Simulators and Platforms: Intellwheels 2.0 - Intelligent Wheelchair with Multimodal Interface

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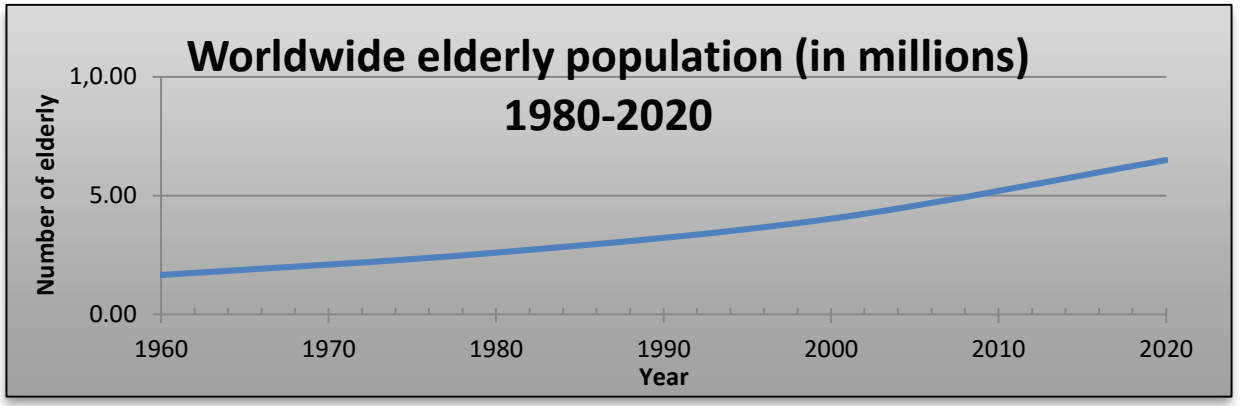
Intellwheels Project Motivation

- **Limited mobility of certain individuals**
  - Increment of the population aged over 60 years



- **Individuals with severe physical disabilities**
  - Cerebral palsy
  - Tetraplegia
- **Inability to control conventional electric wheelchairs**

Intelligent Wheelchair

- **Definition:**

  Robotic device with sensorial and actuation systems and processing capabilities:

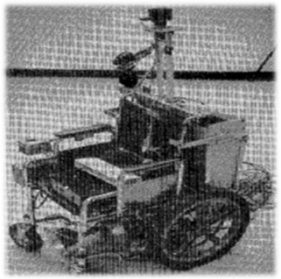
  - Semi-Autonomous behavior with **obstacle avoidance**
  - **Autonomous navigation** and planning capabilities
  - Flexible **Human-Machine interaction**
  - **Cooperation** with other IW and with other devices (e.g. automatic doors)

Related Work

- **More than 50 IW international projects**
  - Obstacle avoidance
  - Human-machine interface
  - MAS very restricted use
  - IW built from scratch
- **Inexistence**
  - IW useful in practice:
    - Very low cost
    - Low ergonomic impact
    - Useful for handicapped individuals
  - Mixed reality environment
  - Flexible multi-modal interface
  - IW development platform

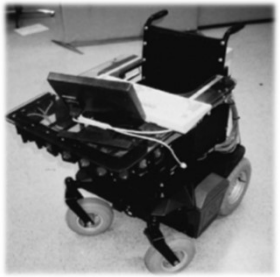
Related Work

- **Projects and Prototypes**


Madarasz [1986]


Omnidireccional IW [1993]


Two legs´IW [1994]


NavChair [1996]


Tin Man I [1995]


Tin Man II [1998]


FRIEND´s Project [1999]


LURCH [2007]


Robochair [2009]


VAHM [2010]


ARTY [2012]

