

Shared control for assistive and collaborative robotics: taking into account user intention and capacities

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IRISA / INSA Rennes – GdR MACS 2026

Assistive robotics: placing the user at the center of the system

Mobility assistance: support for everyday life

- Total or partial motor impairments
  - > Upper limbs, lower limbs
- Increased difficulties with complex disability situation



Assistive robotics

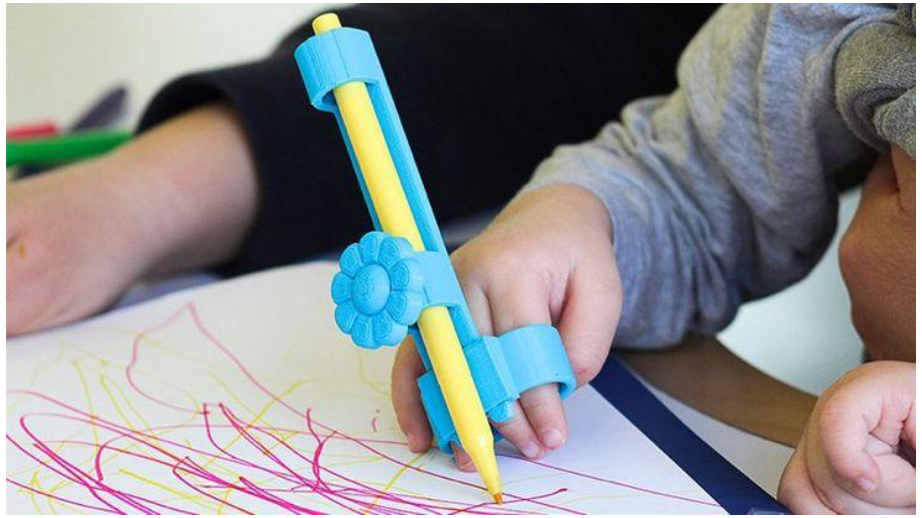
- Objective: to compensate for permanent or progressive limitations
- Assistive technologies that are accessible, configurable, and suited to long-term daily use
- Personalization
  - > Need to understand the user's state and intention at all times in order to adapt the control
  - > User-centered design is essential: users, clinicians, caregivers

Restorative / compensatory rehabilitation

Principle: two successive steps in supporting people with disabilities

- Two different words in French: “rééducation” and “readaptation”
- Functional recovery
  - > Neurorehabilitation, motor retraining
  - > Task-oriented training, motion repetition
  - > Objective: no longer depending on hospitalization or medical care
- Adaptation: adjusting to a chronic condition
  - > Compensation
  - > Goal: successful completion of the task
    - Daily life, leisure, work…
  - > Objective: autonomy, independence and social participation





Restorative / compensatory rehabilitation

A different philosophy for assistive robotics

- Rehabilitation robot: leveraging neuroplasticity
  - > « Performing the right movement »
  - > Following predefined trajectories, movement patterns
  - > Playful (game-based) tasks
- **Assistive robotics**
  - > No expert movement
  - > No a priori assumption about the movement performed

Open problem: human-robot interaction

- How to account for the user's abilities?
- How to account for the user's intention?

Challenges : design, shared control, intention detection



Lokomat – Hokoma Melbourne Physiotherapy Clinic 2025



Keeogo 2025

Detecting the user intention



Orthopus Supporter 2025 - buttons



Torque [Bey, Mechatronics 2025]

Depends on the robotic assistive device

- Direct detection
  - > joystick, buttons…
  - > Mobilizes one function to do something other than the targeted task

Intention inferred from physiological or postural data

- Eye tracking, head position, brain-machine interfaces, EMG…
- High mental workload, fatigue, skin lesions…
- Difficult to use in daily life situations

Intention inferred from observations using sensors embedded in the device

- Motor current, pressure, torque…
- Possibly difficult to interpret, but natural use



Neuroprothesis – [Bellicha, JNE 2025]

Adapting the design to users' abilities



Accounting for usage scenarios

- Setting up the device, tasks to be performed (walking, grasping, wheelchair driving…)



Accounting for individual specificities

- Motor and sensorimotor impairments
  - > Residual abilities (e.g., trunk mobility…)
- Posture, morphology, pain, skin sensitivity…
  - > Very active research area on upper-limb and lower-limb exoskeletons
- One individual = one response
  - > One device cannot solve everything!



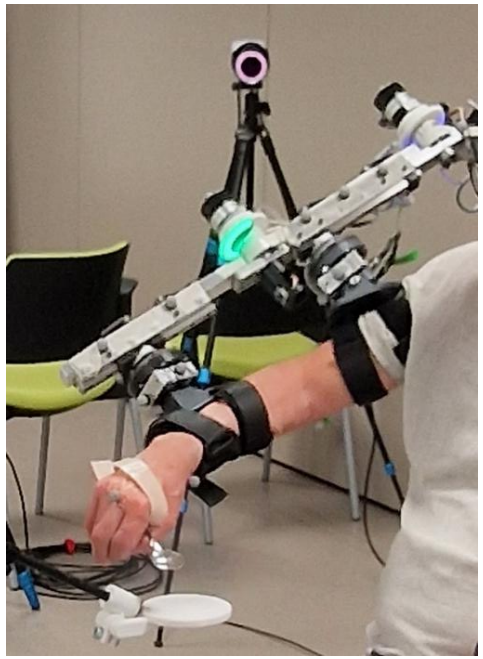
Challenges : how to model individual functional capacities?

