Neuromorphic Tactile Sensory Systems for Prosthetics and Digital Biomarker

L. Chen(1), S.-L. Zhang(1), L. Wang(2), and B. Winblad(2)(3)

(1) Department of Electrical Engineering, Uppsala University, Uppsala, Sweden; (2) Division of Neurogeriatrics, Department of Neurobiology, Care Sciences and Society, Karolinska Institutet, Solna, Sweden; (3) Theme Inflammation and Aging, Karolinska University Hospital, Huddinge, Sweden.

Neuromorphic tactile sensory systems leverage principles of biological neural computation to enable real-time, adaptive, and energy-efficient processing of complex sensory signals [1]. By integrating advanced sensing technologies with both hardware and software based on spiking neural networks (SNNs), these systems emulate key functions of the human peripheral and central nervous systems. Such architectures offer significant advantages, including ultra–low power consumption, high temporal precision, on-device learning, and robust operation under noisy or dynamic conditions.

Here, we present our recent works in neuromorphic tactile sensory systems for prosthetic and digital biomarker applications.

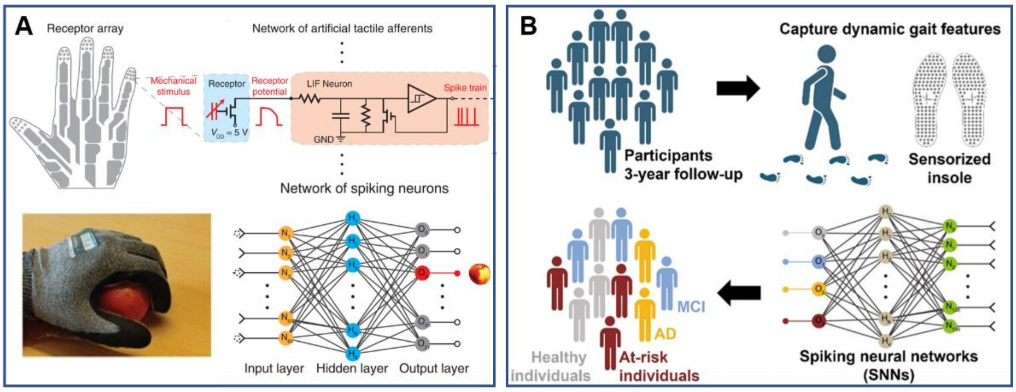

Figure 1: Neuromorphic tactile system for (A) prosthetic and (B) digital biomarker applications.

First, we developed a neuromorphic tactile system that mimics the human biological nervous system [2]. By relying on spike timing to encode tactile information, the system achieves millisecond-level temporal precision comparable to the human counterpart. This enables much more rapid and accurate object discrimination across different grasping tasks, compared with conventional electronic skin, and efficiently extracts the dynamics of tactile features during physical interaction. These capabilities make the neuromorphic tactile system a promising foundation for next-generation prosthetics and robotics that require fast, reliable tactile feedback [1].

Second, we are developing a neuromorphic gait-analysis system, in which the neuromorphic processing of gait data functions as an AI-driven digital biomarker for early diagnosis of Alzheimer's disease (AD). This approach provides a non-invasive, cost-effective, and scalable tool for early detection and long-term monitoring of disease progression, enabling more timely interventions.

Demonstrations of these neuromorphic tactile sensory prototypes illustrate the broad potential of neuromorphic engineering in biomedical applications. Together, they show how biologically inspired sensing and processing can enable long-term, fast, and reliable sensory feedback for assistive robotics and prosthetics, and more accessible diagnostic tools. The convergence of neuromorphic technologies with biomedical needs opens new pathways for next-generation intelligent health systems.

[1] J. Smith et al., Abbrev.Journal, 10, 3456, 2020. S. Micera, Science, 384, 624-625, 2024.

[2] Authors, Abbreviated Journal title, Volume (Issue), Page(s), Year. L. et al., Science, 384, 660-665, 2024.