Human Haptic Robotic Interfaces

Week 1- Introduction and organization

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Mohamed Bouri [1,2]

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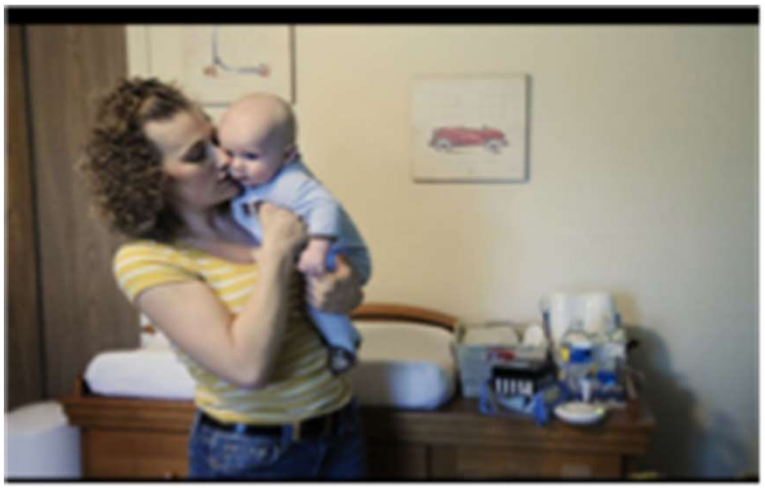
2) Rehabilitation and Assistive Robotics Group (REHAssist) Neuro-X, EPFL, Lausanne

"In the dark, most people can feel
where they’re going
or where they are"

"I can’t"

Julie Malloy

Julie Malloy “Out of touch”



“**Out of touch**: A rare disorder affects woman’s sense of touch and pain”. Daily Record/Sunday News

“York County Woman Raises money for Prosthetic Hands” Pennsylvania News

… « sense of touch » … HAPTICS

Wikipedia:

Haptics (1892) refers to the sense of touch
(Greek ἅπτω = I touch).

It is a form of non-verbal communication.

Every culture may have a different perception of touch to communicate

We also may list*:

Haptic technology, User interface technology through sense of touch

Haptic communication, the means by which people and other animals communicate via touching

Haptic perception, recognizing objects through touch

*[dictionary, Wikipedia]

Classical 5 senses (Aristoteles):

- vision
- audition
- taste
- olfactory (fragrance)
- touch (haptics)

Haptics includes

- force sensing
- texture sensing
- kinesthetic sense (proprioception)
- temperature
- balance (vestibular system)
- pain (nociception)

It is highly multimodal

- Combing several haptic feedback

Haptics from Robotic Telemanipulation to Neuroengineering:

A tale of two cities

Theory

Block 1
Robotic
telemanipulation

Block 2
Neuroengineering

Haptics from Robotic Telemanipulation to Neuroengineering:

A tale of two cities

Theory

Block 1
Robotic telemanipulation

Journal club

Journal club

Block 2
Neuroengineering

Haptics from Robotic Telemanipulation to Neuroengineering:

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Theory

Block 1
Robotic telemanipulation

Journal Club

Journal club

Block 2
Neuroengineering

Hands-on

Giulia Ramella

Xiangyu Xu
Aiden

Jonathan
Muheim

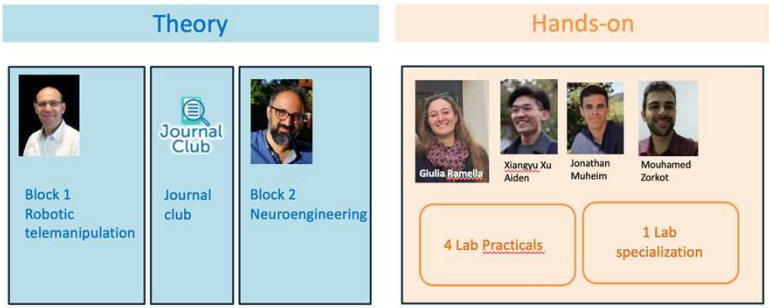
Mouhamed
Zorkot

4 Lab Practicals

1 Lab specialization

Organization of the course

- Seven **theoretical classes**
  - Block 1: 3 sessions
  - Block 2: 4 sessions
- Two **keynote lectures** by external experts in the field of Haptics
- One **journal club** (in groups of 4)
  - Two papers for each group of students
  - Oral presentation (Graded)
- 4 Lab Practical (in groups of 2)
  - One paddle for each group of students
  - Lab 0 – exercises (Hands-on on the hardware)
  - Lab 1 – Sensor calibration and filtering
  - Lab 2 – Simulation and PID tuning
  - Lab 3 – Impedance control (open loop with and without model compensation)
  - **Labs 2 and 3 will require a paper report** (Graded**)**
- **Lab specializations** (in groups of 2)
  - You will be given a choice between 5 different specialization labs
  - Requires a paper report (Graded) + questions during the oral exam



Organization of the course

Rules for labs

- ✓ Assistants will verify the goals' fulfillment at the end of the practical and check the work done by each student *in the class*
- ✓ All the reports **have to be uploaded to Moodle**. The deadline for submission is 23:59 pm one week (the day before the next session) after the last period dedicated to the lab (see course schedule chart)

Link to Moodle: https://moodle.epfl.ch/course/view.php?id=13939#section-1

Organization of the course - grades

Grades	
Lab 0	
Lab 1	
Lab 2	25%
Lab 3	
Journal club	10%
Lab specialization	25%
Exam	40%
	100%

Organization of the course - grades

Grades	
Lab 0	
Lab 1	
Lab 2	25%
Lab 3	
Journal club	10%
Lab specialization	25%
Exam	40%
	100%

