Root-Finding Algorithms Solver

1.0

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Chapter 1

Root-Finding Algorithms Solver

Using various numerical methods

The program allows users to choose from the following root-finding algorithms:

- Bisection Method
- Hybrid Method
- Brent Method
- Ridder Method
- Newton-Raphson Method

Users can either use default parameters or customize them according to their needs. The program outputs include the root of the function, the number of iterations, and detailed steps.

Additionally, the program offers options to compare all the methods and display their performance side by side.

1.0.1 Key Features

- Implements five distinct root-finding algorithms
- Interactive user interface for method selection
- Customizable parameters such as tolerance and initial guesses
- Displays detailed performance metrics and results
- Provides comparative analysis across the algorithms

1.0.2 How to Use

1. Run the program.
2. Select a root-finding algorithm or choose to compare all methods.
3. Enter custom parameters or use the default values.
4. View the results and performance metrics.

Chapter 2

Class Index

2.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

Chapter 3

File Index

3.1 File List

Here is a list of all files with brief descriptions:

Chapter 4

Class Documentation

4.1 RootInfo Struct Reference

`#include <methods.h>`

Public Attributes

- long double root
- int iterations
- int decimal_places

4.1.1 Member Data Documentation

4.1.1.1 decimal_places

`int RootInfo::decimal_places`

4.1.1.2 iterations

`int RootInfo::iterations`

4.1.1.3 root

`long double RootInfo::root`

The documentation for this struct was generated from the following file:

- methods.h

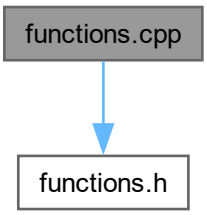
Chapter 5

File Documentation

5.1 functions.cpp File Reference

```
#include "functions.h"
```

Include dependency graph for functions.cpp:



Functions

- long double f (long double x)
- long double f_prime (long double x)

5.1.1 Function Documentation

5.1.1.1 f()

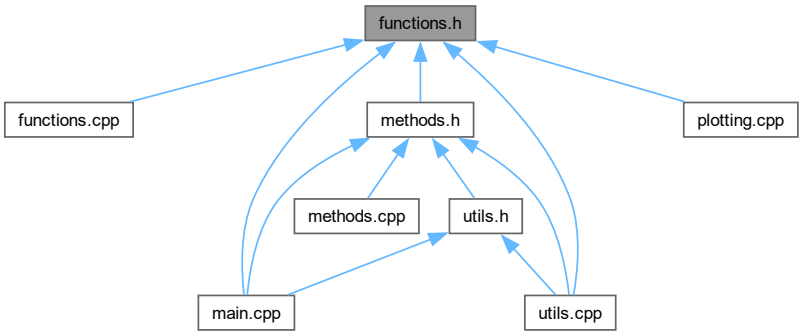
```
long double f (
              long double x)
00014 {
00015     return x * x * x - 5 * x + 3;
00016 }
```

5.1.1.2 f_prime()

```
long double f_prime (
            long double x)
00020 {
00021     return 3 * x * x - 5;
00022 }
```

5.2 functions.h File Reference

This graph shows which files directly or indirectly include this file:



Functions

- long double f (long double x)
- long double f_prime (long double x)

5.2.1 Function Documentation

5.2.1.1 f()

```
long double f (
            long double x)
00014 {
00015     return x * x * x - 5 * x + 3;
00016 }
```

5.2.1.2 f_prime()

```
long double f_prime (
            long double x)
00020 {
00021     return 3 * x * x - 5;
00022 }
```

5.3 functions.h

Go to the documentation of this file.

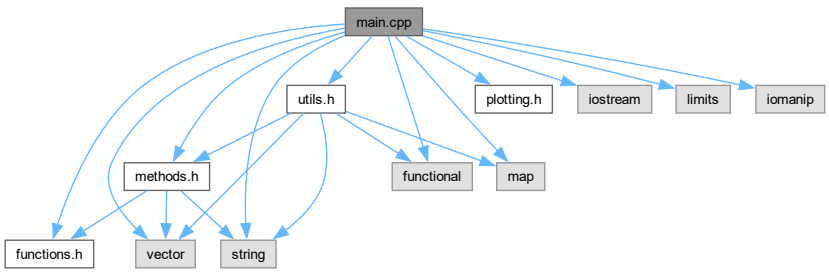
```
00001 /*
00002 @Author: Gilbert Young
00003 @Time: 2024/09/19 01:47
00004 @File_name: functions.h
00005 @IDE: VSCode
00006 @Formatter: Clang-Format
00007 @Description: Declaration of the function f(x) and its derivative f'(x).
00008 */
00009
00010 #ifndef FUNCTIONS_H
00011 #define FUNCTIONS_H
00012
00013 long double f(long double x);
00014 long double f_prime(long double x);
00015
00016 #endif // FUNCTIONS_H
```

5.4 main.cpp File Reference

The main entry point for the Root-Finding Algorithms Solver project.

```
#include "functions.h"
#include "methods.h"
#include "plotting.h"
#include "utils.h"
#include <iostream>
#include <limits>
#include <map>
#include <vector>
#include <functional>
#include <string>
#include <iomanip>
```

Include dependency graph for main.cpp:



Functions

- int main ()

5.4.1 Detailed Description

The main entry point for the Root-Finding Algorithms Solver project.

Author

Gilbert Young

Date

2024/09/19

5.4.2 Function Documentation

5.4.2.1 main()

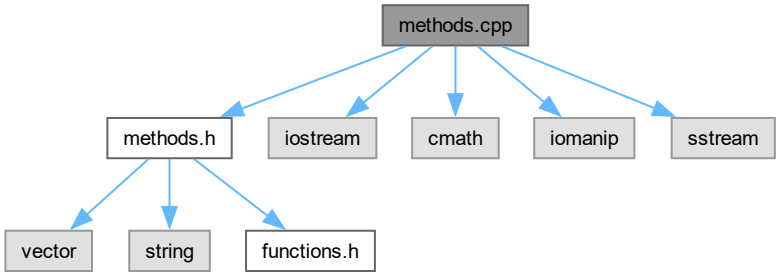
```
int main ()
00055 {
00056     // Plot the function once at the beginning with range [-3, 3]
00057     plot_function(-3.0L, 3.0L, -10.0L, 10.0L);
00058
00059     char choice;
00060     do
00061     {
00062         long double a = 0.0L, b = 0.0L, x0 = 0.0L, tol = 1e-14L;
00063         std::string method_name;
00064
00065         // Get user input for method selection
00066         get_user_input(a, b, x0, method_name, tol);
00067
00068         int max_iter = 1000;
00069
00070         // Map of methods excluding Newton-Raphson and Compare All Methods
00071         std::map<std::string, std::function<long double(long double, long double, long double, int,
      std::vector<std::string> &, int)>> methods = {
00072             {"Bisection Method", [](long double a, long double b, long double tol, int max_iter,
      std::vector<std::string> &iterations, int decimal_places) -> long double
00073              {
00074                  return bisection(a, b, tol, max_iter, iterations, decimal_places);
00075              }},
00076             {"Hybrid Method", [](long double a, long double b, long double tol, int max_iter,
      std::vector<std::string> &iterations, int decimal_places) -> long double
00077              {
00078                  return hybrid_method(a, b, tol, max_iter, iterations, decimal_places);
00079              }},
00080             {"Brent Method", [](long double a, long double b, long double tol, int max_iter,
      std::vector<std::string> &iterations, int decimal_places) -> long double
00081              {
00082                  return brent_method(a, b, tol, max_iter, iterations, decimal_places);
00083              }},
00084             {"Ridder Method", [](long double a, long double b, long double tol, int max_iter,
      std::vector<std::string> &iterations, int decimal_places) -> long double
00085              {
00086                  return ridder_method(a, b, tol, max_iter, iterations, decimal_places);
00087              }}};
00088
00089         if (method_name == "Newton-Raphson Method")
00090         {
00091             std::vector<std::string> iterations;
00092             long double root = newton_raphson(x0, tol, max_iter, iterations,
      calculate_decimal_places(tol));
00093             RootInfo info{root, static_cast<int>(iterations.size()), calculate_decimal_places(tol)};
00094             summary[method_name].emplace_back(info);
00095
00096             // Display results
00097             std::cout « "\nMethod: " « method_name « "\n";
00098             std::cout « "Initial guess: x0 = " « std::fixed « std::setprecision(info.decimal_places) «
      x0 « "\n";
00099             std::cout « "Root: " « std::fixed « std::setprecision(info.decimal_places) « root « "\n";
00100             std::cout « "Iterations:\n";
00101             for (const auto &iter : iterations)
00102             {
00103                 std::cout « iter « "\n";
```

```
00104             }
00105             std::cout « "Iterations Count: " « iterations.size() « "\n";
00106         }
00107         else if (method_name == "Problem Steps Mode")
00108         {
00109             // Run the problem steps
00110             run_problem_steps();
00111         }
00112         else if (method_name == "Compare All Methods")
00113         {
00114             // Run the comparison
00115             compare_all_methods();
00116         }
00117         else
00118         {
00119             // Get the method function
00120             auto it = methods.find(method_name);
00121             if (it != methods.end() && it->second != nullptr)
00122             {
00123                 run_method_user_selection(method_name, it->second, a, b, tol, max_iter);
00124             }
00125             else
00126             {
00127                 std::cerr « "Method not found or not implemented.\n";
00128             }
00129         }
00130
00131         // Output summary of all results
00132         if (method_name != "Problem Steps Mode" && method_name != "Compare All Methods")
00133         {
00134             std::cout « "\n--- Summary of All Results ---\n";
00135             for (const auto &method : summary)
00136             {
00137                 std::cout « "\nMethod: " « method.first « "\n";
00138                 int idx = 1;
00139                 for (const auto &info : method.second)
00140                 {
00141                     std::cout « "  Root " « idx++ « ": " « std::fixed «
      std::setprecision(info.decimal_places) « info.root
00142                               « " | Iterations: " « info.iterations « "\n";
00143                 }
00144             }
00145             // Clear summary for next run
00146             summary.clear();
00147         }
00148
00149         // Ask user if they want to run again
00150         std::cout « "\nDo you want to run the program again? (y/n): ";
00151         std::cin » choice;
00152
00153     } while (choice == 'y' || choice == 'Y');
00154
00155     // Pause and wait for user input before exiting
00156     std::cout « "\nPress Enter to exit...";
00157     std::cin.ignore(std::numeric_limits<std::streamsize>::max(), '\n');
00158     std::cin.get();
00159
00160     return 0;
00161 }
```

