EASTERN MEDITERRANEAN UNIVERSITY

Department of Computer Engineering

MT Exam CMPE-523 Parallel Programming 27.11.2017 (30 points, 110 min)

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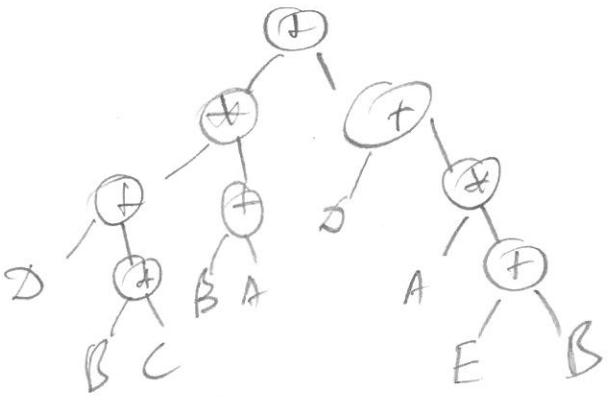
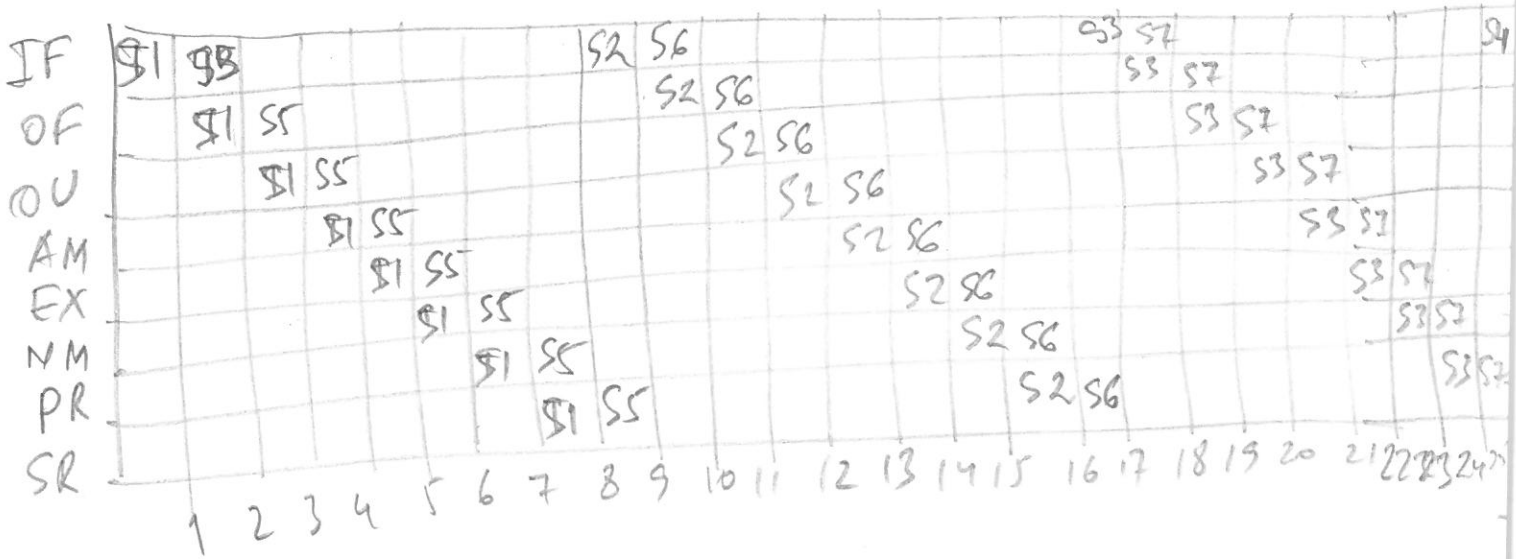
Totally 5 tasks, 30 points, 6 pages

