Assistive robotics and mobility aids: Compensation, rehabilitation and interaction

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Mobility assistance: needs and trends

**Mobility deficiency: a worldwide challenge**

- 110 to 190 millions of adults with mobility difficulties
- Mobility aids as an answer
- Limitation of use due to visual/cognitive deficiencies

**Designing assistive technologies should…**

- Enhance mobility capacities
- Compensate impairments
- Match individual needs

**… but should not**

- Increase cognitive workload
- Lower capacities or overcompensate
- Do tasks in place of the user
Creation and innovation

User-centered conception for people with disabilities

- Enhancing mobility performances
- Increasing motivation for rehabilitation
- Improving and securing rehabilitation processes

Rennes: multidisciplinary teams and projects

- Computer science, Robotics, Electroniques, Mechanics, Virtual reality
- Biomechanics, psychology
- Physical medicine and rehabilitation
A truly useful and used device: methodology

Co-design with medical staffs

- to guarantee the acceptance of the solution
- to prevent from a mismatch between user expectations and final design

Iterative and pragmatic process

- regular clinical trials
- continuous integration of hardware and software components
Enhancing the mobility: contributions

Achieving effective navigation

- Robotics and shared control
- Navigation assistance: smart power wheelchair, smart walker…
- Social navigation and interaction: respect of social conventions for an inclusive mobility

For an augmented navigation experience

- Creation and fabrication of the next generation of physical human-robot-environment interfaces
  > provide multiple sensations
  > improve the performance of navigation tasks

Simulation and Virtual Reality

- Design of an immersive simulator for assisted power wheelchair driving: towards training and rehabilitation applications
Trajectory correction and obstacle avoidance

**Shared control: principles** [ICORR2017][IROS 2016]

- Sensor-based servoing and user intention detection
Trajectory correction and obstacle avoidance

Case study – Indoor navigation

- Patient from Pôle Saint Hélier – cognitive and visual deficiencies
  - First time driving with a power wheelchair

- Navigation in corridor
- Navigation in cluttered environment
- Elevator entrance

- Navigation without collision
- Enhance motivation for rehabilitation
- Positive feedback from clinicians
**SWADAPT 1**

**Clinical trials on standardized courses**

- Tests in Rehab center Pôle Saint Hélier (Rennes) in June 2019
- 30 patients with neurological disorders, regular power wheelchair drivers
- Increase of driving performances (less collisions, smoothness...)

![Graphs showing performance comparisons with and without assistance across different circuits.](image-url)
SWADAPT 2

Clinical trials on standardized courses

- Tests in INSA (Rennes) in July 2020
- 8 patients experiencing driving difficulties and/or not allowed to have a power wheelchair
- Illustrative trial: patient with cerebellar syndrome and visual impairment

- Without assistance: 27 collisions, 8 emergency stops
- With assistance: no collision
Immersive driving simulator [ICORR2019]

Objectives

- Training (first-time users, people experiencing driving difficulties…)
- Rehabilitation
- Evaluation of shared control solutions for research purposes

Driving virtual and immersive experience challenges

- Virtual Reality
  - Multisensory simulator
  - Motion platform: reproducing wheelchair motion cues and physical interaction with Virtual Environment
  - Visual, haptic, auditory feedbacks
Various scenarios and display modalities

Indoor navigation – Immersia (large immersive room)
SIMADAPT1

Real PWC vs simulator

- Evaluation of the quality and impression of driving with the INSA simulator
SIMADAPT1

High Sense of presence

- Personal presence: sense of being in the virtual environment
  - Driving on a ramp: realistic “emptiness”
  - Approaching an obstacle
- Environmental presence: feel motion reaction of the platform

Limited cybersickness

- Big difference between with and without motion platform!
Social interaction for efficient virtual/real navigation

Objectives

- Defining smart assistance and efficient path-planning strategy
- Defining realistic behavior of virtual humans in case of interaction with wheelchair driver

Understanding social convention and interactions

- Walker / power wheelchair driver interaction: asymmetrical physical risk inducing differences in the walker’s behavior in comparison to walker-walker situations.
- Adaptation of the personal space model

[SOFPEL 2019] [IROS 2016]
Enhancing navigation comfort

Path planning and trajectory curvature [ongoing...]

- Trajectory curvature directly linked to feasibility and comfort
- Cubic Bézier based RRT* version

RRT* vs CBB-RRT* in a complex environment
Enriching perception

**Haptic tools** [SMC 2018, IEEE TH 2020] – Inria Associated team ISI4NaVE

- Analysis of **physical** Human-Robot Interaction
- Innovative **multisensory** physical interfaces
  - Compensate both sensorimotor disabilities and cognitive impairments
  - Definition of control strategies for warning and for rehabilitation
  - Haptic joystick, haptic bracelet, tactile metaphors…
Interaction and assistance

Smart walker - Co-creation with the pediatric center Rey-Leroux

- Haptic feedback to help a blind boy (with severe cerebellar syndrome) to navigate safely
  - not able to walk alone
  - same sensors mounted onto the walker
  - vibrating motors in the handles
Conclusion

Enhancing the mobility: a multidisciplinary question

- Assisting to increase accessibility and independance
- Co-creation as a key of success

Need of people at the interface of clinical and scientific worlds

> 1 PhD in robotics (Louise Devigne) co-supervised by Marie Babel (INSA) and Philippe Gallien (medical doctor PSH) – 2015/2018

> 1 medical doctor (Emilie Leblong) will realize a PhD work with Marie Babel and Anne-Hélène Olivier (M2S) – 2020/2024
Next steps, new ideas, future projects…

**Multimodal haptics, shared control, social interaction…**

- **Inria Challenge Dornell**: A multimodal, shapeable haptic handle for mobility assistance of people with disabilities
- **Collaboration with CEA-List / Clinatec**: human-robot shared control through motor neuroprostheses (BCI) and multisensory feedback for severe motor disabilities
  - wheelchair driving assistance
  - upper-limb reach-to-grasp assistance
- **Collaboration M2S/Pôle Saint Hélier/ University of Laval (Quebec)**: Integrating social Interaction in a Virtual Reality powered wheelchair simulator: Improving learning for inclusive mobility
Thanks!