Recurrent neural networks and flow control mechanisms

Preprint !

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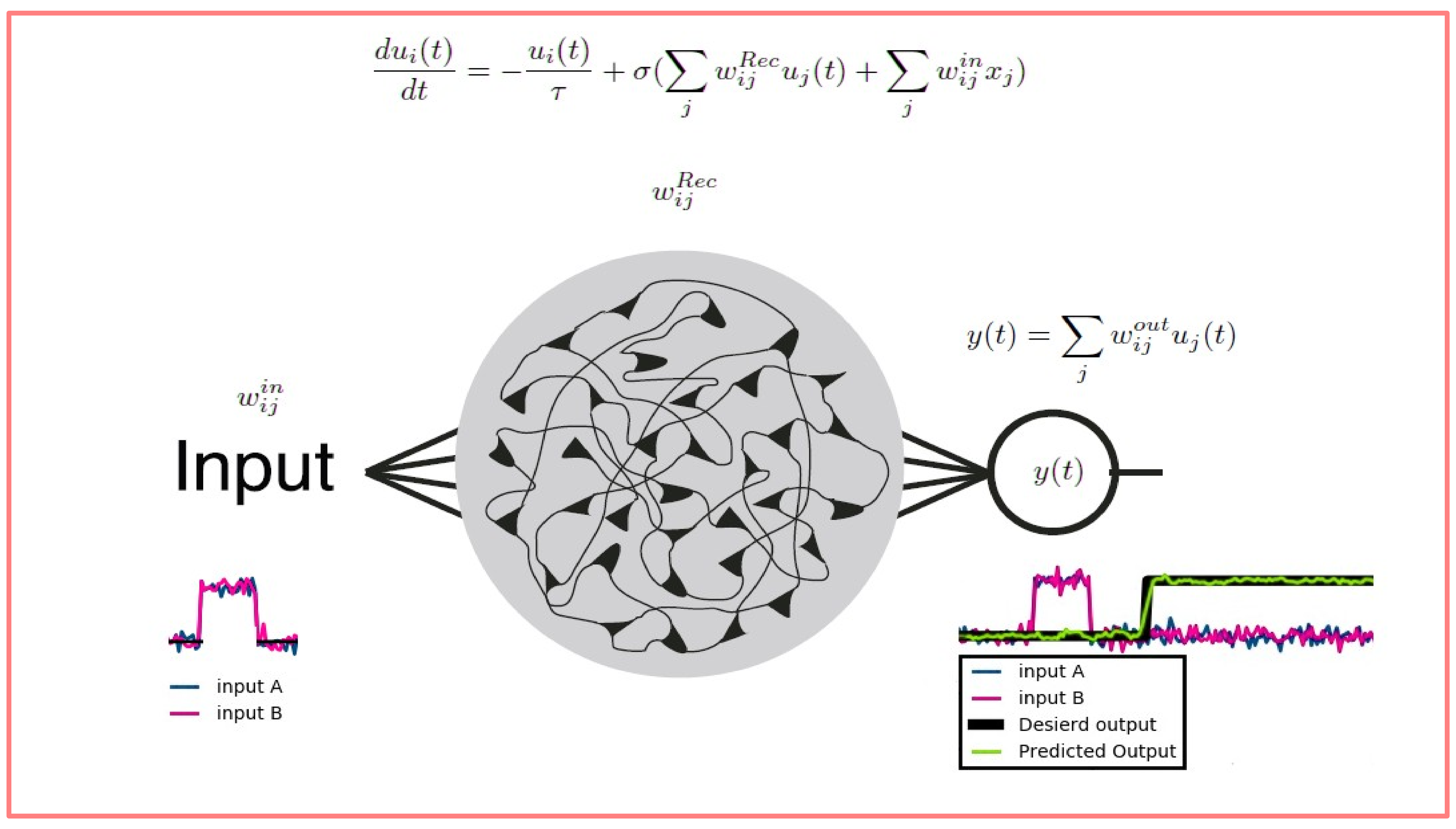
Recurrent neural network models have been used in different fields during the last 35 years to help understand the fundamental characteristics of a great variety of dynamical systems. The main goal of this work is to present a simple model and a framework to perform a set of tasks and discuss the obtained results using this new framework. The proposed model represents a brain area or population of neurons that perform sensory response to stimulus, typically cortex where both recurrent inhibition and excitation occur. We trained our minimal recurrent neural network model to perform a series of tasks relevant to understand information processing and the control of information flow.

