COMPUTER ARCHITECTURE - PROJCET 2
ANALYSIS OF CACHE PARAMETERS AND TRADE-OFFS ON X86 PROCESSOR USING GEM5 SIMULATION

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***Abstract*— The primary focus of our project is predict simulate the following benchmarks 401.bzip2, 429.mcf, 456.hmmer, 458.sjeng and 470.lbm. The parameters changed to identify this simulation are**

1) **L1d cache size**
2) **L1i cache size**
3) **L2 cache size**
4) **Block size**
5) **L1i associativity**
6) **L1d associativity**
7) **L2 associativity**

$$CPI = 1 + \frac{(IL1.miss\_num + DL1.miss\_num) \times 6 + L2.miss\_num \times 50}{Total\_Inst\_num}$$

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I. Results and Evaluation

I ran the visualization locally, and have hosted it on Google colab to generate a sharable link.
https://colab.research.google.com/drive/1wDYy8iJ9QlbYIIVRsxUW6CISIPBAVn2t

A. *401.bzip2*

Command

```
$time ./build/X86/gem5.opt -d /home/csgrad/davidjeg
    /401/op1_1 ./configs/example/se.py -c ./
    benchmark/401.bzip2/src/benchmark -o ./
    benchmark/401.bzip2/data/input.program -I
    100000000 --caches --l2cache -- l2_size=1MB --
    l1d_size=64kB --l1i_size=64kB --cacheline_size
    =64 --l1d_assoc=2 -- l1i_assoc=2 --l2_assoc=2
```

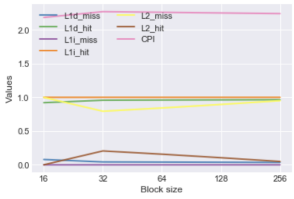
Results

*1) **L1d(Data) cache size:***

- The default parameter values for L1i size is 64kB, L2 size is 1MB, Block size is 64B, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The L1d cache is changed in size and miss/hit rate is determined.
- We increase L1d sizes 16, 32, 64, 128, 256 in Kbs respectively.
- The L2 miss rate is decreasing and increasing based on the L1d size. This is because, L1d content is a subset of L2 cache.

```
--- iteration # 1 for 401bzip2o.csv ---
```

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
0	0.079055	0.920945	1e-05	0.99999	0.999549	0.000451	2.18366	16
1	0.042719	0.957281	4e-06	0.999996	0.794108	0.205892	2.26974	32
2	0.040267	0.959733	4e-06	0.999996	0.8424	0.1576	2.26009	64
3	0.037894	0.962106	4e-06	0.999996	0.894922	0.105078	2.25056	128
4	0.035656	0.964344	4e-06	0.999996	0.95033	0.04967	2.24095	256




```
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--- iteration # 2 for 401bzip2o.csv ---
```
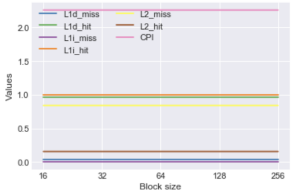

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
5	0.040267	0.959733	5e-06	0.999995	0.842383	0.157617	2.26012	16
6	0.040267	0.959733	4e-06	0.999996	0.842395	0.157605	2.26011	32
7	0.040267	0.959733	4e-06	0.999996	0.8424	0.1576	2.26009	64
8	0.040267	0.959733	4e-06	0.999996	0.842403	0.157597	2.26009	128
9	0.040267	0.959733	4e-06	0.999996	0.842403	0.157597	2.26009	256



*2) **L1i(Instruction) cache size:***

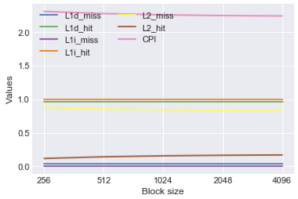
- The default parameter values for L1d size is 64kB, L2 size is 1MB, Block size is 64B, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The L1i cache is changed in size and miss/hit rate is determined.
- We increase L1i sizes 16, 32, 64, 128, 256 in kbs respectively.
- The L1i miss rate is decreasing and L1i hit rate is increasing. because of this , CPI is decreasing as size of L1i increases.

*3) **L2 cache size:***

- The default parameter values for L1d size is 64kB, L1i size is 64kB, Block size is 64B, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The L2 cache is changed in size and miss/hit rate is determined.

--- iteration # 3 for 401bzip2o.csv ---

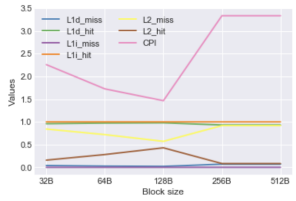
	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
10	0.040267	0.959733	4e-06	0.999996	0.881304	0.118696	2.31103	256
11	0.040267	0.959733	4e-06	0.999996	0.856761	0.143239	2.2789	512
12	0.040267	0.959733	4e-06	0.999996	0.8424	0.1576	2.26009	1024
13	0.040267	0.959733	4e-06	0.999996	0.834338	0.165662	2.24954	2048
14	0.040267	0.959733	4e-06	0.999996	0.829756	0.170244	2.24354	4096



- We increase L2 sizes 256, 512, 1024, 2048, 4096 in kbs respectively.
- The L2 miss rate is decreasing and the L2 hit rate is increasing. This is because there is more data available in L2, therefore the number of hits shoot up.Also the CPI is reduced as the L2 cache size increases.

