Challenges in stochastic time series prediction

Maximilian Hornung, Jens Settelmeier

April 21, 2019

Abstract

Predicting the future development of time series is of interest in different areas of computational biology. The time series in biological models exhibit challenging characteristics such as chaotic or stochastic behavior. In this report, time series prediction is done on different kind of biological time series using deep neural networks. In our evaluation, we identify challenges and limitations of this approach, and compare different architectures of deep neural networks with regard to their performance.

1 Introduction

The remaining report is structured as follows. First, we perform proper time series prediction on the *sine* function and show how different noise models impact the prediction ability of our network models. We conduct an evaluation how these results can be extended to the prediction of ordinary differential equations (**ODE**s) at the example of the differential equations of the harmonic oscillator. After that, we show how the stochasticity of noise impactss the possibility to predict deterministic chaotic time series at the example of the *Mackey Glass* time series. Last but not least, we report how the poor results of numerical approximations on stocastic differential equations (**SDE**s) can be explained based on our previous results.

2 Methods

3 Evaluation

3.1 Time series prediction of continuous functions

3.2 Time series prediction of ODEs

3.3 Mackey Glass time series prediction

In order to model diseases related to dynamic respiratory and hematopoietic diseases, Mackey *et al.* proposed the mackey-glass equations, a kind of first-order nonlinear differential delay equations [5]. If the delayed time ($x_\tau = x(t-\tau)$) exceeds the delay $\tau > 16.8$, then equation 1 behaves chaotic [2].

$$\frac{dx}{dt} = \beta \cdot \frac{x_\tau}{1 + x_\tau^n} \tag{1}$$

The first approach to predict the short-time behavior of chaotic time series was done by Farmer *et al.* who proposed a `local approximation` technique [3]. After improval of predictions using support vector machines by Mller *et al.* [6], the focus in research shifted towards artifical neural networks which enable even better predictions. Two of the latest developments are the usage of Wavelet Networks [1] and particle swarm optimization [4].

3.4 SDE time series prediction

4 Conclusion

References

[1] Antonios K Alexandridis and Achilleas D Zapranis. Wavelet neural networks: A practical guide. *Neural Networks*, 42:1–27, 2013.

[2] J Doyne Farmer. Chaotic attractors of an infinite-dimensional dynamical system. *Physica D: Nonlinear Phenomena*, 4(3):366–393, 1982.

[3] J Doyne Farmer and John J Sidorowich. Predicting chaotic time series. *Physical review letters*, 59(8):845, 1987.

[4] CH López-Caraballo, I Salfate, JA Lazzús, P Rojas, M Rivera, and L Palma-Chilla. Mackey-glass noisy chaotic time series prediction by a swarm-optimized neural network. In *Journal of Physics: Conference Series*, volume 720, page 012002. IOP Publishing, 2016.

[5] Michael C Mackey and Leon Glass. Oscillation and chaos in physiological control systems. *Science*, 197(4300):287–289, 1977.

[6] K-R Müller, Alexander J Smola, Gunnar Rätsch, Bernhard Schölkopf, Jens Kohlmorgen, and Vladimir Vapnik. Predicting time series with support vector machines. In *International Conference on Artificial Neural Networks*, pages 999–1004. Springer, 1997.