DEPARTMENT OF COMPUTER ENGINEERING

Semester	T.E. Semester VI– SPCC
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Project Title	Multiplication TM Simulator (Unary)

Video Demonstration:

Approach:

1. **Input of Numbers**: The program takes two numbers as input from the user. These numbers are then converted to unary format.

2. **Unary Conversion**: The **conver_to_unary** function converts the input numbers into unary format by appending '1' to a string a number of times equal to the value of the input number.

3. **Setting up the Tape**: The **setTape** function sets up the initial configuration of the tape for the Turing Machine. It places the unary representations of the input numbers on the tape, separated by a '*' symbol to denote the multiplication operation.

4. **Turing Machine States**: The program defines the states and transitions of the Turing Machine in the **TMstateRecord** map. Each state–transition entry consists of the current state and the tape symbol it reads, along with the next state, symbol to write on the tape, and direction to move the tape head.

5. **Multiplication Algorithm**: The **Multiplication_TM** function executes the Turing Machine according to the defined state transitions. It iterates through the states and updates the tape and tape head position accordingly until it reaches the final state.

6. **Printing**: The program includes functions to print the current state of the tape and the unary representations of the numbers at each step of the Turing Machine execution.

7. **User Interaction**: During the execution of the Turing Machine, the program pauses after each step and allows the user to proceed to the next step or continue until the end.

8. **Main Function**: The main function orchestrates the execution of the entire program by calling the necessary functions and initializing the Turing Machine with the appropriate configurations.

