

Question of the day:

What is an event-driven sensor?

Neuromorphic Touch

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Event-Driven Perception for Robots www.edpr.iit.it

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Touch in biology

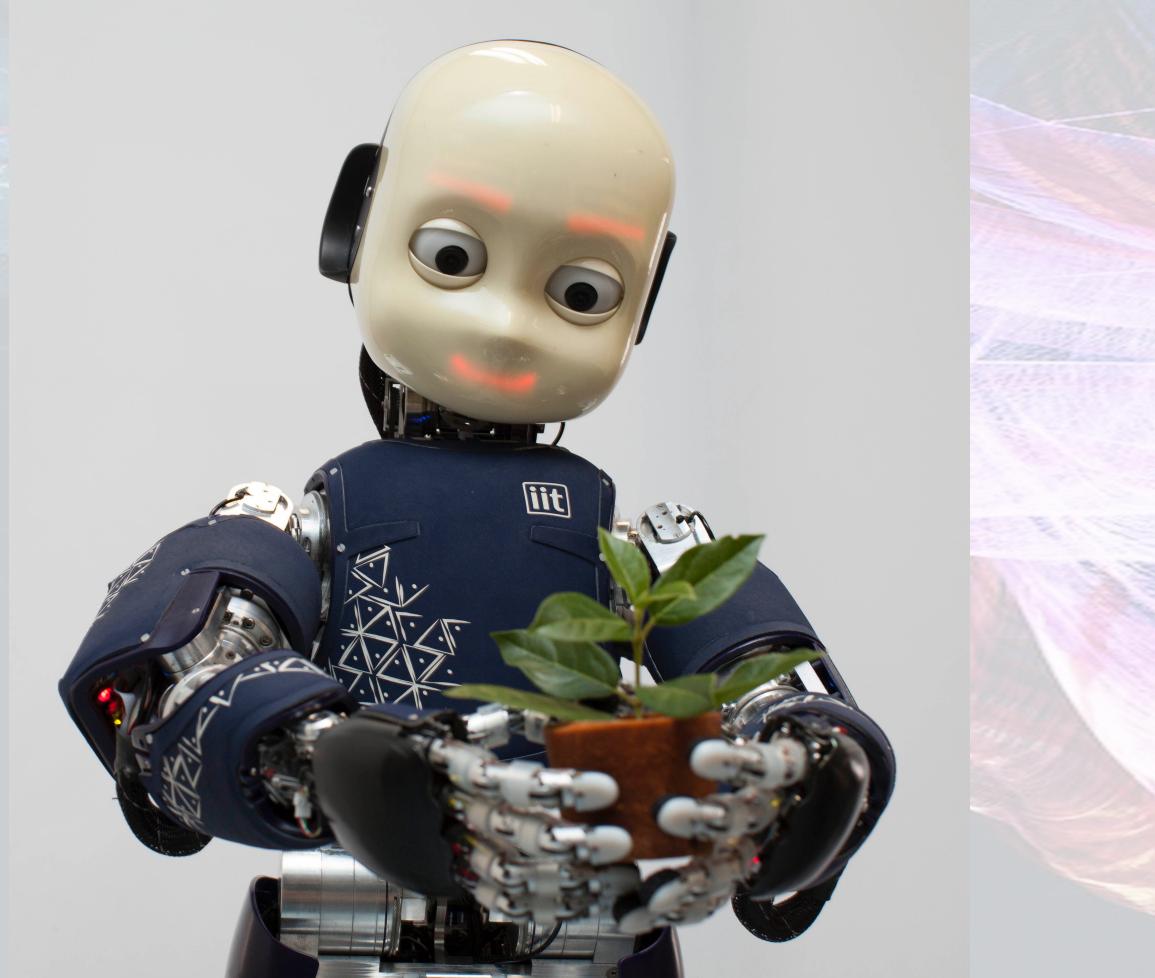
Object's manipulation

Perception of self in space (touch and proprioception)

