Learning Linear Dynamical Systems using Spectral Wave-Filtering

A Machine Learning Algorithmus which learns the Properties of a Linear Dynamical System

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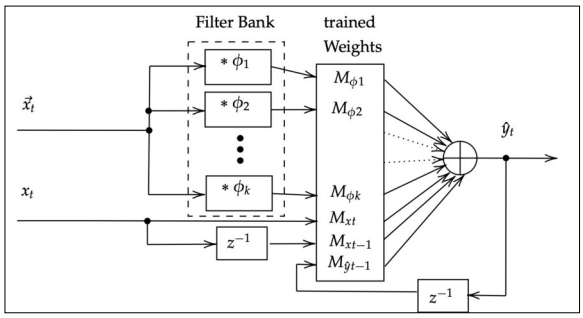
Introduction: Linear Dynamical Systems are a class of state-space models that are often used to model natural events. One task for engineers today is to identify such a linear system. That is to measure and calculate the parameters that define the system. However, if the system can be observed for a certain time, it may be possible to learn these parameters with a machine learning algorithm.
Researchers of the Department of Computer Science at Princeton University developed an algorithm to predict such discrete-time linear dynamical systems online. Learning online prediction of such systems is usually a non-convex optimization problem. By overparameterize the LDS, the loss function gets convex.

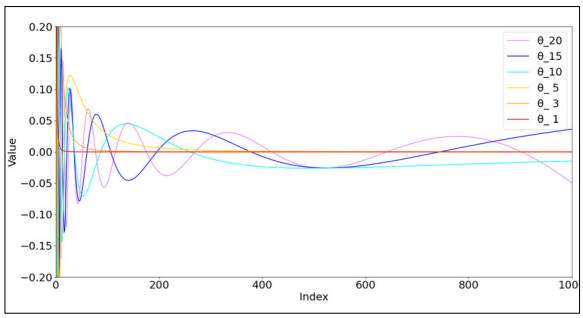
Approach: The wave-filter was implemented and tested with several optimization methods. Tests were done with multiple linear dynamical systems and input signals.
To contribute to the work done so far on this algorithm, it was tested with slightly nonlinear systems and systems with asymmetrical matrices. In addition, it was tested how well the algorithm performs if it has to predict future samples.

Conclusion: The proposed algorithm performed surprisingly well in various tests. As an optimization method, the least-squares seem to outperform the rest. This optimization, however, needs increased computational power.
As the authors claimed, tests done with asymmetric system matrices yielded poor results. Also, nonlinear systems could not be handled by several implementations of the wave-filter
To predict future samples, the wave-filter algorithm does not perform well. It often gets beaten by a simple persistence predictor.

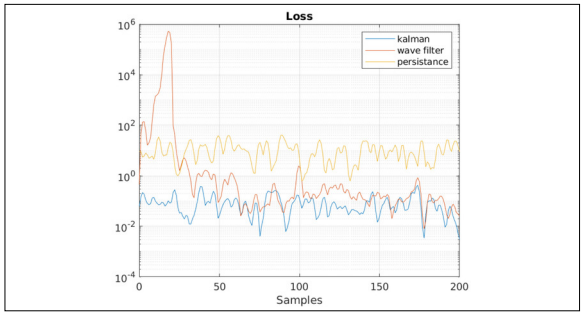
The structure of the algorithm.
Own presentment



The wave-filters which get convolved with the input signal are the eigenvectors of a specific Hankel matrix.
Own presentment



The performance of the wave-filter converges to the one of the Kalman filter.
Own presentment



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Sensor, Actuator and Communication Systems