Turing Machine=>
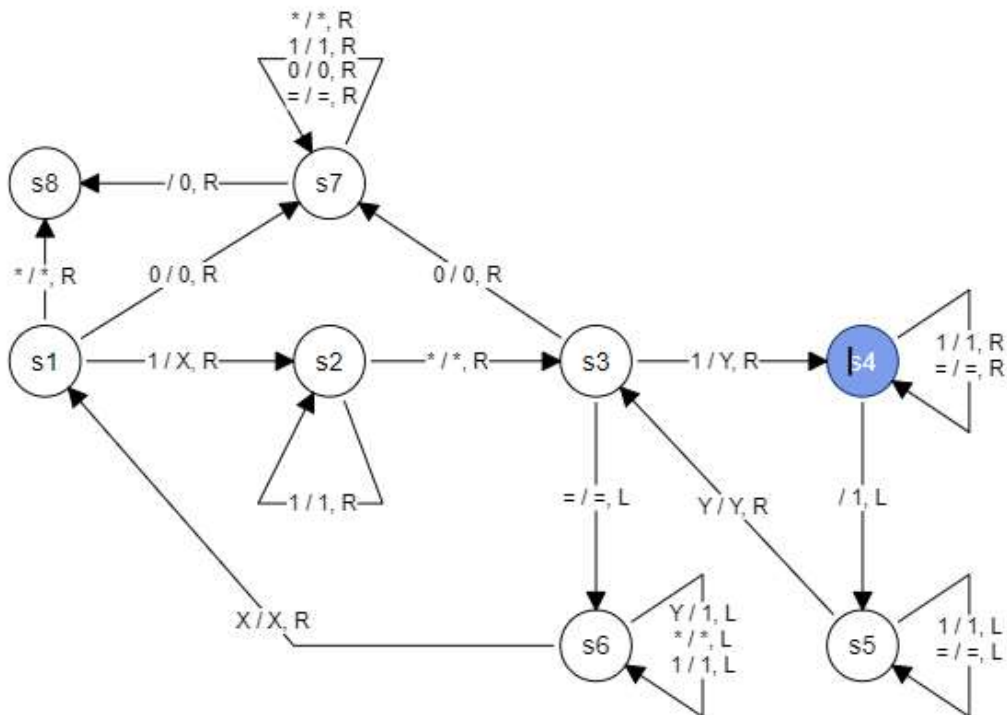
Implementation:

```cpp
#include<iostream>
#include<vector>
#include<map>
using namespace std;

void take_operand(int &num1,int &num2){
    cout<<"Enter the first number: ";
    cin>>num1;
    cout<<"Enter the second number: ";
    cin>>num2;
```

```cpp
}

void conver_to_unary(int num,string &unaryNum){
    for(int i=0;i<num;i++){
        unaryNum+="1";
    }
}

void setTape(vector<string> &tape,string unaryNum1,string unaryNum2){
    int i=1;
    for(int j=0;j<unaryNum1.size();j++){
        tape[i]=unaryNum1[j];
        i++;
    }
    tape[i]="*";

    i++;
    for(int j=0;j<unaryNum2.size();j++){
        tape[i]=unaryNum2[j];
        i++;
    }

    tape[i]="=";


}

void printTape(vector<string> tape){
    for(int i=0;i<tape.size();i++){
        cout<<tape[i];
    }
    cout<<endl;
}

void printUnary(string unaryNum){
    cout<<unaryNum<<endl;
}

void Multiplication_TM(vector<string> &tape,vector<string> &pointer,map<vec-
tor<string>,vector<string>> TMstateRecord){
    string nextState="s1";
    int pl=1;
    int counter=1;
    int choice;
```

```cpp
bool pauser=true;
cout<<"Lets start the Turing Machine"<<endl;
cout<<endl;
cout<<endl;
cout<<endl;


 while(true){
    if(nextState=="s8"){
        break;
    }

    string currentState=nextState;
    string tapeSymbol=tape[pl];
    vector<string> key={currentState,tapeSymbol};
    vector<string> value=TMstateRecord[key];
    nextState=value[0];
    tape[pl]=value[1];
    string move=value[2];



    pointer[pl]="|";
    cout<<"Step: "<<counter<<endl;
    cout<<"The current state is: "<<currentState<<endl;
    cout<<"The tape symbol is: "<<tapeSymbol<<endl;
    cout<<"The next state is: "<<nextState<<endl;
    cout<<"The write symbol is: "<<value[1]<<endl;
    cout<<"The move is: "<<move<<endl;
    printTape(pointer);
    printTape(tape);
    cout<<"-------------------------------------------------------------
-----------------------------------------------------------"<<endl;
    cout<<endl;
    counter++;

    pointer[pl]=" ";
     if(move=="R"){
        pl++;