Focus on power wheelchair users need: designing assistive devices for mobility

Mobility as a whole

- Power wheelchair: moving around safely when mobility is limited
- Upper-limb exoskeleton: reducing muscular effort to perform daily life movements





Driving assistance for power wheelchair

Driving a wheelchair: complex task

- Medical device: requires a medical prescription
- Requires to complete Wheelchair Skill Test
  - > Learning and training
  - > Indoor/outdoor environments

- Safe navigation = authorization to obtain a wheelchair
  - > No collision, ability to realize difficult maneuvers…
  - > Can be impossible in case of motor/cognitive/visual impairments



From need to use:

How can we help people to drive safely?

Taking into account user intention

Steering a wheelchair

- Adapted physical human-robot interface
  - > proportional controls (joystick, T-shape joystick..), switch controls,…

Shared control

- Blending the user's intention with the robot control
- Challenges
  - > Interpreting the intention
  - > Providing assistance that is compatible with this intention: not hindering, frustrating, or preventing
  - > Assisting only when needed, assisting according to the need ("assist-as-needed")
- Formalisms
  - > Fusion, linear blending, constrained optimization problem

[IROS, 2016]
[SMC, 2019]

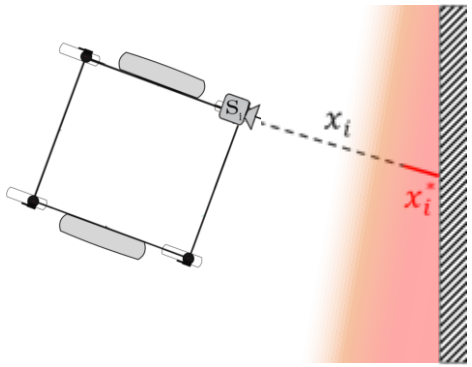
Designing a trajectory correction to avoid collisions

An embedded plug & play kit providing reactive collision avoidance

- Shared Control with the user through sensor-based servoing

Principle: 1 sensor

s_i: distance (IT ToF) sensor
x_i: measured distance
x_i^*: min allowed distance



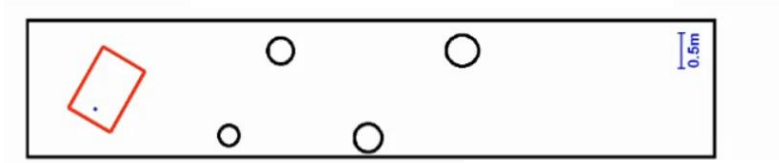
Interaction matrix $\dot{x}_i = \mathbf{L}_{x_i} \mathbf{v}_{s_i}$

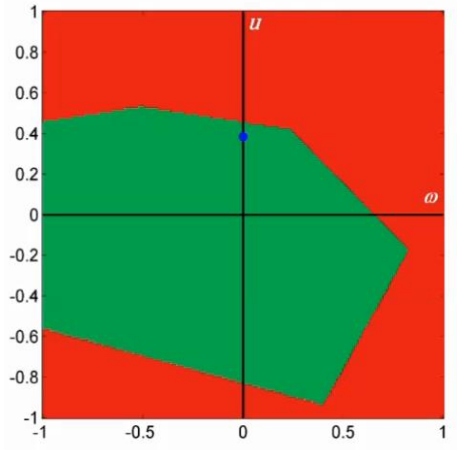
Proportionnal velocity limit $\dot{x}_i \geq -\lambda e_{s_i}$

$$\mathbf{L}_{x_i} \mathbf{v}_{s_i} \geq -\lambda e_{s_i}$$

⟹ Equation of a half plane $a_{s_i} v + b_{s_i} \omega \geq -\lambda e_{s_i}$

For n sensors: $\begin{cases} \mathbf{u}_{cmd} = \min_{\mathbf{u}} f(\mathbf{u}_{op}, \mathbf{u}) \\ \mathbf{A}\,\mathbf{u} \geq \mathbf{B} \end{cases}$





- user input
- computed safe input

« allowed » safe area

« forbidden » unsafe area

[Rehabilitation: AT, 2023]
[RAM 2023]



Wheelchair navigation assistance

How far have we come?

- **Clinical studies:** definition of standard circuits reproducing daily life situations
- **Real-life experiments**
  - > user study with volunteers in rehabilitation centers
  - > testing in the museums of Rennes: accessibility of cultural activities.







