Project #4: Branch Predictors

The objective of this project is to understand the working of the branch predictors and their impact on performance, using the model branch predictor unit in the simplescalar tool. The benchmark is the same as in project 3, the 'Compress' SPEC integer benchmark.

The objective of this lab, as before, is to build understanding of the how branch predictors affect performance, and to use this to optimise the branch predictor with knowledge of trade-offs such as area.

As will be discussed in class, there are a few types of branch predictors:

- Always Taken
- Branch is always taken
- Always Not taken
- Branch is always not taken
- Bimodal
- 2 level BP or correlating BP
- Combined (not in this Lab)

Bimodal branch predictors use a bank of 2-bit saturating counters, the MSB determining whether to take branch or not. A few LSBs of the program counter determine which counter to use (so different jumps in a loop have separate histories). 2 Level predictors are described in the appendix.

Specific guidelines and hints:

Use the compress.ss and test.in provided for lab 3.
1) Read the SimpleScalar documentation to find out how to specify different branch predictors.

2) Vary the different parameters of Bimodal and 2-Level predictors. Measure mis-prediction rates for different parameters and plot curves.

2) For Bimodal : Vary size of the Pattern history Table from $2^8$ to $2^{16}$ TOTAL bits.

3) For 2 Level predictors:
   - Calculate area of branch predictor in term of bits
   - Assume entries in pattern history tables are always 2 bits
   - Plot mis-prediction rate by varying the parameters in the 2 level predictor
   - Use total area numbers (in bits) to be $2^8$ to $2^{16}$ in power-of-two steps
   - For each fixed area, figure out optimal points for minimizing mis-prediction rate by varying one of the 2 parameters (N,W). (since area is fixed, varying N will vary W as system is constrained)

4) Using sim-profile with "–all" argument, investigate at the looping patterns of the program, and use this information to analyse and explain the results of the above experiments and the
curves that you get.

5) For each of the total area numbers as mentioned above ($2^8$ to $2^{16}$), explain why different predictors have better/worse mis-prediction rates.

6) Again, grading will be done based on explanation and reasoning and not the answers.

7) Please do not submit numbers without reasons. The objective of this is to make you think about branch prediction.

8) Bonus question:
   - Perform energy estimation of the branch predictor using the Wattch tool
   - Get power numbers from watch
   - Multiply by number of cycles and use cycle times to get energy for the whole computation.
   - Bonus points will be awarded to students who not just show the data, but EXPLAIN WHY they got these results.

Project 4 is due 1 week from now, Friday 20th of February. E-mail report by 11:59pm as usual.
**APPENDIX: 2 level / correlating branch predictors:**

Different types of 2 level Branch Predictors are shown in the figure. Implementing the predictor, here are 2 tables, the one on the left is the branch history table and the one on the right is the pattern history table.

**GAg**: Branch history is global with Hist Size W  
Pattern history is addressed with W bits

**GAp**: Branch history is global with Hist Size W  
Pattern history is addressed with those W bits + extra PC LSB bits. 
Adds semblance of Locality

**PAg**: Separate Branch History for N addresses. 
\( \log_2 N \) bits of PC taken.  
Branch history of each address, W bits.  
Only uses Branch history to address Pattern History

**PAp**: Separate Branch History for N addresses. 
\( \log_2 N \) bits of PC taken.  
Branch history of each address, W bits.  
Combines LSBs of PC and Branch History to address 
Pattern History \( N \times 2^W \)

---

**Figure 6. 2-level adaptive predictor structure**

![Diagram of 2-level adaptive predictor structure](image)

**Table 2: Branch predictor parameters**

<table>
<thead>
<tr>
<th>predictor</th>
<th>I1_size</th>
<th>hist_size</th>
<th>I2_size</th>
<th>xor</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAg</td>
<td>1</td>
<td>W</td>
<td>2^W</td>
<td>0</td>
</tr>
<tr>
<td>GAp</td>
<td>1</td>
<td>W</td>
<td>&gt;2^W</td>
<td>0</td>
</tr>
<tr>
<td>PAa</td>
<td>N</td>
<td>W</td>
<td>2^W</td>
<td>0</td>
</tr>
<tr>
<td>PAp</td>
<td>N</td>
<td>W</td>
<td>N\times2^W</td>
<td>0</td>
</tr>
<tr>
<td>gshare</td>
<td>1</td>
<td>W</td>
<td>2^W</td>
<td>1</td>
</tr>
</tbody>
</table>