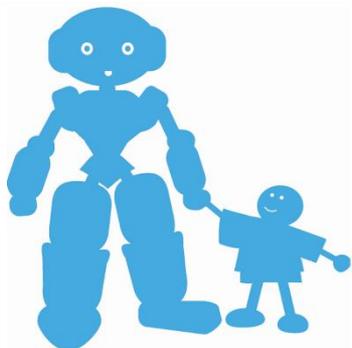


A Three-Layer Planning Architecture for the Autonomous Control of Rehabilitation Therapies Based on Social Robots

José Carlos González, José Carlos Pulido and Fernando Fernández

Planning and Learning Group



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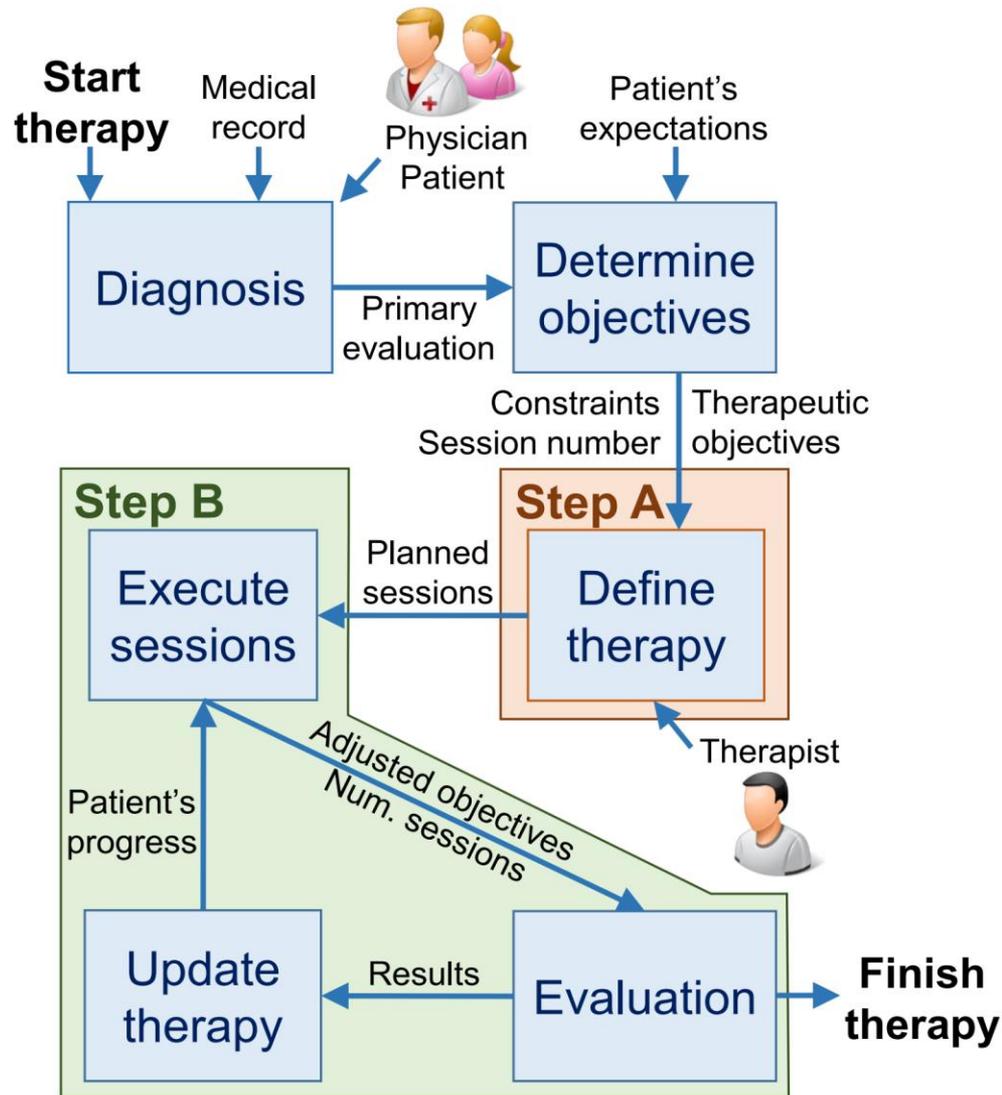
NAO THERAPIST

