tinyML® Talks

Enabling Ultra-low Power Machine Learning at the Edge

"Mudra: Reinventing Tiny Interfaces for Ubiquitous Digital Interaction"

Leeor Langer – Co-founder and CTO, Wearable Devices
Oleksandr Pirotskiy – Team Leader of Firmware Development, Wearable Devices

August 15, 2023

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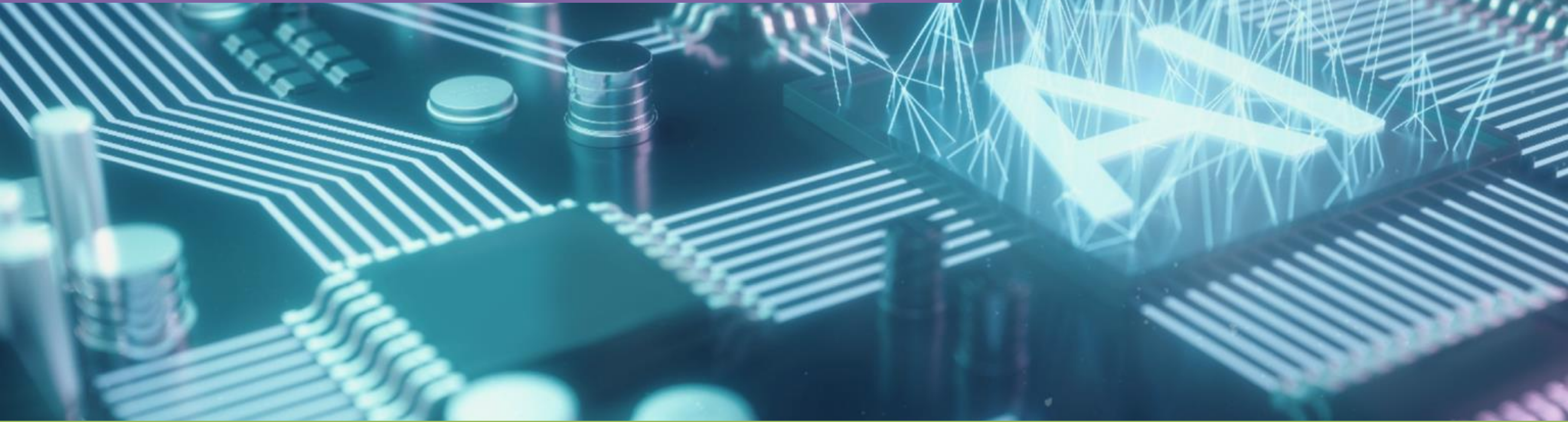

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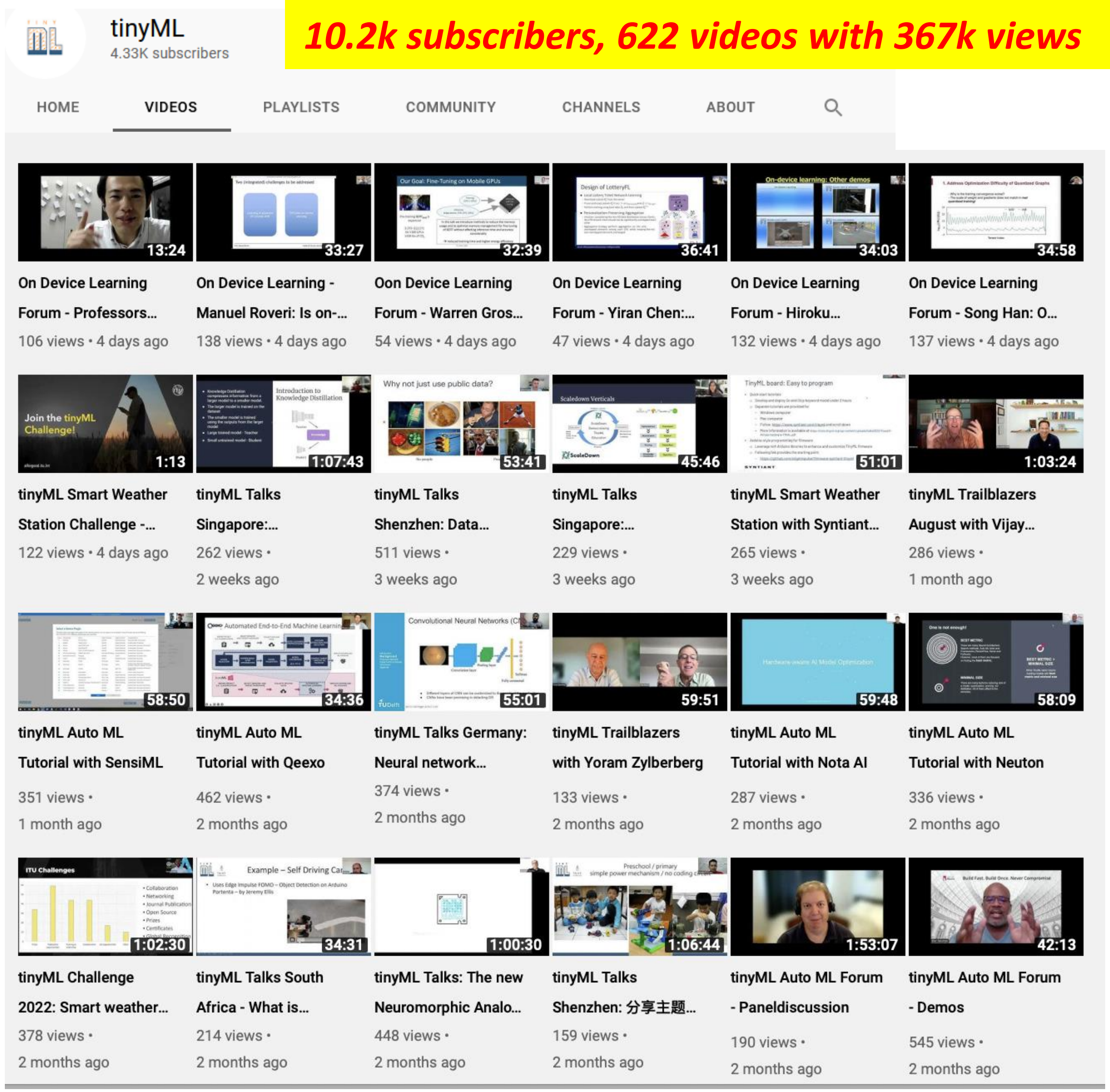

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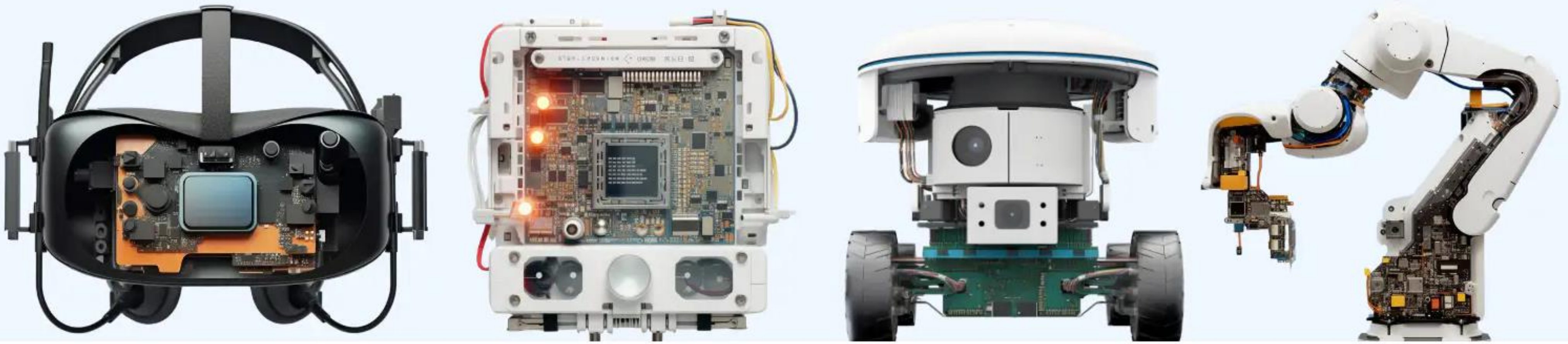
Call for Presentations and Posters – Deadline August 7
https://www.tinyml.org/event/asia-2023/

https://www.wevolver.com/article/2023-edge-ai-technology-report

2023 Edge AI Technology Report

The guide to understanding the state of the art in hardware & software in Edge AI.



Reminders

Slides & Videos will be posted tomorrow

tinyml.org/forums

youtube.com/tinyml

Please use the Q&A window for your questions

Leeor Langer

Leeor Langer serves as a seasoned data scientist and the co-founder and CTO of Wearable Devices. He has been leading the company's bio-potential sensing algorithms from a garage initiative all the way to a successful Initial Public Offering (IPO) on NASDAQ. Before his venture with Wearable Devices, Mr. Langer held key roles driving algorithmic developments in numerous organizations across diverse modalities, including content ranking and X-ray applications. He earned a BSc in Electrical Engineering from the Technion - Israel Institute of Technology and an MSc in Applied Mathematics from Tel Aviv University.

Oleksandr Pirotskiy

Oleksandr Pirotskiy is the Team Leader of Firmware Development at Wearable Devices Ltd, specializing in the field of embedded software development. Oleksandr is currently focused on the development of gesture recognition algorithms, bringing extensive experience in the development and integration of sensor drivers. His work is distinguished by his innovative approach to low-power solutions, ensuring the efficient use of resources without compromising functionality. Oleksandr has a proven track record in implementing a substantial number of HID devices and ensuring their seamless integration across multiple operating systems. He holds a Master's degree in Computer Sciences from the Kiev National Polytechnic Institute. His unique combination of academic rigor, passion for technological innovation, and dedication to energy efficiency continues to propel him forward in the wearable devices industry.

Mudra: Reinventing tiny Interfaces for Ubiquitous Digital Interaction

Wearable Devices

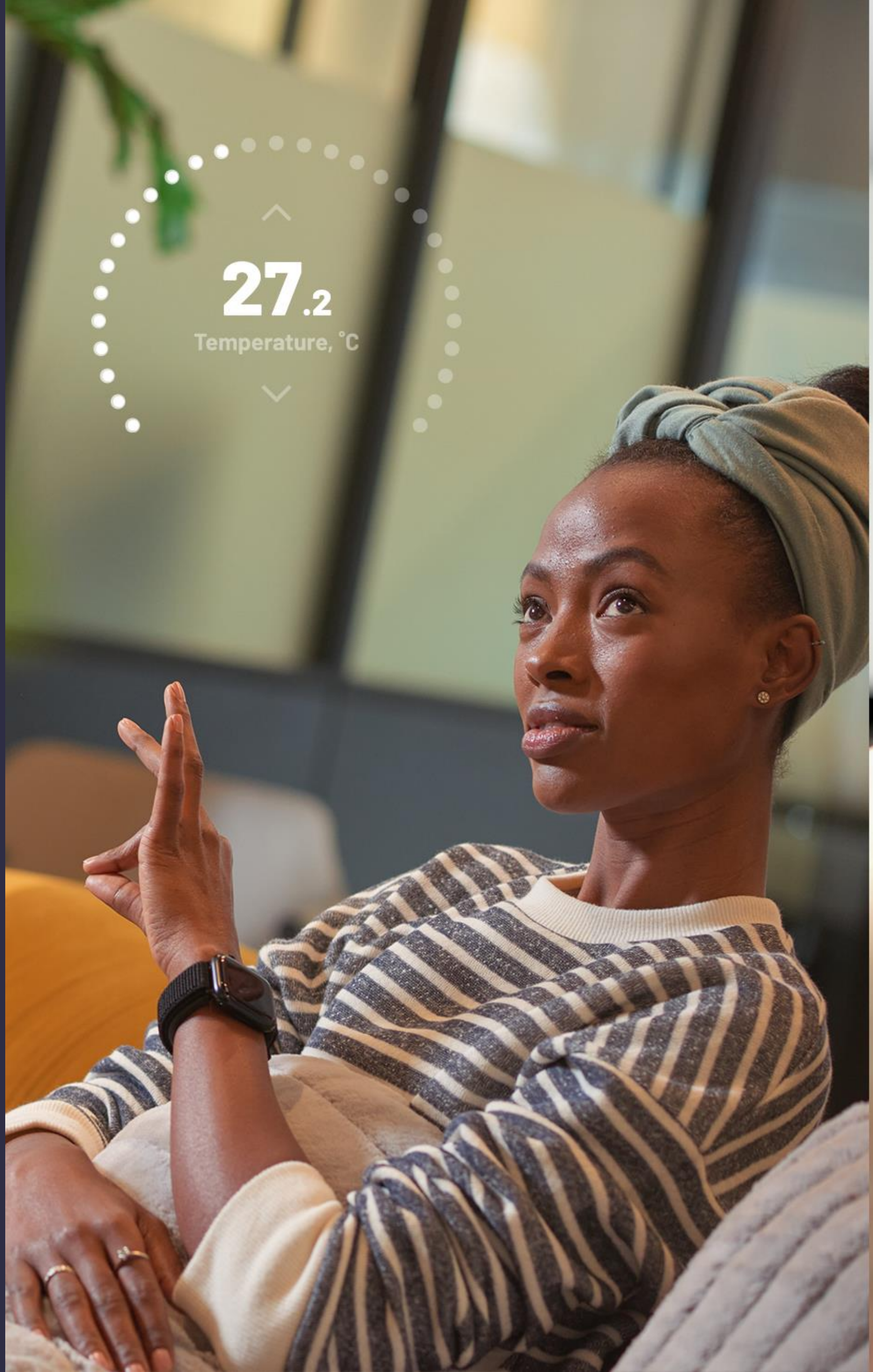
mudra

Content

- **Human Computer Interaction**
  - Examples of digital interaction
  - Today\Tomorrow
- **Ionic Exchange**
  - Biopotentials
  - Sensing
- **Sensor Fusion**
  - Data Acquisition
  - Neural Networks
  - Random Forests
- **Software implementation**
  - System overview
  - Interaction within Apple Ecosystem

