

ASSIGNMENT – 5

PERFORMANCE PROFILING WITH PERF

REPORT

AIM :-

- To analyze the performance of two matrix multiplication algorithms [Naïve multiplication and Blocked multiplication] in terms of instructions , cache references , cache misses/miss-rate , L1-dcache-misses/miss-rate , L1-icache-misses/miss-rate using PERF.

TOOL :- PERF

PROCEDURE :-

- First , we design two different algorithms for matrix multiplication i) Naïve multiplication ii) Blocked multiplication.
- In Naïve method , we do the matrix multiplication as we do on paper.
- In Blocked method , we use the concept of divide and conquer where we divide the matrix into matrices of required block size and multiply blockwise.
- The implementation of both algorithms is done in “template.cpp” .

- Now , for testing , we generate input square matrices of any size containing random values in “gen_input.cpp”.
- This can be done using commands :-

```
$ g++ gen_input.cpp
```

```
$ ./a.out 128 input128
```

- Now , “template.cpp” can be run by :-

```
$ g++ template.cpp
```

```
$ ./a.out block_size inputfile outputfile
```

Note :- Here , blocksize is ‘0’ means we are using naïve algorithm or else the blocked algorithm of given blocksize.

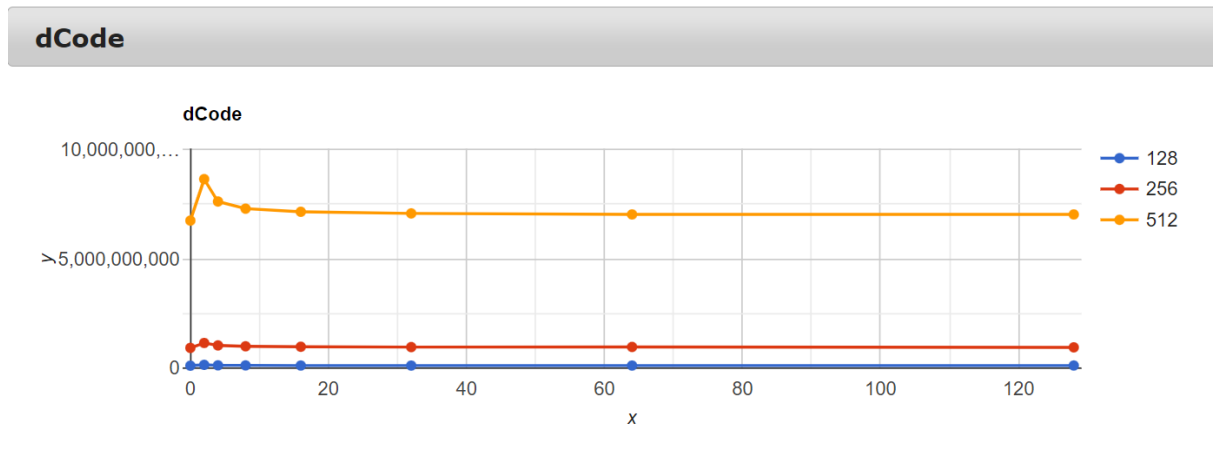
- As the output file is ready , we can now use perf for analyzing the performance by using the command :-
- “sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r runs ./a.out block_size inputfile outputfile”
- Here , this command displays the required stats only and calibrated as an average of the given number of runs.

OBSERVATIONS :-

- We analyze the performance of both algorithms for blocksizes ‘128’ , ‘256’ , ‘512’.

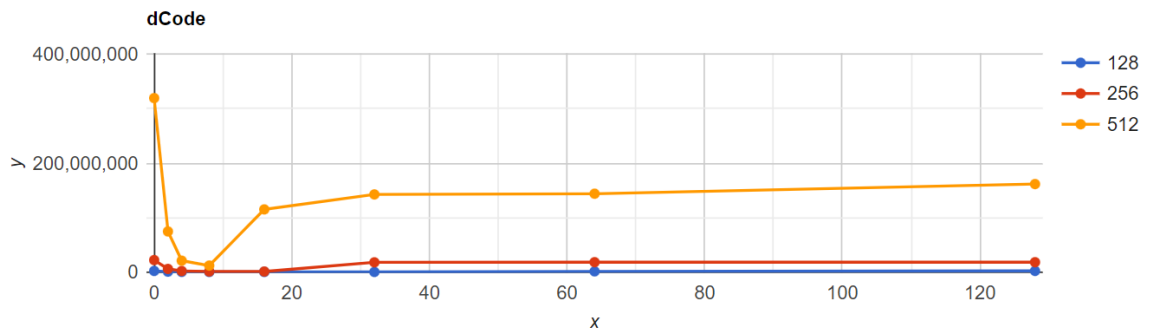
- Note that the result data sheets are attached at the end for reference.

1.) INSTRUCTIONS :-



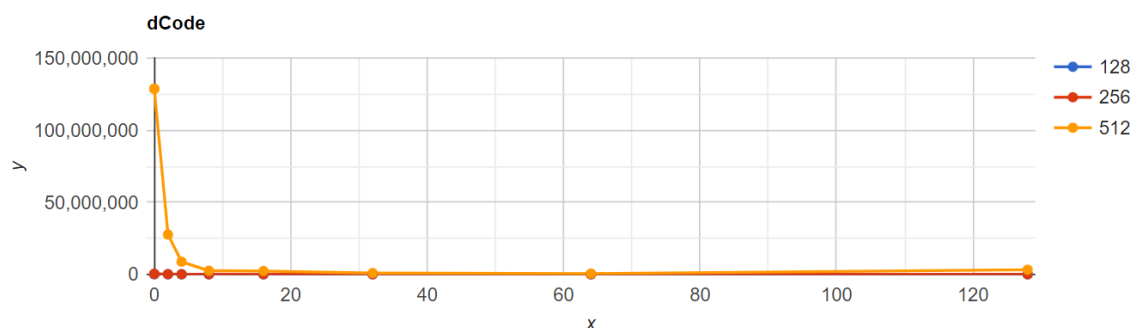
- From the graph , it is clear that the number of instructions for blocked algorithm is always greater than or equal to the naïve algorithm.
- Moreover , the instructions number decreases as the block size increases.
- This observation is consistent for all three sizes.

