EASTERN MEDITERRANEAN UNIVERSITY

Department of Computer Engineering

Quiz1 CMPE-523 Parallel Programming 20.11.2017 (2 points, 100 min)

Student's Name-Surname ______________________

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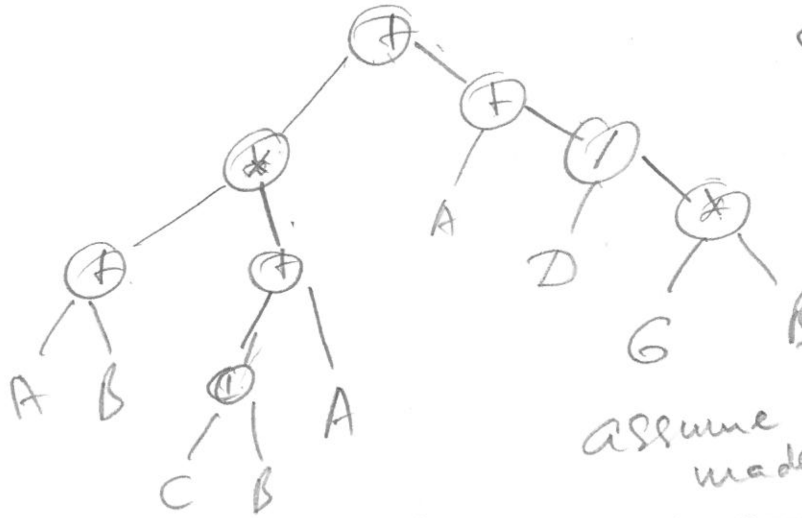
Totally 5 tasks, 2 points, 6 pages

Task 1	Task 2	Task 3	Task 4	Task 5	Total

Task 1. (0.4 point). Consider an expression $(A+B)*(C+B+A)+A+D/(G*B)$. Draw a dependence graph for the expression, give its size and depth. Generate code for evaluation of the expression using instructions of the format:

Op1= op2 "operation" op3,

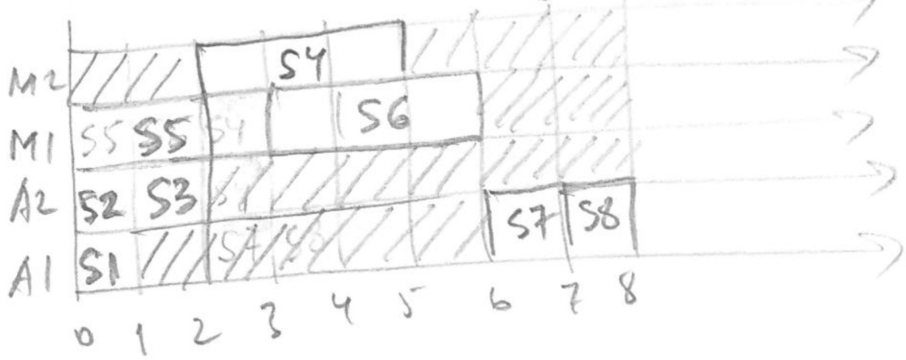
where op2 and op3 are the operands of the "operation", and op1 is a variable for keeping the result of the operation. Assume that a computer has 2 adders and 2 multipliers. Addition takes 1 time unit, and multiplication takes 3 time units. Draw a time diagram showing execution of the code for the expression.