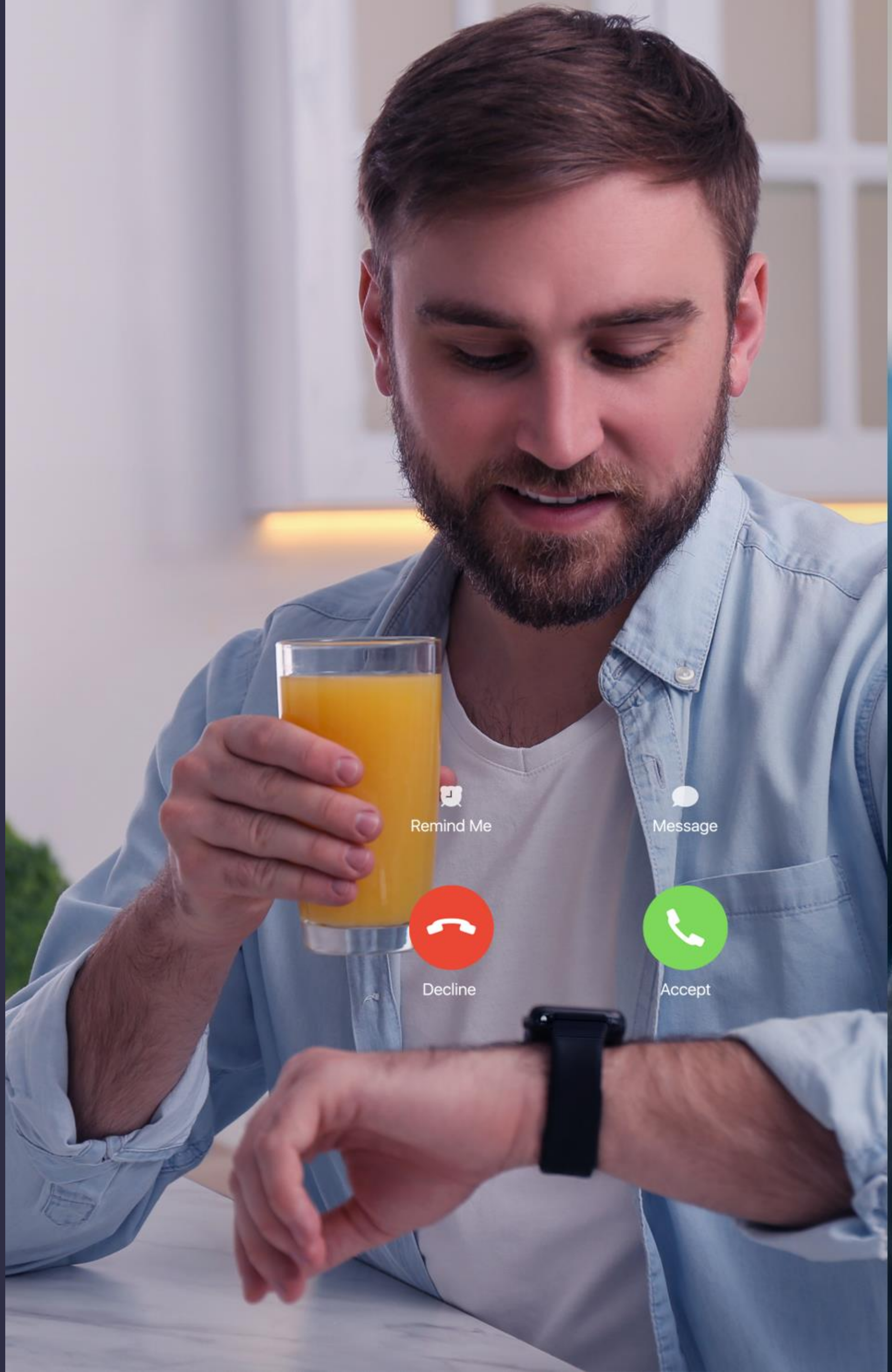
Wearable Devices

HCI – Today & Tomorrow



Wearable Devices

HCI – Today & Tomorrow



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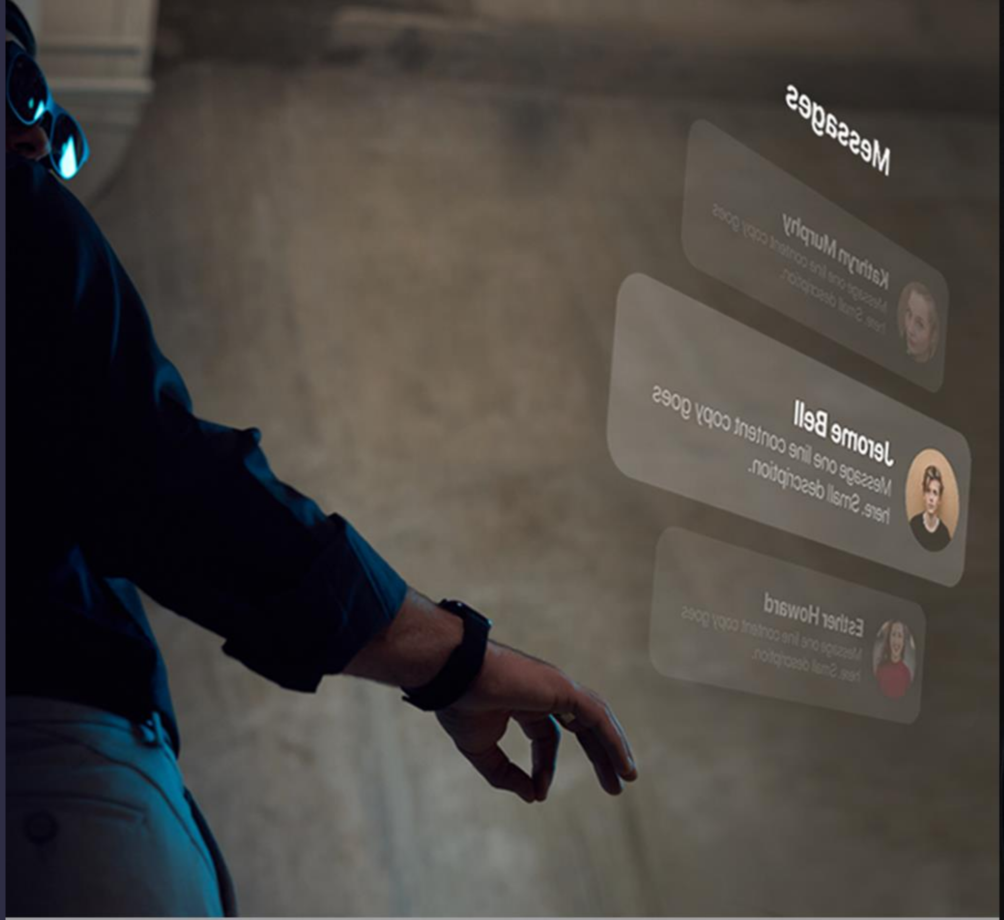
HCI – Today & Tomorrow



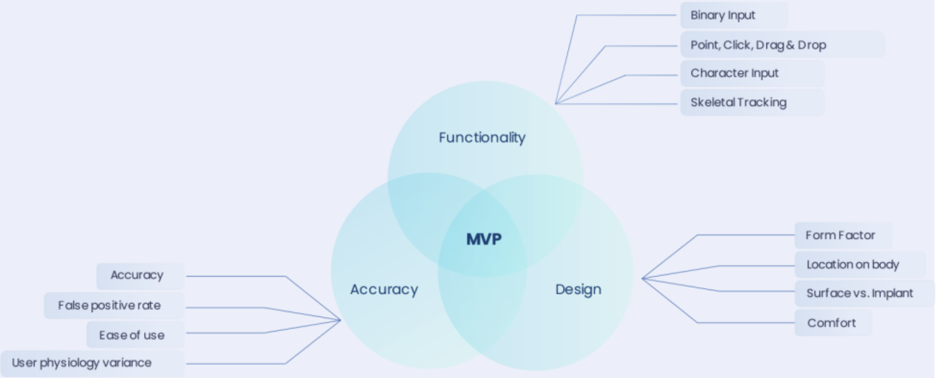
No limitation

Wearable Devices

Mudra Band

* WLD White paper

Mudra Band – Neural Clicker– Fingertip Pressure



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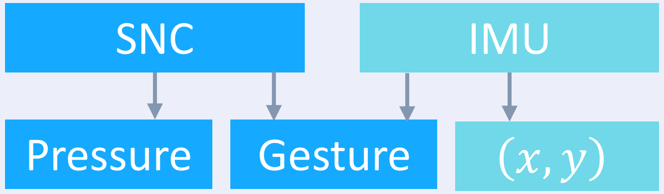
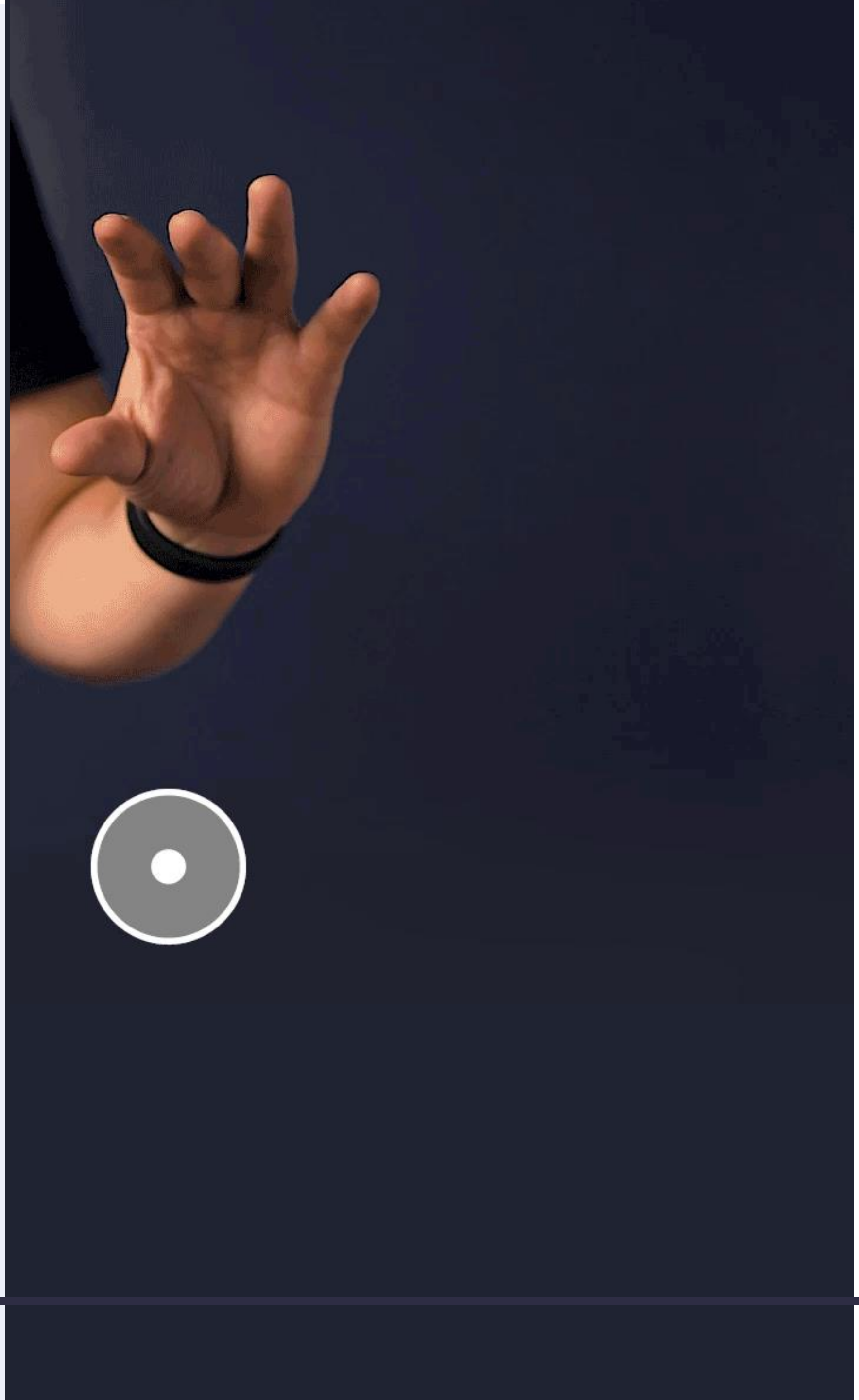
Neural Clicker



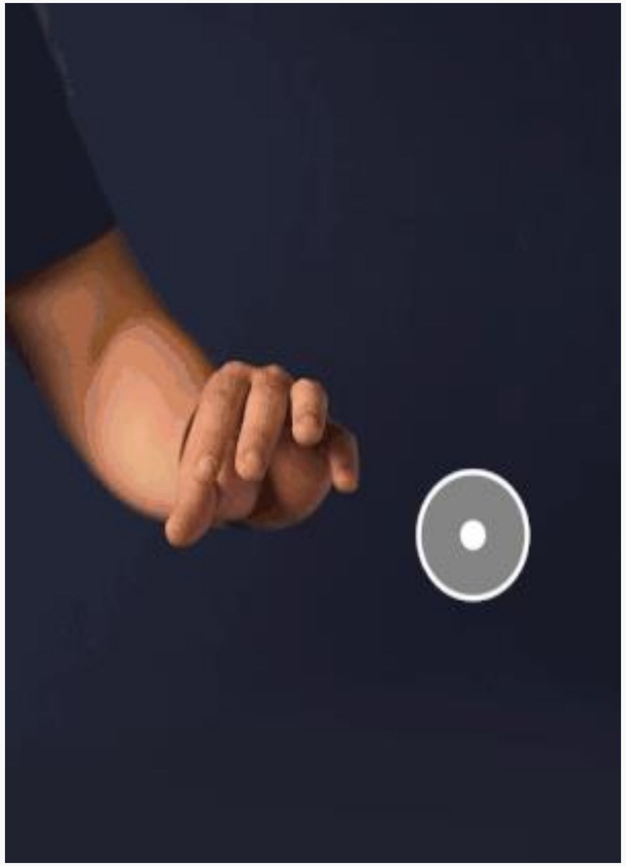


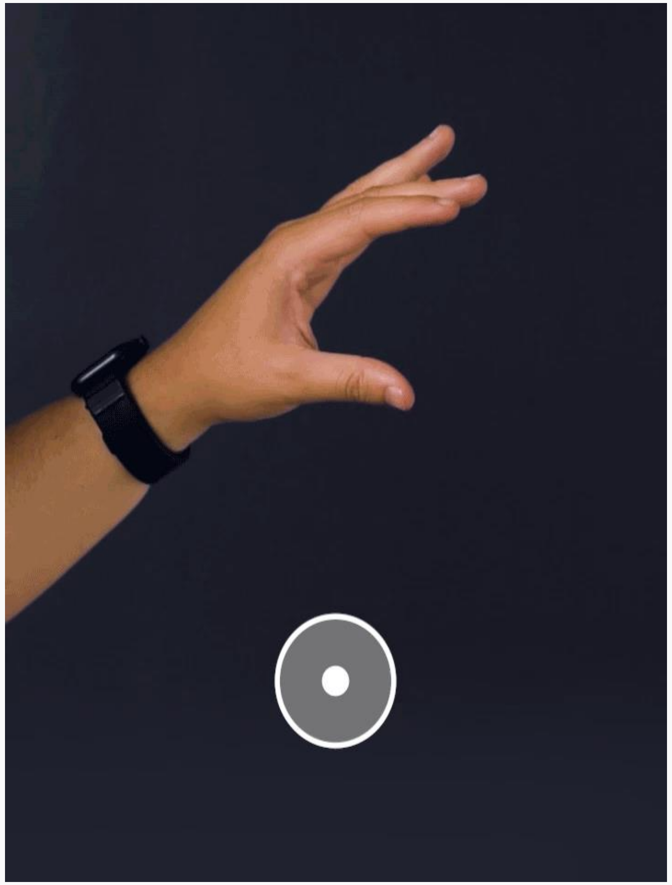
Wearable Devices

Drag & Drop - SNC Fingertip Pressure Estimation

SNC

Pressure





Wearable Devices

Biopotentials

01.

