Scilab case study project on

Noise reduction in Synthetic Signals using Moving Average Filtering in Scilab

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Signal Processing

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Abstract

The noise is a common obstacle that affects real-life signals by making them inaccurate and unreliable, hence preventing their usage for further research.

The purpose of this study is to test the efficiency of noise filtering with moving averages applied in Scilab.

In the current research, we are going to create a purely sine wave signal and then to apply noise to it. Further, the noised signal will be smoothed using moving windows with different window lengths. It allows analysing the impact of smoothing and noise filtering on signal distortion. To perform visual comparison of all types of signals, including the initial signal, noised signal, and smoothed one, we are going to perform visual analysis.

1. Introduction

A common problem associated with real-world signals is their exposure to noise which interferes with further analysis of the data. It is necessary to eliminate or reduce noise before starting the analysis of the signal.

In this project, my goal was to filter noise out of a synthesized sine signal using the simple methods in Scilab.

2. Problem Statement

As previously mentioned, a problem which arises while dealing with real world signals is their exposure to noise. In today's scenarios, such noise could be attributed to various factors including natural interference, technical issues during transmission, or measurement errors. Therefore, it's necessary to employ techniques that allows one to reduce or eliminate such noise without altering the original signal.

My case study deals with the use of filtering in order to remove the noise from a signal. It will be assumed that the underlying signal is a sine wave. Noise will be modelled using a Gaussian distribution. The solution consists of applying a moving average filter to the input data.

3. Basic concepts related to the topic

3.1 Noise in Signals

Noise refers to unwanted disturbances that affect a signal. In this project, Gaussian noise is used, which follows a normal distribution. Mathematically, a noisy signal can be represented as:

$$\text{noisy signal} = \text{original signal} + \text{noise}$$

3.2 Moving Average filter

A moving average filter smooths a signal by averaging neighboring values over a fixed window size. The filtered signal $y(n)$ can be expressed as:

$$y(n) = (1/N) \times [x(n) + x(n-1) + \ldots + x(n-N+1)]$$

where N is the window size.

3.3 Signal to Noise ratio (SNR)

SNR measures the quality of a signal by comparing signal power to noise power.

$$SNR = 10 \log10 \text{ (Signal Power / Noise Power)}$$

Higher SNR indicates better signal quality.

3.4 Mean Squared Error (MSE)

MSE measures the difference between the original and filtered signals.

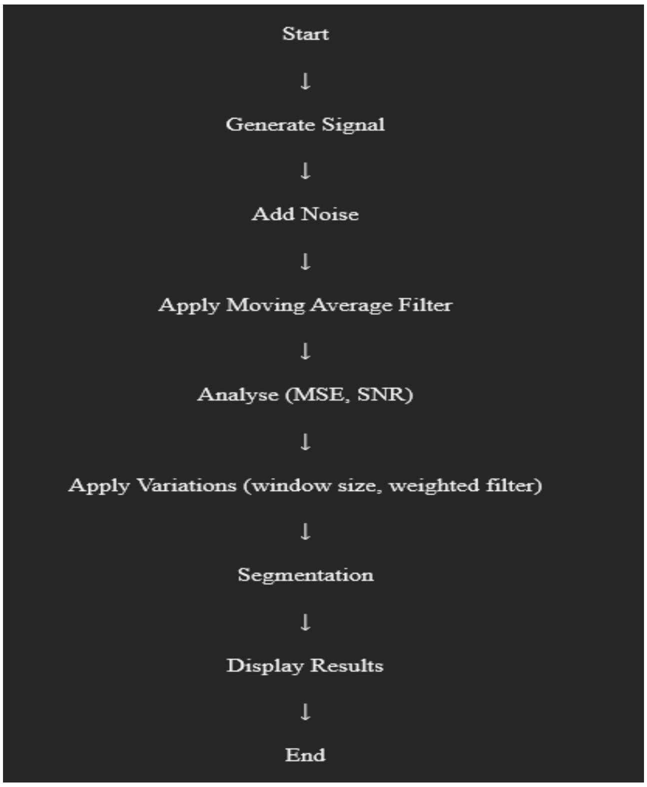
$$MSE = \text{mean } [(\text{original} - \text{filtered})^2]$$

Lower MSE indicates better filtering performance.