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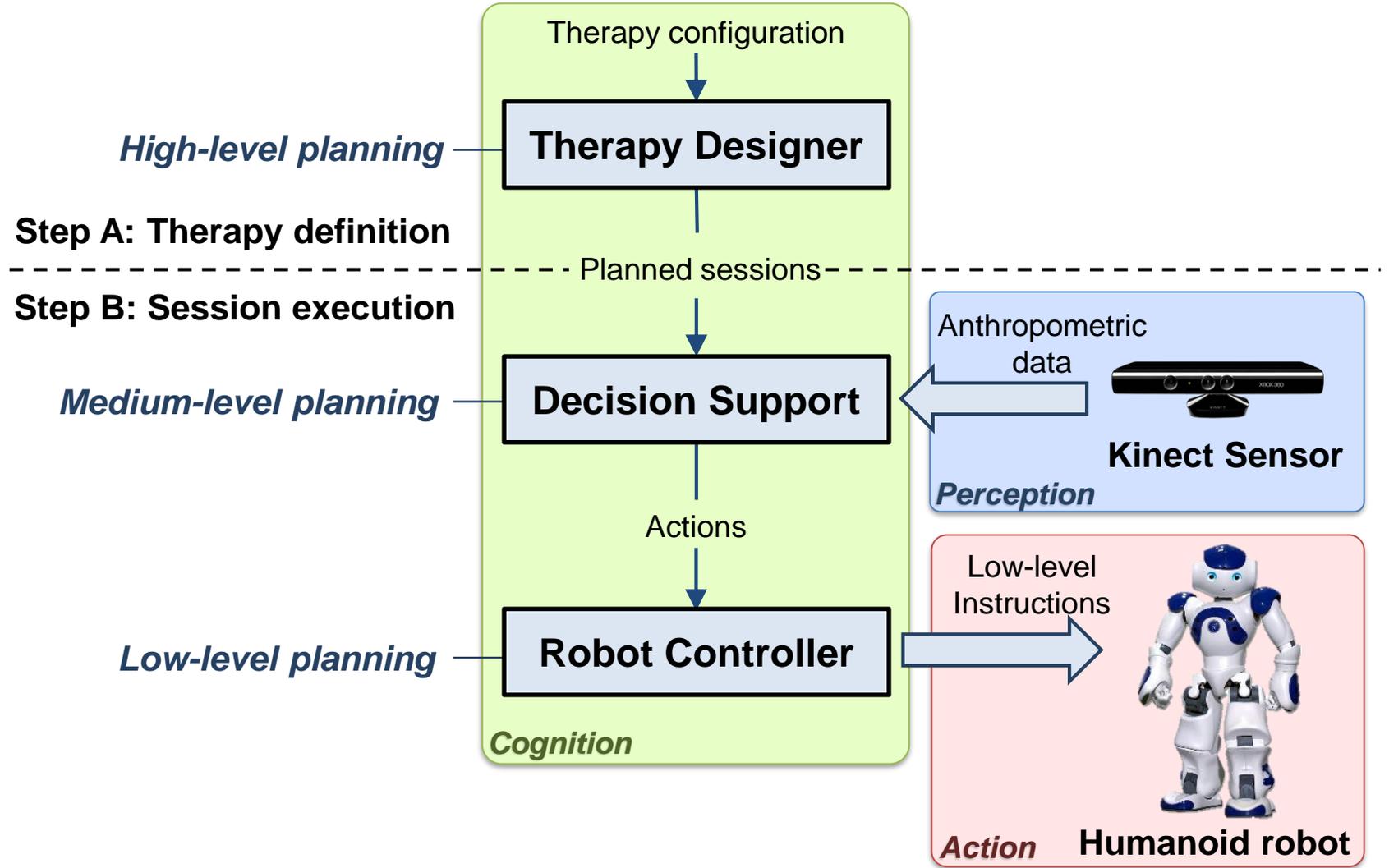