What is a bio-potential signal?

Biopotentials are electrical signals generated by the body's cells, known as excitable cells. On our arm, such cells can be found in the nervous and muscular systems.

02.

What is a biopotential sensor?

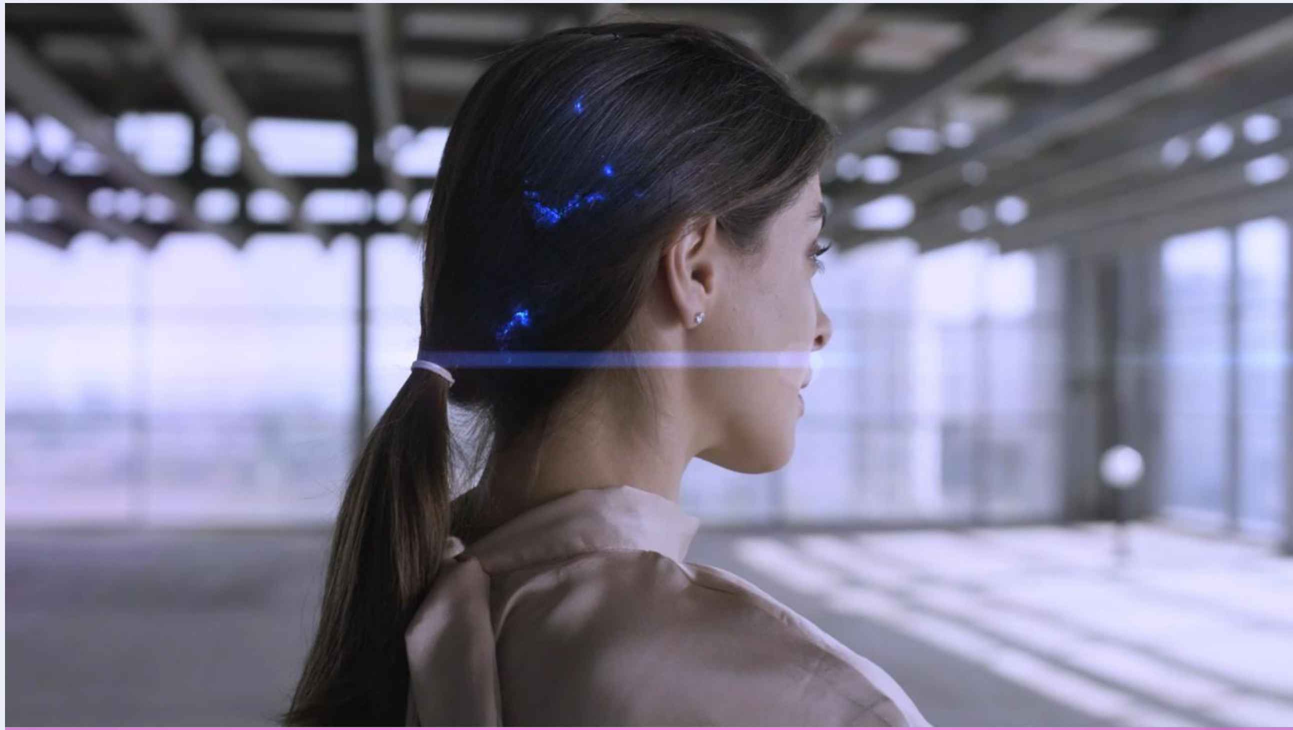
A mechanism designed to detect and respond to extremely low-voltage electrical fields produced by biological processes within the human body.

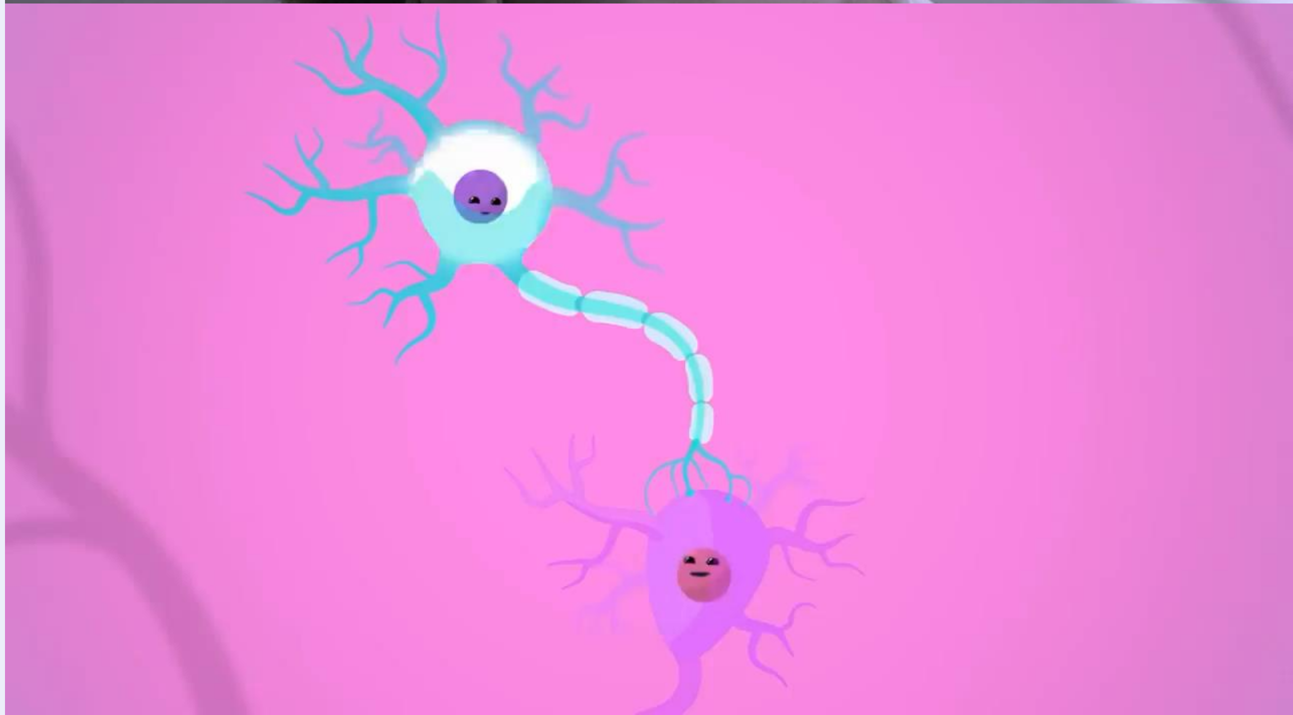
Biopotentials – Ionic Exchange

Direct glimpse
into the mechanics of our body

** Anatomy and Physiology*

Wearable Devices



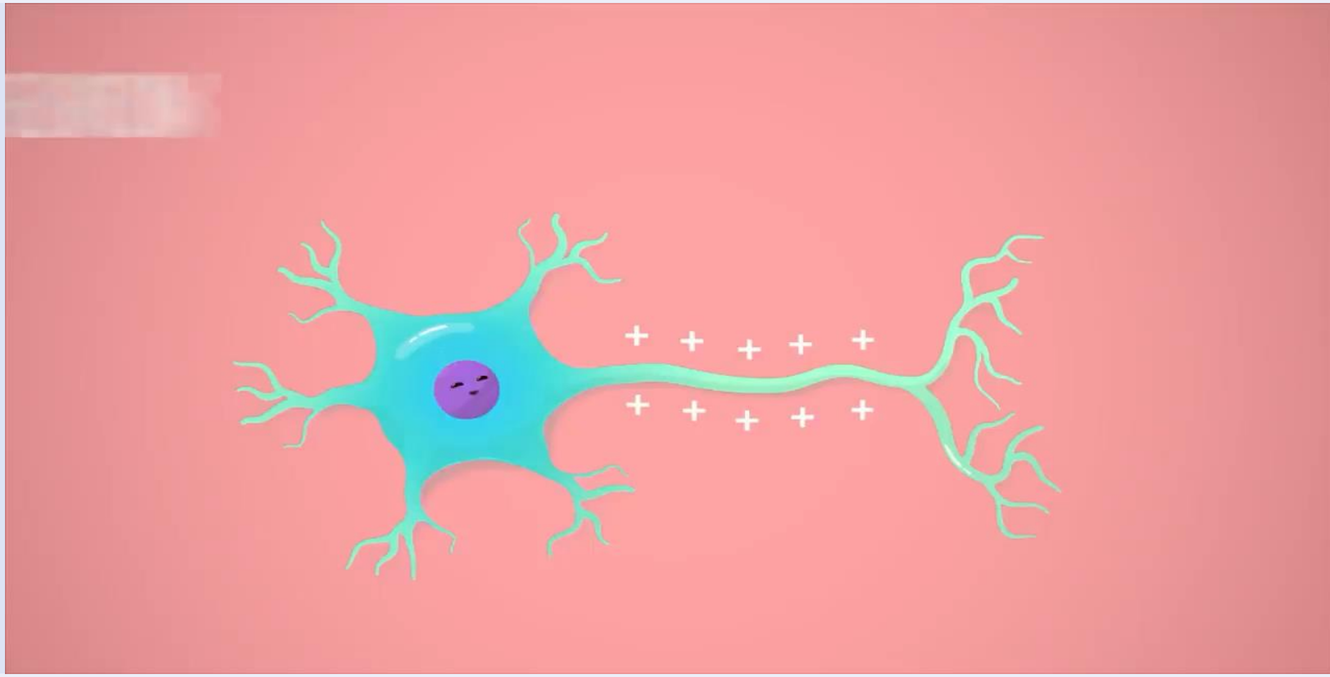


Biopotentials

Three stages:

1. Action Potential Formation
2. Propagation
3. Innervation

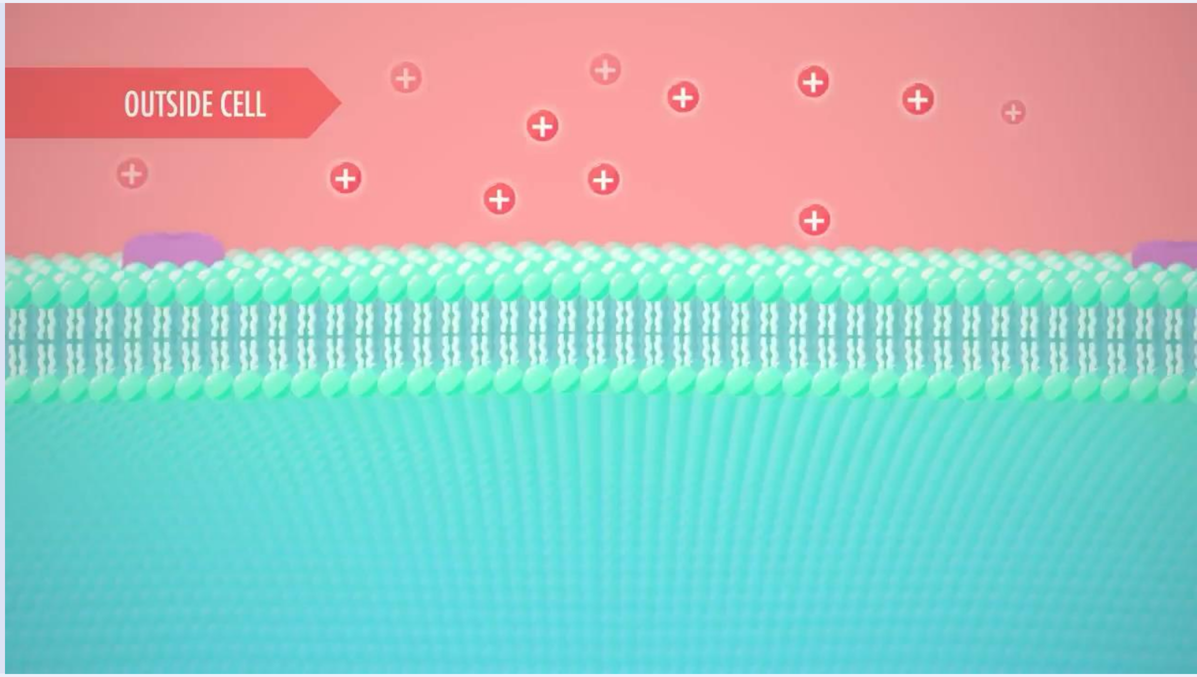
See Anatomy and Physiology



Biopotentials AP Initiation (1a)

What is an *Action Potential*?

a. **Resting potential**
b. Rising phase (depolarization)
c. Falling phase (repolarization)
d. Hyperpolarization



Wearable Devices

Biopotentials AP Initiation (1a)

What is an *Action Potential*?