Size = 8

depth = 4

assume division is also made by a multiplier



S1: T1 = A+B

S2: T2 = C+B

S3: T2 = T2+A

S4: T1 = T1*T2

S5: T3 = G*B

S6: T3 = D/T3

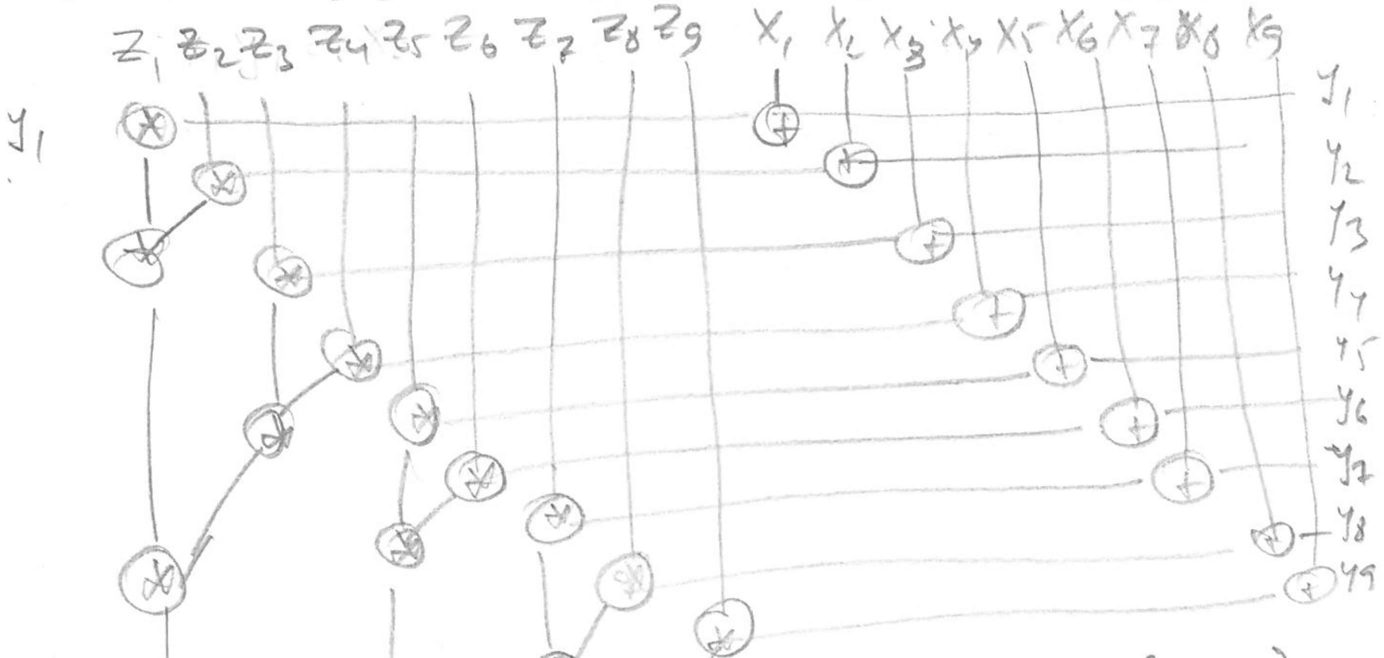
S7: T3 = A+T3

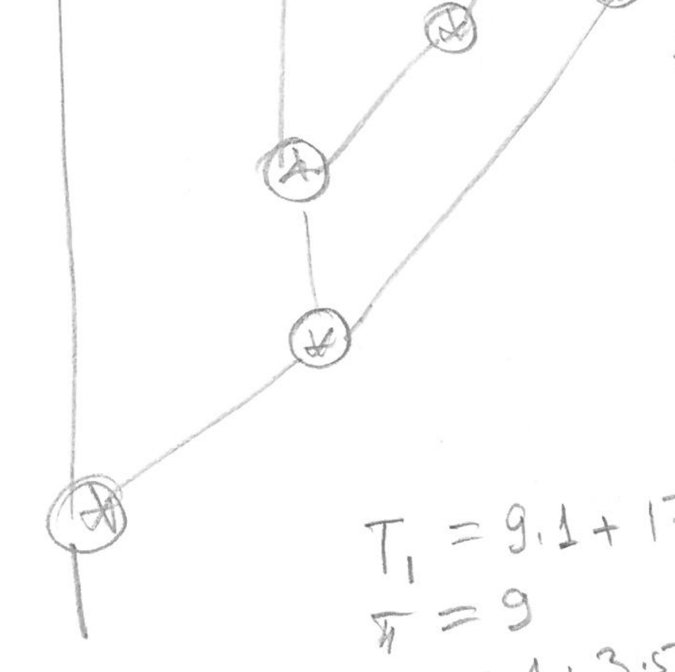
S8: T1 = T1+T3

Task 2. (0.4 point). Using associativity, draw the flattest possible dependence graph for the following product calculation

$$\prod_{i=1}^{9} z_i(x_i + y_i).$$

Write SIMD pseudocode for its calculation. Assume that addition takes 1 time unit, and multiplication takes 3 time units. What is the minimal number π of processors providing maximal performance for that program? Estimate speedup and efficiency for that number π of processors.





