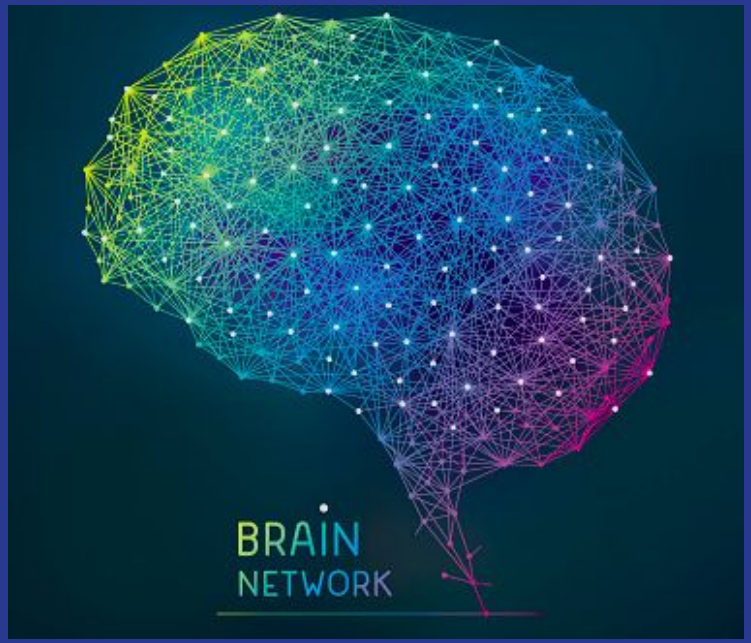
Recurrent Neural Networks

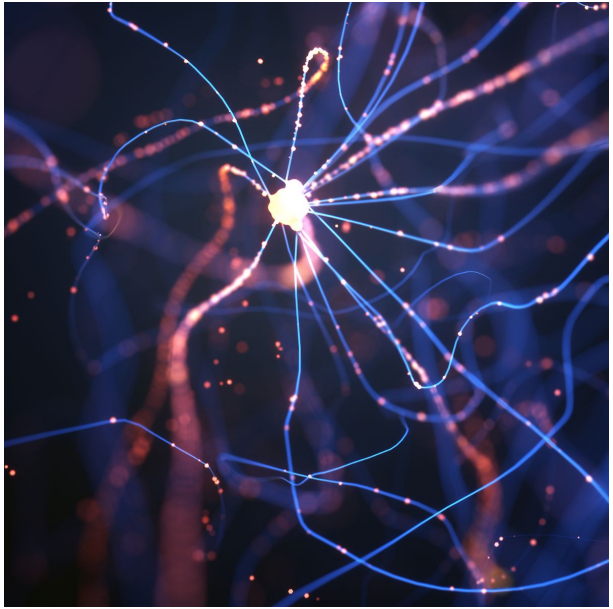
BRAIN AND COGNITIVE SOCIETY
IIT KANPUR

Modelling the Networking of Brain



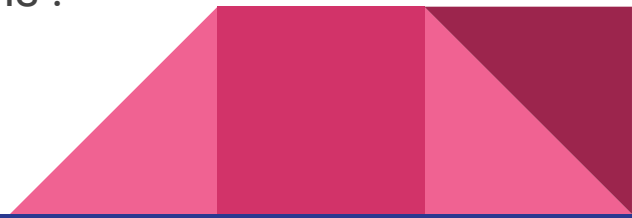
What are RNNs

- ★ RNNs are neural networks that capture the time dependence of the given data.
- ★ They are also used to implement a certain dynamical principle.
- ★ Neuroscientists train RNNs for a particular task and then reverse engineer them , this serves the purpose of hypothesis generation tool.



