CS1FC16 - Matrix and Fibonacci algorithms

Module Code: CS1FC16

Git Repository: https://csgitlab.reading.ac.uk/il021591/cs1fc16_algorithms

Assignment report Title: Matrix and Fibonacci algorithms

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Actual hrs spent for the assignment: 12hrs

Assignment evaluation (3 key points): Learned how to create fibonacci, matrix multiplications, additions, transpose and finding dot product in C++. I have grasped the basic understand of Functional and imperative programming and the effects on performance.

Introduction

For this report I have been instructed to create two sets of algorithms. One will print out the nth number of the **Fibonacci sequence** using two different paradigms of programming. one **recursively** and the other using **imperative**. for the other algorithm I will be using the provided matrix library to extend it to compute matrix multiplications, additions, transpose, dot product and to get a column of the matrix from the provided column number. I will also be using the **C++ programming language** to write these algorithms.

Matrix Library

As stated previously I will be extending the matrix library to support **matrix multiplications, additions, transpose, dot product and to get columns form a matrix**. This will be implemented using 5 functions.

Firstly, the matrix library comes with the following matrix structure.

```
struct myMat {       // allows for matrices up to size 4*4
  int numRows;    // number of rows
  int numCols;
  int data[256];    // data are stored in row order //** Had to switch from 4 to somet
```

```
hing over 200 for some reason.**//
};
```

As stated, the **myMat struct** will allow to create matrices up to 4 rows and 4 columns. The `numRows` variable and `numCols` variable stores the number of rows and columns to be created. The `data` variable holds the value of the matrix.

To **get the column of a matrix** I will have to create a new matrix using the struct for the output. Then as shown below for every row it will loop and append each element from the matrix to the output vector.

```
myMat mGetCol(myMat m, int col) {
  myMat res = zeroMat(m.numRows, 1);        // create new matrix with 1 column
  for (int row = 0; row < m.numRows; row++)   // for each element in column
    res.data[row] = getElem(m, row, col);   // copy row element to res
  return res;
}
```

Next, I had to create a function to calculate the **dot product** of a given vector. This was simple as I had to loop over the columns and add the multiple of both the vectors to the result. This that can be outputted as an integer.

```
int dotProd(myMat v1, myMat v2) {
  int prod = 0;                  // initiate prod variable
  for (int I = 0; i < v1.numCols; i++){      // for each column in vector add prod plus
the multiple of both the vectors
    prod = prod + getElem(v1,0,i) * getElem(v2,0,i);
  }
  return prod;
}
```

For `mTranspose` I created a matrix `mO` with the same number of rows and columns as the input matrix. Then using a loop each of the values of the matrix were flipped and copied to `mO`.

```
myMat mTranspose(myMat m) {
  myMat mO = zeroMat(m.numCols, m.numRows);   // create a matrix mO with the same numb
er of rows and columns as the input matrix.
  for(int i=0; i< m.numRows; ++i) {       // for each item in rom and for each column
 in row flip the values that reffer to  i and j.
    for(int j=0; j< m.numCols; ++j){
      int val = getElem(m, i, j);
      setElem(mO, j, i, val);
    }
  }
```

```
  return m0;
}
```

The **matrix addition** function uses a loop that get the value `i` and `j` using the `getElem` function from both the matrices and add them together. The value of it is then set to the same location in the output matrix.

```
myMat mAdd(myMat m1, myMat m2) {
  myMat m3 = zeroMat(m1.numRows, m2.numCols);   // create a matrix with the same numbe
r of rows as the matrix1 and the same number of columns as the matrix2.
  for(int i = 0; i < m1.numRows; i++) {     //loop until all numbers in matrix1 and ma
trix1 are added to matrix3 and returned the matrix.
            for(int j = 0; j < m2.numCols; j++) {
        int val = getElem(m1, i, j) + getElem(m2, i, j);
                setElem(m3, i, j, val);
            }
        }
    return m3;
}
```

For the **Matrix multiplication** function, I created an object `m3` and if the rows and columns are equal to 1 the rows and columns are set to the number of rows and columns of the other matrix. if none of the matrices have 1 row or column the row on the new matrix is set to the number of rows as the first matrix and the column is sat to the number of columns as the second matrix.

