Student Project II

Fading memory in recurrent spiking networks

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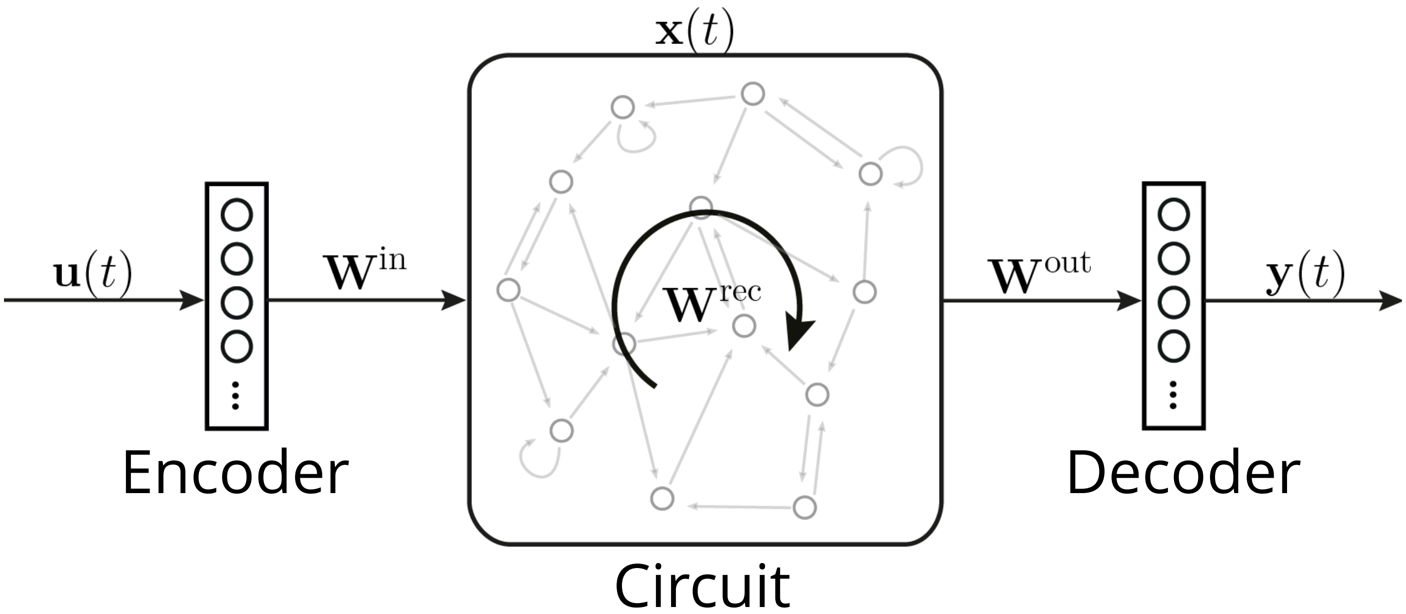
Background