$t_i = (x_i + y_i) \cdot z_i, \ (i = 1, 9)$

$t_{2i-1} = t_{2i-1} \cdot t_{2i}, \ (i = 1, 4)$

$t_{4i-3} = t_{4i-3} \cdot t_{4i-1}, \ (i = 1, 2)$

$t_5 = t_5 \cdot t_9$

$t_1 = t_1 \cdot t_5$

$T_1 = 9 \cdot 1 + 17 \cdot 3 = 60$

$\pi = 9$

$T_9 = 1 + 3 \cdot 5 = 16$

$S_9 = \frac{T_1}{T_9} = \frac{60}{16} = \frac{15}{4} = 3,75$

$E_9 = \frac{S_9}{9} = \frac{3,75}{9} = 0,416$

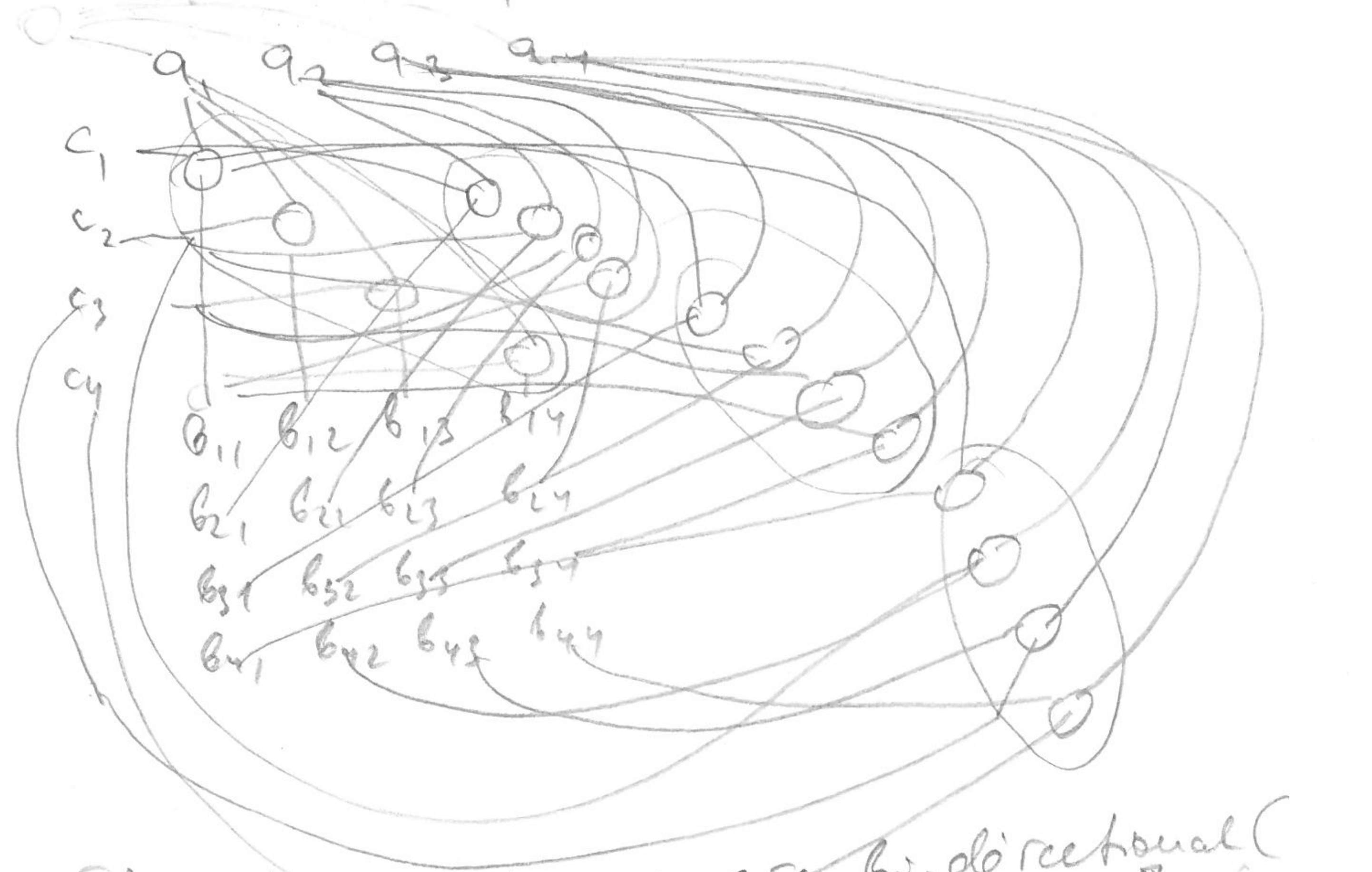
Task 3. (0.4 point). Consider the code below.

```
For i:=1 step 1 until N begin
  a[i]:=0;
  For k:=1 step 1 until N
    a[i];=a[i]+b[I,k]*c[k];
end;
```