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

Safely reaching a desired position: regaining independance in daily living

Dealing with daily difficulties

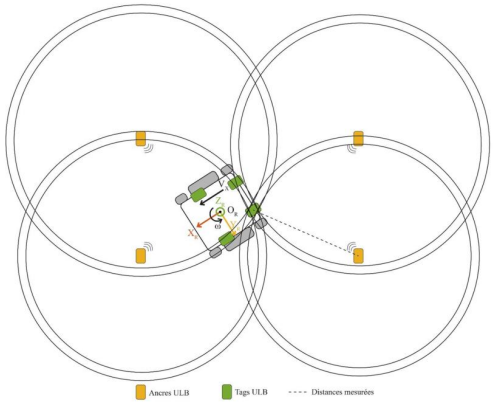
- Compensating for cognitive disorders: helping to navigate to reach a long-term position in cluttered environment
- Assisting the user or the carer in difficult maneuvers: positioning for transfer (bed, toilets…)

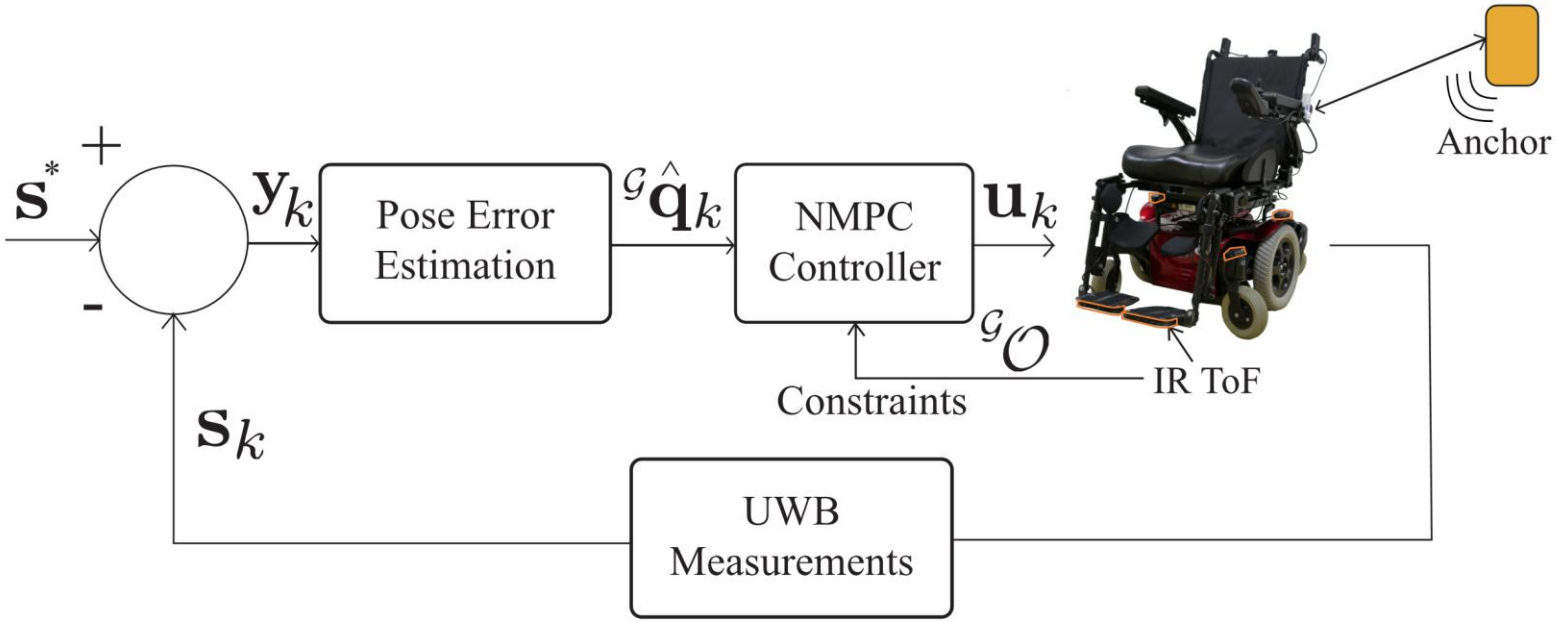


Safely reaching a desired position: regaining independance in daily living

Combining reactive assistance with long-term navigation

- Design nonlinear Model Predictive Conctrol scheme for power wheelchair indoor navigation
  - > Ultra-Wideband (UWB) for indoor positioning and IR ToF sensor for obstacle avoidance
  - > Indoor coarse localization through set-membership pose estimation





[Acta Cybernetica 2025]

