

Article

Efficient computation of statistical measures using C programming

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Abstract: Accurate computation of statistical measures such as mean, median, mode, variance, and standard deviation is fundamental to data analysis and decision making. Many traditional approaches rely on manual calculations or high-level languages like R and Python, which may not be applicable or feasible in resource-constrained environments or for educational reasons. In this paper, we present a C language implementation capable of calculating central tendency and dispersion measures on a dataset. The program is implemented to take user input dynamically, using loops and functions present results for maximum computational efficiency. A dataset is analyzed using Python to compare the statistical results with those obtained from the C programs. We compared the execution times of Excel and C for large datasets. The results, measured in seconds, show that C is significantly faster than Excel for big data.

Keywords: central tendencies, measure of dispersion, Python, C programming, computational statistics.

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1. Introduction

Statistical analysis plays a central role in various fields such as economics, engineering, social sciences, and particularly data science. Central tendency and dispersion statistics provide useful information on how data is distributed, dispersed, or centralized. Manual calculation or spreadsheet software, however, is ineffective and error-prone when dealing with large data. We study the application of such statistical measures with the programming language C, exploiting its efficiency and low memory layer to efficiently process data. Statistical measures of central tendency and dispersion are fundamental to data analysis, traditionally computed manually or via spreadsheet software such as Microsoft Excel [3]. While manual calculations provide insight, they are time-consuming and prone to human error, especially with large datasets [5]. Programming languages such as Python, R, and MATLAB have been widely adopted for statistical computations due to their built-in functions and libraries [4]-[6]. C is often preferable over Python and R in practical research scenarios due to its superior computational efficiency. Moreover, C allows explicit management of memory and

hardware-level optimization, enabling researchers to implement algorithms with slight overhead and highest performance

Few studies have explored the implementation of statistical measures using C language, despite its advantages in speed, memory management, and applicability to embedded systems and educational tools [1], [2], [11], [14], [17] and [19]. Other studies have highlighted computational statistics education and low-level programming applications [7], [8], [10], [12], [13], [15], [18] and [20]. This study addresses the gap by designing a C-based program to compute measures of central tendency and dispersion, validating its accuracy and efficiency, and providing a framework that can be extended for advanced statistical computations.

Previous studies explored statistical computing using high-level languages such as python, R and MATALAB focusing on ease of implementation and access to comprehensive libraries for regression, machine learning, and data visualization [23]-[26]. Other researchers have implemented core statistical algorithms in C, demonstrating for specific computational tasks [21]-[22]. However, these studies often focus on isolated statistical measures without providing a comprehensive framework that compares the accuracy and efficiency of C language. Consequently, there remains a gap in understanding how C can be systematically applied for statistical analysis in practical research.

The main idea of this article is on developing an efficient and reliable method for computing basic statistical measures using C programming language. While high-level language like R, python and MATLAB dominate statistical computation, they are relying heavily on built-in libraries and are less suitable for environments requiring speed, low-level memory control, and optimized performance. This study addresses the gap by implementing statistical measures of central tendency and dispersion such as mean, median, mode, variance, and standard deviation using C programming language.

2. Methodology

The methodology involves the systematic design and implementation of python and C programs to compute the statistical measures i-e (Mean, Median, Mode, Variance and Standard deviation). The workflow is also illustrated in the flowchart given in Figure 1.

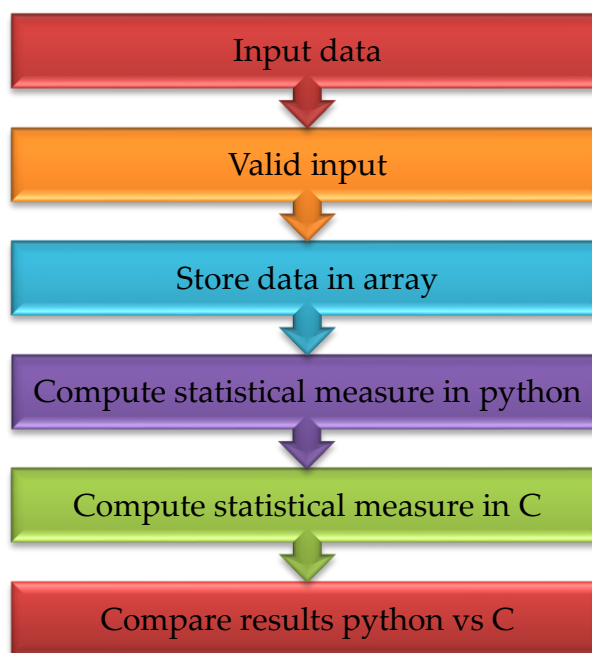


Figure 1. Flowchart for data input and procedure.