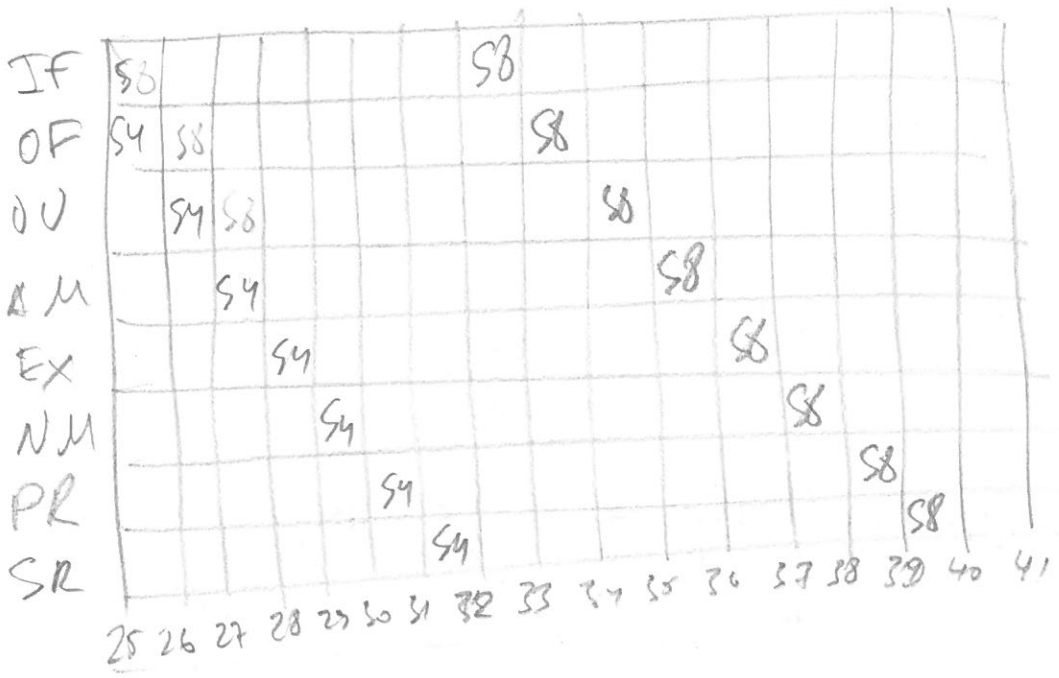
Task 1	Task 2	Task 3	Task 4	Task 5	Total

Task 1. (6 points). Consider an expression $(D+B*C)(B+A)+D+A*(E+B)$. 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. Draw a time diagram showing execution of the code for the expression. Draw a time diagram showing execution of the code for the expression on the pipelined processor with four stages: Instruction Fetch (IF), Operand Fetch (OF), Operand Unpack(OU), Align Mantissa (AM), Execution (Ex), Normalize Mantissa (NM), Pack Result (PR), Save Results (SR), each taking 1 time unit for execution



S1: T1 = B + C
S2: T1 = D + T1
S3: T2 = B + A
S4: T1 = T1 * T2
S5: T3 = E + B
S6: T3 = A * T3
S7: T3 = D + T3
S8: T1 = T1 + T3



