

Project C: User-Centric Sensor Data Mining for Smart Energy Systems

Majid Khoshrou, Eric J. Pauwels

CWI

Objectives

- Recasting timeseries as matrices
- Forecasting
- Detecting pattern in timeseries
- Detecting events
- Drift in data

Introduction

- Time series related to the use of infrastructures often show **significant diurnal patterns**.
- Recasting such *quasi-periodic* time series as a matrix, often helps to gain a better understanding of the data.
- Two advantages:
 - Better visualization: it can lead to a better appreciation of indistinct or subtle features.
 - Use numerically stable matrix decomposition methods, such as SVD, e.g., to elucidate the underlying data structure [1].

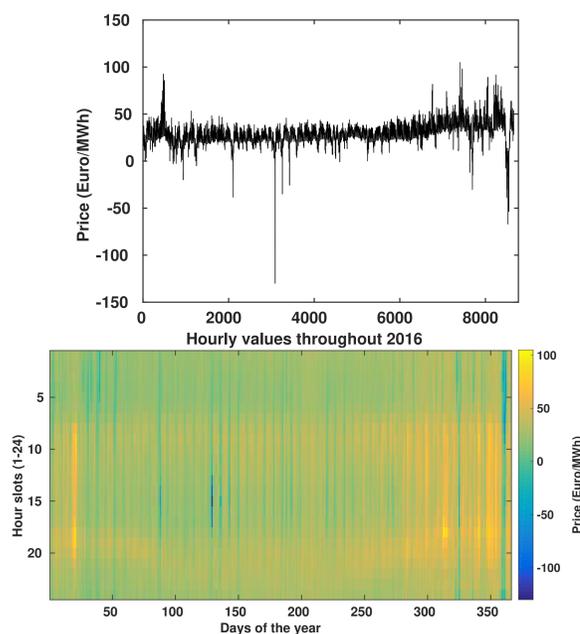


Figure 1: Alternative representation of timeseries data

Materials

The following materials were required to complete the research:

- Timeseries data analytics
- Detecting the underlying patterns
- Volatility of the timeseries

The materials were prepared according to the steps outlined below:

- Geometric interpretations of SVD
- Global energy forecasting competition 2014
- Periodicity detection

Methods

- Singular value decomposition
- Ensemble of trees

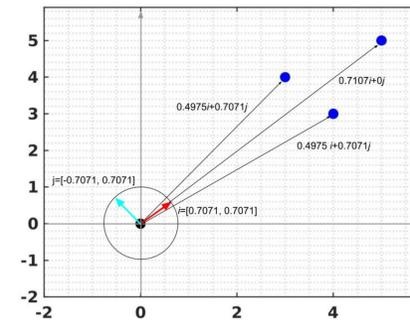


Figure 2: Geometrical interpretation of SVD

Publications

- “Quantifying volatility reduction in German day-ahead spot market in the period 2006 through 2016”, **IEEE Power & Energy Society General Meeting** (August 2018), Portland, Oregon, USA
- “Data-driven pattern identification and outlier detection in time series”, **IEEE Computing Conference** (July 2018), London, UK
- “Propagating uncertainty in tree-based load forecasts”, **IEEE ELECO 2017** 10th International Conference on Electrical and Electronics Engineering (November 2017), Bursa, Turkey
- “SVD-based visualisation and approximation for time series data in smart energy systems”, **IEEE PES Conference on Innovative Smart Grid Technologies** (September 2017), Torino, Italy

Important Result

Alternative representation of the timeseries can indeed open up promising avenues in timeseries analysis.

Mathematical Section

- In order to use the singular value spectrum as a tool for the analysis of periodic time series, we need to know how the spectrum is affected by noise and trend characteristics (extending the work in the original paper [2]).

- To this end we use results from
 - Spectral theory for random matrices;
 - Perturbation theory for eigenvalues of matrices

Results

- Enhancing the underlying trends
- Volatility quantification
- Day-ahead (next cycle) forecasting
- Periodicity detection

Ongoing works

- Detecting periodicity
- Non-stationary data
- Apply to larger and more diverse data sets

References

- Abdolrahman Khoshrou, Andre B Dorsman, and Eric J Pauwels. Svd-based visualisation and approximation for time series data in smart energy systems. In *Innovative Smart Grid Technologies Conference Europe (ISGT-Europe), 2017 IEEE PES*, pages 1–6. IEEE, 2017.
- Partha Pratim Kanjilal and Sarbani Palit. On multiple pattern extraction using singular value decomposition. *IEEE transactions on signal processing*, 43(6):1536–1540, 1995.

Acknowledgements

The authors gratefully acknowledge partial support by the Dutch NWO-TTW under project grant *Smart Energy Management and Services in Buildings and Grids (SES-BE)*

Address

Science Park 123, 1098 XG Amsterdam