a. **Resting potential**
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c. Falling phase (repolarization)
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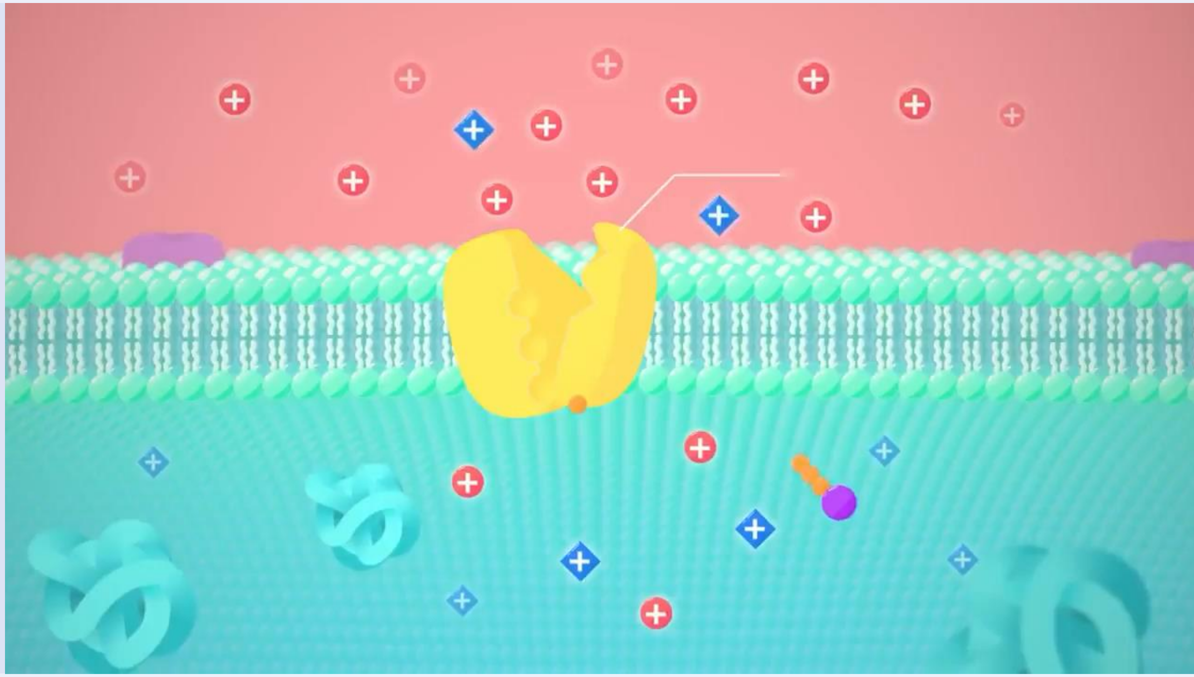
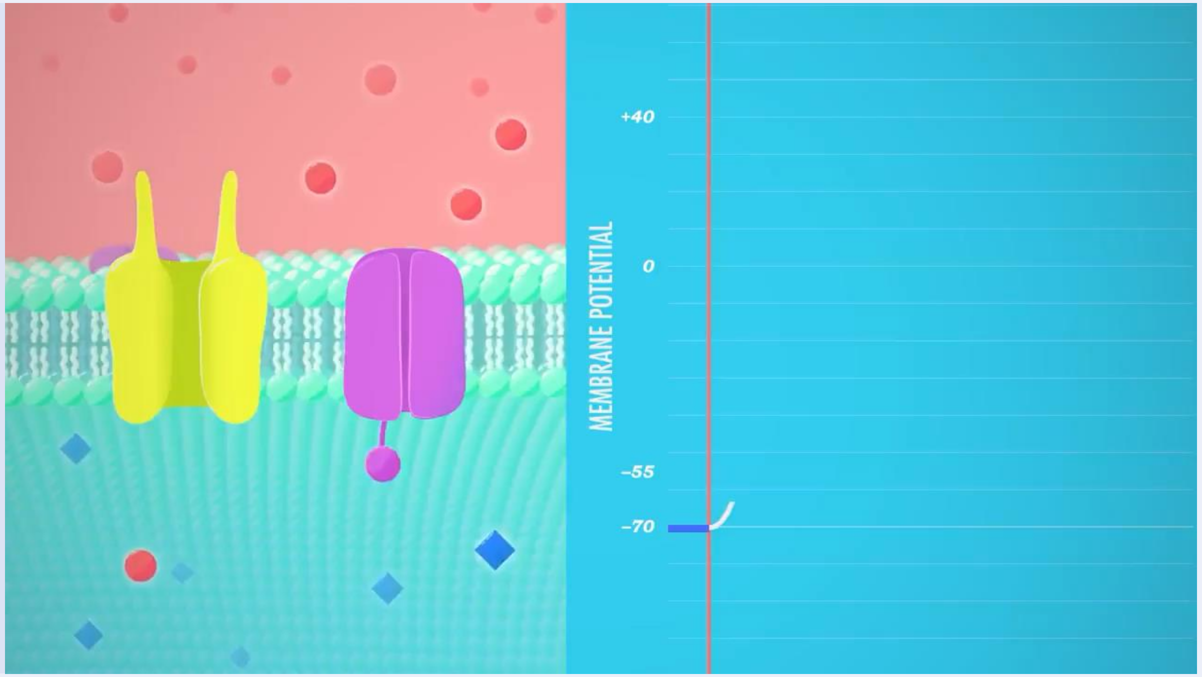


Biopotentials AP Initiation (1b)

- What is an *Action Potential*?
- Resting potential
- **Rising phase (depolarization)**
- Falling phase (repolarization)
- Hyperpolarization

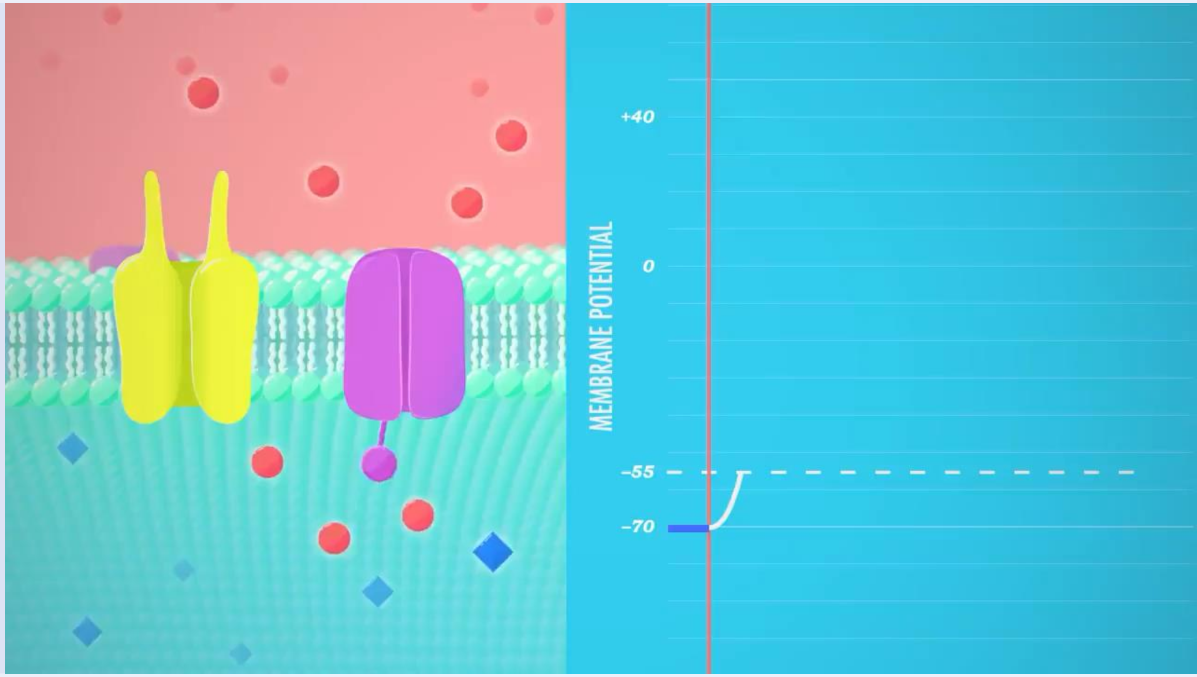


Wearable Devices

Biopotentials AP Initiation (1b)

What is an *Action Potential*?

- Resting potential
- **Rising phase (depolarization)**
- Falling phase (repolarization)
- Hyperpolarization

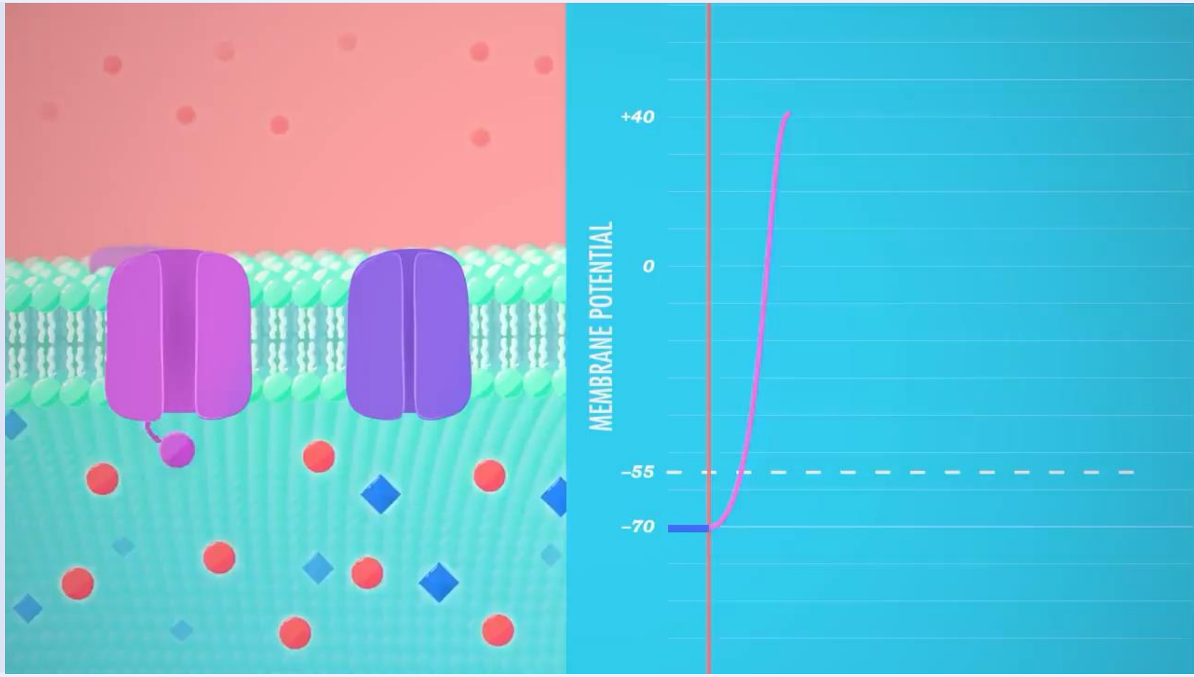


Wearable Devices

Biopotentials AP Initiation (1c)

What is an *Action Potential*?

- Resting potential
- Rising phase (depolarization)
- **Falling phase (repolarization)**
- Hyperpolarization

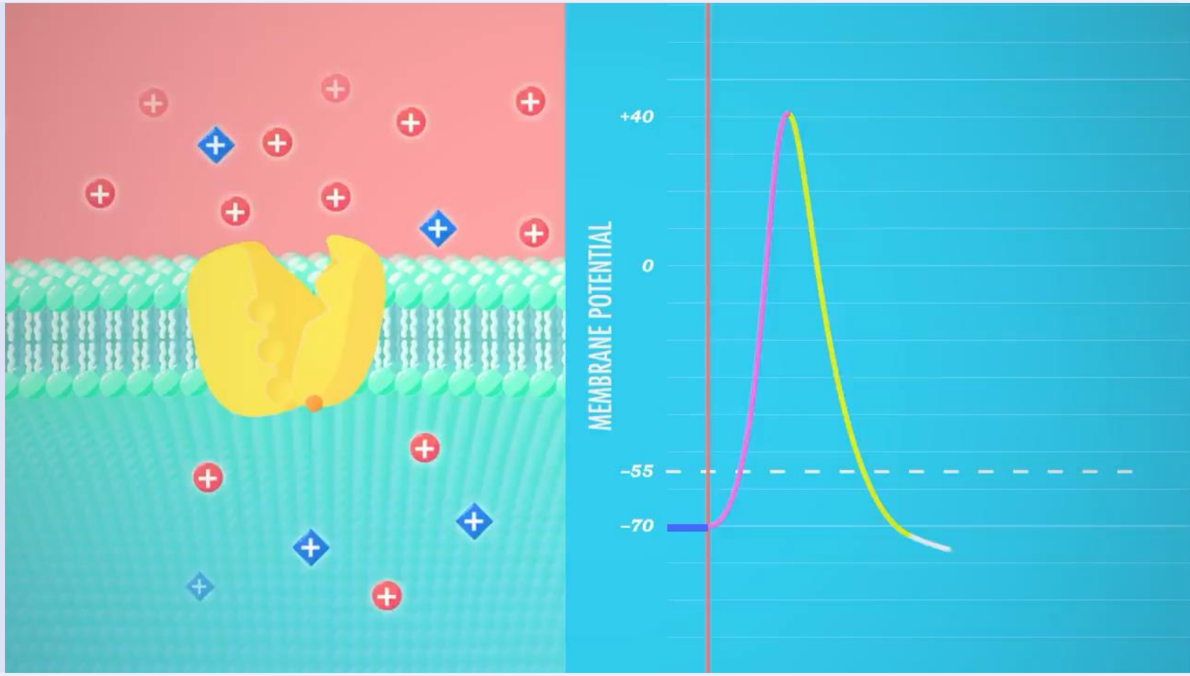


Wearable Devices

Biopotentials AP Initiation (1d)

What is an *Action Potential*?

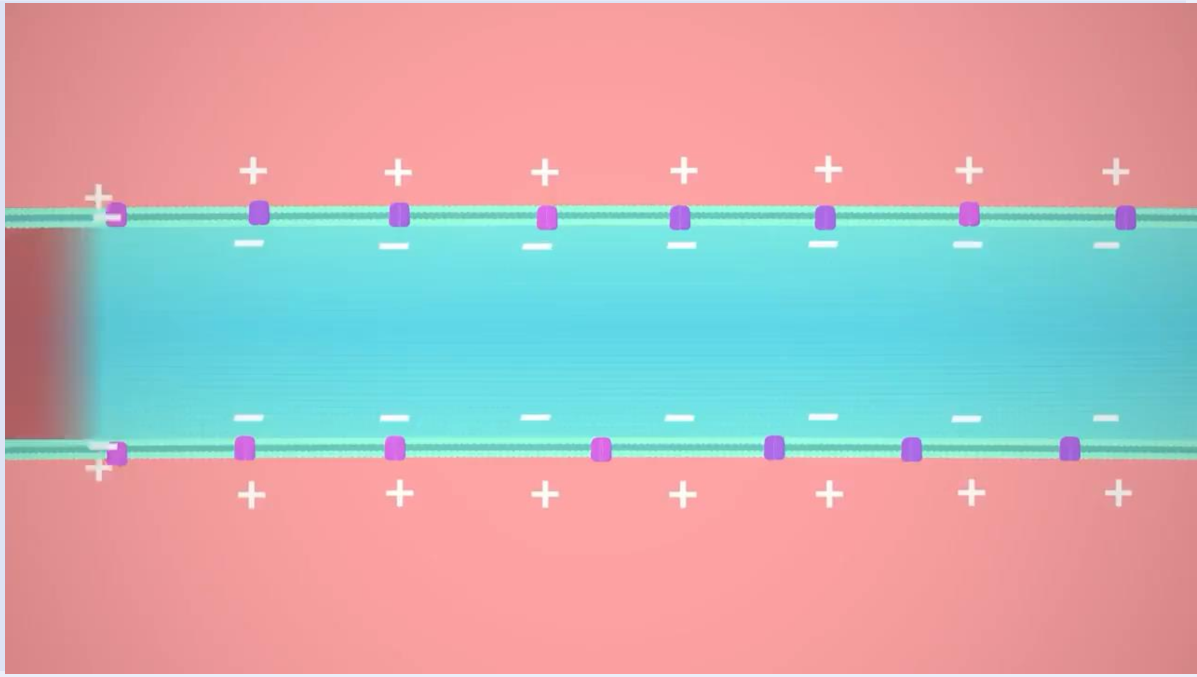
- Resting potential
- Rising phase (depolarization)
- Falling phase (repolarization)
- **Hyperpolarization**



Wearable Devices

Biopotentials Propagation (2)

