PROJECT REPORT

Cache design

Team

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Description

This project aims to simulate a set-associative cache by adjusting parameters like cache size, block size, and associativity. The purpose is to evaluate performance based on hit and miss rates using different memory trace files. By modifying cache size, block size, and associativity while holding other parameters constant, the project explores the impact of these variations on cache performance.

Code Requirements

- NumPy, Matplotlib need to be installed.
- The code and the trace files need to be in the same directory.

Design

Classes:

- Cache:
  - Models the cache with attributes for no of ways, cache size, block size, index bits and hit count.
  - index_match(self, address) extracts the index bits from the address.
  - tag_match(self, address) extracts the tag bits and checks for a match.

The main function simulates cache performance using memory trace files, evaluating hits, misses, and rates based on user-defined cache parameters. It visualizes performance comparisons across various configurations by plotting miss or hit rates.

Inputting code no 1 gives PART A & B, 2 gives PART C, 3 gives PART D. Parameters like block size, no of ways and cache size is always left to the user as input.

Findings

PART A –

-Cache size 1024 KiB -Block size 4 -4 Way Associative

Number of cache lines = [cache size (bytes)] ÷ [block size (bytes) × no of ways]

= (1024×1024 B) ÷ (4 B×4)

= $2^{20} \div 2^4 = 2^{16} = 65536$

```
PS C:\Users\ankit\OneDrive\Desktop> python t.py
Code no: 1
Enter the size of the cache in KB: 1024
Enter the number of ways: 4
Enter the size of the blocks in bytes: 4

_____________________________________________________________________________________
File: gcc.trace

_____________________________________________________________________________________
Details of cache with user-given inputs:
Number of addresses: 515683
Hits: 483894
Misses: 31789
Hit Rate: 0.9383555401283347
Miss Rate: 0.06164445987166534
Hit/Miss Ratio: 15.222057944572022

_____________________________________________________________________________________
File: gzip.trace

_____________________________________________________________________________________
Details of cache with user-given inputs:
Number of addresses: 481044
Hits: 320883
Misses: 160161
Hit Rate: 0.6670554044952229
Miss Rate: 0.3329445955047771
Hit/Miss Ratio: 2.003502725382584

_____________________________________________________________________________________
File: mcf.trace

_____________________________________________________________________________________
Details of cache with user-given inputs:
Number of addresses: 727230
Hits: 7508
Misses: 719722
Hit Rate: 0.010324106541259299
Miss Rate: 0.9896758934587407
Hit/Miss Ratio: 0.01043180561383423

_____________________________________________________________________________________
File: swim.trace

_____________________________________________________________________________________
Details of cache with user-given inputs:
Number of addresses: 303193
Hits: 280825
Misses: 22368
Hit Rate: 0.9262252096849202
Miss Rate: 0.07377479031507983
Hit/Miss Ratio: 12.554765736766809

_____________________________________________________________________________________
File: twolf.trace

_____________________________________________________________________________________
Details of cache with user-given inputs:
Number of addresses: 482824
Hits: 476844
Misses: 5980
Hit Rate: 0.9876145344887578
Miss Rate: 0.012385465511242191
Hit/Miss Ratio: 79.73979933110368

_____________________________________________________________________________________
```

PART B –

-Cache size varies from 128KiB - 4096 KiB -Block size 4 -4 Way Associative

We have simulated it for the user input of (1024, 4 ,4) and also by varying cache size from 128 to 4096 KiB.

For each trace file we have simulated the cache with varying cache sizes and we have output details like hit rate, miss rate, hit/miss ratio, etc.

