_bound 4' (5 runs):

```
 25,503,324,771      cycles                                       ( +-  1.02% )

 23,105,608,670      instructions              #   0.91  insn per cycle      ( +-
0.03% )

    947,827,916      cache-references                             ( +-  0.43% )

    846,106,286      cache-misses              #  89.27% of all cache refs      ( +-
0.26% )

          162      context-switches                              ( +- 24.14% )

           21      cpu-migrations                                ( +- 17.91% )
```

6.1261 +- 0.0328 seconds time elapsed (+- 0.54%)

Running memory_bound with 8 threads...

Execution Time with 8 threads: 26.375214 seconds

Execution Time with 8 threads: 25.227440 seconds

Execution Time with 8 threads: 25.712238 seconds

Execution Time with 8 threads: 26.430014 seconds

Execution Time with 8 threads: 27.028005 seconds

 Performance counter stats for './memory_bound 8' (5 runs):

    38,830,414,007   cycles   (+- 1.32%)

    23,198,619,065   instructions   #   0.60 insn per cycle   (+- 0.05%)

       934,014,271   cache-references   (+- 0.90%)

       859,190,066   cache-misses   # 91.99% of all cache refs   (+- 0.35%)

             3,352   context-switches   (+- 18.90%)

                62   cpu-migrations   (+- 12.65%)

      6.3523 +- 0.0986 seconds time elapsed (+- 1.55%)

Running memory_bound with 10 threads...

Execution Time with 10 threads: 27.522029 seconds

Execution Time with 10 threads: 28.254136 seconds

Execution Time with 10 threads: 27.220004 seconds

Execution Time with 10 threads: 26.747871 seconds

Execution Time with 10 threads: 26.489187 seconds

Performance counter stats for './memory_bound 10' (5 runs):

```
 52,741,947,570      cycles                                          ( +-  1.06% )

 23,213,276,942      instructions         #   0.44  insn per cycle         ( +-
0.04% )

    886,213,768      cache-references                                ( +-  0.44% )

    833,957,801      cache-misses         #  94.10% of all cache refs      ( +-
0.28% )

          4,343      context-switches                                ( +- 11.76% )

             97      cpu-migrations                                  ( +-  4.80% )


      5.993 +- 0.101 seconds time elapsed  ( +-  1.68% )
```

Running memory_bound with 50 threads...

Execution Time with 50 threads: 27.061893 seconds

Execution Time with 50 threads: 25.823679 seconds

Execution Time with 50 threads: 27.961970 seconds

Execution Time with 50 threads: 26.873308 seconds

Execution Time with 50 threads: 25.997325 seconds

Performance counter stats for './memory_bound 50' (5 runs):

   52,669,467,186   cycles   (+- 0.86%)

   23,272,698,081   instructions   #   0.44 insn per cycle   (+- 0.03%)

     901,599,413   cache-references   (+- 0.31%)

     840,154,122   cache-misses   # 93.18% of all cache refs   (+- 0.28%)

        7,881   context-switches   (+- 2.43%)

         619   cpu-migrations   (+- 11.69%)

     6.2774 +- 0.0528 seconds time elapsed (+- 0.84%)

Running memory_bound with 100 threads...

Execution Time with 100 threads: 25.629665 seconds

Execution Time with 100 threads: 26.513026 seconds

Execution Time with 100 threads: 26.251474 seconds

Execution Time with 100 threads: 26.054586 seconds

Execution Time with 100 threads: 26.661929 seconds

Performance counter stats for './memory_bound 100' (5 runs):

   53,341,427,202   cycles   (+- 0.53%)

```
   23,272,721,760    instructions              #   0.44  insn per cycle          ( +-
0.05% )

      898,100,694    cache-references                                           ( +-  0.42% )

      821,026,207    cache-misses              #  91.42% of all cache refs       ( +-
0.52% )

            7,362    context-switches                                           ( +-  4.88% )

            1,188    cpu-migrations                                             ( +- 11.45% )


      6.4369 +- 0.0951 seconds time elapsed  ( +-  1.48% )
```

==== Profiling io_bound ====

Running io_bound with 2 threads...

Execution Time with 2 threads: 0.010191 seconds

Execution Time with 2 threads: 0.013843 seconds

Execution Time with 2 threads: 0.013611 seconds

Execution Time with 2 threads: 0.015536 seconds

Execution Time with 2 threads: 0.014918 seconds

 Performance counter stats for './io_bound 2' (5 runs):

```
       21,868,228    cycles                                                     ( +-  3.75% )

       30,131,496    instructions              #   1.38  insn per cycle          ( +-
0.34% )

          584,175    cache-references                                           ( +-  5.56% )
```

```
        135,142      cache-misses              #   23.13% of all cache refs        ( +-
8.10% )

            5    context-switches                                ( +- 14.70% )

            2    cpu-migrations                                  ( +- 20.00% )



        0.010313 +- 0.000594 seconds time elapsed  ( +-  5.76% )
```

Running io_bound with 4 threads...