The *Action Potential propagates like a wave!*

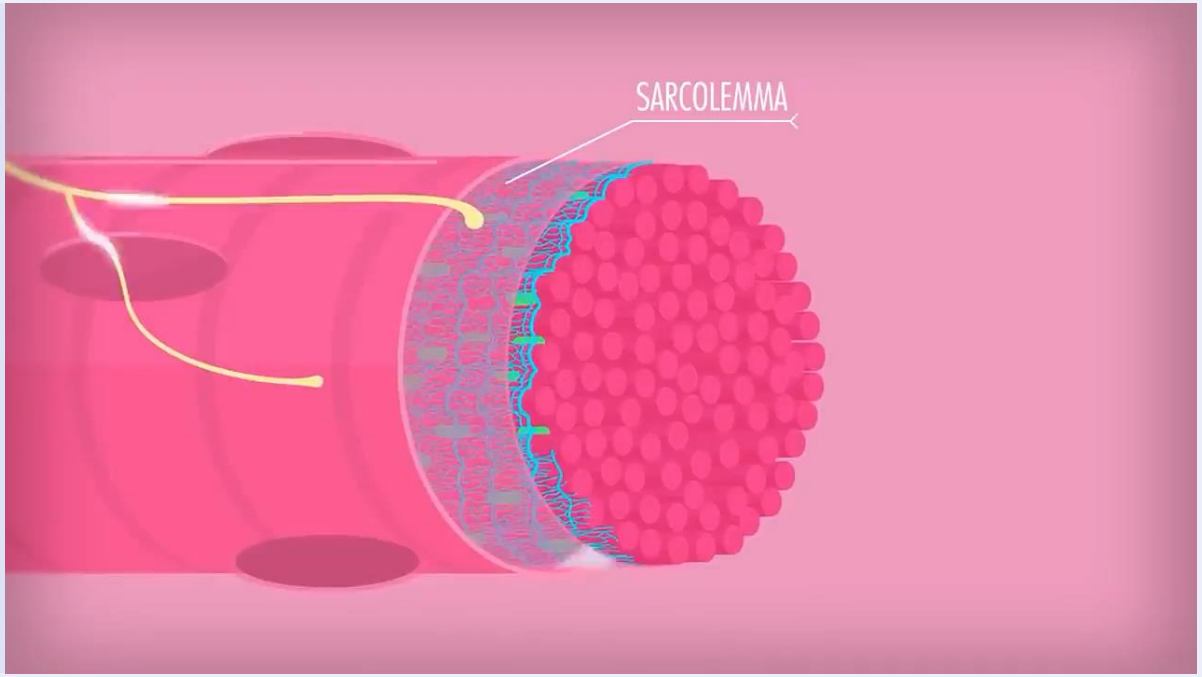


Biopotentials Innervation (3)

Electrical → Chemical

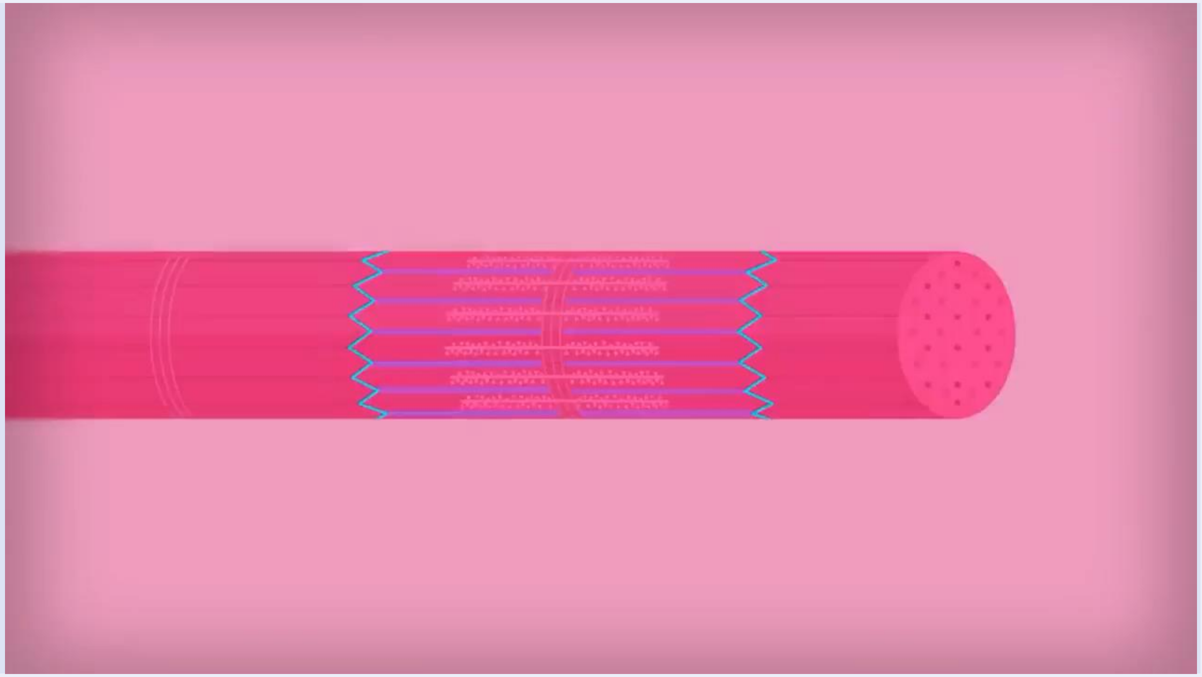
Biopotentials Muscle Contraction (3)

Another conversion from electrical → chemical → mechanical



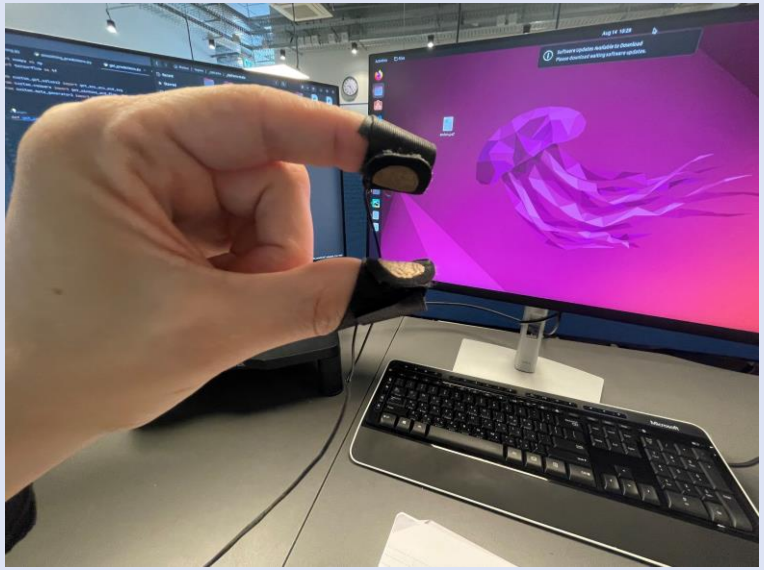
Biopotentials Muscle Contraction (3)

Our body is like a *marionette*, our muscles contract and pull on the tendons connected to the bone structure.

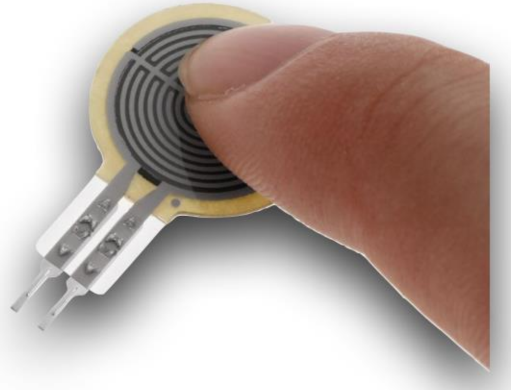


Data Acquisition

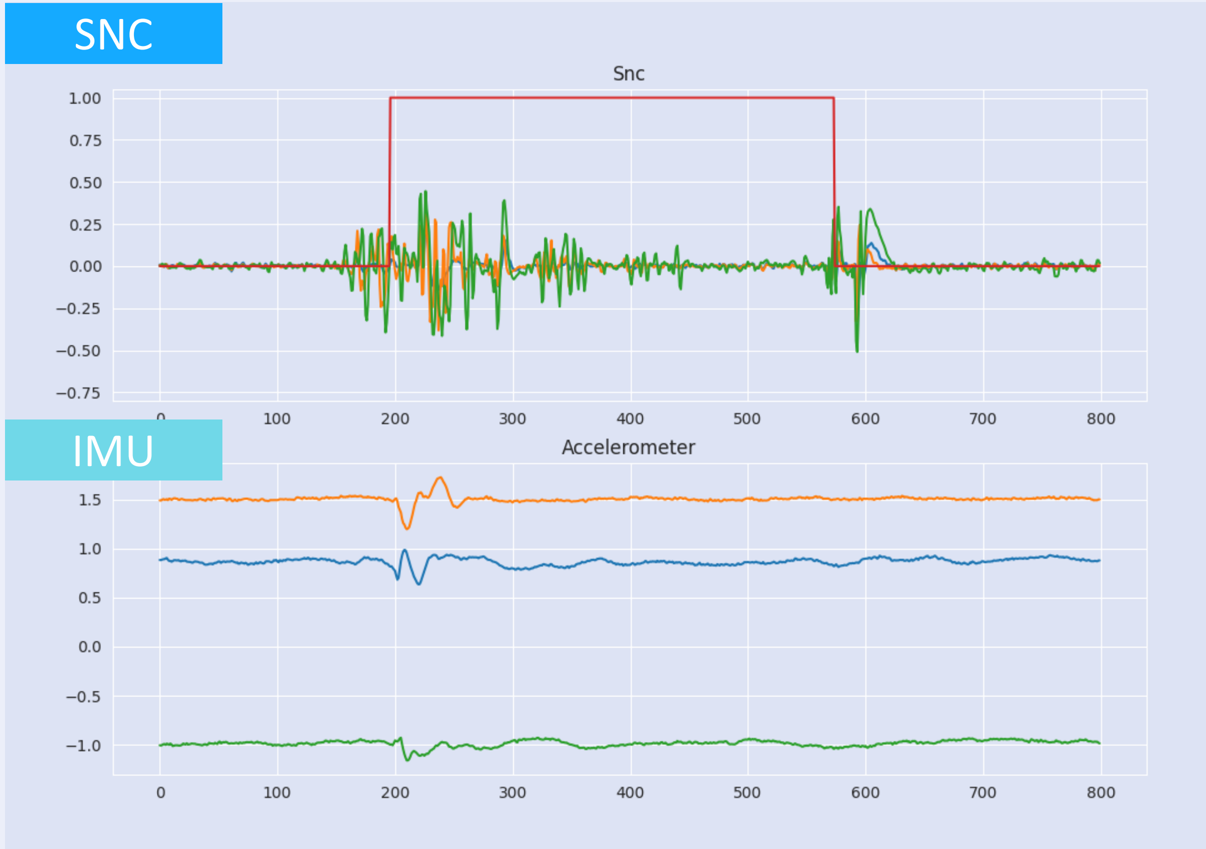
- **In order to collect data we need an API into our nervous system?**
- Manual segmentation was our first method!

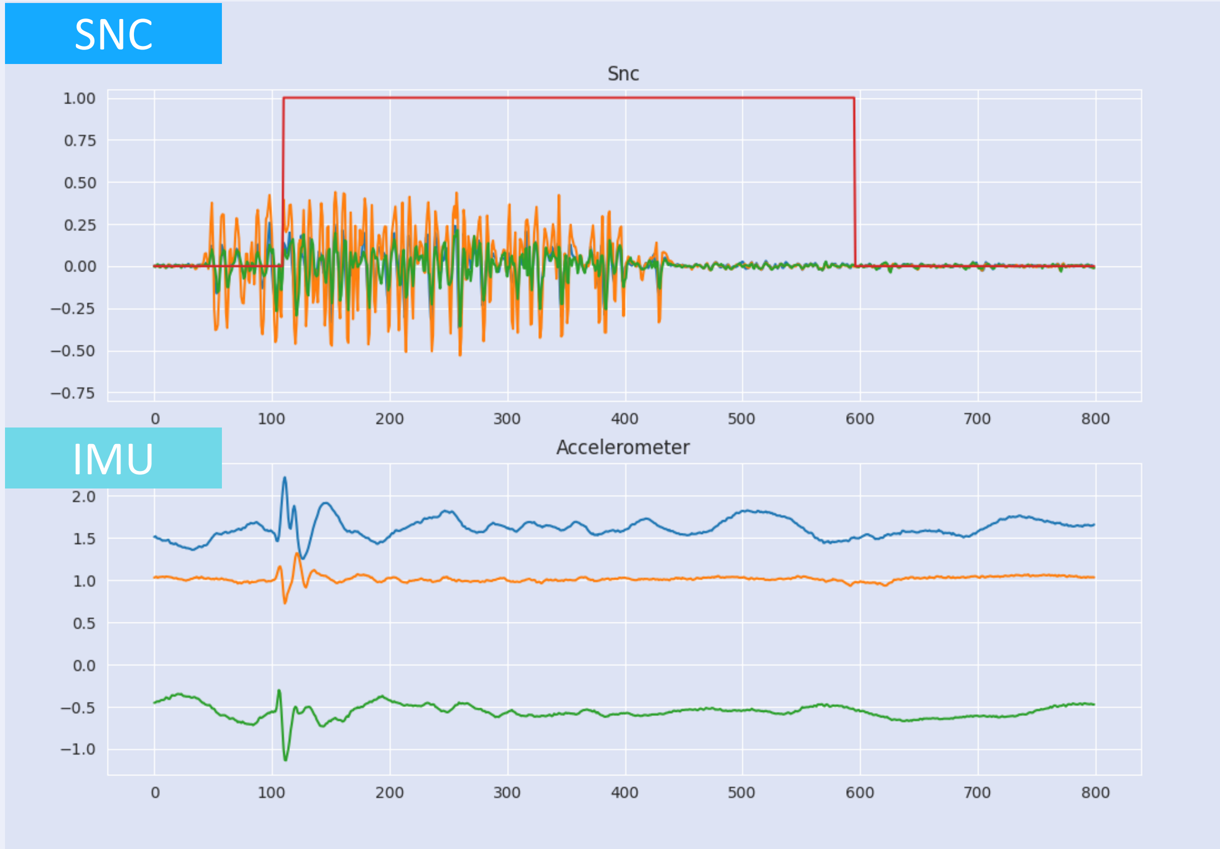


- **Technion IIT**
- Automated labeling with a conductive fabric based "button"

