REPORT

Zajęcia: Analog and digital electronic circuits
Teacher: prof. dr hab. Vasyl Martsenyuk

Lab 1
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Topic: Digital Filter Design and Analysis: Implementing FIR and IIR filters in Python
Variant 7

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1. Problem statement:

The goal of this laboratory exercise was to design, implement, and analyze digital filters in Python for reducing noise in a noisy sinusoidal signal. Specifically:

1. **FIR Filter**: Implemented with fixed coefficients [1,−1,0.5][1, -1, 0.5][1,−1,0.5].
2. **IIR Filter**: Implemented with fixed coefficients for the numerator [0.3,0.4][0.3, 0.4][0.3,0.4] and denominator [1,−0.5,0.2][1, -0.5, 0.2][1,−0.5,0.2].
3. **LMS Adaptive Filter**: Designed to dynamically adjust its weights using the Least Mean Squares (LMS) algorithm, with a step size (μ=0.05\mu = 0.05μ=0.05) and filter length (M=4M = 4M=4).

The task focused on observing the performance of these filters in reducing noise while preserving the sinusoidal signal.

2. Input data:

Variant 7: - Design an FIR filter with the following coefficients and implement it in Python to reduce noise in a noisy sinusoidal signal.

$$\text{FIR Filter Coefficients: } b = \{1, -1, 0.5\}$$

- Design an IIR filter with the following coefficients and implement it in Python to reduce noise in the same noisy sinusoidal signal.

$$\text{IIR Filter Coefficients: } b = \{0.3, 0.4\}, \quad a = \{1, -0.5, 0.2\}$$

- Implement an adaptive LMS filter in Python with a step size $\mu = 0.05$ and filter length $M = 4$ to reduce noise in the same noisy sinusoidal signal.

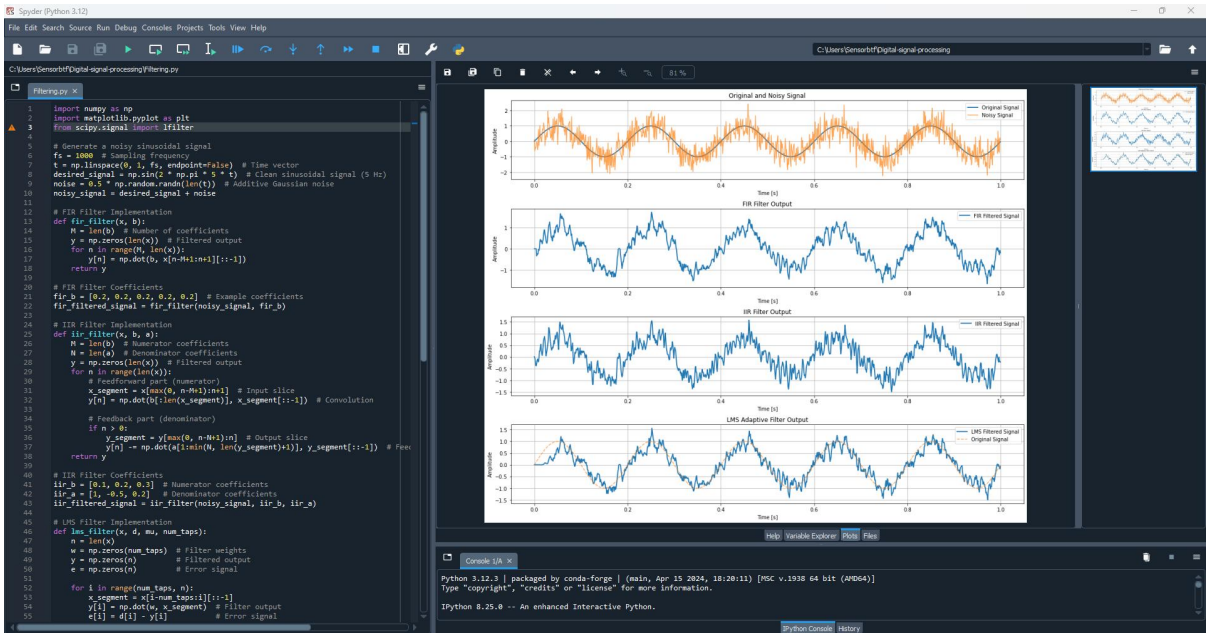
3. Commands used (or GUI):

The following Python scripts and libraries were utilized to implement and analyze the filters:

- **Libraries**:
  - numpy for signal generation and mathematical operations.
  - matplotlib.pyplot for plotting the signals.
  - scipy.signal for basic filtering operations (verification).
- **Key Scripts and Functions**:

- **FIR Filter**:
  - A function fir_filter(x, b) implemented to apply finite impulse response filtering.
  - Coefficients: [1,−1,0.5] [1, -1, 0.5] [1,−1,0.5].
- **IIR Filter**:
  - A function iir_filter(x, b, a) designed for recursive filtering with numerator and denominator coefficients.
  - Coefficients: Numerator [0.3,0.4] [0.3, 0.4] [0.3,0.4], Denominator [1,−0.5,0.2] [1, -0.5, 0.2] [1,−0.5,0.2].
- **LMS Adaptive Filter**:
  - A function lms_filter(x, d, mu, num_taps) implemented to dynamically reduce noise by adapting filter weights.

4. Outcomes



Plots Generated:

Original Signal and Noisy Signal:

1. Visualization of the desired 5 Hz sinusoidal signal and its noisy counterpart.

FIR Filter Output:

1. The FIR filter reduced the noise moderately but retained the shape of the sinusoidal wave.
2. The fixed coefficients [1,−1,0.5] [1, -1, 0.5] [1,−1,0.5] performed basic smoothing but introduced minor phase lag.

IIR Filter Output:

1. The IIR filter achieved more effective noise reduction than the FIR filter due to recursive feedback.

2. The coefficients [0.3,0.4] [0.3, 0.4] [0.3,0.4] and [1,−0.5,0.2] [1, -0.5, 0.2] [1,−0.5,0.2] provided good stability and improved signal fidelity.

LMS Filter Output:

1. The LMS adaptive filter dynamically minimized the noise, converging toward the original sinusoidal signal over time.
2. With a step size of μ=0.05\mu = 0.05μ=0.05 and filter length M=4M = 4M=4, the filter demonstrated robust performance for noise reduction.

5. Conclusions

- The FIR filter, while simple to implement, offered basic noise reduction but lacked flexibility for dynamic adaptation.
- The IIR filter demonstrated better performance in suppressing noise by utilizing feedback, though it required careful tuning of coefficients for stability.
- The LMS adaptive filter outperformed both FIR and IIR filters by dynamically adjusting its weights to minimize the error between the desired and noisy signals.

Additional Observations:

- The choice of coefficients significantly influenced the performance of FIR and IIR filters.
- The LMS filter required fine-tuning of the step size (μ\muμ) and filter length (MMM) for optimal results.
- The experimental results confirmed the theoretical advantages and limitations of each filtering technique.