    }else if(move=="L"){
        pl--;
    }
```

```cpp
        if(pauser){
            cout<<"1=>next Step"<<"   ";
            cout<<"{any}-{1}=>run till end"<<endl;
            cin>>choice;
            if(choice!=1){
                pauser=false;
            }
        }


    }
}

int main(){
    //The value to be multiplied
    int num1,num2;
    take_operand(num1,num2);

    //Declaring tape for the Turing Machine
    vector<string> tape(100,"_");
    vector<string> pointer(100," ");


    //Converting the numbers to unary
    string unaryNum1="";
    string unaryNum2="";
    conver_to_unary(num1,unaryNum1);
    conver_to_unary(num2,unaryNum2);

    //Printing the unary numbers
    cout<<"The unary number 1 "<<endl;
    printUnary(unaryNum1);
    cout<<"The unary number 2"<<endl;
    printUnary(unaryNum2);

     //Setting the tape
     setTape(tape,unaryNum1,unaryNum2);



     //The state of the Turing Machine
     //  Sate+tape_symbol->new_state+write_symbol+move
```

```cpp
map<vector<string>,vector<string>> TMstateRecord;

TMstateRecord[{"s1","1"}]={"s2","X","R"};
TMstateRecord[{"s1","*"}]={"s8","*","R"};
TMstateRecord[{"s1","0"}]={"s7","0","R"};

TMstateRecord[{"s2","1"}]={"s2","1","R"};
TMstateRecord[{"s2","*"}]={"s3","*","R"};

TMstateRecord[{"s3","1"}]={"s4","Y","R"};
TMstateRecord[{"s3","0"}]={"s7","0","R"};
TMstateRecord[{"s3","="}]={"s6","=","L"};

TMstateRecord[{"s4","1"}]={"s4","1","R"};
TMstateRecord[{"s4","="}]={"s4","=","R"};
TMstateRecord[{"s4","_"}]={"s5","1","L"};

TMstateRecord[{"s5","1"}]={"s5","1","L"};
TMstateRecord[{"s5","="}]={"s5","=","L"};
TMstateRecord[{"s5","Y"}]={"s3","Y","R"};

TMstateRecord[{"s6","1"}]={"s6","1","L"};
TMstateRecord[{"s6","Y"}]={"s6","1","L"};
TMstateRecord[{"s6","X"}]={"s1","X","R"};
TMstateRecord[{"s6","*"}]={"s6","*","L"};

TMstateRecord[{"s7","1"}]={"s7","1","R"};
TMstateRecord[{"s7","*"}]={"s7","*","R"};
TMstateRecord[{"s7","0"}]={"s7","0","R"};
TMstateRecord[{"s7","="}]={"s7","=","R"};
TMstateRecord[{"s7","_"}]={"s1","0","R"};




//The Turing Machine
Multiplication_TM(tape,pointer,TMstateRecord);


return 0;
}
```