We observe that for –

- gcc.trace we see a slight increase in hit rate when cache size is increased from 128 to 1024 KiB. Beyond 1024 KiB we see no increase in number of hits. This is presumably because on increasing cache size the number of sets increases, and at 1024KiB all the addresses in the trace can sit within the cache without evicting one another; hence leading to no further increase beyond 1024 KiB.
- gzip.trace we see that the cache size has had no effect in the hit rates, presumably because similar to gcc.trace at 1024KiB and beyond, all the addresses can be present at once without evicting one another.
- mcf.trace we see no increase in hit rate until the cache size reaches 4096KiB, at 4096 KiB we see a slight increase in hit rate.
- swim.trace we see the hit rate increases when the cache size is increased from 128 to 256 KiB, but the rate improves no further upon further cache expansion; presumably the same reason why gcc.trace and gzip.trace hit rates saturate.
- twolf.trace we see the same as with swim.trace, slight improvement on increasing cache size from 128 to 256 KiB, but no further increase.

```
PS C:\Users\ankit\OneDrive\Desktop> python t.py
Code no: 1
Enter the size of the cache in KB: 1024
Enter the number of ways: 4
Enter the size of the blocks in bytes: 4

_____________________________________________________________________________________________
File: gcc.trace

_____________________________________________________________________________________________
Details of cache with user-given inputs:
Number of addresses: 515683
Hits: 483894
Misses: 31789
Hit Rate: 0.9383555401283347
Miss Rate: 0.06164445987166534
Hit/Miss Ratio: 15.222057944572022

_____________________________________________________________________________________________
Details of cache with cache size = 128 KB:
Number of addresses: 515683
Hits: 483719
Misses: 31964
Hit Rate: 0.9380161843613227
Miss Rate: 0.06198381563867725
Hit/Miss Ratio: 15.133243649105243

_____________________________________________________________________________________________
Details of cache with cache size = 256 KB:
Number of addresses: 515683
Hits: 483871
Misses: 31812
Hit Rate: 0.9383109390846702
Miss Rate: 0.06168906091532977
Hit/Miss Ratio: 15.21032943543317

_____________________________________________________________________________________________
Details of cache with cache size = 512 KB:
Number of addresses: 515683
Hits: 483893
Misses: 31790
Hit Rate: 0.9383536009525232
Miss Rate: 0.06164639904747684
Hit/Miss Ratio: 15.221547656495753

_____________________________________________________________________________________________
Details of cache with cache size = 1024 KB:
Number of addresses: 515683
Hits: 483894
Misses: 31789
Hit Rate: 0.9383555401283347
Miss Rate: 0.06164445987166534
Hit/Miss Ratio: 15.222057944572022

_____________________________________________________________________________________________
Details of cache with cache size = 2048 KB:
Number of addresses: 515683
Hits: 483894
Misses: 31789
Hit Rate: 0.9383555401283347
Miss Rate: 0.06164445987166534
Hit/Miss Ratio: 15.222057944572022

_____________________________________________________________________________________________
Details of cache with cache size = 4096 KB:
Number of addresses: 515683
Hits: 483894
Misses: 31789
Hit Rate: 0.9383555401283347
Miss Rate: 0.06164445987166534
Hit/Miss Ratio: 15.222057944572022

_____________________________________________________________________________________________
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```
File: gzip.trace

Details of cache with user-given inputs:
Number of addresses: 481044
Hits: 320883
Misses: 160161
Hit Rate: 0.6670554044952229
Miss Rate: 0.3329445955047771
Hit/Miss Ratio: 2.003502725382584

Details of cache with cache size = 128 KB:
Number of addresses: 481044
Hits: 320883
Misses: 160161
Hit Rate: 0.6670554044952229
Miss Rate: 0.3329445955047771
Hit/Miss Ratio: 2.003502725382584

Details of cache with cache size = 256 KB:
Number of addresses: 481044
Hits: 320883
Misses: 160161
Hit Rate: 0.6670554044952229
Miss Rate: 0.3329445955047771
Hit/Miss Ratio: 2.003502725382584

Details of cache with cache size = 512 KB:
Number of addresses: 481044
Hits: 320883
Misses: 160161
Hit Rate: 0.6670554044952229
Miss Rate: 0.3329445955047771
Hit/Miss Ratio: 2.003502725382584

Details of cache with cache size = 1024 KB:
Number of addresses: 481044
Hits: 320883
Misses: 160161
Hit Rate: 0.6670554044952229
Miss Rate: 0.3329445955047771
Hit/Miss Ratio: 2.003502725382584

Details of cache with cache size = 2048 KB:
Number of addresses: 481044
Hits: 320883
Misses: 160161
Hit Rate: 0.6670554044952229
Miss Rate: 0.3329445955047771
Hit/Miss Ratio: 2.003502725382584

Details of cache with cache size = 4096 KB:
Number of addresses: 481044
Hits: 320883
Misses: 160161
Hit Rate: 0.6670554044952229
Miss Rate: 0.3329445955047771
Hit/Miss Ratio: 2.003502725382584

File: mcf.trace

Details of cache with user-given inputs:
Number of addresses: 727230
Hits: 7508
Misses: 719722
Hit Rate: 0.010324106541259299
Miss Rate: 0.9896758934587407
Hit/Miss Ratio: 0.01043180561383423
```

```
--------------------------------------------------------------------------------
Details of cache with cache size = 128 KB:
Number of addresses: 727230
Hits: 7508
Misses: 719722
Hit Rate: 0.010324106541259299
Miss Rate: 0.9896758934587407
Hit/Miss Ratio: 0.01043180561383423

--------------------------------------------------------------------------------
Details of cache with cache size = 256 KB:
Number of addresses: 727230
Hits: 7508
Misses: 719722
Hit Rate: 0.010324106541259299
Miss Rate: 0.9896758934587407
Hit/Miss Ratio: 0.01043180561383423

--------------------------------------------------------------------------------
Details of cache with cache size = 512 KB:
Number of addresses: 727230
Hits: 7508
Misses: 719722
Hit Rate: 0.010324106541259299
Miss Rate: 0.9896758934587407
Hit/Miss Ratio: 0.01043180561383423

--------------------------------------------------------------------------------
Details of cache with cache size = 1024 KB:
Number of addresses: 727230
Hits: 7508
Misses: 719722
Hit Rate: 0.010324106541259299
Miss Rate: 0.9896758934587407
Hit/Miss Ratio: 0.01043180561383423

--------------------------------------------------------------------------------
Details of cache with cache size = 2048 KB:
Number of addresses: 727230
Hits: 7508
Misses: 719722
Hit Rate: 0.010324106541259299
Miss Rate: 0.9896758934587407
Hit/Miss Ratio: 0.01043180561383423

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```

```
Details of cache with cache size = 4096 KB:
Number of addresses: 727230
Hits: 7603
Misses: 719627
Hit Rate: 0.010454739215928936
Miss Rate: 0.989545260784071
Hit/Miss Ratio: 0.010565195580488225

File: swim.trace

Details of cache with user-given inputs:
Number of addresses: 303193
Hits: 280825
Misses: 22368
Hit Rate: 0.9262252096849202
Miss Rate: 0.07377479031507983
Hit/Miss Ratio: 12.554765736766809

Details of cache with cache size = 128 KB:
Number of addresses: 303193
Hits: 280817
Misses: 22376
Hit Rate: 0.9261988238514741
Miss Rate: 0.07380117614852585
Hit/Miss Ratio: 12.549919556667858

Details of cache with cache size = 256 KB:
Number of addresses: 303193
Hits: 280825
Misses: 22368
Hit Rate: 0.9262252096849202
Miss Rate: 0.07377479031507983
Hit/Miss Ratio: 12.554765736766809

Details of cache with cache size = 512 KB:
Number of addresses: 303193
Hits: 280825
Misses: 22368
Hit Rate: 0.9262252096849202
Miss Rate: 0.07377479031507983
Hit/Miss Ratio: 12.554765736766809

Details of cache with cache size = 1024 KB:
Number of addresses: 303193
Hits: 280825
Misses: 22368
Hit Rate: 0.9262252096849202
Miss Rate: 0.07377479031507983
Hit/Miss Ratio: 12.554765736766809

Details of cache with cache size = 2048 KB:
Number of addresses: 303193
Hits: 280825
Misses: 22368
Hit Rate: 0.9262252096849202
Miss Rate: 0.07377479031507983
Hit/Miss Ratio: 12.554765736766809