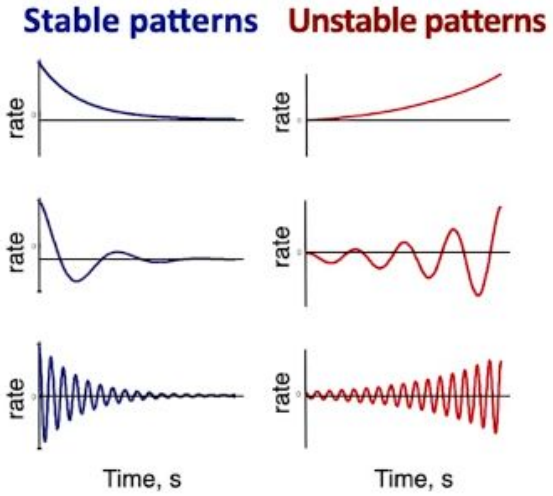
Building Blocks of RNNs

- ★ The basic blocks are neuron like units which are of two types :
  - Continuous dynamics based
  - Rate based
- ★ Then there are activation functions to introduce some sort of non linearity.
  - Linear
  - Non linear :
    - Tanh / hyperbolic tangent
    - Relu
    - Sigmoid
- ★ There can be 2 types of connections between neurons :
  - Fully connected
  - Sparsely connected



Modelling Equations

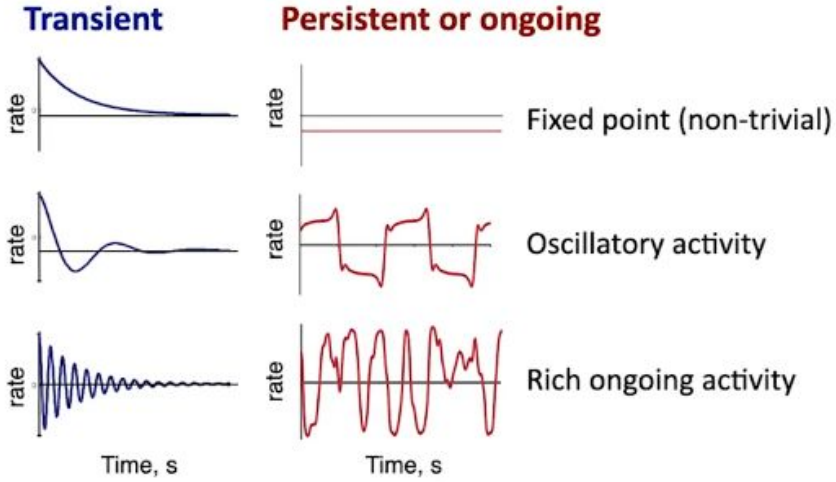
$$\tau \frac{dx_i}{dt} = -x_i + \sum_j^N J_{ij} x_j$$

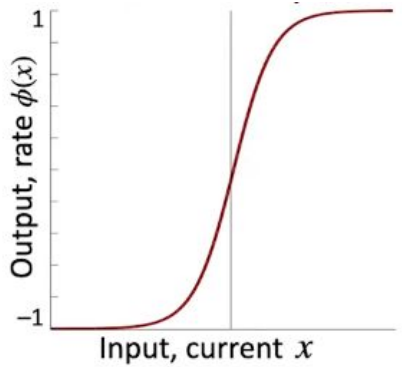


- ★ Linear RNN , xis are pre synaptic current , tau is time constant, N is total number of neurons.
- ★ J is the weight of connections between each neuron, randomly picked from a probability distribution like the gaussian distribution.
- ★ Some problems :
  - Unstable patterns
- ★ Solution : introduce non linearities i.e instead of pre synaptic firing current , we will use pre synaptic firing rate.

