

Assignment: Exploring Noisy Data and Denoising Techniques

18751 Applied Stochastic Process Fall 2024 Homework 6

November 30, 2024

DUE: Saturday December 6th 2024

Objective

The objective of this assignment is to explore how noise affects various real-world processes and how denoising techniques can be applied to recover meaningful trends. You will use a provided Jupyter notebook to simulate noisy data, apply denoising techniques, and generate results. Your task is to prepare a detailed report that analyzes the outputs and answers the reflection questions for each task.

Instructions

1. Use the provided Jupyter notebook to run the code for each question.
2. For each task, analyze the outputs, answer the reflection questions, and provide insights based on the results.
3. Prepare a report in PDF format with the following sections:
 - Introduction
 - Analysis for each task (Questions 1-3)
 - Conclusion

Questions

1. Quality Control with Noisy Measurements

Scenario: A factory produces light bulbs, and each has a 60% probability of passing quality control. However, noise in the measurements causes some pass/fail outcomes to be flipped.

Tasks:

1. Simulate a Bernoulli process for 1000 trials where 10% of the values are randomly flipped.
2. Denoise the noisy outcomes using one of the provided techniques (e.g., SMA, Gaussian Weighted Average).
3. Compare the noisy, denoised, and true means.

Reflection Points:

- How does the noisy mean deviate from the true mean? What does this tell you about the quality of measurements?
- How does the choice of denoising method impact the recovered mean? Which method works best for this scenario?
- How can similar noise and denoising techniques be applied in real-world scenarios like medical testing or manufacturing quality control?

Report Expectations:

- Include plots of the noisy and denoised data, with the true mean marked.
- Provide numerical comparisons of the true, noisy, and denoised means.
- Discuss which denoising method you used and why.

2. Temperature Trends with Noisy Measurements

Scenario: Daily temperature measurements are simulated with a sinusoidal trend over a year, but measurement noise is added. You will explore how noise affects seasonal trends and how denoising can restore them.

Tasks:

1. Simulate noisy daily temperature data for a year.
2. Denoise the data using one of the provided techniques.
3. Analyze the autocorrelation of both the noisy and denoised data to assess seasonal patterns.

Reflection Points:

- How does noise affect the strength and clarity of autocorrelation at different lags?
- How does smoothing improve the visibility of seasonal trends in the autocorrelation plot?
- Why is autocorrelation important for detecting patterns in temperature data or other periodic data?

Report Expectations:

- Include plots of noisy and denoised temperature data.
- Provide autocorrelation plots for both noisy and denoised data.
- Discuss how the chosen denoising method affects the detection of seasonal patterns.

3. Stationarity Analysis of an Audio Signal

Scenario: An audio signal is simulated with a sinusoidal waveform and added noise. The task is to analyze its stationarity by examining the mean and variance over time.

Tasks:

1. Simulate a noisy audio signal.
2. Apply a denoising method to smooth the signal.
3. Compute and compare the mean and variance over time for both the noisy and denoised signals.

Reflection Points:

- How does noise affect the stationarity of the audio signal (i.e., its mean and variance over time)?
- How does smoothing restore stationarity? Which method is most effective?
- Why is stationarity important in signal processing and time-series analysis?

Report Expectations:

- Include plots of the noisy and smoothed signals.
- Provide mean and variance plots over time for both noisy and smoothed signals.
- Explain the impact of smoothing on stationarity and discuss practical applications.

Conclusion

In your report, summarize the key findings from each task and discuss the broader implications of noise and denoising in real-world scenarios. Reflect on the effectiveness of different denoising techniques and provide recommendations for their use in various contexts.

Submission Instructions

1. Submit a PDF report by the deadline.
2. Ensure that your report includes all required plots, numerical analyses, and written reflections for each question.

Acknowledgment

Use the accompanying Jupyter notebook to generate all the plots and results. Focus on interpreting the data and writing a well-structured report.