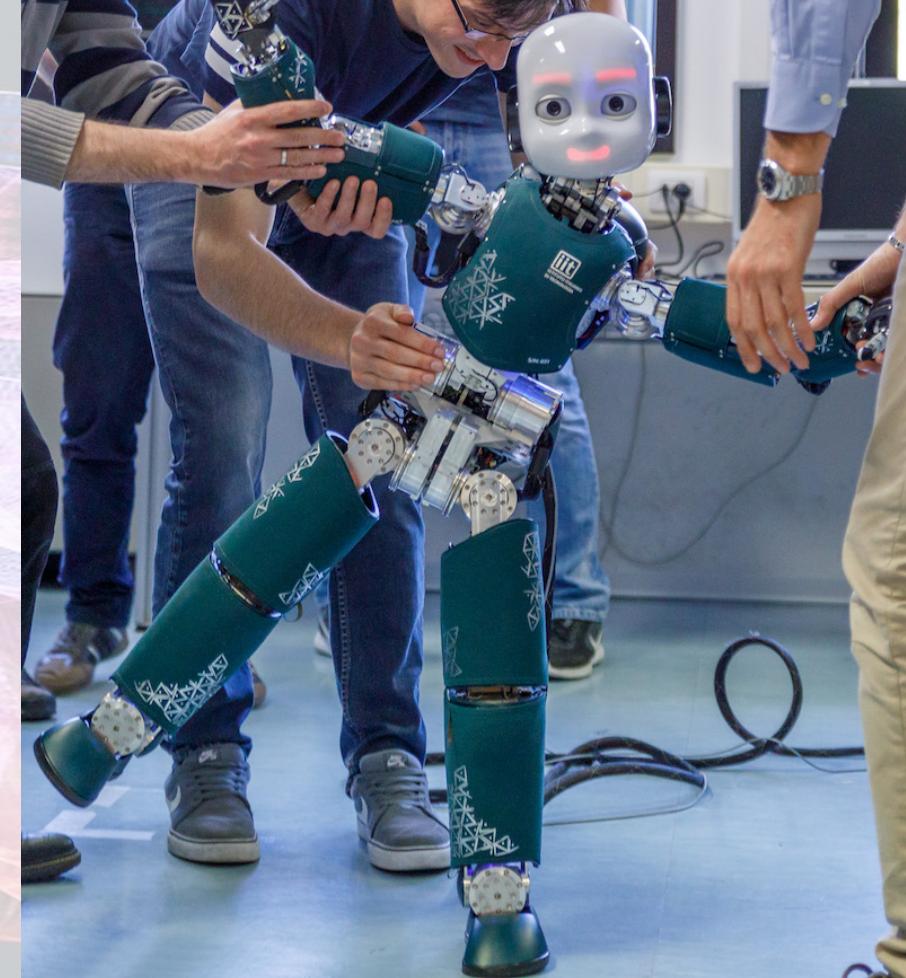


Touch in robotics

Object's manipulation (grasp, exploration, use, etc.)



Physical interaction (balancing, safety, perception of own body in space, etc.)



Touch in prosthetics

Tactile feedback to user and low-level control



Object's manipulation (grasp, exploration, use, etc.)

Physical interaction (safety)

Perception of the prosthetic device as part of the body (easier to use, higher acceptability)

Image courtesy of
SENSARS
NEUROPROSTHETICS



From biology to artificial touch

How does touch work in biology?

Sensory transduction, properties of tactile afferents

How is tactile information encoded and decoded?

Spike patterns and spiking neural networks for information decoding and decision making

How can we design tactile sensors?

Neuromorphic encoding for different transducers

How can we use tactile information in robots and prosthetics?

Tactile exploration, sensory feedback

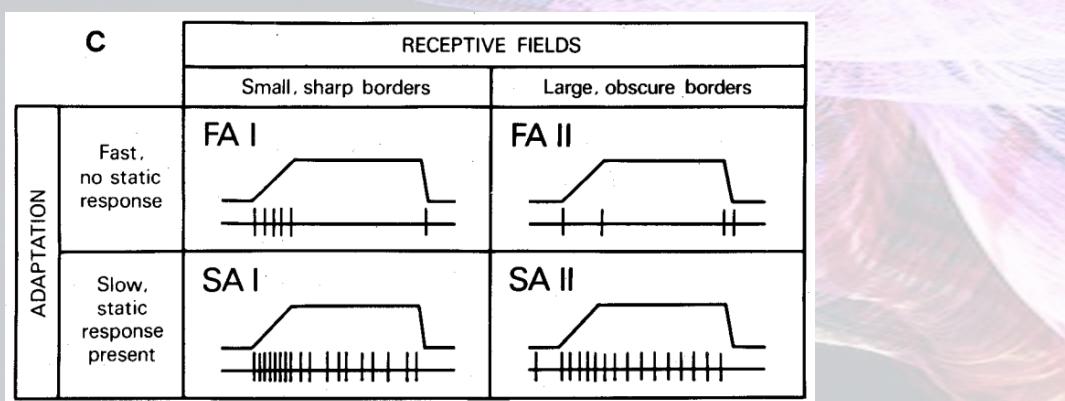
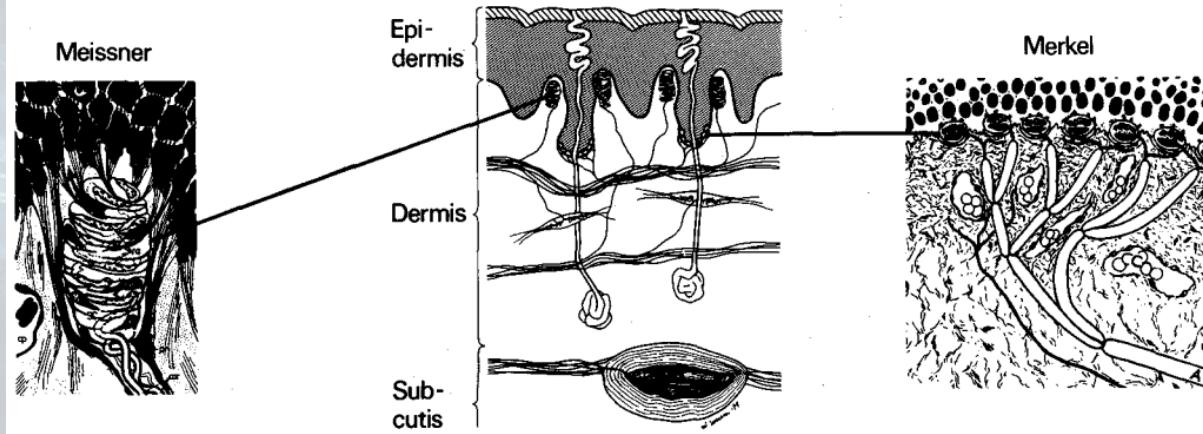
“Soft” Neuromorphic Touch