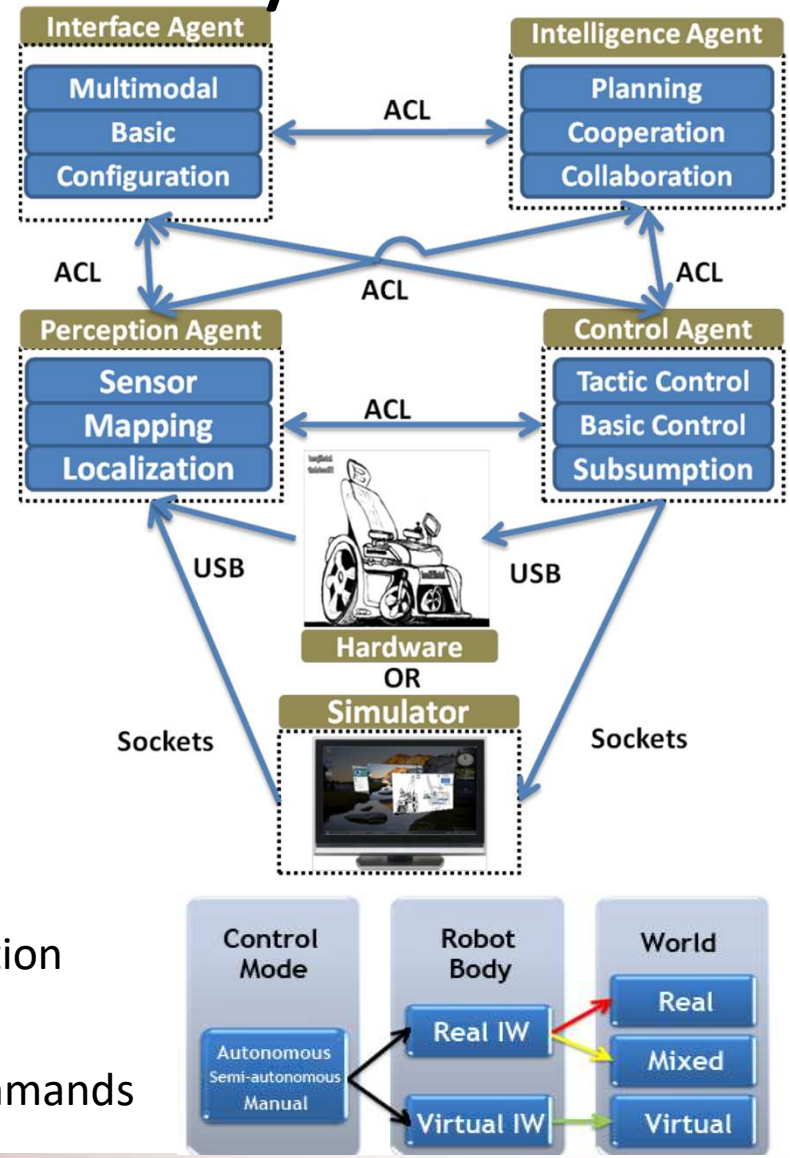

SDA [2012]

IntellWheels Software/MAS

Multi Agent approach

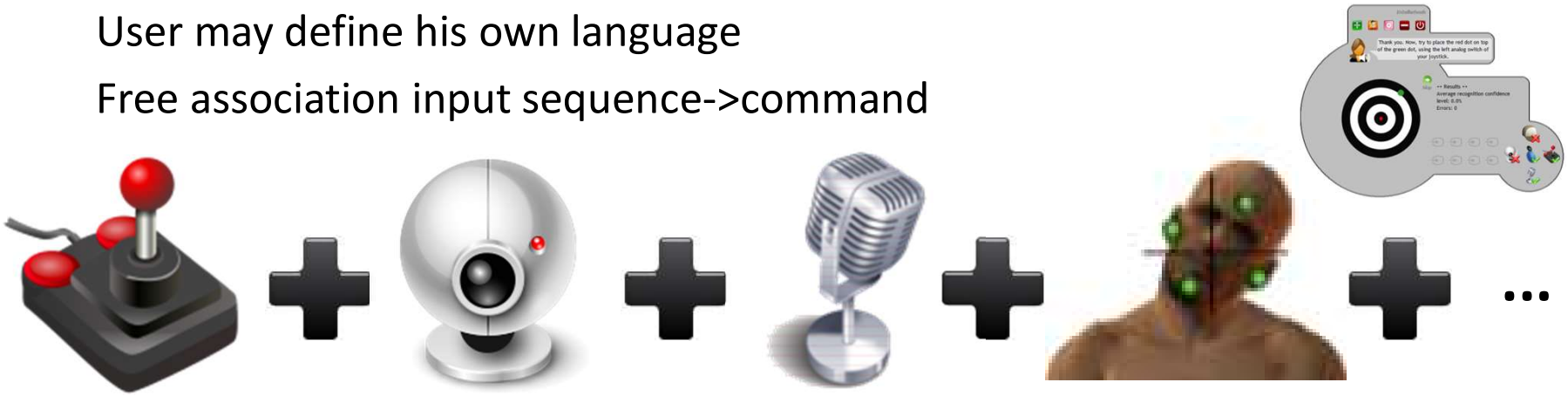
- Interaction, communication, redundancy
- Easy to add new functionalities

