Optical Bistability As Neural Network Nonlinear Activation Function

Davide Bazzanella

20th March 2018

Università degli studi di Trento

All-Optical Neural Networks

2018-03-09

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Introduction

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Applying integrated photonics to artificial neural networks architecture design

Develop simulations on standard software libraries that help performance comparisons

All-optical Artificial Neural Networks

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Outline

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Artificial Neural Networks
Microring Resonator
ANN Simulations
Conclusion

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Artificial Neural Networks

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ANNs

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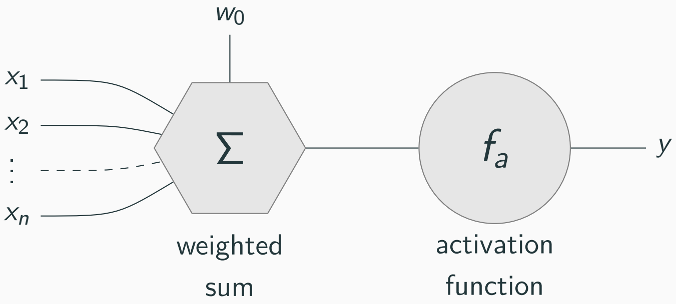
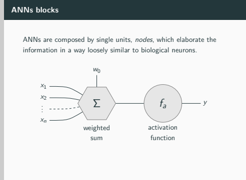
ANNs blocks

ANNs are composed by single units, *nodes*, which elaborate the information in a way loosely similar to biological neurons.





What can they do?

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ANNs can solve complex problems:

- classification
- clustering
- pattern recognition
- time series prediction

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figures/foo.png

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figures/foo.png

How do they work?

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ANNs can obtain arbitrary decision regions[1]

The amount of free parameters in an ANN, allow .. ?

[1] R. O. Duda et al., *Pattern classification*, (John Wiley & Sons, 2012)

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- training
  - evaluate loss
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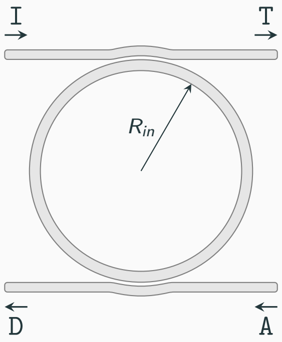
Microring Resonator

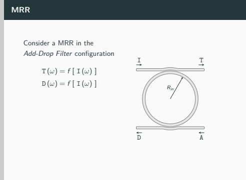
MRR

Consider a MRR in the
Add-Drop Filter configuration

$$\mathtt{T}(\omega) = f\,[\ \mathtt{I}(\omega)\ ]$$

$$\mathtt{D}(\omega) = f\,[\ \mathtt{I}(\omega)\ ]$$





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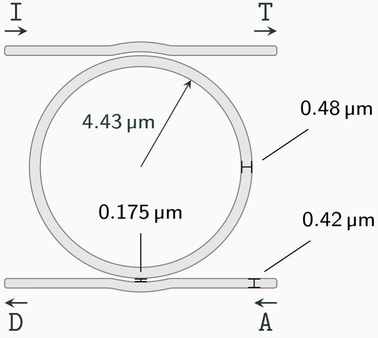

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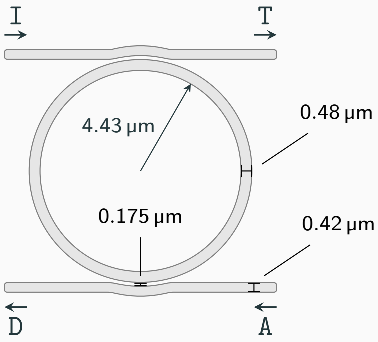
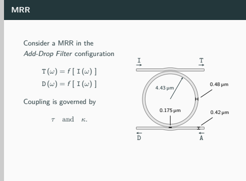
Coupling is governed by

$$\tau \quad \text{and} \quad \kappa.$$





Theory

Linear

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Theory

Linear

Theory

Nonlinear

Theory

Nonlinear

Experiments

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└─Experiments

Experiments

ANN Simulations

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Simulation Framework

What means simulating? PyTorch library

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Fundamental blocks

model ($FF[f_a]$)

loss criteria (CEL)

weight update criteria (SGD)

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Cross-Entropy Loss (also known as negative log likelihood),

$$L(y, \hat{y}) = f_{CEL}(y, \hat{y}) = -\frac{1}{N} \sum_{n=1}^{N} \sum_{i=1}^{C} y_{n,i} \log\left(\hat{y}_{n,i}\right)$$

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Stochastic Gradient Descent

with *momentum*

and *learning rate scheduler*.