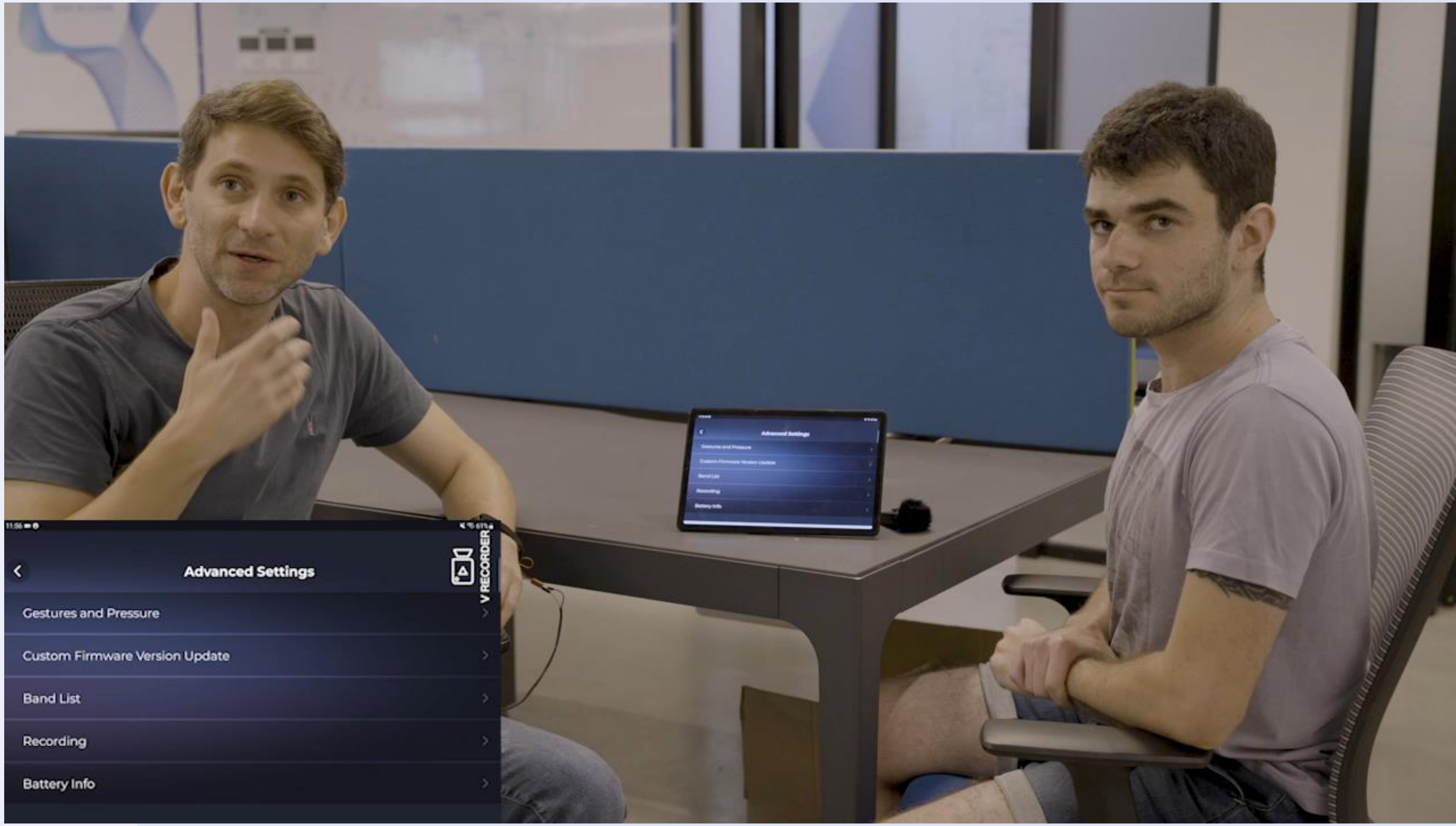


Examples: Tap



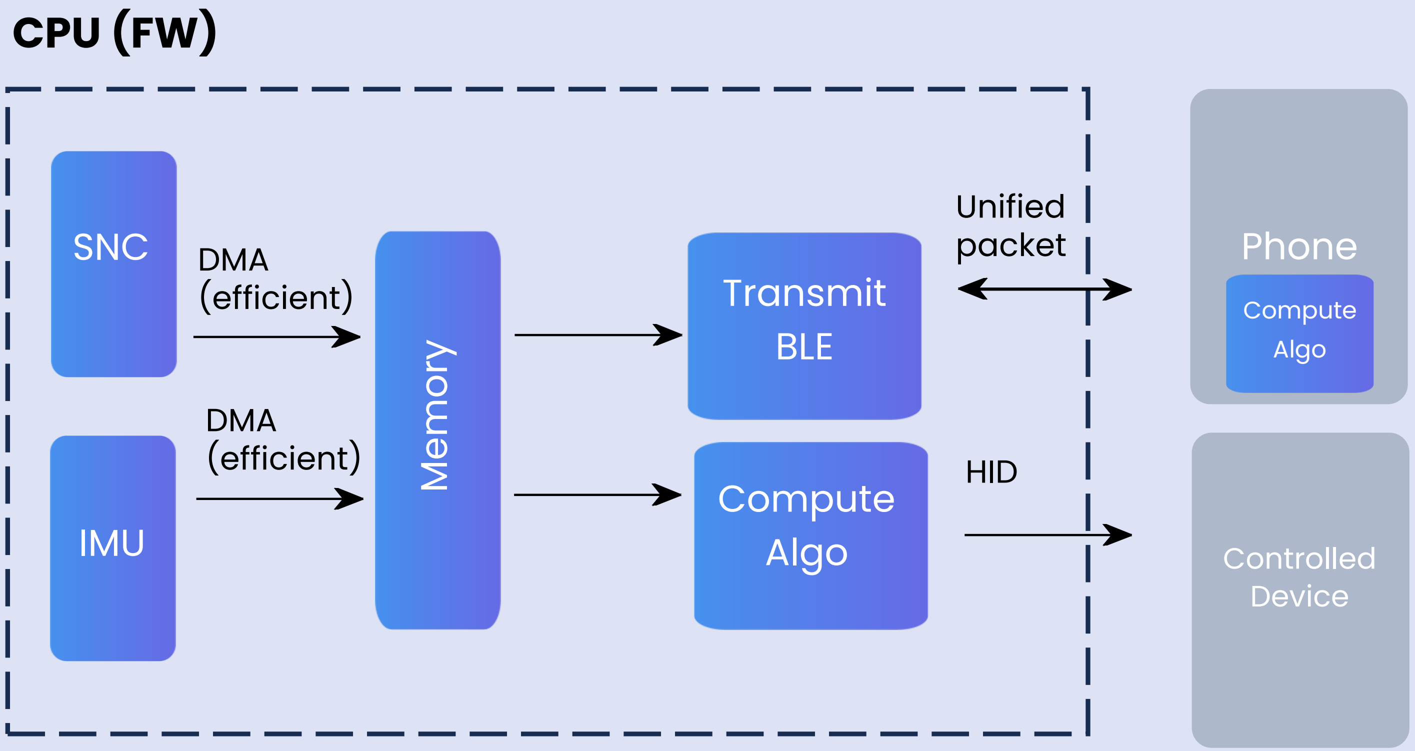


Data Acquisition Real-time



System Optimization

- Queuing mechanism with additional allocation to prevent data corruption.
- Decision tree to make dynamic prioritize, what to send.
- Adaptation of gap and gatts parameters : connection interval, event length , data length, MTU, etc.
- Reducing cpu usage.



Wearable Devices

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Biopotentials

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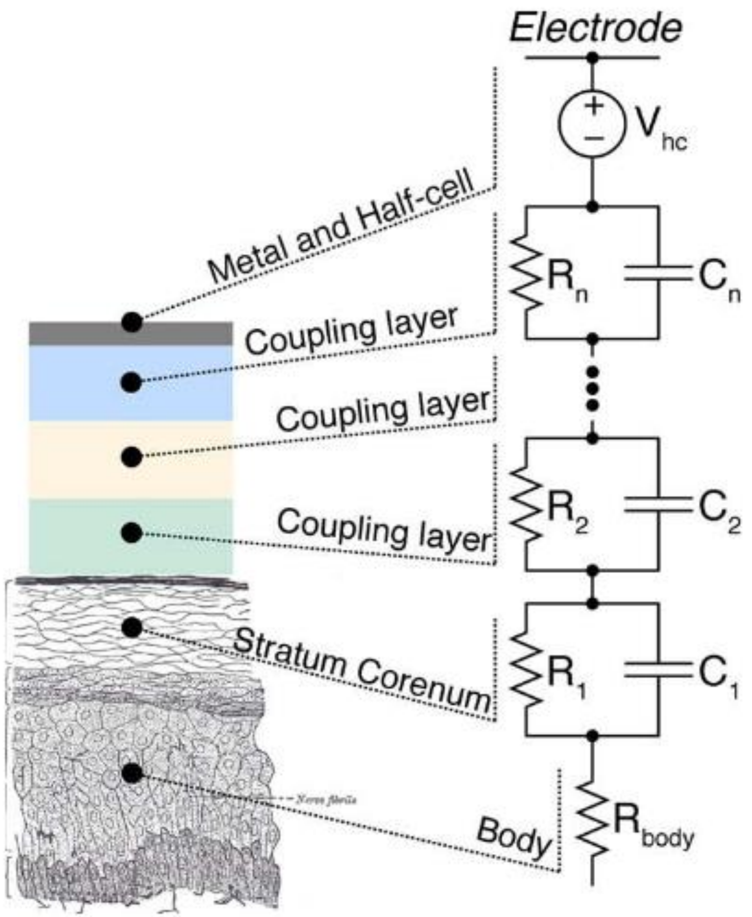

* *Anatomy and Physiology link*

Wearable Devices

Biopotentials

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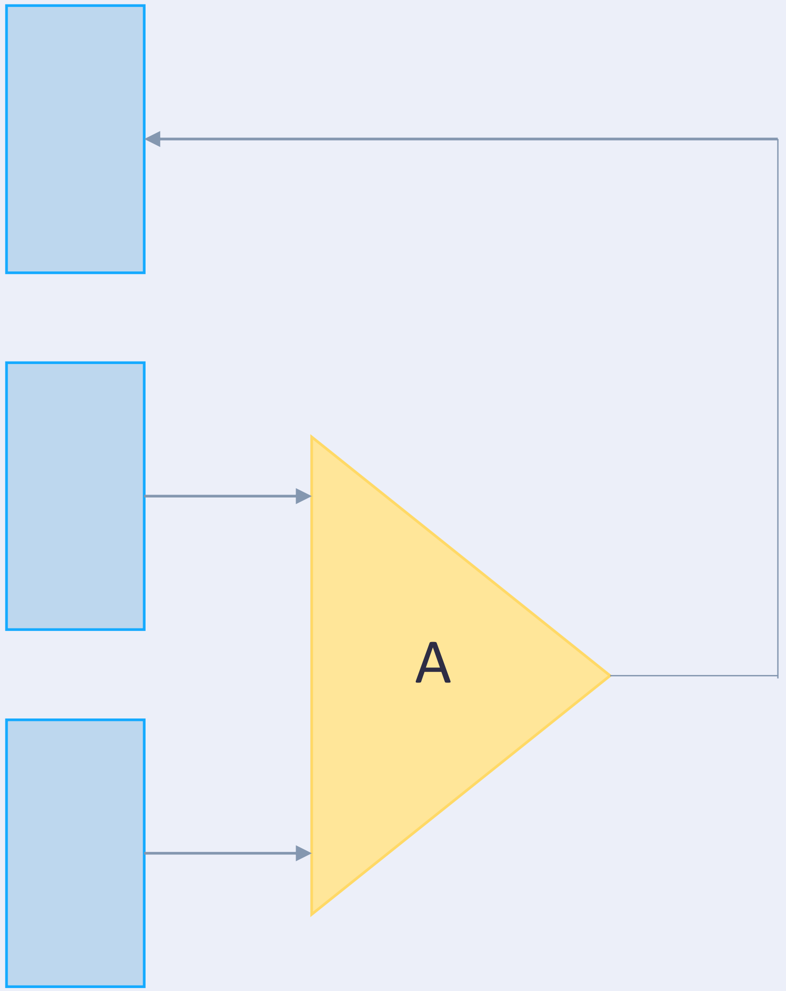

