Model-Free Prediction of Spectral Evolution in Optic Fibers Using Machine Learning

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Knowledge of the dynamics of an ultrashort pulse plays a vital role in its applications.The dynamics of ultra-short pulses in an optic fiber are highly non-linear and this is governed by the Non-Linear Schrödinger Equation (NLSE)[1]. NLSE is solved numerically by the use split-step Fourier method. This is computationally expensive to solve and thus cannot be used in real-time applications. In this work, we have proposed model-free prediction of the spectral evolution of an ultra-short pulse in an optic fiber using recurrent neural networks (RNNs), specifically GRUs (gated recurrent units). In a 2021 article by Lauri Salmela Et al.[2] tried to achieve this using Long short-term memory(LSTM) but when we compare GRUs and LSTMs the latter is faster due to the decreased number of gates in its architecture. We have also benchmarked our work against the original paper. Our results also show that GRUs are significantly faster than LSTMs, making them a more suitable option for real-time applications. Whenever our intensity profile changes as it propagates

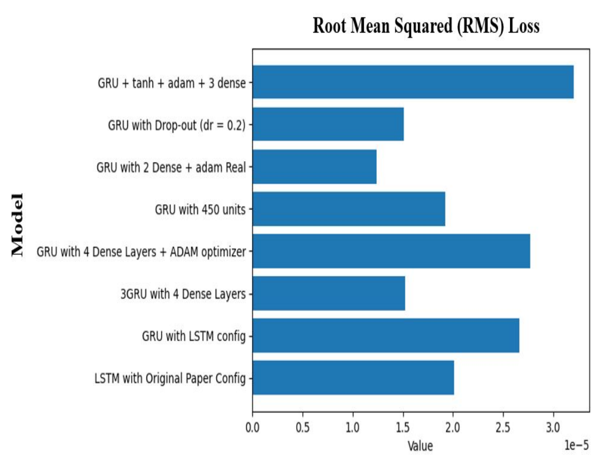

Figure 1: Comparative Study of Different Architectures

through the fiber, it can be treated as a sequence. Each step's intensity profile can be considered a step in the sequence. GRUs can capture long-term dependencies in the sequence, making them very effective in predicting the next state in the sequence. This is also the reason why it is widely used in natural language processing (NLP). We used the Python TensorFlow and Keras libraries for the

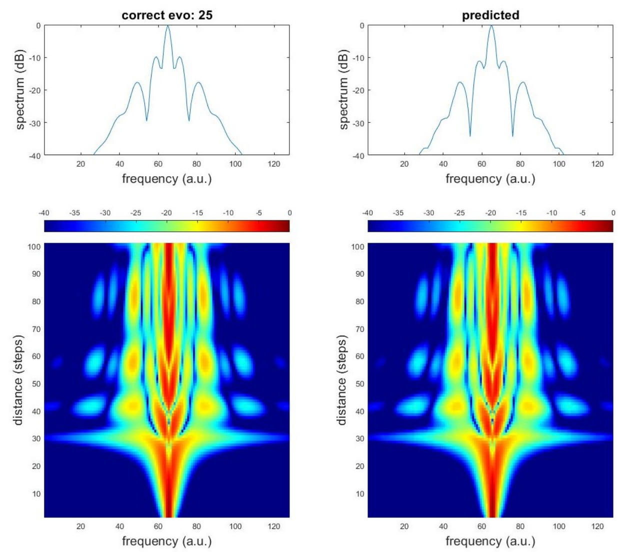

Figure 2: Spectral Evolution prediction of an ultra-short pulse through an optic fiber

implementation and training of the RNNs. The various network designs that were evaluated and benchmarked using the root mean squared error (RMS) are shown in Figure 1. The split-step Fourier approach with a spectral resolution of 128 points was used to simulate the data and retrieve it for training. With a hyperbolic secant pulse as the input, it is clear from the error data that the network with one GRU layer and two dense layers optimised with the Adam optimizer works better than alternative configurations and provides a very precise prediction of the spectrum evolution (Fig. 2). As incremental work, GRUs can be useful for predicting complex non-linear effects, like higher-order solitons and supercontinuum generation.

References

[1] Govind P Agrawal. Nonlinear fiber optics. In *Nonlinear Science at the Dawn of the 21st Century*, pages 195–211. Springer, 2000.

[2] Lauri Salmela, Nikolaos Tsipinakis, Alessandro Foi, Cyril Billet, John M Dudley, and Goëry Genty. Predicting ultrafast nonlinear dynamics in fibre optics with a recurrent neural network. *Nature machine intelligence*, 3(4):344–354, 2021.

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