NMPC for power wheelchair indoor Navigation

Constraints in the NMPC

- actuation limits
- driving comfort
- obstacle avoidance

Target pose

$$
\begin{aligned}
&\min_{\substack{\boldsymbol{q}_0 \dots \boldsymbol{q}_N \\ \mathbf{u}_0 \dots \mathbf{u}_{N-1} \\ \boldsymbol{\rho}_0 \dots \boldsymbol{\rho}_N}} \quad \sum_{k=0}^{N-1} \ell(\mathbf{q}_k, \mathbf{u}_k, \boldsymbol{\rho}_k, \mathcal{O}) + V_f(\mathbf{q}_N, \boldsymbol{\rho}_N, \mathcal{O}) \\
&\text{s.t.} \quad \mathbf{q}_0 = \hat{\mathbf{q}}(t) && \text{Pose estimation} \\
&\quad \mathbf{q}_{k+1} = \mathrm{f}(\mathbf{q}_k, \mathbf{u}_k), \quad k \in \{0, \dots, N-1\} && \text{Evolution model} \\
&\quad \underline{\mathbf{u}} \leq \mathbf{u}_k \leq \overline{\mathbf{u}}, \quad k \in \{0, \dots, N-1\} && \text{Speed/Acceleration Constraints} \\
&\quad \underline{\dot{\mathbf{u}}} \leq \dot{\mathbf{u}}_k \leq \overline{\dot{\mathbf{u}}}, \quad k \in \{0, \dots, N-1\} \\
&\quad \boldsymbol{g}(\mathbf{q}_k, \mathcal{O}) > \mathbf{1} - \boldsymbol{\rho}_k \quad k \in \{0, \dots, N\} && \text{Obstacle Avoidance Constraints} \\
&\quad \boldsymbol{\rho}_{k,i} \geq 0, \quad k \in \{0, \dots, N\}, i \in \{1, \dots, n_{\text{obs}}\}
\end{aligned}
$$

Optimal inputs

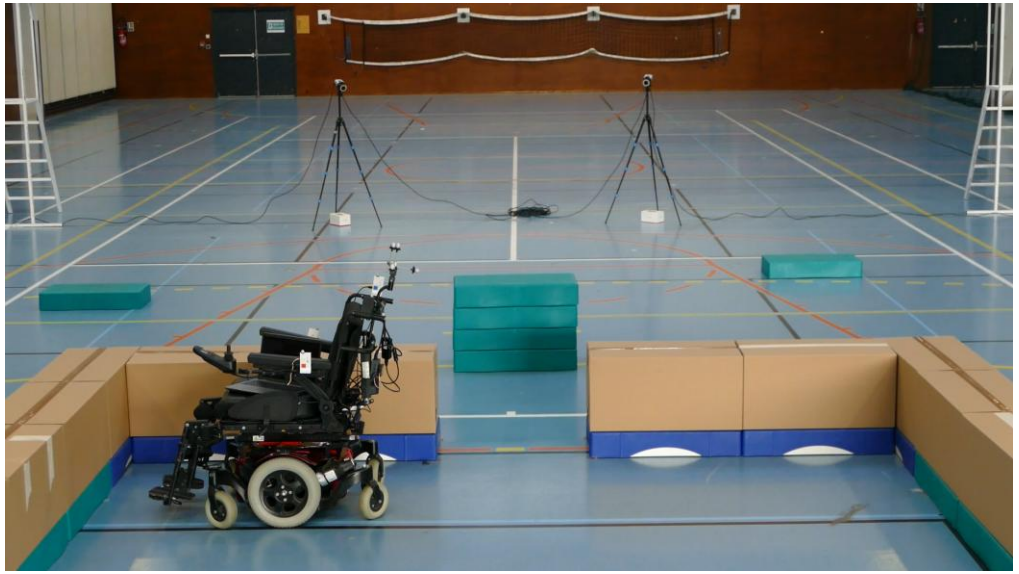
NMPC for power wheelchair indoor Navigation

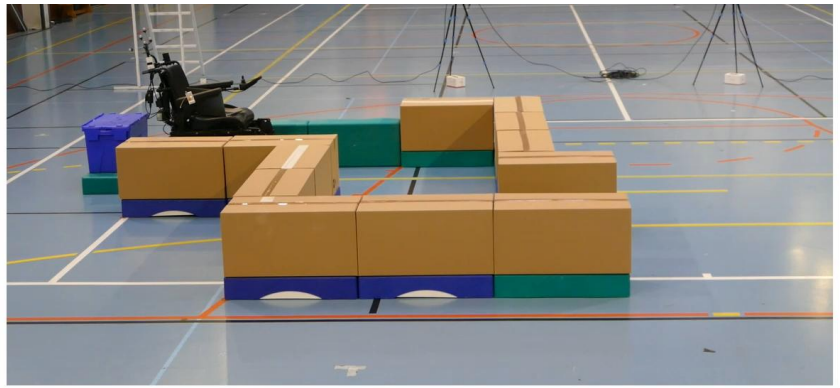
Efficient and safe navigation

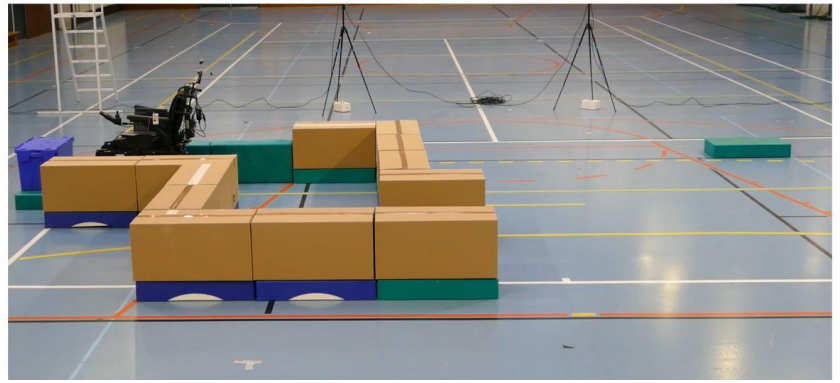
> Even in hard environmental conditions

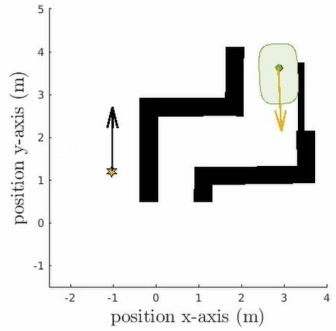
> In progress: blending user intent with the MPC

