NC State University

Department of Electrical and Computer Engineering

ECE 463/563 (Prof. Rotenberg)

Project #2: Branch Prediction

REPORT TEMPLATE (Version 1.0)

by

Chandan Srinivas

NCSU Honor Pledge: "I have neither given nor received unauthorized aid on this project."

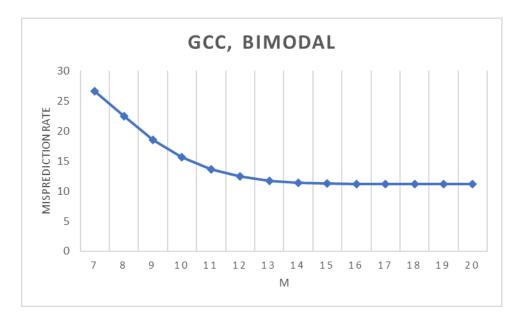
Student's electronic signature: Chandan Srinivas (sign by typing your name)

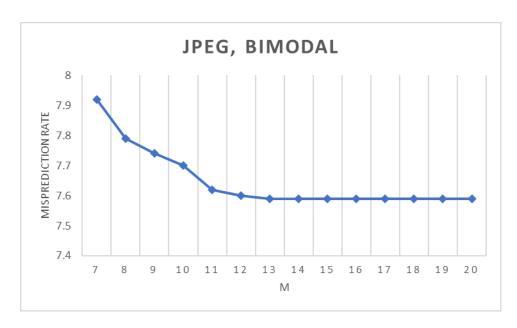
Course number: 563 (463 or 563 ?)

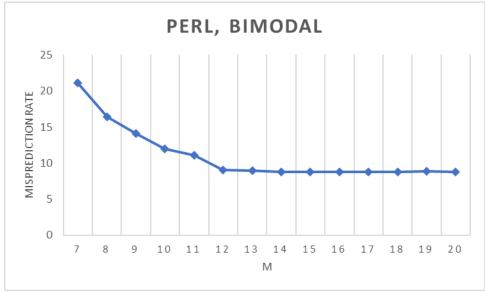
Grading Breakdown, Experiments, and Report

PART 1: BIMODAL PREDICTOR

- (a) [ECE463: 25 points] or [ECE563: 20 points] Gradescope will evaluate your simulator on the four validation runs "val_bimodal_1.txt", "val_bimodal_2.txt", "val_bimodal_3.txt", and "val_bimodal_4.txt", posted on the website for the BIMODAL PREDICTOR. Gradescope will also evaluate your simulator on one bimodal predictor mystery run. Each validation run and mystery run is worth ½ of the points for this part (5 or 4 points each). Gradescope must say that you match all four validation runs to get credit for the experiments with the bimodal predictor, however.
- (b) [ECE463: 25 points] or [ECE563: 20 points] Simulate BIMODAL PREDICTOR for different sizes $(7 \le m \le 20)$. Use the traces gcc, jpeg, and perl. [20 or 15 points] Graphs: Produce one graph for each benchmark. Graph title: "<benchmark>, bimodal". Y-axis: branch misprediction rate. X-axis: m. Per graph, there should be only one curve consisting of 14 datapoints (connect the datapoints with a line).







[5 points] Analysis:

- 1. [1 point] As the bimodal predictor's table size increases, the branch misprediction rate <u>decreases</u>.
- 2. [2 points] For each benchmark, indicate the minimum value of m at which the misprediction rate bottoms-out (reaches its minimum) and indicate its minimum misprediction rate. Fill in the table below. (Use a precision of two digits after the decimal point for misprediction rate. That's what should be in your simulator's output file, in any case.)

output me, m	output int, in the custo				
Benchmark	Minimum "m" at which misprediction rate (two digits of precision after the decimal point)				
	reaches its minimum	the decimal point)			
gcc	m = 18	11.17 %			
jpeg	m = 13	7.59 %			

perl m = 14 8.82%

3. [1 point] At some point, increasing the bimodal predictor's table size is of no value. At this point, each static branch (*i.e.*, each static branch PC) is allocated a dedicated **entry depending on its's index** in the table. Given that interference among different static branches is eliminated at this point, the only way to improve accuracy further is a better prediction algorithm.

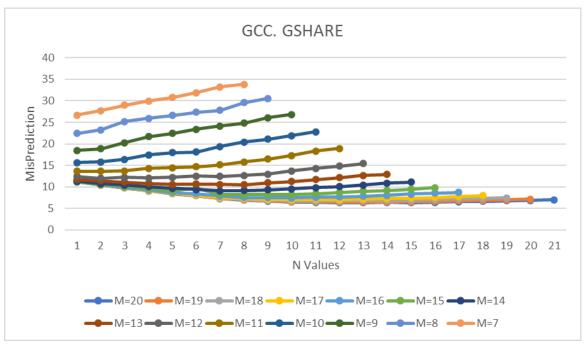
4. [1 point] I infer that *gcc* has more static branches (*i.e.*, unique static branch PCs) than *jpeg*, because *gcc* requires more table entries than *jpeg* before its misprediction rate bottoms-out.