5.5 methods.cpp File Reference

```
#include "methods.h"
#include <iostream>
#include <cmath>
#include <iomanip>
#include <sstream>
```

Include dependency graph for methods.cpp:



Functions

- long double bisection (long double a, long double b, long double tol, int max_iter, std::vector< std::string > &iterations, int decimal_places)
- long double newton_raphson (long double x0, long double tol, int max_iter, std::vector< std::string > &iterations, int decimal_places)
- long double hybrid_method (long double a, long double b, long double tol, int max_iter, std::vector< std::string > &iterations, int decimal_places)
- long double brent_method (long double a, long double b, long double tol, int max_iter, std::vector< std::string > &iterations, int decimal_places)
- long double ridder_method (long double a, long double b, long double tol, int max_iter, std::vector< std::string > &iterations, int decimal_places)

5.5.1 Function Documentation

5.5.1.1 bisection()

```
long double bisection (
              long double a,
              long double b,
              long double tol,
              int max_iter,
              std::vector< std::string > & iterations,
              int decimal_places)
00018 {
00019     long double fa = f(a), fb = f(b);
00020     if (fa * fb >= 0)
00021     {
00022         std::cerr « "Bisection method fails. f(a) and f(b) should have opposite signs.\n";
00023         return NAN;
00024     }
00025
00026     long double c = a;
00027     for (int i = 0; i < max_iter; ++i)
00028     {
00029         c = (a + b) / 2.0L;
00030         long double fc = f(c);
00031         std::ostringstream oss;
00032         oss « "Step " « i + 1 « ": [" « std::fixed « std::setprecision(decimal_places) « a « ", " « b
      « "]";
00033         iterations.push_back(oss.str());
00034         if ((b - a) / 2.0L < tol)
00035             break;
00036         if (fa * fc < 0)
```

```
00037         {
00038             b = c;
00039             fb = fc;
00040         }
00041         else
00042         {
00043             a = c;
00044             fa = fc;
00045         }
00046     }
00047     return c;
00048 }
```

5.5.1.2 brent_method()

```
long double brent_method (
              long double a,
              long double b,
              long double tol,
              int max_iter,
              std::vector< std::string > & iterations,
              int decimal_places)
00140 {
00141     long double fa = f(a), fb = f(b);
00142     if (fa * fb >= 0)
00143     {
00144         std::cerr « "Brent's method fails. f(a) and f(b) should have opposite signs.\n";
00145         return NAN;
00146     }
00147
00148     if (fabs(fa) < fabs(fb))
00149     {
00150         std::swap(a, b);
00151         std::swap(fa, fb);
00152     }
00153
00154     long double c = a, fc = fa, s = b, fs = fb;
00155     bool mflag = true;
00156     long double d = 0.0;
00157
00158     for (int i = 0; i < max_iter; ++i)
00159     {
00160         if (fb != fc && fa != fc)
00161         {
00162             // Inverse quadratic interpolation
00163             s = (a * fb * fc) / ((fa - fb) * (fa - fc)) +
00164                 (b * fa * fc) / ((fb - fa) * (fb - fc)) +
00165                 (c * fa * fb) / ((fc - fa) * (fc - fb));
00166         }
00167         else
00168         {
00169             // Secant method
00170             s = b - fb * (b - a) / (fb - fa);
00171         }
00172
00173         // Conditions to accept s
00174         bool condition1 = (s < (3 * a + b) / 4.0L || s > b);
00175         bool condition2 = (mflag && fabs(s - b) >= fabs(b - c) / 2.0L);
00176         bool condition3 = (!mflag && fabs(s - b) >= fabs(c - d) / 2.0L);
00177         bool condition4 = (mflag && fabs(b - c) < tol);
00178         bool condition5 = (!mflag && fabs(c - d) < tol);
00179
00180         if (condition1 || condition2 || condition3 || condition4 || condition5)
00181         {
00182             // Bisection method
00183             s = (a + b) / 2.0L;
00184             mflag = true;
00185         }
00186         else
00187         {
00188             mflag = false;
00189         }
00190
00191         long double fs_new = f(s);
00192         std::ostringstream oss;
00193         oss « "Step " « i + 1 « ": a = " « std::fixed « std::setprecision(decimal_places) « a
00194             « ", b = " « b « ", s = " « s;
00195         iterations.push_back(oss.str());
00196
00197         d = c;
```

```
00198         c = b;
00199         fc = fb;
00200
00201         if (fa * fs_new < 0)
00202         {
00203             b = s;
00204             fb = fs_new;
00205         }
00206         else
00207         {
00208             a = s;
00209             fa = fs_new;
00210         }
00211
00212         if (fabs(fa) < fabs(fb))
00213         {
00214             std::swap(a, b);
00215             std::swap(fa, fb);
00216         }
00217
00218         if (fabs(b - a) < tol)
00219             break;
00220     }
00221
00222     return b;
00223 }
```

5.5.1.3 hybrid_method()

```
long double hybrid_method (
             long double a,
             long double b,
             long double tol,
             int max_iter,
             std::vector< std::string > & iterations,
             int decimal_places)
00077 {
00078     long double fa = f(a), fb = f(b);
00079     if (fa * fb >= 0)
00080     {
00081         std::cerr « "Hybrid method fails. f(a) and f(b) should have opposite signs.\n";
00082         return NAN;
00083     }
00084
00085     long double c = a;
00086     for (int i = 0; i < max_iter; ++i)
00087     {
00088         c = (a + b) / 2.0L;
00089         long double fc = f(c);
00090         std::ostringstream oss;
00091         oss « "Step " « i + 1 « ": [" « std::fixed « std::setprecision(decimal_places) « a « ", " « b
    « "]";
00092         iterations.push_back(oss.str());
00093         if ((b - a) / 2.0L < tol)
00094             break;
00095
00096         long double fpc = f_prime(c);
00097         if (fpc != 0.0)
00098         {
00099             long double d = c - fc / fpc;
00100             if (d > a && d < b)
00101             {
00102                 long double fd = f(d);
00103                 std::ostringstream oss_newton;
00104                 oss_newton « "Newton Step: c = " « std::fixed « std::setprecision(decimal_places) « c
00105                            « ", d = " « d;
00106                 iterations.push_back(oss_newton.str());
00107                 if (fabs(d - c) < tol)
00108                     return d;
00109                 if (fa * fd < 0)
00110                 {
00111                     b = d;
00112                     fb = fd;
00113                 }
00114                 else
00115                 {
00116                     a = d;
00117                     fa = fd;
00118                 }
00119                 continue;
```

```
00120             }
00121         }
00122
00123         // Fallback to bisection
00124         if (fa * fc < 0)
00125         {
00126             b = c;
00127             fb = fc;
00128         }
00129         else
00130         {
00131             a = c;
00132             fa = fc;
00133         }
00134     }
00135     return c;
00136 }
```

5.5.1.4 newton_raphson()

```
long double newton_raphson (
              long double x0,
              long double tol,
              int max_iter,
              std::vector< std::string > & iterations,
              int decimal_places)
00052 {
00053     long double x1;
00054     for (int i = 0; i < max_iter; ++i)
00055     {
00056         long double fx0 = f(x0);
00057         long double fpx0 = f_prime(x0);
00058         if (fpx0 == 0.0)
00059         {
00060             std::cerr « "Newton-Raphson method fails. Derivative zero.\n";
00061             return NAN;
00062         }
00063         x1 = x0 - fx0 / fpx0;
00064         std::ostringstream oss;
00065         oss « "Step " « i + 1 « ": x0 = " « std::fixed « std::setprecision(decimal_places) « x0
00066             « ", x1 = " « x1;
00067         iterations.push_back(oss.str());
00068         if (fabs(x1 - x0) < tol)
00069             break;
00070         x0 = x1;
00071     }
00072     return x1;
00073 }
```