Neuromorphic Touch



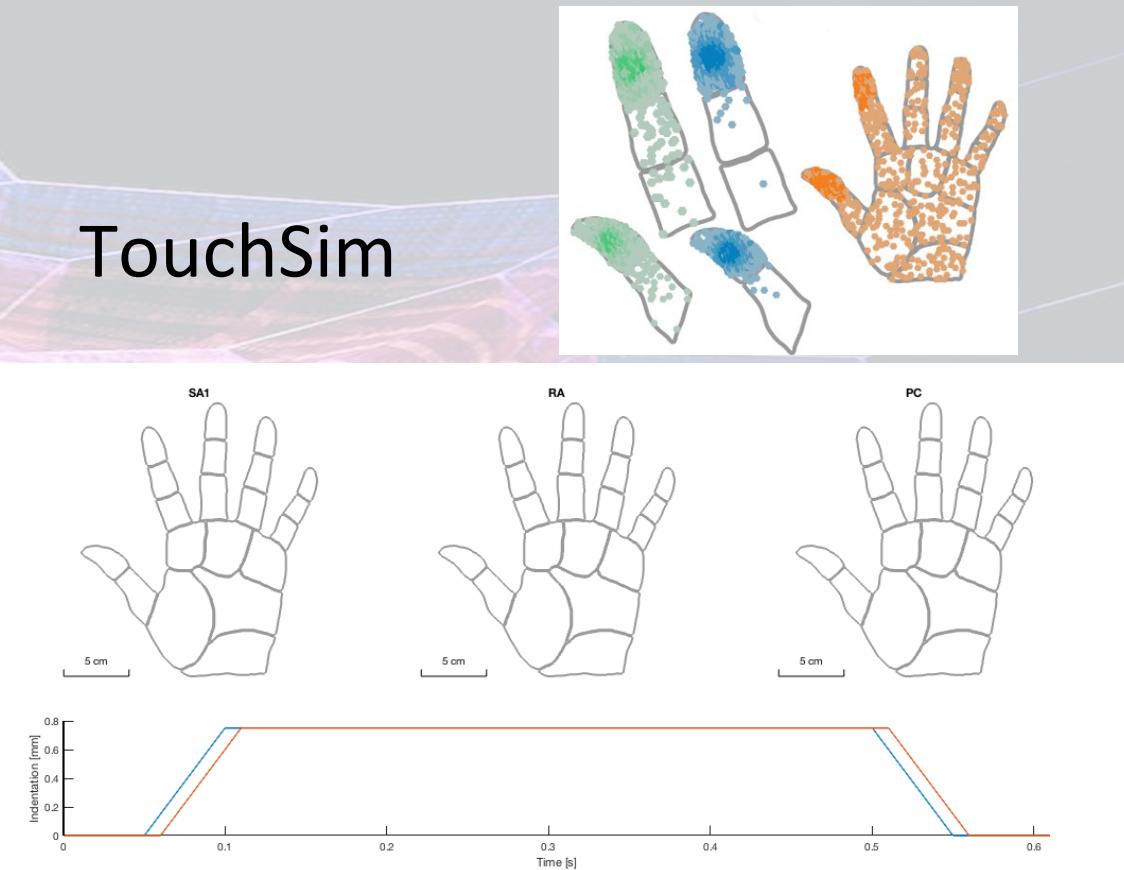
Touch in biology

Glabrous skin (fingertips)



Vallbo, A. B., & Johansson, R. S. (1984). Properties of cutaneous mechanoreceptors in the human hand related to touch sensation. *Hum neurobiol*, 3(1), 3-14.

TouchSim



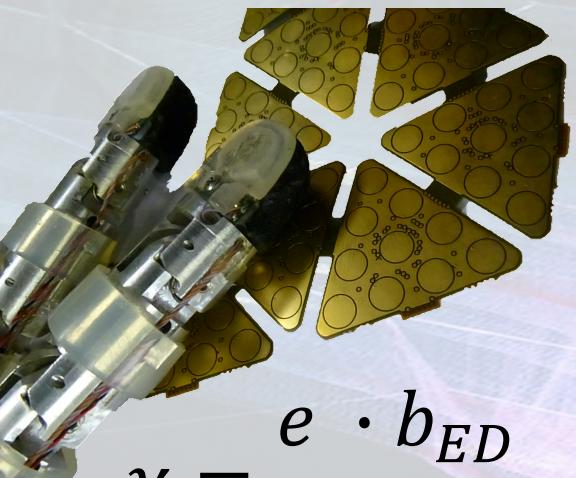
Video courtesy of H. Saal

Saal, H. P., Delhaye, B. P., Rayhaun, B. C., & Bensmaia, S. J. (2017). Simulating tactile signals from the whole hand with millisecond precision. *Proceedings of the National Academy of Sciences*, 114(28), E5693-E5702.

