Politecnico di Torino
Dipartimento di Automatica e Informatica

PhD in Computer and Control Engineering
XXXV cycle

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Study and implementation of new computational paradigms exploiting neuromorphic hardware architectures

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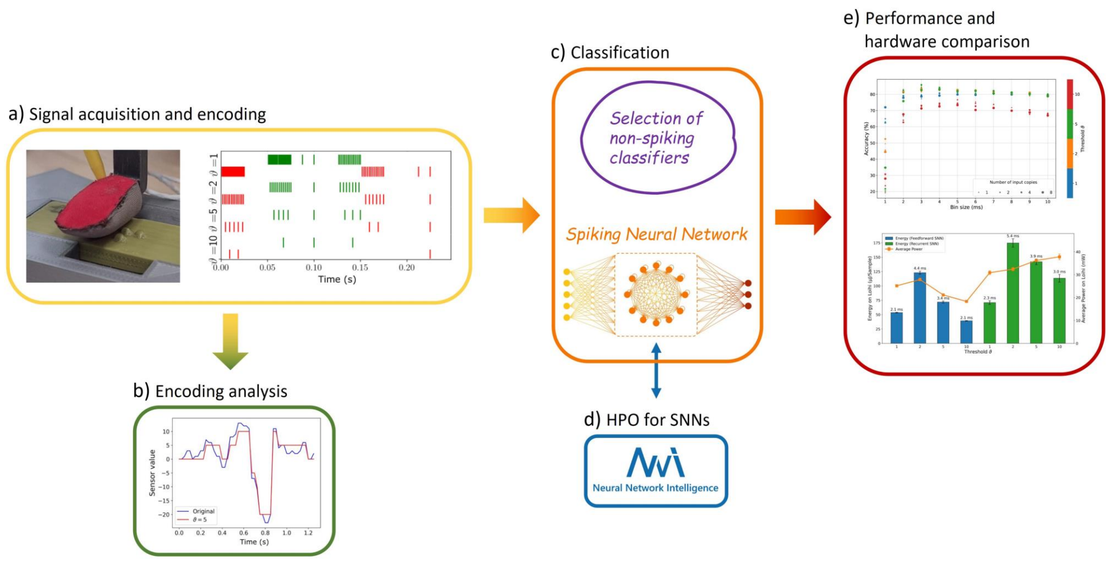
1. Context & Goal

Neuromorphic engineering is a biologically inspired computing paradigm, characterized by very-low-power, event-based operation and efficient communication among many computational units. These features make it an ideal tool for neural network-powered applications targeting embedded ML, IoT and edge computing; to that end, detailed study of this emerging field is required to produce a unified pipeline for the development and deployment of such applications.

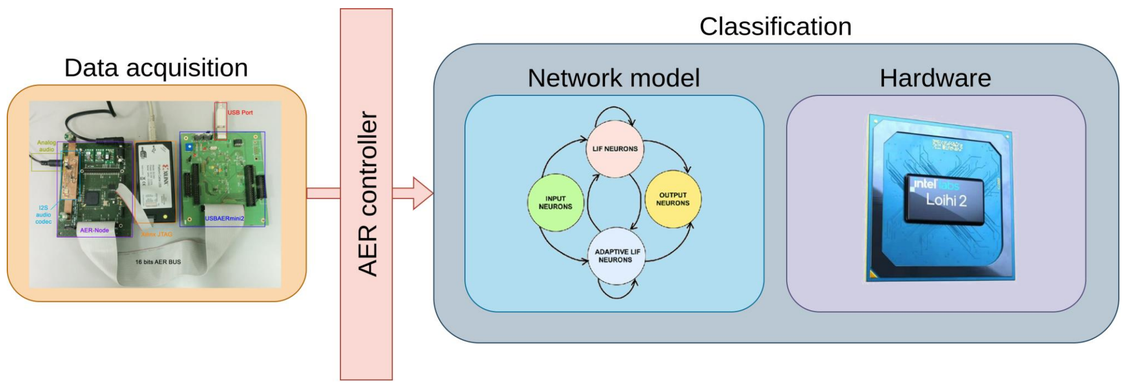
2. Example A: Braille reading



This neuromorphic pipeline for reading Braille letters with a digital sensor is a proof of concept for time-varying pattern recognition in edge applications with neuromorphic hardware. The digital sensor data requires encoding into the spike domain; the network runs on Intel Loihi.

- **Sensor:** digital taxels on robotic finger (iCub @ Istituto Italiano di Tecnologia (IIT), Genova)
- **Encoding:** sigma-delta modulator
- **Model:** feed-forward or recurrent *Spiking Neural Network* (SNN), gradient descent
- **Software tools:** sPyTorch (Python libraries for defining SNNs), NNI (hyperparameter optimization), NxSDK (Intel Loihi port)
- **Hardware:** Intel Loihi

3. Example B: Speech commands



A completely neuromorphic pipeline for classification of spoken commands. The spike train can be fed directly to a SNN, enabling real-time speech recognition.

- **Sensor:** Neuromorphic Auditory Sensor (NAS) @ Universidad de Sevilla (US), Seville
- **Model:** Spiking Long-Short Term Memory (LSNN), eligibility propagation (e-prop)
- **Software tools:** pyNAVIS (Python libraries for manipulating NAS output), NNI, Lava (Intel Loihi port)
- **Hardware:** Intel Loihi, SpiNNaker 2

4. Conclusion

The field of neuromorphic computing has produced a variety of sensors, encoding methods, network models, software tools and hardware platforms. By introducing appropriate interfaces between these layers, it is possible to build a fully neuromorphic pipeline for time-varying pattern recognition with strict power, memory and real-time requirements.

5. References

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