Assignment - Root Finding Methods

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V.1 - Algorithms for Computational Mathematics: Numerical Methods

B. Tech. (Information Technology and Mathematical Innovations)

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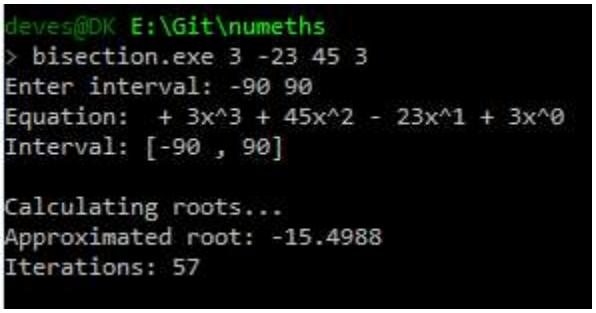
Bisection Method

```
/**
 - Program to find root of a polynomial using Bisection method.
 *
 - @author Devesh Khandelwal
 - @created 21-08-2015
 - @modified 27-08-2015
 */

#include <iostream>
#include <cmath>
#include <string>
#include <vector>

// Error tolerance of polynomial.
#define EPSILON 0.000000000001

using namespace std;

// Number of iterations.
long iterations = 0;

/**
 - Calculates the polynomial value.
 -
 - @param  coefficients Array of coefficients
 - @param  size         Order of equation
 - @param  x            Value to calculate, independent variable
 - @return             Polynomial value, dependent variable
 */
double polynomial(double *coefficients, int size, double x)
{
    double sum=0;
    for (int i = 0; i < size; ++i)
    {
```

```
        sum += coefficients[i]*pow(x, i);
    }
    return sum;
}

/**
 - Find root in a given interval.
 -
 - @param  coefficients Array of coefficients
 - @param  size         Order of equation
 - @param  a            Interval start
 - @param  b            Interval end
 - @return              Root of polynomial, if found
 */
double bisection(double *coefficients, int size, double a, double b)
{
    if (abs(polynomial(coefficients, size, (a+b)/2))<EPSILON)
    {
        return (a+b)/2;
    }
    else
    {
        if (polynomial(coefficients, size, (a+b)/2)*
            polynomial(coefficients, size, a) < 0)
            bisection(coefficients, size, a, (a+b)/2);
        else
            bisection(coefficients, size, (a+b)/2, b);
    }
}

/**
 - main function. Takes coefficients of a polynomial equation
 - as command line arguments in increasinig polynomial degree.
 -
 - @param  argc Number of arguments
 - @param  argv Arguments
 - @return      Status code.
 */
int main(int argc, char const *argv[])
{

    string degree;                      // No of coefficients not used.
    float a, b;
    vector<string> arguments;
    double *coefficients;
    coefficients = new double[argc-1];

    // Taking coefficientsfrom command line argument into double array.
    if (argc > 1)
    {
        degree = argv[1];   // Not used.
        arguments.assign(argv + 1, argv + argc);
```

```
    }
    for(int i=0; i<arguments.size() ;i++)
    {
        coefficients[i] = stod(arguments[i], 0);
    }

    // Taking the interval limits.
    cout<<"Enter interval: ";
    cin>>a>>b;

    // Displaying equation.
    cout<<"Equation: ";
    for(int i=0; i<arguments.size() ; i++)
        cout<<((coefficients[arguments.size()-1-i]>0)?" + ":" - ")
            <<abs(coefficients[arguments.size()-1-i])<<"x^"
            <<arguments.size()-1-i;

    cout<<"\nInterval: ["<<a<<" , "<<b<<"]"<<endl;

    if (polynomial(coefficients, arguments.size(), a)*
        polynomial(coefficients, arguments.size(), b) > 0)
    {
        cerr<<"Interval does not contain any root!!!"<<endl<<"Aborting...";
        return 1;
    }
    else
    {
        cout<<endl;
        cout<<"Calculating roots..."<<endl;
        cout<<"Approximated root: "
            <<bisection(coefficients, arguments.size(), a, b)<<endl;
        cout<<"Iterations: "<<iterations<<endl;
        return 0;
    }
}
```