--- iteration # 4 for 401bzip2o.csv ---

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
15	0.040267	0.959733	4e-06	0.999996	0.8424	0.1576	2.26009	32B
16	0.026613	0.973387	2e-06	0.999998	0.719257	0.280743	1.72623	64B
17	0.02073	0.97927	2e-06	0.999998	0.571375	0.428625	1.46601	128B
18	0.069238	0.930762	7e-06	0.999993	0.917971	0.082029	3.33683	256B
19	0.069238	0.930762	7e-06	0.999993	0.917971	0.082029	3.33683	512B

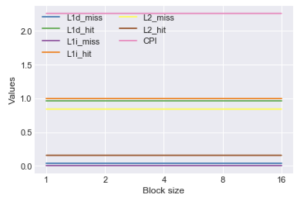


4) *Block size:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The Block is changed in size and miss/hit rate is determined.
- We increase Block sizes 32, 64, 128, 256, 512 in terms of B respectively.
- As block size increases, L1i miss rate is decreasing and accordingly the hit rates are increasing.The CPI is decreasing till 128B and then increasing

--- iteration # 5 for 401bzip2o.csv ---

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
20	0.040267	0.959733	4e-06	0.999996	0.842395	0.157605	2.2601	1
21	0.040267	0.959733	4e-06	0.999996	0.8424	0.1576	2.26009	2
22	0.040267	0.959733	4e-06	0.999996	0.842402	0.157598	2.26009	4
23	0.040267	0.959733	4e-06	0.999996	0.842403	0.157597	2.26009	8
24	0.040267	0.959733	4e-06	0.999996	0.842403	0.157597	2.26009	16

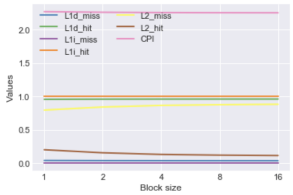


5) *L1i Associativity:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, Block size is 64B, L1d associativity is 2, L2 associativity is 2
- The L1i associativity is changed in size and miss/hit rate is determined.
- We increase L1d associativity sizes 1, 2, 4, 8, 16 respectively.
- The CPI remains the same, though the L1i associativity is increased.

--- iteration # 6 for 401bzip2o.csv ---

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
25	0.04258	0.95742	4e-06	0.999996	0.796708	0.203292	2.2692	1
26	0.040267	0.959733	4e-06	0.999996	0.8424	0.1576	2.26009	2
27	0.039129	0.960871	4e-06	0.999996	0.866861	0.133139	2.2556	4
28	0.038653	0.961347	4e-06	0.999996	0.877482	0.122518	2.2537	8
29	0.038389	0.961611	4e-06	0.999996	0.883495	0.116505	2.25265	16

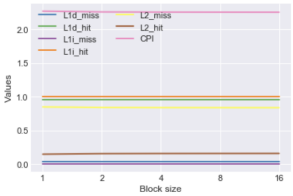


6) *L1d Associativity:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, Block size is 64B, L1i associativity is 2, L2 associativity is 2
- The L1d Associativity is changed in size and miss/hit rate is determined.
- We increase L1d Associativity sizes 1, 2, 4, 8, 16 respectively.
- As L1d associativity increases, L1d miss rate is decreasing and accordingly the L1d hit rates are increasing.The CPI is decreasing with the increase of L1d associativity

--- iteration # 7 for 401bzip2o.csv ---

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
30	0.040267	0.959733	4e-06	0.999996	0.85073	0.14927	2.271	1
31	0.040267	0.959733	4e-06	0.999996	0.8424	0.1576	2.26009	2
32	0.040267	0.959733	4e-06	0.999996	0.840486	0.159514	2.25759	4
33	0.040267	0.959733	4e-06	0.999996	0.839761	0.160239	2.25664	8
34	0.040267	0.959733	4e-06	0.999996	0.839247	0.160753	2.25596	16



7) *L2 Associativity:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, L1i associativity is 2, L1d associativity is 2, Block size is 64B
- The L2 Associativity is changed in size and miss/hit rate is determined.
- We increase L2 Associativity sizes 1, 2, 4, 8, 16 respectively.

- As the L2 associativity is increasing, the L2 miss rate is decreasing and the hit rate is increasing. The CPI is decreasing as the L2 associativity is increasing

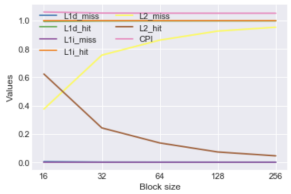
B. *429.mcf*

Command

```
$time ./build/X86/gem5.opt -d /home/csgrad/davidjeg/429/op1_1 ./configs/example/se.py -c ./benchmark/429.mcf/src/benchmark -o ./benchmark/429.mcf/data/inp.in -I 100000000 --caches --l2cache --l2_size=1MB -- l1d_size=64kB -- l1i_size=64kB --cacheline_size=64 --l1d_assoc=2 --l1i_assoc=2 -- l2_assoc=2
```

Results

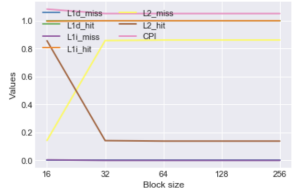
```
--- iteration # 1 for 429mcfo.csv ---
+----+-----------+-----------+-----------+-----------+-----------+-----------+---------+--------+
|    |  L1d_miss |  L1d_hit  |  L1i_miss |  L1i_hit  |  L2_miss  |  L2_hit   |   CPI   | xaxis  |
|----+-----------+-----------+-----------+-----------+-----------+-----------+---------+--------|
|  0 |  0.006868 |  0.993132 |    4e-06  |  0.999996 |  0.376679 |  0.623321 | 1.05961 |   16   |
|  1 |  0.003414 |  0.996586 |    4e-06  |  0.999996 |  0.756085 |  0.243915 | 1.05239 |   32   |
|  2 |  0.002994 |  0.997006 |    4e-06  |  0.999996 |  0.861892 |  0.138108 | 1.05151 |   64   |
|  3 |  0.002791 |  0.997209 |    4e-06  |  0.999996 |  0.925462 |  0.074538 | 1.05114 |  128   |
|  4 |  0.002712 |  0.997288 |    4e-06  |  0.999996 |  0.952646 |  0.047354 |  1.051  |  256   |
+----+-----------+-----------+-----------+-----------+-----------+-----------+---------+--------+
```



1) *L1d(Data) cache size:*

- The default parameter values for L1i size is 64kB, L2 size is 1MB, Block size is 64B, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The L1d cache is changed in size and miss/hit rate is determined.
- We increase L1d sizes 16, 32, 64, 128, 256 in Kbs respectively.
- The L2 miss rate is decreasing and increasing based on the L1d size. This is because, L1d content is a subset of L2 cache. The CPI is found to be decreasing wrt increase in L1d.