Details of cache with cache size = 4096 KB:
Number of addresses: 303193
Hits: 280825
Misses: 22368
Hit Rate: 0.9262252096849202
Miss Rate: 0.07377479031507983
Hit/Miss Ratio: 12.554765736766809

File: twolf.trace

Details of cache with user-given inputs:
Number of addresses: 482824
Hits: 476844
Misses: 5980
Hit Rate: 0.9876145344887578
Miss Rate: 0.012385465511242191
Hit/Miss Ratio: 79.73979933110368
```

```
Details of cache with cache size = 128 KB:
Number of addresses: 482824
Hits: 476843
Misses: 5981
Hit Rate: 0.987612463340679
Miss Rate: 0.012387536659320995
Hit/Miss Ratio: 79.72629994984116

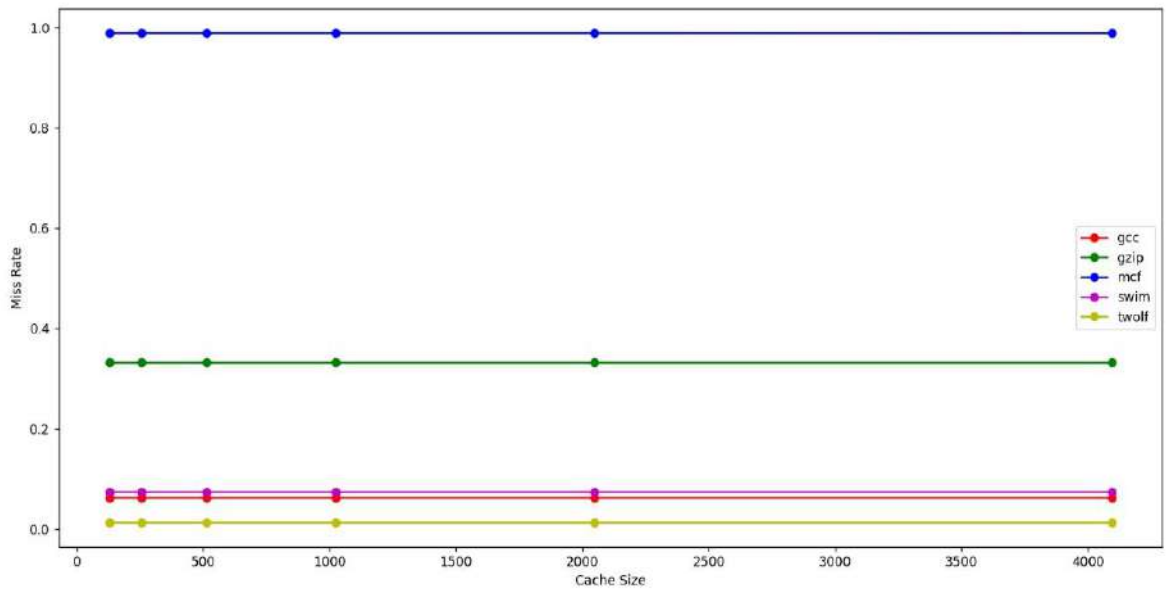
Details of cache with cache size = 256 KB:
Number of addresses: 482824
Hits: 476844
Misses: 5980
Hit Rate: 0.9876145344887578
Miss Rate: 0.012385465511242191
Hit/Miss Ratio: 79.73979933110368

Details of cache with cache size = 512 KB:
Number of addresses: 482824
Hits: 476844
Misses: 5980
Hit Rate: 0.9876145344887578
Miss Rate: 0.012385465511242191
Hit/Miss Ratio: 79.73979933110368

Details of cache with cache size = 1024 KB:
Number of addresses: 482824
Hits: 476844
Misses: 5980
Hit Rate: 0.9876145344887578
Miss Rate: 0.012385465511242191
Hit/Miss Ratio: 79.73979933110368

Details of cache with cache size = 2048 KB:
Number of addresses: 482824
Hits: 476844
Misses: 5980
Hit Rate: 0.9876145344887578
Miss Rate: 0.012385465511242191
Hit/Miss Ratio: 79.73979933110368

Details of cache with cache size = 4096 KB:
Number of addresses: 482824
Hits: 476844
Misses: 5980
Hit Rate: 0.9876145344887578
Miss Rate: 0.012385465511242191
Hit/Miss Ratio: 79.73979933110368
```



PART C –

-Cache size 1024 KiB -Block size 1B to 128B -4 Way Associative

For each trace file we have simulated the cache with varying block sizes and we have output details like hit rate, miss rate, hit/miss ratio, etc.

We observe that for –

- gcc.trace we see that the hit rates increase continuously as the block sizes are increased; presumably because of using special locality to its benefit. However, there are diminishing returns when you keep increasing the block size.
- gzip.trace we see steady and minimal increments in hit rates. Presumably similar reasons as to gcc.trace's performance.
- mcf.trace we see slight increase in hit rates until 8B block size. After this we see a substantial increase in hit rates for every increase, this is possibly because the addresses accessed by this particular trace file happens to exploit spatial locality really well after a certain point.
- swim.trace we see performance similar to gcc.trace
- twolf.trace we see the same as gzip.trace, steady minimal increments in hits.