2.1. Data Input and procedure:

- Users can enter data manually or read from a file.
- Arrays are used to store the data.
- Input validation ensures only valid numbers are accepted.
- A sample is collected and then the statistical measure is calculated using Python.
- The same dataset is processed using C program to compute this statistical measure.
- Both results are compared to ensure correctness.

Computational of Statistical Measure:

We use a real-life example to calculate this statistical measure. The example is given below

Example 1.

The dataset consists of 66 observations which are used by Cordeiro and Lemonte [27] and Al-Aqtash et al. [28]. The dataset is about on the breaking stress of carbon fibers of 50 mm length. The observations of the data are: 0.39, 1.47, 1.57, 1.61, 1.61, 1.69, 1.80, 1.84, 1.87, 1.89, 2.03, 2.03, 2.05, 2.55, 2.56, 2.59, 2.67, 2.73, 2.74, 2.79, 2.81, 2.82, 2.85, 2.87, 2.88, 2.93, 2.95, 2.96, 2.12, 2.35, 2.41, 2.43, 2.48, 2.50, 2.53, 2.55, 2.97, 0.85, 1.08, 1.25, 3.09, 3.11, 3.11, 3.15, 3.15, 3.19, 3.22, 3.60, 3.65, 3.68, 3.70, 3.75, 4.20, 4.38, 3.22, 3.27, 3.28, 3.31, 3.31, 3.33, 3.39, 3.39, 3.56, 4.42, 4.70, 4.90.

Mean: Implemented as a function to sum all elements and divide by the number of elements. The mean can be calculated as

$$\bar{X} = \frac{1}{n} \sum_{i=1}^n X_i \quad (1)$$

First, we use python programming language to find the mean. To find mean in python we use statistics module. The statistics module contains `statistics.mean` function for calculated the mean. The code is given below

```
import statistics
data = [0.39, 1.47, 1.57, 1.61, 1.61, 1.69, 1.80, 1.84, 1.87, 1.89, 2.03,
        2.03, 2.05, 2.55, 2.56, 2.59, 2.67, 2.73, 2.74, 2.79, 2.81, 2.82, 2.85,
        2.87, 2.88, 2.93, 2.95, 2.96, 2.12, 2.35, 2.41, 2.43, 2.48, 2.50, 2.53,
        2.55, 2.97, 0.85, 1.08, 1.25, 3.09, 3.11, 3.11, 3.15, 3.15, 3.19, 3.22,
        3.60, 3.65, 3.68, 3.70, 3.75, 4.20, 4.38, 3.22, 3.27, 3.28, 3.31, 3.31,
        3.33, 3.39, 3.39, 3.56, 4.42, 4.70, 4.90]
round(statistics.mean(data), 2)
## 2.76
```

The C language code is given in Appendix.

Median: Calculated by sorting the array and selecting the middle element(s). Median can be calculated as

If the dataset has odd number of observations, then median can be calculated as

$$Median = x_{\frac{n+1}{2}} \quad (2)$$

If the dataset has even number of observations, then median can be calculated as

$$Median = \frac{x_{\frac{n}{2}} + x_{\frac{n}{2}+1}}{2} \quad (3)$$

In python programming language `statistics.median` function in the statistics module is use to find

median. For the same data set given in **Example 1** the python code for the median is given as

```
import statistics
data = [0.39, 1.47, 1.57, 1.61, 1.61, 1.69, 1.80, 1.84, 1.87, 1.89, 2.03,
        2.03, 2.05, 2.55, 2.56, 2.59, 2.67, 2.73, 2.74, 2.79, 2.81, 2.82, 2.85,
        2.87, 2.88, 2.93, 2.95, 2.96, 2.12, 2.35, 2.41, 2.43, 2.48, 2.50, 2.53,
        2.55, 2.97, 0.85, 1.08, 1.25, 3.09, 3.11, 3.11, 3.15, 3.15, 3.19, 3.22,
        3.60, 3.65, 3.68, 3.70, 3.75, 4.20, 4.38, 3.22, 3.27, 3.28, 3.31, 3.31,
        3.33, 3.39, 3.39, 3.56 ,4.42, 4.70, 4.90]
round(statistics.median(data), 2)
## 2.83
```

The C language code is given in Appendix.