Theory

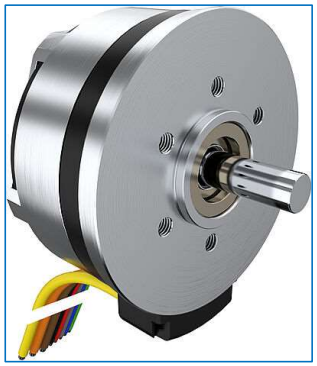
Hands-on

Organization of the course - Agenda

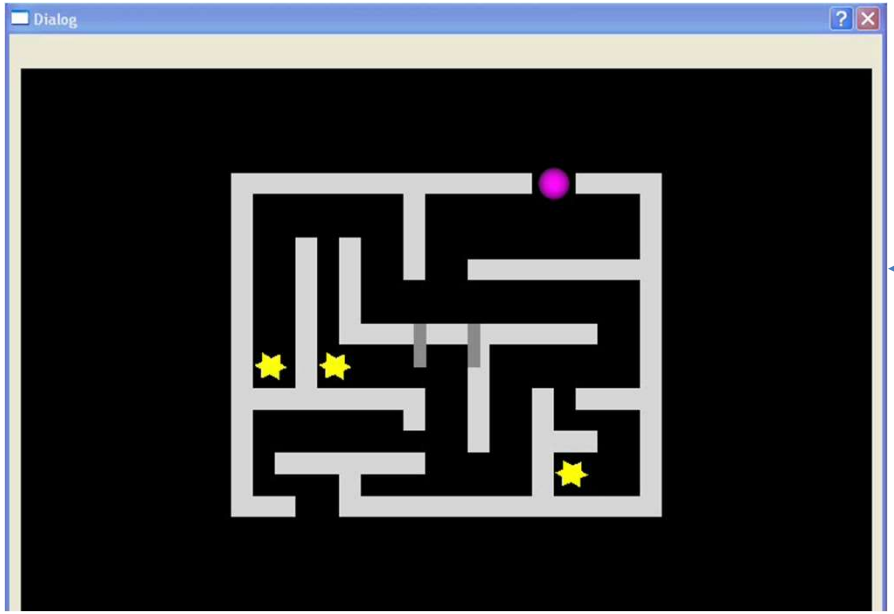
		Periods				
Session	Date	1	2	3	4	Reports
1	18/02/2025	Introduction - lecture organization - external lecturers - Exams....[Dr Mohamed Bouri / Dr Solaiman Shokur]	Haptic applications and technology [Dr Patrick Helmer, Force dimension]		Introduction and setting hardware Consolidate groups. Introduction to hardware & Software setup [Giulia]	
2	25/02/2025	Lab 0			Lab 1- data acquisition and filtering	
3	04/03/2025	Interaction / haptics and friction Modeling [Bouri]		Lab 1 - data acquisition and filtering		
4	11/03/2025	Advanced Modeling and Control [Bouri]		Lab 1 - data acquisition and filtering		
5	18/03/2025	Performance metrics, Step Response, BandWidh, Z-Width, Friction Saturation, Transparency, Acceleration, Velocity, User Evaluation [M. Bouri]		Lab 2 - Simulation and position control		
6	25/03/2025	Lab 2- Simulation and position control				
7	01/04/2025	Romain Baud (Simulation of visco elastic effects)		Lab 3 - impedance control and Z - width		Lab 2 report
8	08/04/2025	How we perceive the world [Shokur]		LabS- distribution of projects + distribution of literature review papers	Lab 3 - impedance control and Z - width	
9	15/04/2025	Lab 3 - Impedance control				
10	22/04/2025	Holiday				
11	29/04/2025	Haptic devices [Shokur]		Lab Specialization		Lab 3 report
12	06/05/2025	Lab specialization				
13	13/05/2025	Sensory motor restoration via PNS [Shokur]		Lab- Specialization	Class Evaluation	
14	20/05/2025	Journal club presentation	Journal club presentation	Journal club presentation		
15	27/05/2025	Sensory motor restoration via CNS [Shokur]		Lab- Specialization		
16	No more class					Lab Specialization Report
17						

