**Programming Project Report**

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Date: 11/11/19

**Academic Integrity Statement:** I pledge that I have neither given nor received unauthorized help on this programming assignment.

**Problem Statement:**

The primary goal of this programming assignment was to provide experience working with two dimensional arrays in C++. A partial implementation of the overall project was provided, and the rest had to be implemented. The program contains 3 inputs from the user; the number of rabbits in the simulation, the number of foxes in the simulation, and the number of steps to run the simulation for. The program outputs are the board itself that represents the forest in the simulation, the rabbits on the board, and the foxes on the board. Upon each step of the simulation, the number of rabbits and foxes on the board gets updated after running reproduction and battle simulations, and then the board is printed out again after the simulations are ran; if the user wants to run the simulation 10 times, the board and the rabbits and foxes on the board will be printed out 10 times as well. This programming project required checking array bounds in every rabbit reproduction, fox reproduction, and battle simulation that occurred in the program.

**Design:**

For this project, functions were used primarily to execute code, and then those functions were called in the main body of the program. The first function of the program is to initialize the board, an array, and add rabbits and foxes at random locations in the array. The whole array itself is first initialized to whitespace, e.g. ‘ ‘, and then the rabbits and foxes are added in. The second function draws the board on the screen, initializes a counter for rabbits and a counter for foxes, updates them according to how many R’s and F’s are on the board, and prints out the animal counts at the end. The third function chooses the moves that the rabbits and foxes will do next, and moves them to an adjacent location if the location is in bounds and that location is currently empty. The last provided function actually moves the animals on the board, and changes the letters on the board to upper-case if they are not an upper-case letter. There were 3 functions that needed to be defined for this project: simulate rabbit reproduction, simulate fox reproduction, and simulate fox-rabbit battles.

To simulate rabbit and fox reproduction, both functions had to check if the location where a new rabbit or fox was being placed was within the bounds of the array. If the location was within the array bounds, and the right conditions were met for rabbit or fox reproduction, reproduction would occur. For the rabbits, reproduction occurred 100% of the time. For the foxes, reproduction occurred 50% of the time; to achieve this, the random chance was divided by two, and the remainder determined whether or not reproduction occurred, based on if the remainder was a 1 or 0. To simulate the fox-rabbit battles, the function contains a loop with an if statement. The if statement executes if a rabbit is detected anywhere next to a fox on four sides- directly above, directly below, directly to the left, or directly to the right. If the statement is found to be true, the rabbit has a 10% chance to be eaten by the fox, and wiped off of the board. To do this, a random number is generated and modulo’d by 10, giving a remainder range from 0-9. If the remainder is equal to 1, the rabbit is eaten by the fox and removed from the board.

**Testing**

Testing this project was a little bit difficult. The simulation had to be ran a multitude of times in order to make sure that the fox-rabbit battles were working properly. For this, an input of 15 rabbits, 40 foxes, and 10 steps was used. This input was used because there was, at the very least, a 1:2 ratio of rabbits to foxes, thus giving the foxes a higher chance to keep the rabbit population at bay, and ideally, a decrease in rabbit population would be seen between steps. There were not really any special cases that needed to be test in this scenario, and everything worked as expected. The only difficult was finding outputs that do show a decrease in rabbit population because the reproduction rate is 100% for rabbits, and the chance for a rabbit to die in a fox-rabbit battle is 10%, the rabbits can reproduce at a rate faster than their death rate.

