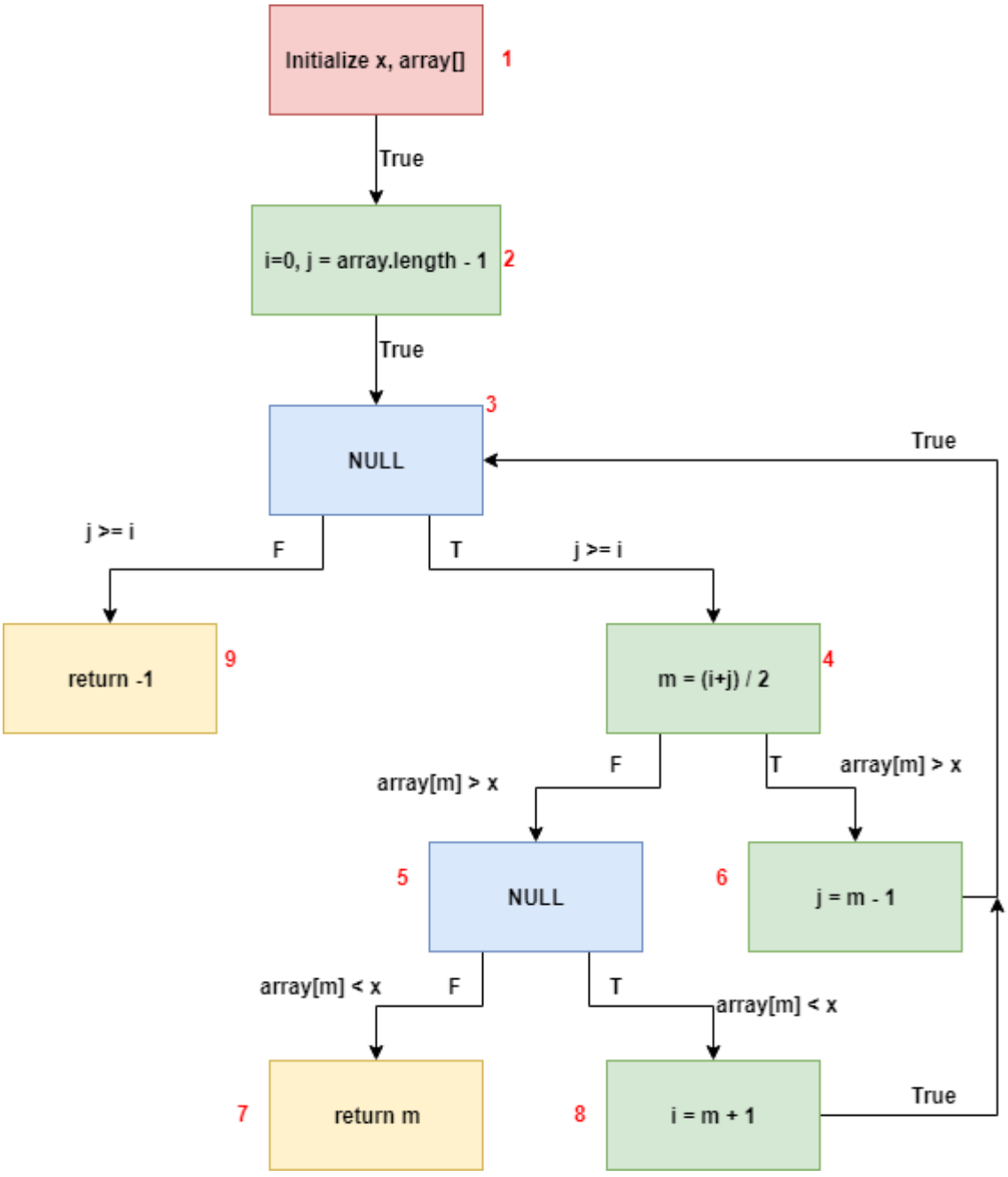