- **Hardware module**
  - Electric wheelchair, sensors, actuators, microprocessor, PC
- **Simulator module**
  - Virtual environment and mixed reality
- **Control Agent**
  - Low-level control algorithms
- **Perception Agent**
  - Sensors, mapping and localization
- **Intelligence/Cognitive Agent**
  - High-level decision, planning and cooperation
- **Interface Agent**
  - Interprets user's inputs into high level commands

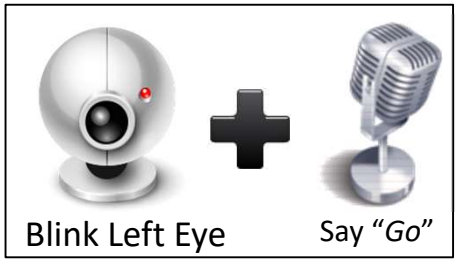


IntellWheels Multimodal Interface

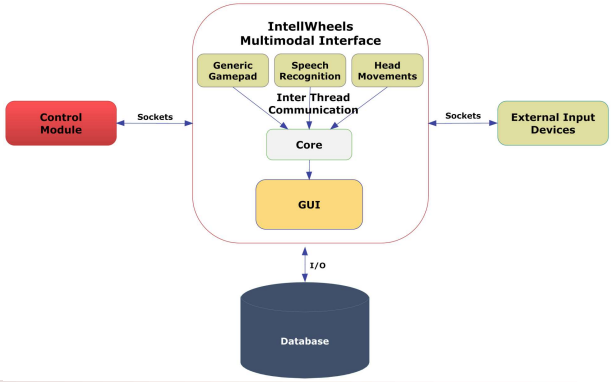
- **There is no single input well adapted for all physical limitations**
  - IntellWheels combines user inputs (e.g. speech, pen, touch, gestures)
  - User may define his own language
  - Free association input sequence->command