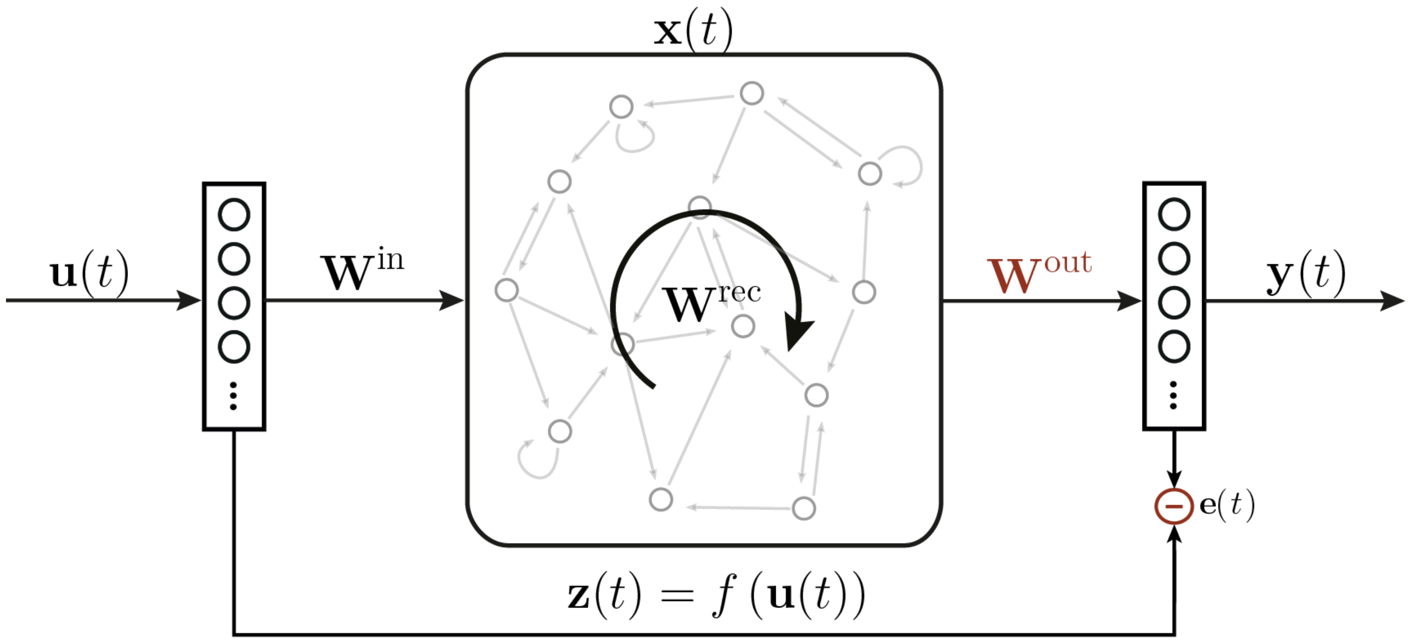


$$\mathbf{W}^{\text{rec}} \in \mathbb{R}_{\mathrm{N}\times\mathrm{N}}$$

$$\mathbf{u}(t) = \begin{bmatrix} u_1(t) \\ u_2(t) \\ \cdots \\ u_{\mathrm{N}_u}(t) \end{bmatrix} \xrightarrow[\mathbf{W}^{\text{in}} \in \mathbb{R}_{\mathrm{N}_u\times\mathrm{N}_x}]{} \mathbf{x}(t) = \begin{bmatrix} x_1(t) \\ x_2(t) \\ \cdots \\ x_{\mathrm{N}}(t) \end{bmatrix} \xrightarrow[\mathbf{W}^{\text{out}} \in \mathbb{R}_{\mathrm{N}\times\mathrm{N}_y}]{} \mathbf{y}(t) = \begin{bmatrix} y_1(t) \\ y_2(t) \\ \cdots \\ y_{\mathrm{N}_y}(t) \end{bmatrix}$$

Background

nest::



Linear readouts as metrics

Offline / batch:

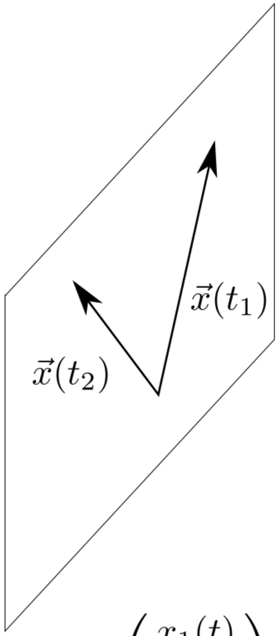
$$\mathbf{W}^{\text{out}} = \mathbf{Z}\mathbf{X}^{T}\left(\mathbf{X}\mathbf{X}^{T} + \beta\mathbb{I}\right)^{-1}$$

Online:

$$\Delta\mathbf{W}^{\text{out}} = -\eta(t)\mathbf{e}(t)\mathbf{x}(t) + \beta\left\|w^{out}\right\|_{2}$$