Output



Regula Falsi Method

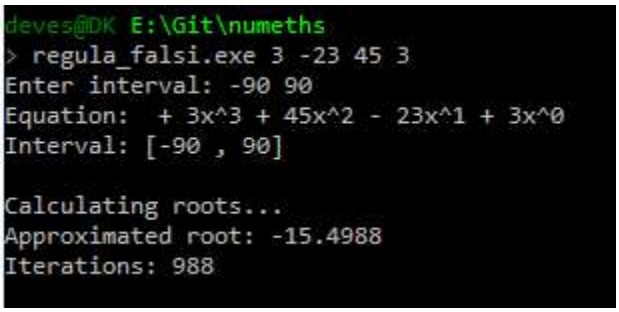
```
/**
 - Program to find root of a polynomial using Regula Falsi (False Position) method.
 *
 - @author Devesh Khandelwal
 - @created 27-08-2015
 - @modified 27-08-2015
 */

#include <iostream>
#include <iomanip>
#include <cmath>
#include <string>
#include <vector>

// Error tolerance of polynomial.
#define EPSILON 9.16978e-005`

using namespace std;

// Number of iterations.
long iterations = 0;

// Last two iterations.
double pn = 0, pn1 = 0, pn2 = 0, error = 0;

/**
 - Calculates the polynomial value.
 -
 - @param  coefficients Array of coefficients
 - @param  size         Order of equation
 - @param  x            Value to calculate, independent variable
 - @return             Polynomial value, dependent variable
 */
double polynomial(double *coefficients, int size, double x)
{
    double sum=0;
    for (int i = 0; i < size; ++i)
    {
        sum += coefficients[i]*pow(x, i);
    }
    return sum;
}

/**
 - Calcuates the approximated root in the given interval.
 -
 - @param  a Interval start point
 - @param  b Interval end point
 - @return   x-intercept value of the secant in the given interval
 */
double x_intercept(double a, double b, double f_a, double f_b)
```

```
{
    return b - (f_b*((b-a)/(f_b-f_a)));
}

void calculate_error()
{
    // Check if
    if (++iterations > 3)
    {
        error = (pn - pn1) / (pn1 - pn2);
        error = (abs(error)/abs(error-1))*abs(pn-pn1);
    }
}

/**
 - Find root in a given interval.
 -
 - @param  coefficients Array of coefficients
 - @param  size         Order of equation
 - @param  a            Interval start
 - @param  b            Interval end
 - @return              Root of polynomial, if found
 */
double falsi(double *coefficients, int size, double a, double b)
{
    iterations++;

    calculate_error();

    pn2 = pn1;
    pn1 = pn;
    pn = x_intercept(a, b, polynomial(coefficients, size, a),
            polynomial(coefficients, size, b));

    if (abs(polynomial(coefficients, size,
        x_intercept(a, b, polynomial(coefficients, size, a),
        polynomial(coefficients, size, b))))<EPSILON)
    {
        return x_intercept(a, b, polynomial(coefficients, size, a),
        polynomial(coefficients, size, b));
    }
    else
    {
        if (polynomial(coefficients, size, x_intercept(a, b,
            polynomial(coefficients, size, a),
            polynomial(coefficients, size, b)))*
            polynomial(coefficients, size, a) < 0)
            falsi(coefficients, size, a, x_intercept(a, b,
                    polynomial(coefficients, size, a),
                    polynomial(coefficients, size, b)));
        else
            falsi(coefficients, size, x_intercept(a, b,
```

```
                    polynomial(coefficients, size, a),
                    polynomial(coefficients, size, b)), b);
    }
}

/**
 - main function. Takes coefficients of a polynomial equation
 - as command line arguments in increasinig polynomial degree.
 - @param  argc Number of arguments
 - @param  argv Arguments
 - @return      Status code.
 */
int main(int argc, char const *argv[])
{

    string degree;                      // No of coefficients not used.
    float a, b;
    vector<string> arguments;
    double *coefficients;
    coefficients = new double[argc-1];

    // Taking coefficients from command line argument into double array.
    if (argc > 1)
    {
        degree = argv[1];   // Not used.
        arguments.assign(argv + 1, argv + argc);
    }
    for(int i=0; i<arguments.size() ;i++)
    {
        coefficients[i] = stod(arguments[i], 0);
    }

    // Taking the interval limits.
    cout<<"Enter interval: ";
    cin>>a>>b;

    // Displaying equation.
    cout<<"Equation: ";
    for(int i=0; i<arguments.size() ; i++)
        cout<<((coefficients[arguments.size()-1-i]>0)?" + ":" - ")
            <<abs(coefficients[arguments.size()-1-i])
            <<"x^"<<arguments.size()-1-i;

    cout<<"\nInterval: ["<<a<<" , "<<b<<"]"<<endl;

    if (polynomial(coefficients, arguments.size(), a)*
        polynomial(coefficients, arguments.size(), b) > 0)
    {
        cerr<<"Interval does not contain any root!!!"<<endl<<"Aborting...";
        return 1;
    }
    else
```

```
    {
        cout<<endl;
        cout<<"Calculating roots..."<<endl;
        cout<<"Approximated root: "
            <<falsi(coefficients, arguments.size(), a, b)<<endl;
        cout<<"Iterations: "<<iterations<<endl;
        return 0;
    }
}
```