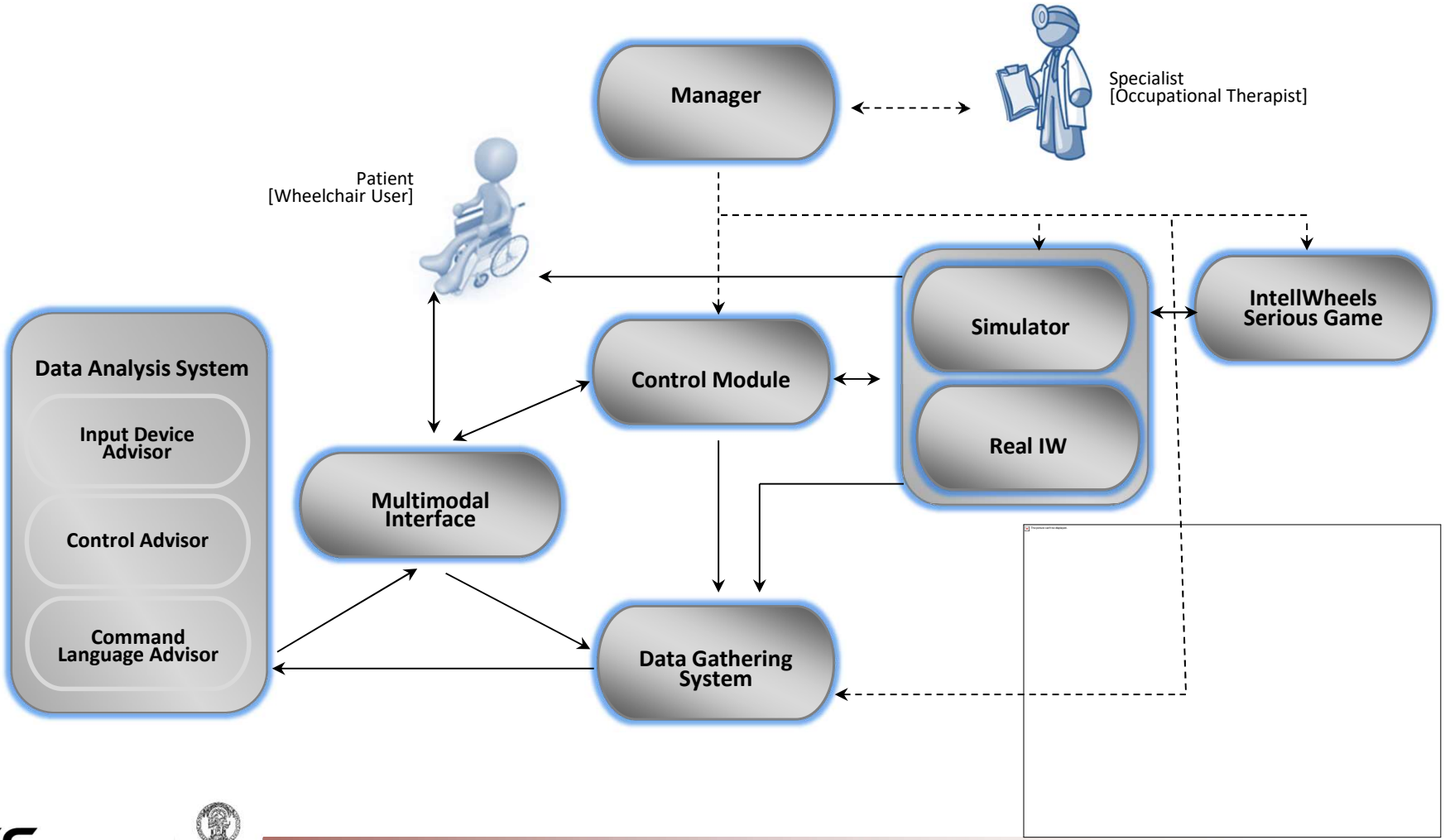
Joystick / Buttons **Facial Expressions** **Voice Commands** **Head Gestures**