Idea:

Consider a recurrent neural network N units → train it to perform bio-inspired tasks → Study the properties via population analysis techniques → Statistical studies on weights matrices of trained networks

A description of the model

- The connectivity matrix of the RNN determines the dynamics of the system.
- The state of the system is represented by a point in the N-dimensional space of neural activity.
- Different tasks give rise to different dynamical objects in the space state.



$$\frac{du_i(t)}{dt} = -\frac{u_i(t)}{\tau} + \sigma\Big(\sum_j w_{ij}^{Rec} u_j(t) + \sum_j w_{ij}^{in} x_j\Big)$$

$$y(t) = \sum_j w_{ij}^{out} u_j(t)$$

Motivation I: A problem of interest

- To model the dynamics of the Cerebral Cortex and how it processes the flow of information.

- We chose tasks :

*Relevant to information processing and flow control.
*That traditionally were used in previous works to model the behavior of different brain areas, particularly cortex.

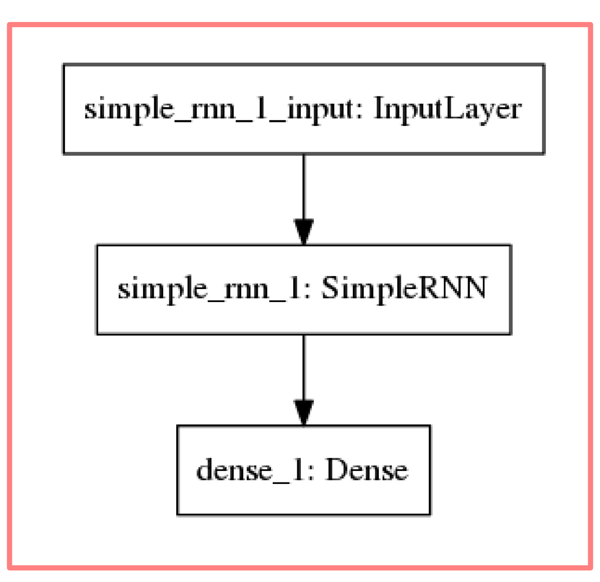
Processing of stimulus as temporal inputs:

1. Time reproduction task.
2. Logic gates (AND, OR, NOT, XOR)
3. Flip-Flop task. i. e. memorizing and forgetting a stimulus.
4. A stimulus-triggered oscillation of certain duration.

Motivation II: a new tool Tensor flow and Keras

- We propose to use Keras and Tensorow as frameworks, instead of the traditional Matlab or Theano.

- These new scientific libraries are open source and their use is rapidly growing.

