Interferometric stabilisation of a fiber-based optical computer

Experimental study

Denis Verstraeten

ULB - Opera Photonics

April 5, 2019

Outline

Context

- The need for always faster data processing devices is ever increasing
- This motivates the study of a new physical computation paradigm, the optical computer
- This kind of computer relies on light to process information
- Different ways to implement computing logic
- In this work, focus on **Reservoir Computing** (RC)

Outline

Reservoir Computing (RC) in a nutshell...

- Artificial Neural Network
- Real-time data processing scheme
- Can be implemented in physical systems
- State of the art performances in time series prediction

Mathematical model of a RC

Discrete time dynamics of a neuron [Jae01]:

$$x_i(t+1) = f_{NL}\Big(W^{ij}\ x_j(t) + W^{ij}_{\text{in}}\ u_j(t) + W^{ij}_{\text{fb}}\ y_j(t) \Big) \quad (1)$$

Discrete time output of the reservoir:

$$y_i(t) = W^{ij}_{\text{out}}\ x_j(t) \quad (2)$$

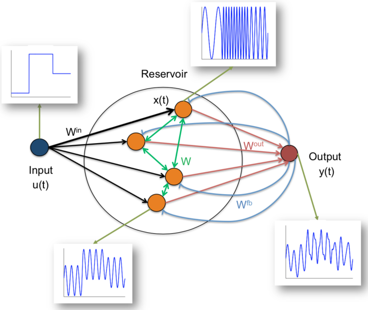
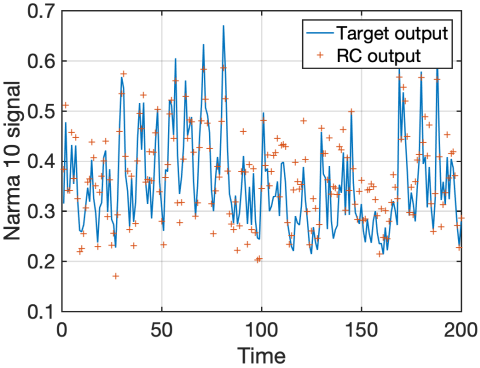


Figure: [BFP12]

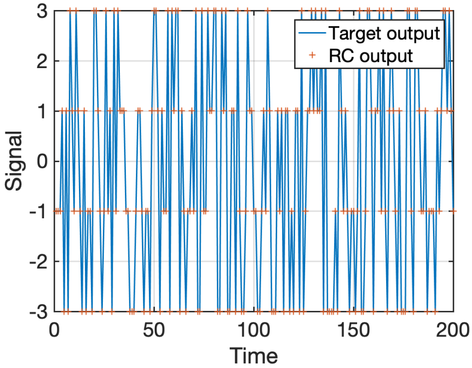
Example - NARMA 10

- Nonlinear AutoRegressive Moving Average
- 50 neurons
- Washout : 300
- Learning : 3000
- Testing : 6000
- NMSE = 0.1439



Example - Nonlinear Channel Equalisation

- 50 neurons
- SNR = 32 dB
- Washout : 300
- Learning : 3000
- Testing : 6000
- SER= $3.33 \cdot 10^{-4}$



Outline

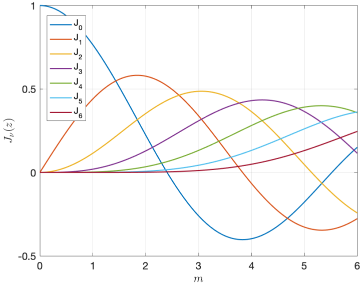
Motivations

- Blablabla
- Coupling of the different frequencies

Frequency coupling - phase modulator I

Effect of a *phase modulator* :

$$Ee^{-i\omega t} \underset{\Omega}{\rightarrow} Ee^{-i\omega t}e^{im\sin\Omega t} = \sum_{k=-\infty}^{\infty} EJ_k(m)e^{-i(\omega+k\Omega)t} \tag{3}$$



- m usually small (≤ 2)
- $J_k(m)$ decrease fast with k
- Series can be truncated
- **Finite number of frequencies can be coupled**

Frequency coupling - phase modulator II

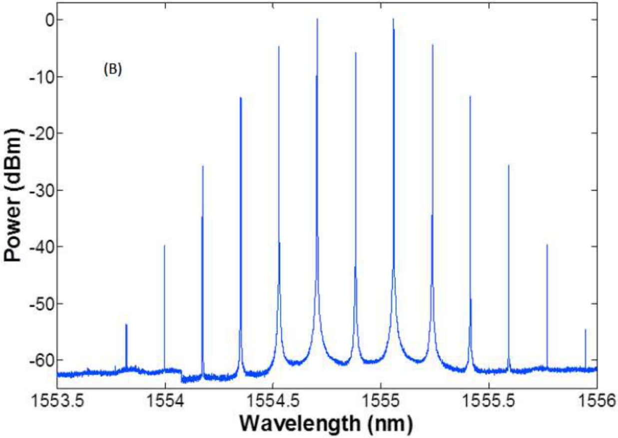


Figure: Spectrum inside the cavity. 13 frequencies are usable.[Akr+16]

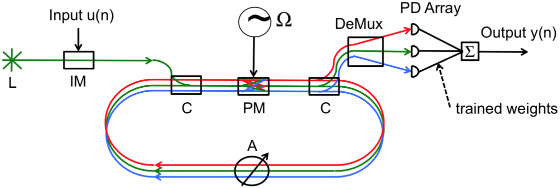


Figure: [Akr+16]

Outline

Outline

[Akr+16] A. Akrout et al. "Parallel photonic reservoir computing using frequency multiplexing of neurons". In: (2016).

[BFP12] A. Bernal, S. Fok, and R. Pidaparthi. "Financial Market Time Series Prediction with Recurrent Neural Networks". In: (2012). URL: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.278.3606&rep=rep1&type=pdf.

[Jae01] H. Jaeger. *The "echo state" approach to analysing and training recurrent neural networks*. 2001.