```
PS C:\Users\ankit\OneDrive\Desktop> python t.py
Code no: 2
Enter the size of the cache in KB: 1024
Enter the number of ways: 4
Enter the size of the blocks in bytes: 4

_____________________________________________________________________________
File: gcc.trace

_____________________________________________________________________________
Details of cache with user-given inputs:
Number of addresses: 515683
Hits: 483894
Misses: 31789
Hit Rate: 0.9383555401283347
Miss Rate: 0.06164445987166534
Hit/Miss Ratio: 15.222057944572022

_____________________________________________________________________________
Details of cache with block size = 1 Bytes:
Number of addresses: 515683
Hits: 480611
Misses: 35072
Hit Rate: 0.9319892259391913
Miss Rate: 0.06801077406080867
Hit/Miss Ratio: 13.70355269160584

_____________________________________________________________________________
Details of cache with block size = 2 Bytes:
Number of addresses: 515683
Hits: 482807
Misses: 32876
Hit Rate: 0.9362476560212378
Miss Rate: 0.06375234397876214
Hit/Miss Ratio: 14.685697773451759

_____________________________________________________________________________
Details of cache with block size = 4 Bytes:
Number of addresses: 515683
Hits: 483894
Misses: 31789
Hit Rate: 0.9383555401283347
Miss Rate: 0.06164445987166534
Hit/Miss Ratio: 15.222057944572022

_____________________________________________________________________________
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```
Details of cache with block size = 8 Bytes:
Number of addresses: 515683
Hits: 494677
Misses: 21006
Hit Rate: 0.9592656729037025
Miss Rate: 0.04073432709629753
Hit/Miss Ratio: 23.5493192421213

Details of cache with block size = 16 Bytes:
Number of addresses: 515683
Hits: 504467
Misses: 11216
Hit Rate: 0.9782502040982541
Miss Rate: 0.02174979590174584
Hit/Miss Ratio: 44.97744293865906

Details of cache with block size = 32 Bytes:
Number of addresses: 515683
Hits: 509644
Misses: 6039
Hit Rate: 0.9882893172743721
Miss Rate: 0.011710682725627954
Hit/Miss Ratio: 84.39211790031462

Details of cache with block size = 64 Bytes:
Number of addresses: 515683
Hits: 512310
Misses: 3373
Hit Rate: 0.993459159987822
Miss Rate: 0.006540840012178024
Hit/Miss Ratio: 151.88556181440853

Details of cache with block size = 128 Bytes:
Number of addresses: 515683
Hits: 513728
Misses: 1955
Hit Rate: 0.9962089112885242
Miss Rate: 0.0037910887114758485
Hit/Miss Ratio: 262.77647058823527
```

```
File: gzip.trace

Details of cache with user-given inputs:
Number of addresses: 481044
Hits: 320883
Misses: 160161
Hit Rate: 0.6670554044952229
Miss Rate: 0.3329445955047771
Hit/Miss Ratio: 2.003502725382584

Details of cache with block size = 1 Bytes:
Number of addresses: 481044
Hits: 320875
Misses: 160169
Hit Rate: 0.6670387739998835
Miss Rate: 0.33296122600001164
Hit/Miss Ratio: 2.003352708701434

Details of cache with block size = 2 Bytes:
Number of addresses: 481044
Hits: 320876
Misses: 160168
Hit Rate: 0.667040852811801
Miss Rate: 0.332959147188199
Hit/Miss Ratio: 2.0033714599670347

Details of cache with block size = 4 Bytes:
Number of addresses: 481044
Hits: 320883
Misses: 160161
Hit Rate: 0.6670554044952229
Miss Rate: 0.3329445955047771
Hit/Miss Ratio: 2.003502725382584
```

```
Details of cache with block size = 8 Bytes:
Number of addresses: 481044
Hits: 320891
Misses: 160153
Hit Rate: 0.6670720349905622
Miss Rate: 0.33292796500943783
Hit/Miss Ratio: 2.00365275705107

Details of cache with block size = 16 Bytes:
Number of addresses: 481044
Hits: 321268
Misses: 159776
Hit Rate: 0.6678557470834269
Miss Rate: 0.3321442529165731
Hit/Miss Ratio: 2.010740036050471

Details of cache with block size = 32 Bytes:
Number of addresses: 481044
Hits: 321459
Misses: 159585
Hit Rate: 0.6682528001596527
Miss Rate: 0.33174719984034723
Hit/Miss Ratio: 2.01434345333208

Details of cache with block size = 64 Bytes:
Number of addresses: 481044
Hits: 321559
Misses: 159485
Hit Rate: 0.668460681351394
Miss Rate: 0.331539318648606
Hit/Miss Ratio: 2.016233501583221

Details of cache with block size = 128 Bytes:
Number of addresses: 481044
Hits: 321609
Misses: 159435
Hit Rate: 0.6685646219472647
Miss Rate: 0.3314353780527353
Hit/Miss Ratio: 2.0171794148085427
```

```
File: mcf.trace

Details of cache with user-given inputs:
Number of addresses: 727230
Hits: 7508
Misses: 719722
Hit Rate: 0.010324106541259299
Miss Rate: 0.9896758934587407
Hit/Miss Ratio: 0.01043180561383423

Details of cache with block size = 1 Bytes:
Number of addresses: 727230
Hits: 7451
Misses: 719779
Hit Rate: 0.010245726936457518
Miss Rate: 0.9897542730635425
Hit/Miss Ratio: 0.010351788535092022

Details of cache with block size = 2 Bytes:
Number of addresses: 727230
Hits: 7481
Misses: 719749
Hit Rate: 0.010286979360037403
Miss Rate: 0.9897130206399626
Hit/Miss Ratio: 0.010393901207226408

Details of cache with block size = 4 Bytes:
Number of addresses: 727230
Hits: 7508
Misses: 719722
Hit Rate: 0.010324106541259299
Miss Rate: 0.9896758934587407
Hit/Miss Ratio: 0.01043180561383423
```

```
Details of cache with block size = 8 Bytes:
Number of addresses: 727230
Hits: 7551
Misses: 719679
Hit Rate: 0.010383235015057135
Miss Rate: 0.9896167649849429
Hit/Miss Ratio: 0.01049217776258582

Details of cache with block size = 16 Bytes:
Number of addresses: 727230
Hits: 367273
Misses: 359957
Hit Rate: 0.505030045515174
Miss Rate: 0.494969954484826
Hit/Miss Ratio: 1.0203246498887366

Details of cache with block size = 32 Bytes:
Number of addresses: 727230
Hits: 547152
Misses: 180078
Hit Rate: 0.7523782022193803
Miss Rate: 0.2476217977806196
Hit/Miss Ratio: 3.0384166861026887

