IntellWheels: Intelligent Wheelchair with Flexible Multimodal Interface
Introduction | Architecture | Hardware | Simulator

MMI | Shared Control | Experiments | Conclusions
Introduction
Participant Institutions

Research Labs
• LIACC – Artificial Intelligence and Computer Science Laboratory, Univ. Porto
• INESC-P – Institute for Systems Engineering and Computers, Porto
• IEETA – Institute of Electronics and Telematics Engineering of Aveiro

Universities/Faculties
• University of Porto – DEI/Faculty of Engineering and DEEC/Faculty of Engineering
• University of Aveiro – DETI/University of Aveiro
• University of Minho – DSI/School of Engineering

Health Institutions
• IPP/ESTSP – Porto Polytechnic Institute/ Health Technology Superior School
• APPC – Portuguese Association for Cerebral Palsy
Motivation

Individuals with Limited mobility
- Elderly individuals with limited or reduced mobility (Increment of the population aged over 60 years)

Individuals with severe physical disabilities
Physically disabled individuals with mobility impairment, including conditions like:
- Cerebral palsy
- Tetraplegia

Individuals with inabilities to use conventional joysticks
Intelligent Wheelchairs

Intelligent wheelchair Definition:

- Robotic device with sensorial and actuation systems and processing capabilities:
  - Autonomous behavior
  - Obstacle avoidance
  - Flexible Human-Machine interaction
  - Cooperation with other devices
More than 50 IW international projects

- Obstacle avoidance
- Interface method
- IW built from scratch

Inexistence

- IW useful in practice:
  - Very low cost
  - Low ergonomic impact
- IW development platform
- Flexible multi-modal interface
- Mixed reality environment
Goals and Main Achievements

- Intelligent wheelchair with generic platform: hardware/software
- Modular architecture: Multi-Agent System
- Easy integration with new sensors, actuators and modules
- Flexible Human Machine Interface (Multimodal Interface)
  - Joystick, voice commands, head movements, facial expressions and brain-computer interface
- High-level planning and navigation
- Obstacle avoidance
- Realistic Simulation and Mixed-Reality
- Autonomous, shared and manual control
- Low visual and ergonomic impact and very low cost
IntellWheels Architecture
IntellWheels MAS

Multi-Agent approach

- Interaction, communication, redundancy
- Easy to add new functionalities
Hardware
Off-the-shelf devices (low cost)

- Human-machine interface
- Easy to adapt to other wheelchair models

Basic functions in firmware

- Sensor reading
- Obstacle avoidance
IntellWheels Hardware

Left Side

Right Side
IntellWheels Hardware
IntellWheels Hardware

IntellWheels | Motivation | Image Representation | Vision-based Localization | Research Approach | Results
Simulator
IntellWheels Simulator

Advantages

• Fast evaluation of new methodologies
• Tool for training patients in a safe environment
• Interact with virtual objects and virtual IW

USARSim

• Based on Unreal Tournament 2004 (UT2004)
• Unreal Engine 2.5 and the Karma physics engine
• Unreal Editor to develop new objects and environments
IntellWheels Simulator

Real Environment
- No Connection to virtual information

Mixed Environment
- Virtual objects interfere with real world
- Real objects interfere with virtual world

Virtual Environment
- No connection with real world information
Wheelchair Model

- The simulated wheelchair was modelled using 3D Studio Max
- Imported to the Unreal Editor as separated static meshes (*.usx)
- The model has fully autonomous caster wheels and two differential steering wheels
- In simulation
  - camera
  - 16 sonars
  - laser range finder
  - encoders
IntellWheels Simulator

Environment Model

- The map was created using Unreal Editor 3
- Similar to the Cerebral Palsy Institution
- Several components in the map were modelled using 3DStudioMax
Multimodal Interface
Multimodal Interface

- Which interaction is the best for wheelchair patients?

Several patient-wheelchair interfaces were proposed in the literature:

- Joystick / Buttons
  - Standard

- Facial Expressions
  - OSAKA IW

- Voice Commands
  - MIT IW

- Head Gestures
  - RoboChair IW

...
Multimodal Interface

- There is no single input well adapted for all physical limitations

IntellWheels combines user inputs (e.g. speech, pen, touch, manual gestures) in a coordinated manner with multimedia system output.