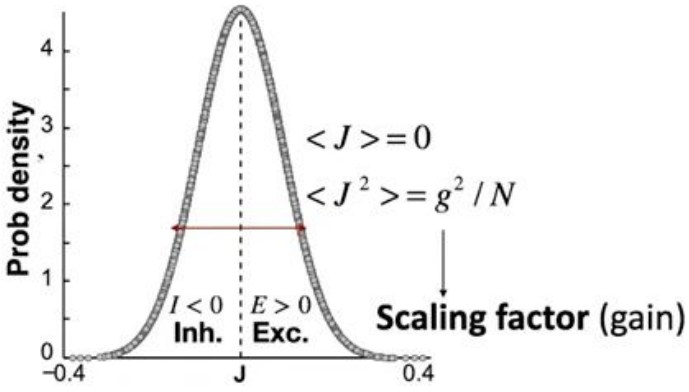
Non Linear RNN

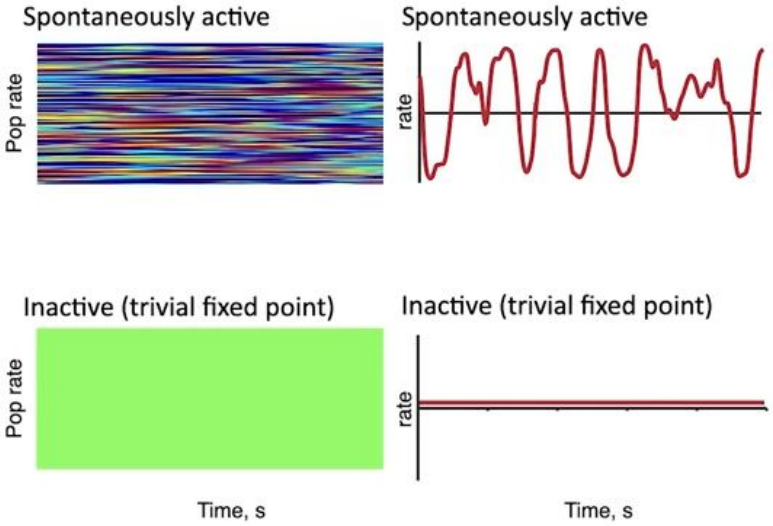
$$\tau \frac{dx_i}{dt} = -x_i + \sum_j^N J_{ij}\phi(x_j)$$





Recurrent weight matrix J

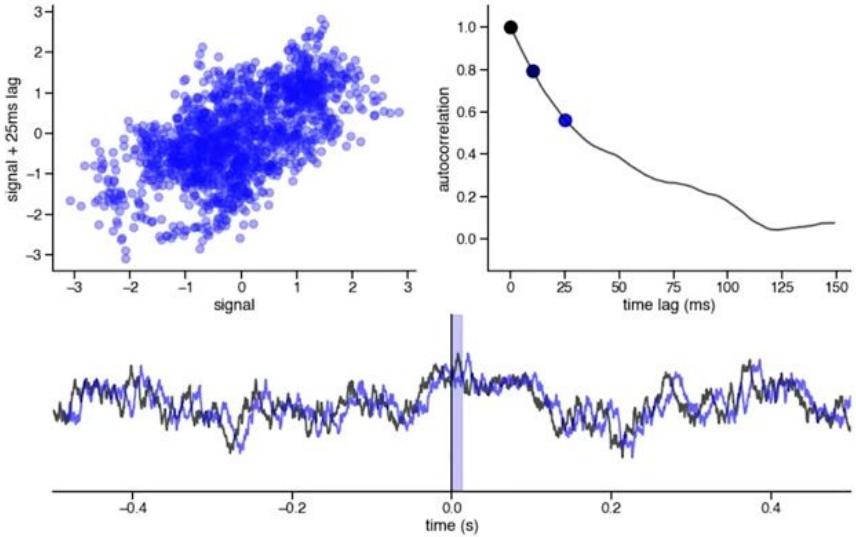


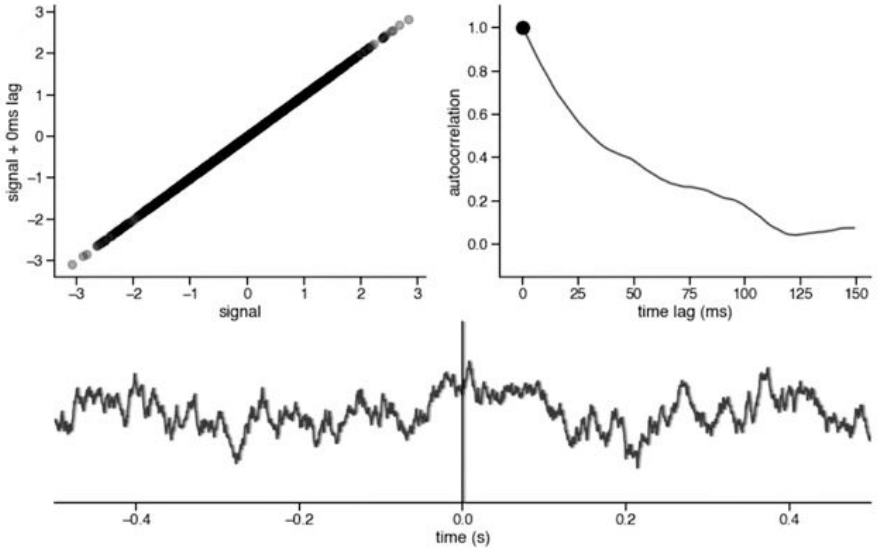


★ As g (can be thought of as a measure of variance / gain) increases , spontaneous activity becomes more chaotic and vice-versa.