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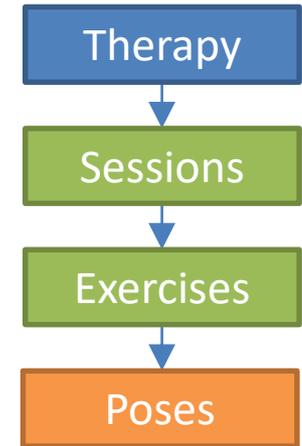
Therapeutic procedure



Automated Planning Levels



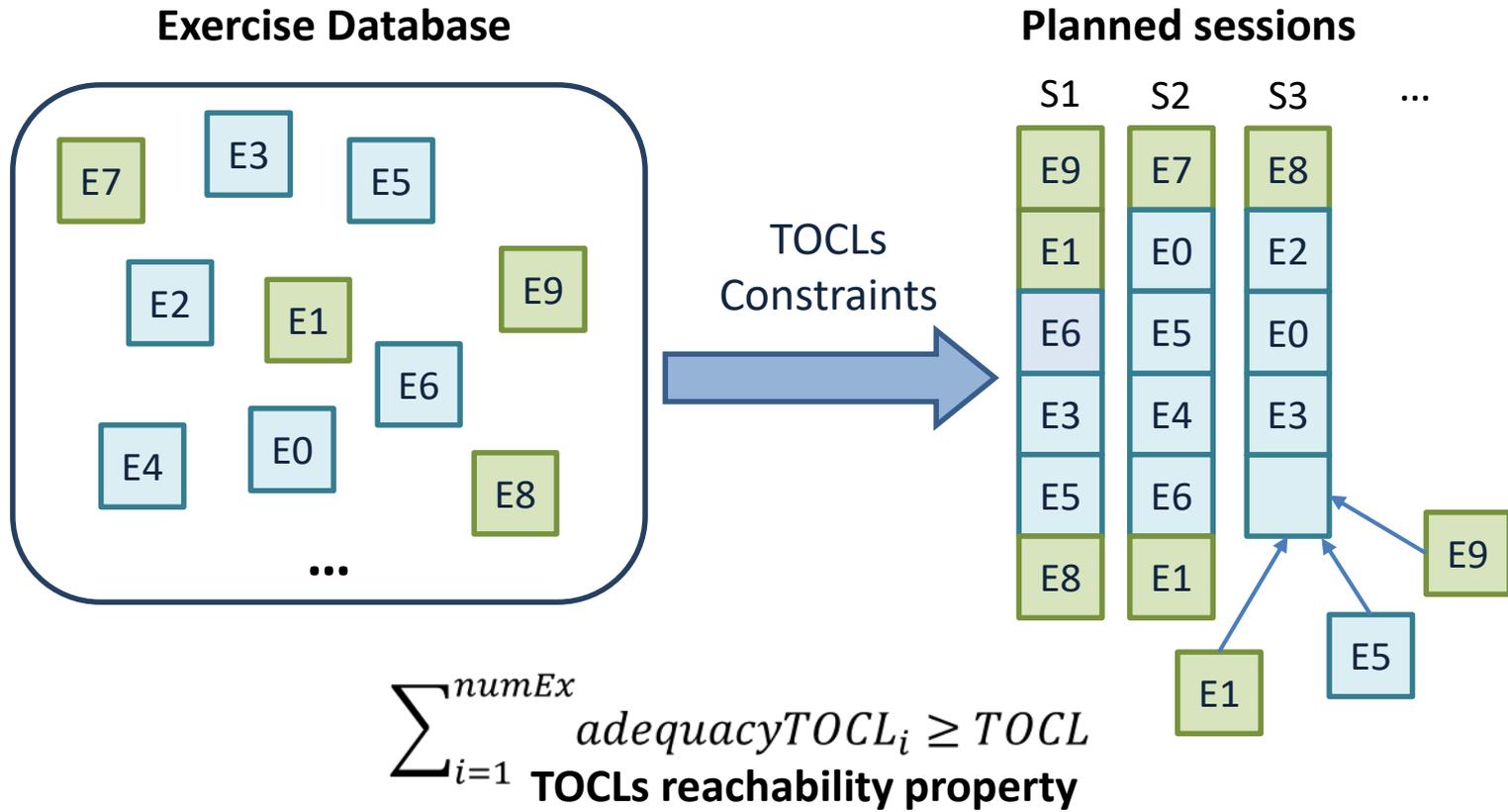
- **Sessions have exercises**
 - Maximum and minimum duration
 - Warming up, Training or Cooling down
- **Exercises have poses**
 - Set, perception, evaluation and correction
- **Variability and patient constraints**
 - Exercises cannot reappear in one session
 - Exercise distribution should be assorted throughout sessions
 - Avoid groups of exercises according to patient conditions



