Comparison of Optoelectronic Reservoir Computing and LSTM

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INTRODUCTION

- Optoelectronic implementation of reservoir computing consisting of a single non-linear node and a delay line has been used in classification and reconstruction of optical communication signals. The implementation is sufficiently fast for real-time information processing[2].
- Recurrent Neural Networks (RNN), which are a subset of machine learning, are widely used to deal with nonlinear time dependent sequences such as signal classification, natural language processing, and nonlinear signal reconstruction. Unfortunately, computation time, and complexity, limits the use of RNNs.

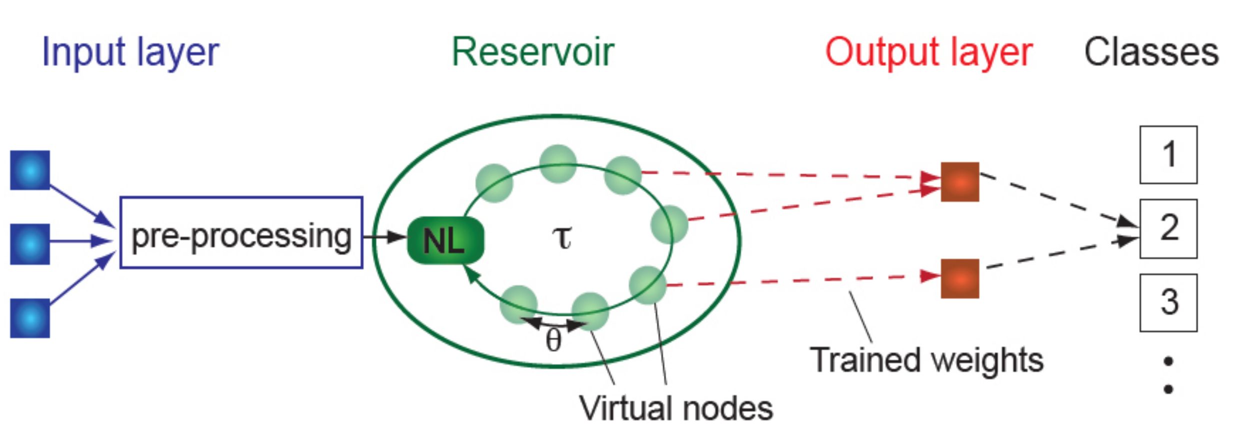

Fig1. Delayed feedback reservoir computing

METHODS

- We implemented a simulation-based study of the optoelectronic reservoir computing system compared to Long short time memory (LSTM) and test these two networks on a non-linear equalization task.
- A Mach-Zehnder modulator is used to introduce nonlinearity. An optical fiber produces the time delay.
- We introduce a bias on the Mach-Zehnder modulator – which will make our system more robust against white noise on the input.
- We perform a standard benchmark, nonlinear channel equalization on our RC. The symbol error rate (SER) and root mean square error (RMSE) are used to estimate the performance of networks.
- A Long short-term memory (LSTM) network performs the same task in order to compare the performance between LSTM and our delayed feedback RC.