Then for each row in the first matrix and the column in the second matrix get the value of i and j in the new matrix and it to the multiple of i and k from the first matrix and k and j from the second matrix. This is done until all the rows and columns have been processed.

```
myMat mMult(myMat m1, myMat m2) {
  myMat m3;                 // initiate matrix m3
  if (m1.numRows == 1 && m1.numCols == 1)   // if single row, column matrix inputted u
se the number of rows and columns as the other matrix.
  {
    m3 = zeroMat(m2.numRows, m2.numCols);
  }else if (m2.numRows == 1 && m2.numCols == 1) {
    m3 = zeroMat(m1.numRows, m1.numCols);

  }else {                   // else set the number of rows the same size as the first
 matrix and column as the second matrix.
    m3 = zeroMat(m1.numRows, m2.numCols);
  }

  int val;                  // variable to store values when loopes

  for(int i = 0; i < m1.numRows; ++i) {     // loop trough A and B, multiply and to re
```

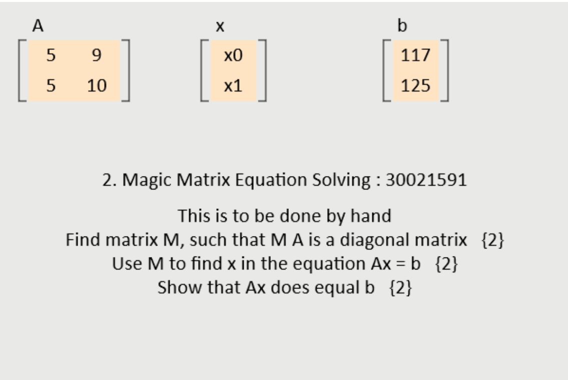
```
sult, then return.
    for(int j = 0; j < m2.numCols; ++j) {
      for(int k = 0; k < m2.numRows; ++k) {
        int val = getElem(m3, i, j) + getElem(m1, i, k) * getElem(m2, k, j);
        setElem(m3, i, j, val);     // save the value of val to m3 and output when don
e
      }
    }
  }
  return m3;
}
```

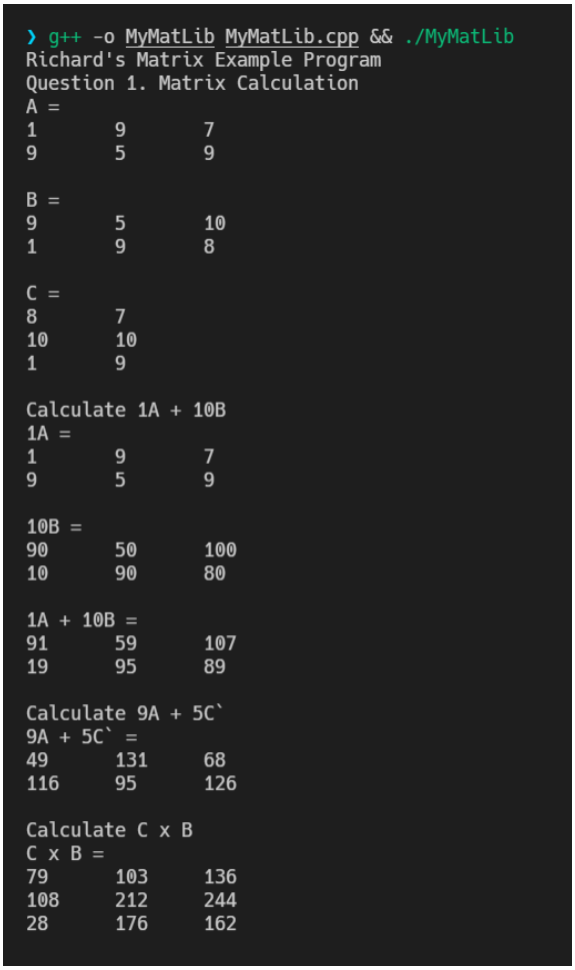
The Following code try’s to compute the questions set by Prof Richard Mitchell from his webpages accessible here. The Pictures after the code show the Output of set main function.

```
int main()
{
  cout << "Richard's Matrix Example Program\n";

  cout << "Question 1. Matrix Calculation\n"; // Question 1 -------------------------
--

  myMat Q1A = mFromStr("1,9,7;9,5,9");    // Matrix A
  printMat("A", Q1A);

  myMat Q1B = mFromStr("9,5,10;1,9,8");     // Matrix B
  printMat("B", Q1B);

  myMat Q1C = mFromStr("8,7;10,10;1,9");    // Matrix C
  printMat("C", Q1C);

  cout << "Calculate 1A + 10B\n";

  myMat Q1_1_mat = mFromStr("1");       // create 1x1 matrix of 1 (ik its unnecessary
 but its used to check if it works)
  myMat Q1_10_mat = mFromStr("10");     // create 1x1 matrix of 10
  myMat Q1_1A = mMult(Q1_1_mat, Q1A);     // Multiply 1 by Matrix A
  printMat("1A", Q1_1A);
  myMat Q1_10B = mMult(Q1_10_mat ,Q1B);   // Multiply 10 by Matrix B
  printMat("10B", Q1_10B);

  myMat Q1Ans1 = mAdd(Q1_1A, Q1_10B);     // Multiply 1A with Matrix 10B
  printMat("1A + 10B", Q1Ans1);       // print out the matrix


  cout << "Calculate 9A + 5C`\n";

  myMat Q1_9_mat = mFromStr("9");       // create 1x1 matrix of 9
  myMat Q1_5_mat = mFromStr("5");       // create 1x1 matrix of 5
  myMat Q1_9A = mMult(Q1_9_mat, Q1A);     // Multiply 9 by Matrix A
  myMat Q1_5C = mMult(Q1_5_mat, Q1C);     // Multiply 5 by Matrix C
  myMat Q1_5Ct = mTranspose(Q1_5C);     // get the transpose of the matrix 5C
  myMat Q1Ans2 = mAdd(Q1_9A, Q1_5Ct);     // Multiply 9A with Matrix 5C'
```

```
    printMat("9A + 5C`", Q1Ans2);       // print out the matrix

    cout << "Calculate C x B\n";

    myMat Q1Ans3 = mMult(Q1C, Q1B);       // Multiply Matrix C with Matrix B
    printMat("C x B", Q1Ans3);
    return 0;
```