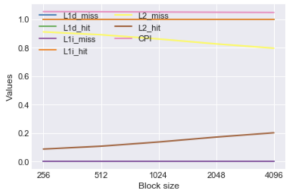
```
---------------------
--- iteration # 2 for 429mcfo.csv ---
+----+-----------+-----------+-----------+-----------+-----------+-----------+---------+--------+
|    |  L1d_miss |  L1d_hit  |  L1i_miss |  L1i_hit  |  L2_miss  |  L2_hit   |   CPI   | xaxis  |
|----+-----------+-----------+-----------+-----------+-----------+-----------+---------+--------|
|  5 |  0.002994 |  0.997006 |  0.003859 |  0.996141 |  0.1428   |  0.8572   | 1.08322 |   16   |
|  6 |  0.002994 |  0.997006 |    7e-06  |  0.999993 |  0.858407 |  0.141593 | 1.05153 |   32   |
|  7 |  0.002994 |  0.997006 |    4e-06  |  0.999996 |  0.861892 |  0.138108 | 1.05151 |   64   |
|  8 |  0.002994 |  0.997006 |    4e-06  |  0.999996 |  0.861925 |  0.138075 | 1.05151 |  128   |
|  9 |  0.002994 |  0.997006 |    4e-06  |  0.999996 |  0.861925 |  0.138075 | 1.05151 |  256   |
+----+-----------+-----------+-----------+-----------+-----------+-----------+---------+--------+
```



2) *L1i(Instruction) cache size:*

- The default parameter values for L1d size is 64kB, L2 size is 1MB, Block size is 64B, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The L1i cache is changed in size and miss/hit rate is determined.
- We increase L1i sizes 16, 32, 64, 128, 256 in kbs respectively.
- The L1i miss rate is decreasing and L1i hit rate is increasing. because of this , CPI is decreasing as size of L1i increases.

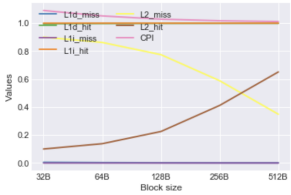
```
---------------------
--- iteration # 3 for 429mcfo.csv ---
+----+-----------+-----------+-----------+-----------+-----------+-----------+---------+--------+
|    |  L1d_miss |  L1d_hit  |  L1i_miss |  L1i_hit  |  L2_miss  |  L2_hit   |   CPI   | xaxis  |
|----+-----------+-----------+-----------+-----------+-----------+-----------+---------+--------|
| 10 |  0.002994 |  0.997006 |    4e-06  |  0.999996 |  0.91162  |  0.08838  | 1.05411 |   256  |
| 11 |  0.002994 |  0.997006 |    4e-06  |  0.999996 |  0.891575 |  0.108425 | 1.05306 |   512  |
| 12 |  0.002994 |  0.997006 |    4e-06  |  0.999996 |  0.861892 |  0.138108 | 1.05151 |  1024  |
| 13 |  0.002994 |  0.997006 |    4e-06  |  0.999996 |  0.827339 |  0.172661 | 1.04969 |  2048  |
| 14 |  0.002994 |  0.997006 |    4e-06  |  0.999996 |  0.797209 |  0.202791 | 1.04811 |  4096  |
+----+-----------+-----------+-----------+-----------+-----------+-----------+---------+--------+
```



3) *L2 cache size:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, Block size is 64B, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The L2 cache is changed in size and miss/hit rate is determined.
- We increase L2 sizes 256, 512, 1024, 2048, 4096 in kbs respectively.
- The L2 miss rate is decreasing and the L2 hit rate is increasing. This is because there is more data available in L2, therefore the number of hits shoot up.Also the CPI is reduced as the L2 cache size increases.

```
---------------------
--- iteration # 4 for 429mcfo.csv ---
+----+-----------+-----------+-----------+-----------+-----------+-----------+---------+--------+
|    |  L1d_miss |  L1d_hit  |  L1i_miss |  L1i_hit  |  L2_miss  |  L2_hit   |   CPI   | xaxis  |
|----+-----------+-----------+-----------+-----------+-----------+-----------+---------+--------|
| 15 |  0.005057 |  0.994943 |    6e-06  |  0.999994 |  0.899871 |  0.100129 | 1.09041 |  32B   |
| 16 |  0.002994 |  0.997006 |    4e-06  |  0.999996 |  0.861892 |  0.138108 | 1.05151 |  64B   |
| 17 |  0.001823 |  0.998177 |    2e-06  |  0.999998 |  0.774643 |  0.225357 | 1.02858 |  128B  |
| 18 |  0.001368 |  0.998632 |    1e-06  |  0.999999 |  0.58834  |  0.41166  | 1.01697 |  256B  |
| 19 |  0.001381 |  0.998619 |    1e-06  |  0.999999 |  0.348807 |  0.651193 | 1.01132 |  512B  |
+----+-----------+-----------+-----------+-----------+-----------+-----------+---------+--------+
```

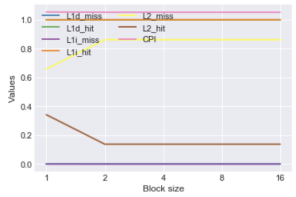


4) *Block size:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The Block is changed in size and miss/hit rate is determined.
- We increase Block sizes 32, 64, 128, 256, 512 in terms of B respectively.
- As block size increases, L1i miss rate is decreasing and accordingly the hit rates are increasing.The CPI is decreasing as block size increases.