Output



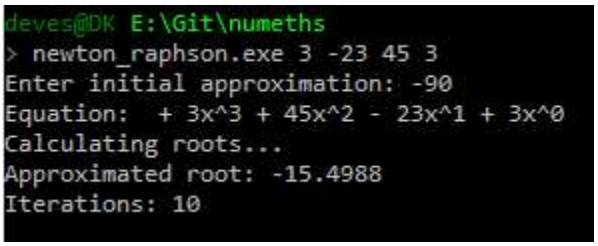
Newton-Raphson Method

```
/**
 + Program to find root of a polynomial using Newton-Raphson method.
 *
 + @author Devesh Khandelwal
 + @created 04-09-2015
 + @modified 04-09-2015
 */

#include <iostream>
#include <iomanip>
#include <cmath>
#include <string>
#include <vector>

// Error tolerance of polynomial.
#define EPSILON 9.16978e-005

using namespace std;

// Number of iterations.
long iterations = 0;

// Last two iterations.
double pn = 0, pn1 = 0, pn2 = 0, error = 0;

/**
```

```
 + Calculates the polynomial value.
 +
 + @param  coefficients Array of coefficients
 + @param  size         Order of equation
 + @param  x            Value to calculate, independent variable
 + @return              Polynomial value, dependent variable
 */
double polynomial(double *coefficients, int size, double x)
{
    double sum=0;
    for (int i = 0; i < size; ++i)
    {
        sum += coefficients[i]*pow(x, i);
    }
    return sum;
}

/**
 + Calculates the derivative of the polynomial.
 +
 + @param  coefficients Array of coefficients
 + @param  size         Order of equation
 + @param  x            Value to calculate, independent variable
 + @return              Polynomial's derivative value, dependent variable
 */
double derivative(double *coefficients, int size, double x)
{
    double sum=0;
    for (int i = 1; i < size; ++i)
    {
        sum += coefficients[i]*i*pow(x,i-1);
    }
    return sum;
}

/**
 + Find root using an initial approximation.
 +
 + @param  coefficients Array of coefficients
 + @param  size         Order of equation
 + @param  x            Initial approximation
 + @return              Approximated root
 */
double newton_raphson(double *coefficients, int size, double x)
{
    iterations++;
    if (abs(polynomial(coefficients, size, x))<EPSILON)
    {
        return x;
    }
    else
        return newton_raphson(coefficients, size,
```

```
                x - polynomial(coefficients, size, x)
                /derivative(coefficients, size, x));
}

/**
 + main function. Takes coefficients of a polynomial equation
 + as command line arguments in increasinig polynomial degree.
 + @param  argc Number of arguments
 + @param  argv Arguments
 + @return      Status code.
 */
int main(int argc, char const *argv[])
{

    string degree;                      // No of coefficients not used.
    float x;
    vector<string> arguments;
    double *coefficients;
    coefficients = new double[argc-1];

    // Taking coefficientsfrom command line argument into double array.
    if (argc > 1)
    {
        degree = argv[1];   // Not used.
        arguments.assign(argv + 1, argv + argc);
    }
    for(int i=0; i<arguments.size() ;i++)
    {
        coefficients[i] = stod(arguments[i], 0);
    }

    // Taking the interval limits.
    cout<<"Enter initial approximation: ";
    cin>>x;

    // Displaying equation.
    cout<<"Equation: ";
    for(int i=0; i<arguments.size() ; i++)
        cout<<((coefficients[arguments.size()-1-i]>0)?" + ":" - ")
            <<abs(coefficients[arguments.size()-1-i])
            <<"x^"<<arguments.size()-1-i;

    {
        cout<<endl;
        cout<<"Calculating roots..."<<endl;
        cout<<"Approximated root: "
            <<newton_raphson(coefficients, arguments.size(), x)<<endl;
        cout<<"Iterations: "<<iterations<<endl;
        return 0;
    }
}
```