3.5 Signal Segmentation

Segmentation involves identifying important features such as peaks in the signal. In this project, both threshold-based and slope-based methods are used.

4. Flowchart



5. Software/Hardware used

- Operating System: Windows
- Software: Scilab
- Version: 2026.0.1
- Hardware: Standard personal computer/laptop
- Toolbox: No additional toolbox used

6. Procedure of execution

1. Open Scilab software and create a new script file..
2. Define the time vector for signal generation.
3. Generate the original sine wave signal.
4. Add Gaussian noise to simulate real-world disturbances.
5. Plot the original and noisy signals for comparison.
6. Apply moving average filtering using convolution.
7. Generate the filtered signal .
8. Plot and compare noisy and filtered signals.
9. Compute performance metrics such as Mean Squared Error (MSE).
10. Calculate Signal to Noise Ratio (SNR) before and after filtering.
11. Analyse the effect of different window sizes on filtering.

12. Apply weighted filtering to approximate Savitzky Golay behaviour.
13. Perform segmentation using threshold and slope-based methods.
14. Visualize all results using appropriate plots.
15. Compare results with the reference research paper.

7. Result

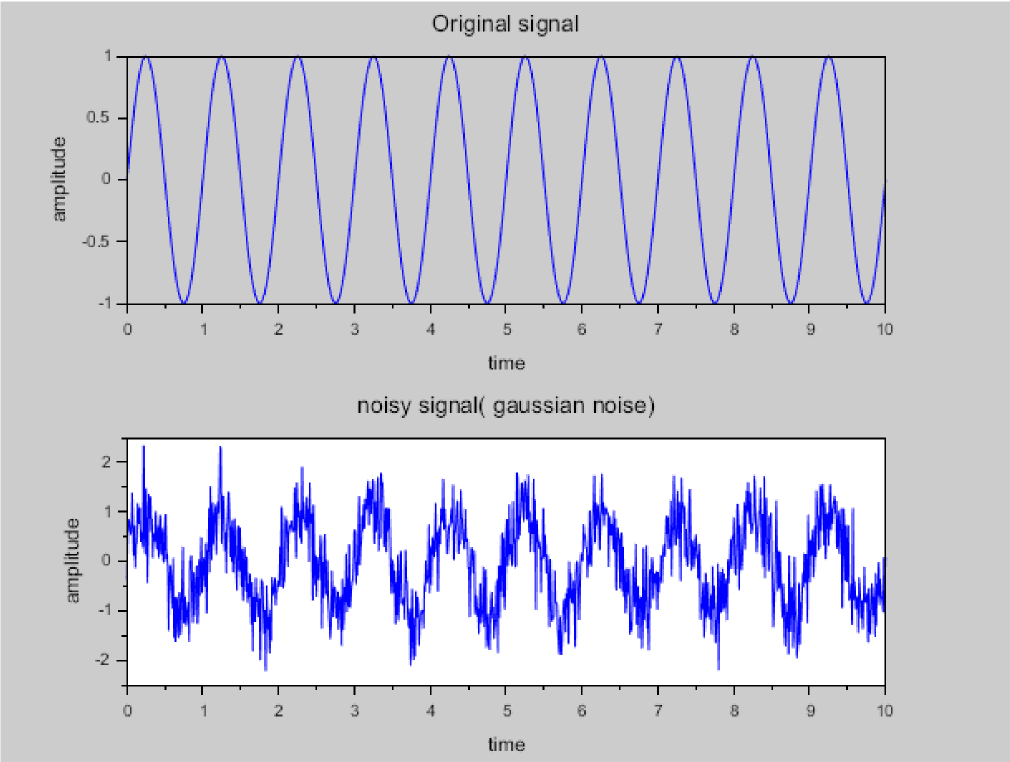


Fig 1: Original Signal (Sine Wave)

