Worksheet 3

Monday, November 13, 2023 10:27 AM

CS219 Ch4_Worksheet-3 **Fall 2023**

Purpose: Become familiar with the Hazards in pipelining, introducing stalls to encounter Hazards, introducing forwarding technique to reduce stalls and improve performance

Points: 80

Reading/References: Chapter 4, Class Lecture / Lecture Notes

Assignment: Responses must be submitted in writing via the class web site. I recommend you to use ".pdf" format, when you submit this worksheet. You can copy/paste the tables as needed that are provided at the end of this document. You can edit those tables as needed. For RAW hazards, always check with the next two instructions. Detect WAR and WAW hazards for back-to-back instructions only.

1) Given the MIPS five stage pipeline and the following instruction sets:
   a) What is the number of cycles required for executing the following programs in a pipelined processor, and not considering any dependencies/hazards. [5 pts]
   b) Identify all data hazards for the given Instruction set. [5pts]
   c) If there is no forwarding or hazard detection, write the instructions (same order) and insert **nop**'s (nop-no operation) to force the appropriate number of stalls which would be required. [10 pts]
   d) If the processor has forwarding, but the hazard detection unit is defective, what would happen when each of these instruction sets are executed? [10 pts]
   e) Rearrange and/or forward the instructions to avoid hazards where possible. Insert **nop**'s to force the appropriate number of stalls when a hazard cannot be avoided. If needed, update/change the instructions. You can use register $15 to hold temporary values in the modified code. [10 pts]

Instruction set # :

1b)

I1: add $4, $5, $2 W — WAW; I1 & I2, ; $4 - no stalls - useless value
I2: lw $4, 0($1) W — RAW; I2 & I3; $4 - two stalls
I3: sw $4, 4($10) R
I4: or $1, $2, $4 W — RAW; I4 & I5; $1 - two stalls
I5: lw $5, 8($1) R
I6: sub $3, $5, $2 W — RAW; I5 & I6; $5 - two stalls
I7: add $8, $9, $2 W

1a) 7 + (7-1) =
7 + 6 =
13 cycles

1e) I1 → I7
I4 → I3
I3 → I4
I5 → I6
I6 → I5

lw $4, 0($1)
or $1, $2, $4
sw $4, 4($10)
sub $3, $5, $2
lw $5, 8($1)
add $8, $9, $2
add $4, $5, $2

1c) **No forwarding- insert bubbles/stalls or nop(s) as needed**

Instruction Set	Pipeline Cycle												
	1	2	3	4	5	6	7	8	9	10	11	12	13
add $4, $5, $2	F	D	E	M	W								
lw $4, 0($1)		F	D	E	M	W							
			S	S	S	S	S						
				S	S	S	S	S					
sw $4, 4($10)					F	D	E	M	W				
or $1, $2, $4						F	D	E	M	W			
							S	S	S	S	S		
								S	S	S	S	S	
lw $5, 8($1)									F	D	E	M	W
										S	S	S	S

14 15 16

lw $s,8($1)													

sub $3, $5, $2
add $8, $9, $2

Forwarding allowed- insert bubbles/stalls or nop(s) as needed

Instruction Set	Pipeline Cycle													14	15
	1	2	3	4	5	6	7	8	9	10	11	12	13		
add $4,$5,$2															
lw $4, 0($1)															
sw $4, 4($10)															
or $1, $2, $4															
lw $s,8($2)															

sub $3, $5, $2
add $8, $9, $2

2) Given basic MIPS five stage pipeline, complete the tables with no-forwarding and forwarding, for the following instruction set: (Refer Ch4_PracticeSheet-3_KEY)
[40 pts, 10 pts each]

a) Detect all the Data Hazards for the given instruction set (RAW, WAR, WAW)
b) For part (a) table: Assuming no delayed branches and forwarding not allowed. Assume that branches execute in the EX stage, draw the pipeline execution diagram for each set of code.
c) For part (b) table: Forwarding allowed and insert stall if forwarding is not possible. Assume forwarding is available within the same cycle if registers, else in the next cycle for other instructions.
d) What is speed-up you attain by allowing forwarding?

Instruction set #1:

1a)

```
1  L1:  lw    $1, 24($6)
2       beq   $2, $3, L2     # taken
3       add   $1, $6, $4
4  L2:  beq   $1, $2, L1     # not taken
5       sw    $2, 12($4)
6       and   $1, $1, $4
```

RAW I1&I4

2b)

No forwarding- insert bubbles/stalls or nop(s) as needed

Instruction Set	Pipeline Cycle												
	1	2	3	4	5	6	7	8	9	10	11	12	13
lw $1, 24($6)	F	D	E	M	W								
Beq $2, $3, L2		F	D	E	M	W							
			F	F	F	F	F						
				S	S	S	S	S					
Beq $1, $2, L1					F	D	E	M	W				
sw $2, 12($4)						F	D	E	M	W			
and $1, $1, $4							F	D	E	M	W		

2c)

Forwarding allowed- insert bubbles/stalls or nop(s) as needed

Instruction Set	Pipeline Cycle												
	1	2	3	4	5	6	7	8	9	10	11	12	13
lw $1, 24($6)	F	D	E	M	W								
Beq $2, $3, L2		F	D	E	M	W							
			F	F	F	F	F						
Beq $1, $2, L1				F	D	E	M	W					
sw $2, 12($4)					F	D	E	M	W				
and $1, $1, $4						F	D	E	M	W			

2d) $11/10 = 1.1$

The speed up attained by forwarding is 1.1.