

**NC State University**

**Department of Electrical and Computer Engineering**

**ECE 463/563 (Prof. Rotenberg)**

**Project #2: Branch Prediction**

**REPORT TEMPLATE (Version 1.0)**

**by**

**Austin Dolan**

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

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

Course number:   
(463 or 563 ?)

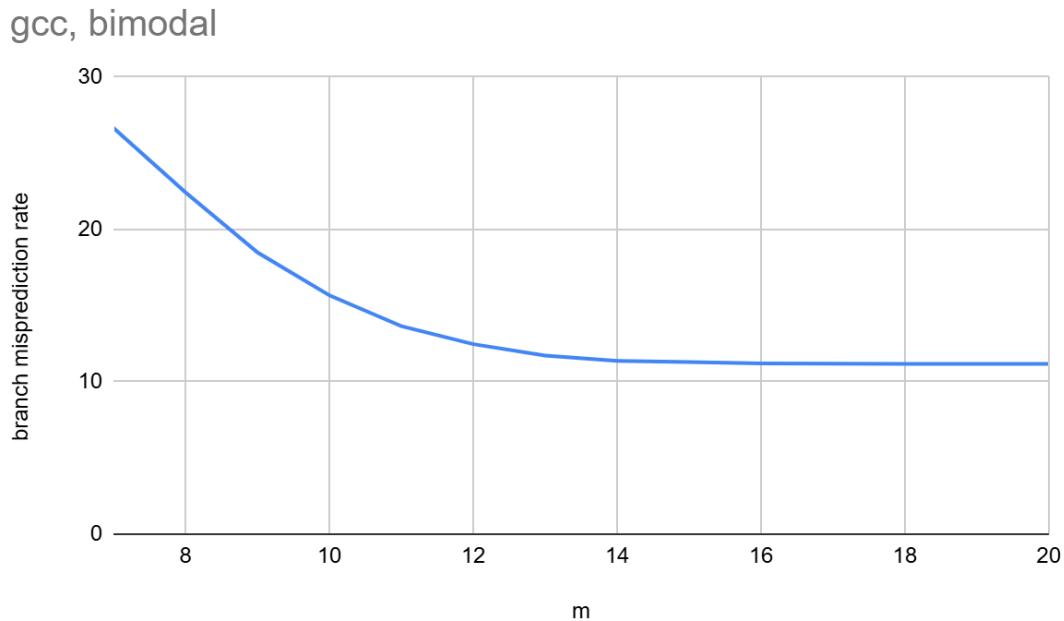
# Grading Breakdown, Experiments, and Report

## PART 1: BIMODAL PREDICTOR

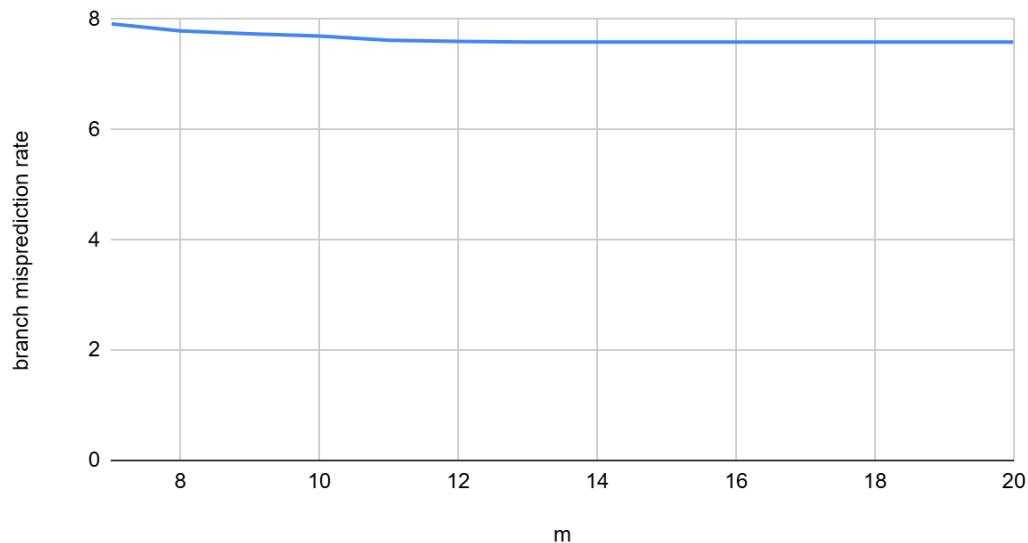
(a) [ECE463: 25 points] or [ECE563: 20 points] Gradescope will evaluate your simulator on the four validation runs “val\_bimodal\_1.txt”, “val\_bimodal\_2.txt”, “val\_bimodal\_3.txt”, and “val\_bimodal\_4.txt”, posted on the website for the BIMODAL PREDICTOR. Gradescope will also evaluate your simulator on one bimodal predictor mystery run. Each validation run and mystery run is worth  $\frac{1}{5}$  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 ( $7 \leq m \leq 20$ ). Use the traces *gcc*, *jpeg*, and *perl*.