Bouri
Shokur
Practicals
Guest
Lab specialization

Block 1:
Haptics for robotic telemanipulation

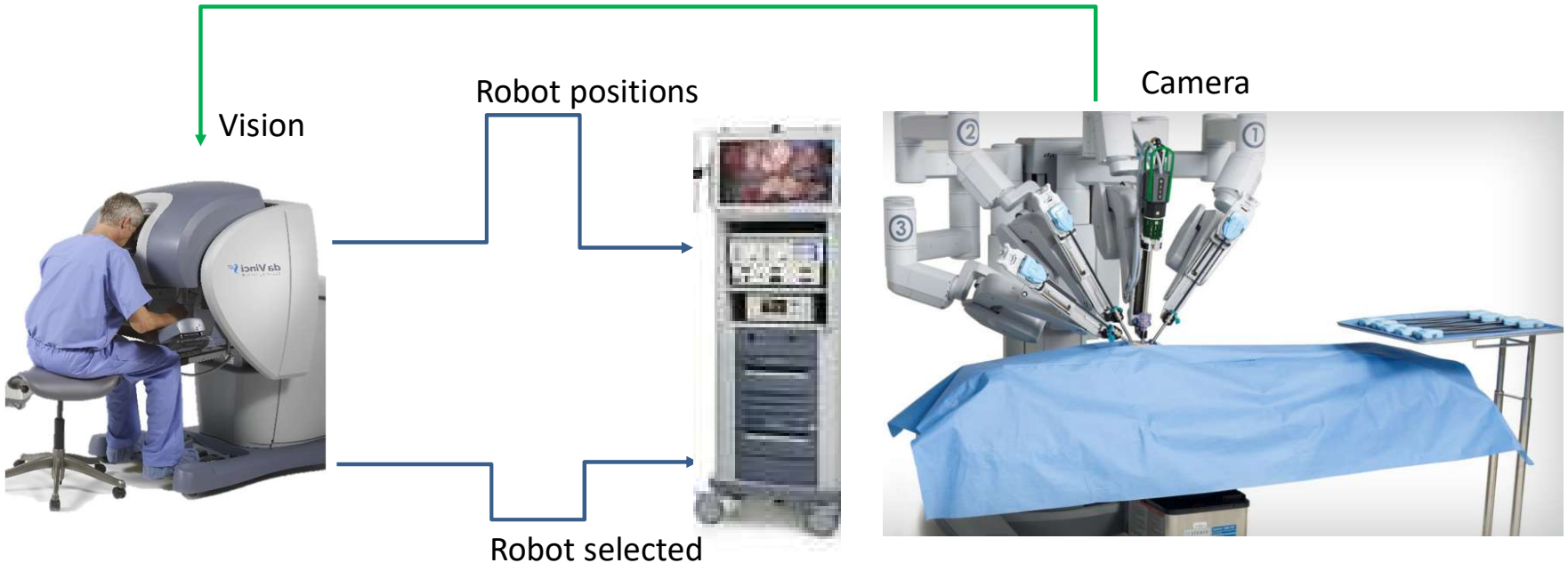


Control interfaces

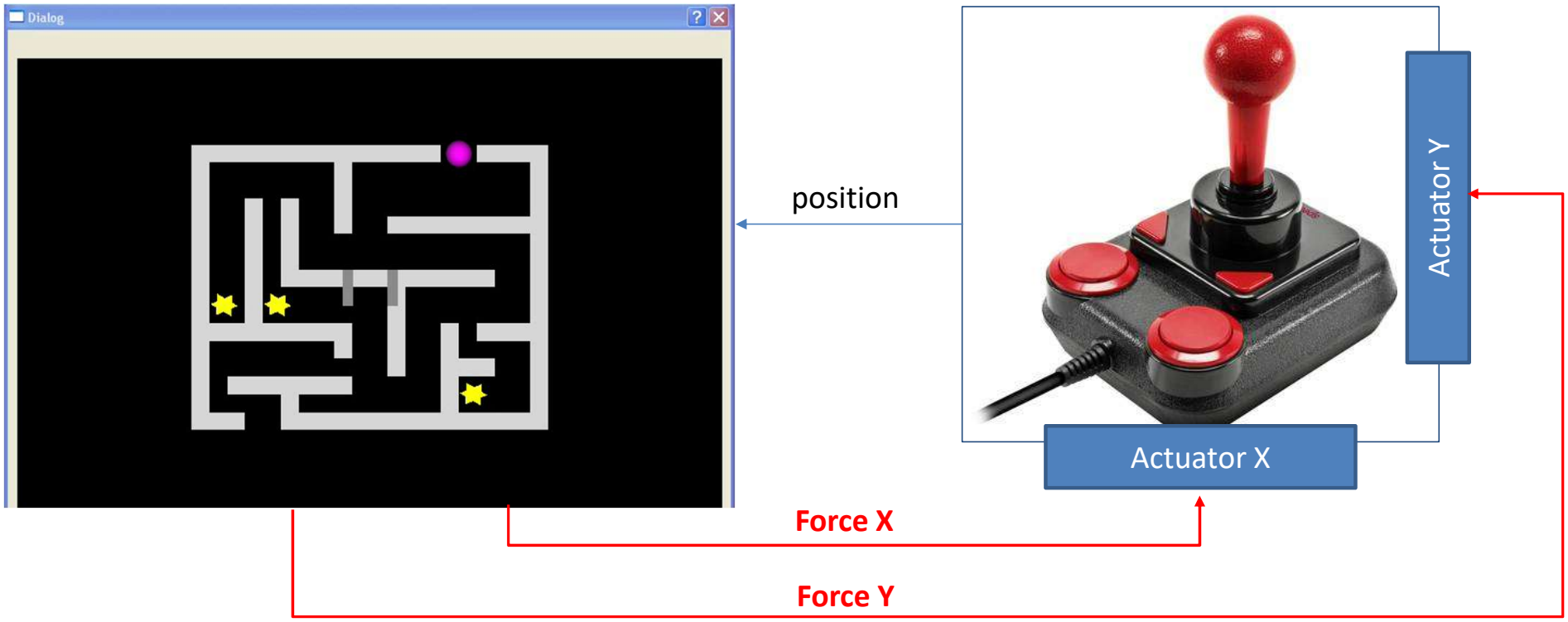


position

Control interfaces



Haptic interfaces



Haptic interfaces

Rehabilitation

Credit REHAssist, EPFL

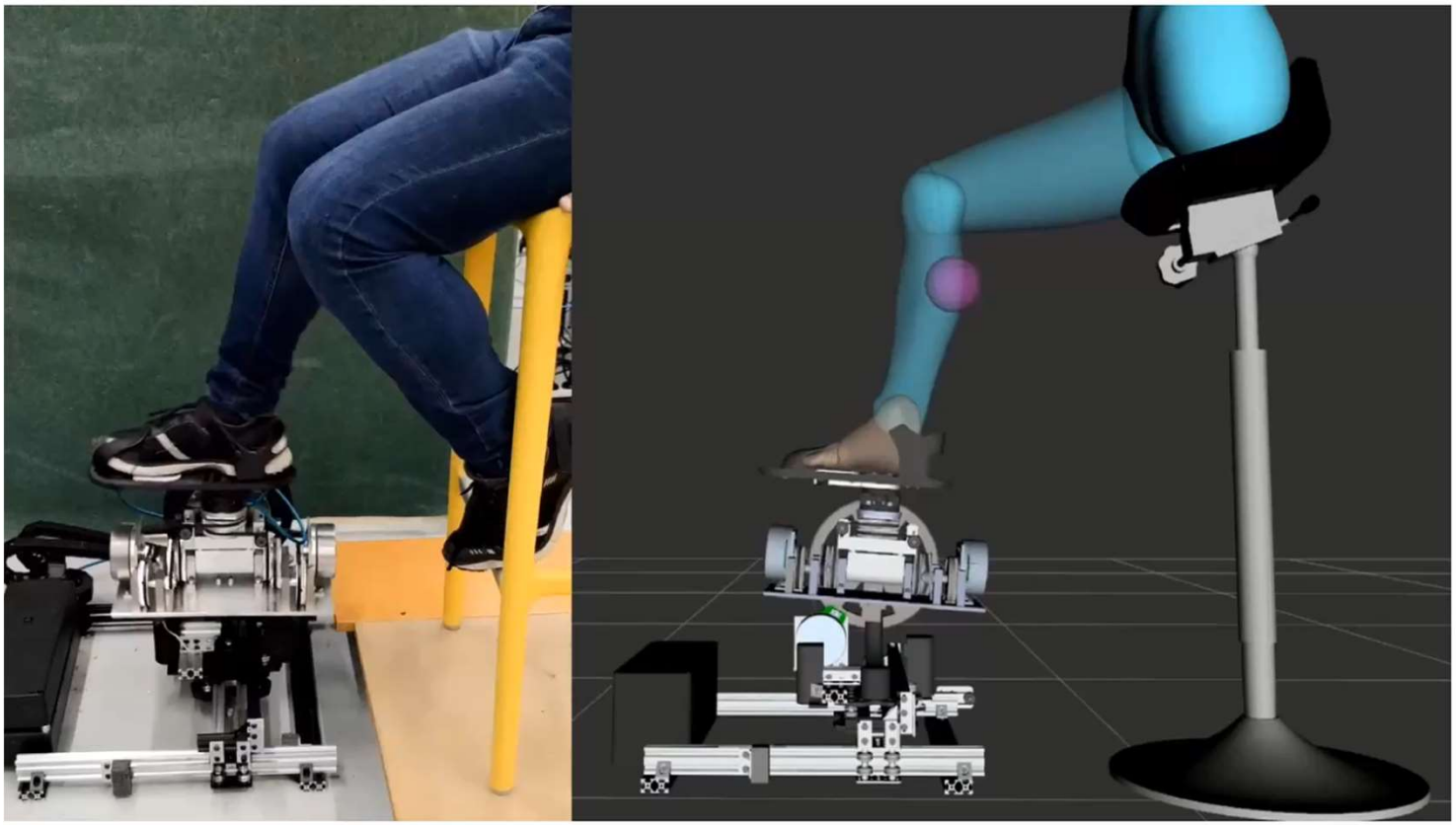
Training and/or assembly

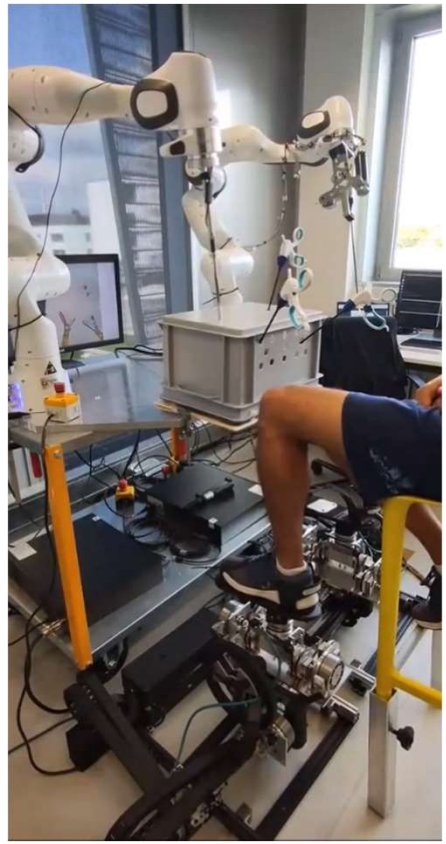
Credit HAPtion

Surgery

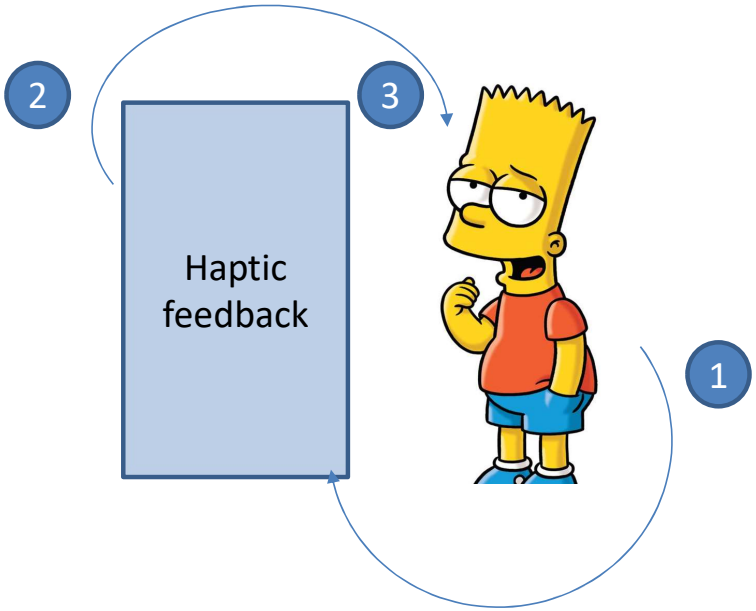
Credit Force Dimension and DLR (Ge)
The surgical robot is Mirosurge

A haptic pedal interface assists the operator by compensating for the gravity of the leg and by reflecting the forces applied





Haptic interfaces and Haptic feedback



Ultimately “Interaction”

….. From action **to** device feeding **to** sensing **to** action

1 2 3