Output for num1=2 & num2=2:

```
Enter the first number: 2
Enter the second number: 2
The unary number 1
11
The unary number 2
11
Lets start the Turing Machine



Step: 1
The current state is: s1
The tape symbol is: 1
The next state is: s2
The write symbol is: X
The move is: R
 |
_X1*11=_____
_____
--------------------------------------------------------------------------
----------------------------------------

1=>next Step    {any}-{1}=>run till end
2
Step: 2
The current state is: s2
The tape symbol is: 1
The next state is: s2
The write symbol is: 1
The move is: R
  |
_X1*11=_____
_____
--------------------------------------------------------------------------
----------------------------------------

Step: 3
The current state is: s2
The tape symbol is: *
The next state is: s3
The write symbol is: *
The move is: R
   |
```

```
_X1*11=_____
_____
-------------------------------------------------------------------------
----------------------------------------

Step: 4
The current state is: s3
The tape symbol is: 1
The next state is: s4
The write symbol is: Y
The move is: R
     |
_X1*Y1=_____
_____
-------------------------------------------------------------------------
----------------------------------------

Step: 5
The current state is: s4
The tape symbol is: 1
The next state is: s4
The write symbol is: 1
The move is: R
      |
_X1*Y1=_____
_____
-------------------------------------------------------------------------
----------------------------------------

Step: 6
The current state is: s4
The tape symbol is: =
The next state is: s4
The write symbol is: =
The move is: R
       |
_X1*Y1=_____
_____
-------------------------------------------------------------------------
----------------------------------------

Step: 7
The current state is: s4
The tape symbol is: _
```

```
The next state is: s5
The write symbol is: 1
The move is: L
       |
_X1*Y1=1_____
_____
```


```
Step: 8
The current state is: s5
The tape symbol is: =
The next state is: s5
The write symbol is: =
The move is: L
        |
_X1*Y1=1_____
_____
```


```
Step: 9
The current state is: s5
The tape symbol is: 1
The next state is: s5
The write symbol is: 1
The move is: L
        |
_X1*Y1=1_____
_____
```


```
Step: 10
The current state is: s5
The tape symbol is: Y
The next state is: s3
The write symbol is: Y
The move is: R
        |
_X1*Y1=1_____
_____
```


```
Step: 11
The current state is: s3
The tape symbol is: 1
The next state is: s4
The write symbol is: Y
The move is: R
        |
_X1*YY=1_____
_____
------------------------------------------------------------------------
----------------------------------------

Step: 12
The current state is: s4
The tape symbol is: =
The next state is: s4
The write symbol is: =
The move is: R
            |
_X1*YY=1_____
_____
------------------------------------------------------------------------
----------------------------------------

Step: 13
The current state is: s4
The tape symbol is: 1
The next state is: s4
The write symbol is: 1
The move is: R
                |
_X1*YY=1_____
_____
------------------------------------------------------------------------
----------------------------------------

Step: 14
The current state is: s4
The tape symbol is: _
The next state is: s5
The write symbol is: 1
The move is: L
                    |
```

```
_X1*YY=11_____
_____
--------------------------------------------------------------------------------
------------------------------------------

Step: 15
The current state is: s5
The tape symbol is: 1
The next state is: s5
The write symbol is: 1
The move is: L
        |
_X1*YY=11_____
_____
--------------------------------------------------------------------------------
------------------------------------------

Step: 16
The current state is: s5
The tape symbol is: =
The next state is: s5
The write symbol is: =
The move is: L
        |
_X1*YY=11_____
_____
--------------------------------------------------------------------------------
------------------------------------------

Step: 17
The current state is: s5
The tape symbol is: Y
The next state is: s3
The write symbol is: Y
The move is: R
        |
_X1*YY=11_____
_____
--------------------------------------------------------------------------------
------------------------------------------

Step: 18
The current state is: s3
The tape symbol is: =
```

```
The next state is: s6
The write symbol is: =
The move is: L
      |
_X1*YY=11_____
_____
-------------------------------------------------------------------
----------------------------------------

Step: 19
The current state is: s6
The tape symbol is: Y
The next state is: s6
The write symbol is: 1
The move is: L
      |
_X1*Y1=11_____
_____
-------------------------------------------------------------------
----------------------------------------

Step: 20
The current state is: s6
The tape symbol is: Y
The next state is: s6
The write symbol is: 1
The move is: L
     |
_X1*11=11_____
_____
-------------------------------------------------------------------
----------------------------------------

Step: 21
The current state is: s6
The tape symbol is: *
The next state is: s6
The write symbol is: *
The move is: L
    |
_X1*11=11_____
_____
-------------------------------------------------------------------
----------------------------------------
```

```
Step: 22
The current state is: s6
The tape symbol is: 1
The next state is: s6
The write symbol is: 1
The move is: L
   |
_X1*11=11_____
_____
-------------------------------------------------------------------------
---------------------------------------

Step: 23
The current state is: s6
The tape symbol is: X
The next state is: s1
The write symbol is: X
The move is: R
  |
_X1*11=11_____
_____
-------------------------------------------------------------------------
---------------------------------------

Step: 24
The current state is: s1
The tape symbol is: 1
The next state is: s2
The write symbol is: X
The move is: R
   |
_XX*11=11_____
_____
-------------------------------------------------------------------------
---------------------------------------

Step: 25
The current state is: s2
The tape symbol is: *
The next state is: s3
The write symbol is: *
The move is: R
    |
```

```
_XX*11=11_____
_____
---------------------------------------------------------------------------------
---------------------------------------
Step: 26
The current state is: s3
The tape symbol is: 1
The next state is: s4
The write symbol is: Y
The move is: R
     |
_XX*Y1=11_____
_____
---------------------------------------------------------------------------------
---------------------------------------
Step: 27
The current state is: s4
The tape symbol is: 1
The next state is: s4
The write symbol is: 1
The move is: R
      |
_XX*Y1=11_____
_____
---------------------------------------------------------------------------------
