Compiler Design

Static Single Assignment (SSA) :-

1) It is a 3-Address code

2) SSA form is used to represent an intermediate code.

* 3) A variable can not be used more than once in the LHS

* 4) Every variable has a Single Assignment (Definition)

Ex:

$a = b + c$

$d = a - b$

$a = b + d$

$d = a - c$

SSA

SSA

$a_1 = b + c$

$d_1 = a_1 - b$

$a_2 = b + d_1$

$d_2 = a_2 - c$

1, 2

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Question:- Find minimum No. of variables to represent 3-Address code & SSA

$X = a * b + a * b$

3 Address code

$a = a * b$

$a = a + a$

Optimized Best 3-Address code.

2 variables required in 3 Address (a, b)

SSA:

$a_1 = a * b$

$a_2 = a_1 + a_1$

minimum variable in SSA = 4 variable

(a_1, a_2, a_3, a_4) =

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Question:- Consider the following code segment

```
x = u - t
y = x * v
x = y + w
y = t - z
y = x * y
```

5 + 5 -> 10

The mini. No. of total variables required to convert the above code segment to Static single Assignment form is ?

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Question: 3 Address code:

$t_1 = a * a$

$t_2 = a * b$

$t_3 = t_1 * t_2$

$t_4 = t_3 + t_2$

$t_4 = t_3 + t_2 = t_1 * t_2 + a * b$

$= (a*a) * (a*b) + a * b$

$b = a * b$

$a = a * a$

$a = a * b$

$a = a + b$

no of variables $= 2 (a, \& b)$

i) How many minimum of variables in equivalent 3 Address code:

$\Rightarrow$ 2 Ans

ii) Mini. No of variable in equivalent SSA ?

$b_1 = a * b$

$a_1 = a * a$

$a_2 = a_1 * b_1$

$a_3 = a_2 + b_1$

$\Rightarrow$ 6 variables

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Question:-

$t_1 = b * c$

$t_2 = a + t_1$

$t_3 = b * c$

$t_4 = d * t_3$

$t_5 = t_2 + t_4$

Stmt → 1

$t_5 = t_2 + t_4$

$= (a + t_1) + (d * t_3)$

$= (a + b * c) + (d * (b * c))$

$b = b * c$

i) Mini variables in 3 Address Code ? → 4

ii) Mini variable in SSA Code ? SSA → 8

i) $b_1 = b * c$

2) $a_1 = a + b_1$

3) $b_2 = d * b_1$

4) $a_2 = a_1 + b_2$

8

Any

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Basic Block: Basic block is a set of statements that always executes in a sequence one after the other.

The characteristics of basic blocks are-

-They do not contain any kind of jump statements in them.
-There is no possibility of branching or getting halt in the middle.
-All the statements execute in the same order they appear.
-They do not lose the flow control of the program.

Ex: $a = b + c * d$

Basic Block

$t_1 = c * d$
$t_2 = b + t_1$
$a = t_2$

if A < B then 1 else 0

1) if A<B goto 4
2) $t_1 = 0$
3) goto 5
4) $t_1 = 1$
5) ——

Basic Block

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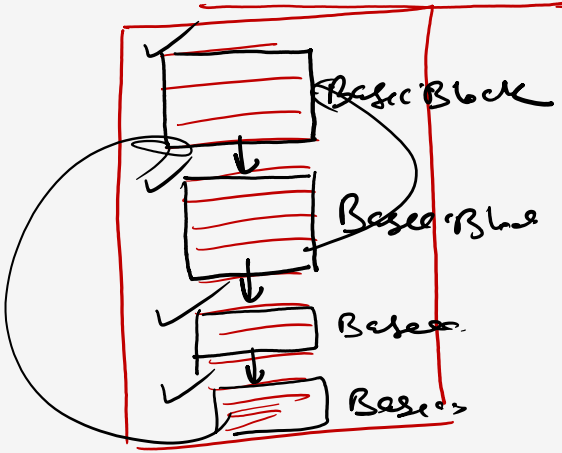
How to find the Basic Blocks

1. First, find the set of leaders from intermediate code, the first statements of basic blocks. The following are the steps for finding leaders:
    1. The first instruction of the three-address code is a leader.
    2. Instructions that are the target of conditional/unconditional goto are leaders.
    3. Instructions that immediately follow any conditional/unconditional goto/jump statements are leaders.
2. For each leader found, its basic block contains itself and all instructions up to the next leader.