Mode: The most frequent value in a data set.

In python programming language `statistics.multimode` function in the statistics module are used to find mode when the data contain more than one mode. For the same data set given in **Example 1** the python code for the mode is given as

```
import statistics
data = [0.39, 1.47, 1.57, 1.61, 1.61, 1.69, 1.80, 1.84, 1.87, 1.89, 2.03,
        2.03, 2.05, 2.55, 2.56, 2.59, 2.67, 2.73, 2.74, 2.79, 2.81, 2.82, 2.85,
        2.87, 2.88, 2.93, 2.95, 2.96, 2.12, 2.35, 2.41, 2.43, 2.48, 2.50, 2.53,
        2.55, 2.97, 0.85, 1.08, 1.25, 3.09, 3.11, 3.11, 3.15, 3.15, 3.19, 3.22,
        3.60, 3.65, 3.68, 3.70, 3.75, 4.20, 4.38, 3.22, 3.27, 3.28, 3.31, 3.31,
        3.33, 3.39, 3.39, 3.56, 4.42, 4.70, 4.90]
modes = statistics.multimode(data)
rounded_modes = [round(x, 2) for x in modes]
print(rounded_modes)
## [1.61, 2.03, 2.55, 3.11, 3.15, 3.22, 3.31, 3.39]
```

The C language code is given in Appendix.

Variance: Calculated by the average of the square of observations from the mean. Variance can be calculated as

$$s^2 = \frac{1}{n-1} \sum_{i=1}^n (X_i - \bar{X})^2 \quad (4)$$

In python programming language `statistics.variance` function in the statistics module are used to find variance. For the same data set given in **Example 1** the python code for the variance is given as

```
import statistics
data = [0.39, 1.47, 1.57, 1.61, 1.61, 1.69, 1.80, 1.84, 1.87, 1.89, 2.03,
        2.03, 2.05, 2.55, 2.56, 2.59, 2.67, 2.73, 2.74, 2.79, 2.81, 2.82, 2.85,
        2.87, 2.88, 2.93, 2.95, 2.96, 2.12, 2.35, 2.41, 2.43, 2.48, 2.50, 2.53,
        2.55, 2.97, 0.85, 1.08, 1.25, 3.09, 3.11, 3.11, 3.15, 3.15, 3.19, 3.22,
        3.60, 3.65, 3.68, 3.70, 3.75, 4.20, 4.38, 3.22, 3.27, 3.28, 3.31, 3.31,
        3.33, 3.39, 3.39, 3.56 ,4.42, 4.70, 4.90]
round(statistics.variance(data), 2)
## 0.79
```

The C language code is given in Appendix.

Standard Deviation: Calculating by taking the positive square root of variance. Standard deviation can be

calculated as

$$s = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (X_i - \bar{X})^2} \tag{5}$$

In python programming language `statistics.stdev` function in the `statistics` module are used to find standard deviation. For the same data set given in **Example 1** the python code for the standard deviation is given as

```
import statistics
data = [0.39, 1.47, 1.57, 1.61, 1.61, 1.69, 1.80, 1.84, 1.87, 1.89, 2.03,
        2.03, 2.05, 2.55, 2.56, 2.59, 2.67, 2.73, 2.74, 2.79, 2.81, 2.82, 2.85,
        2.87, 2.88, 2.93, 2.95, 2.96, 2.12, 2.35, 2.41, 2.43, 2.48, 2.50, 2.53,
        2.55, 2.97, 0.85, 1.08, 1.25, 3.09, 3.11, 3.11, 3.15, 3.15, 3.19, 3.22,
        3.60, 3.65, 3.68, 3.70, 3.75, 4.20, 4.38, 3.22, 3.27, 3.28, 3.31, 3.31,
        3.33, 3.39, 3.39, 3.56, 4.42, 4.70, 4.90]
round(statistics.stdev(data), 2)
## 0.89
```

The C language code is given in Appendix.

3. Results

The C program successfully computes all of the statistical measures for the data in **Example 1**. When compared to common tools (such as software or calculators), the results are very accurate and matched. Additionally, when working with large amounts of data, the C program completes calculations faster than spreadsheet programs like Excel or manual methods. This is especially true when we use optimized coding techniques.