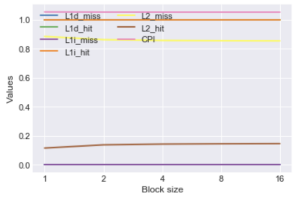
```
--- iteration # 5 for 429mcfo.csv ---
```

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
20	0.002994	0.997006	0.000241	0.999759	0.658007	0.341993	1.05346	1
21	0.002994	0.997006	4e-06	0.999996	0.861892	0.138108	1.05151	2
22	0.002994	0.997006	4e-06	0.999996	0.861917	0.138083	1.05151	4
23	0.002994	0.997006	4e-06	0.999996	0.861925	0.138075	1.05151	8
24	0.002994	0.997006	4e-06	0.999996	0.861925	0.138075	1.05151	16




```
--- iteration # 7 for 429mcfo.csv ---
```

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
30	0.002994	0.997006	4e-06	0.999996	0.884026	0.115974	1.05267	1
31	0.002994	0.997006	4e-06	0.999996	0.861892	0.138108	1.05151	2
32	0.002994	0.997006	4e-06	0.999996	0.856545	0.143455	1.05123	4
33	0.002994	0.997006	4e-06	0.999996	0.854553	0.145447	1.05112	8
34	0.002994	0.997006	4e-06	0.999996	0.853438	0.146562	1.05106	16

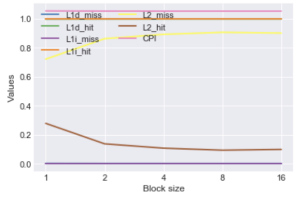


*5) **L1i Associativity**:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, Block size is 64B, L1d associativity is 2, L2 associativity is 2
- The L1i associativity is changed in size and miss/hit rate is determined.
- We increase L1d associativity sizes 1, 2, 4, 8, 16 respectively.
- The CPI remains the same, though the L1i associativity is increased.

```
--- iteration # 6 for 429mcfo.csv ---
```

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
25	0.003582	0.996418	4e-06	0.999996	0.72089	0.27911	1.05274	1
26	0.002994	0.997006	4e-06	0.999996	0.861892	0.138108	1.05151	2
27	0.002893	0.997107	4e-06	0.999996	0.891636	0.108364	1.0513	4
28	0.00285	0.99715	4e-06	0.999996	0.90552	0.09448	1.05122	8
29	0.002866	0.997134	4e-06	0.999996	0.900326	0.099674	1.05124	16



*6) **L1d Associativity**:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, Block size is 64B, L1i associativity is 2, L2 associativity is 2
- The L1d Associativity is changed in size and miss/hit rate is determined.
- We increase L1d Associativity sizes 1, 2, 4, 8, 16 respectively.
- As L1d associativity increases, L1d miss rate is decreasing and accordingly the L1d hit rates are increasing.The CPI is decreasing with the increase of L1d associativity

*7) **L2 Associativity**:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, L1i associativity is 2, L1d associativity is 2, Block size is 64B
- The L2 Associativity is changed in size and miss/hit rate is determined.
- We increase L2 Associativity sizes 1, 2, 4, 8, 16 respectively.
- As the L2 associativity is increasing, the L2 miss rate is decreasing and the hit rate is increasing. The CPI is decreasing as the L2 associativity is increasing

C. *456.hmmer*

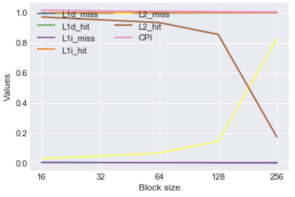
Command

```
$time ./build/X86/gem5.opt -d /home/csgrad/davidjeg
    /456/op1_1 ./configs/example/se.py -c ./
    benchmark/456.hmmer/src/benchmark -o ./
    benchmark/456.hmmer/data/bombesin.hmm.new -I
    100000000 --caches --l2cache - -l2_size=1MB --
    l1d_size=64kB --l1i_size=64kB --cacheline_size
    =64 --l1d_assoc=2 -- l1i_assoc=2 --l2_assoc=2
```

Results

```
--- iteration # 1 for 456hmmer.csv ---
```

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
0	0.004308	0.995692	1.5e-05	0.999985	0.02876	0.97124	1.0165	16
1	0.002592	0.997408	1.5e-05	0.999985	0.047473	0.952527	1.01125	32
2	0.001862	0.998138	1.5e-05	0.999985	0.065702	0.934298	1.00901	64
3	0.000823	0.999177	1.5e-05	0.999985	0.144614	0.855386	1.00583	128
4	0.00011	0.99989	1.5e-05	0.999985	0.827488	0.172512	1.00365	256



*1) **L1d(Data) cache size**:*

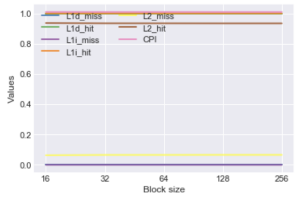
- The default parameter values for L1i size is 64kB, L2 size is 1MB, Block size is 64B, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The L1d cache is changed in size and miss/hit rate is determined.
- We increase L1d sizes 16, 32, 64, 128, 256 in Kbs respectively.
- The L2 miss rate is decreasing and increasing based on the L1d size. This is because, L1d content is a subset of L2 cache. The L1d hit and miss rate is increasing and decreasing respectively.

*2) **L1i(Instruction) cache size**:*

- The default parameter values for L1d size is 64kB, L2 size is 1MB, Block size is 64B, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The L1i cache is changed in size and miss/hit rate is determined.

```
--- iteration # 2 for 456hmmer.csv ---
```

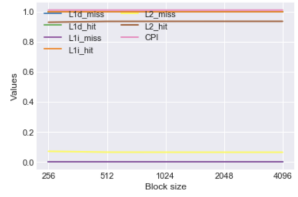
	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
5	0.001862	0.998138	3.6e-05	0.999964	0.063809	0.936191	1.00919	16
6	0.001862	0.998138	1.6e-05	0.999984	0.065646	0.934354	1.00902	32
7	0.001862	0.998138	1.5e-05	0.999985	0.065702	0.934298	1.00901	64
8	0.001862	0.998138	1e-05	0.99999	0.06608	0.93392	1.00896	128
9	0.001862	0.998138	1e-05	0.99999	0.066097	0.933903	1.00896	256



- We increase L1i sizes 16, 32, 64, 128, 256 in kbs respectively.
- The L1i miss rate is decreasing and L1i hit rate is increasing. because of this , CPI is decreasing as size of L1i increases.

```
--- iteration # 3 for 456hmmer.csv ---
```

