Neuro-inspired complex systems for Biorobotics

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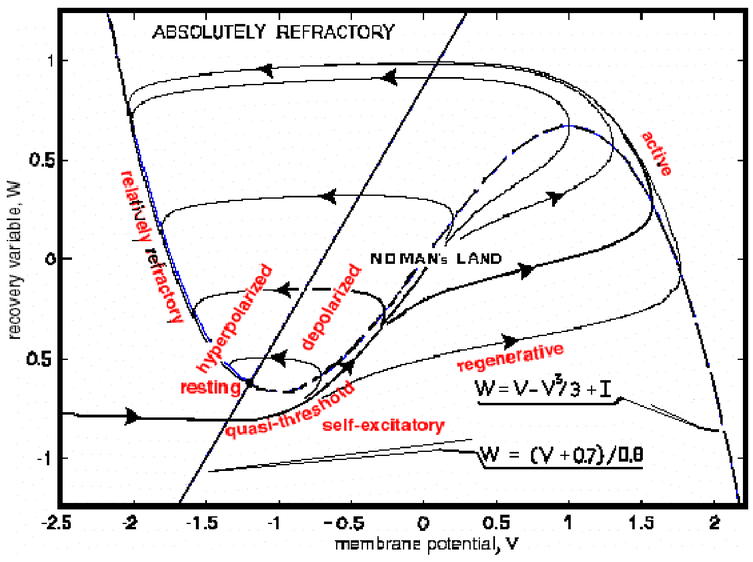
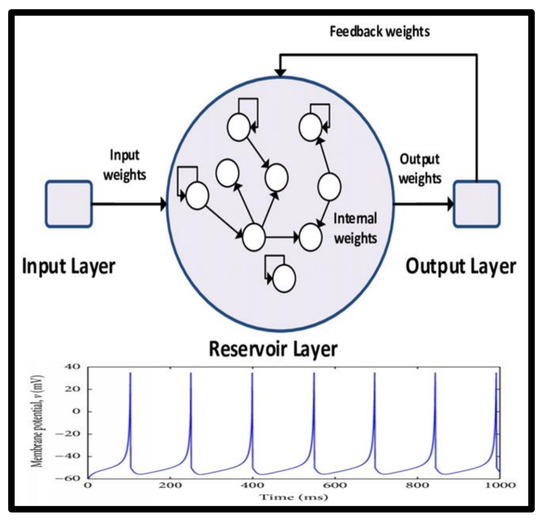




Description of the research activity

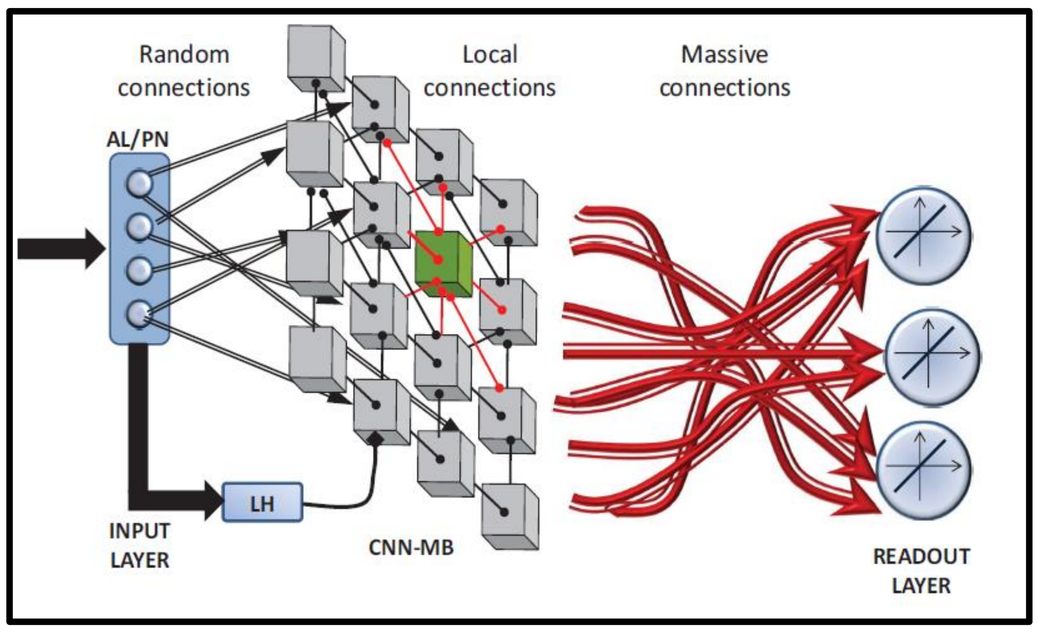
One of the most ambitious and preeminent aspects of Biorobotics regards the development of adaptive and intelligent systems with strong biological plausibility. Thereby, this research activity aims at developing systems capable of eliciting adaptation and cognitive-like, high-level skills by exploiting many of the state-of-art techniques, ranging from machine learning-based tools to nonlinear control theory.

What is Reservoir Computing?