We conduct a comparative analysis of execution times (in seconds) between Excel and C for medium to large datasets. They found that if the data size is large, then the performance of Excel drops significantly because of its overhead and limited memory performance of C which achieves a remarkable efficiency in computations. This emphasizes C's superiority in big data processing, thus positioning it as a better option for high-computing tasks that demand speed and resource control. We give a short difference between C and Excel in Table 1. The execution times (in seconds) for various sample sizes was measured over several runs, and the mean value is presented in Table 2. The comparison is also shown graphically in Figure 2.

Table 1. Difference between C and Excel.

Feature	C Language	Excel
Performance	Very fast (compiled code)	Slow for large data
Handles Big Data	Yes (millions of values)	Crashes or freezes
Memory Control	Efficient	Limited
Speed	High	Low for big data
Suitable for Research/Programming	Yes	Limited
Automation	Yes (loops, files, custom code)	Basic formulas only

Table 2. The execution time (sec) for C and Excel.

Dataset Size	Excel Time (sec)	C Language Time (sec)
50	0.000837	0.003312
500	0.000796	0.005623
5,000	0.001405	0.000234
50,000	0.003656	0.002981

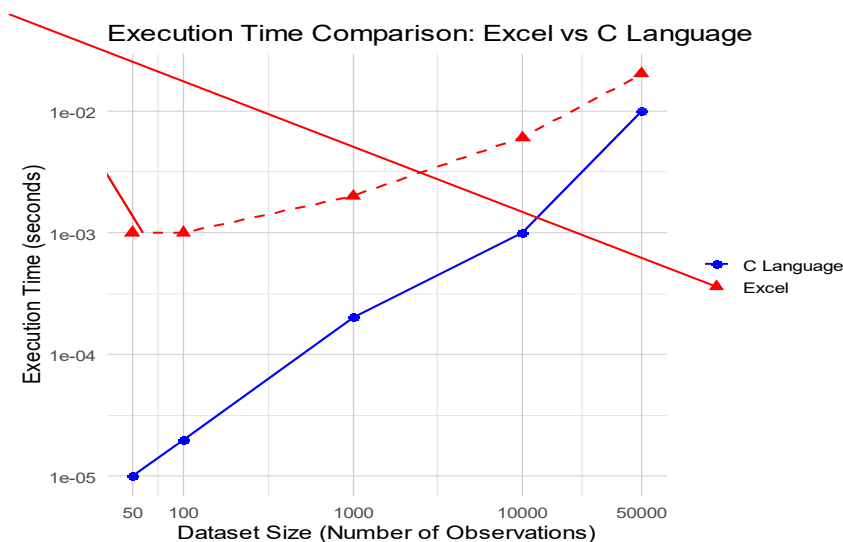


Figure 2. Visual display of the comparison.

From Table 2 and Figure 2 we observe that for large data sets the C language performs better than Excel.

4. Discussion

The study offers several advantages of C language for statistical computation.

- Efficiency: C programs execute faster and use less memory high-level language for large data sets.
- Flexibility: The C programming language offers extensive flexibility, allowing developers to construct optimized, specific algorithms and data structures.
- Practical Application: Suitable for embedded systems, real-time analysis, and scenarios where high-level software is unavailable.

5. Conclusions

This study demonstrates the feasibility and effectiveness of implementing measures of central tendency and dispersion using C programming. The approach provides accurate and efficient computations. Furthermore, the method highlights the advantages of using a low-level programming language for large datasets.

This work contributes to computational statistics education and practice by demonstrating that statistical measures can be implemented efficiently using a low-level programming language such as C. By presenting clear, programs for mean, median, mode, variance, and standard deviation, the study provides learners with practical insights into how statistical formulas translate into executable algorithms. The comparison with Python and Excel further illustrates the performance benefits and computational transparency achieved when using C, helping students and practitioners appreciate the trade-offs between high-level tools and foundational programming approaches.

6. Limitations and Future Work

Limitations include that in C language there is no built-in libraries for statistical computing, requiring manual implementation of all measures. This not only adds to the development effort and allowing for more error-prone code generation, but also provides students and researchers with an opportunity to gain deeper knowledge of algorithms and computational logic. Additionally, this manual method permits greater flexibility in data processing, adapting methods, and optimizing for particular applications, which can be advantageous when dealing with massive datasets or specialized statistical analyses. The methodology can be extended to include other statistical measures such as Harmonic mean, geometric mean, quartiles, skewness and kurtosis.

