Advances in Colloids are Very Close to Regenerative Medicine: The COgITOR-HERMES vision towards neuromorphic liquid interfaces for enhanced brain regeneration

What do neuromorphic colloids have in common with regenerative medicine? Colloids are exploited by the EU-funded project COgITOR for holomorphic computing, aiming at demonstrating their capability of memorization and computation, energy generation, and sensing, all combined in a single material. A peculiarity of magnetic colloids is their memristive behavior; as such, they can become part of the next-generation neuromorphic devices. The latter is a core component of the EU-funded project HERMES, which aims at regenerating brain damage with bioartificial neural implants. In HERMES a neuromorphic neuroprosthesis guides the integration of the grafted cells into the host damaged brain, thus *enhancing* the brain regeneration process with hardware intelligence.

Recent networking activities between the coordinators of COgITOR and HERMES with their scientific staff and exploitation managers, resulted in an important possible exploitation route of the knowledge generated within both projects: the reuse of part of the scientific output of COgITOR in terms of materials science and computation approaches. In fact, the demonstrated scientific news recently published in Advanced Materials[1] [1] show possible neuromorphic computing capabilities using a Ferrofluid, which could be extremely beneficial in the context of the HERMES project. This could lead to a potentially empowering of the Neuromorphic Control System envisioned in HERMES and nowadays under development. A Ferrofluid indeed, can be used as a non-linear memory element and further shows memristive properties. A Ferrofluid is a system of nanoparticles in suspension in which very complex electrical dynamic behavior can be obtained, that can be both mapped to a memristive device or a more complex system. While using a given volume of a Ferrofluid as a device, it could be used as a computation element in a more complex neuromorphic circuit. Preliminary tests show that when the ferrofluid is used in spike-based computing applications the endurance achievable by the colloidal system can be even higher compared to solid state memristors, although, as a whole, the colloid evidence even more complex dynamics compared to solid state devices. This opens the way to the potential exploitation of the published scientific results of COgITOR also in the context of HERMES.

In this framework, an engineered Ferrofluid could be potentially utilized to bond and restore electrical connections among brain cell populations, a property that is not achievable using solid-state devices because they must be designed with a physical architecture and consequently need to be carefully positioned in space / volume to provide this functionality. With a completely amorphous Ferrofluid, and by exploiting a careful engineering of the colloid thanks to the expertise matured within the COgITOR project, we can even think of providing a self-assembled and self-healing neuromorphic interface to restore weak connections among neurons.

[1] [1]. Crepaldi, M., Mohan, C., Garofalo, E., Adamatzky, A., Szaciłowski, K. and Chiolerio, A. (2023), Experimental Demonstration of In-Memory Computing in a Ferrofluid System. Adv. Mater. 2211406. https://doi.org/10.1002/adma.202211406

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The networking and cooperation among these two FET projects can potentially open the way to tremendous advancements, through many years of research and development and exploitation of the expertise of COgITOR in the HERMES project and vice-versa. The deep knowledge built during the HERMES project, and the brand-new results obtained in terms of neuromorphic systems and techniques can surely demystify many computational strategies that with a colloidal system can be potentially better exploited using liquid state matter.

Stay tuned, updates will follow in the next months!

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