Execution Time with 4 threads: 0.033365 seconds

Execution Time with 4 threads: 0.031188 seconds

Execution Time with 4 threads: 0.027695 seconds

Execution Time with 4 threads: 0.029647 seconds

Execution Time with 4 threads: 0.030802 seconds

 Performance counter stats for './io_bound 4' (5 runs):

```
    45,981,659      cycles                                   ( +-  1.62% )

    58,802,507      instructions              #   1.28  insn per cycle         ( +-
0.14% )

       971,602      cache-references                              ( +-  5.05% )

       138,686      cache-misses              #   14.27% of all cache refs        ( +-
3.93% )

            13     context-switches                              ( +- 11.04% )

             1     cpu-migrations                                ( +- 37.42% )
```

0.010825 +- 0.000238 seconds time elapsed (+- 2.20%)

Running io_bound with 8 threads...

Execution Time with 8 threads: 0.059684 seconds

Execution Time with 8 threads: 0.063022 seconds

Execution Time with 8 threads: 0.059116 seconds

Execution Time with 8 threads: 0.060452 seconds

Execution Time with 8 threads: 0.062086 seconds

 Performance counter stats for './io_bound 8' (5 runs):

    94,110,708   cycles   (+- 0.89%)

   116,138,640   instructions   #   1.23 insn per cycle   (+- 0.12%)

     1,516,506   cache-references   (+- 2.32%)

       242,142   cache-misses   #   15.97% of all cache refs   (+- 10.49%)

            26   context-switches   (+- 10.92%)

             7   cpu-migrations   (+- 11.07%)

    0.01950 +- 0.00197 seconds time elapsed (+- 10.11%)

Running io_bound with 10 threads...

Execution Time with 10 threads: 0.079085 seconds

Execution Time with 10 threads: 0.078857 seconds

Execution Time with 10 threads: 0.078631 seconds

Execution Time with 10 threads: 0.075587 seconds

Execution Time with 10 threads: 0.077290 seconds

Performance counter stats for './io_bound 10' (5 runs):

118,443,164	cycles		(+- 0.56%)
145,273,341	instructions	# 1.23 insn per cycle	(+- 0.08%)
1,916,566	cache-references		(+- 1.62%)
300,352	cache-misses	# 15.67% of all cache refs	(+- 6.92%)
41	context-switches		(+- 8.25%)
8	cpu-migrations		(+- 13.46%)

0.02420 +- 0.00128 seconds time elapsed (+- 5.29%)

Running io_bound with 50 threads...

Execution Time with 50 threads: 0.400812 seconds

Execution Time with 50 threads: 0.411525 seconds

Execution Time with 50 threads: 0.429422 seconds

Execution Time with 50 threads: 0.427129 seconds

Execution Time with 50 threads: 0.418802 seconds

Performance counter stats for './io_bound 50' (5 runs):

        590,987,478   cycles   (+- 0.30%)

        728,074,763   instructions   #   1.23 insn per cycle   (+- 0.27%)

          9,824,262   cache-references   (+- 0.95%)

          1,445,540   cache-misses   # 14.71% of all cache refs   (+- 2.98%)

                260   context-switches   (+- 8.23%)

                 64   cpu-migrations   (+- 16.35%)

        0.10121 +- 0.00197 seconds time elapsed (+- 1.95%)

Running io_bound with 100 threads...

Execution Time with 100 threads: 0.814075 seconds

Execution Time with 100 threads: 0.851811 seconds

Execution Time with 100 threads: 0.918067 seconds

Execution Time with 100 threads: 0.818792 seconds

Execution Time with 100 threads: 0.811464 seconds

Performance counter stats for './io_bound 100' (5 runs):

      1,185,079,257   cycles   (+- 0.43%)

```
  1,459,966,871      instructions                #   1.23  insn per cycle         ( +-
0.21% )

     18,989,922      cache-references                              ( +-  2.65% )

      2,779,114      cache-misses                #   14.63% of all cache refs     ( +-
8.10% )

            534      context-switches                              ( +-  8.91% )

            117      cpu-migrations                                ( +- 13.90% )


     0.1949 +- 0.0123 seconds time elapsed  ( +-  6.30% )
```

==== Profiling mixed_workload ====

Running mixed_workload with 2 threads...