Test Case #1 ---------------------------------------------------------

Welcome to the fox and rabbit simulation

Enter the number of rabbits: 15

Enter the number of foxes: 40

Enter the number of simulation steps: 10

+----------------------------------------+

|R F F |

| F |

| F |

| F R F |

|F F F F |

| |

| R F F F |

|F F R R |

| F |

| F R F F F |

| R R F |

| F R |

|F R |

| F F |

| F F F F R F |

| F R |

| F |

| R F |

| F F F R |

|F F R F F |

+----------------------------------------+

Number of rabbits: 15

Number of foxes: 40

Start

+----------------------------------------+

| F |

|R F F |

| F R |

| F F F F F |

| F |

|F F |

| F R R |

|F F F F |

| R R F F F |

| R R F F |

| F |

| R |

| F R F |

|F R R F F |

| F F R |

| F F F |

| R F R |

| F F F R |

| F F |

| F R F F |

+----------------------------------------+

Number of rabbits: 17

Number of foxes: 42

Step 1

+----------------------------------------+

| F F F F |

| R |

| R |

| F F F F F |

| F F F |

| F F |

| F F |

| R F R F R |

| F F F |

| R F F |

|R R |

| R F |

| F F F R |

| F F |

| R F R F R F |

| R F |

| F F |

| F R F R |

| F R F F F |

| F F F |

+----------------------------------------+

Number of rabbits: 17

Number of foxes: 44

Step 2

+----------------------------------------+

| F F |

|R F F |

| F F R |

|F F F |

| F F F F |

| F |

| F F R F |

| F F R |

| F R F F |

|R F |

| R F |

| F R F R |

| R F F |

| F R F |

| R R |

| R F F F |

| F F F R |

| R F R F |

| F F F |

| F F F F |

+----------------------------------------+

Number of rabbits: 17

Number of foxes: 45

Step 3

+----------------------------------------+

| F F |

| R F R F |

| F |

| F F F F F |

| F F F |

| F F R |

| F F |

| F F F F |

| F R |

| R R F |

| R R R F |

| R F F F |

| F R F |

| F |

| R R F |

| F R R |

| R F F F |

| F F F F R |

| F F |

| F F F F F |

+----------------------------------------+

Number of rabbits: 17

Number of foxes: 46

Step 4

+----------------------------------------+

| F F F R F |

|R |

| F F F |

|F F F |

| F R F F F |

| F F F |

| F F R F F |

| |

| F F R |

|F R R R |

| F F F |

| R F R F F |

| R R |

| F |

| R R F F R |

| F R F |

| F |

| R F F R F |

| F F F F F F |

| F F |

+----------------------------------------+

Number of rabbits: 18

Number of foxes: 47

Step 5

+----------------------------------------+

| |

| F F F F R F |

| R F F |

| F R R |

|F F F F |

|F R F F |

| F F F F F |

| F F |

| R R |

|R F F F F |

|F R R |

| R F |

| R F F R F |

| R F R |

| F F |

| R F |

| R F R R F |

|F F F F |

| F F F F F |

| F F F |

+----------------------------------------+

Number of rabbits: 19

Number of foxes: 49

Step 6

+----------------------------------------+

| F F |

| F R F |

| F F F F R |

|F R F F |

| F R F |

| F F F |

|F F F R F |

|F F F |

| F F R F |

| R R R F |

| F R F |

|F R R F |

| F R F R |

| F F F |

| R |

| R F F R |

| F R F F |

| F R |

| F F F F F |

| F F F F |

+----------------------------------------+

Number of rabbits: 19

Number of foxes: 51

Step 7

+----------------------------------------+

| F R F F |

| F F F F R |

| F R F R |

| F |

| R F F F |

|F F F F F F |

| F F F F |

| R F F F |

|F F F |

|R R F R |

| F R |

| R F |

|R R F R R |

| F F |

| F F F |

|F R R R F |

| F R F F F |

| F |

| F F F R F F F |

| F F |

+----------------------------------------+

Number of rabbits: 20

Number of foxes: 53

Step 8

+----------------------------------------+

| F F F F R |

| R F F R |

| R F F |

| F F F F |

| F F F |

| F F R F F F F |

| F F |

|F F R F F |

| R F F F |

| R F |

| F R |

|R F R R F |

| R F |

| F R R |

| F R F F F F |

| R F F |

| F R F |

| F R F F F F |

| F F F |

| F R F F |

+----------------------------------------+

Number of rabbits: 20

Number of foxes: 56

Step 9

+----------------------------------------+

| R F |

|F R F F F F R |

| F R |

| F F F F |

|F F F F F F F |

| F F F F |

| F R F F |

| F R F F |

|F F R F F |

| |

| R R |

|F R F |

| R R R F R F |

| F R |

| R F F |

| F F F |

| R F F F F F |

| R F R F F F |

| F F R F |

| F F F F |

+----------------------------------------+

Number of rabbits: 20

Number of foxes: 58

Step 10

-----------------------------------------------------------

Test case #2

Welcome to the fox and rabbit simulation

Enter the number of rabbits: 15

Enter the number of foxes: 40

Enter the number of simulation steps: 10

+----------------------------------------+

