**IPLC Simulator Write-up**

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**Project Divisions**

Nick and Annie worked on the cache functions while Karina and Liliana worked on the pipeline functions.

**Summary of Implementation**

Our cache line struct includes:

* An array of integers to represent the valid bits
* An array of integers to represent the tags
* An integer to hold information on associativity
* An array of integers for selecting which item in the cache will be replaced

We begin by creating our cache’s valid bit, tag, and replace arrays using malloc. We initialize the valid bit and tag arrays to 0, and the replace array with just the index of whatever number it is. We then initialize the pipeline to 0 and NOP instructions.

Then we implement our LRU\_replace\_on\_miss function. This function takes the index and tag of where we want to replace and uses those values to change the values in the cache. We do a similar method of implementing the LRU\_update\_on\_hit. First we loop through the cache until we find the index of what we want ot update, then we update the LRU.

The pop\_bits function uses a bitmask to do its job, and we included a function to print a 32-bit binary string.

We floor divide first in the trap\_address function to find the bit association. We then set up a bit mask of 1s the size of the cache index and find the index bits of the address, then we remove the unnecessary bits. Then we set up a bit mask to find the tag and repeat the removal of unnecessary bits. We check to see if the tag we get is already in our tag array, and if it is, we stop and take it. If not, we continue on to call the LRU\_update\_on\_hit function. If it’s a miss, we call the LRU\_replace\_on\_miss function.

Now for the pipeline functions.

In the push\_pipeline\_stage function, we set up integers to check for stalls and misses. We then go on to check whether or not the prediction was correct or not. Then, we check for stalls if the lw is loading branch or rtype. Then we check for hits or misses. We then check for SW memory accesses and data misses and add delay cycles if needed. We increment pipe\_cycles by 1, and then we push the stages through.

We finish off the pipeline functions by basing them off of the one we were given. For all of them, we push\_pipeline\_stage and then proceed to assign itypes, stages, and instruction addresses depending on which function we are in.

**Performance Evaluation**

We ran our simulation 18 times. These were our statistics.