*Integrated inputs for the IntellWheels patient-wheelchair Multimodal Interface*
Multimodal Interface

Advantages

• Natural and transparent interaction style
• Flexibility depending on the user and context
• Adaptable to each user: User defined input sequences
• Freely associated to wheelchair output actions and interface actions
• Friendly Graphical User Interface

Action:
Wheelchair goes to Room

Blink Left Eye
Say “Go”
Shared Control

Potential field

- Does not map the environment in a world model representation;
- Instead, each ultrasonic range reading is treated as a repulsive force;
- Forces are computed in real-time;

\[ F_t = F_a + F_r \]

\[ F_r = \sum_{i=0}^{n} F_i \]
Experiments and Results
Experiments and results - MMI

IW Usability Experiment

- 46 individuals - simulated IW
- 12 individuals - real IW

Application of a questionnaire with the System Usability Scale (SUS)

- I felt safe in the management of the IW
- I felt I had control of the IW
- It is easy to drive in narrow places
- IW does not need too much attention

UbiSense System for IW tracking (40 Hz)
Experiments and results - MMI

[Graphs showing different control methods: Marked Route vs. Joystick Manual Mode, Marked Route vs. Gamepad Buttons, Marked Route vs. Head Movements, Marked Route vs. Voice Commands]
Experiments and results – MMI

- No statistical evidences to affirm that are differences between real and simulated environment in terms of safety and control of the IW

- Most of the users considered the multimodal way of driving the wheelchair very practical and satisfactory
Experiments and results – **Shared Control**

**Procedure**

- 1 set of 4 experiments
- 8 volunteers
- Drive the wheelchair through the user’s head position.
- Cluttered environment
- Application of a questionnaire with the System Usability Scale (SUS)

- Simulated environment with Manual control
- Simulated environment with Shared control
- Real environment with Manual control
- Real environment with Shared control
Experiments and results – **Shared Control**

- There is significant difference between both control paradigms in the real and in the simulated environments

- There is significant improvement in the user safety perception

- Volunteers felt that the shared control paradigm helped them to drive the wheelchair
Experiments and results – **Shared Control**

- There is statistical evidence that the shared control is effective to improve user’s safety perception.

- There is evidence that volunteers felt that the shared control paradigm helped them to drive the wheelchair.
Experiments and results – videos
Experiments and results – videos
Experiments and results – videos
IntellWheels in the Media
Conclusions
Conclusions

• **Platform to Develop Intelligent Wheelchairs**
  – Transformation of electric Wheelchairs into an Intelligent Wheelchair
  – Low cost, low ergonomic impact
  – Simulation with mixed reality support

• **Multimodal Interface**
  – Flexible Multimodal Interface – combination of multiple inputs!
  – User may define his own command language!

• **Collaboration with Health Institutions in 2011** *(FCT/RPID/ADA/109636/2009)*
  – Project started September 2010
  – ESTSP/IPP – School of Allied Health Science of Porto
  – APPC – Portuguese Association for Cerebral Palsy

• **New Prototype under Development**
  – Microsoft Kinect for mapping and obstacle avoidance
  – Facial Expression recognition module
  – Patient Modelling using Machine Learning algorithms
Future / Ongoing Work

Prototypes / Hardware
- New prototype under development
- ASUS Xtion for mapping and obstacle avoidance

Simulation
- New simulator based on Usarsim

Multimodal Interface
- Eye Gaze Tracking
- Facial Expression recognition
- Brain Computer interface

Automatic Wheelchair configuration
- Patient Modelling
- Machine Learning

Experiments with real patients (*FCT/RPID/ADA/109636/2009*)
- ESTSP/IPP – School of Allied Health Science of Porto
- APPC – Portuguese Association for Cerebral Palsy
Main Publications

Journals and Book Chapters


5. Brígida Mónica Faria, Sérgio Vasconcelos, Nuno Lau, Luís Paulo Reis, Patient Classification and Automatic Configuration of an Intelligent Wheelchair, Springer-Verlag, selected Papers from ICAART 2012 (accepted July 2012)

Conference Proceedings (Indexed at ISI Web of Knowledge)


Main Publications

Conference Proceedings (Indexed at ISI Web of Knowledge)


Other Publications


Main Publications

PhD Thesis


MSc Thesis

1. Marcelo Roberto Petry, Desenvolvimento do Protótipo e Controlo de uma Cadeira de Rodas Inteligente, MSc Thesis - MIEEC, FEUP, February 2008
4. José Carlos Pinto Miranda, Sistema de Visão para Controlo de Cadeira de Rodas Inteligente, MSc Artificial Intelligence and Intelligent Systems, FEUP and FEP, December 2009
5. Sérgio Miguel Fontes Vasconcelos, Multimodal Interface for an Intelligent Wheelchair, MSc Thesis - MIEIC, FEUP, February 2011

BSc Dissertations

1. Ana Luísa Silva, Condução de uma Cadeira de Rodas Inteligente Simulada Utilizando uma Interface Multimodal - Análise do Desempenho de Jovens Adultos com Paralisia Cerebral em Função da Experiência de Condução de Cadeira de Rodas Electrónica e Prática de Mobilidade de Desporto Adaptado, BSc Dissertation (Occupational Therapy) – ESTSP-IPP, July 2012
2. Sofia Teixeira, Análise da Condução de uma Cadeira de Rodas Inteligente com Interface Multimodal em Crianças entre os 6 e os 12 Anos com Paralisia Cerebral: Módulo de Simulação do Projecto Intellwheels, BSc Dissertation (Occupational Therapy) – ESTSP-IPP, July 2012
Intelligent Systems, Interaction and Multimedia Seminar, November 2012

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