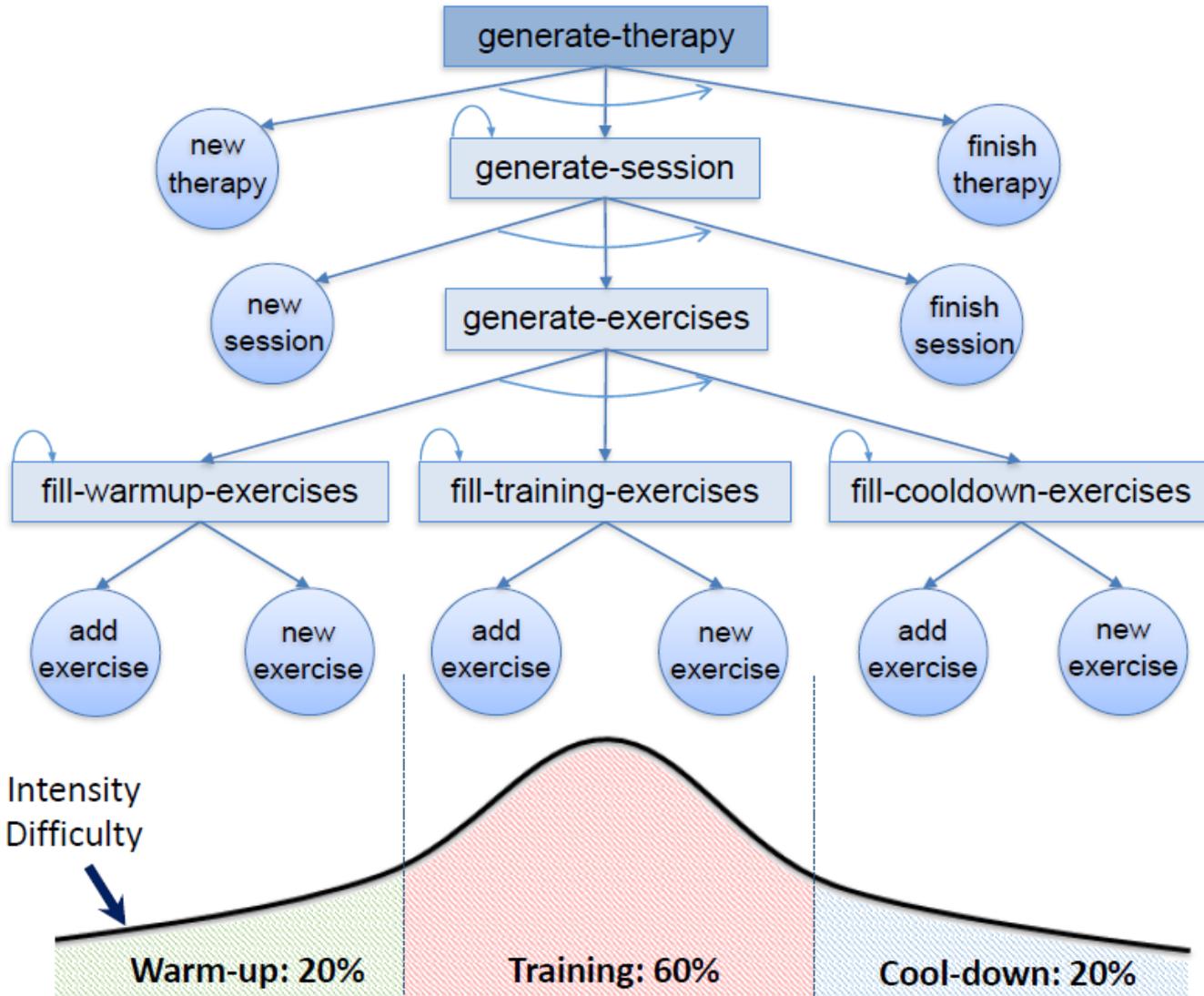
- TOCL (Therapeutic Objectives Cumulative Level)

