

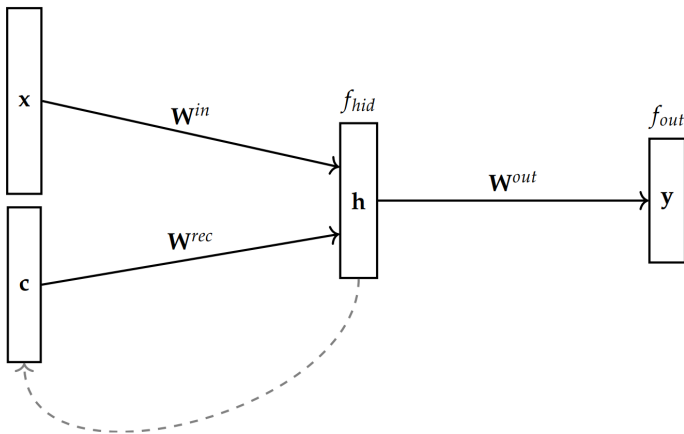
Neural Networks

8. Echo State Networks

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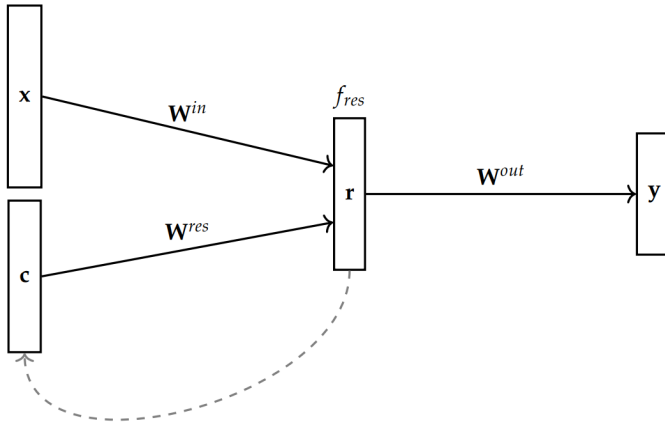
Thursday 11th April, 2024

Simple Recurrent Network (last exercise)



$$c(t) = h(t-1) \quad h = f_{hid}(W^{in}x' + W^{rec}c') \quad y = f_{out}(W^{out}h')$$

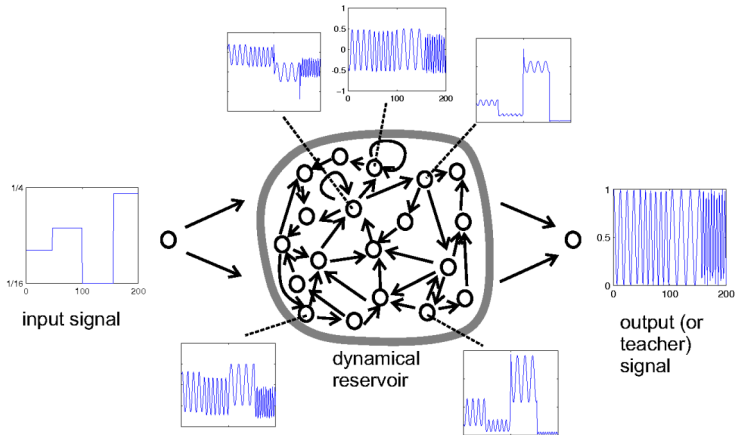
Echo State Network



$$c(t) = r(t-1) \quad r = f_{res}(W^{in}x + W^{res}c) \quad y = W^{out}r$$

hidden layer == "reservoir"

Echo State Network



Echo State Network - training

W^{in} (Untrained)

- ▶ random Gaussian initialisation

W^{res} (Untrained)

- ▶ **Sparse**: some % of weights are set to 0
- ▶ $\max\{|\lambda_i|\} = \rho, \quad 0 \ll \rho < 1$

W^{out} (Trained)

- ▶ **Analytically** - pseudo-inverse (for linear output only):
 $W^{out} := DR^+$
- ▶ **Iteratively** - gradient descent:
 $\Delta W^{out} = \alpha(\mathbf{d} - \mathbf{y})\mathbf{r}^T$

Task

- ▶ `C08.1-seq.py` and `C08.2-seq.py` TODO:
 - ▶ tune the parameters to make the model work better
- ▶ `esn.py` TODO:
 - ▶ initialise weights
 - ▶ initialise the reservoir
 - ▶ forward pass
 - ▶ update weights