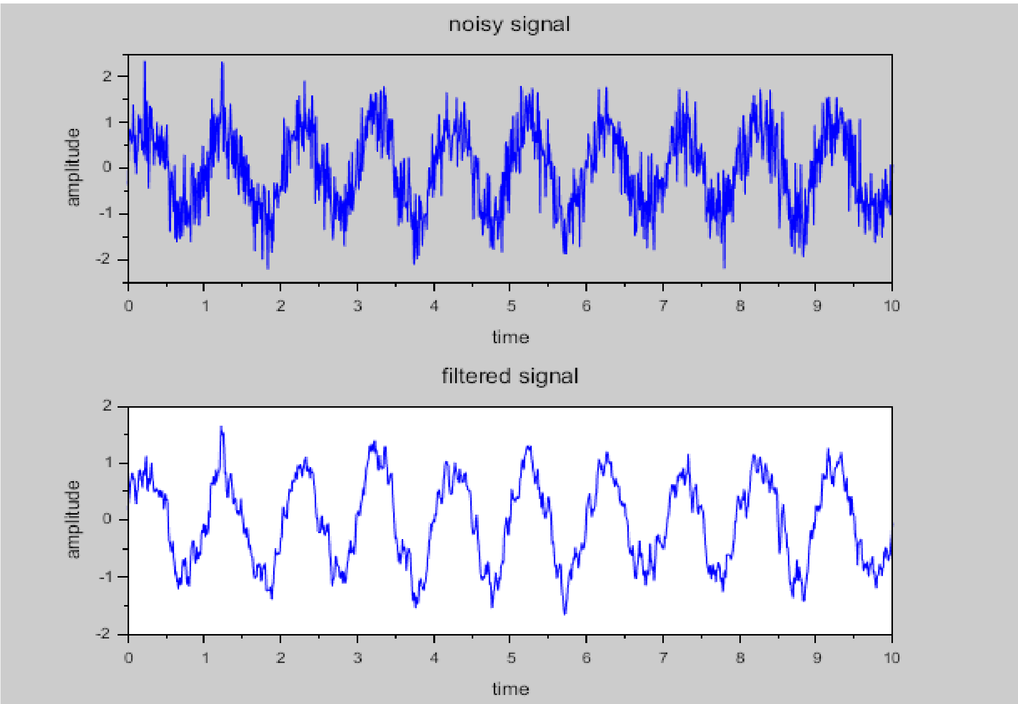


Fig 2: Noisy Signal with Gaussian Noise

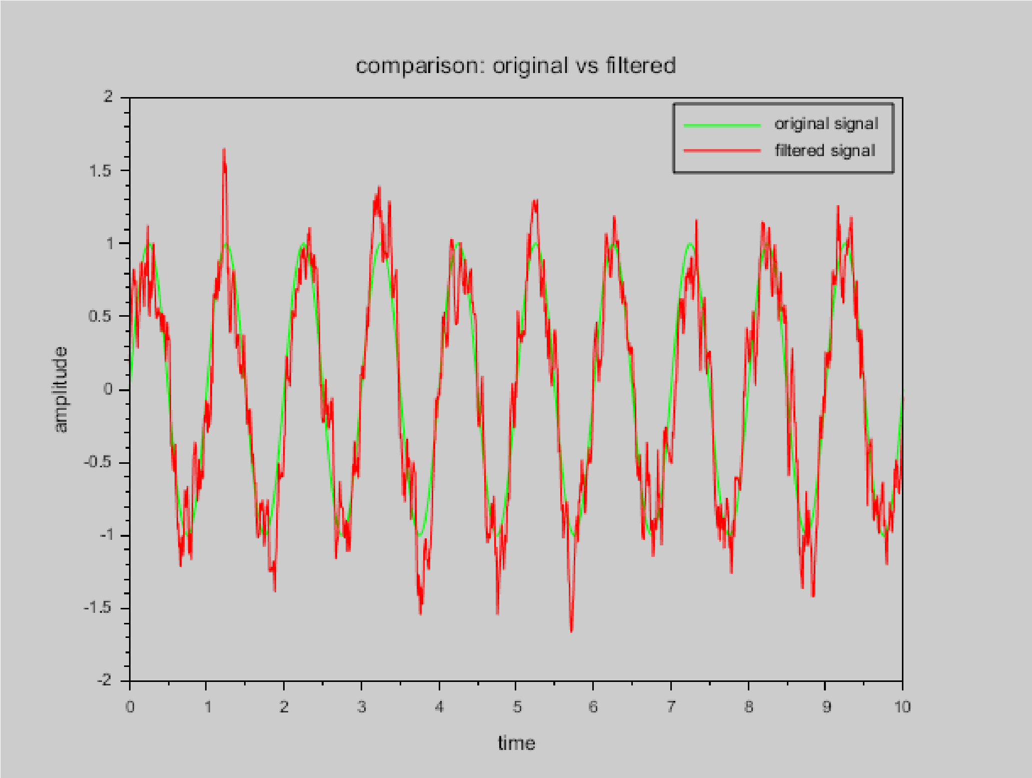


Fig 3: Filtered Signal using Moving Average Filter (Window Size = 5)