We are concerned with haptics as long as we are concerned with mechanical interaction.

Goal of Block1 of the course

Haptics:"the sense of touch"
- How do we perceive it ?
- How do we feed it ?

In order **to improve the manipulation and telemanipulation of objects.**

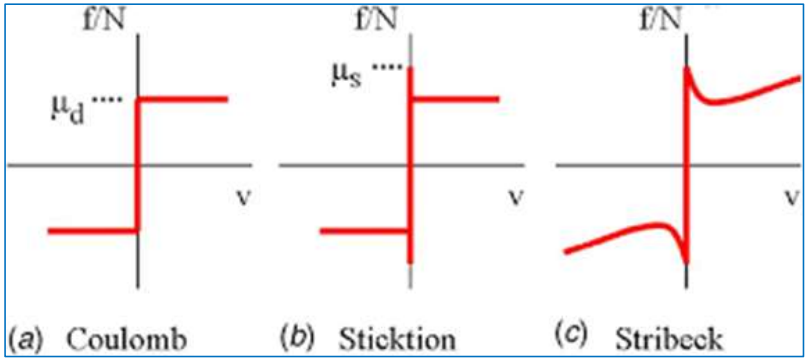
The sense of touch may be :
- Tactile
- Vibro-tactile
- Thermale
- …..

This course introduces the Understanding – Qualification – Development of Haptic interfaces and applications

Block 1.1:

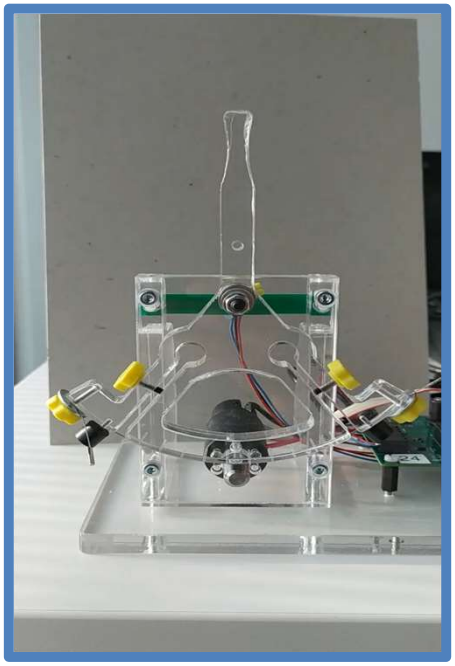
Master friction to improve the tactile perception

- Fundamentals of interaction,
- Devices and applications
- Importance of friction models,
- Friction models (Lugre)
  - Coulomb,
  - Stiction
  - Stribeck
- Identification and friction compensation approaches

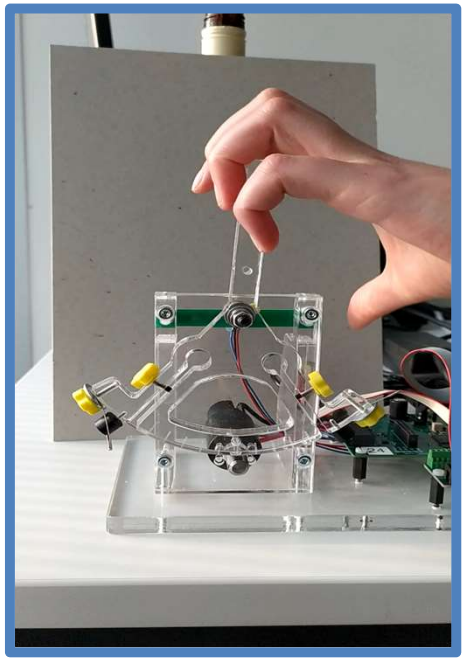


Block 1.2:

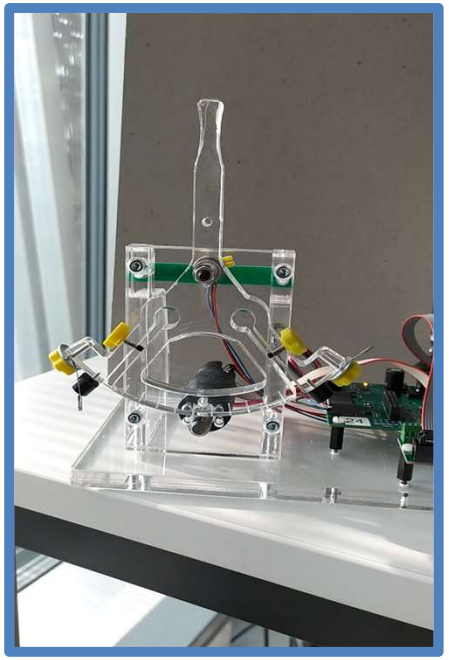
Control interaction by controlling the mechanical impedance



Stiff



compliant

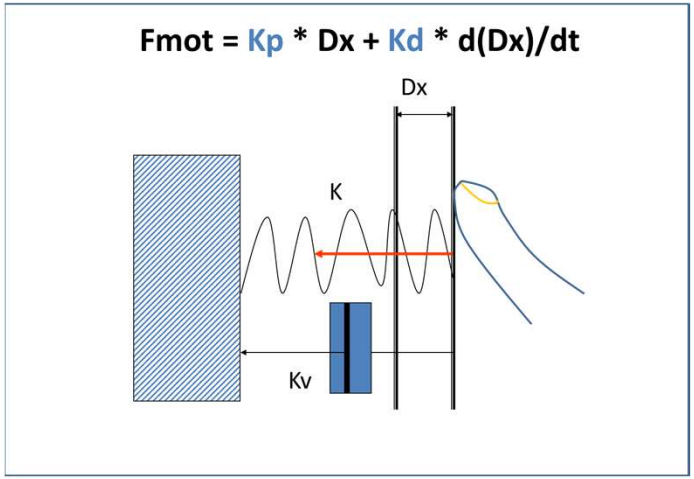


damped

Block 1.2:

Haptic interfaces render impedance perception

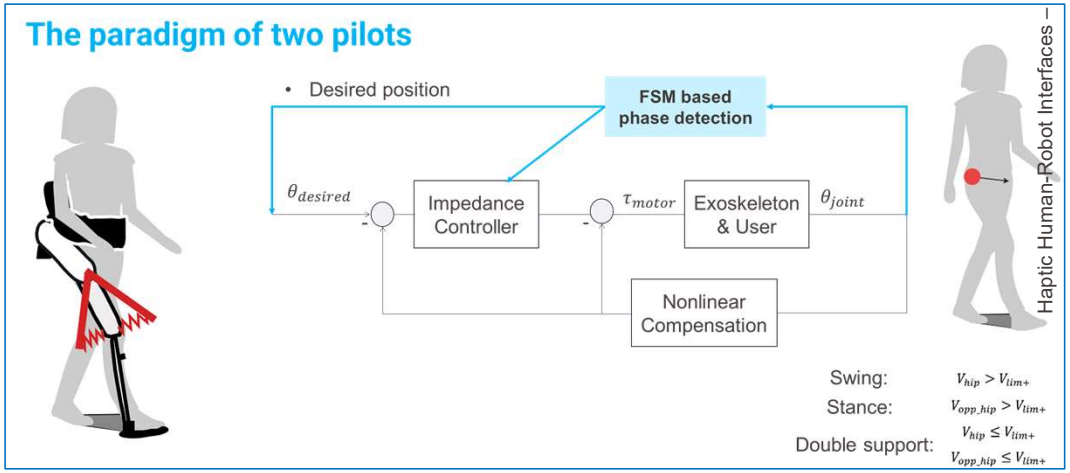
- Challenges to designing “effective” Haptic interfaces
- Mechanical Impedance to quantify the interaction
- Analogy with electrical impedance
- Control modalities and telemanipulation
- Impedance control approaches
  - Open loop
  - Open loop + Model compensation
  - Closed loop with force feedback
- Impedance rendering and Z-width metrics



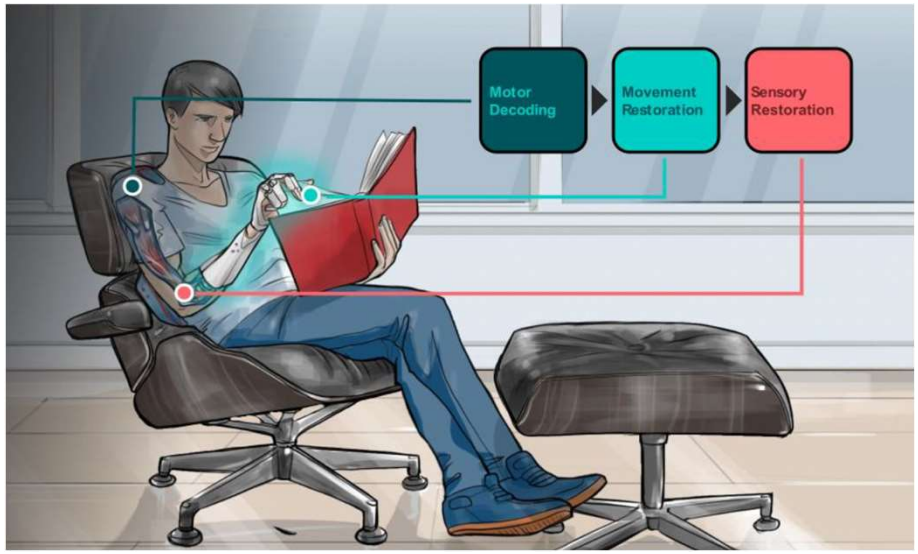
Block 1.3:

Haptic interfaces render impedance perception

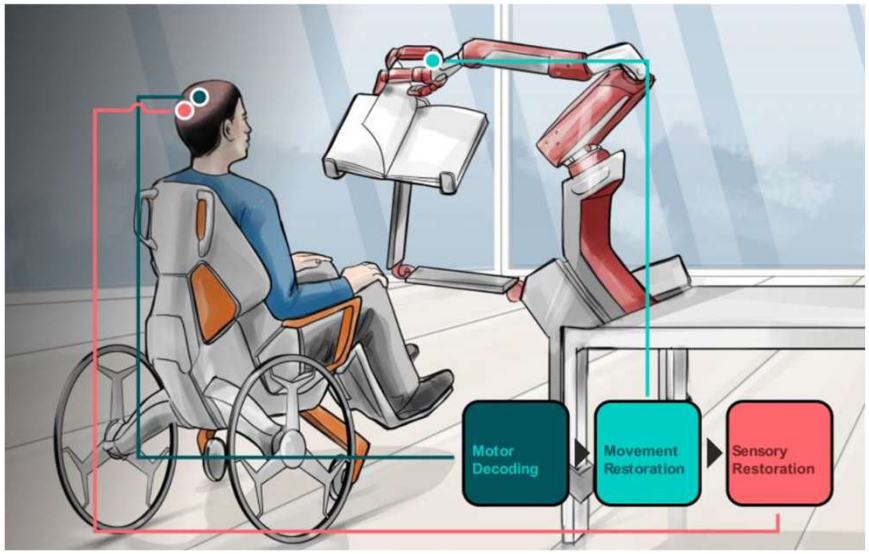
- Applications of impedance control in rehabilitation and assistive technologies
- Admittance control
  - Concept
  - control strategies
  - Application



Block 2:
Haptics for neuroengineering



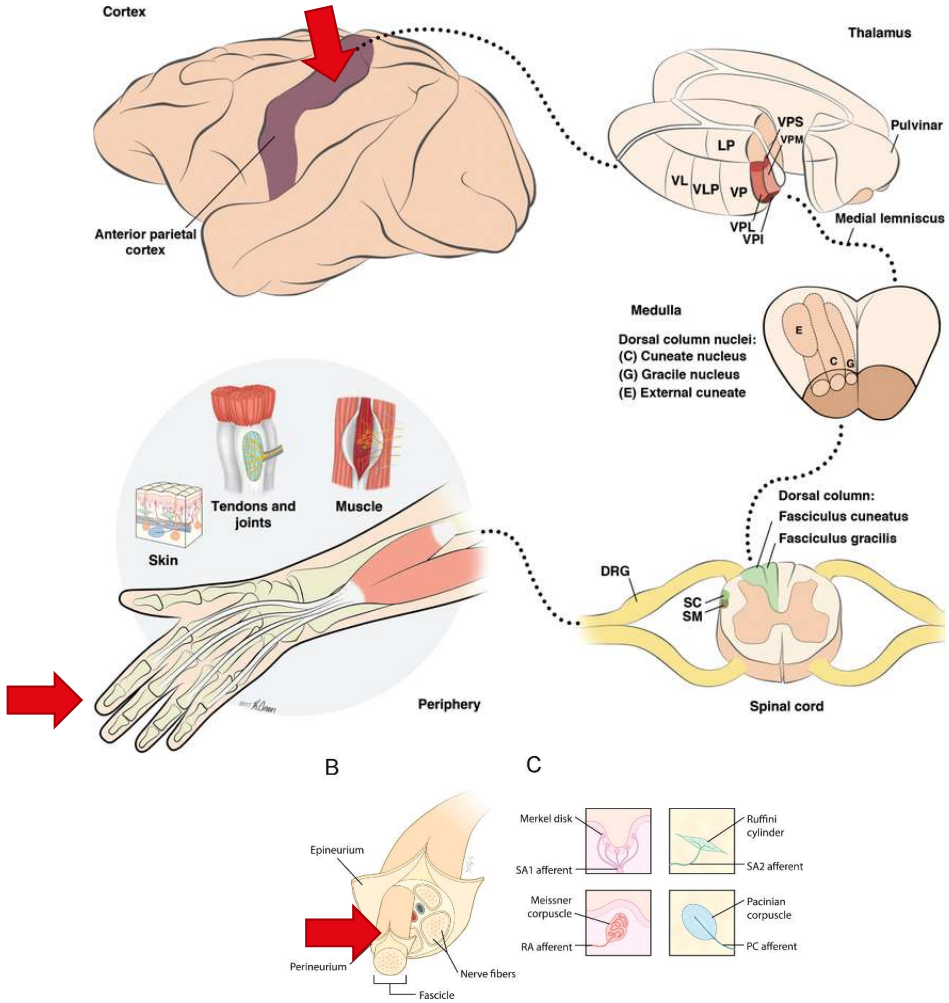
Bionic hands



Brain-machine interfaces

Shokur, S., Mazzoni, A., Schiavone, G., Weber, D. J., & Micera, S. (2021). A modular strategy for next-generation upper-limb sensory-motor neuroprostheses. Med, 2(8), 912-937.

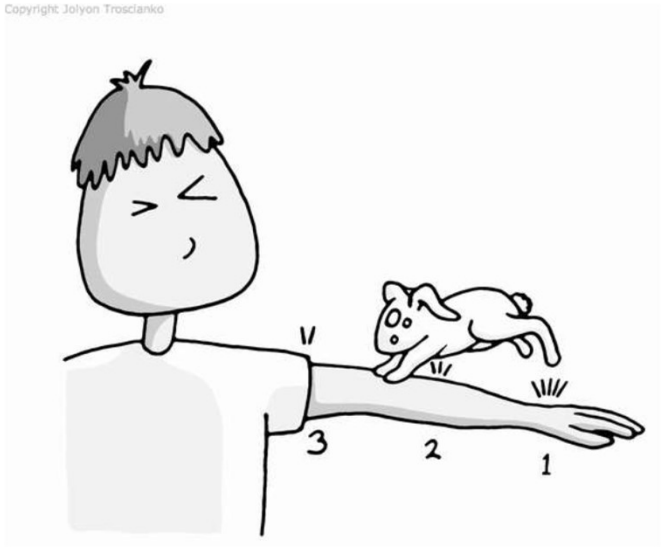
Understanding the sensory neural pathway

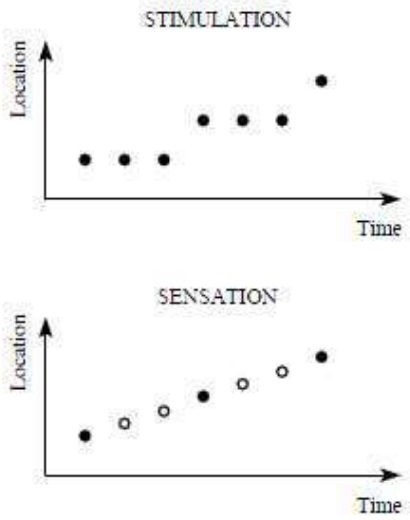


Goals

1) Understand the pathway from the mechanoreceptors in the skin to the nerves, and the central nervous system
2) Learn how to 'hack' it to provide haptic feedback via
    1) Skin
    2) Peripheral nervous system
    3) Central nervous system