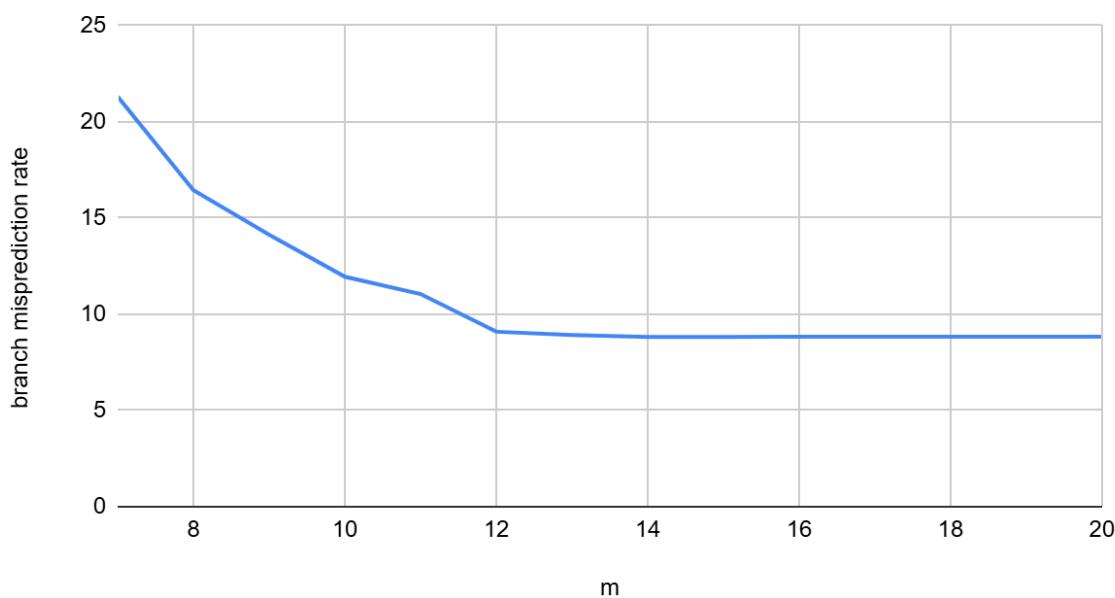
[20 or 15 points] Graphs: Produce one graph for each benchmark. Graph title: “*<benchmark>*, bimodal”. Y-axis: branch misprediction rate. X-axis:  $m$ . Per graph, there should be only one curve consisting of 14 datapoints (connect the datapoints with a line).



jpeg, bimodal



perl, bimodal



[5 points] Analysis:

1. [1 point] As the bimodal predictor's table size increases, the branch misprediction rate decreases.
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.)**

