04444 Advanced Time Series Analysis
FMS110/MAS222 Non-linear Time Series Analysis

EXERCISE 4 – Modelling of Laser Pulse Fluctuations

Background and Problem Formulation

Within the Division of Combustion Physics at Lund University, laser spectroscopic methods are used, among others, for the diagnostics of combustion processes. Many experiments look in principle like the one shown in figure 1. The light from a pulsed laser is aligned into the combustion process, from which a signal is generated, which depends in an often well known manner on the laser intensity.

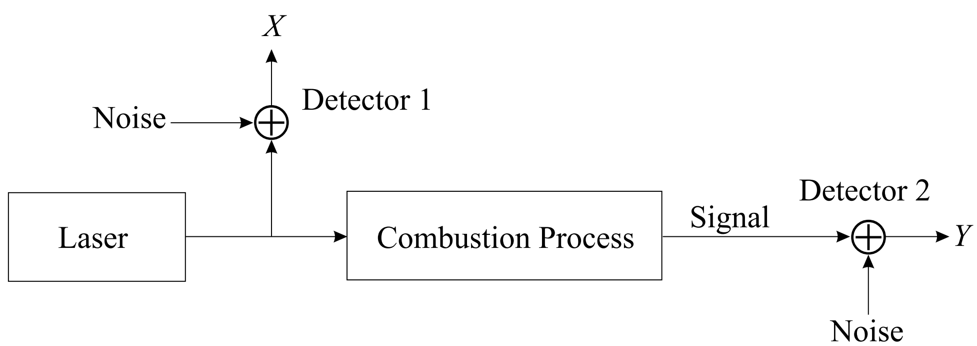

Figure 1: Scheme of a laser spectroscopic experiment

The response can be measured by any kind of physical quantity, giving some kind of output signal. However, often it consists of light, the intensity of which is measured by some kind of detector (Y_t). In addition the laser intensity can be measured at the same time (X_t). In figure 2 the intensity of the laser pulses during one experiment under high energy conditions is shown.

As part of the evaluation of the experiment, the statistical properties of the sequence of laser pulses should be described, in order to be able to characterize its distribution and stationarity.

It is your task in this exercise to do such a description, focussing on timevariations in the dependence structure and the distribution of the intensity of the laser pulses.

Problem Description

The laser pulses are emitted at different energy levels at a rate of 10 Hz and we have two groups of datasets available for analysis, one from experiments made on a high energy level (experiments 15-21) and another from experiments on a low energy level (experiments 87-92).

You are asked to compare data from two experiments, and you can either choose to use the same or different energy levels. The question then is whether the laser properties change between energy levels or between different experiments on the same energy level, and in case how they do change.

A One part of the analysis should concentrate on the dependence (covariance) structure in the sequence of pulses, using linear and non-linear methods. Check whether it pays off to use recursive estimation methods as part of the analysis.

B A second task is to find the distribution of the intensity, and to analyse its timevariation, i.e. to find out if the distribution varies during the experiment, and/or if it varies between different experiments. A possible approach to this part of the exercise could be to estimate the mean and covariance of the

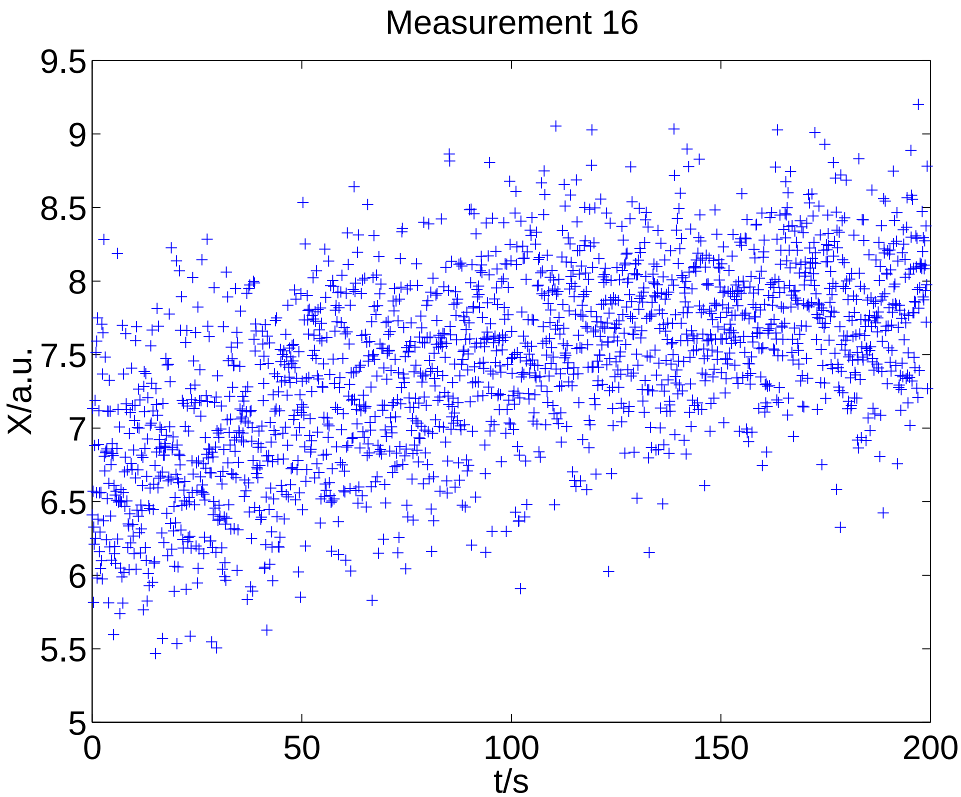

Figure 2: Laser pulse intensities during an experiment on a high energy level

intensities in the experiments you have chosen to work with (and consider recursive as well as non-recursive methods).

C (optional) If you would like to work with the time variations of the entire distribution of the laser pulse intensity, you should consider estimating it and describing its time variation using e.g. the technique from tracking coefficient-functions which is discussed in the course as part of the recursive estimation chapter, you may also find more about that method in [1]. When working with this part of the exercise you could use estimation routines developped at the departments, contact Henrik or Jan.

D Suggest and discuss a test principle to be used in order to decide whether the properties of the sequence of laser pulses is changing during the experiment or between experiments.

Data

Data, including a README file explaining the organisation of data, is available on the homepages of the course at LTH as well as on DTU. It can also be obtained from Jan on request.

References

[1] H A Nielsen, T S Nielsen, A K Joensen, H Madsen, and J Holst (2000): Tracking time-varying-coefficient functions. *Journal for Adaptive Control and Signal Processing*, **14**, pp 813–828.