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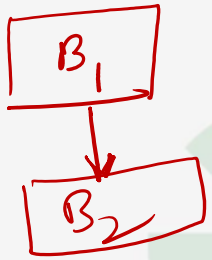
Control Flow Graph(CFG): used in Code optimization & Code generation

→ A CFG gives a flow information b/w the Basic Blocks

→ Each Basic Block is a node in CFG

→ A CFG is a directed graph b/w the Basic Blocks.
There will be a directed edge from Basic Block B_1 to the Basic Block B_2 if B_2 comes immediately after B_1



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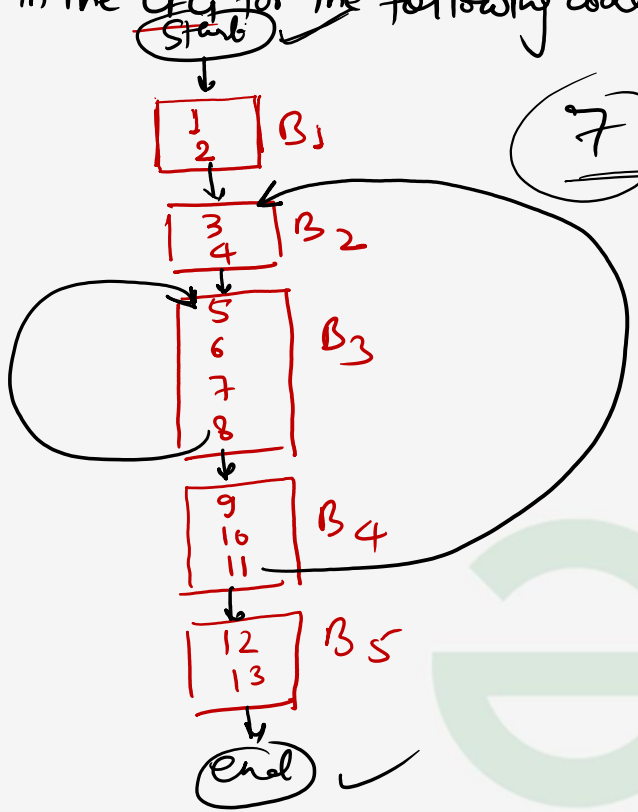
Question: Find the No. of nodes & edges in the CFG for the following code segment

```
1 - a = 1
2 - i = 0
3 - t1 = a+5
4 - t2 = x*a
5 - t3 = 4*b
6 - a = a+t3
7 - i = i+1
8 - if i<t3 goto5
9 - J = J+1
10 - K = K+1
11 - if J<K goto3
12 - i = J+K
13 - K = 0
```

CFG:



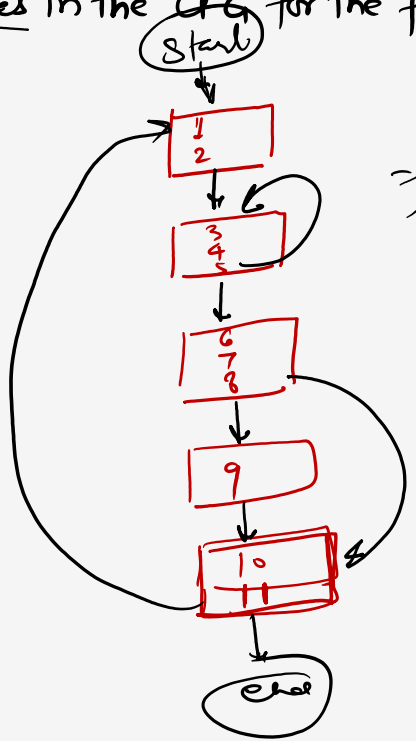
7 nodes & 8 edges

7

Compiler Design

Question:- Find the No. of nodes & edges in the CFG for the following code segment

1- a = b
2- b = a+5
3- c = a-b
4- a = a+5
5- if a>d goto 3
6- b = c*a
7- d = b+c
8- if b<a goto 10
9- c = a-b
10- a = a*10
11- if a<100 goto (1)