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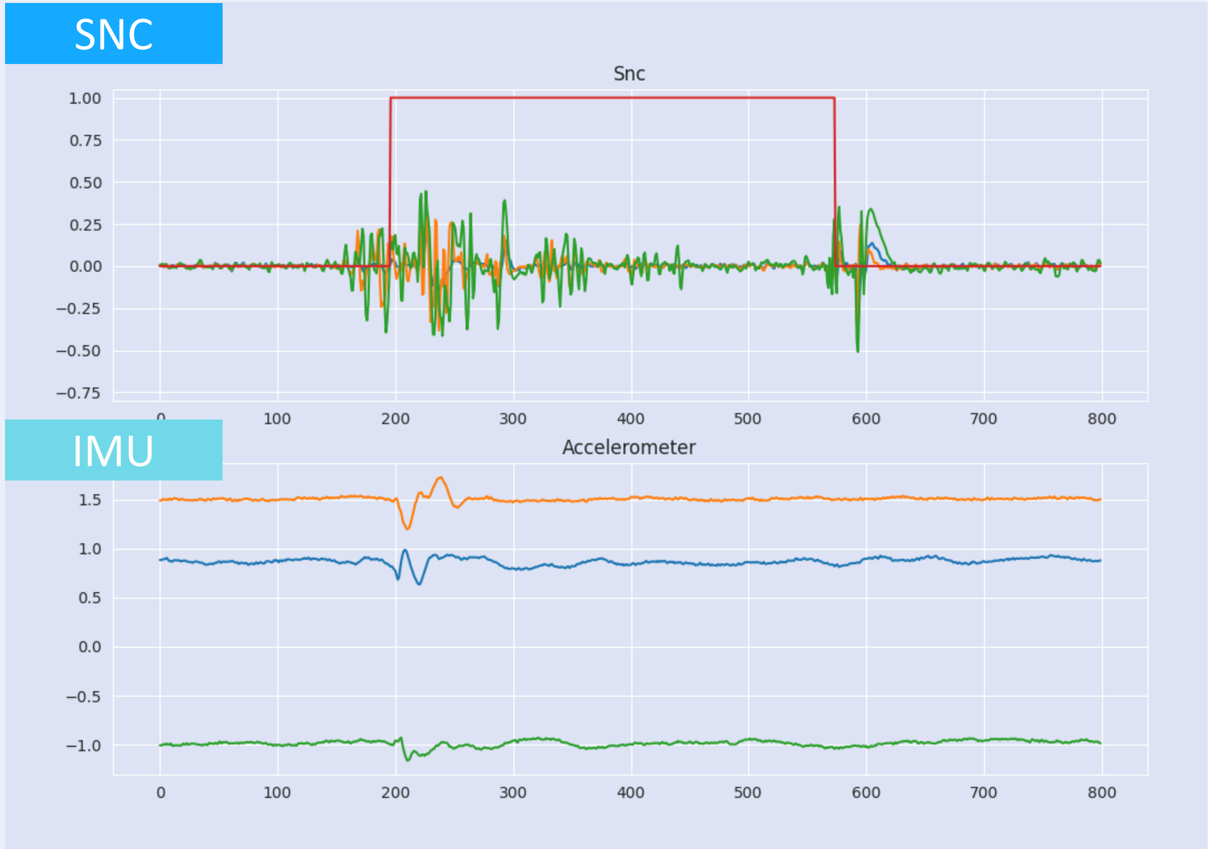
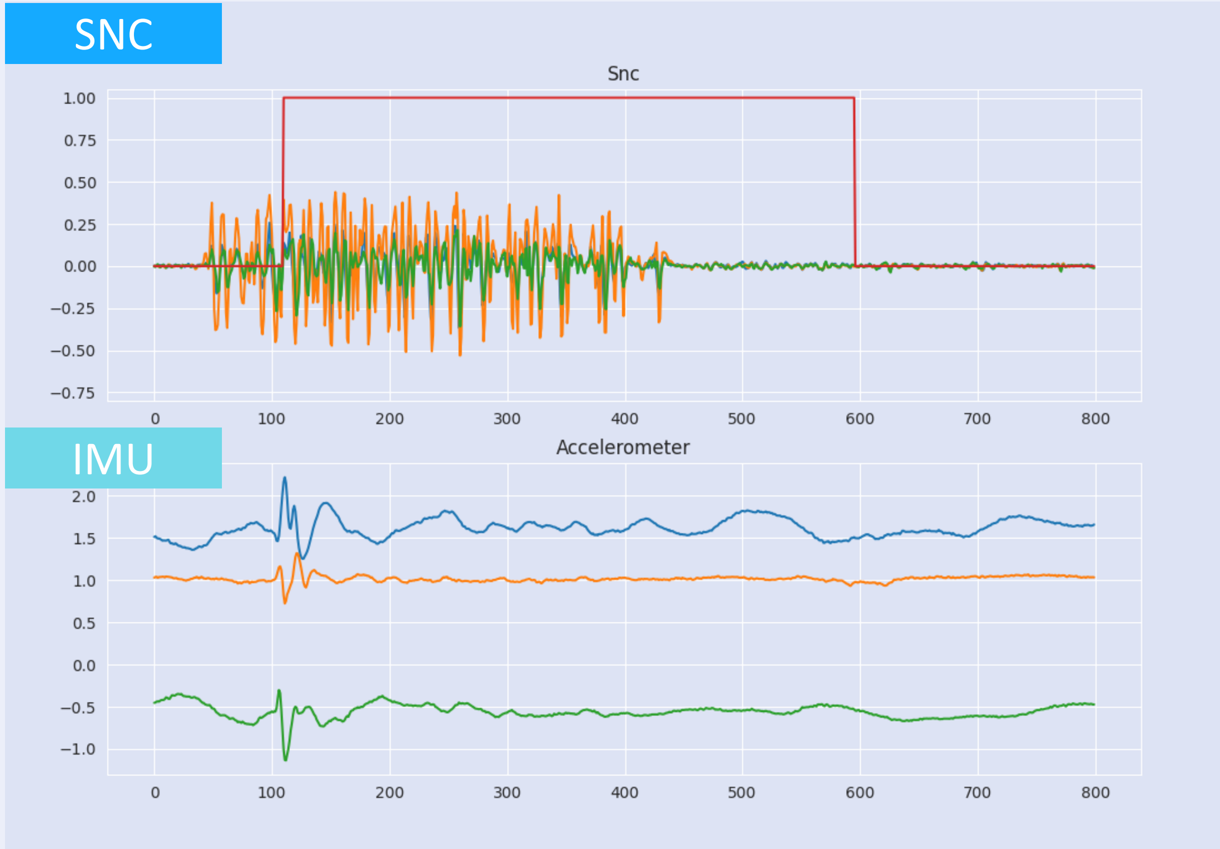
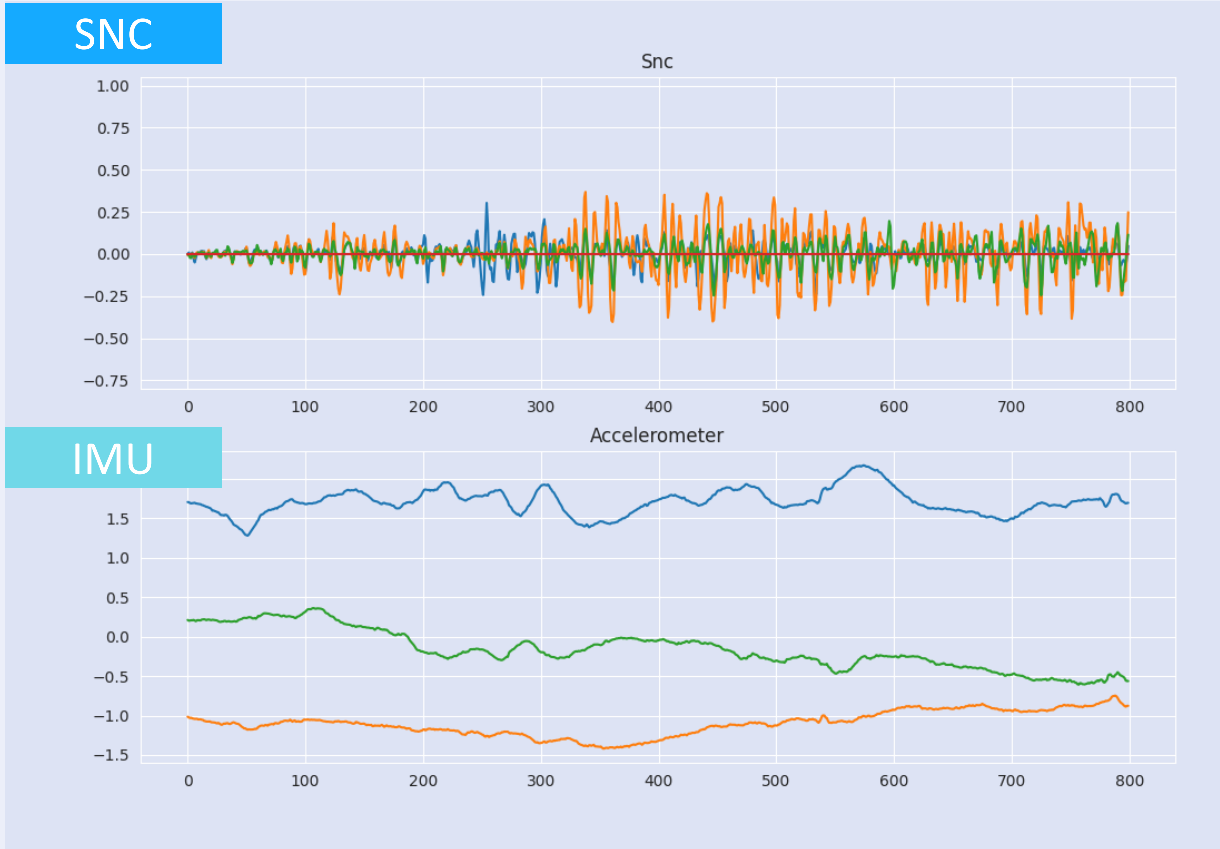
Examples: Tap





Wearable
Devices

Examples: Noise

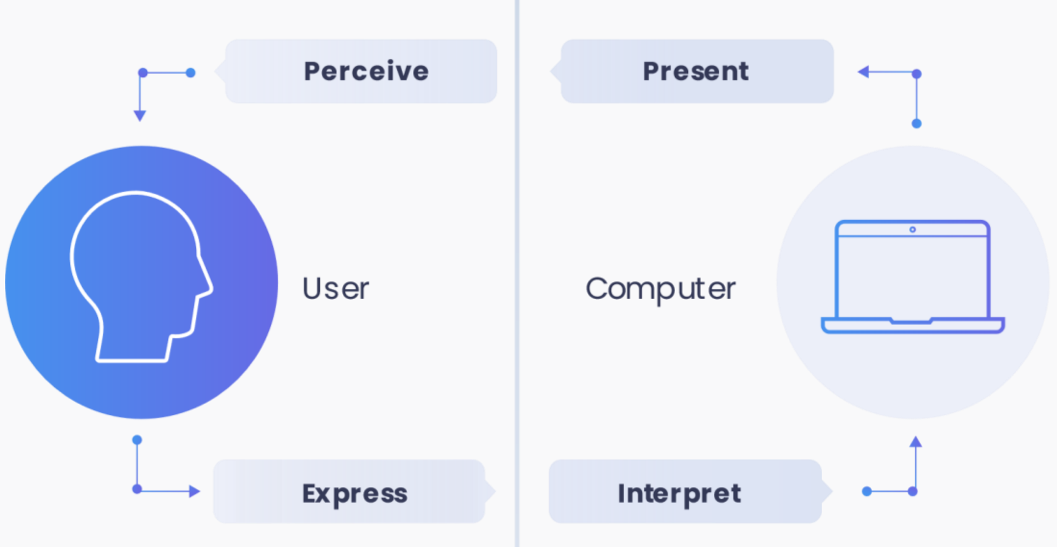


Biopotentials vs Motion Sensors

	IMU	SNC
Latency	X	✓
Power	X	✓
Fingertip-Vibration	✓	✓
Fingertip-Pressure	X	✓
Skin Contact	✓	X

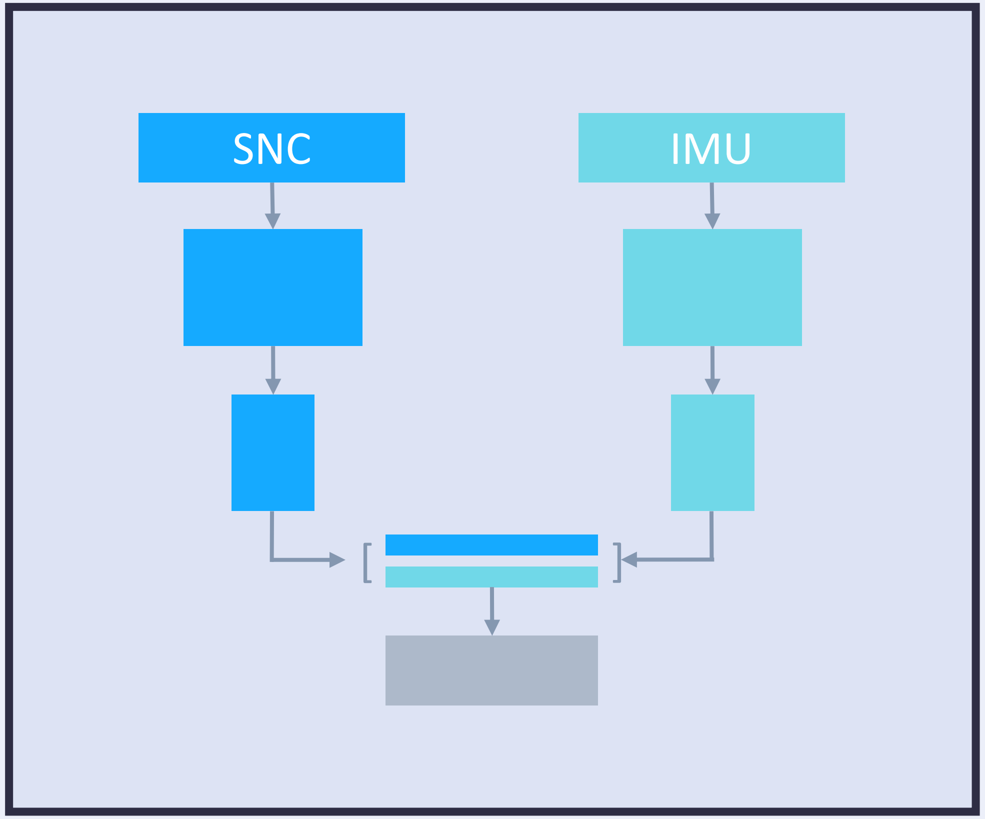
HCI – Keyboard Press Review

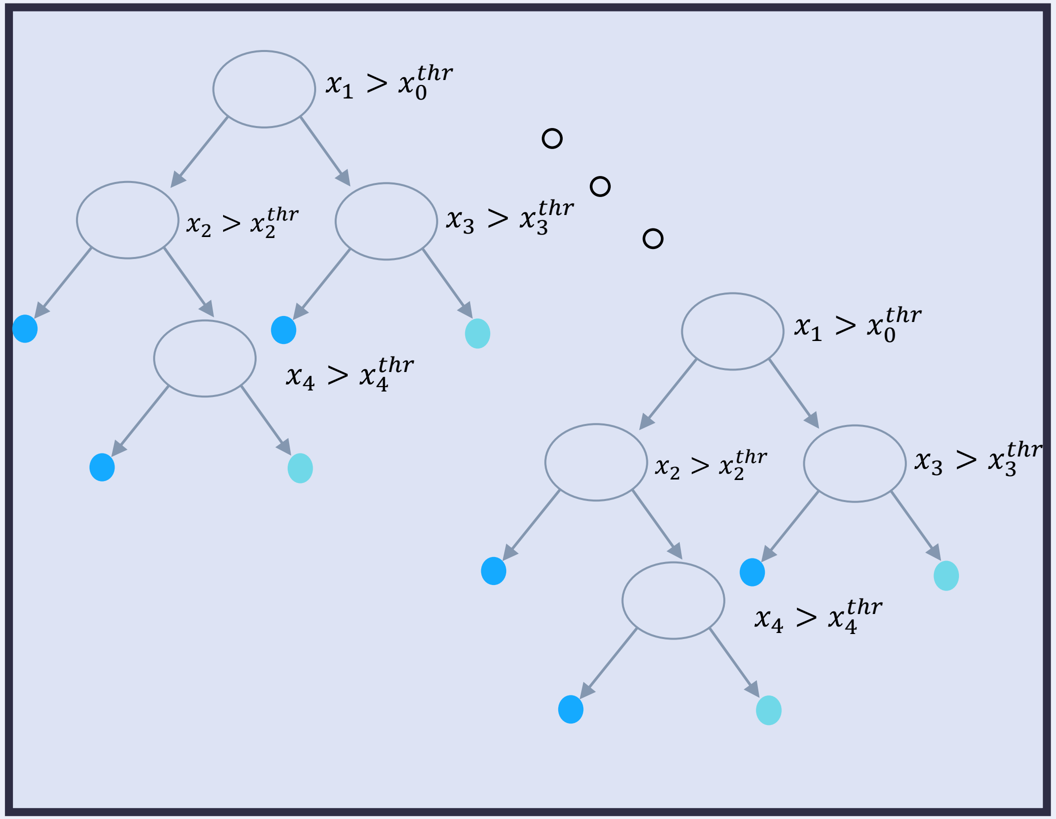
Biopotentials	Mental Intention	"I'd like to press a key"
IMU	Physical Action	Hand\finger movement
Mechanical Switch	Interaction	Button pressed! - closed circuit
	Feedback	Digital command registered, key shows up on screen