| |

| R F |

|R F F F |

| R F |

| R F |

| F |

| R F |

| F R |

| F F |

| R F |

| F F F |

| R F R F F |

| R R F F |

| F F F F F |

| F F |

| F F F F F |

| R |

| R |

| F F F F F R F R |

| F F |

+----------------------------------------+

Number of rabbits: 15

Number of foxes: 40

Start

+----------------------------------------+

| |

| R |

| R F F F |

| R R F |

| F F F |

| F F |

| F |

| R F F R |

| R F |

| F F |

| F F F |

| F R F |

| R F F R F |

| R F F R F F |

| F F |

| F F F |

| F F |

| F F F R R |

| R F F R |

| F F F |

+----------------------------------------+

Number of rabbits: 16

Number of foxes: 42

Step 1

+----------------------------------------+

| |

| R R |

| R F F |

| F F F F |

| R F |

| F F F |

| F F R |

| F |

| F R F |

| R F F F |

| F |

| R F |

| R F F F R F F |

| F F F R F F F |

| R F F F |

| F F F |

| F F R |

| F F F R |

| F F F R |

| R F |

+----------------------------------------+

Number of rabbits: 16

Number of foxes: 46

Step 2

+----------------------------------------+

| R R |

| R F |

| F F |

| F F F |

| R F F |

| F F F |

| F F |

| F R R |

| F F |

| F F |

| R R F |

| F R |

| F F F F F F |

| R F R F F F |

| F F F F |

| F R F R F |

| F F |

| R R |

| F F F F F F |

| F R |

+----------------------------------------+

Number of rabbits: 16

Number of foxes: 46

Step 3

+----------------------------------------+

| |

| R R R |

|F F F |

| F F F |

| R F F |

| F F F F |

| F F |

| F |

| R F F R |

| F |

| F |

| R F F R F F |

| F R F F R F F |

| F F F |

| R F F F F |

| R F F F F F |

| F R |

| F |

| F F R R R |

| F F F F |

+----------------------------------------+

Number of rabbits: 16

Number of foxes: 48

Step 4

+----------------------------------------+

| R F R |

|R F |

| F F |

| F F F F |

| F F F |

| R F F |

| F |

| F F |

| R F |

| R F |

| R F F R F F |

| R R F F |

| F F F |

| F F F F F F |

| R F F F |

| R F F F F F |

| R |

| F F R |

| F F F F F |

| F R R |

+----------------------------------------+

Number of rabbits: 16

Number of foxes: 49

Step 5

+----------------------------------------+

|R R |

| R F F |

| F F R F |

| F F F F |

| F F F |

|R F F |

| F F |

| F F |

| F F F |

| R R R F |

| F F R F |

| R F F |

| R F F |

| R F F F F |

| R F F F F F F F F |

| F F R F |

| F |

| F F R F |

|F F F F F R R |

| F |

+----------------------------------------+

Number of rabbits: 17

Number of foxes: 54

Step 6

+----------------------------------------+

| R F |

| R F |

|R F F F R F |

| F F F F |

|F F F |

| F |

| R F F F |

| F F |

| F F F |

| R F R F |

| R F R |

| F |

| R F F F F |

|R R F F R F F F F F F |

| F F |

| F F F F |

| F F R |

|F F F F R R F |

| F F |

| F F F F R |

+----------------------------------------+

Number of rabbits: 17

Number of foxes: 57

Step 7

+----------------------------------------+

|R R F |

|R F F |

| F F F F |

| F F F F R |

| F F |

|F F |

| F |

| R F F F |

| F F R F F |

| R F |

| R F |

| R F F F F |

| R F F F F |

| R F F F |

| R F R F F F |

| F F F F R |

|F F F F R R F |

| F F F |

| F F F F F R F |

| F |

+----------------------------------------+

Number of rabbits: 17

Number of foxes: 59

Step 8

+----------------------------------------+

| R R F |

| R F F F F |

| F F F |

| F F F R |

| F F R |

| F F F |

| R F F |

| F F F R F |

| F |

| F F |

| F R R F F R F |

| F F |

| R R F F F F F |

| F R F F F F |

| F F F F |

|R F F F R R F |

| F F F F |

| F F F F F R F |

| F R F |

| F |

+----------------------------------------+

Number of rabbits: 18

Number of foxes: 62

Step 9

+----------------------------------------+

| R F |

| R F F |

| R F F F F F R |

| F F R |

| F F F |

| F F F |

| F |

| R F F R F |

| F F F |

| F F F |

| F F F F R F |

| R R R F F F |

| F F F F F F |

| R F R F F |

| R F F F F R |

| F R F |

| F F F F F F F F R F |

| F F F F |

|F F F |

| F R F |

+----------------------------------------+

Number of rabbits: 18

Number of foxes: 67

Step 10

Test Case #3 ---------------------------------------------------------

Welcome to the fox and rabbit simulation

Enter the number of rabbits: 15

Enter the number of foxes: 40

Enter the number of simulation steps: 10

+----------------------------------------+

| R R |

|F R |

| F F F |

| F R F |

| R R F |

| F F |

| F F R |

| F F F F |

| F |

| F F F F |

| F R R F |

| F R F |

| F R |

| F R |

|F R |

| F F |