* Cache Size: 1, Block Size: 1, Levels of Association: 1, Prediction: 0

Cache Performance

        Number of Cache Accesses is 35863

        Number of Cache Misses is 35863

        Number of Cache Hits is 0

        Cache Miss Rate is 1.000000

Pipeline Performance

        Total Cycles is 364569

        Total Instructions is 34752

        Total Branch Instructions is 7044

        Total Correct Branch Predictions is 0

        CPI is 10.490590

* Cache Size: 1, Block Size: 1, Levels of Association: 1, Prediction: 1

Cache Performance

        Number of Cache Accesses is 35863

        Number of Cache Misses is 35863

        Number of Cache Hits is 0

        Cache Miss Rate is 1.000000

Pipeline Performance

        Total Cycles is 357525

        Total Instructions is 34752

        Total Branch Instructions is 7044

        Total Correct Branch Predictions is 7044

        CPI is 10.287897

* Cache Size: 2, Block Size: 1, Levels of Association: 1, Prediction: 0

Cache Performance

        Number of Cache Accesses is 35863

        Number of Cache Misses is 17190

        Number of Cache Hits is 18673

        Cache Miss Rate is 0.479324

Pipeline Performance

        Total Cycles is 192162

        Total Instructions is 34752

        Total Branch Instructions is 7044

        Total Correct Branch Predictions is 4350

        CPI is 5.529523

* Cache Size: 2, Block Size: 1, Levels of Association: 1, Prediction: 1

Cache Performance

        Number of Cache Accesses is 35863

        Number of Cache Misses is 17190

        Number of Cache Hits is 18673

        Cache Miss Rate is 0.479324

Pipeline Performance

        Total Cycles is 193818

        Total Instructions is 34752

        Total Branch Instructions is 7044

        Total Correct Branch Predictions is 2694

        CPI is 5.577175

* Cache Size: 2, Block Size: 1, Levels of Association: 2, Prediction: 0

Cache Performance

        Number of Cache Accesses is 35863

        Number of Cache Misses is 17190

        Number of Cache Hits is 18673

        Cache Miss Rate is 0.479324

Pipeline Performance

        Total Cycles is 192162

        Total Instructions is 34752

        Total Branch Instructions is 7044

        Total Correct Branch Predictions is 4350

        CPI is 5.529523

* Cache Size: 2, Block Size: 1, Levels of Association: 2, Prediction: 1

Cache Performance

        Number of Cache Accesses is 35863

        Number of Cache Misses is 17190

        Number of Cache Hits is 18673

        Cache Miss Rate is 0.479324

Pipeline Performance

        Total Cycles is 193818

        Total Instructions is 34752

        Total Branch Instructions is 7044

        Total Correct Branch Predictions is 2694

        CPI is 5.577175

* Cache Size: 2, Block Size: 2, Levels of Association: 4, Prediction: 0

Cache Performance

        Number of Cache Accesses is 35863

        Number of Cache Misses is 24450

        Number of Cache Hits is 11413

        Cache Miss Rate is 0.681761

Pipeline Performance

        Total Cycles is 256298

        Total Instructions is 34752

        Total Branch Instructions is 7044

        Total Correct Branch Predictions is 5554

        CPI is 7.375058

* Cache Size: 2, Block Size: 2, Levels of Association: 4, Prediction: 1

Cache Performance

        Number of Cache Accesses is 35863

        Number of Cache Misses is 24450

        Number of Cache Hits is 11413

        Cache Miss Rate is 0.681761

Pipeline Performance

        Total Cycles is 260362

        Total Instructions is 34752

        Total Branch Instructions is 7044

        Total Correct Branch Predictions is 1490

        CPI is 7.492000

* Cache Size: 3, Block Size: 3, Levels of Association: 1, Prediction: 0

Cache Performance

        Number of Cache Accesses is 35863

        Number of Cache Misses is 4074

        Number of Cache Hits is 31789

        Cache Miss Rate is 0.113599

Pipeline Performance

        Total Cycles is 73210

        Total Instructions is 34752

        Total Branch Instructions is 7044

        Total Correct Branch Predictions is 5358

        CPI is 2.106641

* Cache Size: 3, Block Size: 3, Levels of Association: 1, Prediction: 1

Cache Performance

        Number of Cache Accesses is 35863

        Number of Cache Misses is 4074

        Number of Cache Hits is 31789

        Cache Miss Rate is 0.113599

Pipeline Performance

        Total Cycles is 76882

        Total Instructions is 34752

        Total Branch Instructions is 7044

        Total Correct Branch Predictions is 1686

        CPI is 2.212304

* Cache Size: 3, Block Size: 3, Levels of Association: 2, Prediction: 0

Cache Performance

        Number of Cache Accesses is 35863

        Number of Cache Misses is 4074

        Number of Cache Hits is 31789

        Cache Miss Rate is 0.113599

Pipeline Performance

        Total Cycles is 73210

        Total Instructions is 34752

        Total Branch Instructions is 7044

        Total Correct Branch Predictions is 5358

        CPI is 2.106641

* Cache Size: 3, Block Size: 3, Levels of Association: 2, Prediction: 1

Cache Performance

        Number of Cache Accesses is 35863

        Number of Cache Misses is 4074

        Number of Cache Hits is 31789

        Cache Miss Rate is 0.113599

Pipeline Performance

        Total Cycles is 76882

        Total Instructions is 34752

        Total Branch Instructions is 7044

        Total Correct Branch Predictions is 1686

        CPI is 2.212304

* Cache Size: 3, Block Size: 3, Levels of Association: 3, Prediction: 0

Cache Performance

        Number of Cache Accesses is 35863

        Number of Cache Misses is 9635

        Number of Cache Hits is 26228

        Cache Miss Rate is 0.268661

Pipeline Performance

        Total Cycles is 122963

        Total Instructions is 34752

        Total Branch Instructions is 7044

        Total Correct Branch Predictions is 5554

        CPI is 3.538300

* Cache Size: 3, Block Size: 3, Levels of Association: 3, Prediction: 1

Cache Performance

        Number of Cache Accesses is 35863

        Number of Cache Misses is 9635

        Number of Cache Hits is 26228

        Cache Miss Rate is 0.268661

Pipeline Performance

        Total Cycles is 127027

        Total Instructions is 34752

        Total Branch Instructions is 7044

        Total Correct Branch Predictions is 1490

        CPI is 3.655243

* Cache Size: 1, Block Size: 1, Levels of Association: 4, Prediction: 0

Cache Performance

        Number of Cache Accesses is 35863

        Number of Cache Misses is 30303

        Number of Cache Hits is 5560

        Cache Miss Rate is 0.844966

Pipeline Performance

        Total Cycles is 314529

        Total Instructions is 34752

        Total Branch Instructions is 7044

        Total Correct Branch Predictions is 0

        CPI is 9.050673

* Cache Size: 1, Block Size: 1, Levels of Association: 4, Prediction: 1

Cache Performance

        Number of Cache Accesses is 35863

        Number of Cache Misses is 30303

        Number of Cache Hits is 5560

        Cache Miss Rate is 0.844966

Pipeline Performance

        Total Cycles is 307485

        Total Instructions is 34752

        Total Branch Instructions is 7044

        Total Correct Branch Predictions is 7044

        CPI is 8.847980

* Cache Size: 4, Block Size: 1, Levels of Association: 4, Prediction: 0

Cache Performance

        Number of Cache Accesses is 35863

        Number of Cache Misses is 35766

        Number of Cache Hits is 97

        Cache Miss Rate is 0.997295

Pipeline Performance

        Total Cycles is 363696

        Total Instructions is 34752

        Total Branch Instructions is 7044

        Total Correct Branch Predictions is 0

        CPI is 10.465470

* Cache Size: 4, Block Size: 1, Levels of Association: 4, Prediction: 1

Cache Performance

        Number of Cache Accesses is 35863

        Number of Cache Misses is 35766

        Number of Cache Hits is 97

        Cache Miss Rate is 0.997295

Pipeline Performance

        Total Cycles is 356652

        Total Instructions is 34752

        Total Branch Instructions is 7044

        Total Correct Branch Predictions is 7044

        CPI is 10.262776