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
10	0.001862	0.998138	1.5e-05	0.999985	0.071782	0.928218	1.00931	256
11	0.001862	0.998138	1.5e-05	0.999985	0.066022	0.933978	1.00903	512
12	0.001862	0.998138	1.5e-05	0.999985	0.065702	0.934298	1.00901	1024
13	0.001862	0.998138	1.5e-05	0.999985	0.065589	0.934411	1.00901	2048
14	0.001862	0.998138	1.5e-05	0.999985	0.065589	0.934411	1.00901	4096

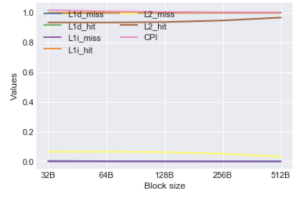


*3) **L2 cache size**:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, Block size is 64B, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The L2 cache is changed in size and miss/hit rate is determined.
- We increase L2 sizes 256, 512, 1024, 2048, 4096 in kbs respectively.
- The L2 miss rate is decreasing and the L2 hit rate is increasing. This is because there is more data available in L2, therefore the number of hits shoot up.Also the CPI is reduced as the L2 cache size increases.

```
--- iteration # 4 for 456hmmer.csv ---
```

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
15	0.00356	0.99644	2.5e-05	0.999975	0.065435	0.934565	1.01716	32B
16	0.001862	0.998138	1.5e-05	0.999985	0.065702	0.934298	1.00901	64B
17	0.001049	0.998951	1.3e-05	0.999987	0.062864	0.937136	1.00505	128B
18	0.000672	0.999328	8e-06	0.999992	0.051989	0.948011	1.00305	256B
19	0.000582	0.999418	9e-06	0.999991	0.032583	0.967417	1.00236	512B

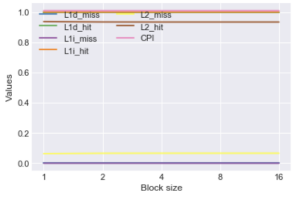


*4) **Block size**:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The Block is changed in size and miss/hit rate is determined.
- We increase Block sizes 32, 64, 128, 256, 512 in terms of B respectively.
- As block size increases, L1i miss rate is decreasing and accordingly the hit rates are increasing.The CPI is decreasing as block size increases.

```
--- iteration # 5 for 456hmmer.csv ---
```

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
20	0.001862	0.998138	4.2e-05	0.999958	0.063173	0.936827	1.00923	1
21	0.001862	0.998138	1.5e-05	0.999985	0.065702	0.934298	1.00901	2
22	0.001862	0.998138	1e-05	0.99999	0.066074	0.933926	1.00896	4
23	0.001862	0.998138	1e-05	0.99999	0.066067	0.933933	1.00896	8
24	0.001862	0.998138	1e-05	0.99999	0.06607	0.93393	1.00896	16

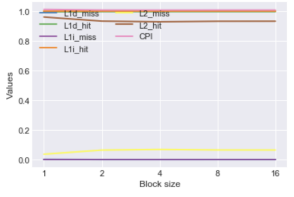


*5) **L1i Associativity**:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, Block size is 64B, L1d associativity is 2, L2 associativity is 2
- The L1i associativity is changed in size and miss/hit rate is determined.
- We increase L1d associativity sizes 1, 2, 4, 8, 16 respectively.
- The CPI remains the same, though the L1i associativity is increased.

```
--- iteration # 6 for 456hmmer.csv ---
```

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
25	0.003251	0.996749	1.5e-05	0.999985	0.037965	0.962035	1.01326	1
26	0.001862	0.998138	1.5e-05	0.999985	0.065702	0.934298	1.00901	2
27	0.001746	0.998254	1.5e-05	0.999985	0.069964	0.930036	1.00866	4
28	0.001837	0.998163	1.5e-05	0.999985	0.066562	0.933438	1.00894	8
29	0.001846	0.998154	1.5e-05	0.999985	0.066244	0.933756	1.00896	16



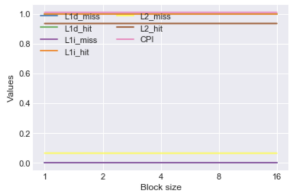
*6) **L1d Associativity**:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, Block size is 64B, L1i associativity is 2, L2 associativity is 2
- The L1d Associativity is changed in size and miss/hit rate is determined.
- We increase L1d Associativity sizes 1, 2, 4, 8, 16 respectively.
- As L1d associativity increases, L1d miss rate is decreasing and accordingly the L1d hit rates are increasing.The

CPI is decreasing with the increase of L1d associativity

```
--------------------
--- iteration # 7 for 456hmmer.csv ---
```

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
30	0.001862	0.998138	1.5e-05	0.999985	0.066011	0.933989	1.00903	1
31	0.001862	0.998138	1.5e-05	0.999985	0.065702	0.934298	1.00901	2
32	0.001862	0.998138	1.5e-05	0.999985	0.065589	0.934411	1.00901	4
33	0.001862	0.998138	1.5e-05	0.999985	0.065589	0.934411	1.00901	8
34	0.001862	0.998138	1.5e-05	0.999985	0.065589	0.934411	1.00901	16




```
----------------------
```

*7) **L2 Associativity**:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, L1i associativity is 2, L1d associativity is 2, Block size is 64B
- The L2 Associativity is changed in size and miss/hit rate is determined.
- We increase L2 Associativity sizes 1, 2, 4, 8, 16 respectively.
- As the L2 associativity is increasing, the L2 miss rate is decreasing and the hit rate is increasing. The CPI is decreasing as the L2 associativity is increasing

D. 458.sjeng

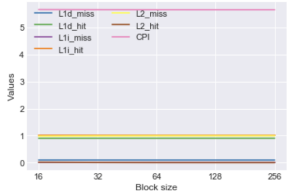
Command

```
$time ./build/X86/gem5.opt -d /home/csgrad/davidjeg
    /458/op1_1 ./configs/example/se.py -c ./
    benchmark/458.sjeng/src/benchmark -o ./
    benchmark/458.sjeng/data/test.txt -I 100000000
    --caches --l2cache --l2_size=1MB --l1d_size=64
    kB --l1i_size=64kB --cacheline_size=64 --
    l1d_assoc=2 --l1i_assoc=2 --l2_assoc=2
```