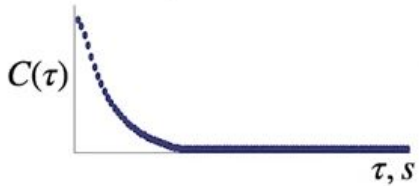
Richness of the Dynamics

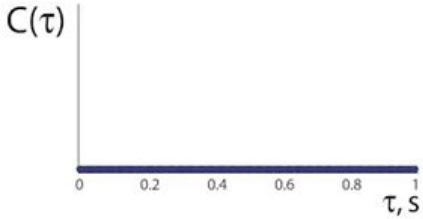
Average autocorrelation





Auto correlation on our data

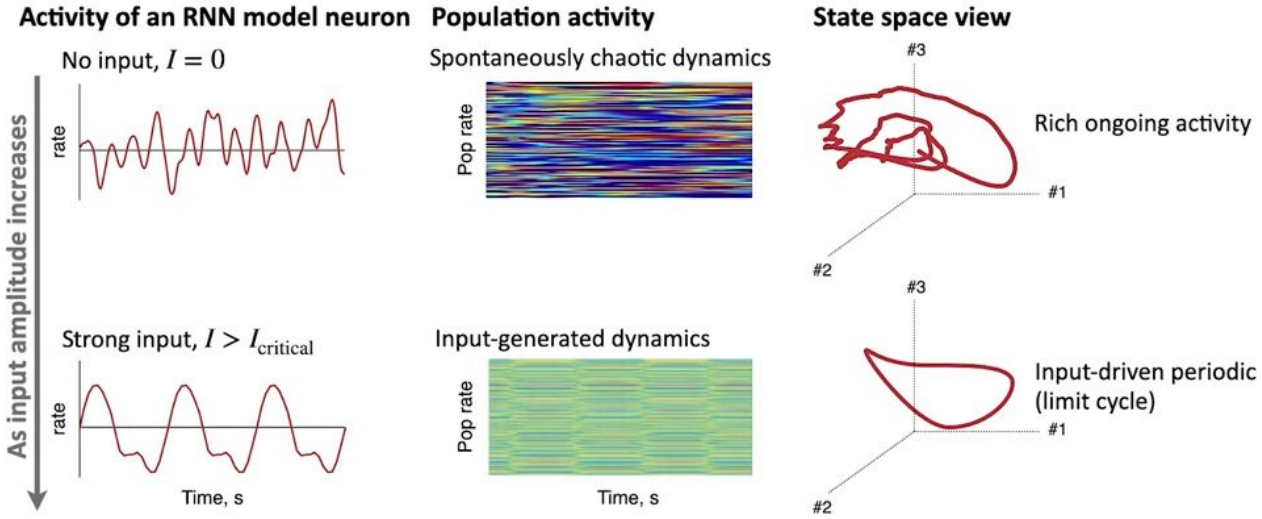




- ★ Problems now : We cannot reliably get same dynamics twice.
- ★ Solution : We introduce external inputs to control chaos . for example a periodic function h_i = *I**cos(ωt + Θi)
- ★ The new equation becomes :

$$\frac{dx_i(t)}{dt} = -x_i(t) + \sum_{j=1}^{N} J_{ij}\phi(x_j(t)) + h_i(t)$$

Dimensionality Reduction



Thank You !!

Hope you enjoyed the lecture.

Post your queries on the BCS discord channel.

Content credit :-

- Mohit Kulkarni (coordinator)
- Tanushree Jalewa (secretary)
- Siddhant Singh (Secretary)