Therapeutic Objectives	TOCLs example
1. Bimanual	15
2. Fine unimanual	30
3. Coarse unimanual	5
4. Arm positioning	0
5. Hand positioning	0

- Exercise attributes
 - **Adequacy level** for each therapeutic objective
 - Duration, intensity and difficulty
 - Group of exercise (capability)
- Problem goal: TOCLs reachability property
 - The sum of the adequacy levels of the planned exercises must **reach the respective TOCL** for each session



High-level planning – Therapy designer



Welcome stage



1. (detect-patient)
2. (identify-patient)
3. (greet-patient)

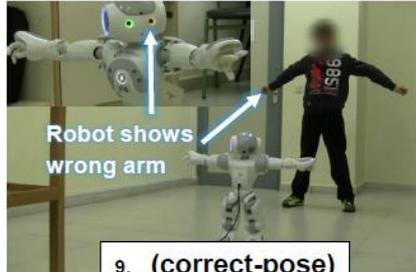


4. (stand-up)
5. (start-training)

Training stage



6. (introduce-exercise)
7. (start-exercise)
8. (execute-pose)



9. (correct-pose)
10. (finish-pose)



11. (finish-exercise)

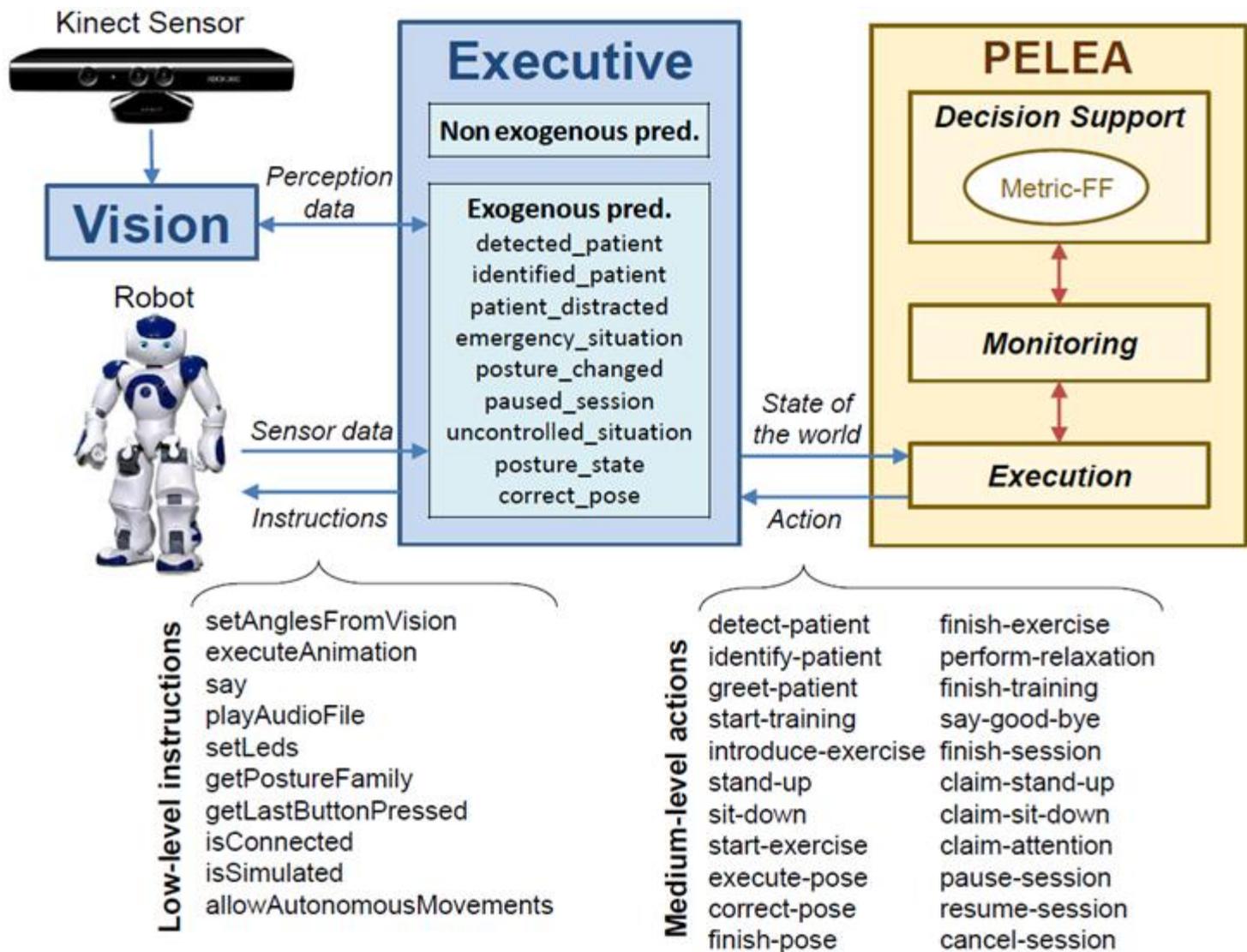
Farewell stage

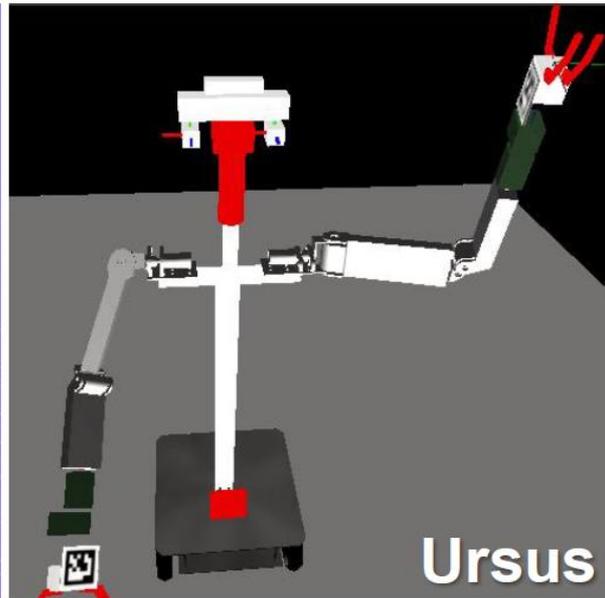


12. (finish-training)