2.) CACHE REFERENCES :-



- From the graph , it is clear that the cache references for blocked algorithm are less than that of the naïve algorithm.
- Moreover , the number decreases till a certain block size and then increases thereafter.
- Here , the number decreases till blocksize – ‘16’ for matrix sizes – ‘128’ , ‘256’ but for matrix size – ‘512’ , the number decreases till blocksize – ‘8’ and then increases.

3.) CACHE MISSES :-

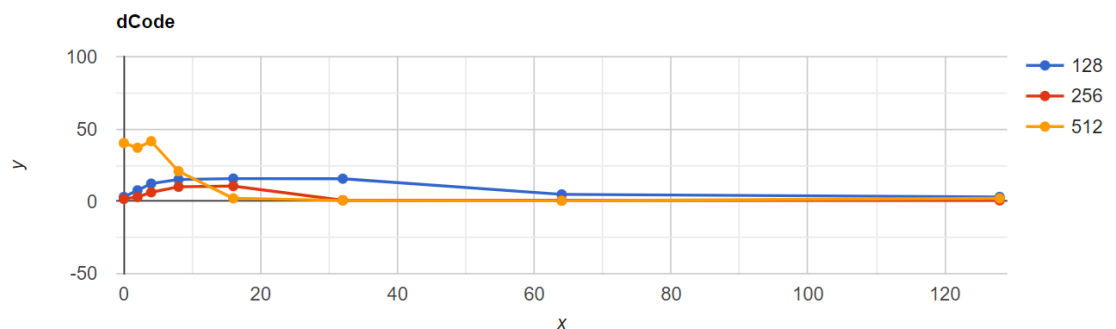


- From the graph , it is clear that the cache misses for blocked algorithm are less than that of the naïve algorithm.

- Moreover , the number decreases as the block size increases (with very - very minor zizag trend).
- Here , this observation is much clearly evident in matrix size – ‘512’ whereas some flaws are seen in matrix size – ‘128’.

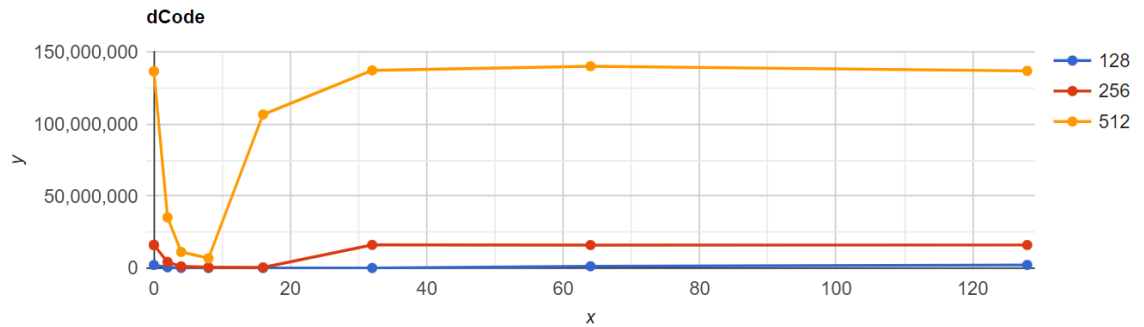
4.) CACHE MISS RATE :-

dCode



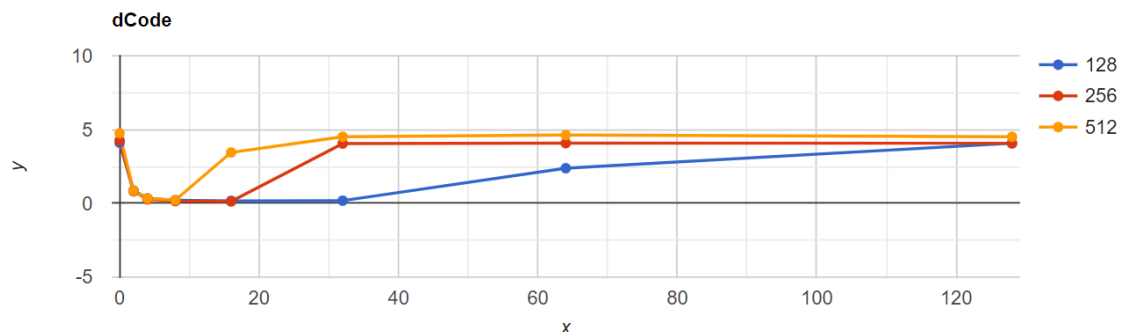
- From the graph , for matrix sizes - ‘128’ , ‘256’ the cache miss rate for blocked algorithm is greater than that of the naïve alogorithm and the cache miss rate decreases as the block size increases.
- For matrix size – ‘512’ the cache miss rate follows a zigzag trend which is a bit unpredictable. The values drop dramatically at block sizes – ‘16’ to ‘128’.

5.) L1 DCACHE LOAD MISSES :-



- From the graph it is clear that the L1-dcache-load-misses for blocked algorithm are less than or equal to that of the naïve algorithm.
- Moreover, the number decreases till a certain block size and then increases thereafter.
- Here, the number decreases till blocksize – ‘16’ for matrix sizes – ‘128’, ‘256’ but for matrix size – ‘512’, the number decreases till blocksize – ‘8’ and then increases.