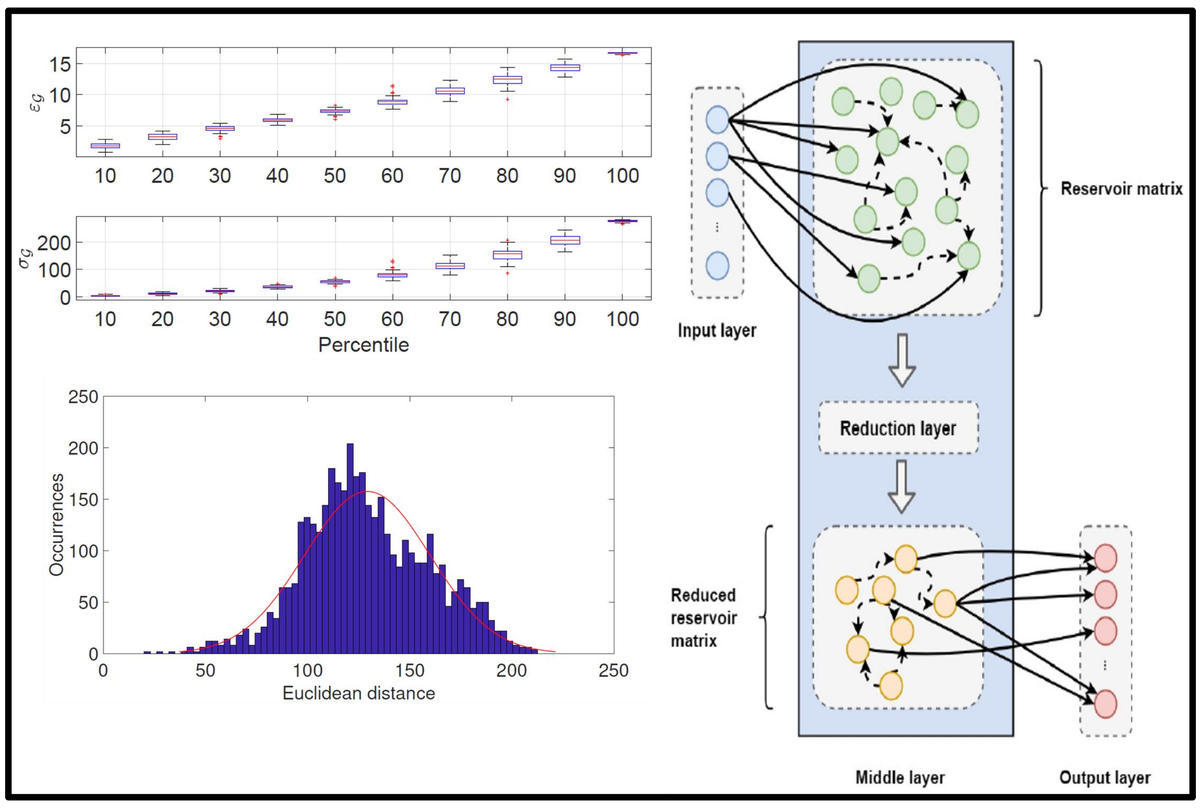
The expression “Reservoir Computing” refers to a design paradigm founded on recurrent neural networks, such as Echo State Networks (ESNs) and Liquid State Machines (LSMs). These networks are usually made up of three layers and the intermediate one acts as a dynamical reservoir of signals, which are turned into output signals through the final processing stage. Very often, these networks undergo a batch training consisting on optimising a Least Mean Square-like error function in order to find the closest set of output weights which produce the desired outcomes.

CNN-like LSMs for classification and decision control

LSMs can be employed for multivariate datasets classification. Additionally, internal connections among intermediate neurons may be set up with local, distance-based constraints. This leads to a Cellular Nonlinear Network (CNN)-like structure with arbitrary, either regular or irregular connectivity schemes.



Example of bio-inspired CNN-like LSM for multivariate classification



Manifold reduction and percentile-based strategy for hyperparameters tuning in Laplacian Eigenmaps computation

Manifold reduction through Laplacian Eigenmaps

The potentialities of Laplacian Eigenmaps for manifold reduction have been analysed and widely utilised in both LSM- and ESN-based classifiers. Additionally, a striking result of the research activity has consisted on the development of a percentile-based, statistic way to semi-automatise the hyperparameters tuning procedure.

Proper tests have shown an interesting noise rejection of Laplacian Eigenmaps against various forms of noise (Gaussian, uniform and quantisation), according to theoretical, expected results provided by literature.

List of Publications

- P. Arena, L. Patané, A. G. Spinosa, *Insect inspired spatial-temporal cellular processing for feature-action learning*, European Conference on Circuit Theory and Design (ECCTD), 2017
- P. Arena, M. Calì, L. Patané, A. Portera, A. G. Spinosa, *A CNN-based neuromorphic model for classification and decision control*, Nonlinear Dynamics, Springer (*3° review ongoing*)
- P. Arena, L. Patané, A. G. Spinosa, *Data-based analysis of Laplacian Eigenmaps for manifold reduction in supervised Liquid State classifiers*, Information Sciences, Elsevier (*1° review ongoing*)
- P. Arena, L. Patané, A. G. Spinosa, *Noise tolerant binary decisions in Laplacian Eigenmaps-based Echo State Networks*, IEEE Transactions on Cybernetics (*1° review ongoing*)