Action: Wheelchair goes to Room A

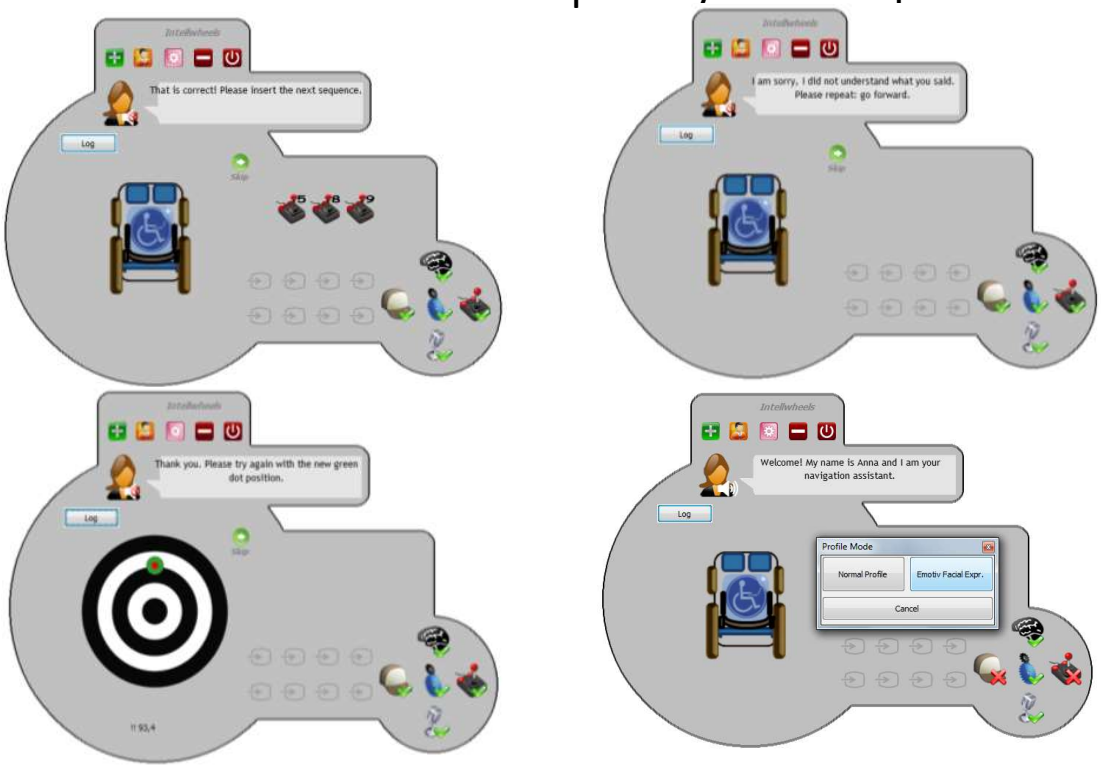


System Architecture



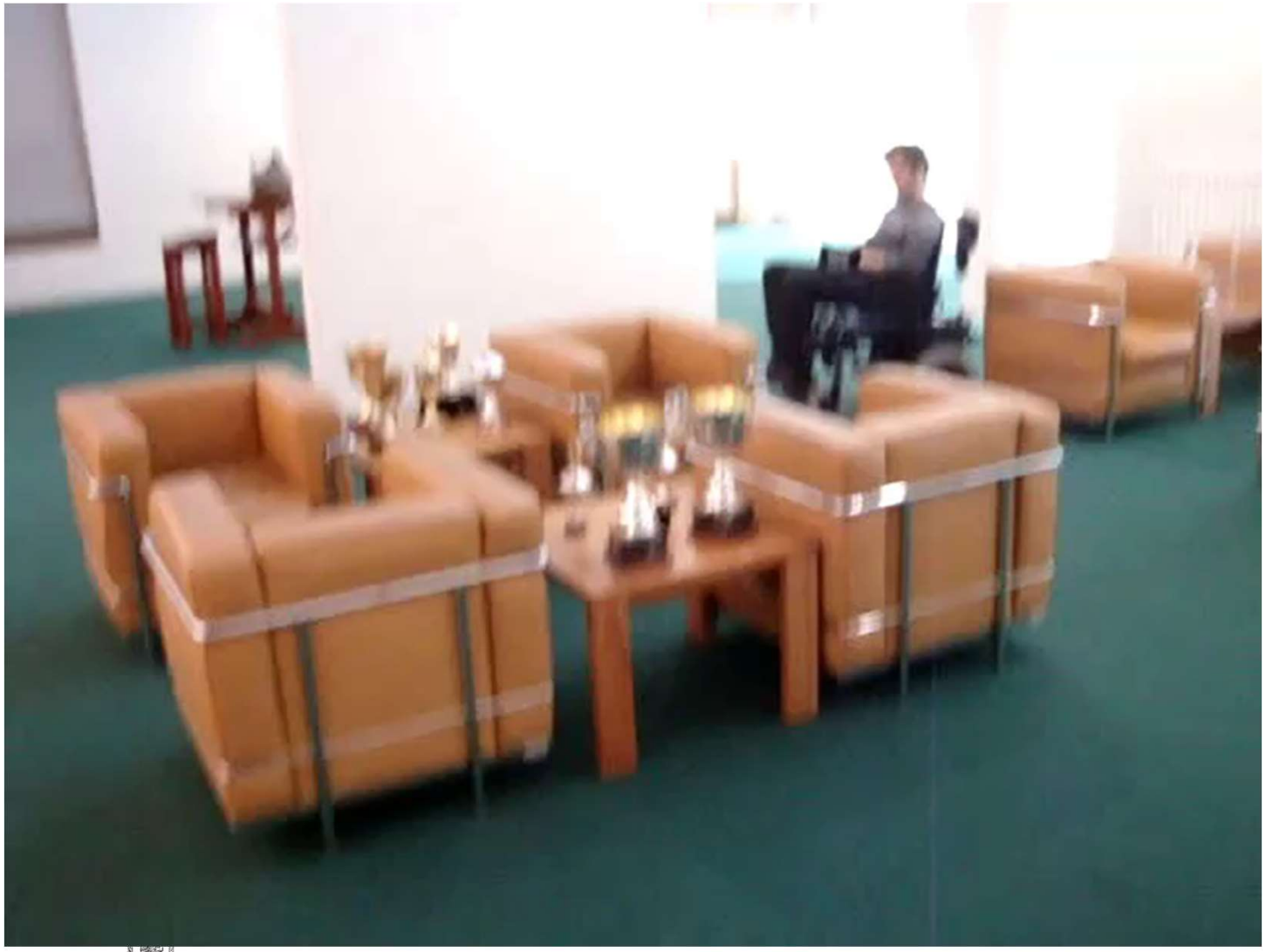
Multi-Modal Interface User Profiling

- **User Profiling**
  - Integrated in the Multimodal Interface
  - Simple interactive tests that do not involve the IW
  - Evaluates user capability to use inputs



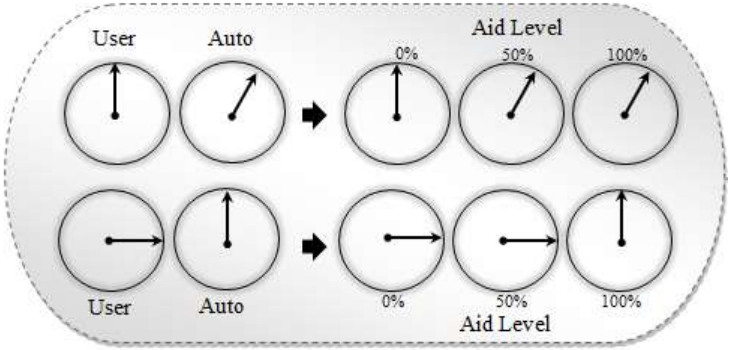
Simulated Environment and Wheelchair

Intellwheels – Prototype Tests



IntellSim – Tests With Cerebral Palsy Patients

- **Shared Wheelchair Control**
  - Aid level of 100%
  - Aid level of 50%
  - Manual with obstacle avoidance

