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Digital Science for Disability Overview of the initiatives undertaken by Inria

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Inria

Inria/IIT DELHI
WORKSHOP
October 25, 2023

Digital Science for Disability *Overview of the initiatives undertaken by Inria*

Christophe Biernacki, *deputy scientific director*

General overview

Researchs involved in disability initiatives @Inria

The Inria logo is written in a red, cursive script font. It features a large, stylized 'i' at the beginning, followed by the letters 'nria' in a fluid, connected style.

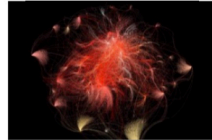
Inria

- French National Research Institute for Digital Sciences and Technologies
- "Scientific Excellence and Transfer"
- Computer Science and Applied mathematics

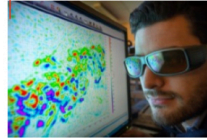
ALGORITHMS & PROGRAMMING



DATA SCIENCE & KNOWLEDGE ENGINEERING



MODELING & SIMULATION



OPTIMIZATION & CONTROL



ARCHITECTURE, SYSTEMS & NETWORKS



SECURITY & PRIVACY



INTERACTION & MULTIMEDIA



ARTIFICIAL INTELLIGENCE & AUTONOMOUS SYSTEMS

Disability

It is associated with a very strong heterogeneity between people, therefore no single solution

We must remain vigilant in the face of stereotypes! Example: “disabled people reject/love technology”

Objectives of our research

Improving the quality of life of people with disabilities

Increase their autonomy

Respect and develop their self-determination

Disability@Inria

About 20 teams have an activity in link with disability

Gait and posture

Avoiding “technological solutionism”

Involve stakeholders upstream and downstream

Take into account constraints (costs, logistics, intrusiveness)

Take ethical aspects into account

Be concerned about the impact: effective implementation, startups as a preferred vector of transfer

Diversity of topics involved in numerical science

Machine learning, Signal processing, Control theory, Automatic language processing, Medical imaging, Sensors, Robotics, Human Machine Interface, Cryptographic protocols...

To keep in mind for having impact

Absolute need for multidisciplinary approaches
Work on needs, practical constraints, acceptability, etc.

Despite several projects, area still underinvested...

FLOWERS A set of educational technologies to promote inclusion for children with Autism Spectrum Disorder (ASD)

ALMANACH Develop Cap'FALC, a text simplification algorithm, for people suffering from disabilities and for non-native speakers learning a given language

CAMIN Neuroprosthesis user interface based on residual motor skills and muscle activity in persons with upper limb disabilities

DEFROST Developing wearable soft exoskeletons with variable damping or stiffness for helping disable people (new soft exoskeletons that may become hard at the period of supporting weight and transferring power, and then become soft at the working mode)

EMPENN Study the impact of lesion damages along the whole motor pathways on disability in multiple sclerosis



HEPHAISTOS Robotized devices for assistance, including smart objects, that may aid disabled or elderly people in their personal life

HYBRID Assistive Robotic Technologies for Next-Generation Smart Wheelchairs: Codesign and Modularity to Improve Users' Quality of Life

MFx, POTIOC, RAINBOW The DORNELL project as a multimodal, shapeable haptic handle for mobility assistance of people with disabilities

MIND Project LargeSmallBrainNets on the learning process for children with mathematical disabilities

MULTISPEECH Voice assistants tool for senior or disabled people, especially for those who are unable to use other interfaces due to lack of hand dexterity, mobility, and/or good vision



POTIOC Accessible applications targeted at users with special needs including people with sensori-motor and/or cognitive disabilities (personalization with Artificial Intelligence)

RAINBOW Using cutaneous haptics for helping the navigation of people with sensory disabilities (vibrotactile sensations, tap stimulations, sensory illusions)



NEURINNOV

Control of movements of paraplegic patients

Sensory feedback: above-knee amputees

Challenges: coordinated stimulation to restore function or regain sensation

Startup



CYBATHLON 2016

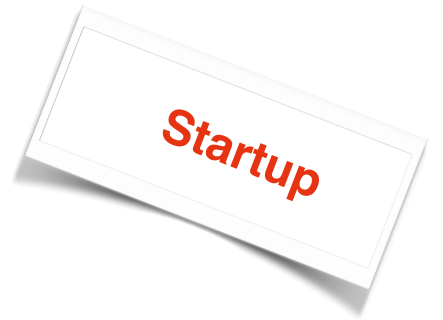


Ulllo

Treatment of anxiety,...