5.5.1.5 ridder_method()

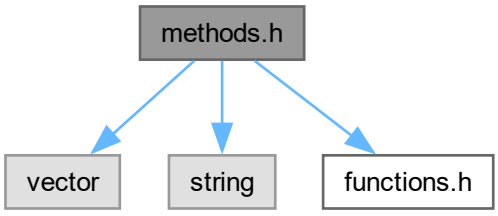
```
long double ridder_method (
              long double a,
              long double b,
              long double tol,
              int max_iter,
              std::vector< std::string > & iterations,
              int decimal_places)
00227 {
00228     long double fa = f(a), fb = f(b);
00229     if (fa * fb >= 0)
00230     {
00231         std::cerr « "Ridder's method fails. f(a) and f(b) should have opposite signs.\n";
00232         return NAN;
00233     }
00234
00235     for (int i = 0; i < max_iter; ++i)
00236     {
00237         long double c = 0.5L * (a + b);
00238         long double fc = f(c);
00239         long double s_sq = fc * fc - fa * fb;
00240         if (s_sq < 0.0)
```

```
00241         {
00242             std::cerr « "Ridder's method fails. Square root of negative number.\n";
00243             return NAN;
00244         }
00245         long double s = sqrt(s_sq);
00246         if (s == 0.0)
00247             return c;
00248 
00249         long double sign = ((fa - fb) < 0) ? -1.0L : 1.0L;
00250         long double x = c + (c - a) * fc / s * sign;
00251         long double fx = f(x);
00252         std::ostringstream oss;
00253         oss « "Step " « i + 1 « ": [" « std::fixed « std::setprecision(decimal_places) « a « ", " « b
      « "]";
00254         iterations.push_back(oss.str());
00255 
00256         if (fabs(fx) < tol)
00257             return x;
00258 
00259         if (fc * fx < 0.0)
00260         {
00261             a = c;
00262             fa = fc;
00263             b = x;
00264             fb = fx;
00265         }
00266         else if (fa * fx < 0.0)
00267         {
00268             b = x;
00269             fb = fx;
00270         }
00271         else
00272         {
00273             a = x;
00274             fa = fx;
00275         }
00276 
00277         if (fabs(b - a) < tol)
00278             break;
00279     }
00280 
00281     return 0.5L * (a + b);
00282 }
```

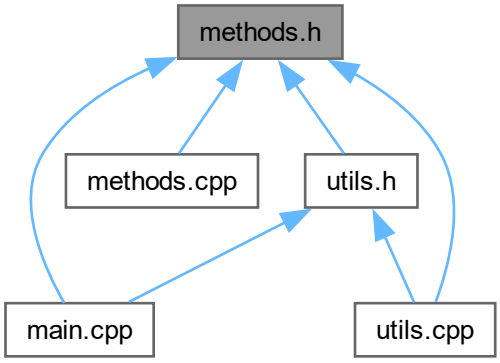
5.6 methods.h File Reference

```
#include <vector>
#include <string>
#include "functions.h"
```

Include dependency graph for methods.h:



This graph shows which files directly or indirectly include this file:



Classes

- struct RootInfo

Functions

- long double bisection (long double a, long double b, long double tol, int max_iter, std::vector< std::string > &iterations, int decimal_places)
- long double newton_raphson (long double x0, long double tol, int max_iter, std::vector< std::string > &iterations, int decimal_places)
- long double hybrid_method (long double a, long double b, long double tol, int max_iter, std::vector< std::string > &iterations, int decimal_places)
- long double brent_method (long double a, long double b, long double tol, int max_iter, std::vector< std::string > &iterations, int decimal_places)
- long double ridder_method (long double a, long double b, long double tol, int max_iter, std::vector< std::string > &iterations, int decimal_places)

5.6.1 Function Documentation

5.6.1.1 bisection()

```
long double bisection (
              long double a,
              long double b,
              long double tol,
              int max_iter,
              std::vector< std::string > & iterations,
              int decimal_places)
00018 {
00019     long double fa = f(a), fb = f(b);
00020     if (fa * fb >= 0)
00021     {
00022         std::cerr « "Bisection method fails. f(a) and f(b) should have opposite signs.\n";
```

```
00023         return NAN;
00024     }
00025
00026     long double c = a;
00027     for (int i = 0; i < max_iter; ++i)
00028     {
00029         c = (a + b) / 2.0L;
00030         long double fc = f(c);
00031         std::ostringstream oss;
00032         oss « "Step " « i + 1 « ": [" « std::fixed « std::setprecision(decimal_places) « a « ", " « b
      « "]";
00033         iterations.push_back(oss.str());
00034         if ((b - a) / 2.0L < tol)
00035             break;
00036         if (fa * fc < 0)
00037         {
00038             b = c;
00039             fb = fc;
00040         }
00041         else
00042         {
00043             a = c;
00044             fa = fc;
00045         }
00046     }
00047     return c;
00048 }
```

5.6.1.2 brent_method()

```
long double brent_method (
              long double a,
              long double b,
              long double tol,
              int max_iter,
              std::vector< std::string > & iterations,
              int decimal_places)
00140 {
00141     long double fa = f(a), fb = f(b);
00142     if (fa * fb >= 0)
00143     {
00144         std::cerr « "Brent's method fails. f(a) and f(b) should have opposite signs.\n";
00145         return NAN;
00146     }
00147
00148     if (fabs(fa) < fabs(fb))
00149     {
00150         std::swap(a, b);
00151         std::swap(fa, fb);
00152     }
00153
00154     long double c = a, fc = fa, s = b, fs = fb;
00155     bool mflag = true;
00156     long double d = 0.0;
00157
00158     for (int i = 0; i < max_iter; ++i)
00159     {
00160         if (fb != fc && fa != fc)
00161         {
00162             // Inverse quadratic interpolation
00163             s = (a * fb * fc) / ((fa - fb) * (fa - fc)) +
00164                 (b * fa * fc) / ((fb - fa) * (fb - fc)) +
00165                 (c * fa * fb) / ((fc - fa) * (fc - fb));
00166         }
00167         else
00168         {
00169             // Secant method
00170             s = b - fb * (b - a) / (fb - fa);
00171         }
00172
00173         // Conditions to accept s
00174         bool condition1 = (s < (3 * a + b) / 4.0L || s > b);
00175         bool condition2 = (mflag && fabs(s - b) >= fabs(b - c) / 2.0L);
00176         bool condition3 = (!mflag && fabs(s - b) >= fabs(c - d) / 2.0L);
00177         bool condition4 = (mflag && fabs(b - c) < tol);
00178         bool condition5 = (!mflag && fabs(c - d) < tol);
00179
00180         if (condition1 || condition2 || condition3 || condition4 || condition5)
00181         {
00182             // Bisection method
```

```
00183             s = (a + b) / 2.0L;
00184             mflag = true;
00185         }
00186         else
00187         {
00188             mflag = false;
00189         }
00190 
00191         long double fs_new = f(s);
00192         std::ostringstream oss;
00193         oss « "Step " « i + 1 « ": a = " « std::fixed « std::setprecision(decimal_places) « a
00194             « ", b = " « b « ", s = " « s;
00195         iterations.push_back(oss.str());
00196 
00197         d = c;
00198         c = b;
00199         fc = fb;
00200 
00201         if (fa * fs_new < 0)
00202         {
00203             b = s;
00204             fb = fs_new;
00205         }
00206         else
00207         {
00208             a = s;
00209             fa = fs_new;
00210         }
00211 
00212         if (fabs(fa) < fabs(fb))
00213         {
00214             std::swap(a, b);
00215             std::swap(fa, fb);
00216         }
00217 
00218         if (fabs(b - a) < tol)
00219             break;
00220     }
00221 
00222     return b;
00223 }
```

5.6.1.3 hybrid_method()

```
long double hybrid_method (
            long double a,
            long double b,
            long double tol,
            int max_iter,
            std::vector< std::string > & iterations,
            int decimal_places)
00077 {
00078     long double fa = f(a), fb = f(b);
00079     if (fa * fb >= 0)
00080     {
00081         std::cerr « "Hybrid method fails. f(a) and f(b) should have opposite signs.\n";
00082         return NAN;
00083     }
00084 
00085     long double c = a;
00086     for (int i = 0; i < max_iter; ++i)
00087     {
00088         c = (a + b) / 2.0L;
00089         long double fc = f(c);
00090         std::ostringstream oss;
00091         oss « "Step " « i + 1 « ": [" « std::fixed « std::setprecision(decimal_places) « a « ", " « b
    « "]";
00092         iterations.push_back(oss.str());
00093         if ((b - a) / 2.0L < tol)
00094             break;
00095 
00096         long double fpc = f_prime(c);
00097         if (fpc != 0.0)
00098         {
00099             long double d = c - fc / fpc;
00100             if (d > a && d < b)
00101             {
00102                 long double fd = f(d);
00103                 std::ostringstream oss_newton;
00104                 oss_newton « "Newton Step: c = " « std::fixed « std::setprecision(decimal_places) « c
```

```
00105                           « ", d = " « d;
00106                 iterations.push_back(oss_newton.str());
00107                 if (fabs(d - c) < tol)
00108                     return d;
00109                 if (fa * fd < 0)
00110                 {
00111                     b = d;
00112                     fb = fd;
00113                 }
00114                 else
00115                 {
00116                     a = d;
00117                     fa = fd;
00118                 }
00119                 continue;
00120             }
00121         }
00122
00123         // Fallback to bisection
00124         if (fa * fc < 0)
00125         {
00126             b = c;
00127             fb = fc;
00128         }
00129         else
00130         {
00131             a = c;
00132             fa = fc;
00133         }
00134     }
00135     return c;
00136 }
```