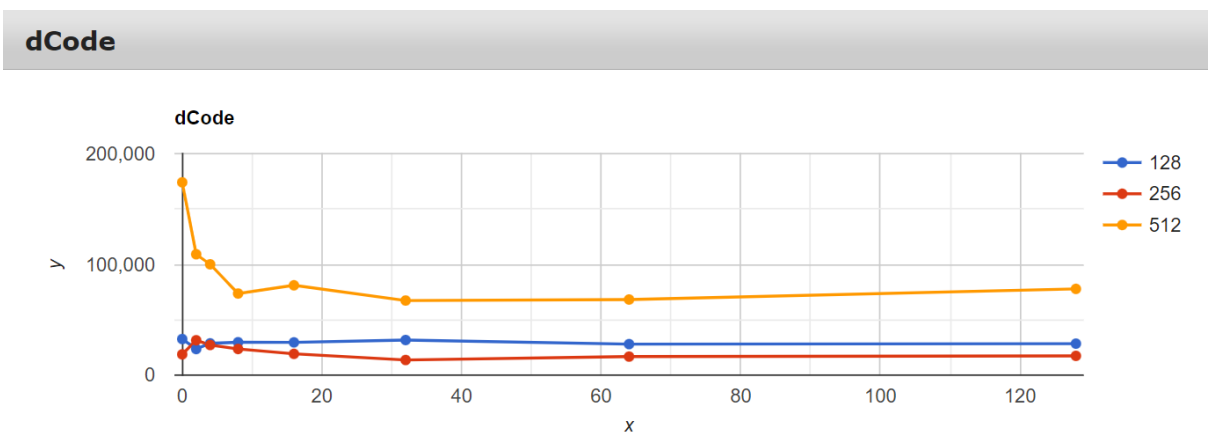
6.) L1 DCACHE MISS RATE :-



- From the graph it is clear that the L1-dcache-load-misses for blocked algorithm are less than or equal to that of the naïve algorithm.

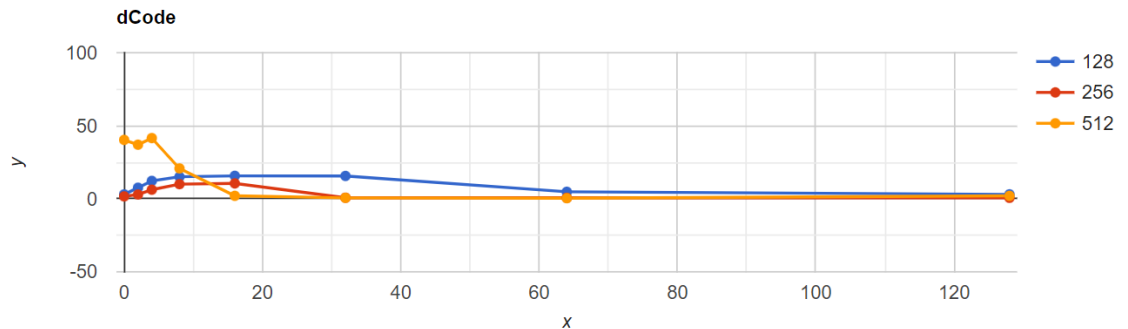
- Moreover , the number decreases till a certain block size and then increases thereafter.
- Here , the number decreases till blocksize – ‘16’ for matrix sizes – ‘128’ , ‘256’ but for matrix size – ‘512’ , the number decreases till blocksize – ‘8’ and then increases.

7.) L1 ICACHE LOAD MISSES :-



- From the graph L1-cache-load-misses for blocked algorithm are less than that of naïve algorithm which is clearly evident in block size – ‘128’ , ‘512’.
- But this trend is inconsistent to block size – ‘256’ which is a bit unpredictable.

8.) L1 ICACHE MISS RATE :-



- In this graph , there is no such perfect trend that is being followed.

RESULT :-

- Blocked algorithm is more efficient than the naïve algorithm due to the added advantage of it using the ‘PRINCIPLE OF LOCALITY’.
- Here , even though the number of instructions are more for blocked algorithm than the naïve algorithm , many other metrics are quite optimal for blocked algorithm.
- The ideal block size for matrix sizes – ‘128’ , ‘256’ is ‘16’ and for matrix size – ‘512’ is ‘8’ especially due to lower L1-dcache-misses.
- Overall , the ideal block size is ‘16’ considering all metrics of all three sizes.