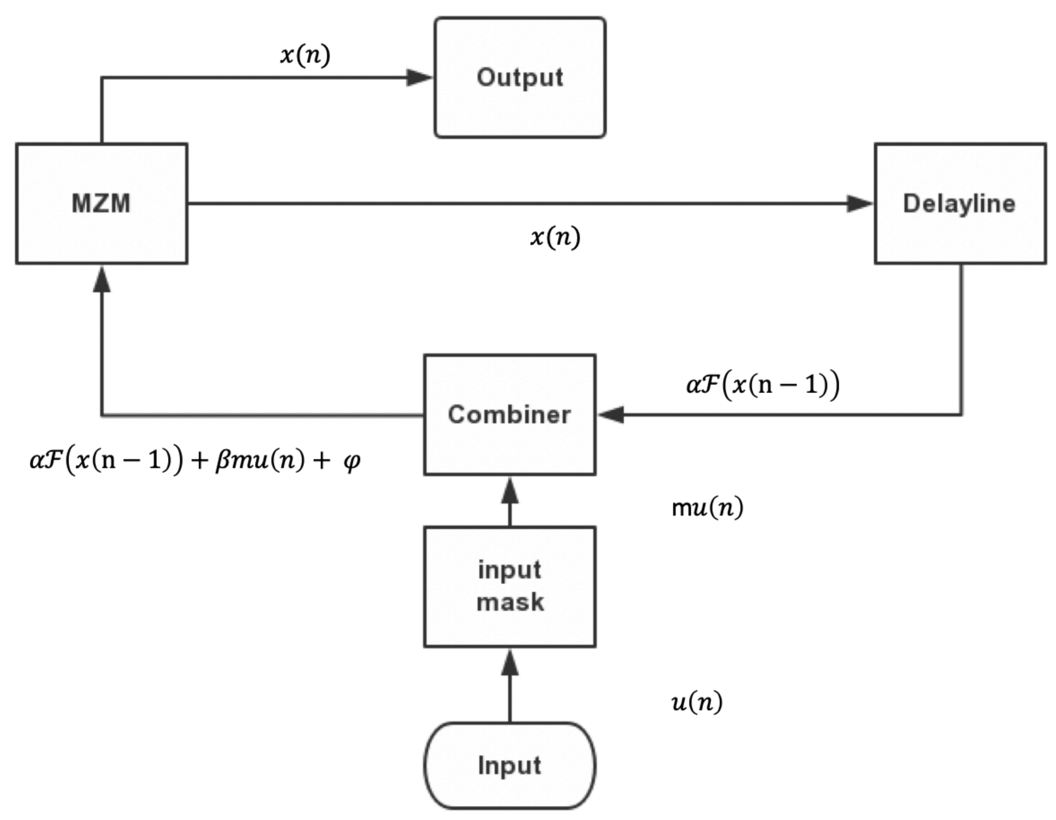

Fig2. Flowchart of optoelectronic reservoir computing

RESULTS

- Our simulated system is more robust against noise than simulation implementation in previous papers[1] by adding bias on the MZM. This is because bias is DC component which can cover the noise and bias can introduce more non-linearity from MZM.

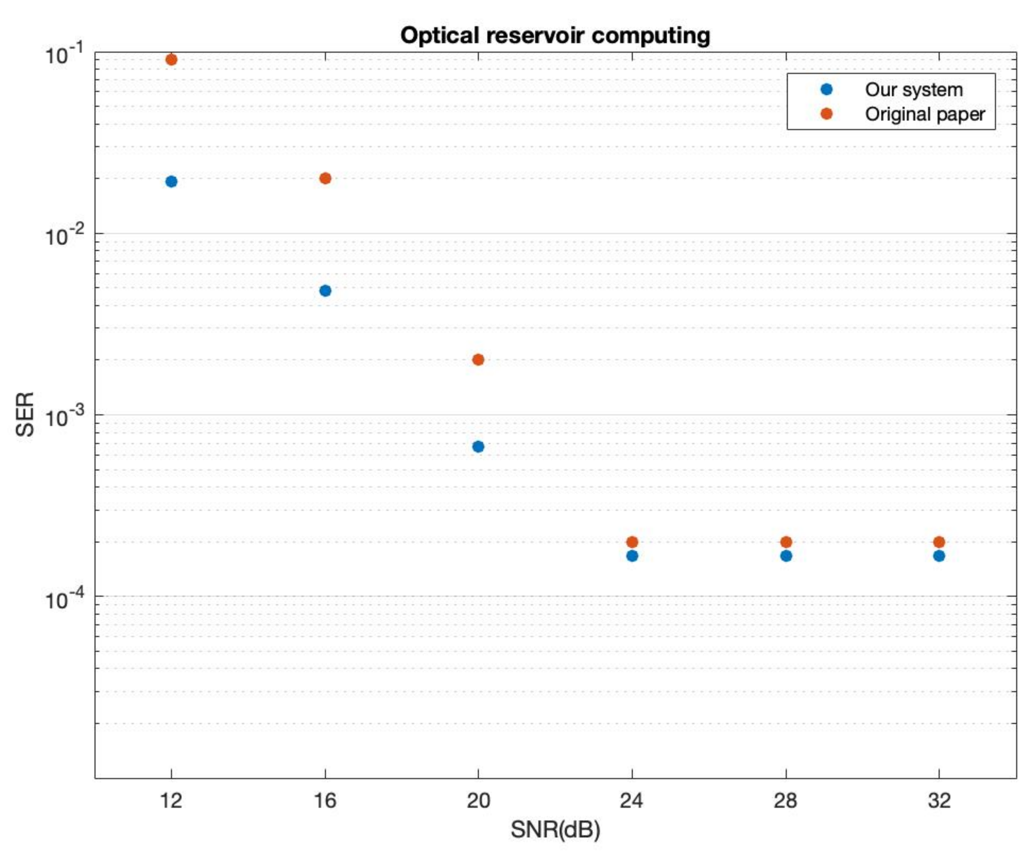

Fig3. SER versus SNR plot of our simulation and previous paper

- Figure 4 shows RMSE vs number of hidden nodes in optoelectronic reservoir computing system and LSTM. LSTM needs less nodes than optoelectronic reservoir computing because of learnable parameters.
- Table 1 shows optoelectronic reservoir computing system need much less computation time and computation memory than the LSTM. And inference time of optoelectronic reservoir computing is also smaller than LSTM. These comparison indicates optoelectronic RC still has its potential in application.