Results

```
--- iteration # 1 for 458sjeng.csv ---
```

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
0	0.099017	0.900983	0.000277	0.999723	0.979588	0.020412	5.65665	16
1	0.098015	0.901985	0.000277	0.999723	0.989557	0.010443	5.65153	32
2	0.097571	0.902429	0.000277	0.999723	0.994044	0.005956	5.64926	64
3	0.097461	0.902539	0.000277	0.999723	0.995158	0.004842	5.64869	128
4	0.097432	0.902568	0.000277	0.999723	0.995449	0.004551	5.64852	256

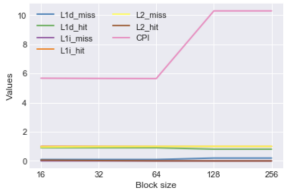


*1) **L1d(Data) cache size**:*

- The default parameter values for L1i size is 64kB, L2 size is 1MB, Block size is 64B, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The L1d cache is changed in size and miss/hit rate is determined.
- We increase L1d sizes 16, 32, 64, 128, 256 in Kbs respectively.
- The L2 miss rate is decreasing and increasing based on the L1d size. This is because, L1d content is a subset of L2 cache. The L1d hit and miss rate is increasing and decreasing respectively.

```
----------------------
--- iteration # 2 for 458sjeng.csv ---
```

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
5	0.097571	0.902429	0.003136	0.996864	0.948841	0.051159	5.67324	16
6	0.097571	0.902429	0.001293	0.998707	0.977502	0.022498	5.65779	32
7	0.097571	0.902429	0.000277	0.999723	0.994044	0.005956	5.64926	64
8	0.194908	0.805092	2.4e-05	0.999976	0.999285	0.000715	10.2898	128
9	0.194908	0.805092	2e-05	0.99998	0.999315	0.000685	10.2898	256

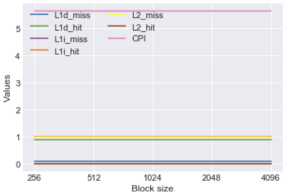


*2) **L1i(Instruction) cache size**:*

- The default parameter values for L1d size is 64kB, L2 size is 1MB, Block size is 64B, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The L1i cache is changed in size and miss/hit rate is determined.
- We increase L1i sizes 16, 32, 64, 128, 256 in kbs respectively.
- The L1i miss rate is decreasing and L1i hit rate is increasing. because of this , CPI is decreasing as size of L1i increases.

```
----------------------
--- iteration # 3 for 458sjeng.csv ---
```

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
10	0.097571	0.902429	0.000277	0.999723	0.994205	0.005795	5.64993	256
11	0.097571	0.902429	0.000277	0.999723	0.994087	0.005913	5.64944	512
12	0.097571	0.902429	0.000277	0.999723	0.994044	0.005956	5.64926	1024
13	0.097571	0.902429	0.000277	0.999723	0.994036	0.005964	5.64923	2048
14	0.097571	0.902429	0.000277	0.999723	0.994005	0.005995	5.6491	4096



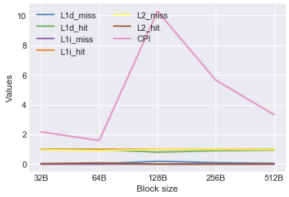
*3) **L2 cache size**:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, Block size is 64B, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The L2 cache is changed in size and miss/hit rate is determined.
- We increase L2 sizes 256, 512, 1024, 2048, 4096 in kbs respectively.
- The L2 miss rate is decreasing and the L2 hit rate is increasing. This is because there is more data available in L2, therefore the number of hits shoot up.Also the CPI is reduced as the L2 cache size increases.

*4) **Block size**:*

--- iteration # 4 for 458sjeng.csv ---

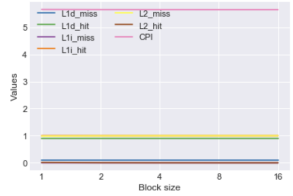
	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
15	0.024808	0.975192	0.0002	0.9998	0.971214	0.028786	2.16775	32B
16	0.012999	0.987001	0.000218	0.999782	0.916683	0.083317	1.58947	64B
17	0.194908	0.805092	0.000319	0.999681	0.996823	0.003177	10.2923	128B
18	0.097571	0.902429	0.000277	0.999723	0.994044	0.005956	5.64926	256B
19	0.048964	0.951036	0.000229	0.999771	0.988182	0.011818	3.32778	512B



- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The Block is changed in size and miss/hit rate is determined.
- We increase Block sizes 32, 64, 128, 256, 512 in terms of B respectively.
- As block size increases, L1i miss rate is decreasing and accordingly the hit rates are increasing.The CPI is decreasing as block size increases till 128kb and then increases.

--- iteration # 5 for 458sjeng.csv ---

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
20	0.097571	0.902429	0.0009	0.9991	0.983831	0.016169	5.65449	1
21	0.097571	0.902429	0.000277	0.999723	0.994044	0.005956	5.64926	2
22	0.097571	0.902429	8e-05	0.99992	0.997316	0.002684	5.6476	4
23	0.097571	0.902429	1.8e-05	0.999982	0.998351	0.001649	5.64708	8
24	0.097571	0.902429	1.5e-05	0.999985	0.998405	0.001595	5.64704	16



*5) **L1i Associativity**:*

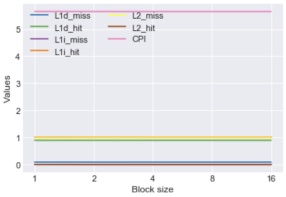
- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, Block size is 64B, L1d associativity is 2, L2 associativity is 2
- The L1i associativity is changed in size and miss/hit rate is determined.
- We increase L1d associativity sizes 1, 2, 4, 8, 16 respectively.
- The CPI remains the same, though the L1i associativity is increased.