13. (say-good-bye)
14. (finish-session)





- **Generic low-level actions**

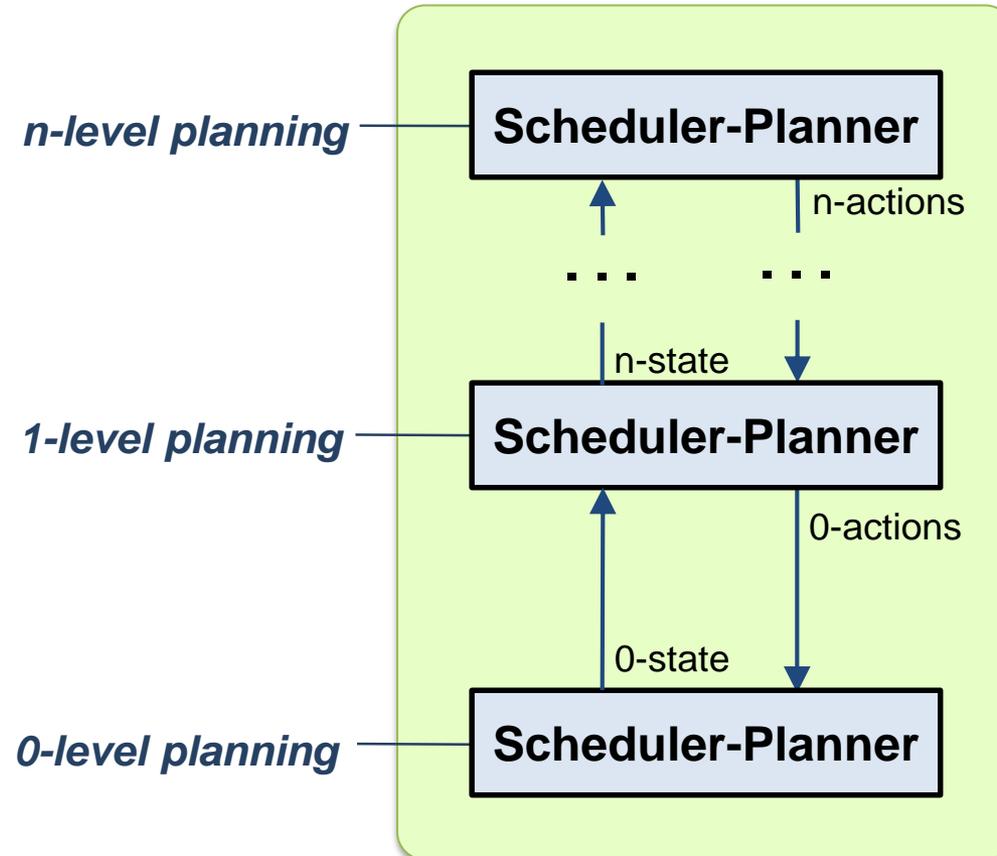
- Can be interpreted by **similar robots**
- Only the Robot component has to be rewritten
- Tested with NAO, Ursus robot (UNEX) and REEM robot (PAL)

- NAOTherapist allows a humanoid robot to **autonomously drive therapeutic sessions** previously planned by the system
- The control is addressed at **three abstraction levels**
 - **High level:** where the whole therapy is planned
 - **Medium level:** where the session is controlled
 - **Low level:** transparent for us, path-planning tasks
- It has been **evaluated with a large group of children...**

- **2015 – Initial tests**
 - **120 healthy children** in schools
 - **3 real patients** in a hospital
 - First interaction tests
 - Children liked the system
- **2016 – Long-term tests**
 - **12 patients** in a hospital
 - **2 times per week for 4 months**
 - Adjustements for real patients
 - Children were motivated
 - Our sessions were repetitive
 - Therapists were very interested
- **2017 – Intensive tests**
 - **25 patients** in a summer camp
 - **Every day for 3 weeks**
 - Polishing to develop a product
 - Several new activities
 - Therapists were very interested too
 - Children maintained their attention