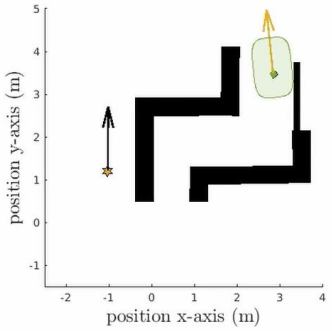
> Experiments with end-users planned in 2027











Addressing limitation of upper-limb mobility of wheelchair users

Performing upper-limb movements, another essential need for social participation and independence

> Drinking, eating, opening a door...

> And also at work!

How can we define an assistance for daily life gestures?

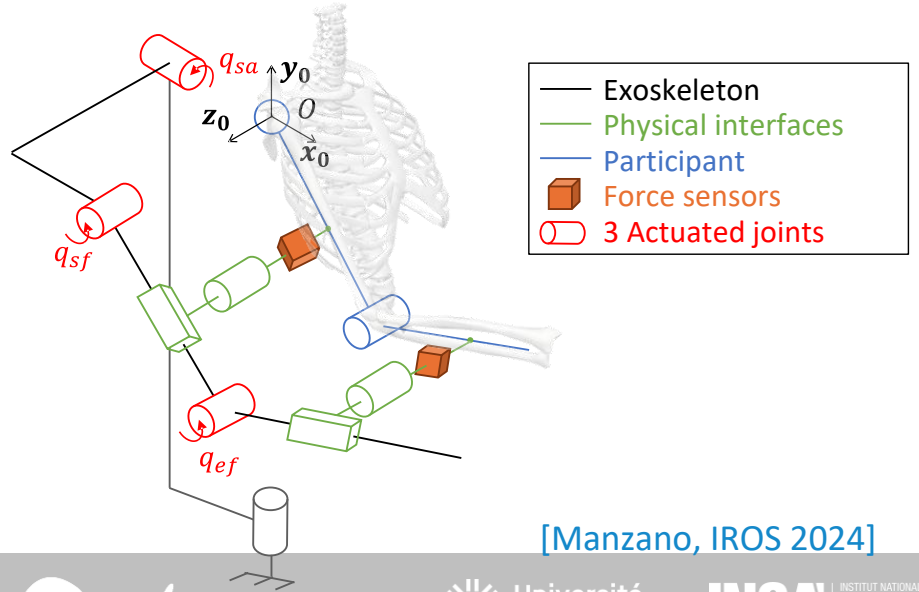
- Design of a lightweight, customizable system for power wheelchair users
  > Compensation of motor deficiencies
  > Anthropomorphic design
  > Active exoskeleton mounted on a power wheelchair



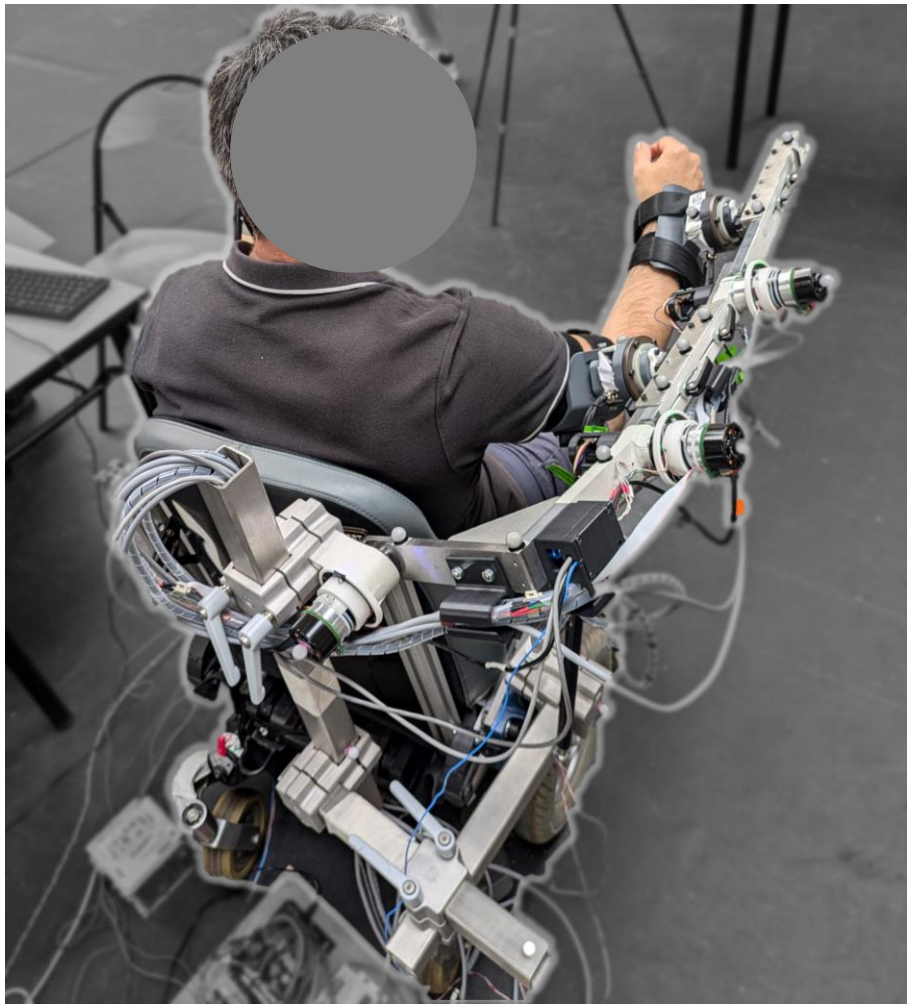
Upper-limb exoskeleton for shoulder and elbow assistance