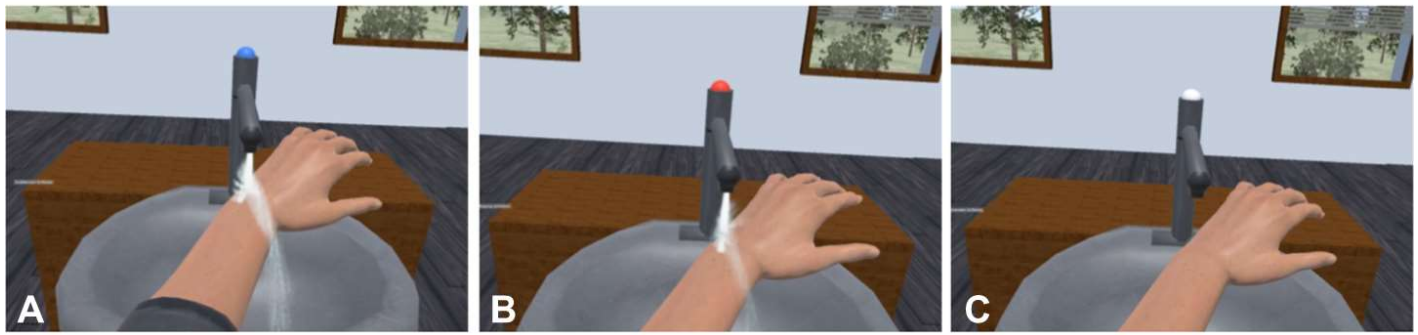
Examples at the skin level: haptic illusions



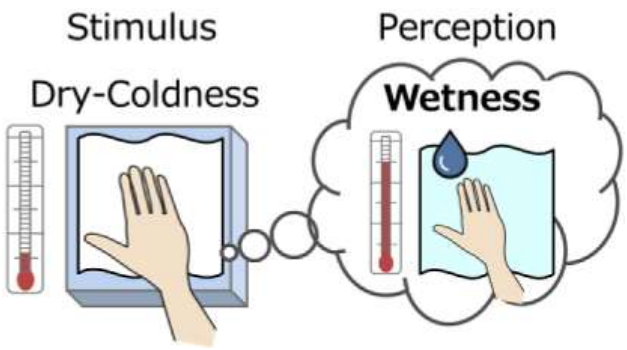


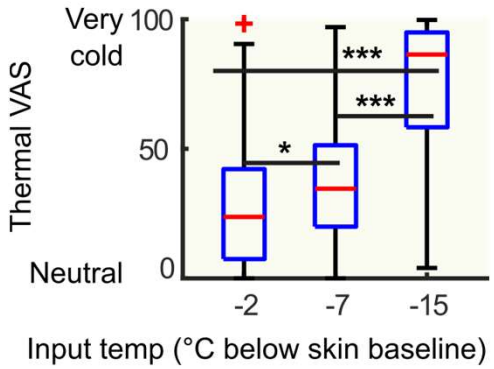
Geldard, F. A., & Sherrick, C. E. (1972). The cutaneous" rabbit": a perceptual illusion. *Science*, *178*(4057), 178-179.

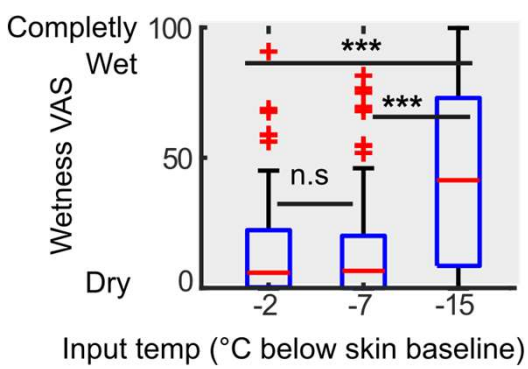
Examples at the skin level: wetness sensation



Examples at the skin level: wetness sensation

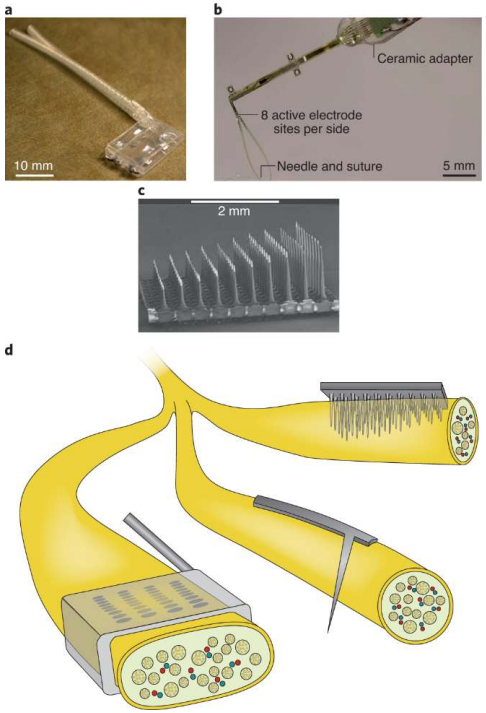


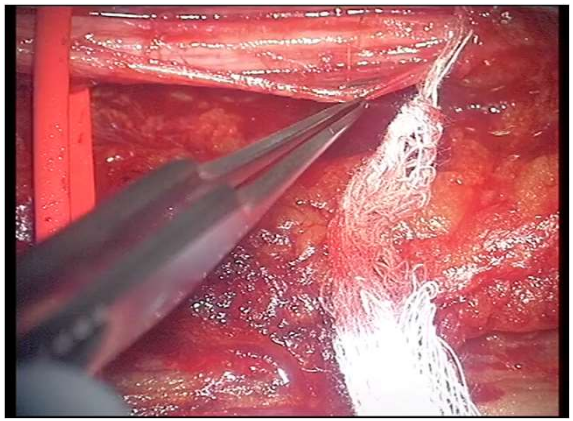


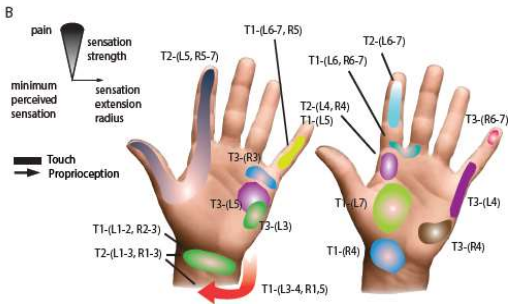


Filingeri, D., Fournet, D., Hodder, S., & Havenith, G. (2014). Why wet feels wet? A neurophysiological model of human cutaneous wetness sensitivity. Journal of neurophysiology, 112(6), 1457-1469.
Ploumitsakou, M., Muheim, J., Felouzis, A., Carbonell Muñoz, N. I., Iberite, F., Akouissi, O., ... & Shokur, S. (2024). Remapping Wetness Perception in Upper Limb Amputees. Advanced Intelligent Systems, 2300512.