5.6.1.4 newton_raphson()

```
long double newton_raphson (
              long double x0,
              long double tol,
              int max_iter,
              std::vector< std::string > & iterations,
              int decimal_places)
00052 {
00053     long double x1;
00054     for (int i = 0; i < max_iter; ++i)
00055     {
00056         long double fx0 = f(x0);
00057         long double fpx0 = f_prime(x0);
00058         if (fpx0 == 0.0)
00059         {
00060             std::cerr « "Newton-Raphson method fails. Derivative zero.\n";
00061             return NAN;
00062         }
00063         x1 = x0 - fx0 / fpx0;
00064         std::ostringstream oss;
00065         oss « "Step " « i + 1 « ": x0 = " « std::fixed « std::setprecision(decimal_places) « x0
00066             « ", x1 = " « x1;
00067         iterations.push_back(oss.str());
00068         if (fabs(x1 - x0) < tol)
00069             break;
00070         x0 = x1;
00071     }
00072     return x1;
00073 }
```

5.6.1.5 ridder_method()

```
long double ridder_method (
              long double a,
              long double b,
              long double tol,
              int max_iter,
              std::vector< std::string > & iterations,
              int decimal_places)
```

```
00227 {
00228     long double fa = f(a), fb = f(b);
00229     if (fa * fb >= 0)
00230     {
00231         std::cerr « "Ridder's method fails. f(a) and f(b) should have opposite signs.\n";
00232         return NAN;
00233     }
00234 
00235     for (int i = 0; i < max_iter; ++i)
00236     {
00237         long double c = 0.5L * (a + b);
00238         long double fc = f(c);
00239         long double s_sq = fc * fc - fa * fb;
00240         if (s_sq < 0.0)
00241         {
00242             std::cerr « "Ridder's method fails. Square root of negative number.\n";
00243             return NAN;
00244         }
00245         long double s = sqrt(s_sq);
00246         if (s == 0.0)
00247             return c;
00248 
00249         long double sign = ((fa - fb) < 0) ? -1.0L : 1.0L;
00250         long double x = c + (c - a) * fc / s * sign;
00251         long double fx = f(x);
00252         std::ostringstream oss;
00253         oss « "Step " « i + 1 « ": [" « std::fixed « std::setprecision(decimal_places) « a « ", " « b
    « "]";
00254         iterations.push_back(oss.str());
00255 
00256         if (fabs(fx) < tol)
00257             return x;
00258 
00259         if (fc * fx < 0.0)
00260         {
00261             a = c;
00262             fa = fc;
00263             b = x;
00264             fb = fx;
00265         }
00266         else if (fa * fx < 0.0)
00267         {
00268             b = x;
00269             fb = fx;
00270         }
00271         else
00272         {
00273             a = x;
00274             fa = fx;
00275         }
00276 
00277         if (fabs(b - a) < tol)
00278             break;
00279     }
00280 
00281     return 0.5L * (a + b);
00282 }
```

5.7 methods.h

Go to the documentation of this file.

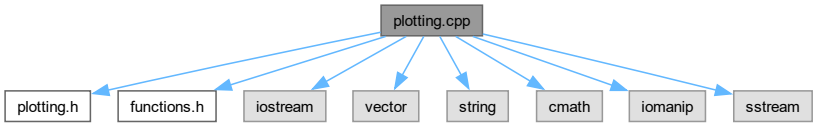
```
00001 /*
00002 @Author: Gilbert Young
00003 @Time: 2024/09/19 01:47
00004 @File_name: methods.h
00005 @IDE: VSCode
00006 @Formatter: Clang-Format
00007 @Description: Declaration of various root-finding methods.
00008 */
00009 
00010 #ifndef METHODS_H
00011 #define METHODS_H
00012 
00013 #include <vector>
00014 #include <string>
00015 #include "functions.h"
00016 
00017 struct RootInfo
00018 {
00019     long double root;   // Root value
00020     int iterations;     // Number of iterations
```

```
00021     int decimal_places; // Number of decimal places to display
00022 };
00023
00024 // Bisection Method
00025 long double bisection(long double a, long double b, long double tol, int max_iter,
      std::vector<std::string> &iterations, int decimal_places);
00026
00027 // Newton-Raphson Method
00028 long double newton_raphson(long double x0, long double tol, int max_iter, std::vector<std::string>
      &iterations, int decimal_places);
00029
00030 // Hybrid Method (Bisection + Newton-Raphson)
00031 long double hybrid_method(long double a, long double b, long double tol, int max_iter,
      std::vector<std::string> &iterations, int decimal_places);
00032
00033 // Brent's Method
00034 long double brent_method(long double a, long double b, long double tol, int max_iter,
      std::vector<std::string> &iterations, int decimal_places);
00035
00036 // Ridder's Method
00037 long double ridder_method(long double a, long double b, long double tol, int max_iter,
      std::vector<std::string> &iterations, int decimal_places);
00038
00039 #endif // METHODS_H
```

5.8 plotting.cpp File Reference

```
#include "plotting.h"
#include "functions.h"
#include <iostream>
#include <vector>
#include <string>
#include <cmath>
#include <iomanip>
#include <sstream>
```

Include dependency graph for plotting.cpp:



Functions

- void plot_function (long double x_min, long double x_max, long double y_min, long double y_max, int width, int height, long double label_interval)

5.8.1 Function Documentation

5.8.1.1 plot_function()

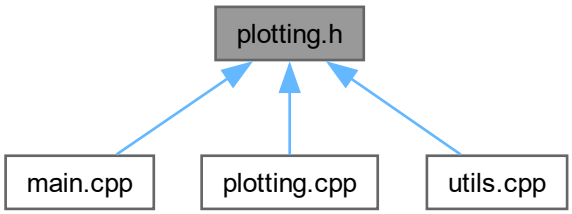
```
void plot_function (
            long double x_min,
            long double x_max,
            long double y_min,
```

```
            long double y_max,
            int width,
            int height,
            long double label_interval)
00022 {
00023     std::vector<std::string> grid(height, std::string(width, ' '));
00024     int x_axis = -1, y_axis = -1;
00025
00026     // Determine x-axis position
00027     if (y_min <= 0 && y_max >= 0)
00028     {
00029         x_axis = static_cast<int>(round((0 - y_min) / (y_max - y_min) * (height - 1)));
00030     }
00031
00032     // Determine y-axis position
00033     if (x_min <= 0 && x_max >= 0)
00034     {
00035         y_axis = static_cast<int>(round((0 - x_min) / (x_max - x_min) * (width - 1)));
00036     }
00037
00038     // Plot the function
00039     for (int i = 0; i < width; ++i)
00040     {
00041         long double x = x_min + i * (x_max - x_min) / (width - 1);
00042         long double y = f(x);
00043         if (y < y_min || y > y_max)
00044             continue;
00045         int j = static_cast<int>(round((y - y_min) / (y_max - y_min) * (height - 1)));
00046         if (j >= 0 && j < height)
00047         {
00048             grid[height - 1 - j][i] = '*';
00049         }
00050     }
00051
00052     // Draw x-axis
00053     if (x_axis != -1)
00054     {
00055         for (int i = 0; i < width; ++i)
00056         {
00057             if (grid[x_axis][i] == ' ')
00058                 grid[x_axis][i] = '-';
00059         }
00060     }
00061
00062     // Draw y-axis
00063     if (y_axis != -1)
00064     {
00065         for (int i = 0; i < height; ++i)
00066         {
00067             if (grid[i][y_axis] == ' ')
00068                 grid[i][y_axis] = '|';
00069         }
00070     }
00071
00072     // Draw origin
00073     if (x_axis != -1 && y_axis != -1)
00074     {
00075         grid[x_axis][y_axis] = '+';
00076     }
00077
00078     // Print the grid
00079     std::cout « "\nFunction Plot:\n";
00080     for (const auto &row : grid)
00081     {
00082         std::cout « row « '\n';
00083     }
00084
00085     // Print x-axis labels
00086     std::string label_line(width, ' ');
00087     for (int label = static_cast<int>(ceil(x_min / label_interval)) *
    static_cast<int>(label_interval);
00088          label <= static_cast<int>(floor(x_max / label_interval)) * static_cast<int>(label_interval);
00089          label += static_cast<int>(label_interval))
00090     {
00091         double relative_pos = (static_cast<double>(label) - x_min) / (x_max - x_min);
00092         int pos = static_cast<int>(round(relative_pos * (width - 1)));
00093         std::ostringstream oss_label;
00094         oss_label « std::fixed « std::setprecision(0) « label;
00095         std::string label_str = oss_label.str();
00096         int start_pos = pos - static_cast<int>(label_str.length() / 2);
00097         if (start_pos < 0)
00098             start_pos = 0;
00099         if (start_pos + static_cast<int>(label_str.length()) > width)
00100             continue;
00101         for (size_t i = 0; i < label_str.length(); ++i)
00102         {
```

```
00103             label_line[start_pos + i] = label_str[i];
00104         }
00105     }
00106     std::cout « label_line « std::endl;
00107     std::cout « "x range: [" « x_min « ", " « x_max « "]\n";
00108     std::cout « "y range: [" « y_min « ", " « y_max « "]\n\n";
00109 }
```