Solutions combining augmented reality, sensory stimulation and breathing exercises

Tested then deployed within EHPADs (elderly people)



HumanLab

Collaborative digital manufacturing or repair spaces of objects, open to people with a disability to appropriate the technology for their own use.

Complementary with the equipment and a medical approach not the replace !

HumanLab@Inria

Create a model of collaboration between Inria and the network of HumanLab

Contribute to meeting the needs expressed by individuals people with disabilities

Frugal innovation approach, open-source



Focus n°1

Electrically stimulate the system peripheral nerve
to restore lost motor functions



Electrically stimulate nervous tissues to

Explore & model the neurophysiological mechanisms

Assist and restore lost functions (gripping, standing, walking, etc.)

Methods

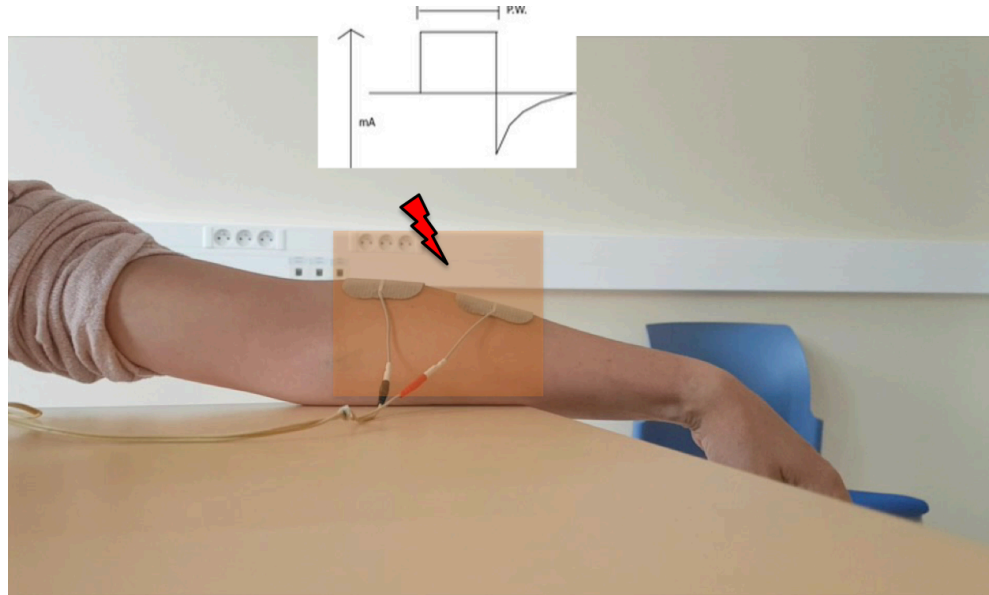
Surface or implanted electrodes

Experiments in humans and animals



Functional Electrical Stimulation (FES)