*6) **L1d Associativity**:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, Block size is 64B, L1i associativity is 2, L2 associativity is 2
- The L1d Associativity is changed in size and miss/hit rate is determined.
- We increase L1d Associativity sizes 1, 2, 4, 8, 16 respectively.

--- iteration # 6 for 458sjeng.csv ---

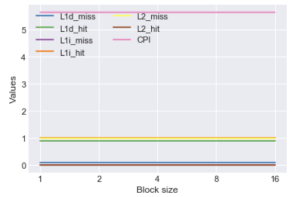
	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
25	0.097888	0.902112	0.000277	0.999723	0.990835	0.009165	5.65089	1
26	0.097571	0.902429	0.000277	0.999723	0.994044	0.005956	5.64926	2
27	0.097514	0.902486	0.000277	0.999723	0.994615	0.005385	5.64897	4
28	0.097472	0.902528	0.000277	0.999723	0.99505	0.00495	5.64875	8
29	0.097463	0.902537	0.000277	0.999723	0.995132	0.004868	5.6487	16



- As L1d associativity increases, L1d miss rate is decreasing and accordingly the L1d hit rates are increasing.The CPI is decreasing with the increase of L1d associativity

--- iteration # 7 for 458sjeng.csv ---

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
30	0.097571	0.902429	0.000277	0.999723	0.994147	0.005853	5.64969	1
31	0.097571	0.902429	0.000277	0.999723	0.994044	0.005956	5.64926	2
32	0.097571	0.902429	0.000277	0.999723	0.99403	0.00597	5.6492	4
33	0.097571	0.902429	0.000277	0.999723	0.994028	0.005972	5.6492	8
34	0.097571	0.902429	0.000277	0.999723	0.994028	0.005972	5.6492	16



*7) **L2 Associativity**:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, L1i associativity is 2, L1d associativity is 2, Block size is 64B
- The L2 Associativity is changed in size and miss/hit rate is determined.
- We increase L2 Associativity sizes 1, 2, 4, 8, 16 respectively.
- As the L2 associativity is increasing, the L2 miss rate is decreasing and the hit rate is increasing. The CPI is decreasing as the L2 associativity is increasing

E. 470.lbm

Command

```
$time ./build/X86/gem5.opt -d /home/csgrad/davidjeg
    /470/op1_1 ./configs/example/se.py -c ./
    benchmark/470.lbm/src/benchmark -o ./benchmark
    /470.lbm/data/lbm.in -I 100000000 --caches --
    l2cache --l2_size=1MB -- l1d_size=64kB --
    l1i_size=64kB --cacheline_size=64 --l1d_assoc=2
     --l1i_assoc=2 -- l2_assoc=2
```

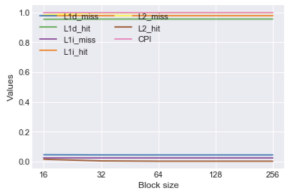
Results

*1) **L1d(Data) cache size**:*

- The default parameter values for L1i size is 64kB, L2 size is 1MB, Block size is 64B, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The L1d cache is changed in size and miss/hit rate is determined.

--- iteration # 1 for 470lbm.csv ---

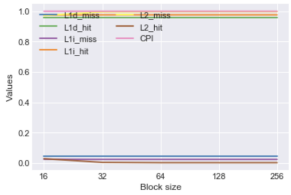
	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
0	0.045413	0.954587	0.023378	0.976622	0.98482	0.01518	1.00029	16
1	0.04403	0.95597	0.023378	0.976622	0.996161	0.003839	1.00029	32
2	0.043799	0.956201	0.023378	0.976622	0.998077	0.001923	1.00029	64
3	0.043799	0.956201	0.023378	0.976622	0.998077	0.001923	1.00029	128
4	0.043799	0.956201	0.023378	0.976622	0.998077	0.001923	1.00029	256



- We increase L1d sizes 16, 32, 64, 128, 256 in Kbs respectively.
- The L2 miss rate is decreasing and increasing based on the L1d size. This is because, L1d content is a subset of L2 cache. The L1d hit and miss rate is increasing and decreasing respectively.

--- iteration # 2 for 470lbm.csv ---

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
5	0.043799	0.956201	0.02437	0.97563	0.97191	0.02809	1.00029	16
6	0.043799	0.956201	0.023449	0.976551	0.996161	0.003839	1.00029	32
7	0.043799	0.956201	0.023378	0.976622	0.998077	0.001923	1.00029	64
8	0.043799	0.956201	0.023378	0.976622	0.998077	0.001923	1.00029	128
9	0.043799	0.956201	0.023378	0.976622	0.998077	0.001923	1.00029	256



---

2) *L1i(Instruction) cache size:*

- The default parameter values for L1d size is 64kB, L2 size is 1MB, Block size is 64B, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The L1i cache is changed in size and miss/hit rate is determined.
- We increase L1i sizes 16, 32, 64, 128, 256 in kbs respectively.
- The L1i miss rate is decreasing and L1i hit rate is increasing. because of this , CPI is decreasing as size of L1i increases.

--- iteration # 3 for 470lbm.csv ---

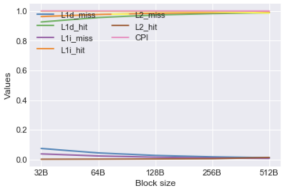
	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
10	0.043799	0.956201	0.023378	0.976622	0.998077	0.001923	1.00029	256
11	0.043799	0.956201	0.023378	0.976622	0.998077	0.001923	1.00029	512
12	0.043799	0.956201	0.023378	0.976622	0.998077	0.001923	1.00029	1024
13	0.043799	0.956201	0.023378	0.976622	0.998077	0.001923	1.00029	2048
14	0.043799	0.956201	0.023378	0.976622	0.998077	0.001923	1.00029	4096

3) *L2 cache size:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, Block size is 64B, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The L2 cache is changed in size and miss/hit rate is determined.
- We increase L2 sizes 256, 512, 1024, 2048, 4096 in kbs respectively.
- The L2 miss rate is decreasing and the L2 hit rate is increasing. This is because there is more data available in L2, therefore the number of hits shoot up.Also the CPI is reduced as the L2 cache size increases.