5.9 plotting.h File Reference

This graph shows which files directly or indirectly include this file:



Functions

- void plot_function (long double x_min, long double x_max, long double y_min, long double y_max, int width=60, int height=20, long double label_interval=1.0)

5.9.1 Function Documentation

5.9.1.1 plot_function()

```
void plot_function (
            long double x_min,
            long double x_max,
            long double y_min,
            long double y_max,
            int width = 60,
            int height = 20,
            long double label_interval = 1.0)
00022 {
00023     std::vector<std::string> grid(height, std::string(width, ' '));
00024     int x_axis = -1, y_axis = -1;
00025
00026     // Determine x-axis position
00027     if (y_min <= 0 && y_max >= 0)
00028     {
00029         x_axis = static_cast<int>(round((0 - y_min) / (y_max - y_min) * (height - 1)));
00030     }
00031
00032     // Determine y-axis position
00033     if (x_min <= 0 && x_max >= 0)
00034     {
00035         y_axis = static_cast<int>(round((0 - x_min) / (x_max - x_min) * (width - 1)));
00036     }
```

```
00037
00038     // Plot the function
00039     for (int i = 0; i < width; ++i)
00040     {
00041         long double x = x_min + i * (x_max - x_min) / (width - 1);
00042         long double y = f(x);
00043         if (y < y_min || y > y_max)
00044             continue;
00045         int j = static_cast<int>(round((y - y_min) / (y_max - y_min) * (height - 1)));
00046         if (j >= 0 && j < height)
00047         {
00048             grid[height - 1 - j][i] = '*';
00049         }
00050     }
00051
00052     // Draw x-axis
00053     if (x_axis != -1)
00054     {
00055         for (int i = 0; i < width; ++i)
00056         {
00057             if (grid[x_axis][i] == ' ')
00058                 grid[x_axis][i] = '-';
00059         }
00060     }
00061
00062     // Draw y-axis
00063     if (y_axis != -1)
00064     {
00065         for (int i = 0; i < height; ++i)
00066         {
00067             if (grid[i][y_axis] == ' ')
00068                 grid[i][y_axis] = '|';
00069         }
00070     }
00071
00072     // Draw origin
00073     if (x_axis != -1 && y_axis != -1)
00074     {
00075         grid[x_axis][y_axis] = '+';
00076     }
00077
00078     // Print the grid
00079     std::cout << "\nFunction Plot:\n";
00080     for (const auto &row : grid)
00081     {
00082         std::cout << row << '\n';
00083     }
00084
00085     // Print x-axis labels
00086     std::string label_line(width, ' ');
00087     for (int label = static_cast<int>(ceil(x_min / label_interval)) *
      static_cast<int>(label_interval);
00088          label <= static_cast<int>(floor(x_max / label_interval)) * static_cast<int>(label_interval);
00089          label += static_cast<int>(label_interval))
00090     {
00091         double relative_pos = (static_cast<double>(label) - x_min) / (x_max - x_min);
00092         int pos = static_cast<int>(round(relative_pos * (width - 1)));
00093         std::ostringstream oss_label;
00094         oss_label << std::fixed << std::setprecision(0) << label;
00095         std::string label_str = oss_label.str();
00096         int start_pos = pos - static_cast<int>(label_str.length() / 2);
00097         if (start_pos < 0)
00098             start_pos = 0;
00099         if (start_pos + static_cast<int>(label_str.length()) > width)
00100             continue;
00101         for (size_t i = 0; i < label_str.length(); ++i)
00102         {
00103             label_line[start_pos + i] = label_str[i];
00104         }
00105     }
00106     std::cout << label_line << std::endl;
00107     std::cout << "x range: [" << x_min << ", " << x_max << "]\n";
00108     std::cout << "y range: [" << y_min << ", " << y_max << "]\n\n";
00109 }
```

5.10 plotting.h

Go to the documentation of this file.

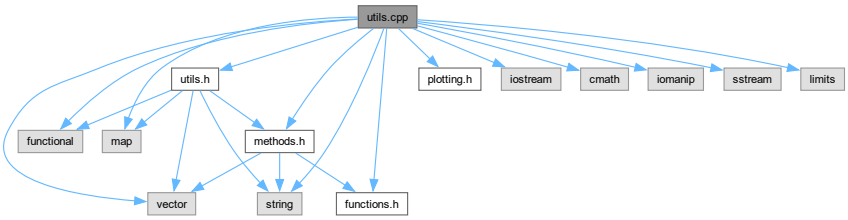
```
00001 /*
00002 @Author: Gilbert Young
00003 @Time: 2024/09/19 01:47
```

```
00004 @File_name: plotting.h
00005 @IDE: VSCode
00006 @Formatter: Clang-Format
00007 @Description: Declaration of function to plot f(x) on a grid.
00008 */
00009
00010 #ifndef PLOTTING_H
00011 #define PLOTTING_H
00012
00013 void plot_function(long double x_min, long double x_max, long double y_min, long double y_max,
00014                    int width = 60, int height = 20, long double label_interval = 1.0);
00015
00016 #endif // PLOTTING_H
```

5.11 utils.cpp File Reference

```
#include "utils.h"
#include "methods.h"
#include "functions.h"
#include "plotting.h"
#include <iostream>
#include <cmath>
#include <iomanip>
#include <sstream>
#include <vector>
#include <map>
#include <string>
#include <functional>
#include <limits>
```

Include dependency graph for utils.cpp:



Functions

- void run_method (const std::string &method_name, std::function< long double(long double, long double, long double, int, std::vector< std::string > &, int)> method_func, long double a, long double b, long double tol, int max_iter, int decimal_places)
- void run_problem_steps ()
- void compare_all_methods ()
- void get_user_input (long double &a, long double &b, long double &x0, std::string &method_name, long double &tol)
- int calculate_decimal_places (long double tol)
- void run_method_user_selection (const std::string &method_name, std::function< long double(long double, long double, long double, int, std::vector< std::string > &, int)> method_func, long double a, long double b, long double tol, int max_iter)

Variables

- std::map< std::string, std::vector< RootInfo > > summary

5.11.1 Function Documentation

5.11.1.1 calculate_decimal_places()

```
int calculate_decimal_places (
            long double tol)
00298 {
00299     if (tol <= 0)
00300         return 0;
00301     return static_cast<int>(ceil(-log10(tol))) + 1;
00302 }
```