PART 2: GSHARE PREDICTOR

- (a) [ECE463: 25 points] or [ECE563: 20 points] Gradescope will evaluate your simulator on the four validation runs "val_gshare_1.txt", "val_gshare_2.txt", "val_gshare_3.txt", and "val_gshare_4.txt", posted on the website for the GSHARE PREDICTOR. Gradescope will also evaluate your simulator on one gshare predictor mystery run. Each validation run and mystery run is worth ½ of the points for this part (5 or 4 points each). Gradescope must say that you match all four validation runs to get credit for the experiments with the gshare predictor, however.
- (b) [ECE463: 25 points] or [ECE563: 20 points] Simulate GSHARE PREDICTOR for different sizes $(7 \le m \le 20)$, and for each size, *i.e.*, for each value of m, sweep the global history length n from 0 to m. Use only the trace gcc.

[20 or 15 points] Graphs: Produce one graph for gcc. Graph title: "gcc, gshare". Y-axis: branch misprediction rate. X-axis: n (spanning n=0 to n=20). For this graph, there should be a total of 203 datapoints plotted as 14 curves. Datapoints having the same value of m (same predictor size) are connected with a line, i.e., one curve for each value of m. Note that not all curves have the same number of datapoints; see the listing below for the number of datapoints for each of the 14 curves, m=7 through m=20. The rationale for this graph is to study the effect of global history length for each predictor size.

```
m=7 curve has 8 datapoints: 0 \le n \le 7
m=8 curve has 9 datapoints: 0 \le n \le 8
m=9 curve has 10 datapoints: 0 \le n \le 9
m=10 curve has 11 datapoints: 0 \le n \le 10
m=11 curve has 12 datapoints: 0 \le n \le 11
m=12 curve has 13 datapoints: 0 \le n \le 12
m=13 curve has 14 datapoints: 0 \le n \le 13
m=14 curve has 15 datapoints: 0 \le n \le 13
m=15 curve has 16 datapoints: 0 \le n \le 14
m=16 curve has 17 datapoints: 0 \le n \le 15
m=16 curve has 18 datapoints: 0 \le n \le 16
m=17 curve has 18 datapoints: 0 \le n \le 17
m=18 curve has 20 datapoints: 0 \le n \le 18
m=19 curve has 21 datapoints: 0 \le n \le 20
```



[5 points] Analysis:

Insight: With the bimodal predictor (n=0: no global history), a given static branch is predicted using only a single 2-bit counter. With the addition of global history, that single counter is *specialized* or *multiplied* into many more counters. All these counters are used by the same static branch for more specialized predictions among its dynamic instances, promising higher accuracy *as long as there are adequate counters available in the table* (not just for this static branch, but for all static branches). Thus, with the addition of global history, there is a need for more 2-bit counters ... the key idea being that, at some point, bimodal cannot even take advantage of more counters (see your analysis section for bimodal, above) whereas gshare *can*. Summarizing: *Gshare needs an abundance of counters and, unlike bimodal, it can exploit abundant counters for higher accuracy*.

- 1. [0.5 points] At small table sizes, global history can hurt accuracy. This is because there are too few counters.
- 2. [0.5 points] At large table sizes, global history can help accuracy. This is because there are abundant counters.
- 3. [2.5 points] For each table size (m), indicate the **smallest** global history length (n) that yields the lowest misprediction rate (use a precision of two digits after the decimal point for misprediction rate; that's what should be in your simulator's output file, in any case), indicate what that lowest misprediction rate is, and indicate the misprediction rate for bimodal. Fill in the table below.

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m	Smallest global history length	Lowest	Bimodal misprediction		
	(n) that yields the lowest	misprediction rate	rate (<i>i.e.</i> , for <i>n</i> =0)		
	misprediction rate (two digits of	(two digits of	(two digits of precision		
	precision after the decimal	precision after the	after the decimal		
	point)	decimal point)	point)		
7	0	26.65%	26.65%		
8	0	22.43%	22.43%		
9	0	18.49%	18.49%		
10	0	15.67%	15.67%		

11	1	13.64%	13.65%
12	1	12.04%	12.47%
13	7	10.56%	11.72%
14	6	9.08%	11.37%
15	7	8.20%	11.30%
16	9	7.49%	11.21%
17	11	7.03%	11.19%
18	10	6.73%	11.17%
19	12	6.47%	11.17%
20	11	6.37%	11.17%

4. [0.5 points] The *smallest* bimodal predictor that achieves the best bimodal accuracy (lowest misprediction rate, **using two digits after the decimal point**, among all bimodal configurations) is as follows:

Best bimodal: m = 18, misp. rate = 11.17%.

5. [0.5 points] The *smallest* gshare predictor that achieves the best gshare accuracy (lowest misprediction rate, **using two digits after the decimal point**, among all gshare configurations) is as follows:

Best gshare: m = 20, n = 11, misp. rate = 6.37.

6. [0.5 points] In conclusion, with adequate predictor storage budget, gshare rocks.

PART 3: HYBRID PREDICTOR (ECE563 students only)

[ECE563: 20 points] Gradescope will evaluate your simulator on the two validation runs "val_hybrid_1.txt" and "val_hybrid_2.txt" posted on the website for the HYBRID PREDICTOR. Gradescope will also evaluate your simulator on two hybrid predictor mystery runs. Each validation run and mystery run is worth ¼ of the points for this part (5 points each).