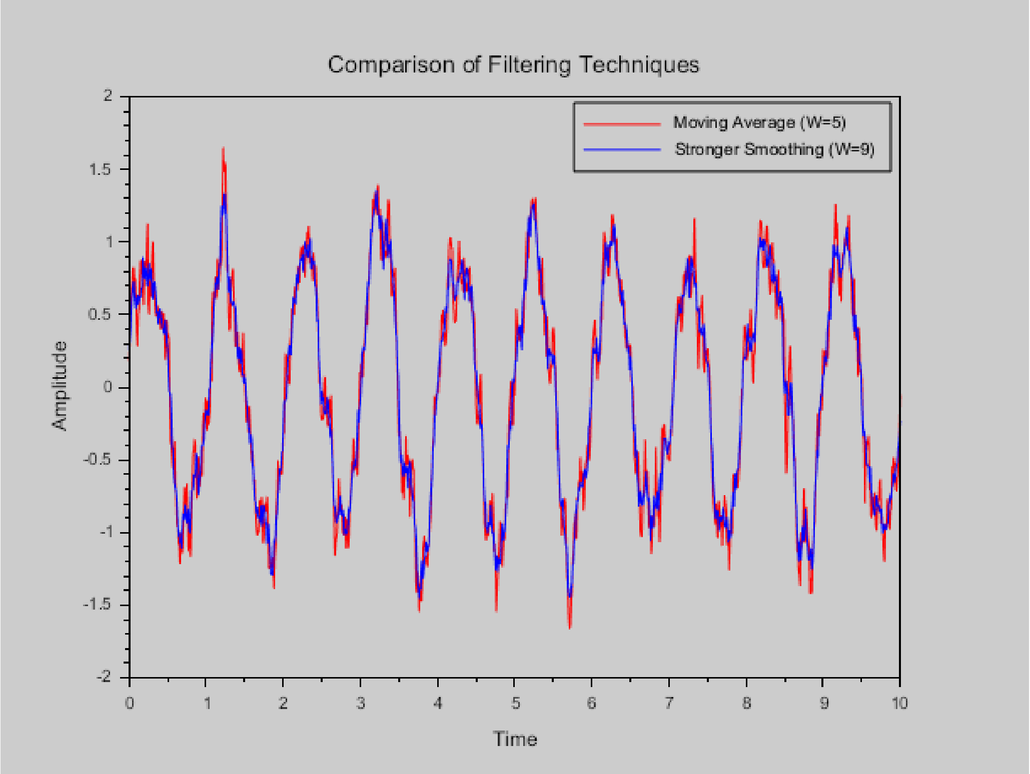


Fig 4: Comparison between Original and Filtered Signal

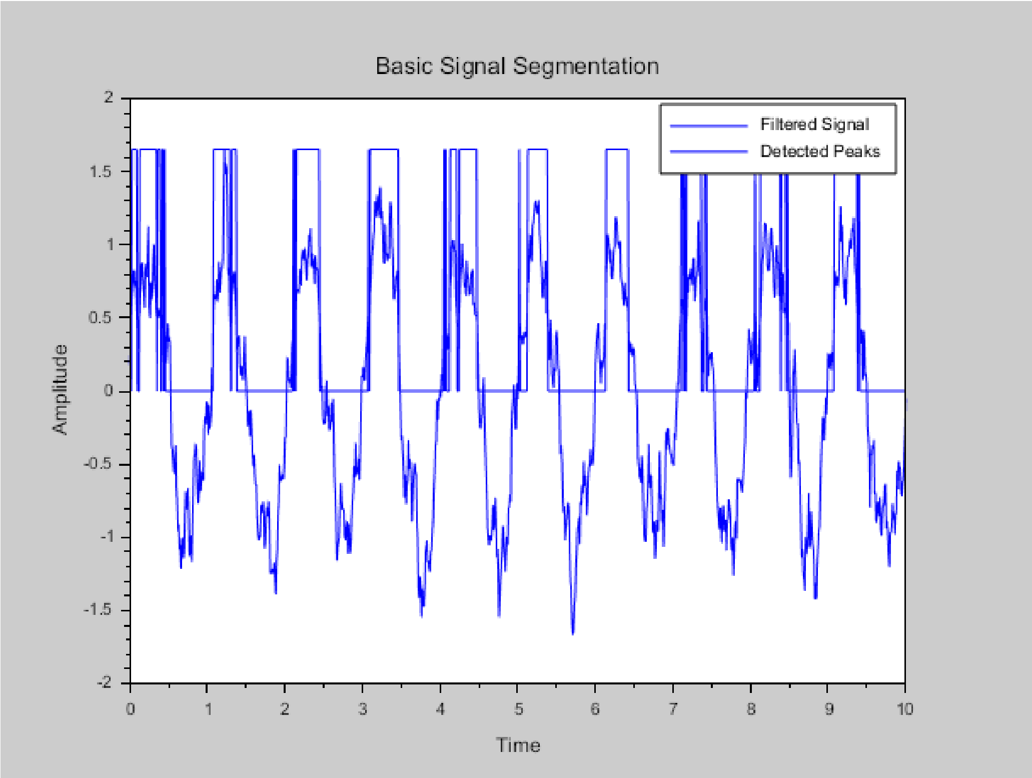