Details of cache with block size = 64 Bytes:
Number of addresses: 727230
Hits: 637112
Misses: 90118
Hit Rate: 0.8760804697275965
Miss Rate: 0.1239195302724035
Hit/Miss Ratio: 7.0697529905235355

Details of cache with block size = 128 Bytes:
Number of addresses: 727230
Hits: 682109
Misses: 45121
Hit Rate: 0.9379549798550665
Miss Rate: 0.062045020144933516
Hit/Miss Ratio: 15.117328959907804

File: swim.trace

Details of cache with user-given inputs:
Number of addresses: 303193
Hits: 280825
Misses: 22368
Hit Rate: 0.9262252096849202
Miss Rate: 0.07377479031507983
Hit/Miss Ratio: 12.554765736766809

Details of cache with block size = 1 Bytes:
Number of addresses: 303193
Hits: 280588
Misses: 22605
Hit Rate: 0.9254435293690817
Miss Rate: 0.07455647063091826
Hit/Miss Ratio: 12.41265206812652

Details of cache with block size = 2 Bytes:
Number of addresses: 303193
Hits: 280737
Misses: 22456
Hit Rate: 0.9259349655170139
Miss Rate: 0.07406503448298608
Hit/Miss Ratio: 12.501647666547916

Details of cache with block size = 4 Bytes:
Number of addresses: 303193
Hits: 280825
Misses: 22368
Hit Rate: 0.9262252096849202
Miss Rate: 0.07377479031507983
Hit/Miss Ratio: 12.554765736766809
```

```
Details of cache with block size = 8 Bytes:
Number of addresses: 303193
Hits: 283377
Misses: 19816
Hit Rate: 0.9346422905542014
Miss Rate: 0.06535770944579855
Hit/Miss Ratio: 14.300413807024627

Details of cache with block size = 16 Bytes:
Number of addresses: 303193
Hits: 291770
Misses: 11423
Hit Rate: 0.9623243280682602
Miss Rate: 0.037675671931739846
Hit/Miss Ratio: 25.542326884356125

Details of cache with block size = 32 Bytes:
Number of addresses: 303193
Hits: 296797
Misses: 6396
Hit Rate: 0.9789045261599048
Miss Rate: 0.021095473840095254
Hit/Miss Ratio: 46.40353345841151

Details of cache with block size = 64 Bytes:
Number of addresses: 303193
Hits: 299740
Misses: 3453
Hit Rate: 0.9886112146388604
Miss Rate: 0.011388785361139605
Hit/Miss Ratio: 86.8056762235737

Details of cache with block size = 128 Bytes:
Number of addresses: 303193
Hits: 301367
Misses: 1826
Hit Rate: 0.9939774335159453
Miss Rate: 0.0060225664840547
Hit/Miss Ratio: 165.0421686746988

File: twolf.trace

Details of cache with user-given inputs:
Number of addresses: 482824
Hits: 476844
Misses: 5980
Hit Rate: 0.9876145344887578
Miss Rate: 0.012385465511242191
Hit/Miss Ratio: 79.73979933110368

Details of cache with block size = 1 Bytes:
Number of addresses: 482824
Hits: 475470
Misses: 7354
Hit Rate: 0.9847687770284824
Miss Rate: 0.015231222971517572
Hit/Miss Ratio: 64.65460973619798

Details of cache with block size = 2 Bytes:
Number of addresses: 482824
Hits: 476358
Misses: 6466
Hit Rate: 0.9866079565224596
Miss Rate: 0.01339204347754047
Hit/Miss Ratio: 73.67120321682647

Details of cache with block size = 4 Bytes:
Number of addresses: 482824
Hits: 476844
Misses: 5980
Hit Rate: 0.9876145344887578
Miss Rate: 0.012385465511242191
Hit/Miss Ratio: 79.73979933110368
```

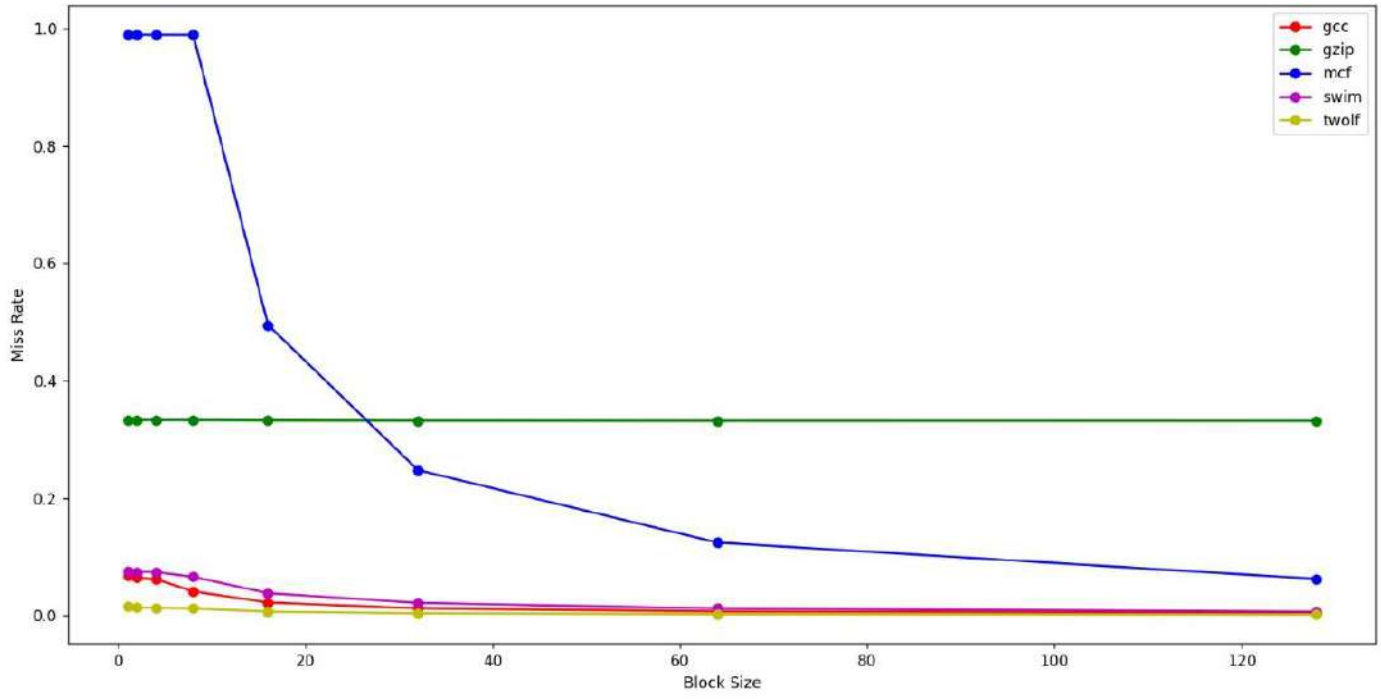
```
Details of cache with block size = 8 Bytes:
Number of addresses: 482824
Hits: 477319
Misses: 5505
Hit Rate: 0.9885983298261892
Miss Rate: 0.011401670173810746
Hit/Miss Ratio: 86.70644868301544