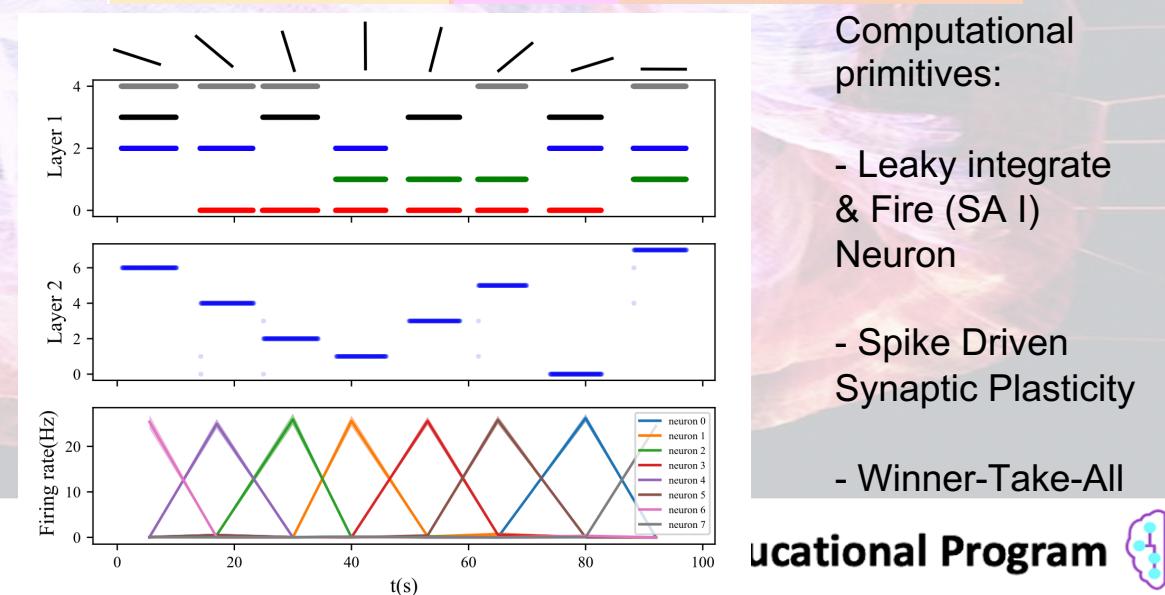
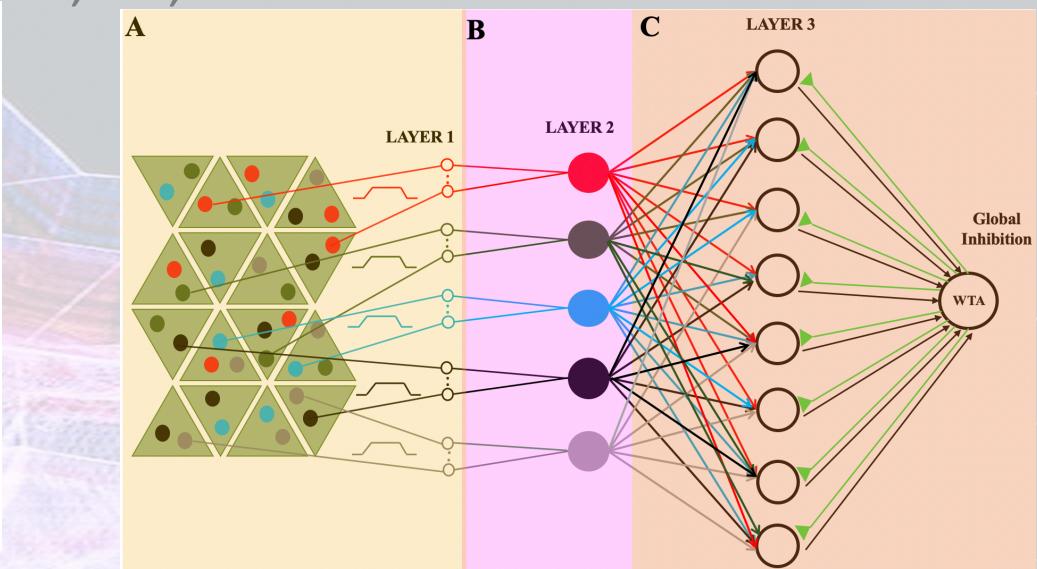