Example with the peripheral nervous system







Bensmaia, S. J., Tyler, D. J., & Micera, S. (2020). Restoration of sensory information via bionic hands. Nature Biomedical Engineering, 1-13.

Examples with the central nervous system

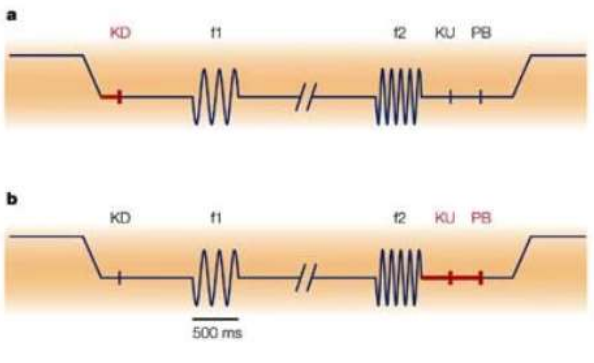
Direct stimulation of the sensory cortex to induce ‘tactile’ sensation

Valle, Giacomo, et al. "Tactile edges and motion via patterned microstimulation of the human somatosensory cortex." Science 387.6731 (2025): 315-322.

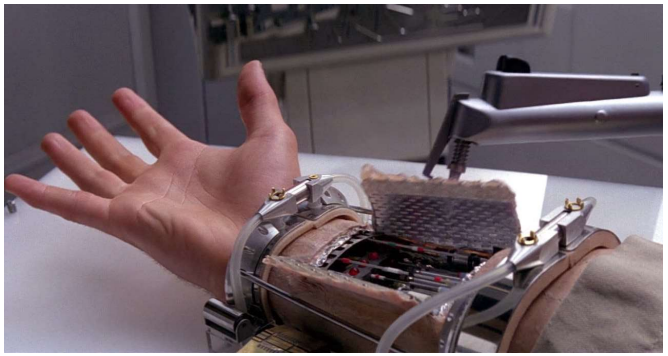
Examples with the central nervous system

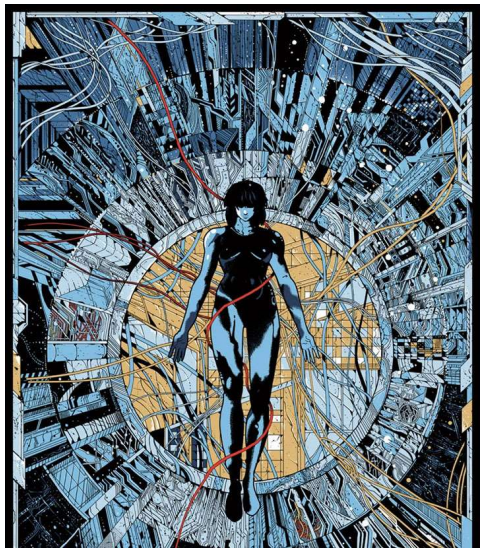
- Electrical stimulation of the hand representation area in the primary somatosensory cortex induces a sensation similar to one of a vibrator placed on the hand.

Psychophysics:
The relation between stimulus and sensation



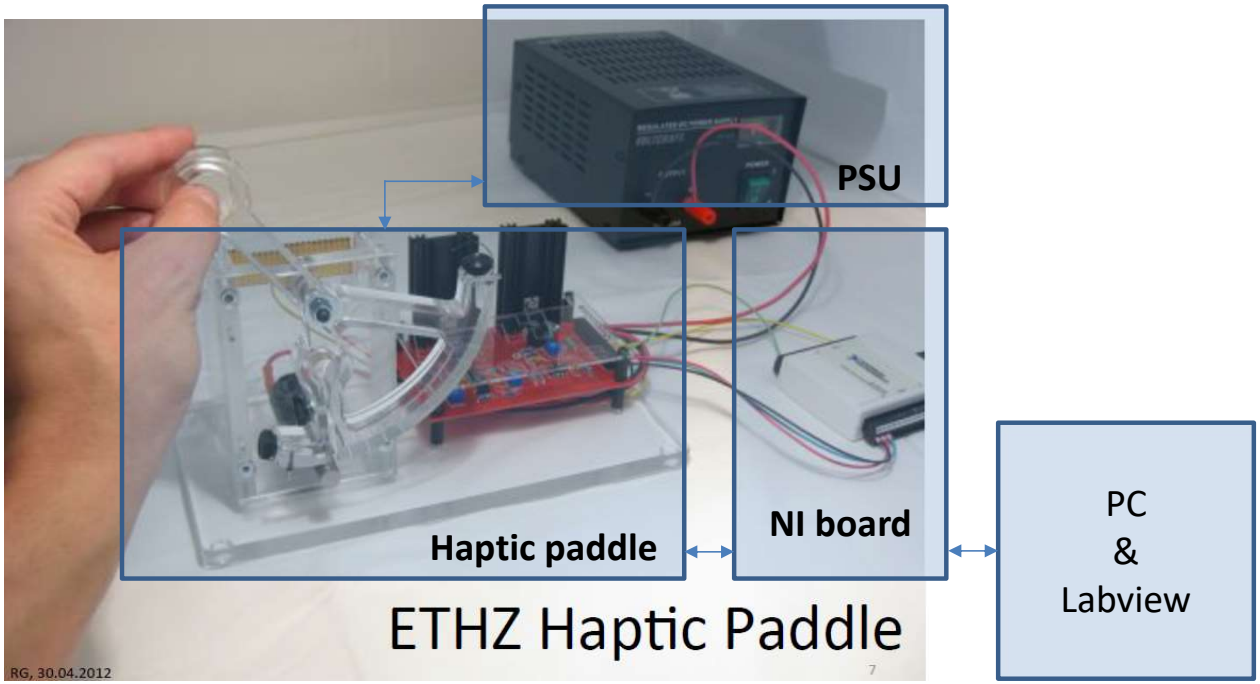
Romo, R., Hernández, A., Zainos, A., & Salinas, E. (1998). Somatosensory discrimination based on cortical microstimulation. Nature, 392(6674), 387–390. https://doi.org/10.1038/32891





How many can you name?

Using Lab View



Haptic Paddle: EPFL version, since 2016

All-in-one electronic board

- **Power electronics**
- **Interface**
- **Embedded controller using an STM32 Arm MCU**

This year, we even improved the mechanical design

Paddle shaft with Hall sensor.
Motor with incremental encoder.