What problem is solved by the code? Let N=4. Draw a dependence graph considering x+y*z as a single operation. Write SIMD pseudocode for the code above. Give necessary explanations.

Problem is the matrix-vector multiplication:

a[N] = B[N,N]·C[N]



Edges incident to a_i are bi-directional (input-output). Each a_i depends on B[i,*] only

a[i] = 0, (i = 1,N)

for k = 1 step 1 until N

a[i] = a[i] + b[i,k]·c[k], (i = 1,N)

SIMD program calculates elements of a concurrently, each element is calculated by consecutive additions.

Task 4. (0.4 point). A SIMD computer's vector unit executes with the rate 220 MFLOPS, and its scalar unit averages at 35 MFLOPS. What is the average execution rate of that machine on an algorithm with 340 M floating point operations for vector execution and 110 M floating point operations for serial execution? Provide details of your calculations together with necessary explanations

$R_p = 220 \quad R_s = 35$

$W = 340 \text{ (parallel)} + 110 \text{ (serial)} = 450$

$R = \frac{W}{T}, \quad T_p = \frac{W_p}{R_p} = \frac{340}{220}; \quad T_s = \frac{W_s}{R_s} = \frac{110}{35}$

$T = T_p + T_s = \frac{340}{220} + \frac{110}{35} = \frac{17}{11} + \frac{22}{7} = \frac{119 + 242}{77} =$

$= \frac{361}{77} \simeq 4{,}8 \text{ s}$

$R = \frac{W}{T} = \frac{450}{4{,}8} \simeq 92 \text{ MFLOPS}$

Task 5. (0.4 point). Consider the code below

```
For k:=1 step 1 until N begin
  P:=1/a[k,k];
  A[k,k]:=p;
  For i:=k+1 step 1 until N
     A[I,k]:=-a[I,k]*p;
  For j:=k+1 step 1 until N begin
     Q:=a[k,j];
     For i:=k+1 step 1 until N
        A[I,j]:=a[I,j]+q*a[I,k];
  End;
End;
```

$\det A = 2\cdot6\cdot2 + 2\cdot7\cdot9 + 5\cdot1\cdot3 - 9\cdot6\cdot3 - 2\cdot5\cdot2 - 1\cdot7\cdot2 =$
$= 24 + 126 + 15 - 162 - 20 - 14 = 4+1-36 = -31$

What problem is solved by the code?

Let N=3 and A(3,3)=

2	2	3
5	6	7
9	1	2

Trace the code (show all the variables after each operation completion).

The Problem is Gaussian elimination

A 11	12	13	21	22	23	31	32	33	k	p	i	j	q
									1	1/2			
2	2	3	5	6	7	9	1	2			2		
1/2													
			-5/2			-9/2					3		
	-3/2											2	
													2
											2		
				1							3		
												3	
							-8						3
											2		
					-1/2						3		
											3		
								-11/2					
									2	1			7
											3		
				1									
								8	[illegible]				
												3	
									1/58				-1/2

1	2	3	4	5	6	7	8	9	10	11	12	13	14
11	12	13	21	22	23	31	32	33	k	p	i	j	q
											3		
								$-\frac{31}{2}$					
									3				
										$-\frac{2}{31}$			
								$-\frac{2}{31}$					

After Gaussian elimination $\prod_{i=1}^{N} a_{ii} = \frac{1}{\det A}$

$$a_{11} \cdot a_{22} \cdot a_{33} = \frac{1}{2} \cdot 1 \cdot \left(-\frac{2}{31}\right) = -\frac{1}{31} \rightarrow$$

$\det A = -31$, complying with the original matrix value obtained from the

$$A' = \begin{pmatrix} \frac{1}{2} & 2 & 3 \\ \times & 1 & -1/2 \\ \times & \times & -\frac{2}{31} \end{pmatrix}$$