Ensuring comfort in use

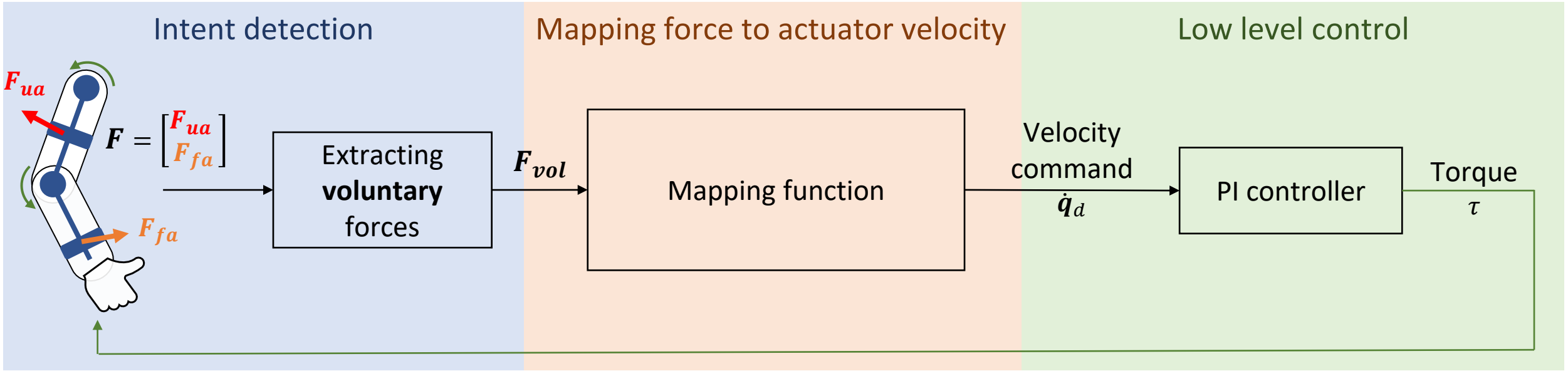
- Ergonomic design challenge
  - > minimizing discomfort due to potential misalignments
- Assistance to reach and grasp objects without fatigue
  - > A personalized effort-based control approach
  - > Modelling the user's abilities to provide better support
  - > Biomechanical modelling to identify muscular capacities



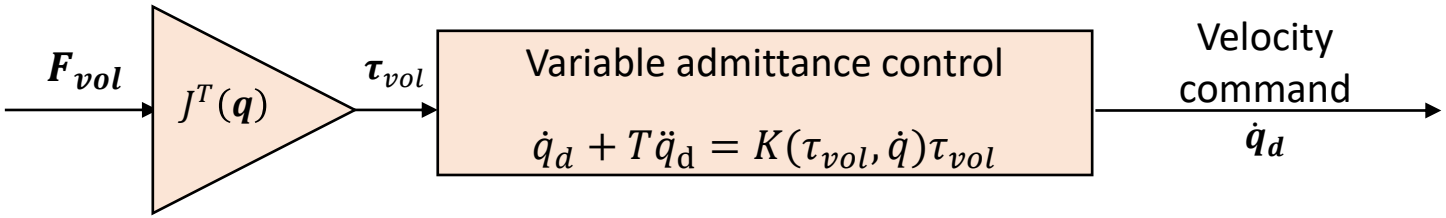
[Manzano, IROS 2024]



Shared control: principle



- Extracting the voluntary forces: designing a personalized model
  - > Suppressing passive forces due to gravity, involuntary muscle activations…
- Variable admittance control to facilitate movement initiation and to avoid undesired movements