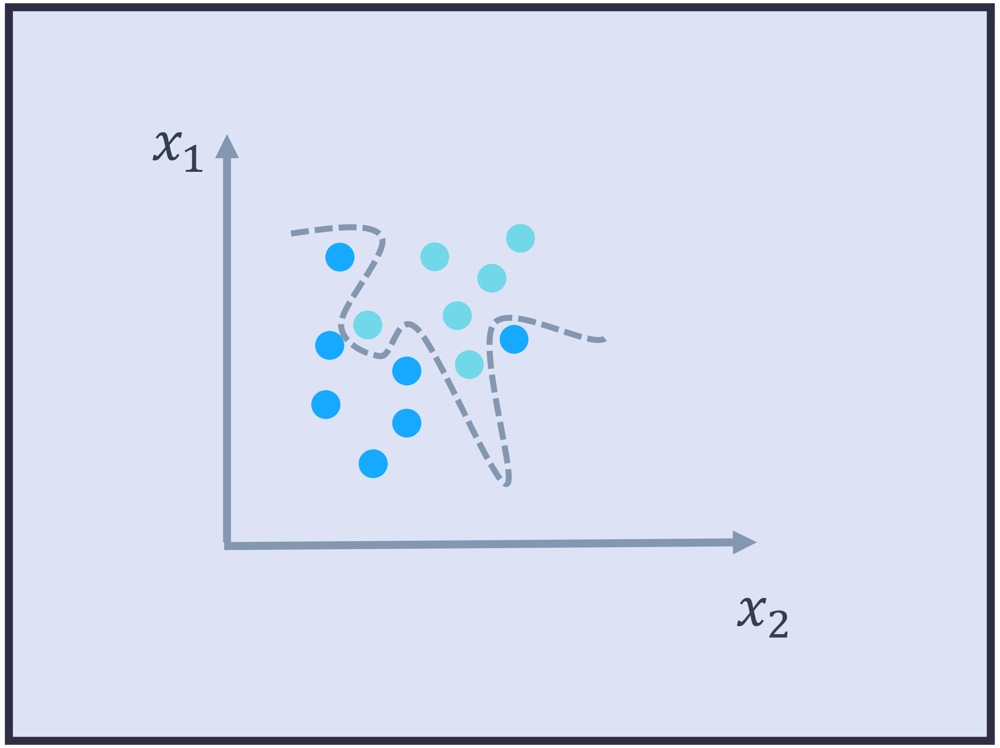
Wearable Devices

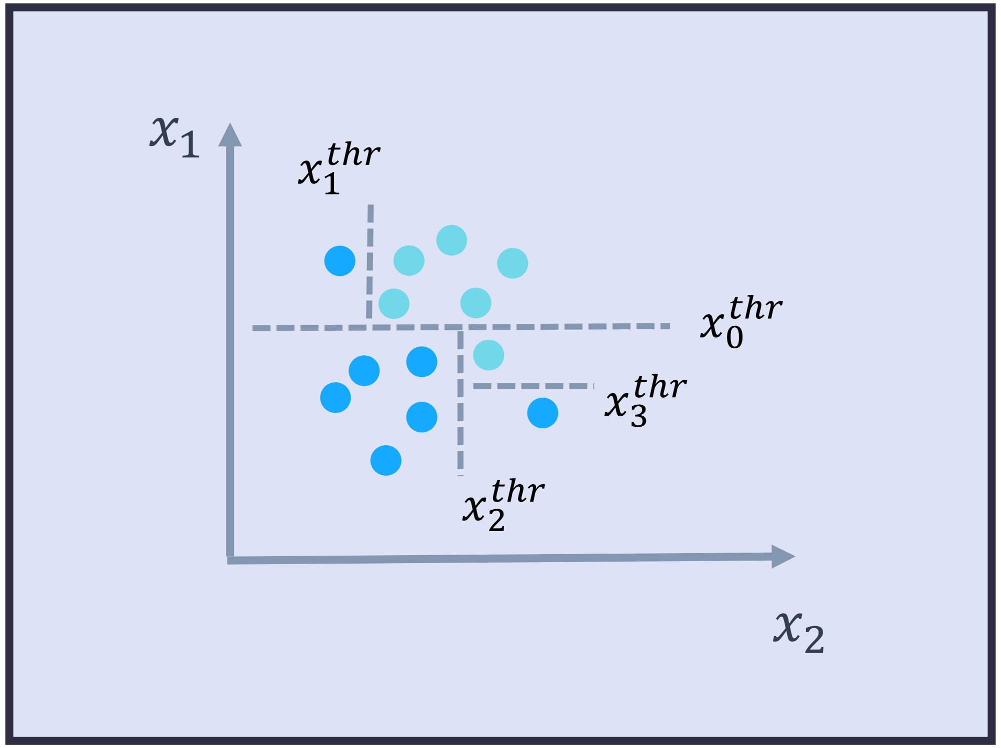
Sensor Fusion NN\RF





Sensor Fusion NN \ RF

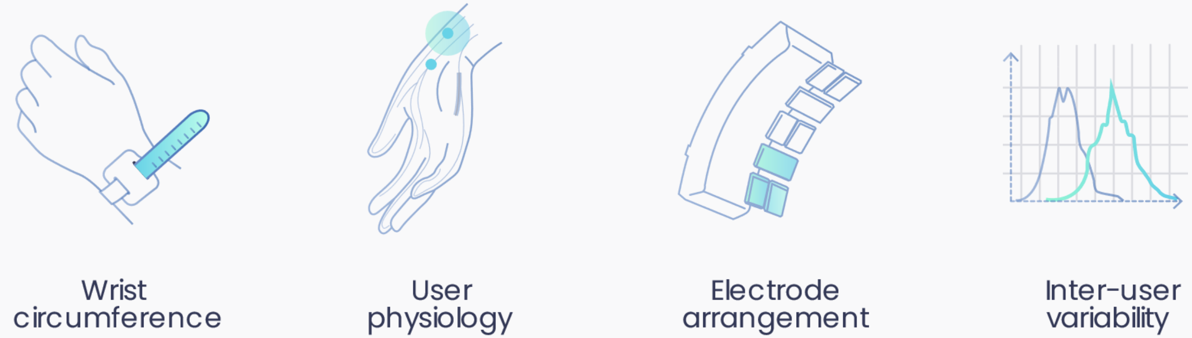




Gesture Recognition

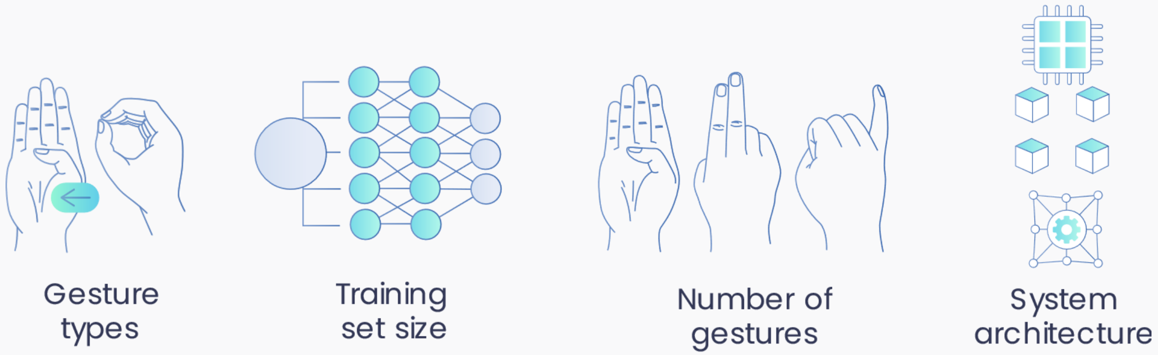
Variability between users:

- Usage characteristics
- Physiological characteristics
- Device characteristics



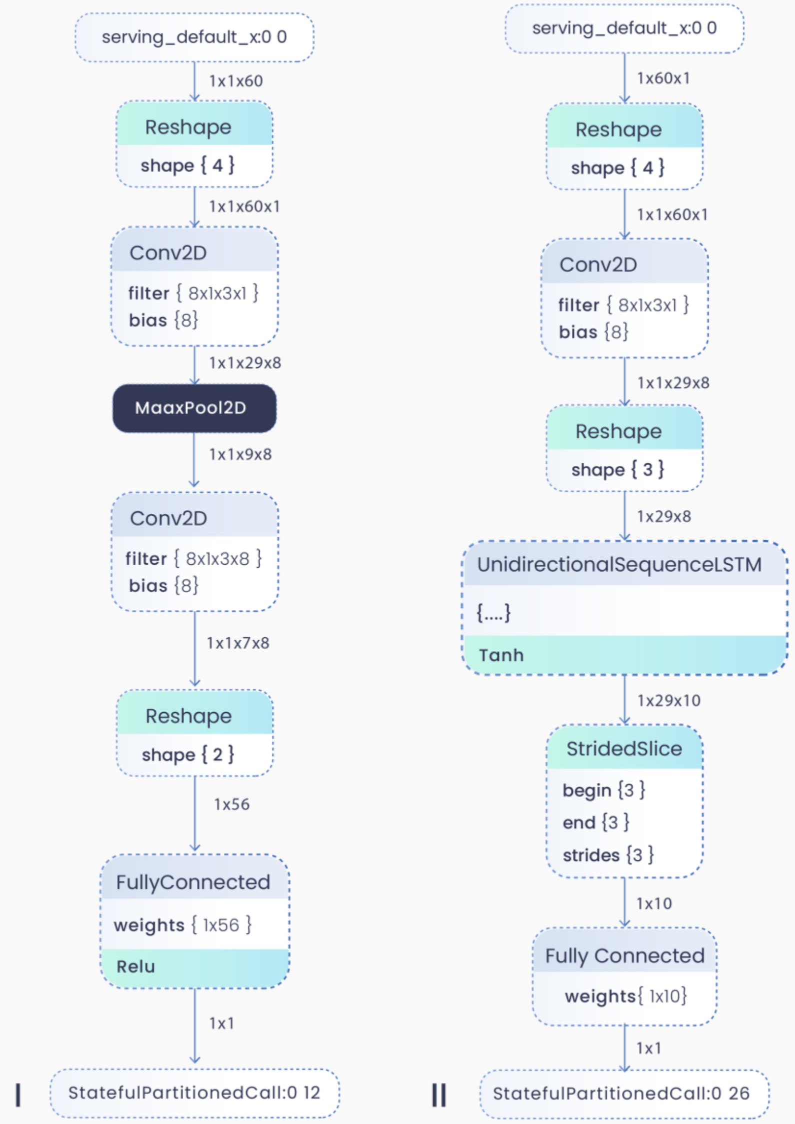
Variability between different gestures and noise:

- Unique noise sources
- No off-the-shelf data
- Computational constraints



Gesture Recognition
MobileNets vs tinyNN

Network	Top1	Params	MAdd	CPU
MobileNetV1	70.6	4.2M	575M	113ms
ShuffleNet (1.5)	71.5	**3.4M**	292M	
ShuffleNet (x2)	73.7	5.4M	524M	
NasNet-A	74.0	5.3M	564M	183ms
MobileNetV2	**72.0**	**3.4M**	**300M**	**75ms**
MobileNetV2 (1.4)	**74.7**	6.9M	585M	**143ms**



* *Implemented with [Tflite-micro]() + [Zephyr]()*

Wearable Devices

(x, y) cursor projection

- If user wear the band not like designed ?
- What happens when we tilt our hand?
- “In the wild” we can simply reorient:

$$x = \tan^{-1}\left(acc_y, \sqrt{acc_x^2 + acc_y^2}\right),$$

$$y = \tan^{-1}\left(-acc_x, \sqrt{acc_y^2 + acc_z^2}\right)$$

Discrete vs Continuous Movements

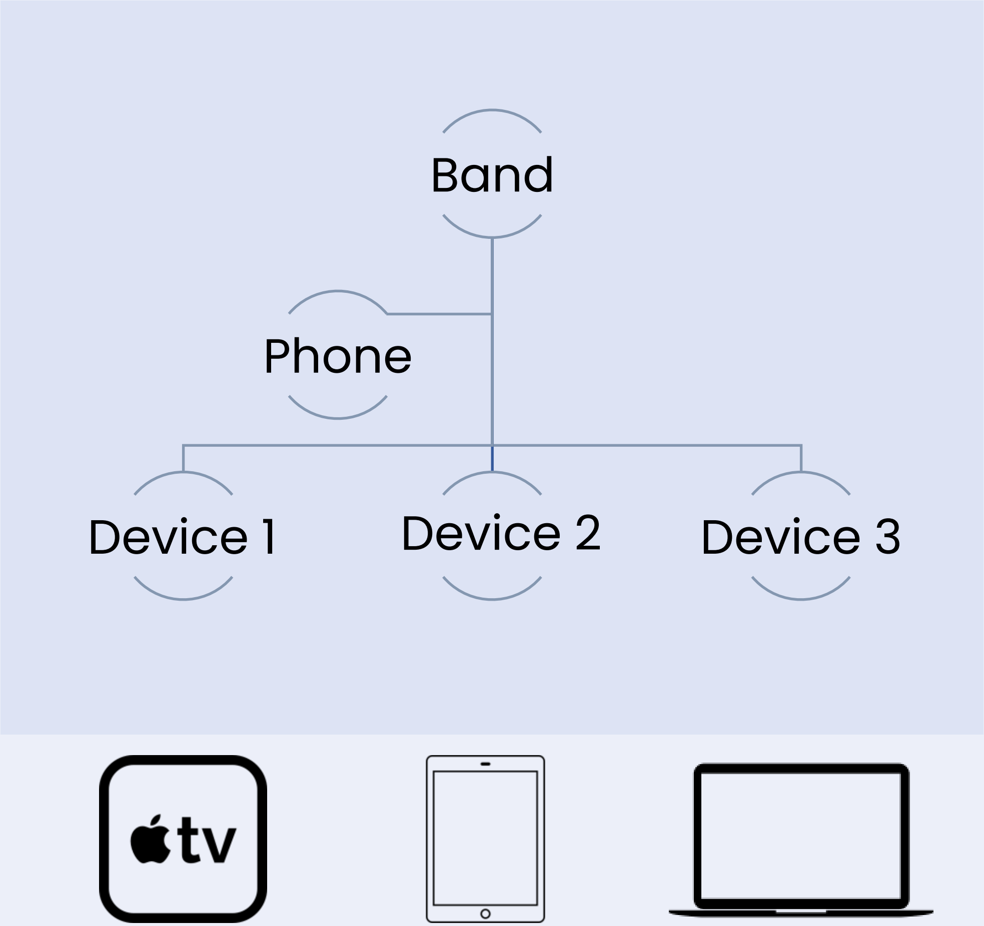
- Momentary tap vs drag and drop

Reactive vs Proactive

- Tap on interface – HID (custom\mouse\touchpad)
- Answer a call – ANCS AMS

2nd Device

Ble broadcast, to achieve all possible usage of gestures with all devices, without any additional software. System req direct adv, custom blacklist adv, pairing mechanism



HCI – Computer Vision vs SNC \ IMU

	Computer Vision	Wearable Devices
Sensor Power Consumption	±500mW	±10mW
Compute Power Consumption	±1000mW	±10mW
Training Complexity	√	√
HUD weight	X	√
Skin Contact	√	X

Wearable Devices

HCI – Computer Vision vs SNC \ IMU

Advantages :

- High accuracy
- Signal denoising not required
- Easy to train

Disadvantages :

- Pseudo real-time, on embedded low power device, no capability to work without latency
- Power consumption - Typically consumes around ±3000ma
- Amount of training data to operate is huge

Please send any questions to the following emails:

leeor.langer@wearabledevices.co.il
alex.p@wearabledevices.co.il

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for committing to take tinyML to the next Level, together

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