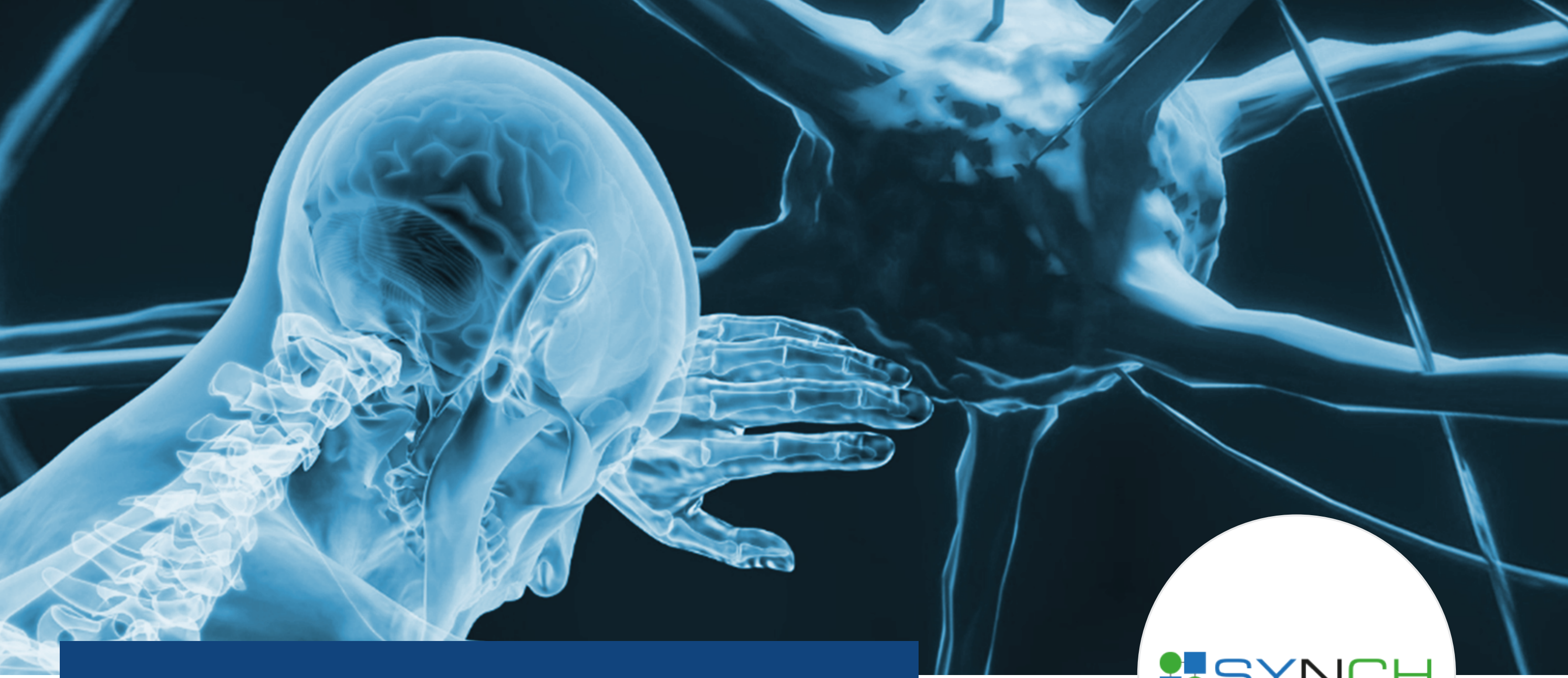

Advancements in neuroprosthetics: the SYNCH Project

by Giovanni Falcitelli
EnginSoft

The SYNCH (SYnaptically connected brain-silicon Neural Closed-loop Hybrid system) Project is a European research project under the Horizon 2020 Future and Emerging Technologies Programme. This innovative effort aims to create a hybrid system in which a neural network in the brain of a living animal interacts with a silicon neural network of spiking neurons via neuromorphic synapses. The goal of the project is to establish a synapse-inspired reciprocal link between these networks and use the silicon neural network as a processing architecture to adaptively stimulate and rescue functionality in an animal model of disease.