Execution Time with 2 threads: 0.033346 seconds

Execution Time with 2 threads: 0.038750 seconds

Execution Time with 2 threads: 0.034924 seconds

Execution Time with 2 threads: 0.034336 seconds

Execution Time with 2 threads: 0.035101 seconds

 Performance counter stats for './mixed_workload 2' (5 runs):

```
    120,643,688      cycles                                        ( +-  0.68% )

    139,841,773      instructions                #   1.16  insn per cycle         ( +-
0.09% )

        972,193      cache-references                              ( +-  7.23% )
```

307,480   cache-misses   #   31.63% of all cache refs   (+-5.83%)

7   context-switches   (+- 16.66%)

2   cpu-migrations   (+- 27.39%)

0.05825 +- 0.00162 seconds time elapsed (+- 2.79%)

Running mixed_workload with 4 threads...

Execution Time with 4 threads: 0.060672 seconds

Execution Time with 4 threads: 0.057245 seconds

Execution Time with 4 threads: 0.045146 seconds

Execution Time with 4 threads: 0.047192 seconds

Execution Time with 4 threads: 0.045494 seconds

 Performance counter stats for './mixed_workload 4' (5 runs):

144,387,305   cycles   (+- 1.72%)

155,490,626   instructions   #   1.08 insn per cycle   (+-0.14%)

1,476,861   cache-references   (+- 4.49%)

392,262   cache-misses   #   26.56% of all cache refs   (+-5.43%)

24   context-switches   (+- 22.61%)

7   cpu-migrations   (+- 22.77%)

0.06217 +- 0.00211 seconds time elapsed (+- 3.39%)

Running mixed_workload with 8 threads...

Execution Time with 8 threads: 0.059706 seconds

Execution Time with 8 threads: 0.066093 seconds

Execution Time with 8 threads: 0.057524 seconds

Execution Time with 8 threads: 0.061534 seconds

Execution Time with 8 threads: 0.062738 seconds

 Performance counter stats for './mixed_workload 8' (5 runs):

     165,472,850   cycles   (+- 1.03%)

     185,427,732   instructions   #   1.12 insn per cycle   (+- 0.14%)

       1,920,171   cache-references   (+- 2.54%)

         423,843   cache-misses   # 22.07% of all cache refs   (+- 3.38%)

              26   context-switches   (+- 10.70%)

              12   cpu-migrations   (+- 4.86%)

     0.05374 +- 0.00157 seconds time elapsed (+- 2.92%)

Running mixed_workload with 10 threads...

Execution Time with 10 threads: 0.071782 seconds

Execution Time with 10 threads: 0.074266 seconds

Execution Time with 10 threads: 0.076558 seconds

Execution Time with 10 threads: 0.072178 seconds

Execution Time with 10 threads: 0.071858 seconds

Performance counter stats for './mixed_workload 10' (5 runs):

    182,064,810   cycles   **(+- 0.65%)**

    201,297,876   instructions   #   1.11 insn per cycle   (+- 0.12%)

      2,278,941   cache-references   **(+- 3.19%)**

        466,523   cache-misses   # 20.47% of all cache refs   (+- 5.10%)

          46   context-switches   **(+- 20.91%)**

          20   cpu-migrations   **(+- 27.90%)**

      0.05654 +- 0.00242 seconds time elapsed (+- 4.27%)

Running mixed_workload with 50 threads...

Execution Time with 50 threads: 0.234553 seconds

Execution Time with 50 threads: 0.241935 seconds

Execution Time with 50 threads: 0.248707 seconds

Execution Time with 50 threads: 0.240062 seconds

Execution Time with 50 threads: 0.248010 seconds

Performance counter stats for './mixed_workload 50' (5 runs):

```
     440,904,025      cycles                                          ( +-  0.45% )

     511,479,570      instructions          #   1.16  insn per cycle          ( +-
0.25% )

       8,852,740      cache-references                                ( +-  0.99% )

       1,200,539      cache-misses          #  13.56% of all cache refs       ( +-
5.01% )

             275      context-switches                                ( +-  6.20% )

              99      cpu-migrations                                  ( +- 10.50% )
```

        0.10404 +- 0.00493 seconds time elapsed (+- 4.74%)

Running mixed_workload with 100 threads...

Execution Time with 100 threads: 0.461714 seconds

Execution Time with 100 threads: 0.475069 seconds

Execution Time with 100 threads: 0.451456 seconds

Execution Time with 100 threads: 0.454051 seconds

Execution Time with 100 threads: 0.446508 seconds

Performance counter stats for './mixed_workload 100' (5 runs):

```
     768,227,805      cycles                                          ( +-  0.40% )
```

902,004,483   instructions   # 1.17 insn per cycle   (+- 0.17%)

17,253,926   cache-references   (+- 0.76%)

1,911,575   cache-misses   # 11.08% of all cache refs   (+- 4.92%)

493   context-switches   (+- 3.11%)

207   cpu-migrations   (+- 2.57%)

0.14020 +- 0.00340 seconds time elapsed (+- 2.43%)

Plots:-

Cache Misses vs Threads

Cache References vs Threads

Execution Time vs Threads