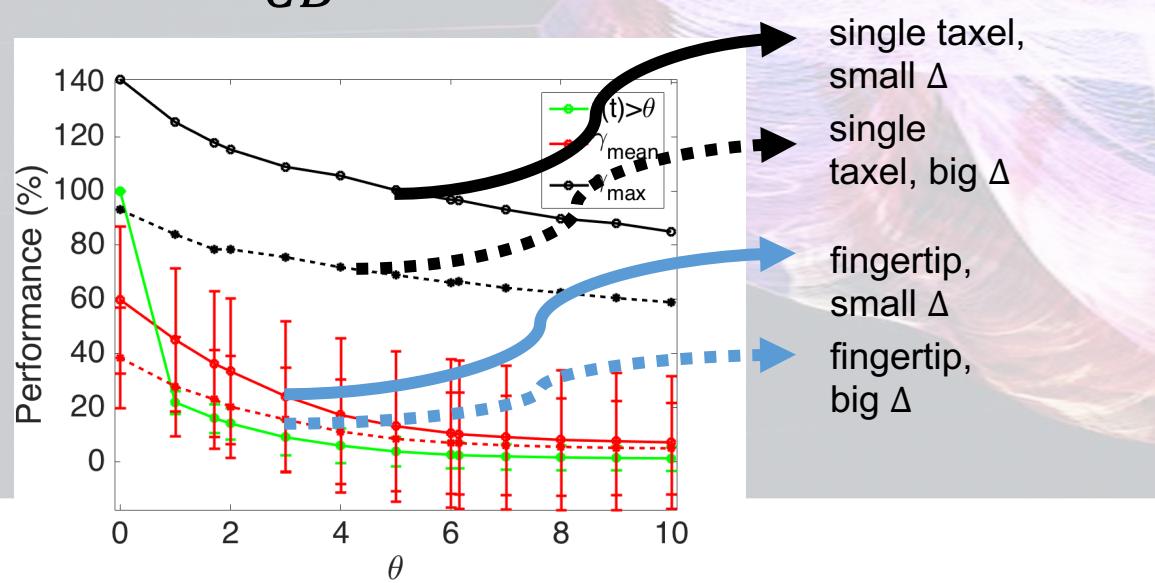
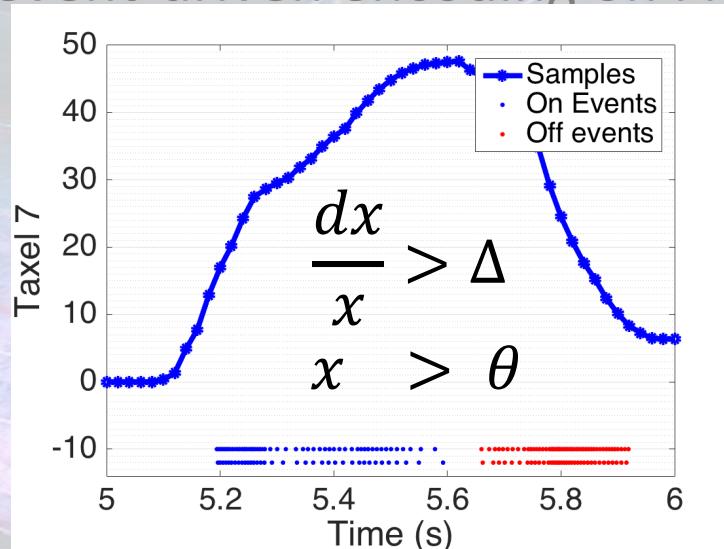