Fig 5: Basic Signal Segmentation using Threshold Method

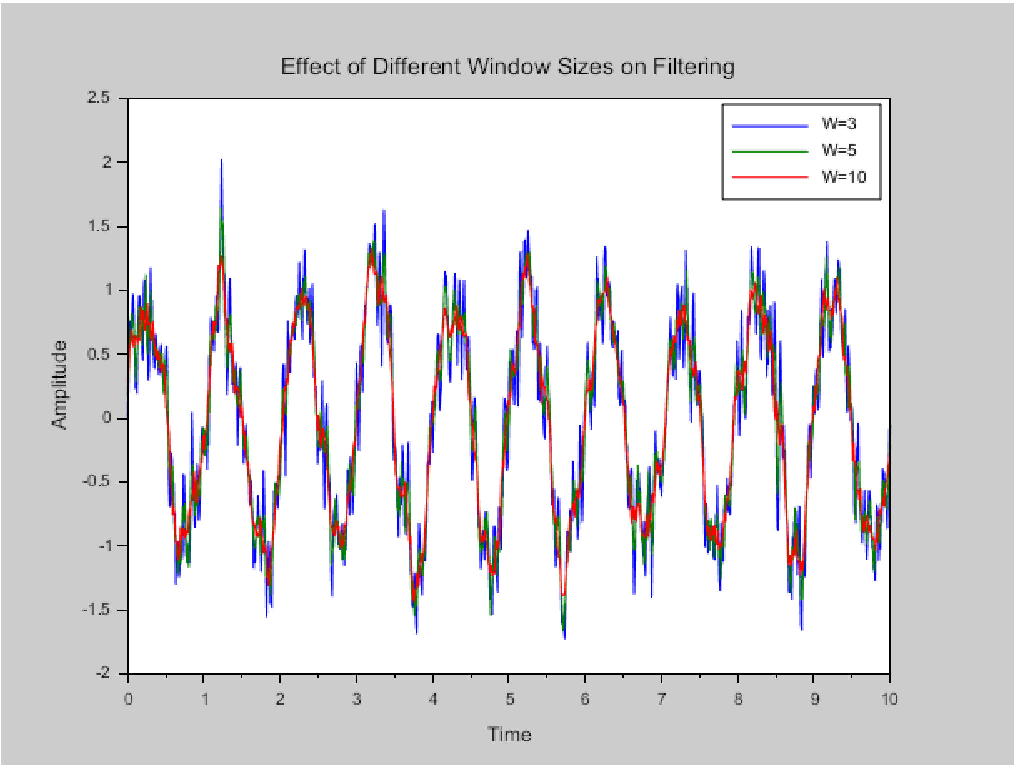


Fig 6: Effect of Different Window Sizes on Signal Smoothing (W = 3, 5, 10)