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Appendix:

C program for Mean:

This C program computes the mean of the dataset given in Example 1.

```
#include <stdio.h>
float Mean(float data[], int size) {
    float sum = 0.0;
    for(int i = 0; i < size; i++) {
        sum += data[i];
    }
    return sum / size;
}
int main() {
    float data[] = {0.39, 1.47, 1.57, 1.61, 1.61, 1.69, 1.80, 1.84, 1.87,
1.89, 2.03, 2.03, 2.05, 2.55, 2.56, 2.59, 2.67, 2.73, 2.74, 2.79, 2.81,
2.82, 2.85, 2.87, 2.88, 2.93, 2.95, 2.96, 2.12, 2.35, 2.41, 2.43, 2.48,
2.50, 2.53, 2.55, 2.97, 0.85, 1.08, 1.25, 3.09, 3.11, 3.11, 3.15, 3.15,
3.19, 3.22, 3.60, 3.65, 3.68, 3.70, 3.75, 4.20, 4.38, 3.22, 3.27, 3.28,
3.31, 3.31, 3.33, 3.39, 3.39, 3.56, 4.42, 4.70, 4.90};
    int size = sizeof(data) / sizeof(data[0]);
    float mean = Mean(data, size);
    printf("Mean = %.2f\n", mean);
    return 0;
}
```

Output:

Mean = 2.76

C program for Median:

This C program computes the median of the dataset given in Example 1.

```
#include <stdio.h>
#include <stdlib.h>
int compare(const void *a, const void *b) {
    float fa = *(const float*)a;
    float fb = *(const float*)b;
    if (fa < fb) return -1;
    if (fa > fb) return 1;
    return 0;
}
// Median function
float Median(float data[], int size) {
    // Sort the array
    qsort(data, size, sizeof(float), compare);
    // If size is odd
    if (size % 2 != 0) {
        return data[size / 2];
    }
    // If size is even
    else {
        return (data[(size - 1) / 2] + data[size / 2]) / 2.0;
    }
}
int main() {
    float data[] = {0.39, 1.47, 1.57, 1.61, 1.61, 1.69, 1.80, 1.84, 1.87,
    1.89, 2.03, 2.03, 2.05, 2.55, 2.56, 2.59, 2.67, 2.73, 2.74, 2.79, 2.81,
    2.82, 2.85, 2.87, 2.88, 2.93, 2.95, 2.96, 2.12, 2.35, 2.41, 2.43, 2.48,
    2.50, 2.53, 2.55, 2.97, 0.85, 1.08, 1.25, 3.09, 3.11, 3.11, 3.15, 3.15,
    3.19, 3.22, 3.60, 3.65, 3.68, 3.70, 3.75, 4.20, 4.38, 3.22, 3.27, 3.28,
    3.31, 3.31, 3.33, 3.39, 3.39, 3.56, 4.42, 4.70, 4.90};
    int size = sizeof(data) / sizeof(data[0]);
    float result = Median(data, size);
    printf("Median = %.2f\n", result);
    return 0;
}
```

Output:

Median = 2.83

C program for Mode:

This C program computes the mode of the dataset given in Example 1.

```
#include <stdio.h>
#include <stdlib.h>
int compare(const void *a, const void *b) {
    float fa = *(const float*)a;
    float fb = *(const float*)b;
    if (fa < fb) return -1;
```

```
    if (fa > fb) return 1;
    return 0;
}
// Function to print all modes
void Mode(float data[], int size) {
    qsort(data, size, sizeof(float), compare); // Sort array
    int maxCount = 1;
    int currentCount = 1;
    for (int i = 1; i < size; i++) {
        if (data[i] == data[i-1]) currentCount++;
        else currentCount = 1;
        if (currentCount > maxCount) maxCount = currentCount;
    }
    currentCount = 1;
    printf("Mode(s): ");
    for (int i = 1; i <= size; i++) {
        if (i < size && data[i] == data[i-1]) currentCount++;
        else currentCount = currentCount;
        if (currentCount == maxCount && (i == size || data[i] != data[i-1])) {
            printf("%.2f ", data[i-1]);
        }
        if (i < size && data[i] != data[i-1]) currentCount = 1;
    }
    printf("\n");
}
int main() {
    float data[] = {0.39, 1.47, 1.57, 1.61, 1.61, 1.69, 1.80, 1.84, 1.87,
1.89, 2.03, 2.03, 2.05, 2.55, 2.56, 2.59, 2.67, 2.73, 2.74, 2.79, 2.81,
2.82, 2.85, 2.87, 2.88, 2.93, 2.95, 2.96, 2.12, 2.35, 2.41, 2.43, 2.48,
2.50, 2.53, 2.55, 2.97, 0.85, 1.08, 1.25, 3.09, 3.11, 3.11, 3.15, 3.15,
3.19, 3.22, 3.60, 3.65, 3.68, 3.70, 3.75, 4.20, 4.38, 3.22, 3.27, 3.28,
3.31, 3.31, 3.33, 3.39, 3.39, 3.56, 4.42, 4.70, 4.90};
    int size = sizeof(data)/sizeof(data[0]);
    Mode(data, size);
    return 0;
}
```