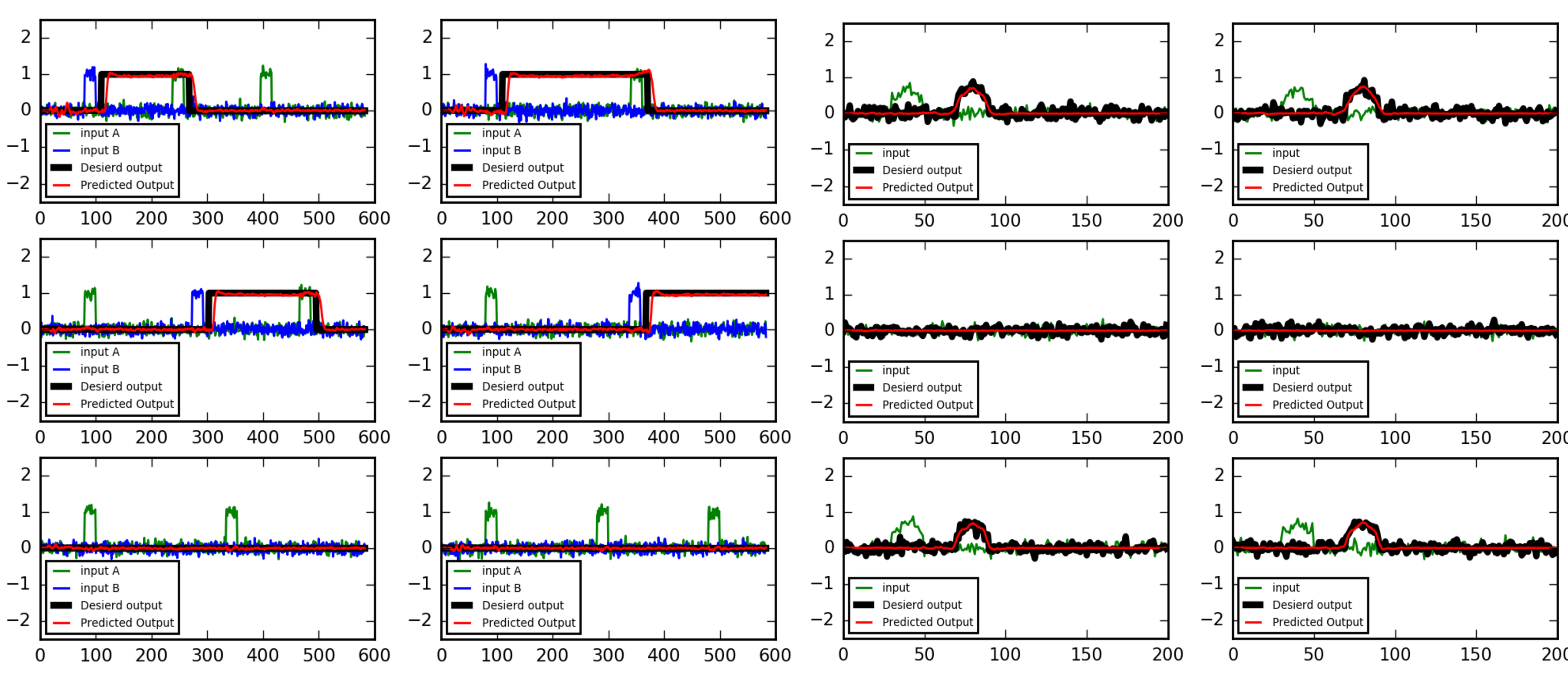


Training the network

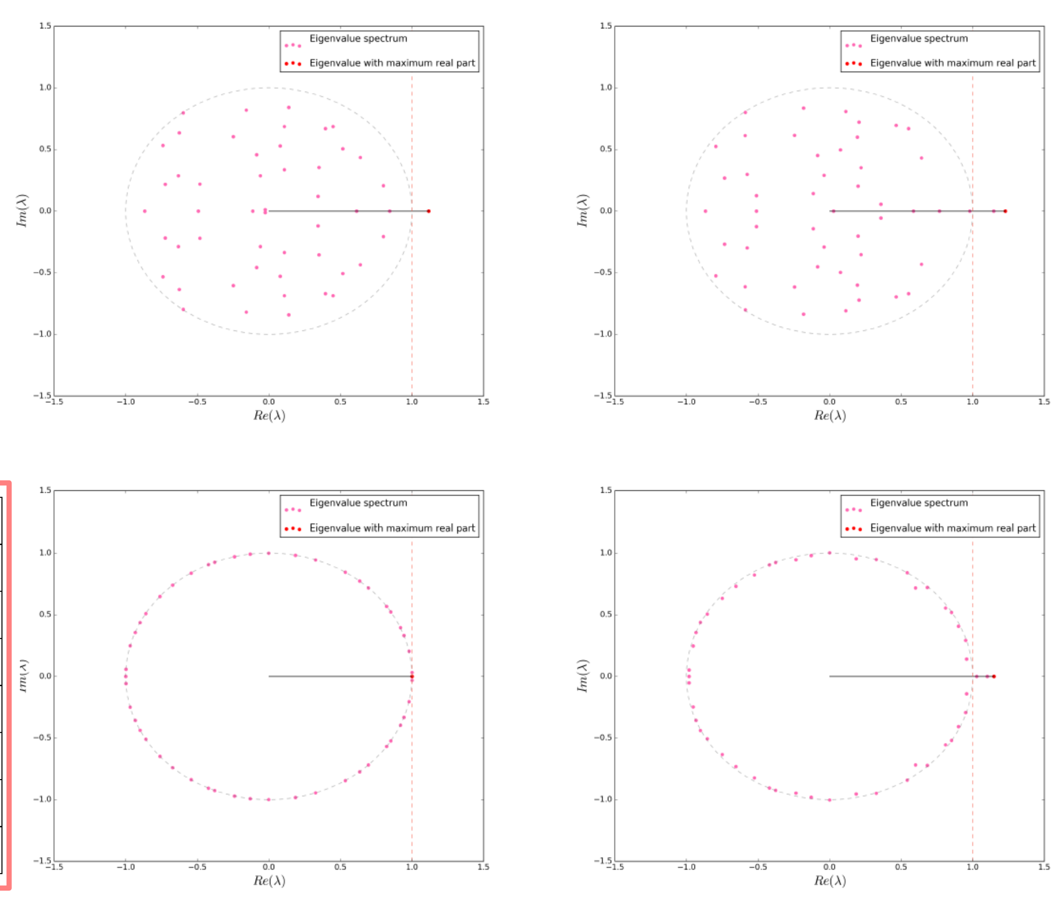
- Supervised learning
- Adaptive SGD training method.
- Noisy input with several training samples.
- An output with simulated time delay answer.

