Exercises

1. Suppose you are given a task to add a branch predictor unit to your baseline processor, and you are provided with two options: `BatPredictor` and `SuperPredictor`. Evaluate the speedup of each predictor relative to your baseline if branches are 15% of all instructions. Assume normal CPI is 1, but the branch misprediction penalty is 2 *extra* stall cycles.

   `BatPredictor`:

   - 10% misprediction rate.
   - Will increase the cycle time (clock period) by 15%.

   `SuperPredictor`:

   - 12% misprediction rate.
   - Will increase the cycle time (clock period) by 20%.

   (a) Which predictor would you choose?

   (b) If branches are instead 25% of all instructions, which predictor would you choose?

2. Assume a given machine has a CPI of 1. Therefore the branches take 1 clock cycle to execute when correctly predicted. Also assume for this problem that branch predictor and BTB mispredictions never occur at the same time.

   (a) Given the following characteristics of the machine, formulate an expression to calculate the average CPI of a branch instruction (CPI_{br}) for an in-order pipeline.

   T_{mp} = penalty, in cycles, for a branch or BTB misprediction
   p_{br} = probability of a branch direction misprediction
   p_{btb} = probability of a BTB target misprediction
   N_{br} = size of the branch predictor (in entries)
   N_{btb} = size of the BTB (in entries)

   (b) A pipeline using 256-entry `Gshare` branch predictor with a 92% accuracy and a 512-entry BTB with a 82% target prediction accuracy, and a 10 cycle branch/BTB midpredict latency. Find out the CPI_{br} using the expression obtained in the previous question.

3. Assume a 3-bit global register (initialized to all 0's) and a two-level Gshare scheme:

   (a) How many entries are there in the PHT (Pattern History Table)?

   (b) Show the contents of the global register and of the PHT (where each entry is initialized to strong not-taken case), and after the following sequence of branch executions has taken place: 1 taken (T) branch, 3 not-taken (NT) branches, 1 T branch, 3 NT branches, 1 T branch. With *pred* being the prediction and *act* the actual outcome as per the given string, show your results for each branch, for example, in the form (GR) (*pred*) (*Updated* GR) (*act*) (PHT). Assume a speculative update for GR (Global Register) and a non-speculative one for the PHT that occurs before the next branch prediction. On misprediction, restore the GP to (001). A typical entry could be: (000)(0)(000)(1)(00,00,00,00,00,00,00,00).