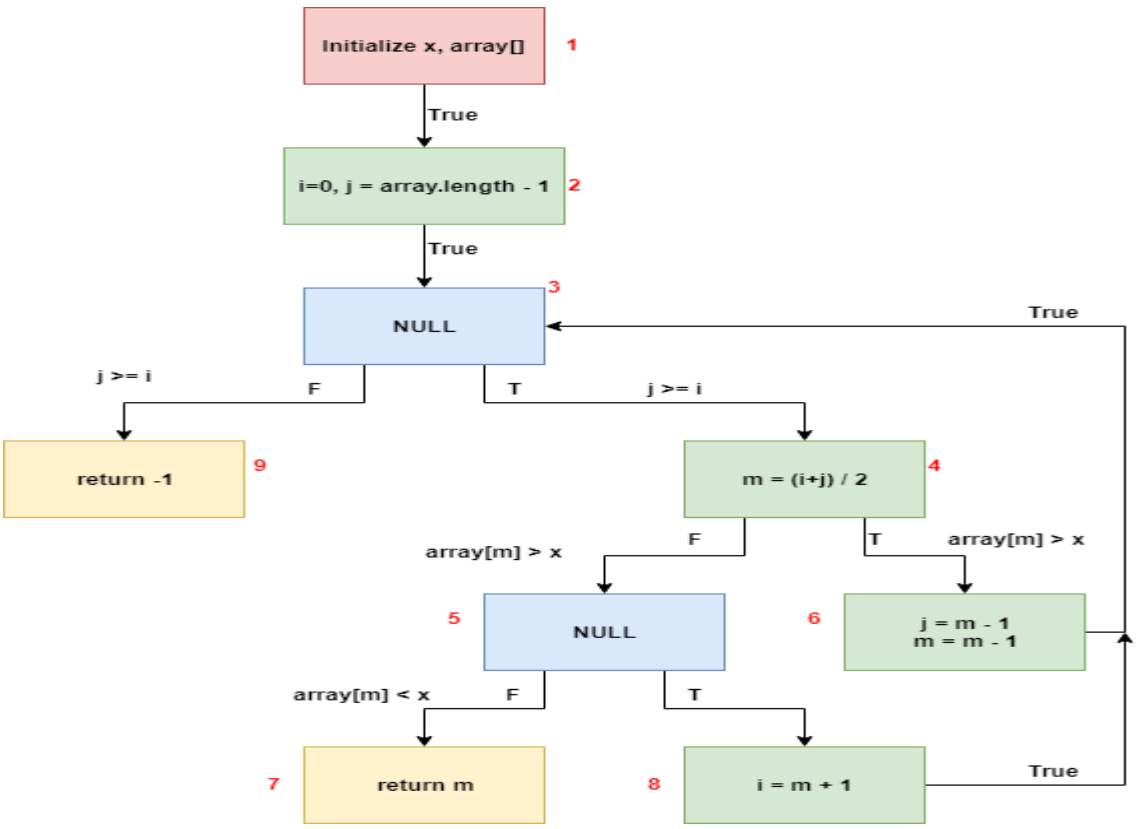
CENG 437 HOMEWORK3