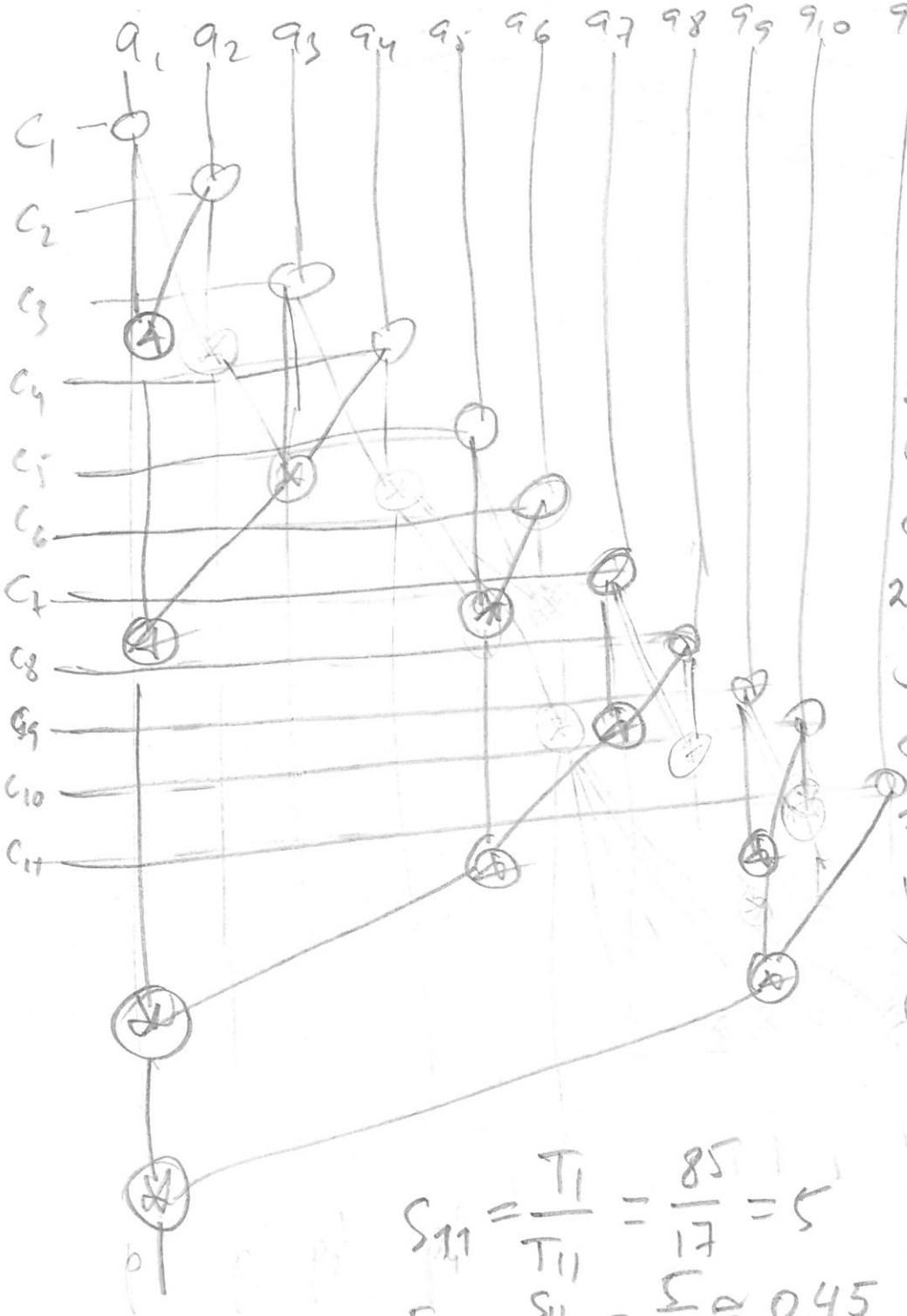

IF
OF
DV
AM
EX
NM
PR
SR
25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41

Task 2. (6 points). Using associativity, draw the flattest possible dependence graph for the following product calculation

$$\prod_{i=1}^{11} \frac{a_i - c_i}{a_i + c_i}.$$

Let $\frac{a-6}{a+c}$ is

Write MIMD pseudocode for its calculation. What is the minimal number π of processors providing maximal performance for that program? Estimate speedup and efficiency for that number π of processors. Assume that addition/subtraction takes 1 time unit, and multiplication/division takes 3 time units (neglect time for other operations such as, e.g., time for children creation by **fork**).



