Homework Assignment: Time Series Analysis of Physiological and Human Movement Data

Course: Time Series Analysis
IEAP Master - University of Montpellier
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Introduction

This homework assignment focuses on applying time series analysis techniques to physiological data. You will select a public dataset containing physiological or movement measurements and apply various analysis methods covered in the course sessions. The goal is to gain practical experience in time series analysis while developing critical thinking about method selection and interpretation.

Assignment Objectives

By completing this assignment, you will:

- Gain experience working with real physiological time series data
- Apply and compare different time series analysis techniques
- Develop skills in method selection and justification
- Interpret results in the context of physiological systems
- Practice scientific writing and data visualization

Data Selection

1. Find a public dataset containing physiological time series data (minimum 1,000 data points per series). Suitable data types include:
    - Gait data
    - Postural sway measurements
    - Electroencephalography (EEG) signals
    - Electromyography (EMG) recordings
    - Electrocardiography (ECG) data (RR intervals)
    - Respiratory signals
2. Recommended data sources:
    - PhysioNet
    - UCI Machine Learning Repository
    - Kaggle Datasets
3. Select at least two different conditions or subjects to compare (e.g., eyes open vs. eyes closed, rest vs. activity, healthy vs. pathological)

Analysis Requirements

For your selected dataset, you must **justify**, apply and report **a selection** of the following analyses:

1. Stochastic Process Analysis (Session 1)

- Compute and plot the Autocorrelation Function (ACF)
- Test for stationarity (visual inspection and statistical test)
- Fit an AR(p) model to your data:
  - Determine optimal order p using AIC/BIC
  - Report model parameters and goodness-of-fit
  - Compare with MA and ARMA models if appropriate
- Justify your model selection based on the data characteristics

2. Spectral Analysis (Session 2)

- Compute and plot the Fourier power spectrum using FFT
- Apply Welch's method for spectral estimation
- Identify dominant frequencies and interpret them physiologically
- Apply a Butterworth filter to remove noise (justify cutoff frequency)
- Compare spectral characteristics between conditions

3. Fractal Analysis (Session 3)

- Compute the fractal dimension using box-counting method
- Perform Detrended Fluctuation Analysis (DFA):
  - Plot fluctuation function and determine scaling exponent
  - Interpret the scaling behavior (persistence/anti-persistence)
- Compare fractal properties between conditions
- Discuss the physiological significance of your findings

4. Nonlinear Analysis (Session 4)

- Perform phase space reconstruction:
  - Determine optimal time delay
  - Plot 2D and 3D phase space reconstructions
- Compute Sample Entropy (SampEn) for different parameter values
- Compare nonlinear characteristics between conditions
- Perform surrogate data testing:
  - Generate phase-randomized (iAAFT) surrogates

  - Confirm preservation of power spectral density and statistical distribution
  - Compare original data statistics (SampEn) with those of surrogates
  - Test for nonlinearity

Report Structure

Your report (maximum 4 pages, excluding references and appendix) should include the following sections:

1. **Introduction**
   - Brief description of the physiological system studied
   - Research questions/hypotheses
   - Description of the dataset (source, sampling rate, conditions)
2. **Methods**
   - Detailed description of analysis methods
   - Justification for parameter choices
   - Software/packages used (Python recommended)
3. **Results**
   - Clear presentation of all analysis results
   - Figures with proper captions and labels
4. **Discussion**
   - Interpretation of results in physiological context
   - Comparison with literature findings
   - Limitations of your analysis
5. **Appendix**
   - Python code used for analyses
   - Additional figures if needed