RESULT DATA SHEETS :-

MATRIX SIZE – ‘128’

```
tejavardhan@tejavardhan-ROG-Zephyrus-G14: ~/Downloads
tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ g++ gen_input.cpp
tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ ./a.out 128 input_128
tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ g++ template.cpp
tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 0 input_128 output0_128

Performance counter stats for './a.out 0 input_128 output0_128' (100 runs):

    18,99,71,972      instructions              ( +- 3.33% ) (36.78%)
    23,01,390         cache-references          ( +- 1.81% ) (58.68%)
    71,181            cache-misses              # 3.014 % of all cache refs ( +- 2.61% ) (80.47%)
    5,37,59,009       L1-dcache-loads           ( +- 0.73% ) (91.26%)
    22,08,972         L1-dcache-load-misses    # 4.11% of all L1-dcache accesses ( +- 0.14% ) (98.54%)
    7,38,238          L1-icache-loads          ( +- 1.30% ) (84.21%)
    32,569            L1-icache-load-misses   # 4.41% of all L1-icache accesses ( +- 5.75% ) (50.07%)
    <not supported>   LLC-loads
    <not supported>   LLC-load-misses

    0.012115 +- 0.000388 seconds time elapsed ( +- 3.20% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 2 input_128 output0_128

Performance counter stats for './a.out 2 input_128 output0_128' (100 runs):

    14,88,94,719      instructions              ( +- 2.62% ) (43.73%)
    9,99,059           cache-references          ( +- 1.71% ) (55.27%)
    75,764             cache-misses              # 7.584 % of all cache refs ( +- 3.63% ) (73.80%)
    6,92,30,428        L1-dcache-loads           ( +- 1.13% ) (86.78%)
    5,96,573           L1-dcache-load-misses    # 0.86% of all L1-dcache accesses ( +- 0.57% ) (95.70%)
    7,59,545           L1-icache-loads          ( +- 2.80% ) (86.12%)
    23,547             L1-icache-load-misses   # 3.10% of all L1-icache accesses ( +- 5.52% ) (50.51%)
    <not supported>   LLC-loads
    <not supported>   LLC-load-misses

    0.014627 +- 0.000415 seconds time elapsed ( +- 2.83% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 4 input_128 output0_128

Performance counter stats for './a.out 4 input_128 output0_128' (100 runs):

    12,69,23,051      instructions              ( +- 3.16% ) (39.06%)
    9,88,087           cache-references          ( +- 3.09% ) (57.87%)
    72,003             cache-misses              # 12.244 % of all cache refs ( +- 2.85% ) (78.40%)
    6,04,95,426        L1-dcache-loads           ( +- 0.95% ) (89.25%)
    5,04,648           L1-dcache-load-misses    # 0.34% of all L1-dcache accesses ( +- 0.95% ) (97.12%)
    7,59,759           L1-icache-loads          ( +- 1.25% ) (84.34%)
    28,639             L1-icache-load-misses   # 3.77% of all L1-icache accesses ( +- 4.14% ) (53.06%)
    <not supported>   LLC-loads
    <not supported>   LLC-load-misses

    0.013139 +- 0.000410 seconds time elapsed ( +- 3.12% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 8 input_128 output0_128
```

```
tejavardhan@tejavardhan-ROG-Zephyrus-G14: ~/Downloads
tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 8 input_128 output0_128

Performance counter stats for './a.out 8 input_128 output0_128' (100 runs):

12,42,10,842      instructions              ( +- 3.04% ) (40.86%)
4,97,060          cache-references          ( +- 3.69% ) (58.31%)
75,854           cache-misses              ( +- 2.90% ) (78.15%)
5,77,56,486       L1-dcache-loads           # 15.081 % of all cache refs ( +- 0.89% ) (88.96%)
1,18,725          L1-dcache-load-misses     # 0.21% of all L1-dcache accesses ( +- 1.02% ) (96.44%)
7,77,334          L1-icache-loads           ( +- 0.97% ) (88.84%)
29,679           L1-icache-load-misses     # 3.82% of all L1-icache accesses ( +- 3.53% ) (84.07%)
<not supported>  LLC-loads
<not supported>  LLC-load-misses

0.013191 +- 0.008425 seconds time elapsed ( +- 3.22% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 16 input_128 output0_128

Performance counter stats for './a.out 16 input_128 output0_128' (100 runs):

11,77,15,595      instructions              ( +- 3.36% ) (40.71%)
4,88,767          cache-references          ( +- 4.02% ) (57.89%)
76,864           cache-misses              ( +- 3.08% ) (76.97%)
5,56,64,875       L1-dcache-loads           # 15.726 % of all cache refs ( +- 0.97% ) (88.84%)
96,437           L1-dcache-load-misses     # 0.17% of all L1-dcache accesses ( +- 1.70% ) (97.85%)
7,45,914          L1-icache-loads           ( +- 1.85% ) (84.41%)
29,548           L1-icache-load-misses     # 3.96% of all L1-icache accesses ( +- 4.86% ) (53.32%)
<not supported>  LLC-loads
<not supported>  LLC-load-misses

0.013259 +- 0.008425 seconds time elapsed ( +- 3.21% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 32 input_128 output0_128

Performance counter stats for './a.out 32 input_128 output0_128' (100 runs):

11,59,63,245      instructions              ( +- 3.23% ) (40.21%)
4,76,818          cache-references          ( +- 4.30% ) (58.94%)
74,423           cache-misses              ( +- 2.83% ) (78.50%)
5,55,28,688       L1-dcache-loads           # 15.635 % of all cache refs ( +- 0.84% ) (89.35%)
1,00,615          L1-dcache-load-misses     # 0.18% of all L1-dcache accesses ( +- 2.81% ) (97.37%)
7,29,691          L1-icache-loads           ( +- 1.25% ) (83.77%)
31,670           L1-icache-load-misses     # 4.34% of all L1-icache accesses ( +- 5.49% ) (51.78%)
<not supported>  LLC-loads
<not supported>  LLC-load-misses

0.012867 +- 0.008427 seconds time elapsed ( +- 3.32% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 64 input_128 output0_128

Performance counter stats for './a.out 64 input_128 output0_128' (100 runs):

<not supported>  LLC-loads
<not supported>  LLC-load-misses

0.013259 +- 0.008425 seconds time elapsed ( +- 3.21% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 32 input_128 output0_128

Performance counter stats for './a.out 32 input_128 output0_128' (100 runs):

11,59,63,245      instructions              ( +- 3.23% ) (40.21%)
4,76,818          cache-references          ( +- 4.30% ) (58.94%)
74,423           cache-misses              ( +- 2.83% ) (78.50%)
5,55,28,688       L1-dcache-loads           # 15.635 % of all cache refs ( +- 0.84% ) (89.35%)
1,00,615          L1-dcache-load-misses     # 0.18% of all L1-dcache accesses ( +- 2.81% ) (97.37%)
7,29,691          L1-icache-loads           ( +- 1.25% ) (83.77%)
31,670           L1-icache-load-misses     # 4.34% of all L1-icache accesses ( +- 5.49% ) (51.78%)
<not supported>  LLC-loads
<not supported>  LLC-load-misses

0.012867 +- 0.008427 seconds time elapsed ( +- 3.32% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 64 input_128 output0_128

Performance counter stats for './a.out 64 input_128 output0_128' (100 runs):

11,66,83,937      instructions              ( +- 3.82% ) (42.56%)
15,70,920          cache-references          ( +- 1.93% ) (58.10%)
75,252           cache-misses              ( +- 2.94% ) (75.47%)
5,47,54,857       L1-dcache-loads           # 4.793 % of all cache refs ( +- 0.95% ) (86.59%)
13,05,164         L1-dcache-load-misses     ( +- 0.78% ) (95.81%)
8,71,189          L1-icache-loads           ( +- 15.55% ) (85.50%)
27,989           L1-icache-load-misses     # 3.21% of all L1-icache accesses ( +- 4.54% ) (55.97%)
<not supported>  LLC-loads
<not supported>  LLC-load-misses

0.014091 +- 0.008494 seconds time elapsed ( +- 3.50% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 128 input_128 output0_128

Performance counter stats for './a.out 128 input_128 output0_128' (100 runs):

11,85,67,121      instructions              ( +- 3.43% ) (39.69%)
24,08,820          cache-references          ( +- 1.71% ) (57.29%)
73,586           cache-misses              ( +- 2.80% ) (76.76%)
5,47,24,340       L1-dcache-loads           # 3.056 % of all cache refs ( +- 0.99% ) (89.14%)
22,25,379         L1-dcache-load-misses     # 4.07% of all L1-dcache accesses ( +- 0.22% ) (97.89%)
7,48,657          L1-icache-loads           ( +- 2.18% ) (85.37%)
28,497           L1-icache-load-misses     # 3.80% of all L1-icache accesses ( +- 4.79% ) (53.86%)
<not supported>  LLC-loads
<not supported>  LLC-load-misses

0.013806 +- 0.008405 seconds time elapsed ( +- 3.11% )
```