“Soft” neuromorphic touch

Clocked front-end & event-driven encoding on FPGA, uC, SW



$$\gamma = \frac{e \cdot b_{ED}}{s \cdot b_{CB}}$$



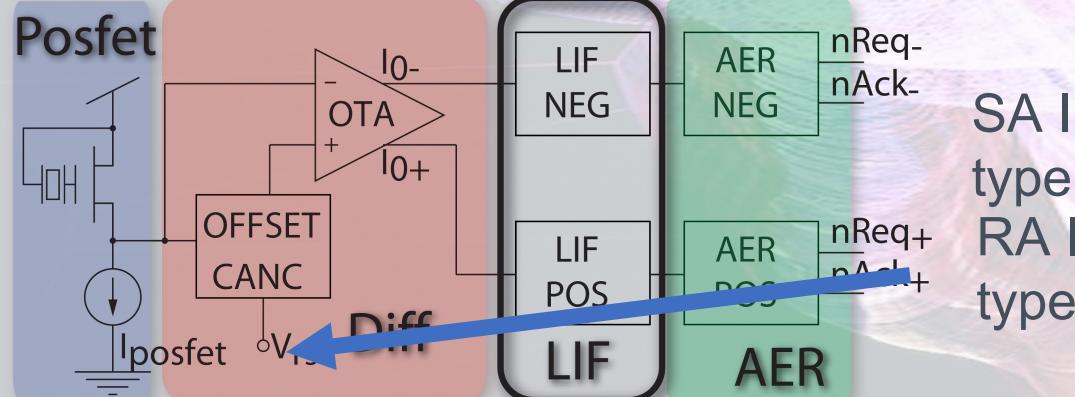
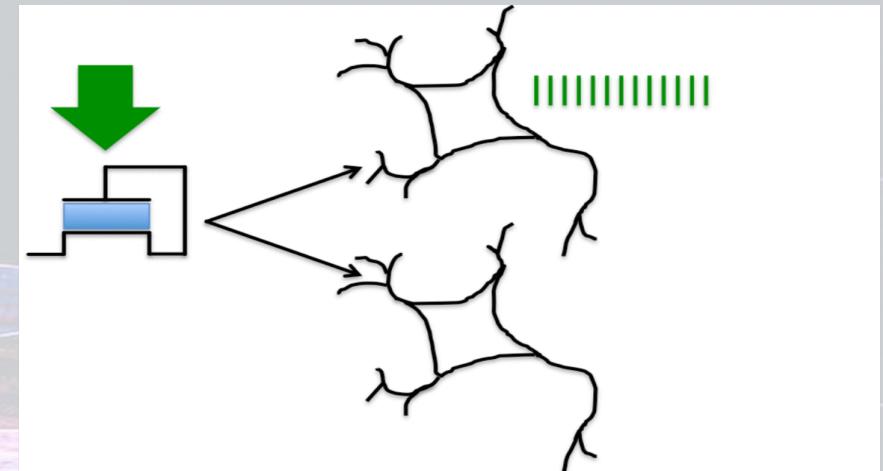
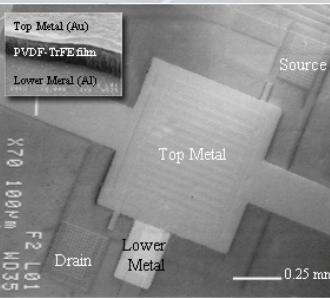
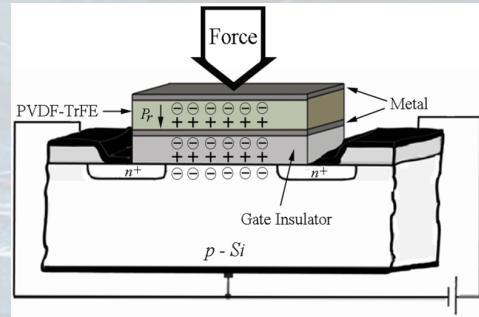
“Soft” neuromorphic touch

Clocked front-end & event-driven encoding on FPGA, uC, SW

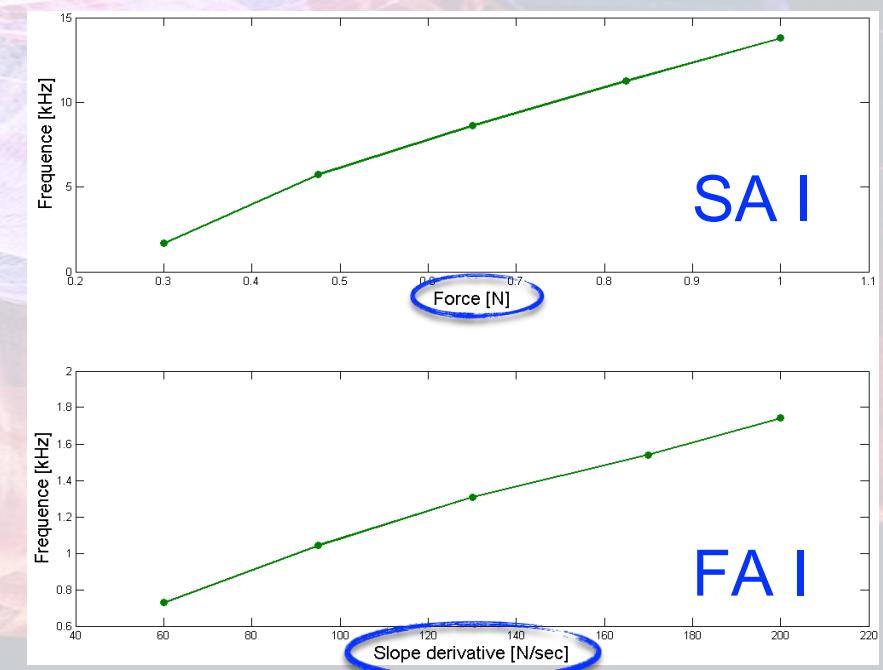
Reference	Physical Transducer	Event Generation	Application
Dabbous A., Mastella M., Natarajan A., Valle M., Chicca E., Bartolozzi, C., Artificial Bio-inspired Tactile Receptive Fields for Edge Orientation Classification. In 2021 IEEE International Symposium on Circuits and Systems (ISCAS). IEEE.	capacitive	Send on Delta, LIF	Large area skin for robots, edge orientation
Parvizi-Fard, A., Amiri, M., Kumar, D., Iskarous, M. M., & Thakor, N. V. (2021). A functional spiking neuronal network for tactile sensing pathway to process edge orientation. <i>Scientific reports</i> , 11(1), 1-16.	piezoresitive	Izhikevich (FA I, SA I)	Edge orientation. Pain and touch sensation feedback to prosthetic users, Grip control
Mazzoni, A., Oddo, C. M., Valle, G., Camboni, D., Strauss, I., Barbaro, M., ... & Micera, S. (2020). Morphological neural computation restores discrimination of naturalistic textures in trans-radial amputees. <i>Scientific reports</i> , 10(1), 1-14.	MEMS	Izhikevich (FA I)	Texture. Touch feedback to prosthetic users
Bergner, F., Dean-Leon, E. and Cheng G. "Design and Realization of an Efficient Large-Area Event-Driven E-Skin." <i>Sensors</i> 20, no. 7 (2020): 1965.	resistive	Integrate and sample	Large area skin for robotics