Task "Flip-Flop"

"Time reproduction task"

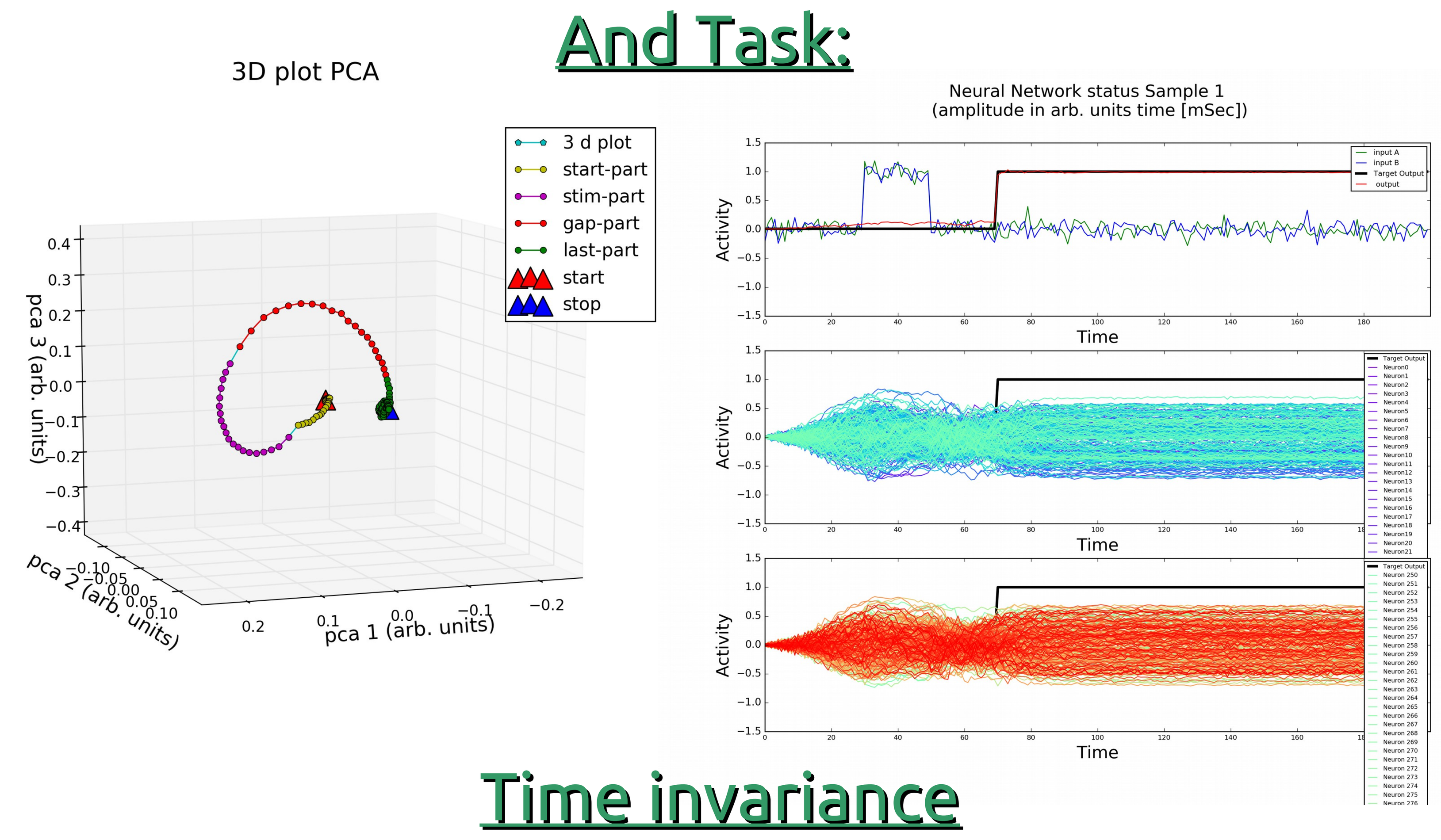


Rate of successful training of 20 networks for orthogonal initial connectivity matrix and random normal initial connectivity matrix.

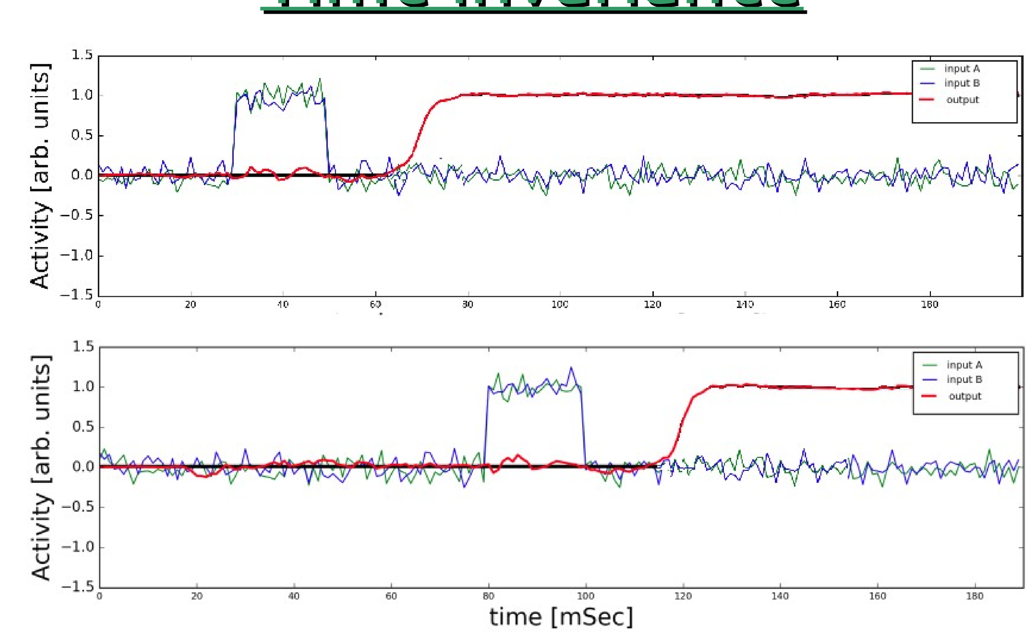


Task	Initial orthogonal	Initial Rand Normal
And	85%	65%
Or	90%	80%
Xor	90%	55%
Not	90%	45%
Flip Flop	95%	65%
Oscillatory	90%	65%
Time pulse	100%	100%

And Task:



Time invariance



Conclusions

- Orthogonal initial condition on the weight matrix improves the success rate.
- Behavior is a ruled only by a set of eigenvalues outside the circle.
- Network reaction is invariant if we change the time where we induce the stimulus.

Further work

-Further statistical studies on weights matrices.
-Studies on damage on trained networks.
-Scaling the network size.
-Paper coming!

References

[1] C. Thompson, L. Shure, Image Processing Toolbox: For Use with MATLAB;[user's Guide], MathWorks, 1995 [2] Theano Development Team, Theano: A Python framework for fast computation of mathematical expressions, arXiv e-prints abs/1605.02688 .[3] S. Kuroki, T. Isomura, , Frontiers in Computational Neuroscience 12 (2018) 83. doi:10.3389/fncom.2018.00083 [4] https://www.tensorflow.org