MATRIX SIZE – ‘256’

```
tejavardhan@tejavardhan-ROG-Zephyrus-G14: ~/Downloads
tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ g++ gen_input.cpp
tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ ./a.out 256 input_256
tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ g++ template.cpp
tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 0 input_256 output0_256

Performance counter stats for './a.out 0 input_256 output0_256' (100 runs):

    92,49,04,736      instructions              ( +- 0.38% ) (68.18%)
    2,22,59,910      cache-references          ( +- 2.66% ) (71.88%)
    3,64,068          cache-misses              ( +- 11.81% ) (73.18%)
    37,53,80,458      L1-dcache-loads           ( +- 0.19% ) (73.95%)
    1,68,03,569      L1-dcache-load-misses     # 4.26% of all L1-dcache accesses ( +- 0.36% ) (74.11%)
    13,68,328        L1-icache-loads           ( +- 5.01% ) (71.02%)
    18,719           L1-icache-load-misses     # 1.37% of all L1-icache accesses ( +- 7.84% ) (67.68%)
<not supported>     LLC-loads
<not supported>     LLC-load-misses

    0.062610 +- 0.008494 seconds time elapsed ( +- 0.79% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 2 input_256 output2_256

Performance counter stats for './a.out 2 input_256 output2_256' (100 runs):

    1,14,96,12,812    instructions              ( +- 0.27% ) (69.27%)
    60,31,920          cache-references          ( +- 0.83% ) (69.42%)
    1,76,873           cache-misses              ( +- 5.53% ) (69.76%)
    52,76,89,856      L1-dcache-loads           ( +- 0.28% ) (71.55%)
    43,43,172         L1-dcache-load-misses     # 0.82% of all L1-dcache accesses ( +- 0.35% ) (74.32%)
    17,64,252         L1-icache-loads           ( +- 2.91% ) (74.41%)
    31,467            L1-icache-load-misses     # 1.78% of all L1-icache accesses ( +- 3.07% ) (71.26%)
<not supported>     LLC-loads
<not supported>     LLC-load-misses

    0.079111 +- 0.008488 seconds time elapsed ( +- 0.62% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 4 input_256 output4_256

Performance counter stats for './a.out 4 input_256 output4_256' (100 runs):

    1,83,65,86,728    instructions              ( +- 0.24% ) (66.25%)
    22,39,651          cache-references          ( +- 0.87% ) (69.35%)
    1,39,430           cache-misses              ( +- 2.76% ) (72.27%)
    44,15,64,984      L1-dcache-loads           ( +- 0.22% ) (74.86%)
    12,09,480         L1-dcache-load-misses     # 0.27% of all L1-dcache accesses ( +- 0.64% ) (76.13%)
    29,86,810         L1-icache-loads           ( +- 1.88% ) (73.48%)
    27,175            L1-icache-load-misses     # 1.30% of all L1-icache accesses ( +- 4.42% ) (67.66%)
<not supported>     LLC-loads
<not supported>     LLC-load-misses

    0.068148 +- 0.008451 seconds time elapsed ( +- 0.66% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 8 input_256 output8_256
```

```
tejavardhan@tejavardhan-ROG-Zephyrus-G14: ~/Downloads
tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e Instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 0 input_256 output0_256

Performance counter stats for './a.out 0 input_256 output0_256' (100 runs):

    99,76,67,888      Instructions              ( +- 0.26% ) (66.44%)
    11,50,563         cache-references          ( +- 1.78% ) (69.88%)
    1,35,281          cache-misses              ( +- 1.95% ) (72.55%)
    41,35,70,991      L1-dcache-loads           # 10.01% of all cache refs ( +- 0.24% ) (74.73%)
    6,26,701          L1-dcache-load-misses    # 0.15% of all L1-dcache accesses ( +- 1.92% ) (75.75%)
    20,41,325         L1-icache-loads          ( +- 3.21% ) (73.21%)
    23,593            L1-icache-load-misses # 1.16% of all L1-icache accesses ( +- 0.11% ) (67.44%)
<not supported>     LLC-loads
<not supported>     LLC-load-misses

    0.066888 +- 0.000450 seconds time elapsed ( +- 0.68% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e Instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 16 input_256 output0_256

Performance counter stats for './a.out 16 input_256 output0_256' (100 runs):

    97,60,40,733      Instructions              ( +- 0.30% ) (67.23%)
    12,57,278         cache-references          ( +- 2.01% ) (70.50%)
    1,32,584          cache-misses              ( +- 1.32% ) (72.84%)
    40,19,52,890      L1-dcache-loads           # 10.54% of all cache refs ( +- 0.20% ) (74.40%)
