

**NC State University**  
**Department of Electrical and Computer Engineering**  
**ECE 463/563: Fall 2022 (Rotenberg)**  
**Project #2: Branch Prediction**

**by**

**<< Nirmal Kumar Sedhumadhavan >>**

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

Student's electronic signature: **Nirmal Kumar Sedhumadhavan**  
(sign by typing your name)

Course number: **563**  
(463 or 563 ?)

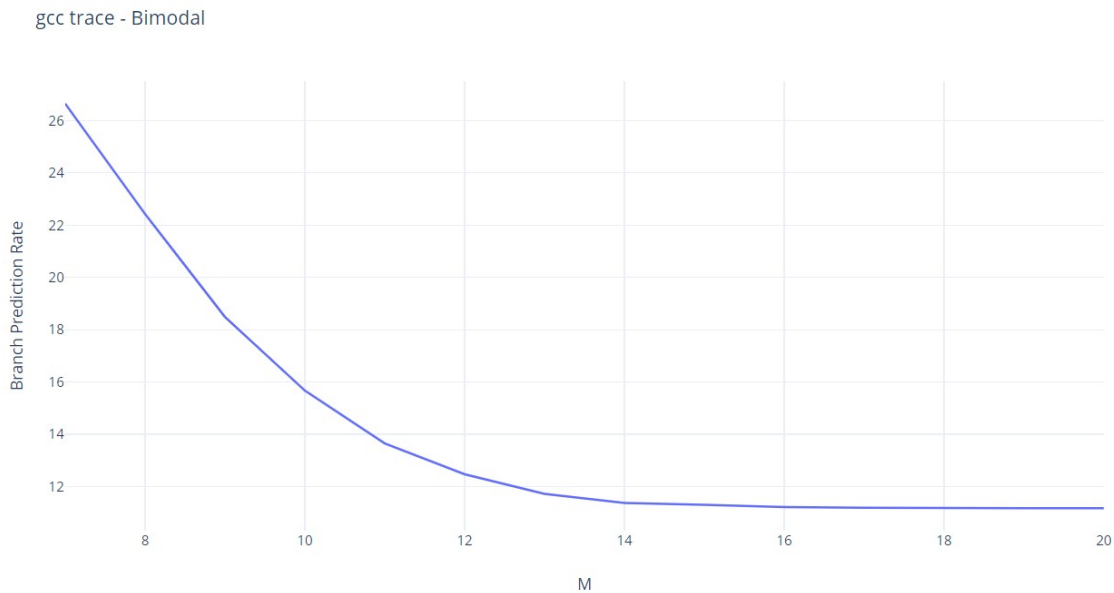
## 7. Tasks, Grading Breakdown

### PART 1: BIMODAL PREDICTOR

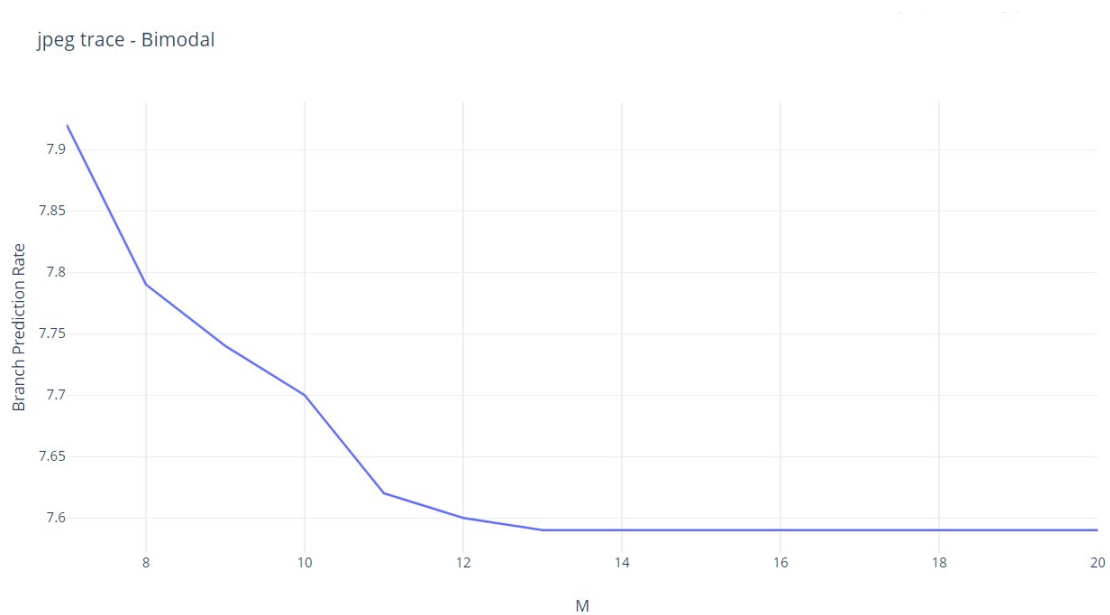