--------------------------------------------------------------------------------
Details of cache with block size = 16 Bytes:
Number of addresses: 482824
Hits: 479869
Misses: 2955
Hit Rate: 0.993879757427137
Miss Rate: 0.006120242572862989
Hit/Miss Ratio: 162.3922165820643

--------------------------------------------------------------------------------
Details of cache with block size = 32 Bytes:
Number of addresses: 482824
Hits: 481182
Misses: 1642
Hit Rate: 0.9965991748546054
Miss Rate: 0.003400825145394595
Hit/Miss Ratio: 293.0462850182704

--------------------------------------------------------------------------------
Details of cache with block size = 64 Bytes:
Number of addresses: 482824
Hits: 481870
Misses: 954
Hit Rate: 0.9980241247328219
Miss Rate: 0.0019758752671781023
Hit/Miss Ratio: 505.104821802935

--------------------------------------------------------------------------------
Details of cache with block size = 128 Bytes:
Number of addresses: 482824
Hits: 482249
Misses: 575
Hit Rate: 0.9988090898546883
Miss Rate: 0.0011909101453117493
Hit/Miss Ratio: 838.6939130434782
```



PART D –

-Cache size 1024 KiB -Block size 4B - 1– 64 way associative

For each trace file we have simulated the cache with varying number of ways and we have output details like hit rate, miss rate, hit/miss ratio, etc.

We observe that for each trace files, the increase in hit rate is very minimal. Increasing number of ways from 1 to 2 or 4 gives a very slight increase in hit rate but anything beyond that seems to generally give negligible benefits.

```
PS C:\Users\ankit\OneDrive\Desktop> python t.py
Code no: 3
Enter the size of the cache in KB: 1024
Enter the number of ways: 4
Enter the size of the blocks in bytes: 4

_____________________________________________________________________________________________
File: gcc.trace

_____________________________________________________________________________________________
Details of cache with user-given inputs:
Number of addresses: 515683
Hits: 483894
Misses: 31789
Hit Rate: 0.9383555401283347
Miss Rate: 0.06164445987166534
Hit/Miss Ratio: 15.222057944572022

_____________________________________________________________________________________________
Details of cache with 1 ways:
Number of addresses: 515683
Hits: 483868
Misses: 31815
Hit Rate: 0.9383051215572358
Miss Rate: 0.06169487844276426
Hit/Miss Ratio: 15.20880088008801

_____________________________________________________________________________________________
Details of cache with 2 ways:
Number of addresses: 515683
Hits: 483890
Misses: 31793
Hit Rate: 0.9383477834250886
Miss Rate: 0.06165221657491133
Hit/Miss Ratio: 15.220016984870883

_____________________________________________________________________________________________
Details of cache with 4 ways:
Number of addresses: 515683
Hits: 483894
Misses: 31789
Hit Rate: 0.9383555401283347
Miss Rate: 0.06164445987166534
Hit/Miss Ratio: 15.222057944572022

_____________________________________________________________________________________________
```

```
--------------------------------------------------------------------------------
Details of cache with 8 ways:
Number of addresses: 515683
Hits: 483894
Misses: 31789
Hit Rate: 0.9383555401283347
Miss Rate: 0.06164445987166534
Hit/Miss Ratio: 15.222057944572022
--------------------------------------------------------------------------------
Details of cache with 16 ways:
Number of addresses: 515683
Hits: 483895
Misses: 31788
Hit Rate: 0.9383574793041461
Miss Rate: 0.061642520695853846
Hit/Miss Ratio: 15.222568264753995
--------------------------------------------------------------------------------
Details of cache with 32 ways:
Number of addresses: 515683
Hits: 483896
Misses: 31787
Hit Rate: 0.9383594184799576
Miss Rate: 0.06164058152004235
Hit/Miss Ratio: 15.223078617044704
--------------------------------------------------------------------------------
Details of cache with 64 ways:
Number of addresses: 515683
Hits: 483896
Misses: 31787
Hit Rate: 0.9383594184799576
Miss Rate: 0.06164058152004235
Hit/Miss Ratio: 15.223078617044704

File: gzip.trace
--------------------------------------------------------------------------------
Details of cache with user-given inputs:
Number of addresses: 481044
Hits: 320883
Misses: 160161
Hit Rate: 0.6670554044952229
Miss Rate: 0.3329445955047771
Hit/Miss Ratio: 2.003502725382584
--------------------------------------------------------------------------------
Details of cache with 1 ways:
Number of addresses: 481044
Hits: 320883
Misses: 160161
Hit Rate: 0.6670554044952229
Miss Rate: 0.3329445955047771
Hit/Miss Ratio: 2.003502725382584
--------------------------------------------------------------------------------
Details of cache with 2 ways:
Number of addresses: 481044
Hits: 320883
Misses: 160161
Hit Rate: 0.6670554044952229
Miss Rate: 0.3329445955047771
Hit/Miss Ratio: 2.003502725382584
--------------------------------------------------------------------------------
Details of cache with 4 ways:
Number of addresses: 481044
Hits: 320883
Misses: 160161
Hit Rate: 0.6670554044952229
Miss Rate: 0.3329445955047771
Hit/Miss Ratio: 2.003502725382584
--------------------------------------------------------------------------------
Details of cache with 8 ways:
Number of addresses: 481044
Hits: 320883
Misses: 160161
Hit Rate: 0.6670554044952229
Miss Rate: 0.3329445955047771
Hit/Miss Ratio: 2.003502725382584
```