    5,10,213          L1-dcache-load-misses    ( +- 2.18% ) (74.90%)
    17,10,801         L1-icache-loads          ( +- 2.48% ) (72.55%)
    19,176            L1-icache-load-misses # 1.12% of all L1-icache accesses ( +- 0.54% ) (67.53%)
<not supported>     LLC-loads
<not supported>     LLC-load-misses

    0.065184 +- 0.000525 seconds time elapsed ( +- 0.80% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e Instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 32 input_256 output0_256

Performance counter stats for './a.out 32 input_256 output0_256' (100 runs):

    96,03,47,822      Instructions              ( +- 0.26% ) (68.00%)
    1,81,27,897         cache-references          ( +- 0.71% ) (71.34%)
    1,32,603          cache-misses              ( +- 1.21% ) (73.10%)
    39,74,29,219      L1-dcache-loads           # 0.731 % of all cache refs ( +- 0.17% ) (74.27%)
    1,61,09,439        L1-dcache-load-misses    # 4.05% of all L1-dcache accesses ( +- 0.26% ) (74.49%)
    15,97,463          L1-icache-loads          ( +- 2.81% ) (71.64%)
    13,438             L1-icache-load-misses    # 0.85% of all L1-icache accesses ( +- 11.45% ) (67.16%)
<not supported>     LLC-loads
<not supported>     LLC-load-misses

    0.063196 +- 0.000444 seconds time elapsed ( +- 0.70% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e Instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 64 input_256 output0_256

Performance counter stats for './a.out 64 input_256 output0_256' (100 runs):

<not supported>     LLC-loads
<not supported>     LLC-load-misses

    0.063196 +- 0.000444 seconds time elapsed ( +- 0.70% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e Instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 64 input_256 output0_256

Performance counter stats for './a.out 64 input_256 output0_256' (100 runs):

    96,66,23,885      Instructions              ( +- 0.36% ) (67.13%)
    1,84,11,286         cache-references          ( +- 0.75% ) (71.27%)
    1,25,254          cache-misses              ( +- 0.96% ) (73.88%)
    39,70,09,415      L1-dcache-loads           # 0.680 % of all cache refs ( +- 0.19% ) (74.64%)
    1,59,99,530        L1-dcache-load-misses    # 4.08% of all L1-dcache accesses ( +- 0.24% ) (74.69%)
    16,61,809          L1-icache-loads          ( +- 2.89% ) (71.65%)
    16,717             L1-icache-load-misses    # 1.01% of all L1-icache accesses ( +- 9.82% ) (66.74%)
<not supported>     LLC-loads
<not supported>     LLC-load-misses

    0.063673 +- 0.000367 seconds time elapsed ( +- 0.58% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e Instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 128 input_256 output0_256

Performance counter stats for './a.out 128 input_256 output0_256' (100 runs):

    96,06,09,081      Instructions              ( +- 0.32% ) (67.24%)
    1,83,66,868         cache-references          ( +- 0.71% ) (70.94%)
    1,20,190          cache-misses              ( +- 1.19% ) (73.33%)
    39,45,63,336      L1-dcache-loads           # 0.654 % of all cache refs ( +- 0.21% ) (74.64%)
    1,60,51,447        L1-dcache-load-misses    # 4.07% of all L1-dcache accesses ( +- 0.27% ) (74.93%)
    15,56,114          L1-icache-loads          ( +- 2.52% ) (71.99%)
    17,358             L1-icache-load-misses    # 1.12% of all L1-icache accesses ( +- 9.62% ) (66.93%)
<not supported>     LLC-loads
<not supported>     LLC-load-misses

    0.064456 +- 0.000429 seconds time elapsed ( +- 0.67% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e Instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 256 input_256 output0_256

Performance counter stats for './a.out 256 input_256 output0_256' (100 runs):

    94,87,80,103      Instructions              ( +- 0.23% ) (68.23%)
    2,30,19,165         cache-references          ( +- 2.20% ) (72.23%)
    3,77,429          cache-misses              ( +- 9.62% ) (73.49%)
    39,51,19,734      L1-dcache-loads           # 1.640 % of all cache refs ( +- 0.32% ) (73.08%)
    1,61,26,831        L1-dcache-load-misses    # 4.08% of all L1-dcache accesses ( +- 0.17% ) (74.08%)
    16,27,924          L1-icache-loads          ( +- 4.12% ) (71.23%)
    10,673             L1-icache-load-misses    # 0.66% of all L1-icache accesses ( +- 12.02% ) (66.76%)
<not supported>     LLC-loads
<not supported>     LLC-load-misses

    0.062860 +- 0.000302 seconds time elapsed ( +- 0.49% )
```