Artificially trigger a muscle contraction



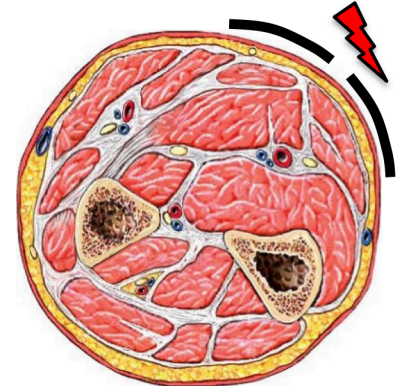
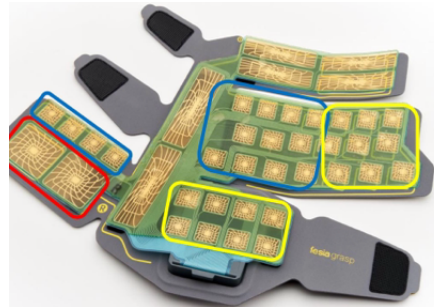
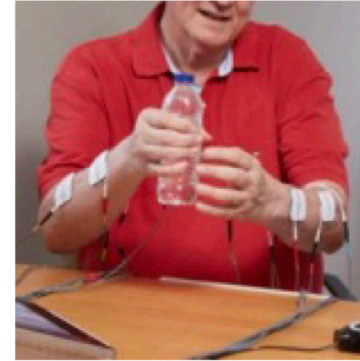
Application of SEF to restoration of grip

Approach 1 - Surface electrical stimulation

But surface electrodes are not very selective, tedious positioning, movements of the skin during contractions...

Solution 1 - Matrix electrodes: selective

Simplified positioning and adjustments, rehabilitation / replacement (control methods)

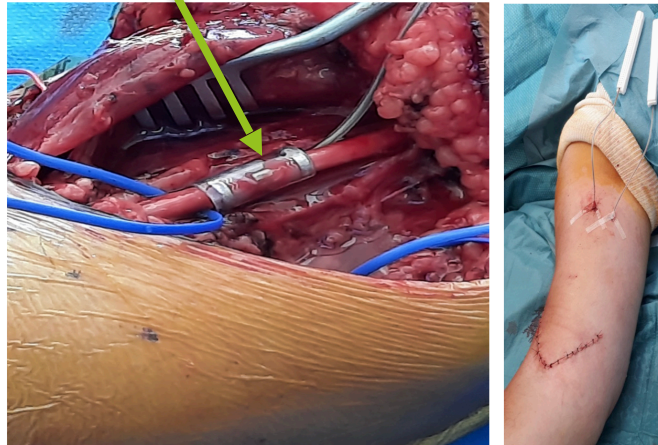


Application of SEF to restoration of grip

Approach 2 - Implanted electrical stimulation

Solution 2 - implanted electrodes

Selectivity and increased efficiency, stability / invasiveness



Basic functional movements

Implantation of 2 electrodes for 28 days



STARS



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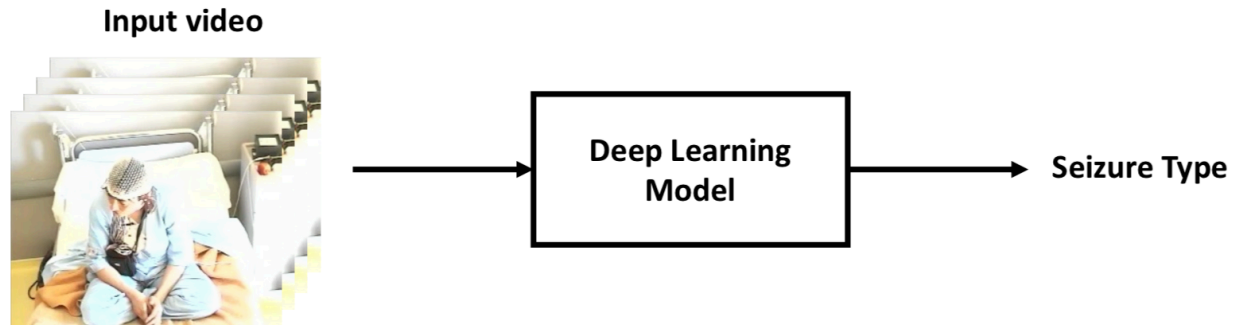
 Inserm