5.11.1.2 compare_all_methods()

```
void compare_all_methods ()
00142 {
00143     // Define intervals for three roots
00144     std::vector<std::pair<long double, long double» intervals = {
00145         {-3.0L, -2.0L}, // Negative root
00146         {0.0L, 1.0L},   // First positive root
00147         {1.0L, 3.0L}    // Second positive root
00148     };
00149
00150     // Define tolerances and maximum iterations
00151     long double tol = 1e-14L; // 14 decimal places
00152     int max_iter = 1000;
00153
00154     // List of methods to compare
00155     std::vector<std::pair<std::string, std::function<long double(long double, long double, long
      double, int, std::vector<std::string> &, int)»> methods = {
00156         {"Bisection Method", [](long double a, long double b, long double tol, int max_iter,
      std::vector<std::string> &iterations, int decimal_places) -> long double
00157          {
00158              return bisection(a, b, tol, max_iter, iterations, decimal_places);
00159          }},
00160         {"Newton-Raphson Method", [](long double a, long double b, long double tol, int max_iter,
      std::vector<std::string> &iterations, int decimal_places) -> long double
00161          {
00162              // For Newton-Raphson, use the midpoint as the initial guess
00163              long double initial_guess = (a + b) / 2.0L;
00164              return newton_raphson(initial_guess, tol, max_iter, iterations, decimal_places);
00165          }},
00166         {"Hybrid Method", [](long double a, long double b, long double tol, int max_iter,
      std::vector<std::string> &iterations, int decimal_places) -> long double
00167          {
00168              return hybrid_method(a, b, tol, max_iter, iterations, decimal_places);
00169          }},
00170         {"Brent's Method", [](long double a, long double b, long double tol, int max_iter,
      std::vector<std::string> &iterations, int decimal_places) -> long double
00171          {
00172              return brent_method(a, b, tol, max_iter, iterations, decimal_places);
00173          }},
00174         {"Ridder's Method", [](long double a, long double b, long double tol, int max_iter,
      std::vector<std::string> &iterations, int decimal_places) -> long double
00175          {
00176              return ridder_method(a, b, tol, max_iter, iterations, decimal_places);
00177          }}};
00178
00179     // Store comparison results
00180     std::map<std::string, std::vector<RootInfo» comparison_results;
00181
00182     // Run each method for each interval
00183     for (const auto &method : methods)
00184     {
00185         for (const auto &interval : intervals)
00186         {
00187             std::vector<std::string> iterations;
00188             long double root = method.second(interval.first, interval.second, tol, max_iter,
      iterations, 15); // 1e-14 -> 15 decimal places
00189             RootInfo info{root, static_cast<int>(iterations.size()), 15};
```

```
00190             comparison_results[method.first].emplace_back(info);
00191         }
00192     }
00193
00194     // Display comparison table
00195     std::cout « "\n--- Comparison of All Methods (Precision: 1e-14) ---\n\n";
00196
00197     // Table header
00198     std::cout « std::left « std::setw(25) « "Method"
00199               « std::setw(30) « "Root 1 (-3,-2)"
00200               « std::setw(15) « "Iterations"
00201               « std::setw(30) « "Root 2 (0,1)"
00202               « std::setw(15) « "Iterations"
00203               « std::setw(30) « "Root 3 (1,3)"
00204               « std::setw(15) « "Iterations" « "\n";
00205
00206     // Separator
00207     std::cout « std::string(130, '-') « "\n";
00208
00209     // Table rows
00210     for (const auto &method : methods)
00211     {
00212         std::cout « std::left « std::setw(25) « method.first;
00213         for (size_t i = 0; i < intervals.size(); ++i)
00214         {
00215             if (comparison_results[method.first][i].root != comparison_results[method.first][i].root)
00216             {
00217                 // Check for NAN
00218                 std::cout « std::left « std::setw(30) « "N/A"
00219                           « std::left « std::setw(15) « "N/A";
00220             }
00221             else
00222             {
00223                 std::cout « std::left « std::setw(30) « std::fixed « std::setprecision(15) «
    comparison_results[method.first][i].root
00224                           « std::left « std::setw(15) «
    comparison_results[method.first][i].iterations;
00225             }
00226         }
00227         std::cout « "\n";
00228     }
00229
00230     std::cout « "\nNote: Precision is set to 1e-14, output displays 15 decimal places.\n\n";
00231 }
```

5.11.1.3 get_user_input()

```
void get_user_input (
            long double & a,
            long double & b,
            long double & x0,
            std::string & method_name,
            long double & tol)
00235 {
00236     // List of available methods
00237     std::vector<std::string> available_methods = {"Bisection Method", "Hybrid Method", "Brent Method",
    "Ridder Method", "Newton-Raphson Method", "Problem Steps Mode", "Compare All Methods"};
00238
00239     // Display available methods
00240     std::cout « "\nAvailable methods:\n";
00241     for (size_t i = 0; i < available_methods.size(); ++i)
00242     {
00243         std::cout « i + 1 « ". " « available_methods[i] « "\n";
00244     }
00245
00246     // Prompt user to select a method
00247     int method_choice;
00248     std::cout « "Select a method (1-" « available_methods.size() « "): ";
00249     std::cin » method_choice;
00250     while (method_choice < 1 || method_choice > static_cast<int>(available_methods.size()))
00251     {
00252         std::cout « "Invalid choice. Please select a method (1-" « available_methods.size() « "): ";
00253         std::cin » method_choice;
00254     }
00255     method_name = available_methods[method_choice - 1];
00256
00257     if (method_name == "Newton-Raphson Method")
00258     {
00259         // Prompt user to input initial guess x0
00260         std::cout « "Enter initial guess x0: ";
```

```
00261         std::cin » x0;
00262     }
00263     else if (method_name != "Problem Steps Mode" && method_name != "Compare All Methods")
00264     {
00265         // Prompt user to input interval [a, b]
00266         std::cout « "Enter interval [a, b]:\n";
00267         std::cout « "a = ";
00268         std::cin » a;
00269         std::cout « "b = ";
00270         std::cin » b;
00271         while (a >= b)
00272         {
00273             std::cout « "Invalid interval. 'a' should be less than 'b'. Please re-enter:\n";
00274             std::cout « "a = ";
00275             std::cin » a;
00276             std::cout « "b = ";
00277             std::cin » b;
00278         }
00279     }
00280
00281     if (method_name != "Problem Steps Mode" && method_name != "Compare All Methods")
00282     {
00283         // Prompt user to input desired precision
00284         std::cout « "Enter desired precision (e.g., 1e-14, up to 1e-16): ";
00285         std::cin » tol;
00286         const long double min_tol = 1e-16L;
00287         const long double max_tol = 1e-4L;
00288         while (tol < min_tol || tol > max_tol)
00289         {
00290             std::cout « "Precision out of bounds (" « min_tol « " to " « max_tol « "). Please
      re-enter: ";
00291             std::cin » tol;
00292         }
00293     }
00294 }
```

5.11.1.4 run_method()

```
void run_method (
             const std::string & method_name,
             std::function< long double(long double, long double, long double, int, std↩
::vector< std::string > &, int)> method_func,
             long double a,
             long double b,
             long double tol,
             int max_iter,
             int decimal_places)
00031 {
00032     std::vector<std::string> iterations;
00033     long double root = method_func(a, b, tol, max_iter, iterations, decimal_places);
00034
00035     RootInfo info{root, static_cast<int>(iterations.size()), decimal_places};
00036     summary[method_name].emplace_back(info);
00037
00038     // Display results
00039     std::cout « "\nMethod: " « method_name « "\n";
00040     if (method_name == "Newton-Raphson Method")
00041     {
00042         std::cout « "Initial guess: x0 = " « std::fixed « std::setprecision(decimal_places) « a «
      "\n";
00043     }
00044     else
00045     {
00046         std::cout « "Interval: [" « std::fixed « std::setprecision(2) « a « ", " « b « "]\n";
00047     }
00048     std::cout « "Root: " « std::fixed « std::setprecision(decimal_places) « root « "\n";
00049     std::cout « "Iterations:\n";
00050     for (const auto &iter : iterations)
00051     {
00052         std::cout « iter « "\n";
00053     }
00054     std::cout « "Iterations Count: " « iterations.size() « "\n";
00055 }
```

5.11.1.5 run_method_user_selection()

```
void run_method_user_selection (
```

```
            const std::string & method_name,
            std::function< long double(long double, long double, long double, int, std↩
::vector< std::string > &, int)> method_func,
            long double a,
            long double b,
            long double tol,
            int max_iter)
00308 {
00309     int decimal_places = calculate_decimal_places(tol);
00310     run_method(method_name, method_func, a, b, tol, max_iter, decimal_places);
00311 }
```

5.11.1.6 run_problem_steps()

```
void run_problem_steps ()
00059 {
00060     // Define intervals for three roots
00061     std::vector<std::pair<long double, long double» intervals = {
00062         {-3.0L, -2.0L}, // Negative root
00063         {0.0L, 1.0L},   // First positive root
00064         {1.0L, 3.0L}    // Second positive root
00065     };
00066
00067     // Vector to store roots found in part (i)
00068     std::vector<long double> found_roots;
00069
00070     // Define tolerances and maximum iterations
00071     long double tol_bisection = 1e-4L; // 4 decimal places
00072     long double tol_newton = 1e-14L;   // 14 decimal places
00073     long double tol_hybrid = 1e-14L;   // 14 decimal places
00074     int max_iter = 1000;
00075
00076     std::cout « "\n--- Problem Steps Execution ---\n";
00077
00078     // Part (i): Bisection Method to find three roots to 4 decimal places
00079     std::cout « "\nPart (i): Bisection Method to find roots to 4 decimal places\n";
00080     for (const auto &interval : intervals)
00081     {
00082         std::vector<std::string> iterations;
00083         long double root = bisection(interval.first, interval.second, tol_bisection, max_iter,
      iterations, 4);
00084         RootInfo info{root, static_cast<int>(iterations.size()), 4};
00085         summary["Bisection Method"].emplace_back(info);
00086
00087         // Store the found root
00088         found_roots.emplace_back(root);
00089
00090         std::cout « "Root in [" « std::fixed « std::setprecision(2) « interval.first « ", " «
      interval.second « "]: "
00091                   « std::fixed « std::setprecision(4) « root « "\n";
00092         std::cout « "Iterations: " « iterations.size() « "\n";
00093     }
00094
00095     // Part (ii): Newton-Raphson Method to refine the three roots to 14 decimal places
00096     std::cout « "\nPart (ii): Newton-Raphson Method to refine roots to 14 decimal places\n";
00097     for (auto &x0 : found_roots)
00098     {
00099         std::vector<std::string> iterations;
00100         long double root = newton_raphson(x0, tol_newton, max_iter, iterations, 14);
00101         RootInfo info{root, static_cast<int>(iterations.size()), 14};
00102         summary["Newton-Raphson Method"].emplace_back(info);
00103
00104         std::cout « "Refined root starting from " « std::fixed « std::setprecision(4) « x0 « ": "
00105                   « std::fixed « std::setprecision(14) « root « "\n";
00106         std::cout « "Iterations: " « iterations.size() « "\n";
00107     }
00108
00109     // Part (iii): Hybrid Method to find three roots to 14 decimal places
00110     std::cout « "\nPart (iii): Hybrid Method to find roots to 14 decimal places\n";
00111     for (const auto &interval : intervals)
00112     {
00113         std::vector<std::string> iterations;
00114         long double root = hybrid_method(interval.first, interval.second, tol_hybrid, max_iter,
      iterations, 14);
00115         RootInfo info{root, static_cast<int>(iterations.size()), 14};
00116         summary["Hybrid Method"].emplace_back(info);
00117
00118         std::cout « "Root in [" « std::fixed « std::setprecision(2) « interval.first « ", " «
      interval.second « "] (Hybrid): "
00119                   « std::fixed « std::setprecision(14) « root « "\n";
```

```
00120         std::cout « "Iterations: " « iterations.size() « "\n";
00121     }
00122
00123     // Output summary of results for problem steps
00124     std::cout « "\n--- Summary of Problem Steps Results ---\n";
00125     for (const auto &method : summary)
00126     {
00127         std::cout « "\nMethod: " « method.first « "\n";
00128         int idx = 1;
00129         for (const auto &info : method.second)
00130         {
00131             std::cout « "  Root " « idx++ « ": " « std::fixed « std::setprecision(info.decimal_places)
      « info.root
00132                       « " | Iterations: " « info.iterations « "\n";
00133         }
00134     }
00135
00136     // Clear summary for next run
00137     summary.clear();
00138 }
```