Encoding

stimulus $\xrightarrow{\textit{encoding}}$ neural activity



$$\vec{x}(t) = \begin{pmatrix} x_1(t) \\ \vdots \\ x_M(t) \end{pmatrix}$$

$\xrightarrow{\text{input currents}}$

$$\vec{I}(t) = \begin{pmatrix} I_1(t) \\ \vdots \\ I_N(t) \end{pmatrix}$$

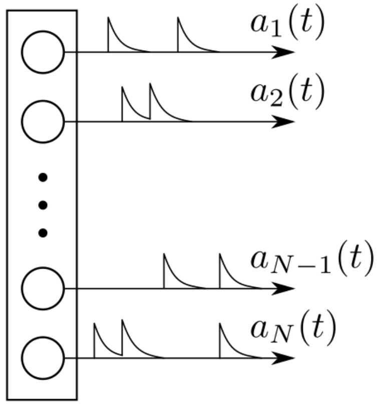
$$I_i(t) = \alpha_i \left\langle \vec{x}^{\mathsf{T}} \vec{e}_i \right\rangle + \beta_i$$

with

preferred stimulus $\vec{e}_i$

gain α_i

background input β_i



$$\vec{a}(t) = \begin{pmatrix} a_1(t) \\ \vdots \\ a_N(t) \end{pmatrix}$$

$$a_i(t) = (s_i * h)(t)$$

with

spike train $s_i(t) = G_i[I_i](t)$

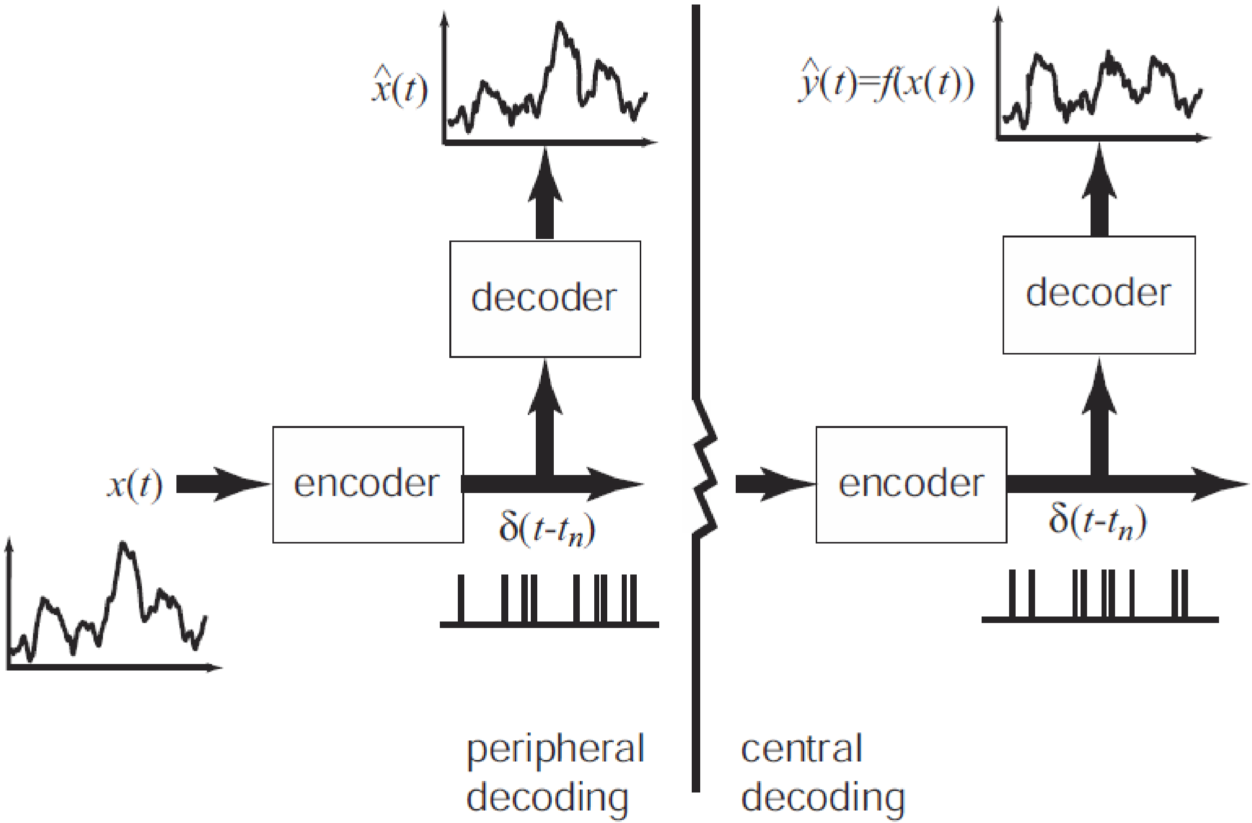
exponential (synaptic) filter $h(t)$

gain function(al) G_i

Encode an input signal into the activity of a layer of spiking neurons

Eliasmith, C. and Anderson, C. (2003). *Neural Engineering: Computation, Representation and Dynamics in neurobiological systems.* MIT Press.