1-a) DFS for binarySearch1():



1-b) DFS for binarySearch2():



2. Assuming that the input array[ ] has at least one element in it, find an infeasible path in the data flow graph for the binarySearch1() function.

1-2-3(F)-9 is the infeasible path, because if array[] has at least one element, initially, result of the j>=i condition always gives True.
Suppose we have 1 element inside input array[]:
After the definitions in node 2: i = 0 and j = 0,
Then in edge (3,9) gives an unsolvable predicate 0 >= 0 = False, and path becomes infeasible.

3. Identify a data flow anomaly in the code binarySearch2().

There is Type1(dd) anomaly in **binarySearch2()** code.

Because, if the code executes the if block, we define variable m (m = m-1) and when if block is executed, program passes the “else if” and “else” code blocks and then again executes the other definition statement of m (m = (i+j)/2). The definition statement(m = m-1) becomes redundant, and this is the Define and Define again anomaly.

NOTE:
I will use the tables(Table1, Table2) for the questions 4 and 5:

- **Table1: def() and c-use() sets of Nodes in DFS for BinarySearch1**

Nodes i	def(i)	c-use(i)
1	x, array	{}
2	i, j	array
3	{}	{}
4	m	j, i
5	{}	{}
6	j	m
7	{}	m
8	i	m
9	{}	{}

- **Table2: Predicates and p-use() Set of Edges in DFS for BinarySearch1**

Edges(i, j)	predicate(i, j)	p-use(i, j)
(1,2)	True	{}
(2,3)	True	{}
(3,4)	j > i	j, i
(4,5)	array[m] > x	array, m, x
(4,6)	array[m] > x	array, m, x
(5,7)	array[m] > x	array, m, x
(5,8)	array[m] > x	array, m, x
(6,3)	True	{}
(8,3)	True	{}
(3,9)	j >= i	j, i

4. By referring to the data flow graph obtained from binarySearch1(), find a set of complete paths satisfying the all-defs selection criterion with respect to variable "m".

For variable "m":

- It has **global definition** in just node 4. (from Table1 column def(i))
- There is **global c-use** of variable "m" in node 6, node 7 and node 8. (from Table1 column c-use(i))
- There is **p-use** of variable "m" in edges (4,5), (4,6), (5,7), (5,8). (from Table2 column p-use(i, j))
- There exist **def-clear paths**:
  = 4-5-7
  = 4-5-8
  = 4-6

➔ **Finally, I have chosen the complete paths:**

- **1 – 2 – 3 –** 4 – 5 – 7 which includes the def-clear path 4-5-7 to satisfy the all-defs criterion.
- **1 – 2 – 3 –** 4 – 5 – 8 **– 3 – 9** which includes the def-clear path 4-5-8 to satisfy the all-defs criterion.
- **1 – 2 – 3 –** 4 – 6 **– 3 – 9** which includes the def-clear path 4-6 to satisfy the all-defs criterion.

5. By referring to the data flow graph obtained from binarySearch1(), find a set of complete paths satisfying the all-defs selection criterion with respect to variable "j".

For variable "j":

- It has **global definition** in just node 2 and node 6. (from Table1 column def(i))
- There is **global c-use** of variable "j" in node 4. (from Table1 column c-use(i))
- There is **p-use** of variable "j" in edges (3,4), (3,9). (from Table2 column p-use(i, j))
- There exist **def-clear paths**:
  = **2-3-4**
  = **2-3-9**
  = **6-3-4**
  = **6-3-9**

➔ **Finally, I choose the complete paths:**

- **1 – 2 – 3 – 4 – 5 – 7** which includes the def-clear path 2-3-5 to satisfy the all-defs criterion.
- **1 – 2 – 3 – 9** which includes the def-clear path 2-3-9 to satisfy the all-defs criterion.
- **1 – 2 – 3 – 4 – 6 – 3 – 4 – 5 - 7** which includes the def-clear path 6-3-9 to satisfy the all-defs criterion.
- **1 – 2 – 3 – 4 – 6 – 3 – 9** which includes the def-clear path 6-3-9 to satisfy the all-defs criterion.

NOTE: I will use the tables(Table3, Table4) for the question 6:

- **Table3: Def() and c-use() Sets of Nodes in DFS for BinarySearch2**

Nodes i	def(i)	c-use(i)
1	x, array	{}
2	i, j	array
3	{}	{}
4	m	j, i
5	{}	{}
6	j,m	m
7	{}	m
8	i	m
9	{}	{}

- **Table4: Predicates and p-use() Set of Edges in DFS for BinarySearch2**

Edges(i, j)	predicate(i, j)	p-use(i, j)
(1,2)	True	{}
(2,3)	True	{}
(3,4)	j > i	j, i
(4,5)	array[m] > x	array, m, x
(4,6)	array[m] > x	array, m, x
(5,7)	array[m] > x	array, m, x
(5,8)	array[m] > x	array, m, x
(6,3)	True	{}
(8,3)	True	{}
(3,9)	j >= i	j, i

6. By referring to the data flow graph obtained from binarySearch2(), find a set of complete paths satisfying the all-defs selection criterion with respect to variable "m".