Focus n°2

Video-based identification of epileptic seizures

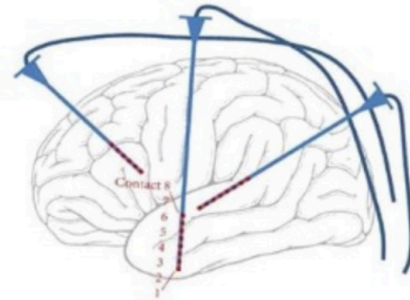
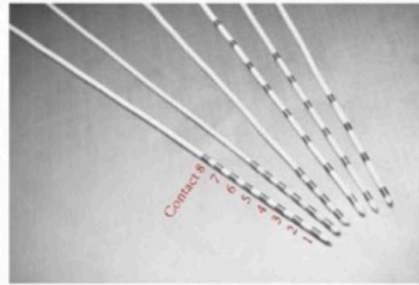
Goal

- Classify **epileptic seizures** and non-epileptic seizures based on videos.



What are epileptic seizures (ES)

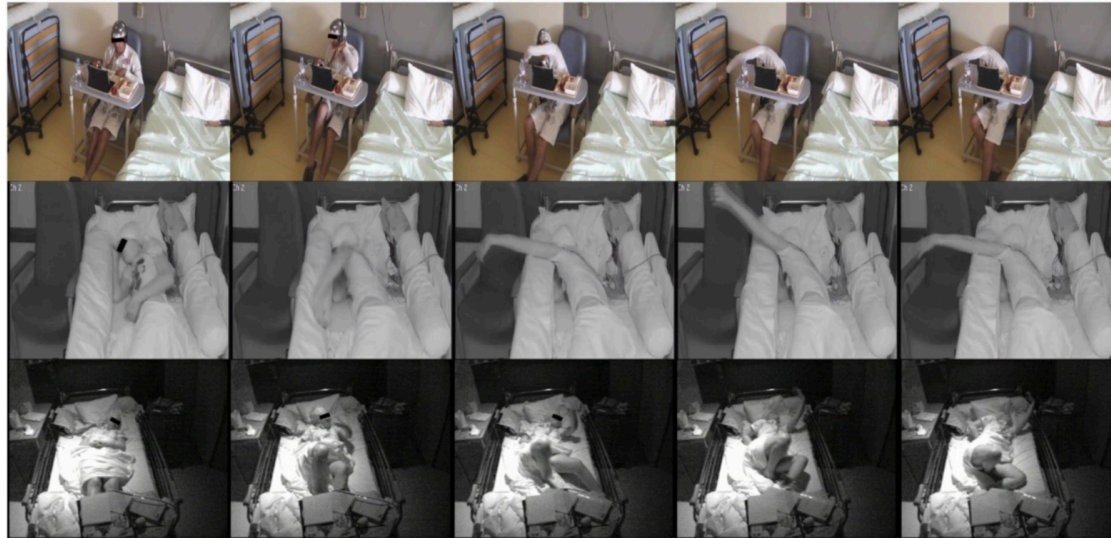
- Abnormal behavior associated with motor activity changes, including repeated or rhythmic movements.
- Caused by epileptic/excessive neuronal activity in the brain.