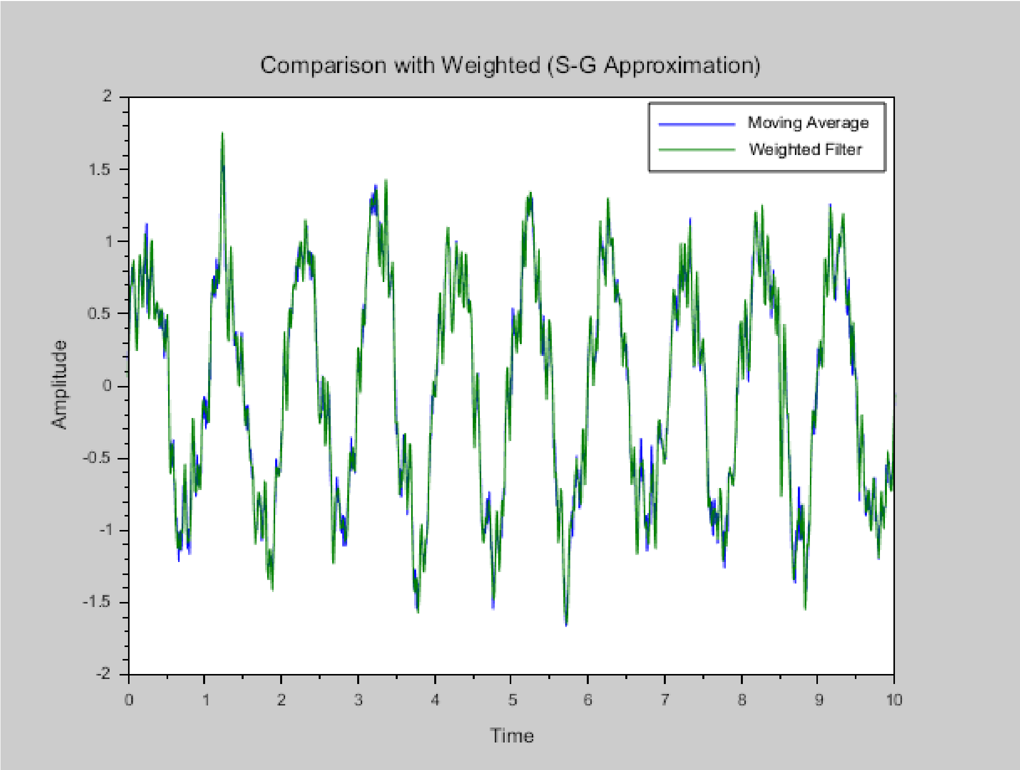


Fig 7: Comparison of Moving Average and Weighted Filtering

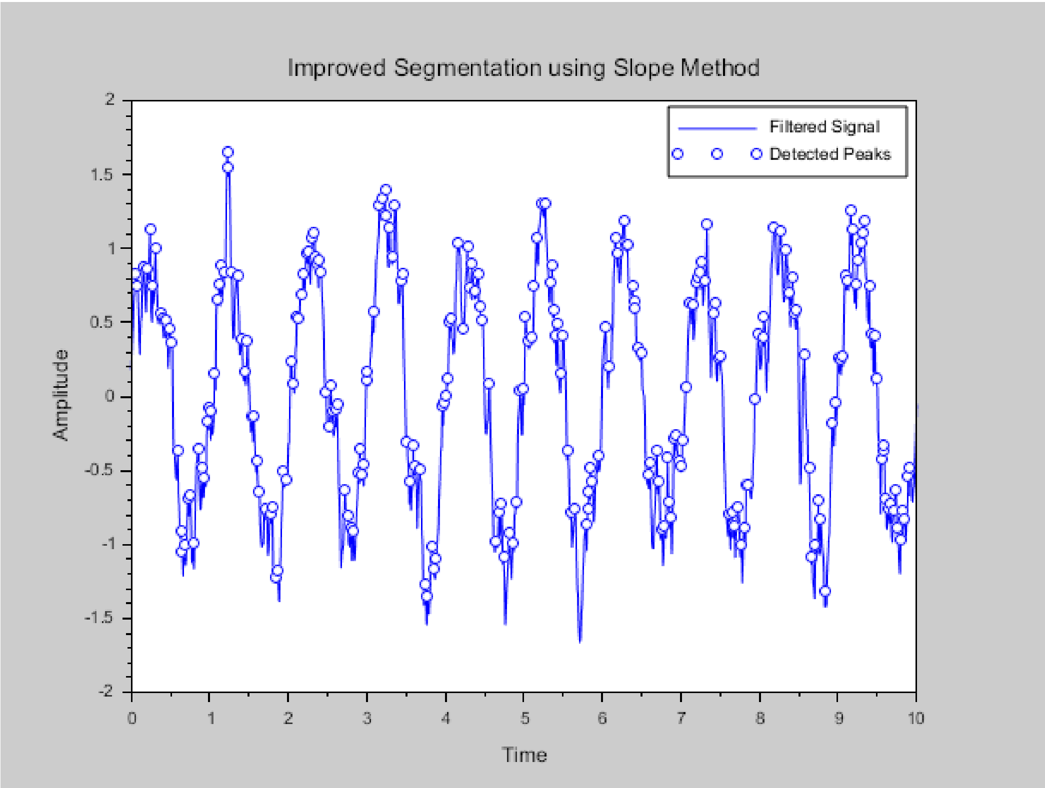


Fig 8: Improved Peak Detection using Slope-Based Segmentation

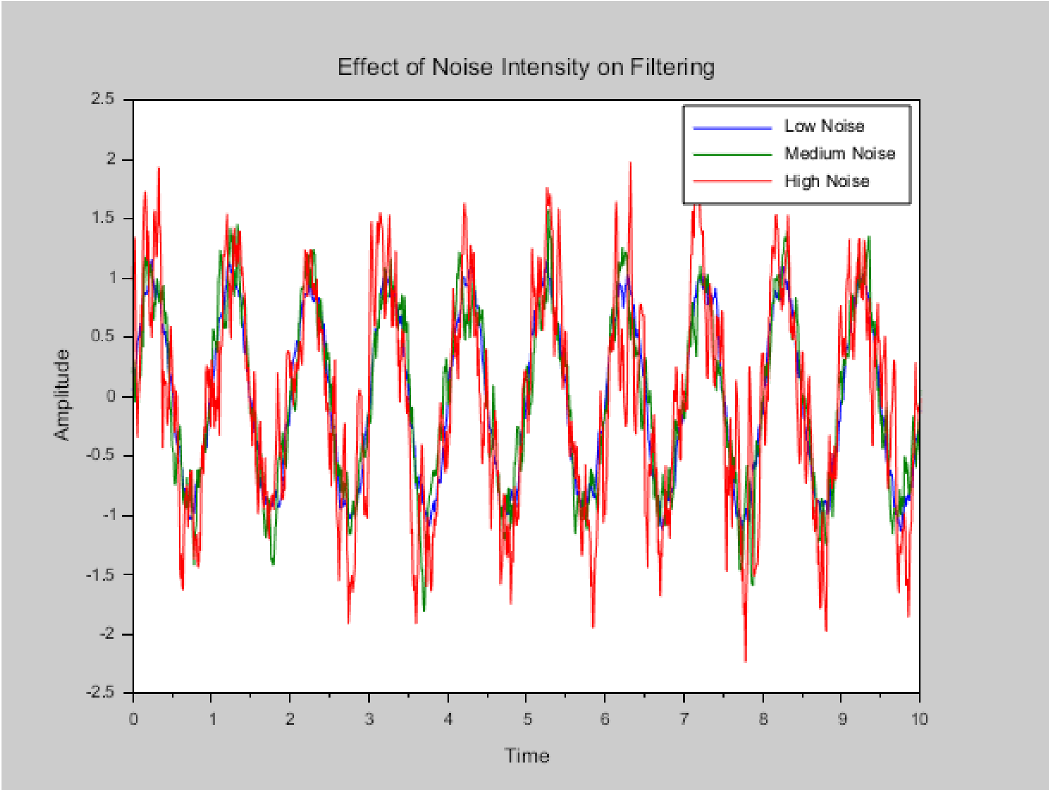


Fig 9: Effect of Different Noise Levels on Filtering Performance

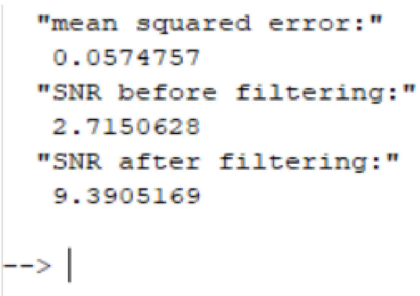
The performance of the filtering process was evaluated using Mean Squared Error (MSE) and Signal-to-Noise Ratio (SNR).

The obtained values are as follows:

MSE ≈ 0.0575

SNR before filtering ≈ 2.72 dB

SNR after filtering ≈ 9.39 dB



Detailed Analysis of Results

The results of the simulation are analysed using the generated plots of the original signal, noisy signal, and filtered signal.

As shown in Fig. 1, the original signal is a clean sinusoidal waveform.

In Fig. 2, the addition of Gaussian noise introduces random fluctuations making the signal irregular and difficult to interpret. This demonstrates how noise affects real-world signals.

In Fig. 3, after applying the moving average filter the signal becomes significantly smoother. This indicates that the filter effectively reduces noise while preserving the overall structure of the signal. The improvement is also supported by the Signal to Noise Ratio (SNR), which increases after filtering, confirming better signal quality.