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Operation Tests

ReLU vs Sigmoid vs f_{fit}

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Overview

I assembled an experimental setup from scratch

I characterized the response of the MRR in several aspects

I implemented the bistable response in standard software libraries

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Future Perspectives

Continue the current work with a quantitative analysis of specific features

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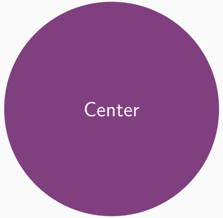
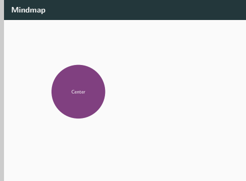
Mindmap





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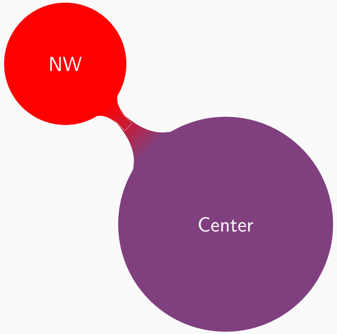

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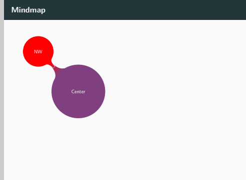

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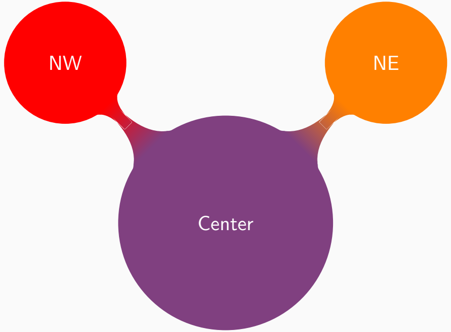

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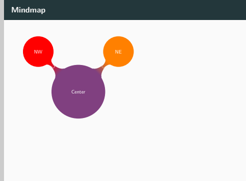

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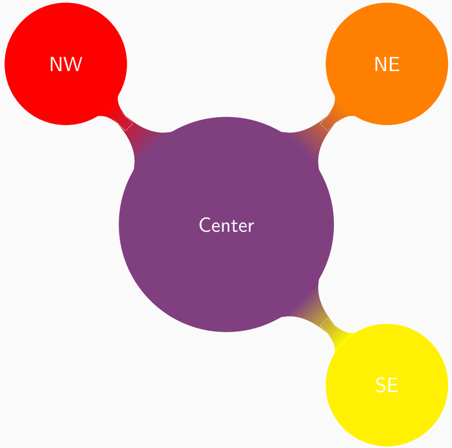

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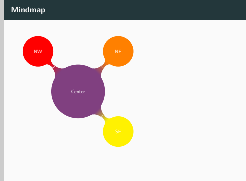

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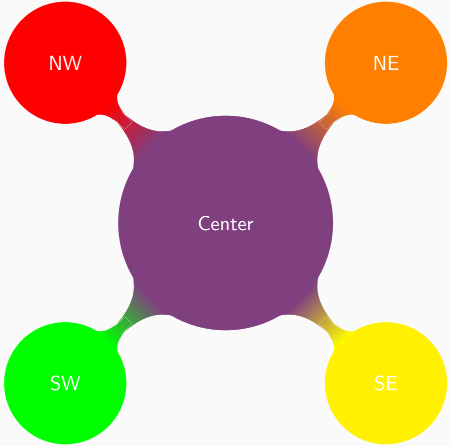

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