

## Digital Signal Processing

Instituto Superior Técnico

Lab assignment 4 – Anomaly detection in energy time series data

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### Introduction

In this assignment, we will address anomaly detection in energy production data. The goal is to model the behaviour of normal energy production along time and subsequently to identify anomalies based on deviations from the normal behaviour. We will model the normal energy signal  $x(n)$  as the output of an autoregressive model (AR). For example, in long term prediction, the model can be used to predict each sample from a previous sample, plus a prediction error or residual:

$$x(n) = ax(n - N) + r(n) \quad (1)$$

Alternatively, in short-term prediction, this model can be used to predict each sample from the previous  $P$  samples, plus a prediction error.

$$x(n) = \sum_{k=1}^P a_k x(n - k) + e(n) \quad (2)$$

The coefficients of the AR model can be obtained by minimizing the sum of squared residuals, using the least squares method.

### Notes

The report of this lab assignment should not exceed three A4 pages. In addition to the report, any Matlab code you developed should also be submitted.

### Experimental work

#### 1. Prediction

**R1.a)** We will start with a model of long term prediction. Write a Matlab function that, given a vector with time series data  $x(n)$  and a delay  $N$ , computes coefficient  $a$  for the following AR model

$$x(n) = ax(n - N) + r(n) \quad (3)$$

Write your own code, do not use any Matlab ready made functions.

**R1.b)** Load the train data `energy_train.mat` which contains energy production data from a residential solar panel, where samples were obtained every 15 minutes and where there are no anomalies. Use your code to compute a prediction using  $N=96$ , which means you are predicting the current sample from the sample of the previous day, at the same time. Plot the training data, the prediction you obtained and the corresponding residual. Comment on what you observe.

**R1.c)** Indicate the coefficient and the energy of the residual  $r(n)$ . Comment.

**R1.d)** Next, we will use a short term model for the prediction of the residual you just obtained. Write a Matlab function that, given a vector with time series data  $r(n)$  and a number of previous samples  $P$ , computes the coefficients of the following AR model

$$r(n) = \sum_{k=1}^P a_k r(n - k) + e(n) \quad (4)$$

Again, write your own code, do not use any Matlab ready made functions.

**R1.e)** Use your code to compute a prediction for  $r(n)$  using  $P=5$ . Use the predicted residual to obtain a new prediction for  $x(n)$ . Plot the training data, the new prediction you obtained and the corresponding residual  $e(n)$ . Comment on what you observe and compare.

**R1.f)** Indicate the coefficients and the energy of residual  $e(n)$ . Comment.

## 2. Anomaly Detection

**R2.a)** Write a Matlab function that detects anomalies in time series data given a time series and its prediction.

**R2.b)** Load the test data `energy_test.mat` and use the previous two models you developed to predict normal behaviour for test data. Use your function to detect anomalous periods of energy production from predictions of both models. Comment on your results and compare both models in what regards their ability for anomaly detection.