The SYNCH Project concept

The SYNCH project envisions an invasive brain-computer interface in which brain-inspired processing replaces standard PC-based computation. The interaction occurs between a biological neural network (BNN) and a silicon neural network (SNN). This concept encompasses many levels of complexity since the brain-inspired processing takes place in separate neuromorphic devices:

- The neural interface (NIF) is the physical prothesis in direct contact with the neural tissue.
- The memristor array (MA) or memory resistors manage synaptic-like processing, linking artificial and biological neurons by emulating synaptic integration and plasticity.
- The CU (control unit) is intended to be versatile and enable the acquisition and generation of analogue/mixed signals, pre-processing, and routing of signals between the BNN and the artificial SNN neural networks.

Memristors in neuroprosthetics

Memristors are noteworthy for their future potential in neuroprosthetics. SYNCH uses a memristor array as a platform to perform analogue or mixed digital-analogue processing of neural signals by implementing algorithms inspired by the way biological synapses process spikes. The MA works synergistically with the CU, acting as a neuromorphic processor in response to signals from the BNN and SNN. Together,

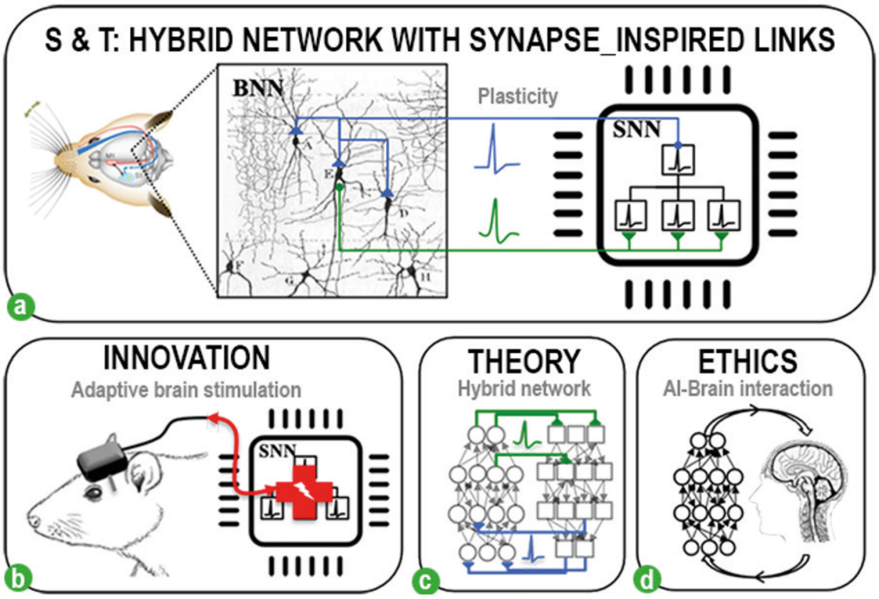

Fig. 1. Star-shaped topology of the locally integrated SYNCH network, with the CU at its centre.