Depth electrode

Examples of epileptic seizures

- Limb dystonia: **rigid/stiff arms**



Non-epileptic seizures

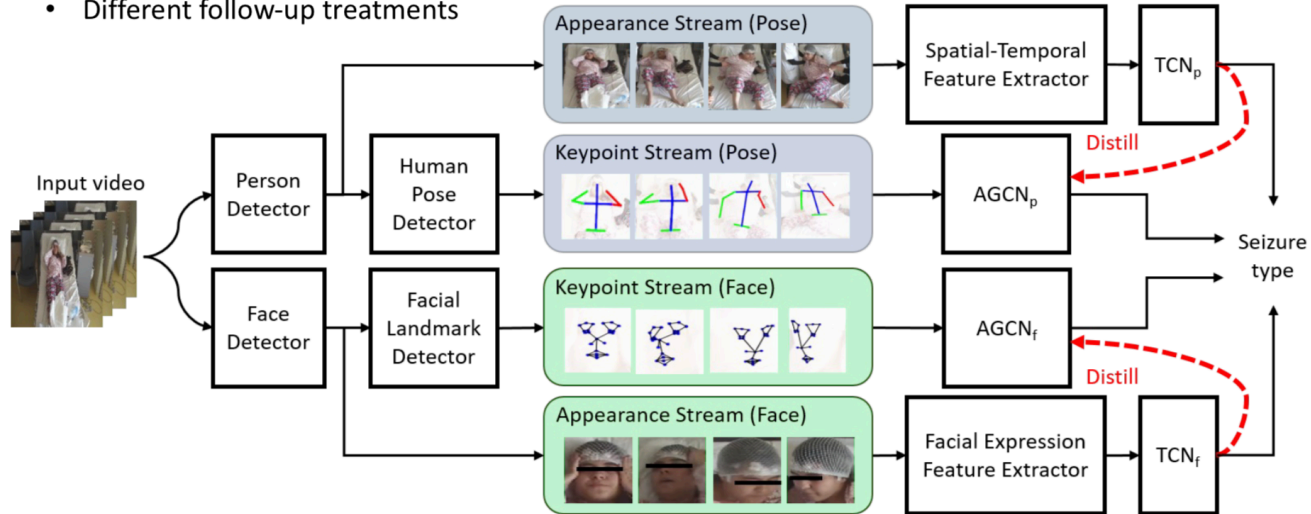
- Not all seizures are epileptic.
- Psychogenic non-epileptic seizures (PNES)
 - Caused by **psychological factors**



A Multi-Stream Approach for Seizure Classification with Knowledge Distillation: Overview of the model

J-C Hou, A Mcgonigal, F Bartolomei, M Thonnat. A Multi-Stream Approach for Seizure Classification with Knowledge Distillation. AVSS 2021

- Goal: A binary classification task for ES vs. PNES
 - Caused by different reasons
 - Different follow-up treatments



*TCN: Temporal Convolutional Network *AGCN: Adaptive Graph Convolutional Network [Shi, CVPR 2019]

Challenges: limited labeled data

- Costly to collect labeled data in medical domains
 - Video dataset for seizure type classification:

Study	# of seizure videos	# of patients
Achilles (2016)	52	10
Aristizabal (2018)	52 (MTLE:40, ETLE:12)	18 (MTLE:12, ETLE:6)
Karácsony (2020)	126 (FLE:85, TLE:41)	35 (FLE:20, TLE:15)
Maia (2019)	143 (ETLE:107, TLE:36)	31
Aristizabal (2019)	161 (MTLE:90, ETLE:71)	34 (MTLE:17, ETLE:17)
Ours	283 (ES:235, PNES:48)	81 (ES:52, PNES:29)

*MTLE: mesial temporal lobe epilepsy, FLE: frontal lobe epilepsy, ETLE, extra-temporal lobe epilepsy

- Action recognition dataset (#Videos): Kinetics (500k), VLOG (114k), HACS (520k)
- Utilize **large amount of unlabeled data**.
 - Without the need for data annotation from clinicians
 - Easier to access and collect.

Focus n°3

ADAPT: Wheelchair navigation assistance

Rainbow

ADAPT : Wheelchair navigation assistance

Intuitive trajectory correction

- An embedded plug & play kit providing reactive collision avoidance.
- Shared Control with the user.



How far have we come?

- **Clinical investigations:** Scenarios of progressive difficulty co-designed with clinicians (+ ethical requirements, compliance with medical device regulation...)
- Experiments **“in real-life”**: testing in the museums of Rennes.



Around **350 users** or people who had failed to drive a wheelchair tested the system, with **100+ participants** included in the clinical investigations.