(a) [ECE463: 25 points] or [ECE563: 20 points] Gradescope will evaluate your simulator on the four validation runs “val\_bimodal\_1.txt”, “val\_bimodal\_2.txt”, “val\_bimodal\_3.txt”, and “val\_bimodal\_4.txt”, posted on the website for the BIMODAL PREDICTOR. Gradescope will also evaluate your simulator 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).

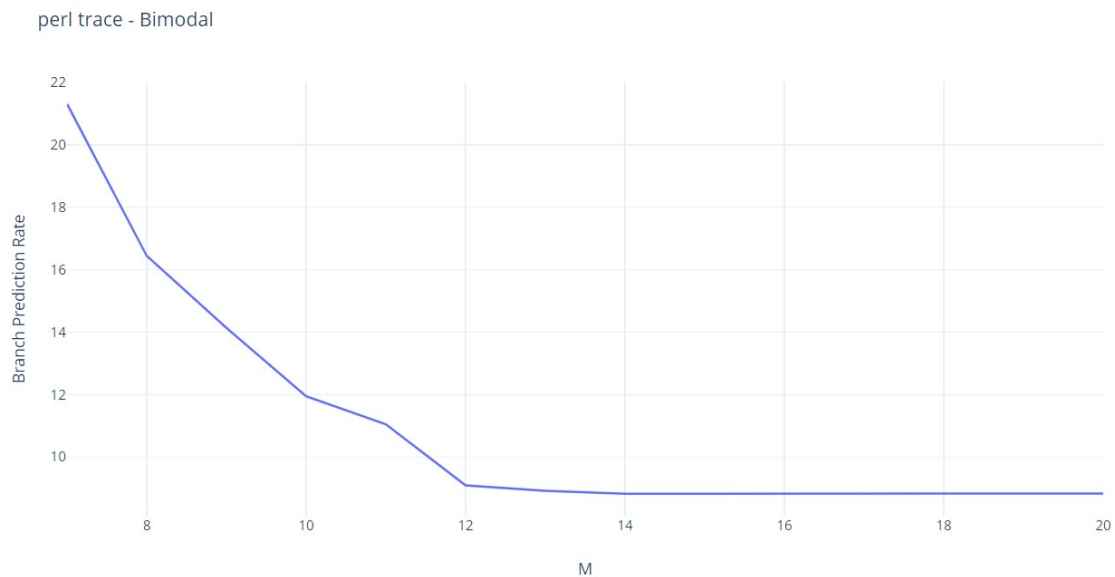
<< INSERT GRAPH “gcc, bimodal” HERE >>



<< INSERT GRAPH “jpeg, bimodal” HERE >>



<< INSERT GRAPH “perl, bimodal” HERE >>



[5 points] Analysis:

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

Benchmark	Minimum “ $m$ ” at which misprediction rate reaches its minimum	Minimum misprediction rate
gcc	$m = 18$	11.17%
jpeg	$m = 13$	7.59%

perl	$m = 14$	8.82%
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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** 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  $\frac{1}{5}$  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:  $0 \leq n \leq 16$

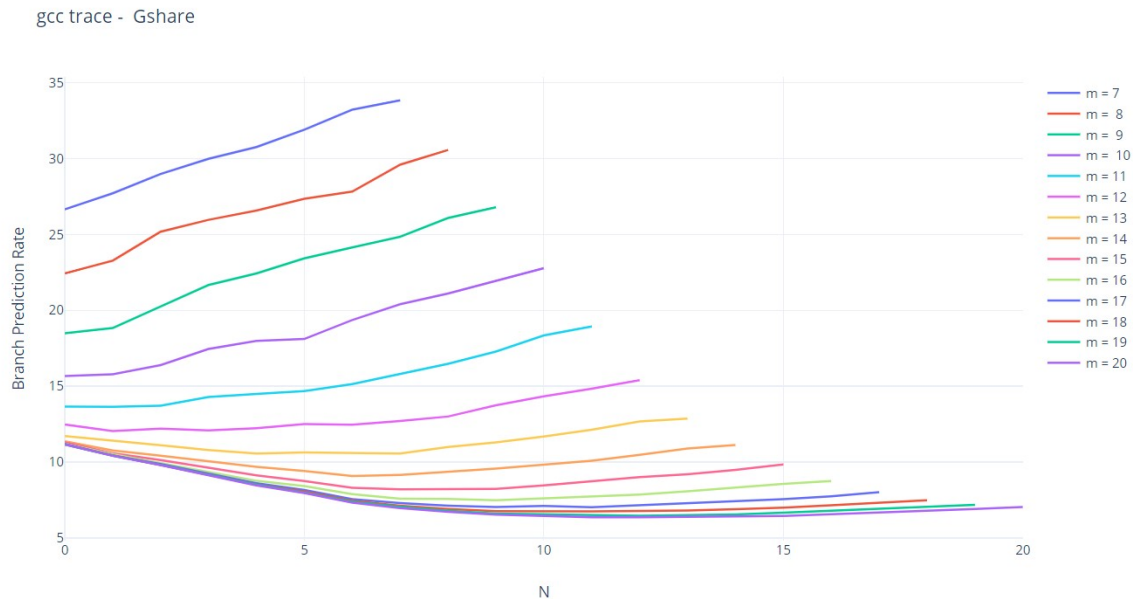
$m=17$  curve has 18 datapoints:  $0 \leq n \leq 17$

$m=18$  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:  $0 \leq n \leq 20$

<< INSERT GRAPH “gcc, gshare” HERE >>



[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.*

- [0.5 points] At small table sizes, global history can **<hurt>** accuracy. This is because there are **<too few>** counters.
- [0.5 points] At large table sizes, global history can **<help>** accuracy. This is because there are **<abundant>** counters.
- [2.5 points] For each table size ( $m$ ), indicate the global history length ( $n$ ) that yields the lowest misprediction rate, indicate what that lowest misprediction rate is, and indicate the misprediction rate for bimodal. **Fill in the table below.**

$m$	Global history length ( $n$ ) that yields the lowest misprediction rate	Lowest misprediction rate	Bimodal misprediction rate ( <i>i.e.</i> , for $n=0$ )
7	$N = 0$	26.65%	26.65%
8	$N = 0$	22.43%	22.43%
9	$N = 0$	18.49%	18.49%
10	$N = 0$	15.67%	15.67%
11	$N = 1$	13.64%	13.65%
12	$N = 1$	12.04%	12.47%

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

4. [0.5 points] The *smallest* bimodal predictor that achieves the best bimodal accuracy (lowest misprediction rate 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 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  $\frac{1}{4}$  of the points for this part (5 points each).