Universidad Nacional Abierta y a Distancia
Vicerrectoría Académica y de Investigación
Course: Course Forecasting
Code 203238431

Learning Guide - Phase 3 Time Series Filtering and Frequency Domain Transformations

1. Data of the Phase

Table 1. *Description.*

Aspect	Description
1. Type of activity	Independent
2. Evaluation moment	**Intermediate**
3. Managing unit	Escuela de Ciencias Básicas Tecnología e Ingeniería ECBTI
4. Score of the Choose an option	**125**
5. The activity starts on:	Monday, September 29, 2025
6. The activity ends on:	Sunday, October 26, 2025
7. Independent work hours of the student	**20**

2. Detailed Description of the Learning Activity

With the development of this activity the following learning outcome is expected to be achieved*:*

Learning Outcome 3: Time Series Filtering and Frequency Domain Transformations

The activity consists of:

- Understanding the conceptual foundations of Kalman filters and their role in estimating dynamic system states in the presence of noise.
- Applying Kalman filtering to time-series data using Python, including the implementation of prediction and update steps.

- Exploring signal transformation techniques, such as the Fourier Transform (FT) and Fast Fourier Transform (FFT), to analyze signals in the frequency domain.
- Interpreting the behavior of different types of filters (low-pass, high-pass, band-pass, band-stop) and understanding their effect on signal components.
- Using window functions (e.g., Tukey and Hann) to improve frequency analysis and reduce spectral leakage.
- Comparing the effectiveness of filtering techniques (Kalman vs. frequency-based) in real or simulated time-series datasets.
- Visualizing results through appropriate plots and evaluating how noise is reduced or signal clarity is improved.

The following materials and resources are required for the development of this activity:

- Jupyter Notebooks or Google Colab with Python runtime support.
- Required Python. libraries: pandas, numpy, matplotlib, scipy, statsmodels, seaborn and pykalman.
- Time-series datasets (real or simulated) containing noise, trend, or periodic components.

Problem Situation

Develop each of the exercises by taking into account each of the attached files and completing all the proposed points. The exercises involve different types of real-world data through which each of the concepts in this phase can be developed.

To develop this activity, follow these steps:

Exercise 1:

You have been provided one dataset:

Appendix 1 - xy_motion_kalman_filter_example.csv

Your task is to leverage what you've learned in this and previous courses.

More specifically, you will do the following:

- Make an initial estimate of your state vector and covariance matrix
- Predict the state and covariance for the next time step
- Computer the Kalman gain
- Make a measurement - Update estimates of state and covariance
- Choose a value for the estimated_model_variance that is larger than estimated_measurement_variance.
- Repeat the analysis of section 1 for this new value.
- Does the KF estimate converge?
- Provide an explanation for the answer in question KF estimate.

Exercise 2:

You have been provided one dataset:

Appendix 1 - xy_motion_kalman_filter_example.csv

This exercise refers to the dynamic one-dimensional example. In the case we examined above, the KF estimate was close to the measurements and both were different from the true value.

Change the parameters of the algorithm until you find some combinations that achieve the following:

- Measurements, KF estimate and true value are all close.
- Measurements, KF estimate and true value are all noticeably different.
- The measurements are close to the true value, but the KF estimate is different.

Exercise 3:

You have been provided two datasets:

Appendix 1 - Appendix 1 xy_motion_kalman_filter_example.csv

Appendix 2 - co2-ppm-mauna-loa-19651980.csv

Appendix 3 - Signal_Transformations_student.ipynb

- Create a signal that contains 2 sine waves of different amplitudes at 1 and 10 Hz as well as a constant term. Plot the time and frequency domain.

- Plot the time and frequency domain representation of Gaussian distrubuted random noise. Noise tends to contain all frequency components.
- Add the three signals together but provide an amplitude of 3, 2, and 1 to the sine, trend, and noise, respectively. Observe the time and frequency domain components.
- Modify the values of "alpha" and "div_factor" to optimize the filter.
- Modify the filter order and cutoff frequency.

3. Guidelines for the Development and Submission of Learning Evidence

Learning evidence refers to the actions, products, or observable processes that are done or delivered to demonstrate acquired capabilities, skills, aptitudes, and attitudes. These serve to allow the teacher to assess and evaluate student performance effectively.

The evidence to be developed **individually** are:

- Participate in the forum corresponding to **Phase 2: Exploration** to engage academically with your tutor and groupmates on the topics discussed. This contribution is not the final work but a meaningful and significant input that includes well-reasoned arguments.
- Submit a consolidated report in **PDF format**. The report must include:
    - Cover page.
    - Development of Exercise 1, 2, and 3, explaining each step and displaying headers and graphics with Python results that are clear and appropriate for understanding.
    - A link to the developed project code (e.g., GitHub, Google Drive, or another repository) must be included in the report.
    - Conclusions
    - Bibliography
- In the **Learning Environment**, please refrain from uploading Python files to ensure the originality and authenticity of your work.

4. Academic Situations

Consider that in Agreement 029 of December 13, 2013, Article 99, the following actions are considered as offenses against academic order, among others: item e) "Plagiarism, that is, presenting as one's own the entirety or part of a work, paper, document, or invention created by another person. It also includes the use of false citations or references, or proposing citations where there is no match between the citation and the reference," and item f) "Reproducing or copying, for profit, educational materials or results of research products that have intellectual property rights reserved for the University."

The academic sanctions that the student will face are as follows:

a) In cases of proven academic fraud in the respective academic work or evaluation, the grade imposed will be zero points without prejudice to the corresponding disciplinary sanction.

b) In cases related to proven plagiarism in academic work of any nature, the grade imposed will be zero points, without prejudice to the corresponding disciplinary sanction.