Fibonacci





```
❯ g++ -o MyMatLib MyMatLib.cpp && ./MyMatLib
Richard's Matrix Example Program
Question 1. Matrix Calculation
A =
1       9       7
9       5       9

B =
9       5       10
1       9       8

C =
8       7
10      10
1       9

Calculate 1A + 10B
1A =
1       9       7
9       5       9

10B =
90      50      100
10      90      80

1A + 10B =
91      59      107
19      95      89

Calculate 9A + 5C`
9A + 5C` =
49      131     68
116     95      126

Calculate C x B
C x B =
79      103     136
108     212     244
28      176     162
```

Writing an algorithm to find and time **Fibonacci sequences** was the second task. Here I have two sets of styles that does the same task which is finding the nth Fibonacci number.

I have used the `chrono` library to get the execution time for each style of the Fibonacci sequences.

To use this program `cd` into the `Fibonacci` directory and type `make`. To execute the program simply type `./main` .

```
Usage:
        ./fib [-i/-r] [count] [-t]

        -i      imperative
        -r      recursive
        -t      output time taken
```

Imperative version

In the imperative version a desired number is passed to the function and is looped that many times, each time adding the value of `fib1` and `fib2` to `fib`. Then moving `fib2` to `fib1`. The Value of `fib` is also moved to `fib2`. Finally the value of `fib2` is returned.

```
int imp_fib(int count) { // function for Fibonacci Number using the imperative method
    std::cout << count << " Fibonacci Number using the imperative methord." << std::en
dl;

    for(int i = 2; i < count; i++){
        fib = fib1 + fib2;
        std::cout << fib2 << std::endl;
        fib1 = fib2;
        fib2 = fib;
    }
    return fib2;
}
```

Recursive version

Using the recursive method, the function here does not use a loop yet is recursively called and the previous count is inputted as an argument. depending on if the value of `count` is 0, 0 is returned. if `count` is 1 then 1 is returned. else the function is called by passing the value of `count` and deducts the value by 1. the function is called again and `count` is passed as an argument this time deducts by 2. This method is usually slow as the values of previously calculated Fibonacci numbers are recalculated. hence the time complexity for it is exponential.

```
int rec_fib(int count) { // function for Fibonacci Number using the recursive method
    if (count == 0)
        return 0;
    if (count == 1)
        return 1;
    return rec_fib(count-1)+rec_fib(count-2);
}
```

Reflection

In conclusion, coding these algorithms has made me more confident in C++ and programming in general. The Fibonacci sequence tasks also showed me the importance of optimization as getting a Fibonacci number in imperative can take significantly less time than recursive. I could have improved the readability of my code in future iterations. I think my code could also be improved in terms of optimization. matrix by a scalar, ‘magic’ matrix and Cramer’s Rule matrix solving algorithms could also be implemented in the future.

To Do

- [x] ~~Fibonacci~~
  - [x] ~~Iterative~~
  - [x] ~~Recursive~~
- [x] ~~Function to create a matrix being a column vector from given matrix~~
- [x] ~~Function to calculate the dot product of two vectors~~
- [x] ~~Function to create a matrix which is the transpose of given matrix~~
- [x] ~~Function to add two matrices~~
- [x] ~~Function to multiply two matrices~~
- [ ] One to multiple each element in a matrix by a scalar
- [ ] One to solve a two variable matrix equation using a ‘magic’ matrix
- [ ] One to calculate the determinant of a 2D matrix and solve an equation using Cramer’s Rule.

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