For variable "m":

- It has global definition in just node 4 and node 6. (from Table3 column def(i))
- There is global c-use of variable "m" in node 6, node 7 and node 8. (from Table3 column c-use(i))
- There is p-use of variable "m" in edges (4,5), (4,6), (5,7), (5,8). (from Table4 column p-use(i))
- There exist def-clear paths:
  = 4-5-7
  = 4-5-8
  = 4-6

➔ **Finally, I have chosen the complete paths:**

- **1 – 2 – 3 –** 4 – 5 – 7 which includes the def-clear path 4-5-7 to satisfy the all-defs criterion.
- **1 – 2 – 3 –** 4 – 5 – 8 **– 3 – 9** which includes the def-clear path 4-5-8 to satisfy the all-defs criterion.
- **1 – 2 – 3 –** 4 – 6 **– 3 – 9** which includes the def-clear path 4-6 to satisfy the all-defs criterion.
- **1 – 2 – 3 –** 4 – 5 – 8 **– 3 – 4 – 5 – 7** which includes the def-clear path 4-5-8 to satisfy the all-defs criterion.

7. The question asks why each three-operation sequences such as:

- **rd(referenced and defined),**
- **rr(referenced and referenced again)**
- **ud(undefined and defined)**

are not considered to be program anomaly.

A program anomaly is an abnormal way of doing something in the program. For example ur is considered as program anomaly because using a variable without initialize it is an abnormal situation. However other sequences such as **ud** and **rr** don't cause an abnormal situation in a program. For example, consider the following code snipped:

```
1-)   int total = 0;
2-)   int counter;
3-)   counter = 0;
4-)   while(counter > 2)
5-)   {
6-)      total = total + counter;
7-)      counter = counter + 1;
8-)   }
```

In the code above, counter is declared in statement 2, and then initialized in statement 3. There are **ud** sequence here and this is very normal situation in a program. We deal with such a sequence in every program normally and absolutely that cannot be a manifestation of potential program error.

Again in statement 6, variable counter is referenced, and in statement 7 counter is referenced again. There are **rr** sequence here and this is again very normal situation in a program, and we use that kind of sequence almost in every while loop and again that cannot be a manifestation of potential program error.

Briefly, as I explained with that example code snipped, other sequences are normal situations in a program and they are not considered to be program anomaly.

Additionally, question ask for us to give a small Java code sinpped example to each program anomaly:

- **dd anomaly(Defined and Then Defined Again):**

```
public int getPrice()
{
    int price = 100;
    int workingHour = getWorkingHourFromUser(); //gets working hour as input from user.

    if(workingHour < 15)
    {
        price = workingHour * 100;
    }
    else if(workingHour < 25)
    {
        price = workingHour * 150;
    }
    else
    {
        price = workingHour * 176;
    }

 }
```

Here price is defined as 100 initially and then according to workingHour, price is defined again inside if-else if and else blocks. That is dd anomaly and the statement(int price = 100) is redundant according to that anomaly.

- **du anomaly(Defined but not Referenced):**

```
public int getPrice()
{
    int price;
    int workingHour = getWorkingHourFromUser(); //gets working hour as input from user.
    EmployeeType empType = EmployeeType.HOURLY_EMPLOYEE;

    if(workingHour < 15)
    {
        price = workingHour * 100;
    }
    else if(workingHour < 25)
    {
        price = workingHour * 150;
    }
    else
    {
        price = workingHour * 176;
    }

 }
```

Here empType is defined as HOURLY_EMPLOYEE and after that statement, empType is not referenced in any other subsequent computation. So there are du anomaly here.

- **ur anomaly(Undefined but Referenced):**

```
public int getPrice()
{
    int price;
    int workingHour;

    if(workingHour < 15)
    {
        price = workingHour * 100;
    }
    else if(workingHour < 25)
    {
        price = workingHour * 150;
    }
    else
    {
        price = workingHour * 176;
    }

 }
```

Here workingHour is not initialized but it is referenced in if- else if and else blocks. Here there are ur anomaly. We are trying to define variable price with an uninitalized variable workingHour and this is an program anomaly.

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