Focus n°4

DORNELL: A multimodal, shapeable haptic handle for mobility assistance of people with visual impairments

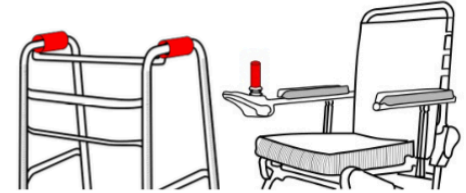
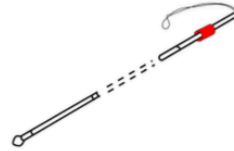
Rainbow



DORNELL: Increase mobility

An innovative haptic handle for efficient and safe navigation

- A **multimodal haptic and tactile feedback**
 - > about the surrounding environment.
 - > about the interaction between the user and the handle.
- A **plug-and-play handle adaptable** with any technical aid.

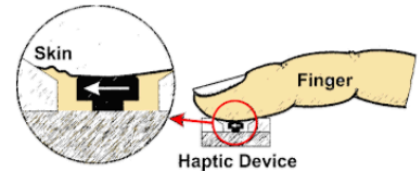
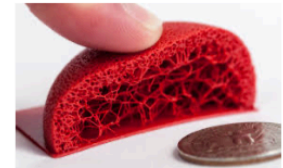


Scientific challenges

Sensory substitution: tactile and haptic feedback (vibrations, pressure, temperature, etc.)

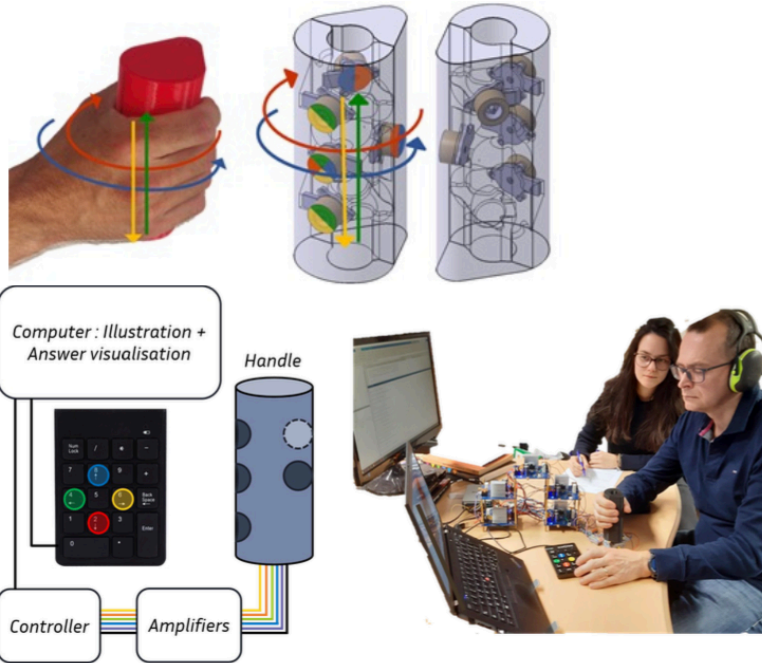
Intelligent and connected device for cane, chair, walker

Adaptable to other disorders



First prototypes

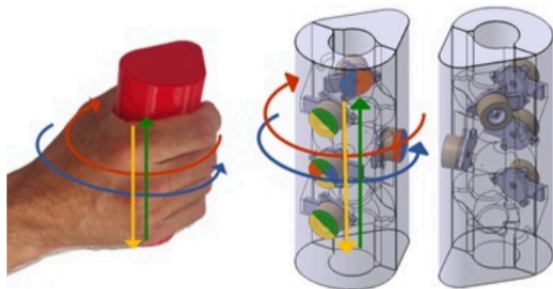
What are we perceiving? Do we succeed navigating thanks to haptic feedback?