5.11.2 Variable Documentation

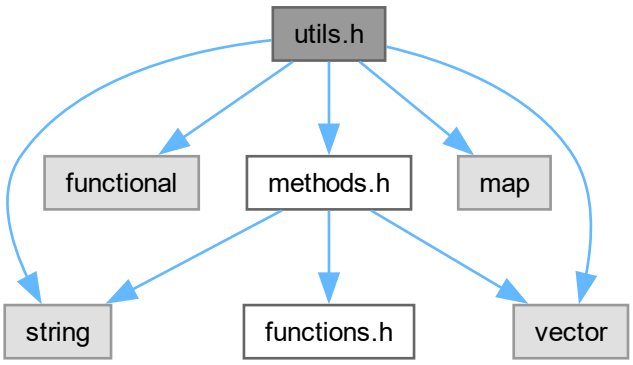
5.11.2.1 summary

```
std::map<std::string, std::vector<RootInfo> > summary
```

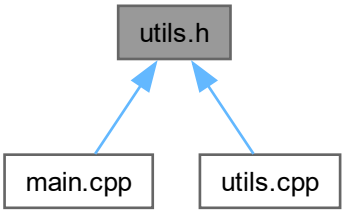
5.12 utils.h File Reference

```
#include <string>
#include <functional>
#include <vector>
#include <map>
#include "methods.h"
```

Include dependency graph for utils.h:



This graph shows which files directly or indirectly include this file:



Functions

- void run_method (const std::string &method_name, std::function< long double(long double, long double, long double, int, std::vector< std::string > &, int)> method_func, long double a, long double b, long double tol, int max_iter, int decimal_places)
- void run_problem_steps ()
- void compare_all_methods ()
- void get_user_input (long double &a, long double &b, long double &x0, std::string &method_name, long double &tol)
- int calculate_decimal_places (long double tol)
- void run_method_user_selection (const std::string &method_name, std::function< long double(long double, long double, long double, int, std::vector< std::string > &, int)> method_func, long double a, long double b, long double tol, int max_iter)

Variables

- std::map< std::string, std::vector< RootInfo > > summary

5.12.1 Function Documentation

5.12.1.1 calculate_decimal_places()

```
int calculate_decimal_places (
            long double tol)
00298 {
00299     if (tol <= 0)
00300         return 0;
00301     return static_cast<int>(ceil(-log10(tol))) + 1;
00302 }
```

5.12.1.2 compare_all_methods()

```
void compare_all_methods ()
00142 {
00143     // Define intervals for three roots
00144     std::vector<std::pair<long double, long double» intervals = {
00145         {-3.0L, -2.0L}, // Negative root
00146         {0.0L, 1.0L},   // First positive root
00147         {1.0L, 3.0L}    // Second positive root
00148     };
00149
00150     // Define tolerances and maximum iterations
00151     long double tol = 1e-14L; // 14 decimal places
00152     int max_iter = 1000;
00153
00154     // List of methods to compare
00155     std::vector<std::pair<std::string, std::function<long double(long double, long double, long
      double, int, std::vector<std::string> &, int)»> methods = {
00156         {"Bisection Method", [](long double a, long double b, long double tol, int max_iter,
      std::vector<std::string> &iterations, int decimal_places) -> long double
00157          {
00158              return bisection(a, b, tol, max_iter, iterations, decimal_places);
00159          }},
00160         {"Newton-Raphson Method", [](long double a, long double b, long double tol, int max_iter,
      std::vector<std::string> &iterations, int decimal_places) -> long double
00161          {
00162              // For Newton-Raphson, use the midpoint as the initial guess
00163              long double initial_guess = (a + b) / 2.0L;
00164              return newton_raphson(initial_guess, tol, max_iter, iterations, decimal_places);
00165          }},
00166         {"Hybrid Method", [](long double a, long double b, long double tol, int max_iter,
      std::vector<std::string> &iterations, int decimal_places) -> long double
00167          {
00168              return hybrid_method(a, b, tol, max_iter, iterations, decimal_places);
00169          }},
00170         {"Brent's Method", [](long double a, long double b, long double tol, int max_iter,
      std::vector<std::string> &iterations, int decimal_places) -> long double
00171          {
00172              return brent_method(a, b, tol, max_iter, iterations, decimal_places);
00173          }},
00174         {"Ridder's Method", [](long double a, long double b, long double tol, int max_iter,
      std::vector<std::string> &iterations, int decimal_places) -> long double
00175          {
00176              return ridder_method(a, b, tol, max_iter, iterations, decimal_places);
00177          }}};
00178
00179     // Store comparison results
00180     std::map<std::string, std::vector<RootInfo» comparison_results;
00181
00182     // Run each method for each interval
00183     for (const auto &method : methods)
00184     {
00185         for (const auto &interval : intervals)
00186         {
00187             std::vector<std::string> iterations;
00188             long double root = method.second(interval.first, interval.second, tol, max_iter,
      iterations, 15); // 1e-14 -> 15 decimal places
00189             RootInfo info{root, static_cast<int>(iterations.size()), 15};
00190             comparison_results[method.first].emplace_back(info);
00191         }
00192     }
00193
00194     // Display comparison table
00195     std::cout « "\n--- Comparison of All Methods (Precision: 1e-14) ---\n\n";
00196
00197     // Table header
00198     std::cout « std::left « std::setw(25) « "Method"
00199               « std::setw(30) « "Root 1 (-3,-2)"
00200               « std::setw(15) « "Iterations"
00201               « std::setw(30) « "Root 2 (0,1)"
00202               « std::setw(15) « "Iterations"
00203               « std::setw(30) « "Root 3 (1,3)"
00204               « std::setw(15) « "Iterations" « "\n";
00205
00206     // Separator
00207     std::cout « std::string(130, '-') « "\n";
00208
00209     // Table rows
00210     for (const auto &method : methods)
00211     {
00212         std::cout « std::left « std::setw(25) « method.first;
00213         for (size_t i = 0; i < intervals.size(); ++i)
00214         {
00215             if (comparison_results[method.first][i].root != comparison_results[method.first][i].root)
00216             {
00217                 // Check for NAN
```

```
00218                 std::cout « std::left « std::setw(30) « "N/A"
00219                           « std::left « std::setw(15) « "N/A";
00220             }
00221             else
00222             {
00223                 std::cout « std::left « std::setw(30) « std::fixed « std::setprecision(15) «
    comparison_results[method.first][i].root
00224                           « std::left « std::setw(15) «
    comparison_results[method.first][i].iterations;
00225             }
00226         }
00227         std::cout « "\n";
00228     }
00229
00230     std::cout « "\nNote: Precision is set to 1e-14, output displays 15 decimal places.\n\n";
00231 }
```

