# Spiking neural network architecture for associative learning of spatio-temporal brain patterns,

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## Abstract

The brain functions as a spatio-temporal information processing machine. Spatio- and spectro-temporal brain data (STBD) are the most commonly collected data for measuring brain response to external stimuli. An enormous amount of such data have been already collected, including brain structural and functional data under different conditions, molecular and genetic data, in an attempt to make a progress in medicine, health, cognitive science, engineering, education, neuro-economics, Brain-Computer Interfaces (BCI), games. Yet, there is no *unifying computational framework* to deal with all these types of data in order to better understand this data and the processes that generated it. Standard machine learning techniques have failed to achieve this. To be fair, these techniques were not designed in the first instance to deal with such complex data. Therefore, there is a need for a new paradigm to deal with STBD. This paper addresses this problem by offering a new paradigm called NeuCube. The NeuCube will allow to model STBD using the *same computational paradigm* that generated the data, namely spiking neural networks (SNN) and neurogenetic networks in particular. The NeuCube framework includes a 3D evolving SNN that is an approximate map of structural and functional areas of interest of the brain related to the modeling STBD. Gene information is included optionally in the form of gene regulatory networks if this is relevant to the problem and the data. The NeuCube learns from STBD and creates connections between clusters of neurons that manifest chains (trajectories) of neuronal activity. Once learning is applied, the NeuCube will reproduce these trajectories, even if only part of the input STBD or the stimuli data is presented, thus acting as an associative memory. The NeuCube can be used not only to discover functional pathways from data, but also as a predictive system of brain activities, to predict and possibly – prevent certain events. STBD include: EEG, MEG, fMRI, neurogenetic data, while stimuli can be: auido-visual, touch and smell, environmental, chemical (drugs), social, evolutionary, etc. Analysis of the internal structure of the model after training can reveal important spatio-temporal relationships hidden in the data. NeuCube will allow the integration in one system of various brain data related to a single subject (personalized modeling) or to a population of subjects (population statistics). Future directions for the NeuCube paradigm are discussed, such as: development of an information theoretic method for the evaluation of the performance of NeuCube architectures; large scale simulations on a high performance computer systems; neuromorphic cognitive systems for embedded engineering applications; practical applications; new, non-invasive sensory systems for capturing STBD.

***Keywords:*** spatio-temporal brain response data; pattern recognition; data mining; EEG; fMRI; MEG; neurogenetic data; spiking neural networks; gene regulatory networks; computational neuro-genetic modelling; associative memory; finite automata for spatio-temporal data.