Time Series Analysis - with a focus on modelling and forecasting in energy systems

Program

Venue: DTU, Kgs. Lyngby, Copenhagen, Denmark
Date: August 27-31, 2018

Overview

Focus is on data from buildings with occupants, and aggregated buildings in districts etc. Also focus on load, solar and wind power forecasting. Furthermore subjects related to indoor climate will be considered.

Some particular examples of applications are:

- When including the *effect of wind and solar in building energy models,* without detailed information about the building and its usage, it is important to describe non-linear effects and interactions. For this *kernel* and *basis function* (e.g. spline) techniques are indispensable in both discrete and continuous time models.

- *Occupancy in buildings (e.g. modelling CO2 levels, presence, heating, etc.)* leads to different patterns of stochasticity in observed data. Even though it is "random" there are still systematic patterns (e.g. varying levels of noise), which must be taken into account in models. Included in the course are very useful techniques for modeling: non-parametric diurnal curves (*Fourier series basis functions*), disaggregating levels of system noise and observation noise from sensors (*noise level functions in grey-box models*), and occupancy behaviour through hidden states (*hidden markov models*).

- *Tracking changing model parameters over time* in order to adapt to changes in systems and use, using recursive estimation techniques such as *Kalman filters and recursive least squares.*

- *Including weather forecasts* as model inputs to *create optimal forecast models*.

- Optimized control and operation of energy systems using *model predictive control*. Examples are optimizing heat pump operation with respect to varying price and optimal charging of batteries.

Each day will be max. 3 hours of lectures (e.g. 2 x 1.5 hours) and computer exercises for the rest.

Computer exercises will be related to both building and district level (also building components, solar pv and wind).

Monday

This day we will start out by briefly presenting the “basic” parametric models (linear regression), and then we will introduce techniques for fitting non-linear models:

- Parametric models - an introduction
- Nonlinear versus linear models
- Nonparametric and semi-parametric models (kernels, splines, etc.)

Tuesday

We will continue with continuous time models and explain how they are best fitted to data, hence grey-box models. The models are expressed as stochastic differential equations and the Kalman filter is used to calculate the likelihood function:

- Grey-box modeling (basics: tests for white noise, test for parameters, SDE's, ...)
- Introduction to the CTSM-R and how it works (Kalman-filter, examples, ...)

Wednesday

Advanced grey-box modelling techniques are introduced:

- Grey-box modelling (advanced: structural identification, model comparison, model selection, ...)
- Modeling the effect of nonlinear phenomena (wind, solar radiation, humidity, …)

\+ An excursion to some interesting sight close to Copenhagen including a dinner.

Thursday

Models suited for tracking changing model parameters over time are introduced. Models fitted in this way can adapt to system changes and changing conditions. Further, it will be introduced how models can be set up to use weather forecasts in an effective way:

- Recursive and adaptive models (RLS)
- Forecasting (load, wind and solar power forecasting)
- Modelling of occupancy (Hidden Markov models (example: models of CO2 level))

Friday

Using the models for control is a vital application. The basics of model predictive control (MPC) are introduced with some examples for building energy applications. Further, more advanced stochastic control techniques will be presented:

- Model predictive control
- Modelling of flexibility
- Stochastic model predictive control

Monday
09:00 - 12:30 Intro + Lecture + CE
12:30 - 13:30 Lunch
13:30 - 17:00 CE + Lecture

Tuesday
09:00 - 12:30 Lecture + CE
12:30 - 13:30 Lunch
13:30 - 17:00 CE + Lecture

Wednesday
09:00 - 12:30 Lecture + CE
12:30 - 13:00 Lunch
13:00 - 22:00 Excursion

Thursday
09:00 - 12:30 Lecture + CE
12:30 - 13:30 Lunch
13:30 - 17:00 CE + Lecture

Friday
09:00 - 12:30 Lecture + CE
12:30 - 13:30 Lunch
13:30 - 16:00 CE + Goodbye