Problem Set 7

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1a)

With branch outcomes determined in the EX stage, each mis-prediction will need three NOPs to clear the pipeline, and thus will cause three missed cycles in 55% (100-45%) of the BEQ instructions. Thus the extra CPI is $3 \times .55 \times .25 = .4125$.

1b)

The two bit predictor is only incorrect 15% of the time, thus the extra CPI is $3 \times .15 \times .25 = .1125$.

1c)

If the branch instructions could be replaced by ALU instructions, there would be no miss-predicted branches. Thus the extra cycles would be 0. Speedup would then be $\frac{1.1125}{1.0} = 1.1125$.

2a)

Branch prediction addresses control hazards by attempting to reduce stalls by guessing the likely outcome of a branch. If no guessing was made, stalls would be necessary. With accurate prediction, guessing is correct more often than wrong and results in fewer wasted cycles.

2b)

Instruction scheduling addresses both structural and data hazards. This technique re-arranges instructions with dependencies so that, as much as possible, no delays need to be introduced.

2c)

Delay slots address data hazards by inserting instructions with no dependence on a load-instruction into the cycle immediately following. This makes sure that any instruction requiring the output of the load is sufficiently separated to avoid needing a stall.

2d)

Increased availability of functional units addresses structural hazards by making sure that any given instruction is not monopolizing hardware necessary for another pipelined instruction.

3a)

Prediction	Outcome
NT	T
NT	NT
NT	T
NT	T
T	NT

The two-bit predictor is only correct $\frac{1}{5}$ of the time for an accuracy of 20%.

3b)

Coding the predictor in python, and running through a sequence of 50,000 branches hit 0.59992%. Presumably this limit hits 60% for infinite trials.

3c)

The perfect predictor would be exactly the same as the pattern: T $->$ NT $->$ T $->$ T $->$ NT $->$ (start). Any mis-prediction would also return to start. Thus, at most a handful of mispredictions would happen before the predictor aligned with the pattern.

3d)

Presuming the question meant c, not d:

Prediction	Outcome
T	NT
T	T
NT	NT
T	NT
T	T

This predictor would hit $\frac{3}{5}$ or 60% for one pass through the pattern.

4a)

Figure 1: Program execution

CYCLE	IF	ID	EX	MEM	WB
1	lw				
1	sub				
2	slt	lw			
2	nop	sub			
3	add	slt	lw		
3	sw	nop	sub		
4		add	slt	lw	
4		sw	nop	sub	
5			add	slt	lw
5			sw	nop	sub
6				add	slt
6				sw	nop
7					add
7					sw

4b)

- In cycle 1, the lw and add instructions will be fetched.
- In cycle 2, lw and add will be send to the reservation station, sub and slt will be fetched.
- In cycle 3, lw will be sent to the load/store functional unit for execution. Also, sub and slt will be sent to the reservation station and sw will be fetched.
- In cycle 4, lw will be send to the memory stage, sub and slt will be sent to the integer functional units for execution, and sw will be sent to the reservation station.
- In cycle 5, lw will be sent to the wb stage, add will move to the integer functional unit for execution, sub and slt will be sent to the wb stage, and sw will be send to the load/store functional unit for execution.

- In cycle 6, add will be sent to the wb stage, and sw will be sent to the memory stage.