MATRIX SIZE – ‘512’

```
tejavardhan@tejavardhan-ROG-Zephyrus-G14: ~/Downloads
tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ g++ gen_input.cpp
tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ ./a.out 512 input_512
tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ g++ template.cpp
tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 0 input_512 output0_512

Performance counter stats for './a.out 0 input_512 output0_512' (100 runs):

      6,74,34,43,240      instructions              ( +- 0.05% ) (71.18%)
      31,91,22,812        cache-references          ( +- 0.12% ) (71.32%)
      12,86,88,485        cache-misses              # 40.32% of all cache refs ( +- 0.23% ) (71.44%)
      2,87,61,31,851      L1-dcache-loads           ( +- 0.04% ) (71.55%)
      13,65,28,675        L1-dcache-load-misses     # 4.75% of all L1-dcache accesses ( +- 0.08% ) (71.66%)
      1,41,65,188         L1-icache-loads           ( +- 1.52% ) (71.58%)
      1,74,998            L1-icache-load-misses     # 1.23% of all L1-icache accesses ( +- 1.46% ) (71.26%)
<not supported>         LLC-loads
<not supported>         LLC-load-misses

      0.59605 +- 0.00137 seconds time elapsed ( +- 0.23% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 2 input_512 output0_512

Performance counter stats for './a.out 2 input_512 output0_512' (100 runs):

      8,64,01,30,462      instructions              ( +- 0.03% ) (71.01%)
      7,47,42,275        cache-references          ( +- 0.30% ) (71.20%)
      2,76,74,803        cache-misses              # 37.02% of all cache refs ( +- 1.09% ) (71.40%)
      4,06,45,12,948      L1-dcache-loads           ( +- 0.03% ) (71.61%)
      3,51,40,955        L1-dcache-load-misses     # 0.86% of all L1-dcache accesses ( +- 0.16% ) (71.87%)
      1,28,39,378        L1-icache-loads           ( +- 0.97% ) (71.72%)
      1,09,141           L1-icache-load-misses     # 0.85% of all L1-icache accesses ( +- 1.94% ) (71.19%)
<not supported>         LLC-loads
<not supported>         LLC-load-misses

      0.580703 +- 0.000873 seconds time elapsed ( +- 0.15% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 4 input_512 output0_512

Performance counter stats for './a.out 4 input_512 output0_512' (100 runs):

      7,61,69,61,655      instructions              ( +- 0.03% ) (71.16%)
      2,11,44,183        cache-references          ( +- 0.21% ) (71.20%)
      87,90,452          cache-misses              # 41.57% of all cache refs ( +- 0.14% ) (71.23%)
      3,40,87,97,879      L1-dcache-loads           ( +- 0.03% ) (71.36%)
      1,12,03,422         L1-dcache-load-misses     # 0.33% of all L1-dcache accesses ( +- 0.32% ) (71.74%)
      97,71,178          L1-icache-loads           ( +- 1.19% ) (71.88%)
      1,00,851           L1-icache-load-misses     # 1.02% of all L1-icache accesses ( +- 1.15% ) (71.43%)
<not supported>         LLC-loads
<not supported>         LLC-load-misses

      0.500510 +- 0.000406 seconds time elapsed ( +- 0.08% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 8 input_512 output0_512

Performance counter stats for './a.out 8 input_512 output0_512' (100 runs):

      7,28,94,04,688      instructions              ( +- 0.03% ) (70.75%)
      1,21,86,489        cache-references          ( +- 1.76% ) (70.86%)
      25,34,881          cache-misses              # 20.801 % of all cache refs ( +- 1.42% ) (71.21%)
      3,17,72,83,778      L1-dcache-loads           ( +- 0.03% ) (71.79%)
      68,83,290          L1-dcache-load-misses     # 0.22% of all L1-dcache accesses ( +- 1.78% ) (72.24%)
      77,99,962          L1-icache-loads           ( +- 1.05% ) (71.98%)
      73,601            L1-icache-load-misses     # 0.94% of all L1-icache accesses ( +- 1.95% ) (71.17%)
<not supported>         LLC-loads
<not supported>         LLC-load-misses

      0.465395 +- 0.000406 seconds time elapsed ( +- 0.09% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 16 input_512 output0_512

Performance counter stats for './a.out 16 input_512 output0_512' (100 runs):

      7,14,71,87,581      instructions              ( +- 0.04% ) (71.05%)
      11,51,14,791        cache-references          ( +- 0.52% ) (71.26%)
      23,50,753          cache-misses              # 2.042 % of all cache refs ( +- 3.77% ) (71.37%)
      3,09,02,59,553      L1-dcache-loads           ( +- 0.04% ) (71.57%)
      10,65,30,610        L1-dcache-load-misses     # 3.45% of all L1-dcache accesses ( +- 0.30% ) (71.87%)
      73,50,524          L1-icache-loads           ( +- 5.41% ) (71.73%)
      81,879            L1-icache-load-misses     # 1.10% of all L1-icache accesses ( +- 1.95% ) (71.15%)
<not supported>         LLC-loads
<not supported>         LLC-load-misses

      0.48103 +- 0.00104 seconds time elapsed ( +- 0.22% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 32 input_512 output0_512

Performance counter stats for './a.out 32 input_512 output0_512' (100 runs):

      7,07,19,92,805      instructions              ( +- 0.04% ) (70.88%)
      14,25,68,143        cache-references          ( +- 0.14% ) (71.25%)
      9,48,070           cache-misses              # 0.665 % of all cache refs ( +- 1.17% ) (71.59%)
      3,04,19,30,232      L1-dcache-loads           ( +- 0.04% ) (71.80%)
      13,71,47,367        L1-dcache-load-misses     # 4.51% of all L1-dcache accesses ( +- 0.13% ) (71.89%)
      62,72,886          L1-icache-loads           ( +- 1.29% ) (71.61%)
      97,333            L1-icache-load-misses     # 1.07% of all L1-icache accesses ( +- 2.43% ) (70.98%)
<not supported>         LLC-loads
<not supported>         LLC-load-misses

      0.457897 +- 0.000877 seconds time elapsed ( +- 0.19% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 64 input_512 output0_512