```
Details of cache with 16 ways:
Number of addresses: 481044
Hits: 320883
Misses: 160161
Hit Rate: 0.6670554044952229
Miss Rate: 0.3329445955047771
Hit/Miss Ratio: 2.003502725382584

--------------------------------------------------------------------------------
Details of cache with 32 ways:
Number of addresses: 481044
Hits: 320883
Misses: 160161
Hit Rate: 0.6670554044952229
Miss Rate: 0.3329445955047771
Hit/Miss Ratio: 2.003502725382584

--------------------------------------------------------------------------------
Details of cache with 64 ways:
Number of addresses: 481044
Hits: 320883
Misses: 160161
Hit Rate: 0.6670554044952229
Miss Rate: 0.3329445955047771
Hit/Miss Ratio: 2.003502725382584

--------------------------------------------------------------------------------
File: mcf.trace

--------------------------------------------------------------------------------
Details of cache with user-given inputs:
Number of addresses: 727230
Hits: 7508
Misses: 719722
Hit Rate: 0.010324106541259299
Miss Rate: 0.9896758934587407
Hit/Miss Ratio: 0.01043180561383423

--------------------------------------------------------------------------------
Details of cache with 1 ways:
Number of addresses: 727230
Hits: 7505
Misses: 719725
Hit Rate: 0.01031998129890131
Miss Rate: 0.9896800187010987
Hit/Miss Ratio: 0.010427593872659697

--------------------------------------------------------------------------------
Details of cache with 2 ways:
Number of addresses: 727230
Hits: 7507
Misses: 719723
Hit Rate: 0.010322731460473304
Miss Rate: 0.9896772685395266
Hit/Miss Ratio: 0.010430401696208125

--------------------------------------------------------------------------------
Details of cache with 4 ways:
Number of addresses: 727230
Hits: 7508
Misses: 719722
Hit Rate: 0.010324106541259299
Miss Rate: 0.9896758934587407
Hit/Miss Ratio: 0.01043180561383423

--------------------------------------------------------------------------------
Details of cache with 8 ways:
Number of addresses: 727230
Hits: 7508
Misses: 719722
Hit Rate: 0.010324106541259299
Miss Rate: 0.9896758934587407
Hit/Miss Ratio: 0.01043180561383423

--------------------------------------------------------------------------------
Details of cache with 16 ways:
Number of addresses: 727230
Hits: 7508
Misses: 719722
Hit Rate: 0.010324106541259299
Miss Rate: 0.9896758934587407
Hit/Miss Ratio: 0.01043180561383423

