



# Michael Thrun

W: [www.iap-gmbh.de](http://www.iap-gmbh.de)



## Multiresolution forecasting for commercial processes

### Research Objectives

Dr Michael Thrun and colleagues Tino Gehlert and Quirin Stier investigate data-driven forecasting techniques for commercially relevant processes.

### Detail

#### Address

IAP-GmbH  
Intelligent Analytics Projects  
In den Birken 10A  
29352 Adelheidsdorf

#### Bio

Dr Thrun received his diploma in Physics (2014) and his doctorate in Data Science (2017) at the Philipps-University Marburg under the chair of Databionics under Professor Dr habil. Alfred H.G. Ultsch. Afterward, he worked for almost two years as a Big Data Scientist for an international manufacturer. He is the author of the book "Projection-Based Clustering through Self-Organization and Swarm Intelligence" and specialises in methods for grouping data, predicting time series, explainable artificial intelligence, and algorithms analyzing data that are borrowed from nature. Additionally, he is researching the topic of recognizing and explaining diseases based on patient's data with a cumulative habilitation under review.

#### Collaborators

Co-Authors of the paper: Tino Gehlert, Quirin Stier

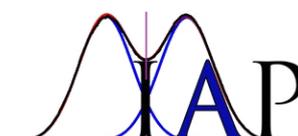
### References

Stier, Q.; Gehlert, T.; Thrun, M.C. 2021, Multiresolution Forecasting for Industrial Applications. *Processes*, 9, 1697. <https://doi.org/10.3390/pr9101697>

### Personal Response

#### **What future improvements do you anticipate when it comes to forecasting techniques?**

Future forecasting techniques will presumably be combined with Artificial Intelligence techniques and report how reliable the forecast is. Moreover, techniques will have to exploit the information stored in several data features at once (multivariate forecasting) to forecast a target feature of interest more accurately. We were already able to build an AI prototype that automatically grades its forecasting performance in a given time frame for a given time series as an application of sales forecasting. However, multivariate forecasting based on wavelets is currently under development. //



# Multiresolution forecasting for commercial processes

Dr Michael Thrun and colleagues Tino Gehlert and Quirin Stier investigated data-driven forecasting techniques for commercially relevant processes, using statistical and machine learning models to investigate future uncertainties in supply chains or call centre management. They found that the new methods, using a so-called wavelet approach – which is able to take varying seasonality into account – performed well compared to state-of-the-art machine learning techniques.

Companies often seek to improve commercial competitiveness by forecasting future uncertainties in areas as diverse as sales figures, supply chain management or workforce management in call centres. Machine learning techniques allow a computer to essentially “learn” from data and provide future predictions from that data in a way that outperforms humans by far. Machine learning techniques typically use a range of different algorithms to analyse so-called training data to create a computational model of the process under investigation. The model is then used to make predictions about future performance.

The predictive process is often complicated by the presence of seasonal fluctuations in the data, which need to be taken into account when undertaking analysis. Datasets focusing on a single feature as a function of time, with seasonal fluctuations, are known as *seasonal univariate time series*. An example is the pricing of electricity.

Dr Michael Thrun and his colleagues, Tino Gehlert and Quirin Stier, have worked on a so-called multiresolution forecasting framework, which enables researchers to swiftly apply an automated algorithm to recognise complex and changing patterns in the data and produce forecasts.

## WHY IS THIS NEW?

Previously, time series have been analysed using a variety of methods, including Fourier analysis. A Fourier transform is a mathematical operation used to decompose a time series into a function of frequency. This analysis can be used to

analyse frequencies in a time series, but it is not an ideal method for taking varying seasonality into account. Nevertheless, it can provide a good analysis of series with regular seasonality throughout the time period under investigation. Dr Thrun and colleagues investigated wavelet-based methods, which allows for more precision. While the Fourier transform creates a representation of a time series in the frequency domain independent of the point in time (e.g., date), wavelet-based methods create a representation of the time series in both the time and frequency domain, thereby allowing efficient access of localised information about the time series at each point in time. Figure 1 outlines the difference between the three domains.

According to Dr Thrun, “Wavelet analysis uses short time intervals for capturing high frequencies in order to relate them to specific time intervals (localization in time) more precisely than Fourier analysis.”

Another major advantage of this new method is that by using an algorithm borrowed from nature (“evolutionary optimization”) there is no need to set parameters – numeric values of methods that require fine-tuning to achieve a high forecasting quality. This makes it easier to apply because any operator can use the method right away.