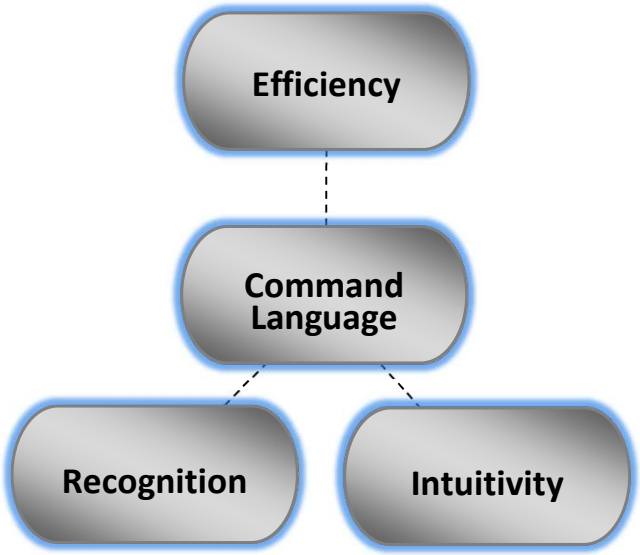



Obstacle Avoidance


Aided 50%

Data Analysis System

Command Language



Sequence of inputs S_i : $I^{(i,1)}\ I^{(i,2)}\ I^{(i,3)} \ldots I^{(i,Ni)}$

Efficiency: $$t_{S_i} = \sum_{k=1}^{N_i} t^{ID}_{I^{(i,k)}} + t_{timeout\,(i)}$$

time to select inputs timeout

$$T_C = \sum_{j=1}^{C_j} t_{S_j}$$ total time for all the commands

$$T_{C_{eff}} = \sum_{j=1}^{C_j} eff\,(t_{S_j})$$

$$eff : [0,+\infty[\rightarrow [0,1]$$

$$t_{S_i} \mapsto \frac{1}{t_{S_i}+1}$$

Sequence S_i recognition value

$$regS_i = \prod_{k=1}^{N_i} F^{ID}_{I^{(i,k)}}$$

Total recognition value of a set of commands

$$T_{reg} = \sum_{j=1}^{C_j} regS_j$$

Intuitiveness of a sequence of inputs S_i

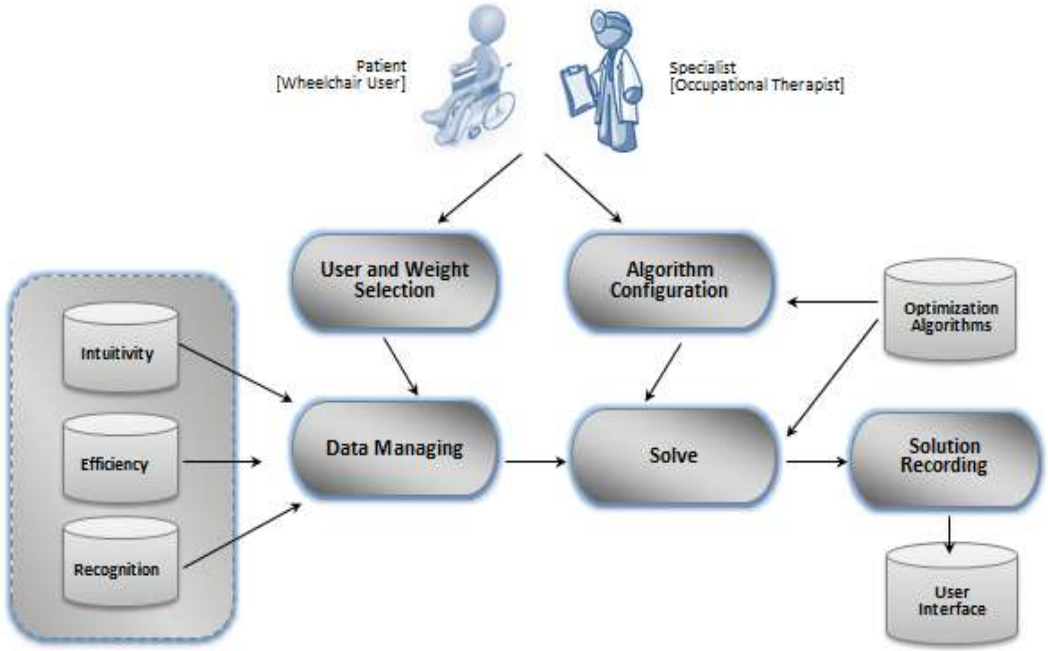
Commands	I_1 ("Go")	I_2 ("Left")	I_3 ("Right")	I_4 ("Back")	I_5 ("Stop")	I_6 ("Front")	I_7 ("Forward")
Forward	1	0	0	0	0	1	1
Left	0	1	0	0	0	0	0
Right	0	0	1	0	0	0	0
Back	0	0	0	1	0	0	0
Stop	0	0	0	0	1	0	0

Data Analysis System

Command Language

Maximizes the function composed by the total time efficiency, total recognition and intuitiveness

$$\arg\max_{T_{eff},T_{reg},T_{\text{int}}} (\alpha T_{eff} + \beta T_{reg} + \gamma T_{\text{int}})$$



