Cognitive Material Systems for Neuromorphic Information Processing

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Conventional computer architectures separate sensing, memory, and computation into predefined functional blocks, whereas biological systems realise information processing through embodiment, where function emerges from adaptive cellular dynamics and structural plasticity across scales. This motivates solid-state material systems in which sensing, learning, memory, energy conversion, and adaptive response are physically co-located, enabling emergent behaviour and intrinsic computation. Such cognitive material systems transform microscopic physical processes into functional macroscopic responses and can natively perform tasks such as pattern recognition or time-series prediction.

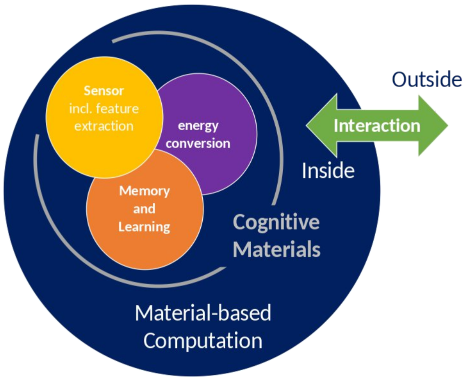

Figure | Physical embodiment of information processing: Cognitive materials integrate sensing, energy conversion, learning, memory and adaptive responses within solid-state ionic and electronic systems enabling material-based computing. The system continuously interacts with its environment, for adaptive information processing.

In this talk, I present neuromorphic approaches as a pathway toward embodied information processing (see figure). I demonstrate how redox-based memristive devices and an adaptive acoustic MEMS sensor exploit their underlying device physics to tightly integrate sensing, memory, and computation, enabling continuous adaptation to changing environmental conditions. Together, these examples delineate a technological route toward cognitive, sustainable, and highly energy-efficient information technology.

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