Output:

Mode = 1.61 2.03 2.55 3.11 3.15 3.22 3.31 3.39

C program for Variance:

This C program computes the variance of the dataset given in Example 1.

```
#include <stdio.h>
float Variance(float data[], int size) {
    float sum = 0, mean, variance = 0;
    // Calculate sum
```

```
for(int i = 0; i < size; i++) {
    sum += data[i];
}
// Calculate mean
mean = sum / size;
// Calculate sum of squared differences
for(int i = 0; i < size; i++) {
    variance += (data[i] - mean) * (data[i] - mean);
}
// Sample variance (divide by size-1)
return variance / (size - 1);
}
int main() {
    float data[] = {0.39, 1.47, 1.57, 1.61, 1.61, 1.69, 1.80, 1.84, 1.87,
1.89, 2.03, 2.03, 2.05, 2.55, 2.56, 2.59, 2.67, 2.73, 2.74, 2.79, 2.81,
2.82, 2.85, 2.87, 2.88, 2.93, 2.95, 2.96, 2.12, 2.35, 2.41, 2.43, 2.48,
2.50, 2.53, 2.55, 2.97, 0.85, 1.08, 1.25, 3.09, 3.11, 3.11, 3.15, 3.15,
3.19, 3.22, 3.60, 3.65, 3.68, 3.70, 3.75, 4.20, 4.38, 3.22, 3.27, 3.28,
3.31, 3.31, 3.33, 3.39, 3.39, 3.56, 4.42, 4.70, 4.90};
    int size = sizeof(data) / sizeof(data[0]);
    float variance = Variance(data, size);
    printf("Variance = %.2f\n", variance);
    return 0;
}
```

Output:

Variance = 0.79

C program for Standard Deviation:

This C program computes the standard deviation of the dataset given in Example 1.

```
#include <stdio.h>
#include <math.h> // for sqrt()
float StandardDeviation(float data[], int size) {
    float sum = 0, mean, variance = 0;
    int i;
    // Calculate sum
    for(i = 0; i < size; i++) {
        sum += data[i];
    }
    // Mean
    mean = sum / size;

    // Sum of squared differences
    for(i = 0; i < size; i++) {
        variance += (data[i] - mean) * (data[i] - mean);
    }
}
```

```
    return sqrt(variance / (size - 1));  
}  
int main() {  
    float data[] = {0.39, 1.47, 1.57, 1.61, 1.61, 1.69, 1.80, 1.84, 1.87,  
1.89, 2.03, 2.03, 2.05, 2.55, 2.56, 2.59, 2.67, 2.73, 2.74, 2.79, 2.81,  
2.82, 2.85, 2.87, 2.88, 2.93, 2.95, 2.96, 2.12, 2.35, 2.41, 2.43, 2.48,  
2.50, 2.53, 2.55, 2.97, 0.85, 1.08, 1.25, 3.09, 3.11, 3.11, 3.15, 3.15,  
3.19, 3.22, 3.60, 3.65, 3.68, 3.70, 3.75, 4.20, 4.38, 3.22, 3.27, 3.28,  
3.31, 3.31, 3.33, 3.39, 3.39, 3.56, 4.42, 4.70, 4.90};  
    int size = sizeof(data) / sizeof(data[0]);  
    float std_dev = StandardDeviation(data, size);  
    printf("Standard Deviation = %.2f\n", std_dev);  
    return 0;  
}
```

Output:

Standard Deviation = 0.89

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