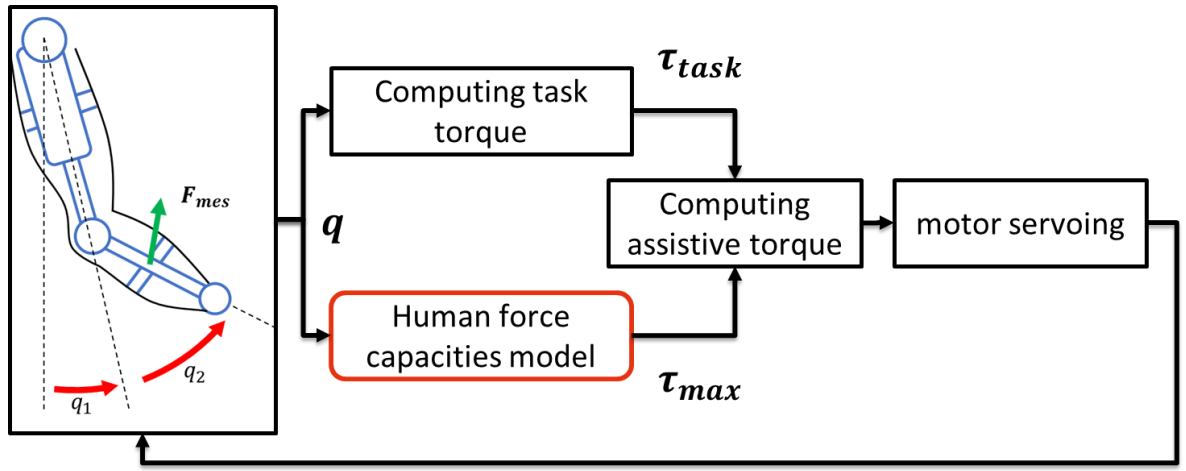


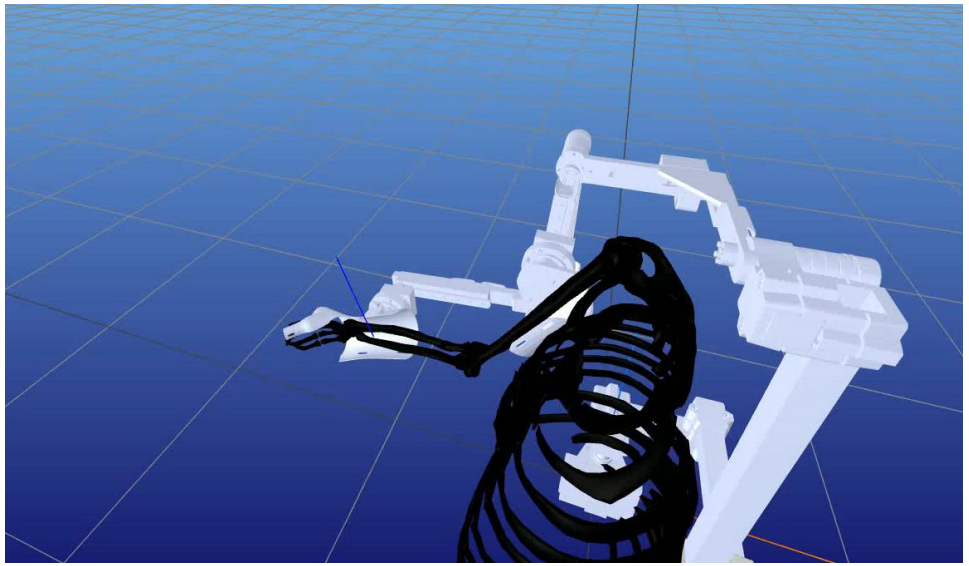
Adapting the control to user residual functional capacities

[Gallois, SB 2025]

Idea: estimating effort generation capabilities to provide assistance according to motor abilities

- Modeling the user and their interaction with the robotic device
  - > obtaining a personalized biomechanical (musculoskeletal) model
  - > identification of muscles parameters
  - > coupling with shared control



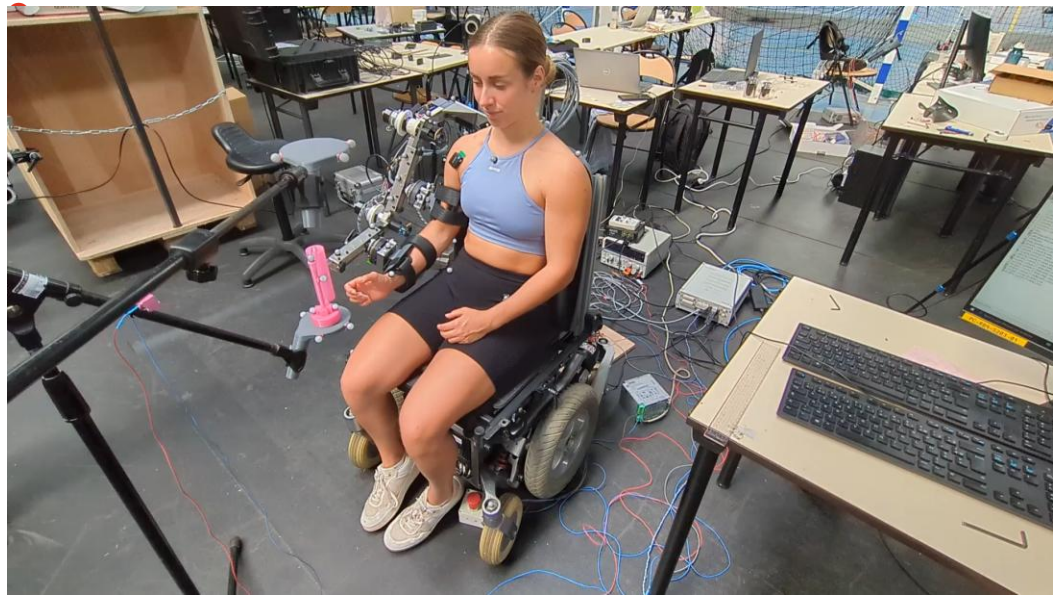


[Gallois, ICORR 2025]