Performance counter stats for './a.out 64 input_512 output0_512' (100 runs):
```



```
tejavardhan@tejavardhan-ROG-Zephyrus-G14: ~/Downloads
tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 64 input_512 output0_512
Performance counter stats for './a.out 64 input_512 output0_512' (100 runs):
    7,02,49,70,730      instructions              ( +- 0.04% ) (71.19%)
    14,38,09,266        cache-references         ( +- 0.13% ) (71.53%)
    5,83,397            cache-misses             # 0.406 % of all cache refs ( +- 0.78% ) (71.64%)
    3,02,62,35,220      L1-dcache-loads          ( +- 0.03% ) (71.65%)
    14,05,20,222        L1-dcache-load-misses   # 4.63% of all L1-dcache accesses ( +- 0.00% ) (71.60%)
    57,04,946          L1-icache-loads         ( +- 1.25% ) (71.24%)
    68,252             L1-icache-load-misses   # 1.20% of all L1-icache accesses ( +- 1.61% ) (70.98%)
    <not supported>     LLC-loads
    <not supported>     LLC-load-misses

    0.452450 +- 0.000426 seconds time elapsed ( +- 0.09% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 128 input_512 output0_512
Performance counter stats for './a.out 128 input_512 output0_512' (100 runs):
    7,02,49,81,755      instructions              ( +- 0.07% ) (71.01%)
    16,15,84,960        cache-references         ( +- 0.07% ) (71.26%)
    32,71,871           cache-misses             # 2.025 % of all cache refs ( +- 0.52% ) (71.45%)
    3,03,19,15,855      L1-dcache-loads          ( +- 0.07% ) (71.62%)
    13,68,19,878        L1-dcache-load-misses   # 4.51% of all L1-dcache accesses ( +- 0.14% ) (71.84%)
    59,24,478          L1-icache-loads         ( +- 2.97% ) (71.69%)
    77,841             L1-icache-load-misses   # 1.31% of all L1-icache accesses ( +- 2.47% ) (71.14%)
    <not supported>     LLC-loads
    <not supported>     LLC-load-misses

    0.48876 +- 0.00101 seconds time elapsed ( +- 0.21% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 256 input_512 output0_512
Performance counter stats for './a.out 256 input_512 output0_512' (100 runs):
    7,01,52,24,875      instructions              ( +- 0.04% ) (70.99%)
    25,75,38,876        cache-references         ( +- 0.21% ) (71.14%)
    5,37,10,980         cache-misses             # 20.855 % of all cache refs ( +- 1.05% ) (71.34%)
    3,01,92,49,222      L1-dcache-loads          ( +- 0.04% ) (71.60%)
    13,57,18,944        L1-dcache-load-misses   # 4.50% of all L1-dcache accesses ( +- 0.11% ) (71.89%)
    1,19,75,561         L1-icache-loads         ( +- 3.92% ) (71.79%)
    1,27,794           L1-icache-load-misses   # 1.07% of all L1-icache accesses ( +- 3.61% ) (71.24%)
    <not supported>     LLC-loads
    <not supported>     LLC-load-misses

    0.55461 +- 0.00110 seconds time elapsed ( +- 0.20% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 512 input_512 output0_512
Performance counter stats for './a.out 512 input_512 output0_512' (100 runs):
    7,02,49,81,755      instructions              ( +- 0.07% ) (71.01%)
    16,15,84,960        cache-references         ( +- 0.07% ) (71.26%)
    32,71,871           cache-misses             # 2.025 % of all cache refs ( +- 0.52% ) (71.45%)
    3,03,19,15,855      L1-dcache-loads          ( +- 0.07% ) (71.62%)
    13,68,19,878        L1-dcache-load-misses   # 4.51% of all L1-dcache accesses ( +- 0.14% ) (71.84%)
    59,24,478          L1-icache-loads         ( +- 2.97% ) (71.69%)
    77,841             L1-icache-load-misses   # 1.31% of all L1-icache accesses ( +- 2.47% ) (71.14%)
    <not supported>     LLC-loads
    <not supported>     LLC-load-misses

    0.48876 +- 0.00101 seconds time elapsed ( +- 0.21% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 512 input_512 output0_512
Performance counter stats for './a.out 512 input_512 output0_512' (100 runs):
    7,01,52,24,875      instructions              ( +- 0.04% ) (70.99%)
    25,75,38,876        cache-references         ( +- 0.21% ) (71.14%)
    5,37,10,980         cache-misses             # 20.855 % of all cache refs ( +- 1.05% ) (71.34%)
    3,01,92,49,222      L1-dcache-loads          ( +- 0.04% ) (71.60%)
    13,57,18,944        L1-dcache-load-misses   # 4.50% of all L1-dcache accesses ( +- 0.11% ) (71.89%)
    1,19,75,561         L1-icache-loads         ( +- 3.92% ) (71.79%)
    1,27,794           L1-icache-load-misses   # 1.07% of all L1-icache accesses ( +- 3.61% ) (71.24%)
    <not supported>     LLC-loads
    <not supported>     LLC-load-misses

    0.55461 +- 0.00110 seconds time elapsed ( +- 0.20% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$ sudo perf stat -e instructions,cache-references,cache-misses,L1-dcache-loads,L1-dcache-load-misses,L1-icache-loads,L1-icache-load-misses,LLC-loads,LLC-load-misses -r 100 ./a.out 512 input_512 output0_512
Performance counter stats for './a.out 512 input_512 output0_512' (100 runs):
    7,06,33,04,333      instructions              ( +- 0.04% ) (70.89%)
    32,26,57,998        cache-references         ( +- 0.10% ) (71.21%)
    12,67,78,145        cache-misses             # 39.292 % of all cache refs ( +- 0.23% ) (71.54%)
    3,01,68,52,810      L1-dcache-loads          ( +- 0.03% ) (71.77%)
    13,57,45,845        L1-dcache-load-misses   # 4.50% of all L1-dcache accesses ( +- 0.06% ) (71.89%)
    1,79,28,686         L1-icache-loads         ( +- 1.56% ) (71.63%)
    1,65,106           L1-icache-load-misses   # 0.92% of all L1-icache accesses ( +- 1.62% ) (71.05%)
    <not supported>     LLC-loads
    <not supported>     LLC-load-misses

    0.599253 +- 0.000573 seconds time elapsed ( +- 0.10% )

tejavardhan@tejavardhan-ROG-Zephyrus-G14:~/Downloads$
```