⇒ 7 nodes & 9 edges

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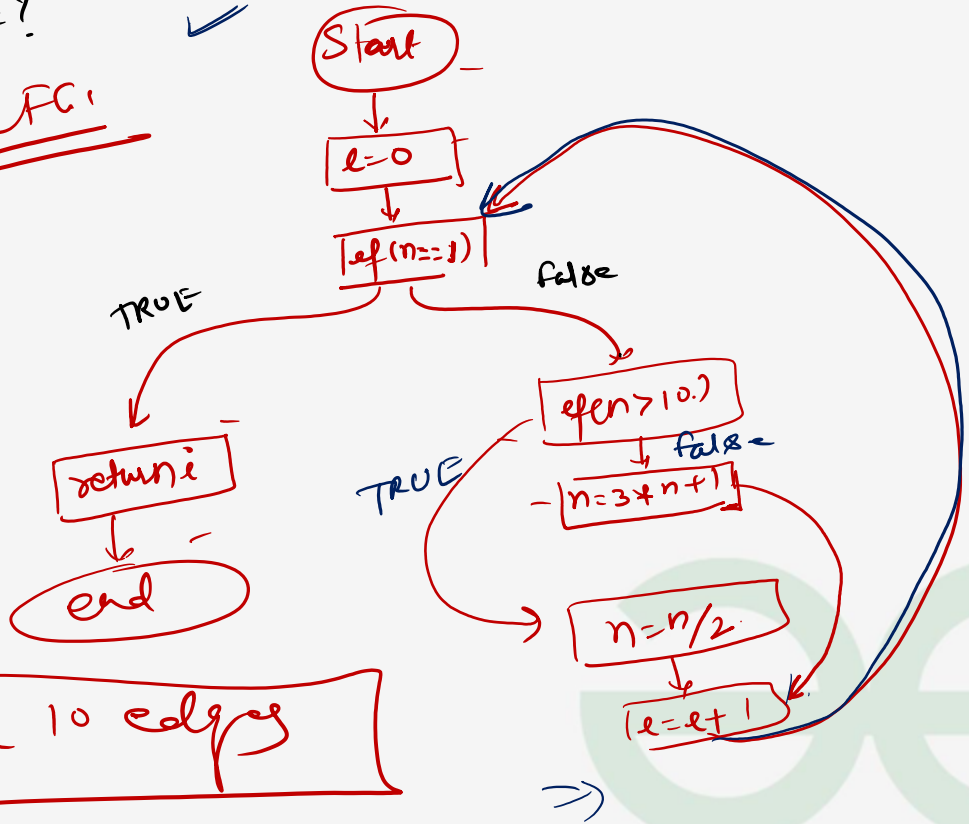
CFG:

Question:- no of nodes & edges = ?

```
i = 0
L1: if(n==1) goto L4
    if(n>10) goto L2
    n = 3*n+1
    Goto L3
L2: n = n/2
L3: i = i+1
    goto L1
L4: return i
```

CFG:



9 nodes & 10 edges

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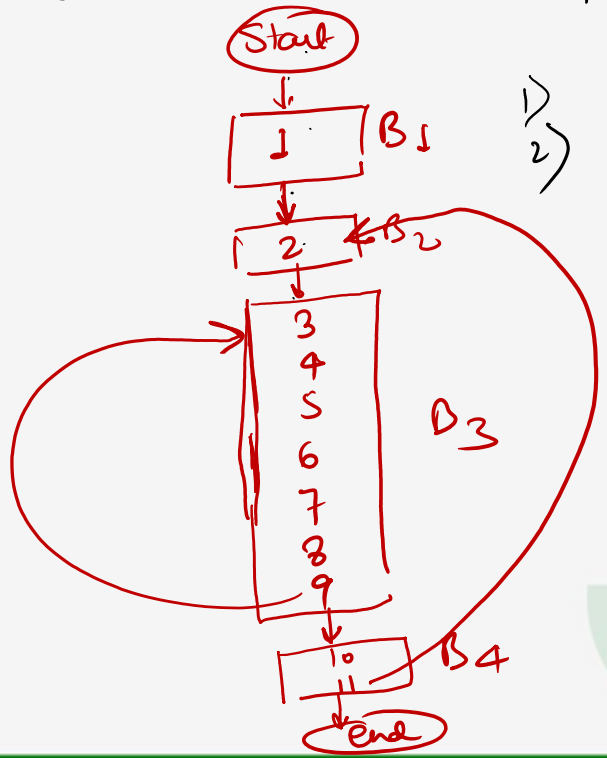
Question:- Consider the following intermediate code given below. The no. of nodes & edges in the Control flow graph constructed for the code respectively are ?

a) 5 and 7
b) 6 and 7
c) 5 and 5
d) 7 and 8

6 & 7



1) $i = 1$
2) $J = 1$
3) $t_1 = 5 * i$
4) $t_2 = t_1 + J$
5) $t_3 = 4 * t_2$
6) $t_4 = t_3$
7) $a[t_4] = -1$
8) $J = J + 1$
9) if ($J <= 5$) goto 3
10) $i = i + 1$
11) if ($i < 5$) goto 2

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Thank You !