---------------------------------------
Step: 28
The current state is: s4
The tape symbol is: =
The next state is: s4
The write symbol is: =
The move is: R
        |
_XX*Y1=11_____
_____
---------------------------------------------------------------------------------
---------------------------------------
Step: 29
The current state is: s4
The tape symbol is: 1
```

```
The next state is: s4
The write symbol is: 1
The move is: R
        |
_XX*Y1=11_____
_____
--------------------------------------------------------------
----------------------------------------

Step: 30
The current state is: s4
The tape symbol is: 1
The next state is: s4
The write symbol is: 1
The move is: R
          |
_XX*Y1=11_____
_____
--------------------------------------------------------------
----------------------------------------

Step: 31
The current state is: s4
The tape symbol is: _
The next state is: s5
The write symbol is: 1
The move is: L
            |
_XX*Y1=111_____
_____
--------------------------------------------------------------
----------------------------------------

Step: 32
The current state is: s5
The tape symbol is: 1
The next state is: s5
The write symbol is: 1
The move is: L
          |
_XX*Y1=111_____
_____
--------------------------------------------------------------
----------------------------------------
```

```
Step: 33
The current state is: s5
The tape symbol is: 1
The next state is: s5
The write symbol is: 1
The move is: L
        |
_XX*Y1=111_____
_____
-----------------------------------------------------------------------------
--------------------------------------
Step: 34
The current state is: s5
The tape symbol is: =
The next state is: s5
The write symbol is: =
The move is: L
        |
_XX*Y1=111_____
_____
-----------------------------------------------------------------------------
--------------------------------------
Step: 35
The current state is: s5
The tape symbol is: 1
The next state is: s5
The write symbol is: 1
The move is: L
        |
_XX*Y1=111_____
_____
-----------------------------------------------------------------------------
--------------------------------------
Step: 36
The current state is: s5
The tape symbol is: Y
The next state is: s3
The write symbol is: Y
The move is: R
        |
```

```
_XX*Y1=111_____
_____
-------------------------------------------------------------------
---------------------------------------

Step: 37
The current state is: s3
The tape symbol is: 1
The next state is: s4
The write symbol is: Y
The move is: R
       |
_XX*YY=111_____
_____
-------------------------------------------------------------------
---------------------------------------

Step: 38
The current state is: s4
The tape symbol is: =
The next state is: s4
The write symbol is: =
The move is: R
         |
_XX*YY=111_____
_____
-------------------------------------------------------------------
---------------------------------------

Step: 39
The current state is: s4
The tape symbol is: 1
The next state is: s4
The write symbol is: 1
The move is: R
          |
_XX*YY=111_____
_____
-------------------------------------------------------------------
---------------------------------------

Step: 40
The current state is: s4
The tape symbol is: 1
```

```
The next state is: s4
The write symbol is: 1
The move is: R
        |
_XX*YY=111_____

_____
----------------------------------------------------------------------
----------------------------------------

Step: 41
The current state is: s4
The tape symbol is: 1
The next state is: s4
The write symbol is: 1
The move is: R
        |
_XX*YY=111_____

_____
----------------------------------------------------------------------
----------------------------------------

Step: 42
The current state is: s4
The tape symbol is: _
The next state is: s5
The write symbol is: 1
The move is: L
          |
_XX*YY=1111_____

_____
----------------------------------------------------------------------
----------------------------------------

Step: 43
The current state is: s5
The tape symbol is: 1
The next state is: s5
The write symbol is: 1
The move is: L
          |
_XX*YY=1111_____

_____
----------------------------------------------------------------------
----------------------------------------
```

```
Step: 44
The current state is: s5
The tape symbol is: 1
The next state is: s5
The write symbol is: 1
The move is: L
        |
_XX*YY=1111_____
_____
----------------------------------------------------------------------
---------------------------------------
Step: 45
The current state is: s5
The tape symbol is: 1
The next state is: s5
The write symbol is: 1
The move is: L
        |
_XX*YY=1111_____
_____
----------------------------------------------------------------------
---------------------------------------
Step: 46
The current state is: s5
The tape symbol is: =
The next state is: s5
The write symbol is: =
The move is: L
        |
_XX*YY=1111_____
_____
----------------------------------------------------------------------
---------------------------------------
Step: 47
The current state is: s5
The tape symbol is: Y
The next state is: s3
The write symbol is: Y
The move is: R
        |
```

```
_XX*YY=1111_____
_____
------------------------------------------------------------------------
-----------------------------------------

Step: 48
The current state is: s3
The tape symbol is: =
The next state is: s6
The write symbol is: =
The move is: L
     |
_XX*YY=1111_____
_____
------------------------------------------------------------------------
-----------------------------------------

Step: 49
The current state is: s6
The tape symbol is: Y
The next state is: s6
The write symbol is: 1
The move is: L
     |
_XX*Y1=1111_____
_____
------------------------------------------------------------------------
-----------------------------------------

Step: 50
The current state is: s6
The tape symbol is: Y
The next state is: s6
The write symbol is: 1
The move is: L
     |
_XX*11=1111_____
_____
------------------------------------------------------------------------
-----------------------------------------

Step: 51
The current state is: s6
The tape symbol is: *
```

```
The next state is: s6
The write symbol is: *
The move is: L
    |
_XX*11=1111_____
_____
----------------------------------------------------------------------
----------------------------------------

Step: 52
The current state is: s6
The tape symbol is: X
The next state is: s1
The write symbol is: X
The move is: R
    |
_XX*11=1111_____
_____
----------------------------------------------------------------------
----------------------------------------

Step: 53
The current state is: s1
The tape symbol is: *
The next state is: s8
The write symbol is: *
The move is: R
    |
_XX*11=1111_____
_____
----------------------------------------------------------------------
----------------------------------------
```