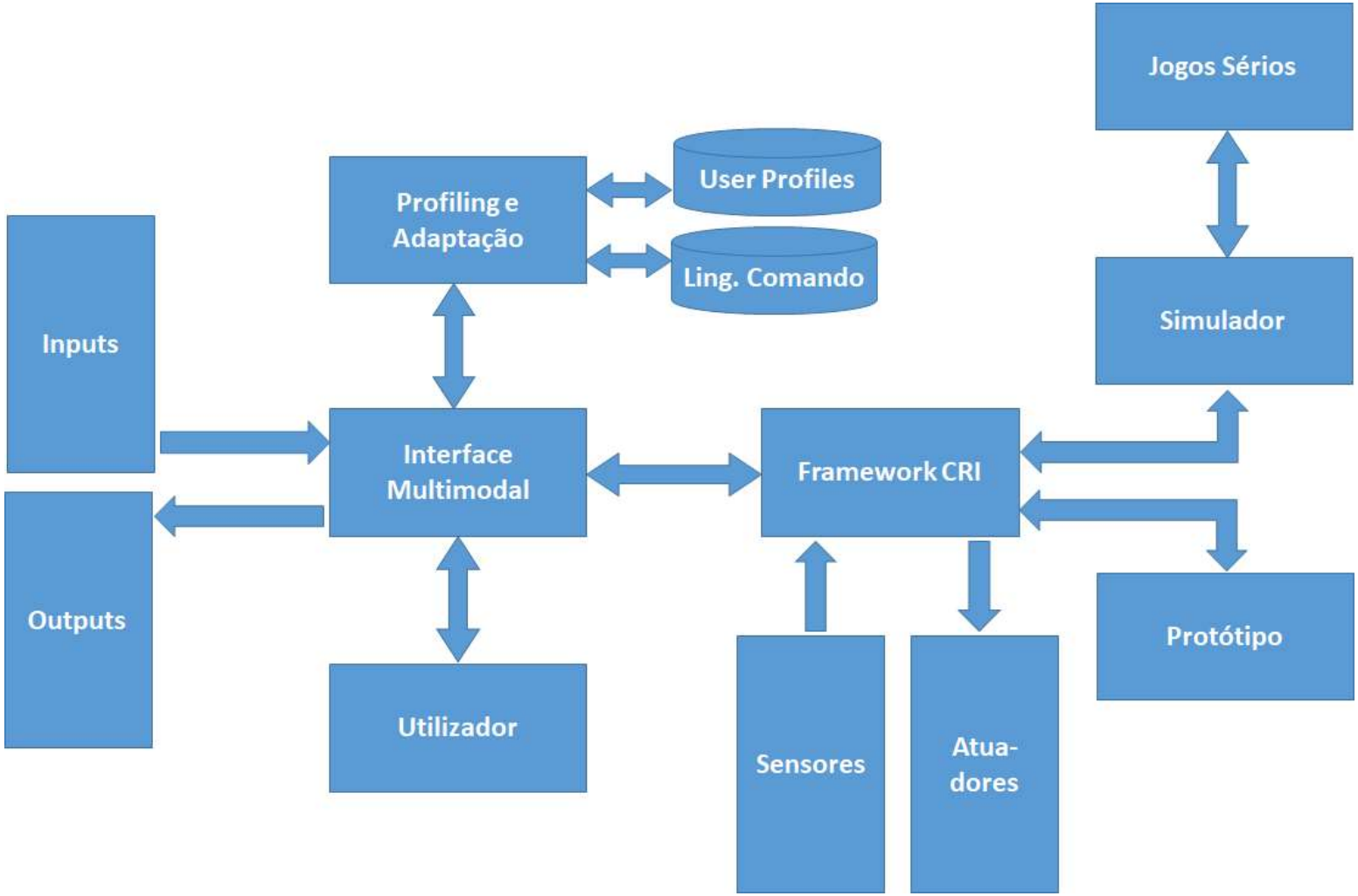

```
(w_rec, w_time, w_intu) = weights; evaluation ← 0
for ncom = 1 to NC do
   recVal ← 1; timeVal ← 0;  intuVal ← 1
   for nseq = 1 to NS do
      inpDev ← inputDevice(solution[ncom][nseq])
      inp ← input(newSolution[ncom][nseq])
      if inpDev = NULL then break
      else
         recVal ← recVal * rec[inpDev][inp]
         timeVal ← timeVal + time[inpDev][inp]
         intuVal ← intuVal * intu[ncom][inpDev][inp]
      endif
   endfor
   evalComm ← w_rec* recVal + w_time*1/(timeVal+1)
                    + w_intu*intuVal
   evaluation ← evaluation  +  evalComm
endfor
return evaluation
```

Intellwheels 2.0 - Institutions

- **Laboratories:**
  - **LIACC and IEETA**
- **Universities:**
  - **UPorto and UAveiro**
- **Companies:**
  - **Optimizer, Rehapoint and Ground Control Studios**

Funding: 1.045 M Euros

IntellWheels 2.0



IntellWheels 2.0

- Mapping
- Navigation
- Interface

IntellWheels 2.0

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Conclusions

- **Many IWs prototypes and games:**
  - User adaptation is often neglected
  - Non realistic games with simple wheelchair model
  - Rigid Interfaces adapted to a single user (or user group)
- **IntellWheels project:**
  - High-level commands through **Multimodal** interface
  - Interface **adapted** to users' characteristics
  - **Realistic simulator** for testing and training
  - **Serious Game** for driving Wheelchair integrated with IntellSim
- **Automatic adaptation** using user profiling and Command language adapted to the user
- **Shared control** with appropriate aid level

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