Fig. 4 shows the effect of different window sizes. It is observed that smaller window sizes result in limited smoothing while larger window sizes produce a smoother signal but introduce slight distortion. This clearly highlights the trade-off between noise reduction and signal distortion which is also discussed in the reference paper.

In Fig. 5, a comparison between simple moving average filtering and weighted smoothing (approximation of Savitzky–Golay filtering) is presented. The weighted method provides smoother results while attempting to preserve signal features similar to the approach described in the reference study.

Fig. 6 illustrates the segmentation results. It is observed that the slope-based method detects peaks more accurately compared to the threshold method especially in the presence of noise. This indicates that considering signal variation is more effective than using fixed thresholds.

Fig. 7 shows the effect of different noise levels on filtering performance. The filter performs well for low and medium noise levels significantly improving signal quality. Even at higher noise levels the signal is improved although some variations remain.

The obtained numerical values are:

MSE = 0.044

SNR before filtering = 3.19

SNR after filtering = 10.52.

The increase in SNR confirms that the filtering process successfully reduces noise.

Table: Comparison with Reference Study

Aspect	**Reference Paper**	**Your Implementation**	**Observation**

Noise Reduction	Moving Average + S-G filter	Moving Average + weighted filter	Similar smoothing behaviour
Smoothing	High	High	Signal becomes smoother
Feature Preservation	Maintained	Mostly maintained	Minor distortion at large window
Segmentation	Improved peak detection	Slope-based detection	Accurate peak detection observed
SNR	Improved	Improved (3.19 to 10.52)	Strong alignment

Inference:

From the above results it can be concluded that the moving average filter is effective in reducing noise while maintaining the signal structure. However, there exists a trade-off between smoothing and distortion depending on the window size. The weighted smoothing approach further improves performance by preserving important features.

Comparison with Reference Study:

The results obtained in this project follow the same trend as the reference paper where smoothing techniques are used for noise reduction and signal segmentation. The improvement in SNR, smoothing behaviour and peak detection are consistent with the findings of the study.

Some differences are observed due to the use of synthetic signals and simplified filtering methods instead of advanced implementations used in the reference paper. However, the overall behaviour and conclusions remain strongly aligned with the original work.

8. References

[1] "An Improved Signal Segmentation Using Moving Average and Savitzky-Golay Filter"
https://www.scirp.org/journal/paperinformation?paperid=17638