$\pi = 11$

$T_{11} = 5 + 4.3 = 17$

$T_1 = 11.5 + 10.3 = 85$

```
for (i = 1, 10) fork 1;
i = 11;
1: pi = (ai - ci)/(ai + ci);
join 11;
for (i = 1, 4) fork 2;
i = 5;
2: p2i-1 = p2i-1 · p2i
join 5;
for (i = 1, 2) fork 3;
i = 3;
3: p4i-3 = p4i-3 · p4i-1
join 3;
p1 = p1 · p5;
p1 = p1 · p9;
```

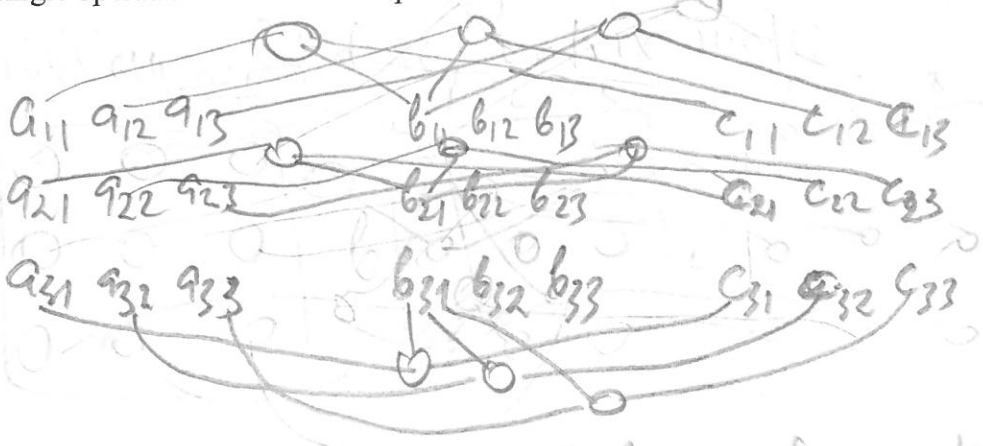
$$S_{11} = \frac{T_1}{T_{11}} = \frac{85}{17} = 5$$

$$E_{11} = \frac{S_{11}}{11} = \frac{5}{11} \approx 0{,}45$$

Task 3. (6 points). Consider the code (case-insensitive) below.

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

What problem is solved by the code? Let N=3. Draw a dependence graph considering a1+a2*a3 as a single operation. Write MIMD pseudocode for the code above. Give necessary explanations.



Dependence graph is shown for k=1, where elements of 1st column of B participate in calculation of the I-th row of C together with k-th column of C. It is clear that operations for the same j, k, may be made in parallel for different j!

```
for (j=1,N-1) for k 1;
j=N;
1: for(i=1,N) aij=0;
join N
for (k=1,N) {
  for (j=1,N-1) for k 2; j=1,N
    j=N;
2: for (i=1,N)
      aij = aij + bik · ckj;
  join N;
}
```

Task 4. (6 points). A MIMD computer executes parallel code with the rate 270 MFLOPS, and serial code at 60 MFLOPS. What is the average execution rate of that machine on an algorithm with serial code fraction part, *f=32%*? Provide details of your calculations together with necessary explanations

$W_S = W \cdot f \quad W_P = W(1-f)$

$T_S = W_S / R_S \quad T_P = W_P / R_P$

$W = W_S + W_P ; \quad T = T_S + T_P$

$$R = \frac{W}{T} = \frac{W}{\frac{Wf}{R_S} + \frac{W(1-f)}{R_P}} = \frac{1}{\frac{f}{R_S} + \frac{1-f}{R_P}}$$

$$\frac{1}{R} = \frac{f}{R_S} + \frac{1-f}{R_P} = \frac{0{,}32}{60} + \frac{0{,}68}{270} =$$

$$= \frac{2{,}88 + 1{,}36}{540} = \frac{4{,}24}{540}$$

$$R = \frac{540}{4{,}24} \approx 127 \text{ GFLOPS}$$

$$\begin{array}{r|l} 540 & 4{,}24 \\ 424 & 127 \\ \hline 1160 & \\ 848 & \\ \hline 3120 & \\ 2968 & \\ \hline \end{array}$$

Task 5. (6 points). Consider the code (case-insensitive) 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;
```

What problem is solved by the code? Can it be used for the determinant calculation? If yes, explain how.

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

2	3	1
6	5	4
3	2	2

What is the matrix A(3,3) determinant? Show your calculations. Trace the code (show all the variables after each operation completion). What is the determinant value resulting from the tracing? Compare the two determinant values obtained.