First experiments – perception

Experiments at INSA Rennes – July 2023

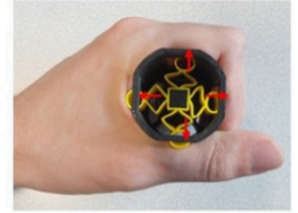
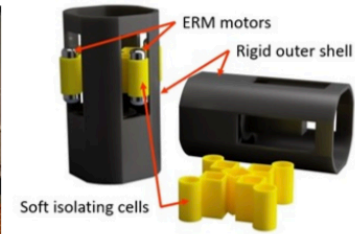
- Perceive haptic feedback direction with handles equipped on a rollator.
- Directional feedback by providing Apparent Haptic Motion Illusion.
- Participation of occupational therapists, physiotherapists, etc.



First navigation experiments

Experiments at INSA Rennes – July 2023

- Navigate on a pre-define virtual trajectory.
- Directional feedback to assist navigating on the virtual trajectory.
- Participation of occupational therapists, physiotherapists, etc.



An available solution: “Swalkit”

Co-design of a rollator with haptic feedback

- Emerged from the need of Esteban, a user of a rollator with blindness and difficulties to navigate safely.
- Vibrotactile sensations to indicate proximity to obstacles.
- “DIY” assistance kit:
 - > Low cost and open-source.
 - > Can be installed with the help of a fablab.



Providing daily assistance for 18 monts...

- Before the kit: no autonomy of movement.
- With the use of the kit: autonomy, motivation, renewed confidence and more social interactions.
- Tests with 2 other end-users with the Institut des Jeunes Aveugles in Moulins: study in progress.

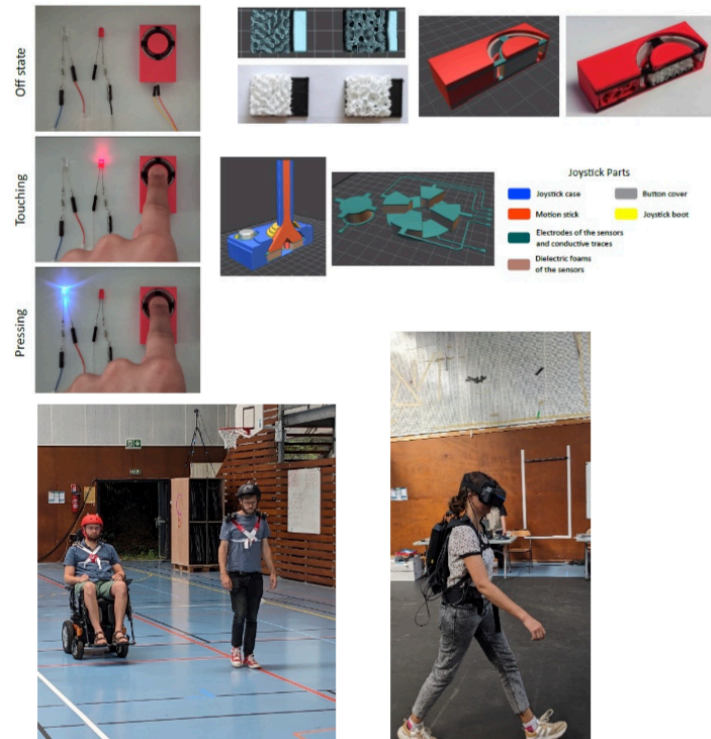
Dornell is at its halfway stage! What are the next steps?

Improve feedback and embedded sensing...

- Iterative co-design.
 - > Use the results and participant feedback of the first experiments to improve designs.
 - > Adapt and personalize the handle feedback as well as ergonomics.
- Innovative one-shot 3D printed sensors to incorporate into the handle.
 - > User state and intention detection.
 - > Bidirectional communication.

Anticipate social navigation challenges

- Evaluate cognitive challenges between the proposed frameworks of haptic feedback and walking/navigation tasks.
- Link with other works on social navigation pedestrian/wheelchair.



Thanks!

Visit www.inria.fr