Benchmark	Minimum " $m$ " at which misprediction rate <b>(two digits of precision after the decimal point)</b>	Minimum misprediction rate <b>(two digits of precision after the decimal point)</b>
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	reaches its minimum	the decimal point)
gcc	$m = 18$	11.17
jpeg	$m = 13$	7.59
perl	$m = 13$	8.92

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/counter 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 fewer 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  $\frac{1}{5}$  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 ( $7 \leq m \leq 20$ ), 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:  $0 \leq n \leq 7$

$m=8$  curve has 9 datapoints:  $0 \leq n \leq 8$

$m=9$  curve has 10 datapoints:  $0 \leq n \leq 9$

$m=10$  curve has 11 datapoints:  $0 \leq n \leq 10$

$m=11$  curve has 12 datapoints:  $0 \leq n \leq 11$

$m=12$  curve has 13 datapoints:  $0 \leq n \leq 12$

$m=13$  curve has 14 datapoints:  $0 \leq n \leq 13$

$m=14$  curve has 15 datapoints:  $0 \leq n \leq 14$

$m=15$  curve has 16 datapoints:  $0 \leq n \leq 15$

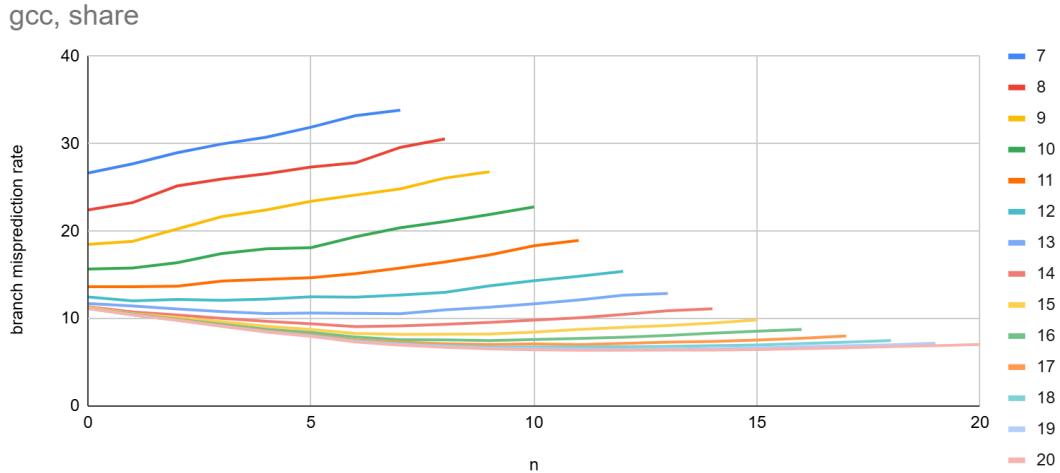
$m=16$  curve has 17 datapoints:  $0 \leq n \leq 16$

$m=17$  curve has 18 datapoints:  $0 \leq n \leq 17$

$m=18$  curve has 19 datapoints:  $0 \leq n \leq 18$

$m=19$  curve has 20 datapoints:  $0 \leq n \leq 19$

$m=20$  curve has 21 datapoints:  $0 \leq n \leq 20$



[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.**

$m$	<b>Smallest</b> global history length ( $n$ ) that yields the lowest misprediction rate ( <b>two digits of precision after the decimal point</b> )	Lowest misprediction rate ( <b>two digits of precision after the decimal point</b> )	Bimodal misprediction rate ( <i>i.e.</i> , for $n=0$ ) ( <b>two digits of precision after the decimal point</b> )
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	8.2	11.3
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:  $m = \underline{18}$ , misp. rate =  $\underline{11.17}$ .

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:  $m = \underline{20}$ ,  $n = \underline{11}$ , misp. rate =  $\underline{6.37}$ .

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  $\frac{1}{4}$  of the points for this part (5 points each).