DUE IN CLASS

STUDENTS IDENTIFICATION:

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2.1 Simple execution, without data forwarding techniques

e)	Clock cycles	81	Instructions	7	Average CPI	$\frac{18}{7} = 2.571$	

f)	Clock cycles	174	Stalls:	- Data	101
	Instructions	61		- Structural	0
	Average CPI	2.852		- Branch Taken	8

A política de previsa de branch utilizada é "predict not taken", uma vez que após a instrução branch é executada a instrução seguinte do programa, e na a que consta no target do branch. Já que a instrução branch se situa no fim do loop o jump vai ser feito em todas as iterações excepto na última, pelo que a instrução su aperas na é anullada neste caso.

2.2 Application of data forwarding techniques

c)	Clock cycles	13	Stalls: - Data	63
	Instructions	61	- Structural	9
	Average CPI	2,230	- Branch Taken	80

CC_{ORJ} = 174
$$CC_{new} = 136$$
Speedup = $\frac{+ime_{new}}{+ime_{new}} = \frac{CC_{oRJ} \times Clock + Time}{CC_{new}} = \frac{CC_{ORJ}}{CC_{new}} = \frac{174}{136} \approx 1.279$
whesher CPU

2.3 Source code optimization: minimization of data and structural hazards

a) Attach a copy of the new assembly program.

c)	Clock cycles	118
	Instructions	61
	Average CPI	1.934

Stalls: - Data	36
- Structural	9
- Branch Taken	8

2.4 Source code optimization: loop unrolling

a) Attach a copy of the new assembly program.

c)	Clock cycles	89
	Instructions	43
	Average CPI	2.070

Stalls: - Data	57
- Structural	9
- Branch Taken	Z

2.5 Source code optimization: branch delay slot

a) Attach a copy of the new assembly program.

d)	Clock cycles	101
	Instructions	61
	Average CPI	1.656

Stalls: - Data	27
- Structural	9
- Branch Taken	Ó

Table 1: Pipeline time diagram, with data forwarding techniques.

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Table 2: Pipeline time diagram, with minimization techniques to reduce the data and structural hazards.

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Table 3: Pipeline time diagram: usage of loop unrolling minimization techniques to reduce the control hazards.

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Table 4: Pipeline time diagram: usage of branch delay slot techniques to reduce the control hazards.

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Table 5: Pipeline time diagram, without data forwarding techniques.

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2.3 a)

```
.data
             .word 1, 3, 1, 6, 4
A:
             .word 2, 4, 3, 9, 5
mult: .word
      .code
      daddi $1, $0, A ; *A[0]
      daddi $5, $0, 1 ; $5 = 1 ;; i
            $6, $0, 10 ; $6 = N ;; N = 10
      daddi
            $9, 0($1)
      lw
      daddi
            $1, $1, 8
loop: lw $12, 0($1) ; $12 = A[i]
            $5, $5, 1 ; i++
      daddi
            $12, $12, $9 ; $12 = $12*$9 ;; $12 = A[i]*mult
      dmul
      daddi
             $1, $1, 8
             $9, $9, $12 ; $9 = $9 + $12 ;; mult = mult +
      dadd
A[i]*mult
      bne
            $6, $5, loop; Exit loop if i == N
            $9, mult($0) ; Store result
      halt
```

```
.data
              .word 1, 3, 1, 6, 4
A:
              .word 2, 4, 3, 9, 5
mult: .word 0
.code
       daddi $1, $0, A ; *A[0]
       daddi $5, $0, 1 ; $5 = 1 ;; i
       daddi $6, $0, 10 ; $6 = N;; N = 10
       lw $9, 0($1)
      lw $12, 8($1)
loop:
      dmul $16, $12, $9 ; $16 = $12*$9 ;; $16 = A[i]*mult
      lw $13, 16($1)
       daddi $1, $1, 24
                            ; $1 += 3
       lw $14, 0($1)
                            ; $14 = A[i - 1]
       dadd $9, $9, $16 ; $9 = $9 + $16 ;; mult = mult +
A[i]*mult
       dmul $17, $13, $9
      lw $12, 8($1)
                            ; $12 = A[i]
       dadd $9, $9, $17
                         ; $9 = $9 + $17 ;; mult = mult +
A[i]*mult
      dmul $18, $14, $9 ; $18 = $14*$9 ;; $18 = A[i]*mult
       daddi $5, $5, 3
       dadd $9, $9, $18
A[i]*mult
       bne $6, $5, loop ; Exit loop if i == N
       sw $9, mult($0)
       halt
```

2.5 a)

```
.data
              .word 1, 3, 1, 6, 4
A:
              .word 2, 4, 3, 9, 5
mult: .word
      .code
      daddi $1, $0, A ; *A[0]
      daddi $5, $0, 1 ; $5 = 1 ;; i
           $6, $0, 10 ; $6 = N ;; N = 10
      daddi
             $9, 0($1)
      lw
            $1, $1, 8
      daddi
loop: lw
             $12, 0($1) ; $12 = A[i]
      daddi $5, $5, 1 ; i++
      dmul $12, $12, $9 ; $12 = $12*$9 ;; $12 = A[i]*mult
      daddi $1, $1, 8
             $6, $5, loop; Exit loop if i == N
      bne
             $9, $9, $12 ; $9 = $9 + $12 ;; mult = mult +
      dadd
A[i]*mult
             $9, mult($0) ; Store result
      SW
      halt
```