Output



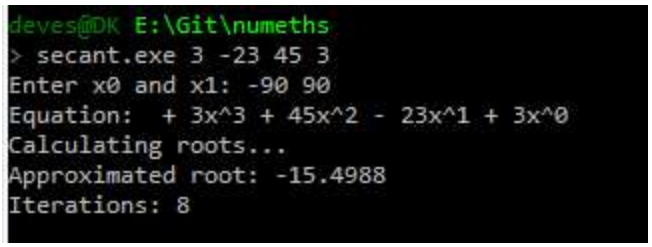
Secant Method

```
/**
 - Program to find root of a polynomial using Bisection method.
 *
 - @author Devesh Khandelwal
 - @created 28-09-2015
 - @modified 28-09-2015
 */

#include <iostream>
#include <cmath>
#include <string>
#include <vector>

// Error tolerance of polynomial.
#define EPSILON 0.000000000001

using namespace std;

// Number of iterations.
long iterations = 0;

/**
 - Calculates the polynomial value.
 -
 - @param  coefficients Array of coefficients
 - @param  size         Order of equation
 - @param  x            Value to calculate, independent variable
 - @return             Polynomial value, dependent variable
 */
double polynomial(double *coefficients, int size, double x)
{
    double sum=0;
    for (int i = 0; i < size; ++i)
    {
        sum += coefficients[i]*pow(x, i);
    }
    return sum;
}
```

```
/**
 - Find root in a given interval.
 -
 - @param  coefficients Array of coefficients
 - @param  size         Order of equation
 - @param  a            Interval start
 - @param  b            Interval end
 - @return              Root of polynomial, if found
 */
double secant(double *coefficients, int size, double x0, double x1)
{
    iterations++;
    if (abs(polynomial(coefficients, size, x1))<EPSILON)
    {
        return x1;
    }
    else
    {
        return secant(coefficients, size, x1,
                x1 - (polynomial(coefficients, size, x1)*(x1-x0))/
                (polynomial(coefficients, size, x1)-
                polynomial(coefficients, size, x0)));
    }
}

/**
 - main function. Takes coefficients of a polynomial equation
 - as command line arguments in increasinig polynomial degree.
 - @param  argc Number of arguments
 - @param  argv Arguments
 - @return      Status code.
 */
int main(int argc, char const *argv[])
{

    string degree;                      // No of coefficients not used.
    double x0, x1;
    vector<string> arguments;
    double *coefficients;
    coefficients = new double[argc-1];

    // Taking coefficientsfrom command line argument into double array.
    if (argc > 1)
    {
        degree = argv[1];   // Not used.
        arguments.assign(argv + 1, argv + argc);
    }
    for(int i=0; i<arguments.size() ;i++)
    {
        coefficients[i] = stod(arguments[i], 0);
    }
```

```
    // Taking the interval limits.
    cout<<"Enter x0 and x1: ";
    cin>>x0>>x1;

    // Displaying equation.
    cout<<"Equation: ";
    for(int i=0; i<arguments.size() ; i++)
        cout<<((coefficients[arguments.size()-1-i]>0)?" + ":" - ")
            <<abs(coefficients[arguments.size()-1-i])
            <<"x^"<<arguments.size()-1-i;

    {
        cout<<endl;
        cout<<"Calculating roots..."<<endl;
        cout<<"Approximated root: "
            <<secant(coefficients, arguments.size(), x0, x1)<<endl;
        cout<<"Iterations: "<<iterations<<endl;
        return 0;
    }
}
```

Output



THE END. *Namaste.*