Neuromorphic Touch

Asynchronous readout of transducer



SA I
type
RA I
type



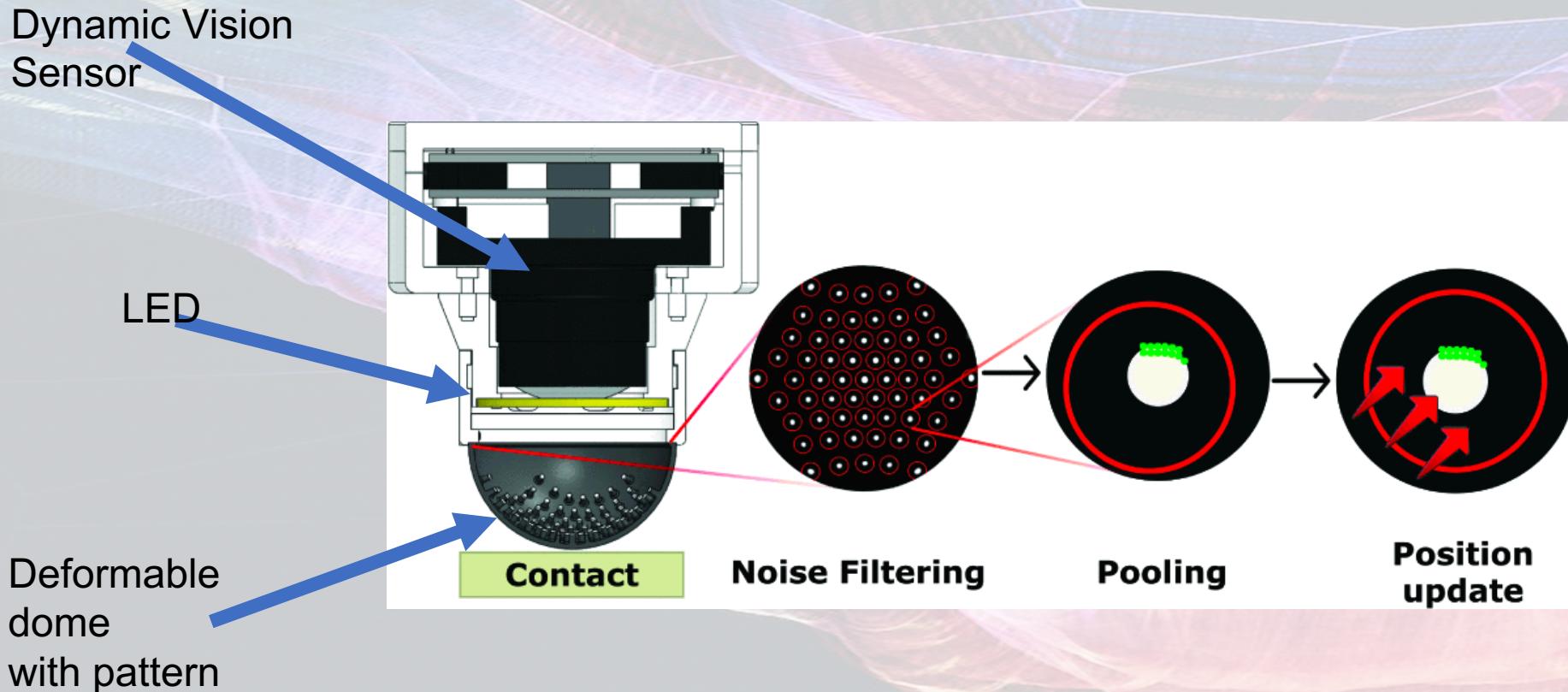
Neuromorphic Touch

Asynchronous readout of transducer

Reference	Transducer	Event Generation	Application
John, R. A., Tiwari, N., Patdillah, M. I. B., Kulkarni, M. R., Tiwari, N., Basu, J., ... & Mathews, N. (2020). Self healable neuromorphic memtransistor elements for decentralized sensory signal processing in robotics. <i>Nature communications</i> , 11(1), 1-12.	Resistive & Memristive devices		Pain, texture, robotic hand
Caviglia, S., Pinna, L., Valle, M., & Bartolozzi, C. (2016). Spike-based readout of POSFET tactile sensors. <i>IEEE Transactions on Circuits and Systems I: Regular Papers</i> , 64(6), 1421-1431.	piezoelectric	LIF (FA I, SA I)	Robotics, prosthetics
Lee, W. W., Tan, Y. J., Yao, H., Li, S., See, H. H., Hon, M., ... & Tee, B. C. (2019). A neuro-inspired artificial peripheral nervous system for scalable electronic skins. <i>Science Robotics</i> , 4(32).	resistive	Unique pulse signature	Hardness, local curvature, slip, gratings (texture), robotic manipulator
Ward-Cherrier, B., Pestell, N., & Lepora, N. F. (2020, May). NeuroTac: A neuromorphic optical tactile sensor applied to texture recognition. In 2020 IEEE International Conference on Robotics and Automation (ICRA) (pp. 2654-2660). IEEE.	Vision sensor	$\frac{\Delta I}{I} > \theta$	Shear force, texture