Encoding



Encode an input signal into the activity of a layer of spiking neurons

Serve as input to the main processing circuit (RNN)

Eliasmith, C. and Anderson, C. (2003). *Neural Engineering: Computation, Representation and Dynamics in neurobiological systems.* MIT Press.

Decoding

decoding → linear readout

Linear readout of population activity to reconstruct target signal

$$x(t), x(t-1), x(t-2), \ldots x(t-\tau)$$

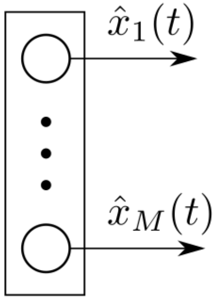
decoders (synaptic weights) →

$$\boldsymbol{D} = \begin{pmatrix} \vec{d}_1 \\ \vdots \\ \vec{d}_N \end{pmatrix} = \boldsymbol{\Gamma}^{-1}\boldsymbol{\Upsilon}$$

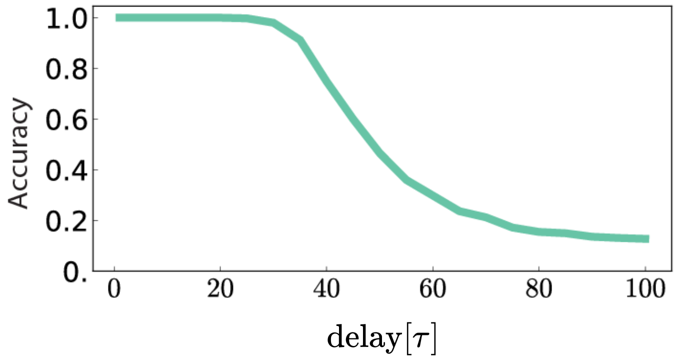
with

$$\boldsymbol{\Gamma} = \int d\vec{x}\, \vec{a}^{\mathsf{T}} \vec{a}$$

$$\boldsymbol{\Upsilon} = \int d\vec{x}\, \vec{a}^{\mathsf{T}} \vec{x}$$