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

```
Details of cache with 32 ways:
Number of addresses: 727230
Hits: 7508
Misses: 719722
Hit Rate: 0.010324106541259299
Miss Rate: 0.9896758934587407
Hit/Miss Ratio: 0.01043180561383423

--------------------------------------------------------------------------------
Details of cache with 64 ways:
Number of addresses: 727230
Hits: 7508
Misses: 719722
Hit Rate: 0.010324106541259299
Miss Rate: 0.9896758934587407
Hit/Miss Ratio: 0.01043180561383423

--------------------------------------------------------------------------------
File: swim.trace

--------------------------------------------------------------------------------
Details of cache with user-given inputs:
Number of addresses: 303193
Hits: 280825
Misses: 22368
Hit Rate: 0.9262252096849202
Miss Rate: 0.07377479031507983
Hit/Miss Ratio: 12.554765736766809

--------------------------------------------------------------------------------
Details of cache with 1 ways:
Number of addresses: 303193
Hits: 280819
Misses: 22374
Hit Rate: 0.9262054203098357
Miss Rate: 0.07379457969016436
Hit/Miss Ratio: 12.551130776794494

--------------------------------------------------------------------------------
Details of cache with 2 ways:
Number of addresses: 303193
Hits: 280825
Misses: 22368
Hit Rate: 0.9262252096849202
Miss Rate: 0.07377479031507983
Hit/Miss Ratio: 12.554765736766809
```

```
Details of cache with 4 ways:
Number of addresses: 303193
Hits: 280825
Misses: 22368
Hit Rate: 0.9262252096849202
Miss Rate: 0.07377479031507983
Hit/Miss Ratio: 12.554765736766809

--------------------------------------------------------------------------------
Details of cache with 8 ways:
Number of addresses: 303193
Hits: 280825
Misses: 22368
Hit Rate: 0.9262252096849202
Miss Rate: 0.07377479031507983
Hit/Miss Ratio: 12.554765736766809

--------------------------------------------------------------------------------
Details of cache with 16 ways:
Number of addresses: 303193
Hits: 280825
Misses: 22368
Hit Rate: 0.9262252096849202
Miss Rate: 0.07377479031507983
Hit/Miss Ratio: 12.554765736766809

--------------------------------------------------------------------------------
Details of cache with 32 ways:
Number of addresses: 303193
Hits: 280825
Misses: 22368
Hit Rate: 0.9262252096849202
Miss Rate: 0.07377479031507983
Hit/Miss Ratio: 12.554765736766809

--------------------------------------------------------------------------------
Details of cache with 64 ways:
Number of addresses: 303193
Hits: 280825
Misses: 22368
Hit Rate: 0.9262252096849202
Miss Rate: 0.07377479031507983
Hit/Miss Ratio: 12.554765736766809

--------------------------------------------------------------------------------
File: twolf.trace

--------------------------------------------------------------------------------
Details of cache with user-given inputs:
Number of addresses: 482824
Hits: 476844
Misses: 5980
Hit Rate: 0.9876145344887578
Miss Rate: 0.012385465511242191
Hit/Miss Ratio: 79.73979933110368

--------------------------------------------------------------------------------
Details of cache with 1 ways:
Number of addresses: 482824
Hits: 476771
Misses: 6053
Hit Rate: 0.9874633406790052
Miss Rate: 0.012536659320994814
Hit/Miss Ratio: 78.76606641334875

--------------------------------------------------------------------------------
Details of cache with 2 ways:
Number of addresses: 482824
Hits: 476841
Misses: 5983
Hit Rate: 0.9876083210445215
Miss Rate: 0.0123916789554786
Hit/Miss Ratio: 79.69931472505432

--------------------------------------------------------------------------------
Details of cache with 4 ways:
Number of addresses: 482824
Hits: 476844
Misses: 5980
Hit Rate: 0.9876145344887578
Miss Rate: 0.012385465511242191
Hit/Miss Ratio: 79.73979933110368

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

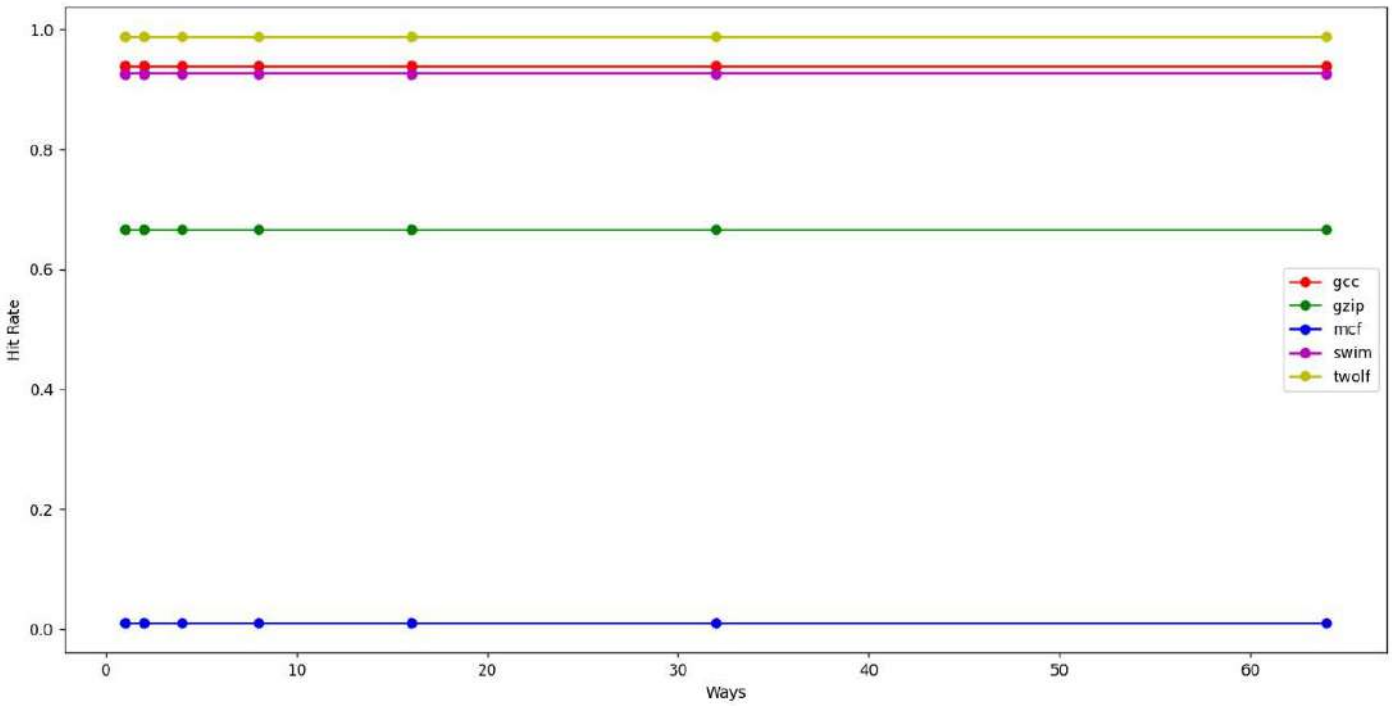
```
Details of cache with 8 ways:
Number of addresses: 482824
Hits: 476844
Misses: 5980
Hit Rate: 0.9876145344887578
Miss Rate: 0.012385465511242191
Hit/Miss Ratio: 79.73979933110368

--------------------------------------------------------------------------------
Details of cache with 16 ways:
Number of addresses: 482824
Hits: 476844
Misses: 5980
Hit Rate: 0.9876145344887578
Miss Rate: 0.012385465511242191
Hit/Miss Ratio: 79.73979933110368

--------------------------------------------------------------------------------
Details of cache with 32 ways:
Number of addresses: 482824
Hits: 476844
Misses: 5980
Hit Rate: 0.9876145344887578
Miss Rate: 0.012385465511242191
Hit/Miss Ratio: 79.73979933110368

--------------------------------------------------------------------------------
Details of cache with 64 ways:
Number of addresses: 482824
Hits: 476844
Misses: 5980
Hit Rate: 0.9876145344887578
Miss Rate: 0.012385465511242191
Hit/Miss Ratio: 79.73979933110368

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



- For gcc .trace, we observe that hit rate is constantly increasing though the increase is minuscule.
- For gzip.trace, the hit rate is constant and doesn't change for any number of ways.
- For mcf.trace, the hit rate increase till 4 way set associative cache and then it remains stagnant.
- We can observe a similar result for swim.trace, except it increases till the number of ways is 2.

Graphs/Tables

This is the link to the spreadsheet containing the tables of the data from all the simulations

https://docs.google.com/spreadsheets/d/1ZR38nn-Q5Rdn6SoVwZDWx-S-ZdM54Et0V1vukwWAHT0/edit?usp=sharing