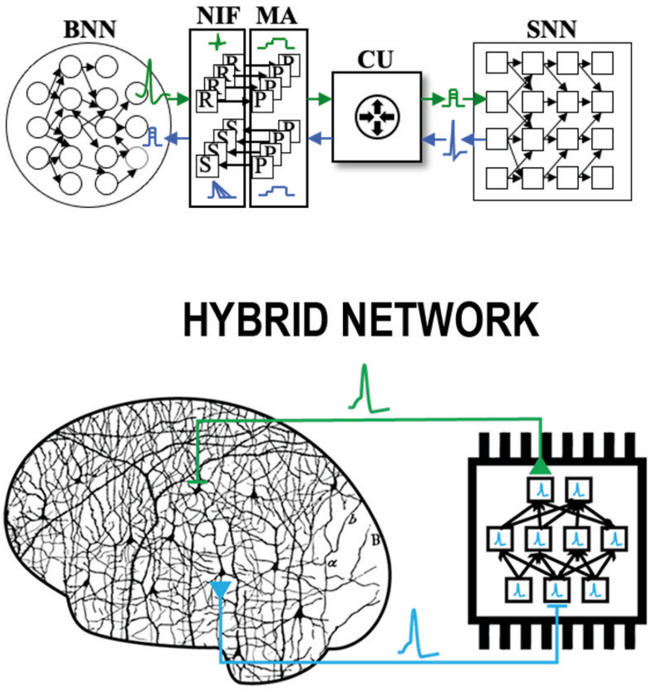

Fig. 2. SYNCH system diagram showing the NIF (neural interface); MA (memristor array platform); CU (control unit); BNN (biological neural network); and SNN (silicon neural network). In our context, the BNN is a biological network in a rat's brain (the somatosensory cortex of an anaesthetized animal at UNIPD, and the basal ganglia of a free-behaving animal at BIU), while the SNN is DynapSE hardware provided by SYNSENSE. The MA is controlled by an ARC board (SOTON and ARC).

they could be used in future implants designed to rescue simple reflex-based circuits located in the integration centres of the spinal cord or brainstem. This could potentially be beneficial in treating autonomic nervous system dysfunctions.

A higher level of processing occurs in the SNN, where brain-inspired computation relies on neuronal network dynamics. The SNN, alone or in combination with memristor arrays, could form part of neuroprostheses to treat focal pathologies in higher brain structures, such as the cortex (in epilepsy or stroke), or the basal ganglia (in Parkinson's disease).

EnginSoft's role in the SYNCH Project

EnginSoft is one of the partners in the SYNCH Project and is contributing by using finite element method (FEM) techniques to model the micro capacitive needles that predict electrical behaviour post-implantation. The NeuroChip laboratory of the Padua Neuroscience Centre (PNC) commissioned EnginSoft to develop a full parametric FE model of a microelectrode array, a crucial component for improving neurostimulation implants.

The microelectrode array developed by EnginSoft is an assembly of ten units, each equipped with one stimulation plate and several sensing microelectrodes. The design integrated three innovative elements:

- The stimulation plate and the electrodes are electrically insulated from each other. This separation physically isolates the channels for signals stimulating the neural tissue from the signals from the neurons.
- The transmission of electrical signals occurs by capacitance rather than by conductivity.
- Titanium dioxide (TiO_2) was used for the microelectrodes instead of iridium oxide (IrO), the standard material.

EnginSoft used Ansys Electronic Desktop to create the challenging parametric FE model of the capacitive needle containing all microelectrodes immersed in a conductive dielectric with properties similar to neural tissue. The software was chosen for its ability to build robust parametric geometries from scratch, the auto-adaptive meshing strategy, high-performance computing solvers, powerful post-processing tools, and automated routines to calculate the capacitance and the conductance matrices.

SYNCH Project progress

The SYNCH project has made significant progress since it started in 2019. It has seen effective cooperation between the different partners, all of whom have made remarkable progress in their respective fields, contributing towards the overall success of the project. A brief summary of the progress made by each of the partners follows:

- EnginSoft successfully designed a full parametric FE model of a microelectrode array that is now capable of predicting the array's electrical behaviour after implantation.
- Padua Neuroscience Centre's NeuroChip laboratory has reached significant milestones in improving neurostimulation implants.
- Memristors have successfully been used to link artificial and biological neurons thereby achieving the project's objective of creating a hybrid system.
- EnginSoft's implementation of FEM techniques has proved instrumental in advancing the project.
- EnginSoft's development of a microelectrode array represented a significant milestone for the project.

EnginSoft's successes in the SYNCH Project

EnginSoft's dedication to the project has led to the successful development of a full parametric FE model of a microelectrode array. This represents a crucial step in improving neurostimulation implants. The company's work in the SYNCH project demonstrates its commitment to the advancement of neuroprosthetics and its ability to effectively collaborate in multi-disciplinary research projects.

Conclusion

The SYNCH project represents a significant stride forward in the field of neuroprosthetics. The advancements that have been made in the project are not only ground-breaking in neuroprosthetics but also highlight the power of effective collaboration in multi-disciplinary research endeavours.

For further information, visit: synch.eucoord2020.com

Or contact: Stefano Vassanelli - University of Padova
stefano.vassanelli@unipd.it