Visual event-driven Touch

Dynamic vision sensor observes pattern deformations



Ward-Cherrier, B., Pestell, N., & Lepora, N. F. (2020, May). NeuroTac: A neuromorphic optical tactile sensor applied to texture recognition. In 2020 IEEE International Conference on Robotics and Automation (ICRA) (pp. 2654-2660). IEEE. Shared with permission from IEEE



Thanks!

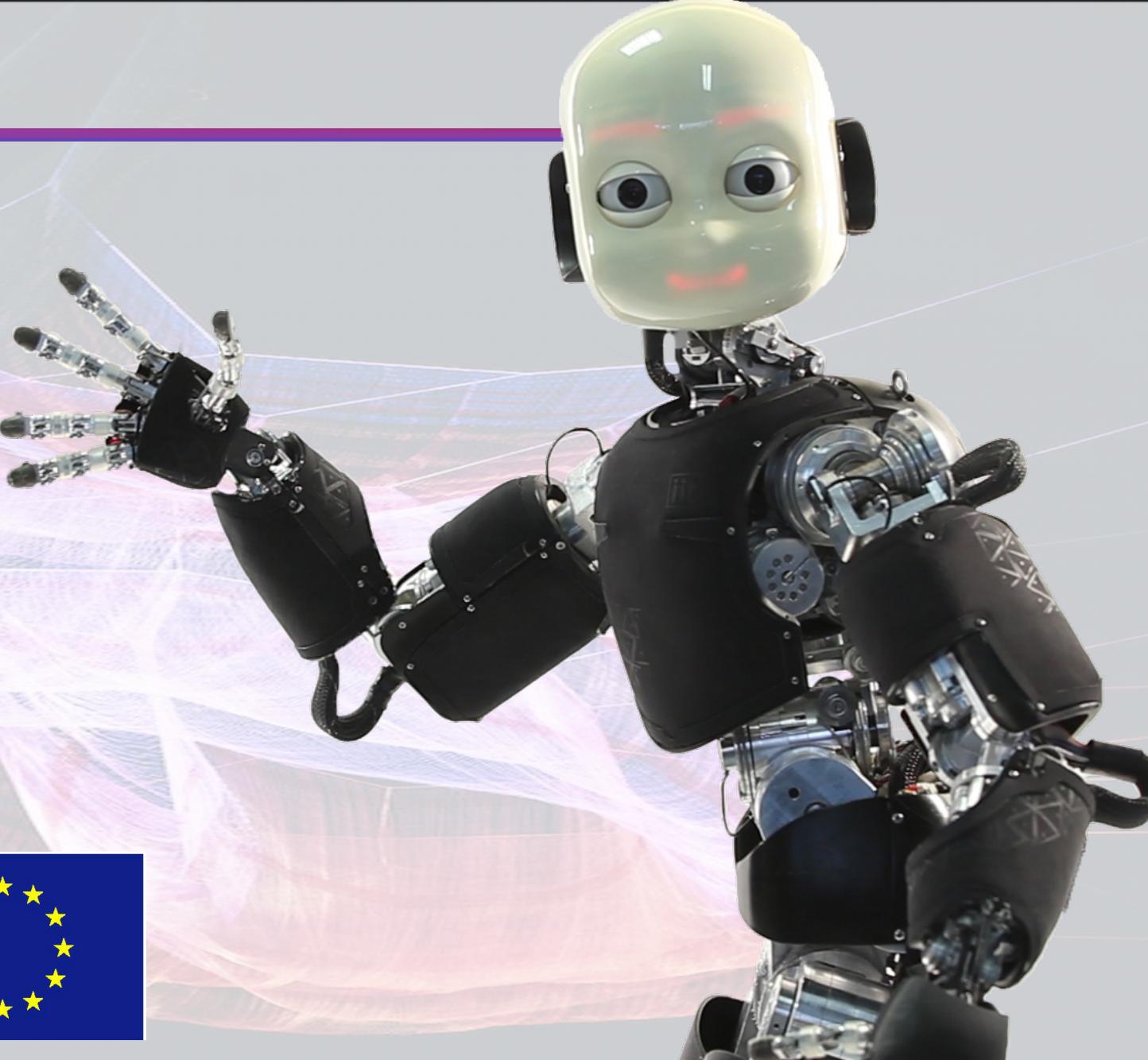


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