Upper limb assistance: evaluation

Experiments to validate the proposed device

- Participants without known upper limb impairment
- Ability to perform tasks
- Significant EMG reductions for assistive modes
- Better estimation for the musculoskeletal model lead to a better assistance



User study

- Participants with upper limb impairments and no cognitive impairments
- Ability to perform tasks, effective assistance
- Anticipated use



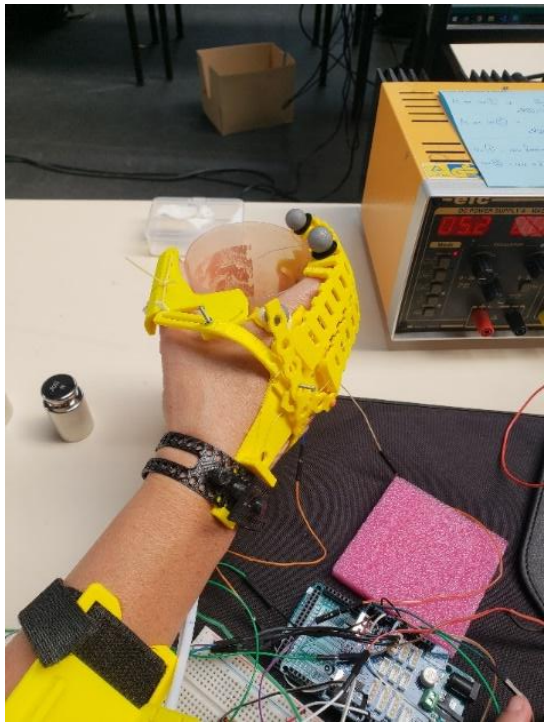
From reach-for-grasp to reach-to-grasp

[Larribau, SB 2026]

Grasping an object, the next issue for independance

- Adding pronosupination assistance and grasping assistance
  > flexion/extension of wrist not addressed at this stage (validated by clinicians)
-



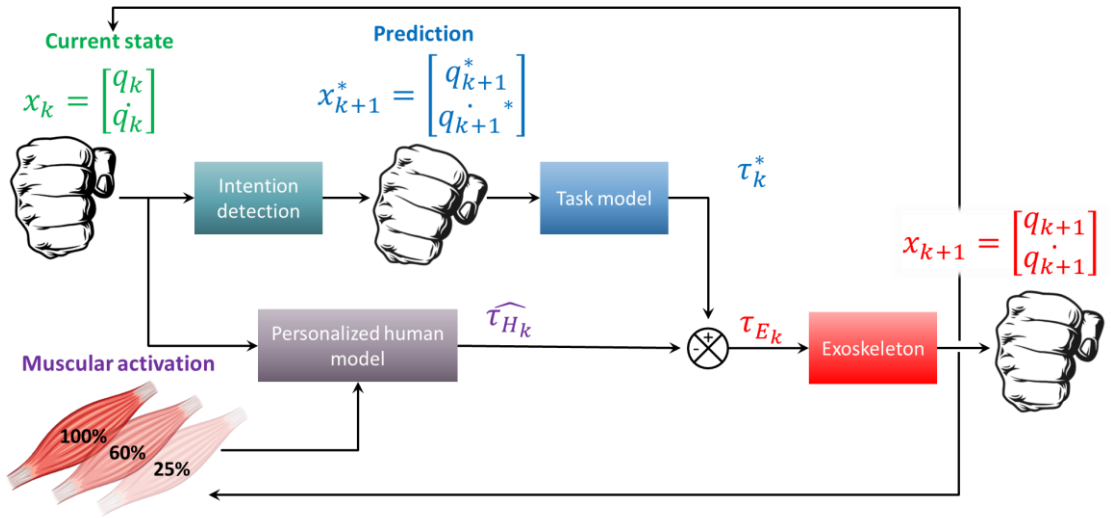


From reach-for-grasp to reach-to-grasp

[Larribau, SB 2026]

Grasping an object, the next issue for independance

- Challenges
  - > Design of the exoskeleton itself
  - > Personalizing the biomechanical models to fit user capacities
  - > Dynamically adjusting shared control to provide « just enough » assistance
  - > Estimating intention…
- Still an open research question, we are hardly working on it!



Conclusion



Robotics and rehabilitation: the human at the heart of the system

- An interdisciplinary domain
- As many solutions as there are users
  - > Challenges: adapting, personalizing
- Experiments with users: ethical considerations

Challenges to be addressed (among others!)

- How to adapt in real time to the user's state?
  - > The robot as a tool to understand this state (fatigue, comfort, pain…)
- What mechatronic design?
  - > Repairability, reasonable cost
- How to prevent technology abandonment?
  - > Co-design
  - > Evolution of the device (design, control…) as the user's abilities change