Computational Capacity of Photonic Delay-based Reservoir Computing

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We simulated a delay-based reservoir computing setup based on a semiconductor laser subjected to feedback. The computational capacities of the setup are investigated for varying node separations, a parameter that determines the computation speed. We also investigate the capacities of our setup for varying mismatches between delay length and input length, which is of interest for experimental setups.

Photonic delay-based reservoir computing

Reservoir computing (RC) is a neuromorphic computing framework, much like neural networks. In RC, however, the training procedure is simplified drastically by keeping a large part of the network fixed and only training a linear output layer [1].

Since the larger part of the network is kept fixed, it can be replaced by any dynamical system with an equally high dimensional state space. One interesting system is a semiconductor laser subjected to optical feedback. In this setup, the number of neurons N are spread along the delay line with a node separation of θ. The computation speed is limited by $N\theta \approx \tau$. The delay time τ will never be precise in practice due to fabrication and measurement limits. In most setups τ and $N\theta$ are intentionally mismatched by a multiple of θ. In this work we look at the computational capacity [2] of our photonic delay-based RC system as a function of θ and a continuous range of delay mismatch.

Results

We simulated our RC-setup with 100 nodes, so according [2] the maximum capacity we can find is 100. In Fig. 1, we see the maximum does not exceed 70. This is mainly due to spontaneous emission noise in our system. When θ is small in the left plot, the capacity decreases because θ gets closer to the photon lifetime and the laser is not able to follow. As θ get larger, the node values will evolve to a steady state value, increasing the chance of redundancy and the performance degrades after an optimum at 30ps.

In the right plot, we swept the delay time continuously. We start with $\tau=(N-2)\theta$ and go up to $\tau=(N+2)\theta$. We see the computational capacity increases steadily, with a clear break when the τ passes $N\theta$. At this transition the lower degree computational capacities obtain a boost, thanks to the extra memory introduced in the system.

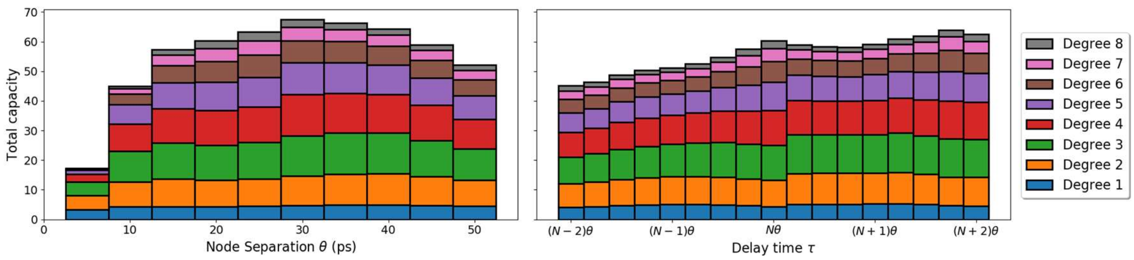

Figure 1 The total computational capacity as the node separation θ (left) and the delay time τ (right) is varied.

References

[1] G. Van der Sande, D. Brunner, & M. C. Soriano. Advances in photonic reservoir computing. Nanophotonics, 6(3), 561-576, 2017.

[2] J. Dambre, D. Verstraeten, B. Schrauwen, & S. Massar. Information processing capacity of dynamical systems. Scientific reports, 2, 514, 2012.