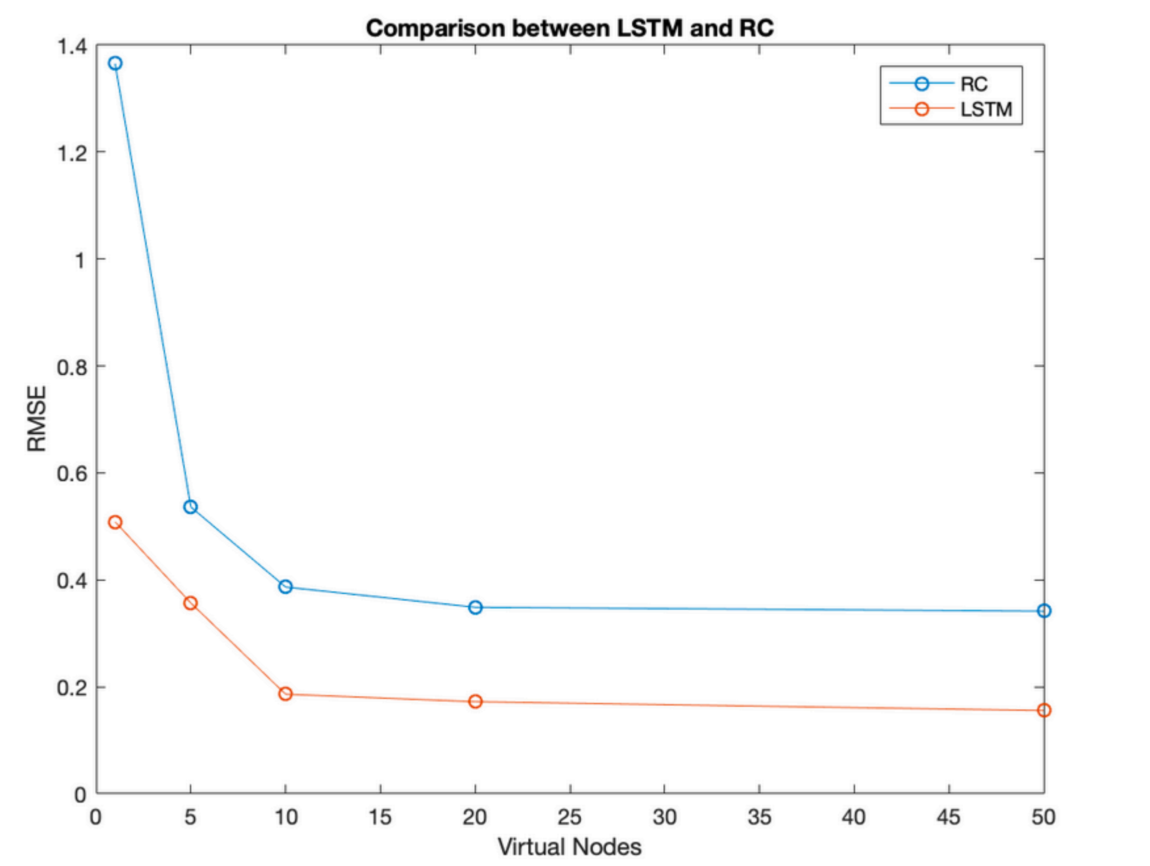

Fig4. RMSE vs hidden nodes in optoelectronic RC and LSTM

	Optoelectronic RC (50 node)	LSTM (50 node)
Training time(s)	0.551	40
Inference time(s)	0.081	0.163078
Computation Complexity (n hidden units, m input size)	n	$4(nm+n^2+n)$

Table1. comparison between Optoelectronic RC and LSTM

CONCLUSIONS

1. **Our optoelectronic reservoir computing system is more robust against bias than the system of original paper because we add a DC bias on Mach-Zender modulator.**
2. **The LSTM network need fewer hidden units to realize same performance (RMSE) of the optoelectronic reservoir computing system because LSTM can update its parameters by gradient while the reservoir and input mask of RC is fixed, which limits the application of RC to more difficult task.**
3. **Optoelectronic reservoir computing system need much less computation time and computation memory than the LSTM.**

REFERENCES

1. Paquot, Y., Duport, F., Smerieri, A., Dambre, J., Schrauwen, B., Haelterman, M., & Massar, S. (2012). **Optoelectronic reservoir computing**. Scientific reports, 2, 287.
2. Tanaka, G., Yamane, T., Héroux, J. B., Nakane, R., Kanazawa, N., Takeda, S., ... & Hirose, A. (2019). **Recent advances in physical reservoir computing: a review**. Neural Networks.