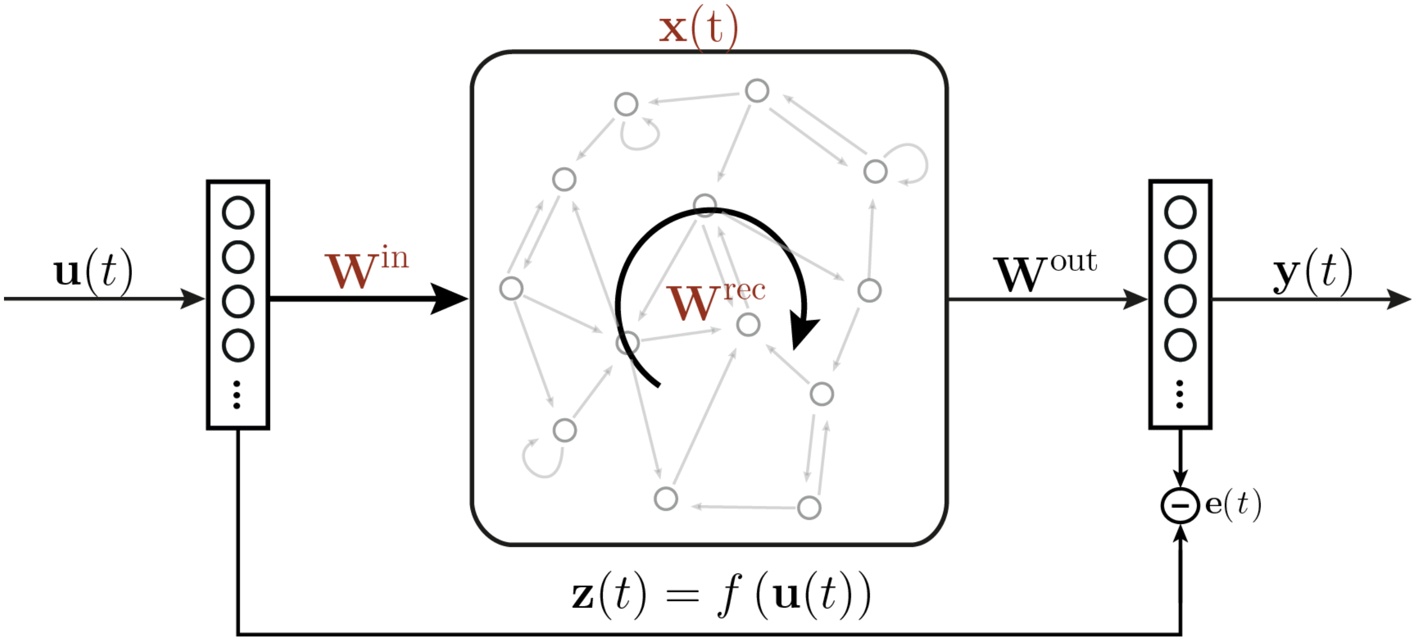


$$\hat{\vec{x}}(t) = \sum_{i=1}^{N} a_i(t)\vec{d}_i$$



Eliasmith, C. and Anderson, C. (2003). *Neural Engineering: Computation, Representation and Dynamics in neurobiological systems.* MIT Press.

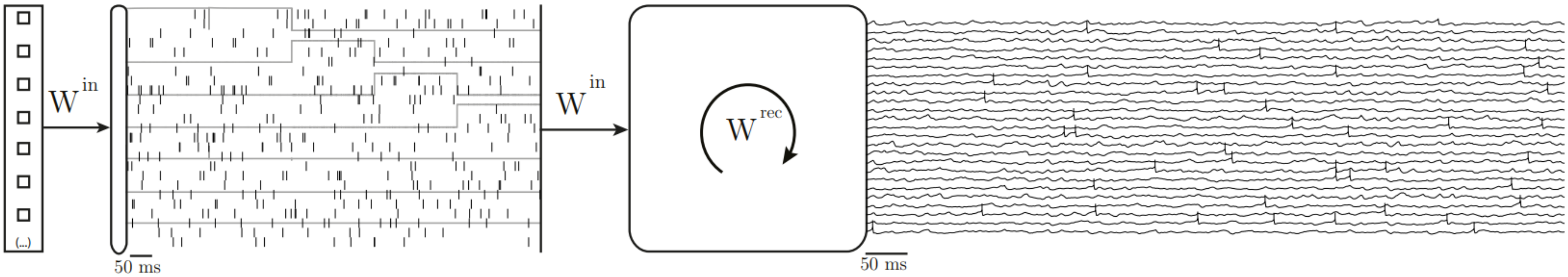
Exploration



- Specifications of circuit composition and dynamics (working examples will be provided)
  - neuron / synapse models
  - model parameters

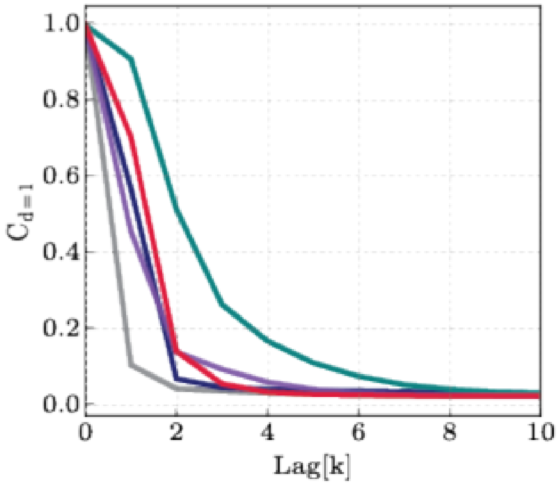
- Mappings (structure of input / recurrent connectivity)

Goals



Determine and compare features of the encoding and processing layers:

- Memory capacity, input sensitivity
- Activity statistics



Explore the impact and consequences of different models, connectivity structures, etc.