--- iteration # 4 for 470lbm.csv ---

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
15	0.073733	0.926267	0.037192	0.962808	0.998817	0.001183	1.00047	32B
16	0.043799	0.956201	0.023378	0.976622	0.998077	0.001923	1.00029	64B
17	0.026759	0.973241	0.015018	0.984982	0.996951	0.003049	1.00018	128B
18	0.017305	0.982695	0.009776	0.990224	0.995305	0.004695	1.00012	256B
19	0.011537	0.988463	0.007084	0.992916	0.986667	0.013333	1.00008	512B

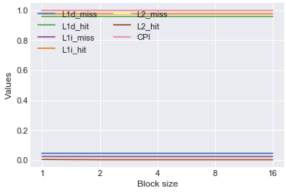


4) *Block size:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, L1i associativity is 2, L1d associativity is 2, L2 associativity is 2
- The Block is changed in size and miss/hit rate is determined.
- We increase Block sizes 32, 64, 128, 256, 512 in terms of B respectively.
- As block size increases, L1i miss rate is decreasing and accordingly the hit rates are increasing.The CPI is decreasing as block size increases till 128kb and then increases.

--- iteration # 5 for 470lbm.csv ---

	L1d_miss	L1d_hit	L1i_miss	L1i_hit	L2_miss	L2_hit	CPI	xaxis
20	0.043799	0.956201	0.023449	0.976551	0.996161	0.003839	1.00029	1
21	0.043799	0.956201	0.023378	0.976622	0.998077	0.001923	1.00029	2
22	0.043799	0.956201	0.023378	0.976622	0.998077	0.001923	1.00029	4
23	0.043799	0.956201	0.023378	0.976622	0.998077	0.001923	1.00029	8
24	0.043799	0.956201	0.023378	0.976622	0.998077	0.001923	1.00029	16

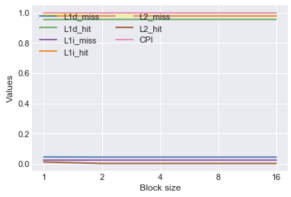


5) *L1i Associativity:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, Block size is 64B, L1d associativity is 2, L2 associativity is 2
- The L1i associativity is changed in size and miss/hit rate is determined.
- We increase L1d associativity sizes 1, 2, 4, 8, 16 respectively.

- The CPI remains the same, though the L1i associativity is increased.

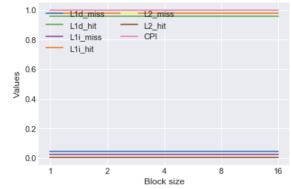
```
----------------------
--- iteration # 6 for 470lbm.csv ---
+----+------------+-----------+------------+-----------+-----------+----------+---------+---------+
|    |   L1d_miss |   L1d_hit |   L1i_miss |   L1i_hit |   L2_miss |   L2_hit |     CPI |   xaxis |
|----+------------+-----------+------------+-----------+-----------+----------+---------+---------|
| 25 |   0.044952 |  0.955048 |   0.023378 |  0.976622 |  0.988571 | 0.011429 | 1.00029 |       1 |
| 26 |   0.043799 |  0.956201 |   0.023378 |  0.976622 |  0.998077 | 0.001923 | 1.00029 |       2 |
| 27 |   0.043799 |  0.956201 |   0.023378 |  0.976622 |  0.998077 | 0.001923 | 1.00029 |       4 |
| 28 |   0.043799 |  0.956201 |   0.023378 |  0.976622 |  0.998077 | 0.001923 | 1.00029 |       8 |
| 29 |   0.043799 |  0.956201 |   0.023378 |  0.976622 |  0.998077 | 0.001923 | 1.00029 |      16 |
+----+------------+-----------+------------+-----------+-----------+----------+---------+---------+
```



*6) **L1d Associativity**:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, Block size is 64B, L1i associativity is 2, L2 associativity is 2
- The L1d Associativity is changed in size and miss/hit rate is determined.
- We increase L1d Associativity sizes 1, 2, 4, 8, 16 respectively.
- As L1d associativity increases, L1d miss rate is decreasing and accordingly the L1d hit rates are increasing.The CPI is decreasing with the increase of L1d associativity

```
----------------------
--- iteration # 7 for 470lbm.csv ---
+----+------------+-----------+------------+-----------+-----------+----------+---------+---------+
|    |   L1d_miss |   L1d_hit |   L1i_miss |   L1i_hit |   L2_miss |   L2_hit |     CPI |   xaxis |
|----+------------+-----------+------------+-----------+-----------+----------+---------+---------|
| 30 |   0.043799 |  0.956201 |   0.023378 |  0.976622 |  0.998077 | 0.001923 | 1.00029 |       1 |
| 31 |   0.043799 |  0.956201 |   0.023378 |  0.976622 |  0.998077 | 0.001923 | 1.00029 |       2 |
| 32 |   0.043799 |  0.956201 |   0.023378 |  0.976622 |  0.998077 | 0.001923 | 1.00029 |       4 |
| 33 |   0.043799 |  0.956201 |   0.023378 |  0.976622 |  0.998077 | 0.001923 | 1.00029 |       8 |
| 34 |   0.043799 |  0.956201 |   0.023378 |  0.976622 |  0.998077 | 0.001923 | 1.00029 |      16 |
+----+------------+-----------+------------+-----------+-----------+----------+---------+---------+
```



*7) **L2 Associativity**:*

- The default parameter values for L1d size is 64kB, L1i size is 64kB, L2 size is 1MB, L1i associativity is 2, L1d associativity is 2, Block size is 64B
- The L2 Associativity is changed in size and miss/hit rate is determined.
- We increase L2 Associativity sizes 1, 2, 4, 8, 16 respectively.
- As the L2 associativity is increasing, the L2 miss rate is decreasing and the hit rate is increasing. The CPI is decreasing as the L2 associativity is increasing

REFERENCES

[1] https://github.com/timberjack/Project1_SPEC