5.12.1.3 get_user_input()

```
void get_user_input (
            long double & a,
            long double & b,
            long double & x0,
            std::string & method_name,
            long double & tol)
00235 {
00236     // List of available methods
00237     std::vector<std::string> available_methods = {"Bisection Method", "Hybrid Method", "Brent Method",
    "Ridder Method", "Newton-Raphson Method", "Problem Steps Mode", "Compare All Methods"};
00238
00239     // Display available methods
00240     std::cout « "\nAvailable methods:\n";
00241     for (size_t i = 0; i < available_methods.size(); ++i)
00242     {
00243         std::cout « i + 1 « ". " « available_methods[i] « "\n";
00244     }
00245
00246     // Prompt user to select a method
00247     int method_choice;
00248     std::cout « "Select a method (1-" « available_methods.size() « "): ";
00249     std::cin » method_choice;
00250     while (method_choice < 1 || method_choice > static_cast<int>(available_methods.size()))
00251     {
00252         std::cout « "Invalid choice. Please select a method (1-" « available_methods.size() « "): ";
00253         std::cin » method_choice;
00254     }
00255     method_name = available_methods[method_choice - 1];
00256
00257     if (method_name == "Newton-Raphson Method")
00258     {
00259         // Prompt user to input initial guess x0
00260         std::cout « "Enter initial guess x0: ";
00261         std::cin » x0;
00262     }
00263     else if (method_name != "Problem Steps Mode" && method_name != "Compare All Methods")
00264     {
00265         // Prompt user to input interval [a, b]
00266         std::cout « "Enter interval [a, b]:\n";
00267         std::cout « "a = ";
00268         std::cin » a;
00269         std::cout « "b = ";
00270         std::cin » b;
00271         while (a >= b)
00272         {
00273             std::cout « "Invalid interval. 'a' should be less than 'b'. Please re-enter:\n";
00274             std::cout « "a = ";
00275             std::cin » a;
00276             std::cout « "b = ";
00277             std::cin » b;
00278         }
00279     }
00280
00281     if (method_name != "Problem Steps Mode" && method_name != "Compare All Methods")
00282     {
00283         // Prompt user to input desired precision
00284         std::cout « "Enter desired precision (e.g., 1e-14, up to 1e-16): ";
00285         std::cin » tol;
00286         const long double min_tol = 1e-16L;
00287         const long double max_tol = 1e-4L;
00288         while (tol < min_tol || tol > max_tol)
```

```
00289         {
00290             std::cout « "Precision out of bounds (" « min_tol « " to " « max_tol « "). Please
      re-enter: ";
00291             std::cin » tol;
00292         }
00293     }
00294 }
```

5.12.1.4 run_method()

```
void run_method (
              const std::string & method_name,
              std::function< long double(long double, long double, long double, int, std↩
::vector< std::string > &, int)> method_func,
              long double a,
              long double b,
              long double tol,
              int max_iter,
              int decimal_places)
00031 {
00032     std::vector<std::string> iterations;
00033     long double root = method_func(a, b, tol, max_iter, iterations, decimal_places);
00034 
00035     RootInfo info{root, static_cast<int>(iterations.size()), decimal_places};
00036     summary[method_name].emplace_back(info);
00037 
00038     // Display results
00039     std::cout « "\nMethod: " « method_name « "\n";
00040     if (method_name == "Newton-Raphson Method")
00041     {
00042         std::cout « "Initial guess: x0 = " « std::fixed « std::setprecision(decimal_places) « a «
      "\n";
00043     }
00044     else
00045     {
00046         std::cout « "Interval: [" « std::fixed « std::setprecision(2) « a « ", " « b « "]\n";
00047     }
00048     std::cout « "Root: " « std::fixed « std::setprecision(decimal_places) « root « "\n";
00049     std::cout « "Iterations:\n";
00050     for (const auto &iter : iterations)
00051     {
00052         std::cout « iter « "\n";
00053     }
00054     std::cout « "Iterations Count: " « iterations.size() « "\n";
00055 }
```

5.12.1.5 run_method_user_selection()

```
void run_method_user_selection (
              const std::string & method_name,
              std::function< long double(long double, long double, long double, int, std↩
::vector< std::string > &, int)> method_func,
              long double a,
              long double b,
              long double tol,
              int max_iter)
00308 {
00309     int decimal_places = calculate_decimal_places(tol);
00310     run_method(method_name, method_func, a, b, tol, max_iter, decimal_places);
00311 }
```

5.12.1.6 run_problem_steps()

```
void run_problem_steps ()
00059 {
00060     // Define intervals for three roots
```

```
00061     std::vector<std::pair<long double, long double» intervals = {
00062         {-3.0L, -2.0L}, // Negative root
00063         {0.0L, 1.0L},   // First positive root
00064         {1.0L, 3.0L}    // Second positive root
00065     };
00066
00067     // Vector to store roots found in part (i)
00068     std::vector<long double> found_roots;
00069
00070     // Define tolerances and maximum iterations
00071     long double tol_bisection = 1e-4L; // 4 decimal places
00072     long double tol_newton = 1e-14L;   // 14 decimal places
00073     long double tol_hybrid = 1e-14L;   // 14 decimal places
00074     int max_iter = 1000;
00075
00076     std::cout « "\n--- Problem Steps Execution ---\n";
00077
00078     // Part (i): Bisection Method to find three roots to 4 decimal places
00079     std::cout « "\nPart (i): Bisection Method to find roots to 4 decimal places\n";
00080     for (const auto &interval : intervals)
00081     {
00082         std::vector<std::string> iterations;
00083         long double root = bisection(interval.first, interval.second, tol_bisection, max_iter,
    iterations, 4);
00084         RootInfo info{root, static_cast<int>(iterations.size()), 4};
00085         summary["Bisection Method"].emplace_back(info);
00086
00087         // Store the found root
00088         found_roots.emplace_back(root);
00089
00090         std::cout « "Root in [" « std::fixed « std::setprecision(2) « interval.first « ", " «
    interval.second « "]: "
00091                   « std::fixed « std::setprecision(4) « root « "\n";
00092         std::cout « "Iterations: " « iterations.size() « "\n";
00093     }
00094
00095     // Part (ii): Newton-Raphson Method to refine the three roots to 14 decimal places
00096     std::cout « "\nPart (ii): Newton-Raphson Method to refine roots to 14 decimal places\n";
00097     for (auto &x0 : found_roots)
00098     {
00099         std::vector<std::string> iterations;
00100         long double root = newton_raphson(x0, tol_newton, max_iter, iterations, 14);
00101         RootInfo info{root, static_cast<int>(iterations.size()), 14};
00102         summary["Newton-Raphson Method"].emplace_back(info);
00103
00104         std::cout « "Refined root starting from " « std::fixed « std::setprecision(4) « x0 « ": "
00105                   « std::fixed « std::setprecision(14) « root « "\n";
00106         std::cout « "Iterations: " « iterations.size() « "\n";
00107     }
00108
00109     // Part (iii): Hybrid Method to find three roots to 14 decimal places
00110     std::cout « "\nPart (iii): Hybrid Method to find roots to 14 decimal places\n";
00111     for (const auto &interval : intervals)
00112     {
00113         std::vector<std::string> iterations;
00114         long double root = hybrid_method(interval.first, interval.second, tol_hybrid, max_iter,
    iterations, 14);
00115         RootInfo info{root, static_cast<int>(iterations.size()), 14};
00116         summary["Hybrid Method"].emplace_back(info);
00117
00118         std::cout « "Root in [" « std::fixed « std::setprecision(2) « interval.first « ", " «
    interval.second « "] (Hybrid): "
00119                   « std::fixed « std::setprecision(14) « root « "\n";
00120         std::cout « "Iterations: " « iterations.size() « "\n";
00121     }
00122
00123     // Output summary of results for problem steps
00124     std::cout « "\n--- Summary of Problem Steps Results ---\n";
00125     for (const auto &method : summary)
00126     {
00127         std::cout « "\nMethod: " « method.first « "\n";
00128         int idx = 1;
00129         for (const auto &info : method.second)
00130         {
00131             std::cout « "  Root " « idx++ « ": " « std::fixed « std::setprecision(info.decimal_places)
    « info.root
00132                       « " | Iterations: " « info.iterations « "\n";
00133         }
00134     }
00135
00136     // Clear summary for next run
00137     summary.clear();
00138 }
```

5.12.2 Variable Documentation

5.12.2.1 summary

```
std::map<std::string, std::vector<RootInfo> > summary  [extern]
```

5.13 utils.h

Go to the documentation of this file.

```
00001 /*
00002 @Author: Gilbert Young
00003 @Time: 2024/09/19 01:47
00004 @File_name: utils.h
00005 @IDE: VSCode
00006 @Formatter: Clang-Format
00007 @Description: Declarations of utility functions for running methods and handling user input.
00008 */
00009
00010 #ifndef UTILS_H
00011 #define UTILS_H
00012
00013 #include <string>
00014 #include <functional>
00015 #include <vector>
00016 #include <map>
00017 #include "methods.h"
00018
00019 extern std::map<std::string, std::vector<RootInfo» summary;
00020
00021 // Function to run the method and display results
00022 void run_method(const std::string &method_name,
00023                 std::function<long double(long double, long double, long double, int,
      std::vector<std::string> &, int)> method_func,
00024                 long double a, long double b, long double tol, int max_iter,
00025                 int decimal_places);
00026
00027 // Function to run the problem steps
00028 void run_problem_steps();
00029
00030 // Function to compare all methods
00031 void compare_all_methods();
00032
00033 // Function to get user input
00034 void get_user_input(long double &a, long double &b, long double &x0, std::string &method_name, long
      double &tol);
00035
00036 // Function to calculate decimal places based on tolerance
00037 int calculate_decimal_places(long double tol);
00038
00039 // Function to run the method and display results (for user-selected methods)
00040 void run_method_user_selection(const std::string &method_name,
00041                                std::function<long double(long double, long double, long double, int,
      std::vector<std::string> &, int)> method_func,
00042                                long double a, long double b, long double tol, int max_iter);
00043
00044 #endif // UTILS_H
```

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