| F R F |

| F F F |

|R F F F |

| F F F |

+----------------------------------------+

Number of rabbits: 15

Number of foxes: 40

Start

+----------------------------------------+

| R |

| F R R |

| F F F |

| R F F |

| R F |

| R F |

| F F R F F |

|F F F F |

| F F F |

| F F R F |

| F F F |

| R R |

| F R |

| F F |

| F R F |

| F R F |

| F F F |

| R |

| R F F F |

| F F F F |

+----------------------------------------+

Number of rabbits: 15

Number of foxes: 42

Step 1

+----------------------------------------+

| R |

| R F F |

|F F R R |

| R F |

| R F |

| F F |

| F F F F |

| F F R F F |

|F F |

| F F F |

| F F F R R |

| R F R R |

| F F |

| |

| F R F F R R |

|F F F |

| F R F |

| F F F |

|R F F F |

| F F |

+----------------------------------------+

Number of rabbits: 17

Number of foxes: 43

Step 2

+----------------------------------------+

| F |

| F R R R |

| F R F |

| F R |

| R |

| F F |

| F F F F F F |

| F F F F |

| F R F |

| F F F F |

| R F F F R |

| F F R R |

| R |

| F F R |

| F F F R |

| F R F F |

| F F |

| R F F R F |

| F F |

| F F F |

+----------------------------------------+

Number of rabbits: 17

Number of foxes: 46

Step 3

+----------------------------------------+

| R |

| F R R F |

| F R R |

| F F |

|F F |

| R F F R F |

| F F F F |

| F F F |

| F F F F F |

| R F |

|F F F |

| R F F R R |

| F F R |

| F R R R |

|F F F F F |

| R |

| R F F F |

| F F |

| F F F R F |

| F F F |

+----------------------------------------+

Number of rabbits: 18

Number of foxes: 48

Step 4

+----------------------------------------+

| R |

| R R R |

| F F R F F |

|F F F |

| F F R |

| R |

| F F F |

| F F F F F F |

| F R F F |

| F F F |

| F F R |

| F F R |

| F R F F R |

| F F R |

| R R R |

| F F F F |

| F F |

| R F F |

| F R F |

| F F F F F |

+----------------------------------------+

Number of rabbits: 18

Number of foxes: 48

Step 5

+----------------------------------------+

| R R |

| F F F R |

| F R F F |

| F R |

| F F F R |

| R F F F |

| F F F F F |

| R |

| F F F |

| F F F F F |

| F F |

| R |

|F F F R |

|F R F R |

| F F F R R F |

| F F F |

| F F |

| F R |

| F F F F F F |

| F |

+----------------------------------------+

Number of rabbits: 15

Number of foxes: 50

Step 6

+----------------------------------------+

| F R |

| F R R F |

| F F F |

| F R R F |

| R F F |

| F F F R F F |

| F F |

| F R F |

| F F F F |

| F F |

| F |

| F F F F F |

| R |

| F F R R |

| F R F F |

| F F R R F |

| F F F R |

| F F |

| F F F F |

| F F |

+----------------------------------------+

Number of rabbits: 15

Number of foxes: 50

Step 7

+----------------------------------------+

| F R |

| F R F |

| F R F |

| F R F F |

| F R F |

| R F F F F R |

| R F F F |

| F F |

| F F F |

| F F F F |

| F F |

| F |

|F F |

| F F R F F R F R |

| F R R F |

| F R |

| F R |

| F F F F F |

| F F |

| F F F |

+----------------------------------------+

Number of rabbits: 15

Number of foxes: 50

Step 8

+----------------------------------------+

| F R |

| F R |

| F R F F F |

| F |

| R F F F R R |

|F F R F R F F |

| F F |

| F |

| F F |

| F F F F F |

| F F |

| F F F |

| F F R |

| F F F R F |

| F R R R R |

| F |

| F F F R F |

| F F F |

| F F F |

| F F |

+----------------------------------------+

Number of rabbits: 15

Number of foxes: 50

Step 9

+----------------------------------------+

|F R |

| F F R |

| F R F |

| F F R F |

| F F |

|F R F R F F |

|F R R F F |

| F F |

| F F |

| F F F |

| F F F |

| F F |

|F F F F F R |

| F F |

| R F R R |

| F R R R F |

| F F F |

| F F F F F F |

|F F |

| F |

+----------------------------------------+

Number of rabbits: 15

Number of foxes: 51

Step 10

**Conclusion**

Overall, this project was a success. The most difficult part of this programming project was checking that the data being accessed was within the array bounds, and no attempts were made to access data outside of the array bounds. Next time, an attempt to update the rabbit counter after the fox-rabbit battles and display the updated count before the next rabbit reproduction would be very useful. This way, it would be easier to tell if the fox-rabbit battle function is working as intended and that the rabbit population is actually decreasing, if indeed it is, after the fox-rabbit battles. Time to complete this project was roughly 8-10 hours of actual coding, debugging, implementation, and testing with input cases.