In their recent paper, “Multiresolution Forecasting for Industrial Applications”, Dr Thrun and colleagues compared two time series forecasting methods using the “redundant Haar” wavelet decomposition method with several state-of-the-art forecasting methods, including a Fourier method and other multiresolution

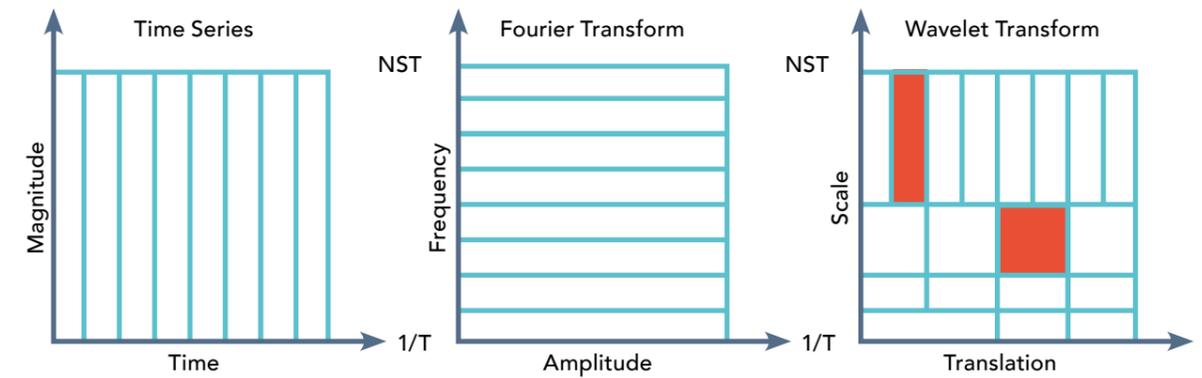


Figure 1. With time changing seasonalities marked in red, wavelets can be identified, contrary to Fourier analysis which assumes that the seasonalities are fixed. Abbr.: NST - Limit by Nyquist frequency.

methods (a general term for methods that explicitly capture changes on a range of different timescales).

The wavelet decomposition methods tendentially outperform in terms of forecasting accuracy the results of other state of the art statistical and machine learning techniques that are typically used for the task of forecasting. The method finds the complex patterns in the data automatically through a highly optimised search strategy. Once an optimal model is found, it can be used regularly as new data comes in to support decision making.

## WHICH TIME SERIES WERE INVESTIGATED?

Dr Thrun and colleagues looked specifically at four time series covering electricity demand, electricity prices, stocks and the volume of calls arriving in a call center.

The electricity demand dataset covers daily usage in Germany between 2006 and 2015. Since electricity use is strongly seasonal, it would be expected to respond well to Fourier analysis.

Another covers hourly prices for each Scandinavian country from 2013 to 2016. By contrast, this dataset has varying seasonal components because electricity prices exhibit varying seasonality on daily, weekly and annual levels as well as unanticipated price spikes.

The stocks dataset contains stock prices for American Airlines from 2013 to 2017. Stock prices are presumed to depend

largely on externalities and would be difficult to predict based solely on a time series of past prices. The call center data is the number of issues in a single call center per day between 2013 and 2018. This dataset also has strong seasonal components and would be expected to be predicted accurately by a Fourier approach.

For the electricity usage dataset, all four multiresolution methods outperform the so-called seasonal naive method (a benchmark representing an essentially random process known as the random walk).

For the call center dataset, the two multiresolution methods with neural networks outperform every other method. The only other method performing better than the naive seasonal method for more than one time step into the future (known as the first horizon) is Prophet (the Fourier method).

## Wavelet-based methods combined with evolutionary optimisation are proposed that predict time series through neural networks and regression.

In contrast, using only the last observed value for prediction for the stocks dataset surpasses more sophisticated forecast methods that seek seasonality in data with no present patterns.

Although predictions for the electricity prices dataset with multiresolution methods result in a lower error with less variance compared to other methods, on average, no significant improvement to

naïve forecast could be demonstrated. The reason lies behind individual spikes occurring individually in the time series, which depend on external information.

## WHAT IS THE SIGNIFICANCE OF THESE RESULTS?

This work applies the wavelet method to industrial tasks making use of automation and avoiding the need to set any parameters, and provides a comparison of performance with state-of-the-art methods. The presented multiresolution method is appropriate for seasonal forecasting and performs equally well or better than the current state-of-the-art methods.

For longer term forecasts, the multiresolution methods, including one of the two wavelet methods, outperform almost every other method on the electricity prices, electricity usage and call center data, and perform as well as

stock prices are more affected by external factors.

The results show that the multiresolution methods perform better than Fourier analysis overall.

For short term forecasting, combining wavelet techniques with advanced neural networks – a technique often used in machine learning which is inspired by the structure of the brain – resulted in considerably better results. Dr Thrun and colleagues suggest that more complex wavelets could also be considered in the future to potentially further improve forecasting techniques.



# research OUTREACH

*The public outreach magazine for the research community*

researchoutreach.org

Partnership enquiries: [simon@researchoutreach.org](mailto:simon@researchoutreach.org)