- High-level (therapy designer)
 - **Replanning for high-level events**
- Medium-level (session execution)
 - **Fully declarative mechanism for our decision support**
 - Planning domain
 - Execution/monitoring of its actions
 - Refinement of actions and abstraction of states
 - **Interruption of actions** in the middle of their execution
 - **New games and interactive activities**
 - Simon with poses, storytelling...
- Low-level
 - **Independence from the 3D sensor**

- Development of a **fully generic multilevel control architecture**
- Comparison with similar control systems



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- **Evaluating the Child-Robot Interaction of the NAOTherapist Platform in Pediatric Rehabilitation:** José Carlos Pulido, José Carlos González, Cristina Suárez, Antonio Bandera, Pablo Bustos, Fernando Fernández. *International Journal of Social Robotics*, 2017.
- **A Three-Layer Planning Architecture for the Autonomous Control of Rehabilitation Therapies Based on Social Robots:** José Carlos González, José Carlos Pulido, Fernando Fernández. *Journal of Cognitive Systems Research*, 2017.
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- **Goal-directed Generation of Exercise Sets for Upper-Limb Rehabilitation:** José Carlos Pulido, José Carlos González, Arturo González-Ferrer, Javier García, Fernando Fernández, Antonio Bandera, Pablo Bustos and Cristina Suárez, in *proceedings of the 5th Workshop on Knowledge Engineering for Planning and Scheduling (KEPS), ICAPS conference*, pp. 38-45, Portsmouth (New Hampshire, USA), 2014.

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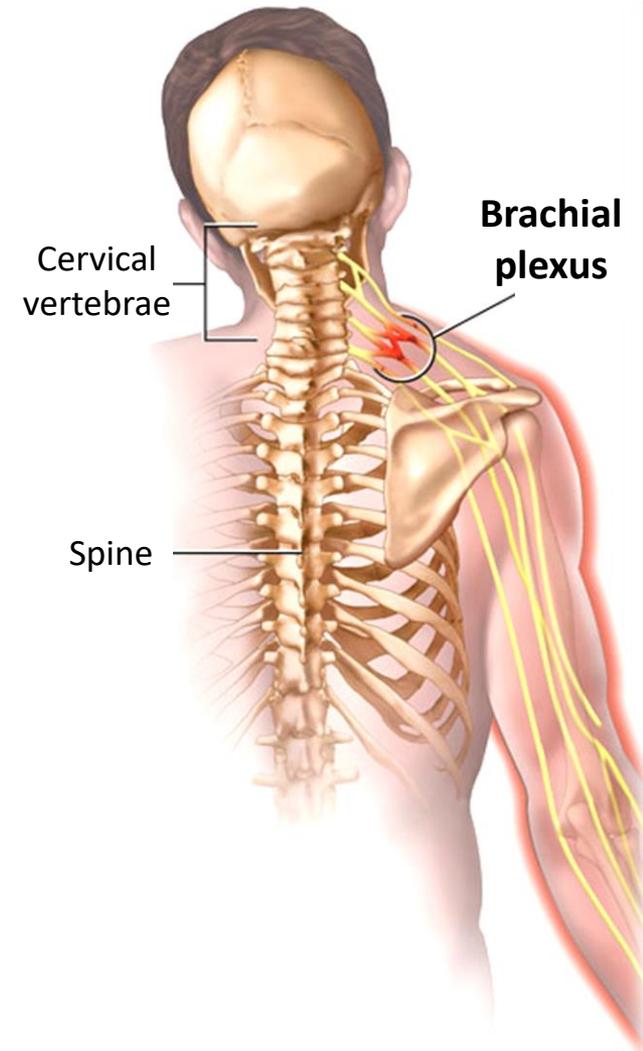
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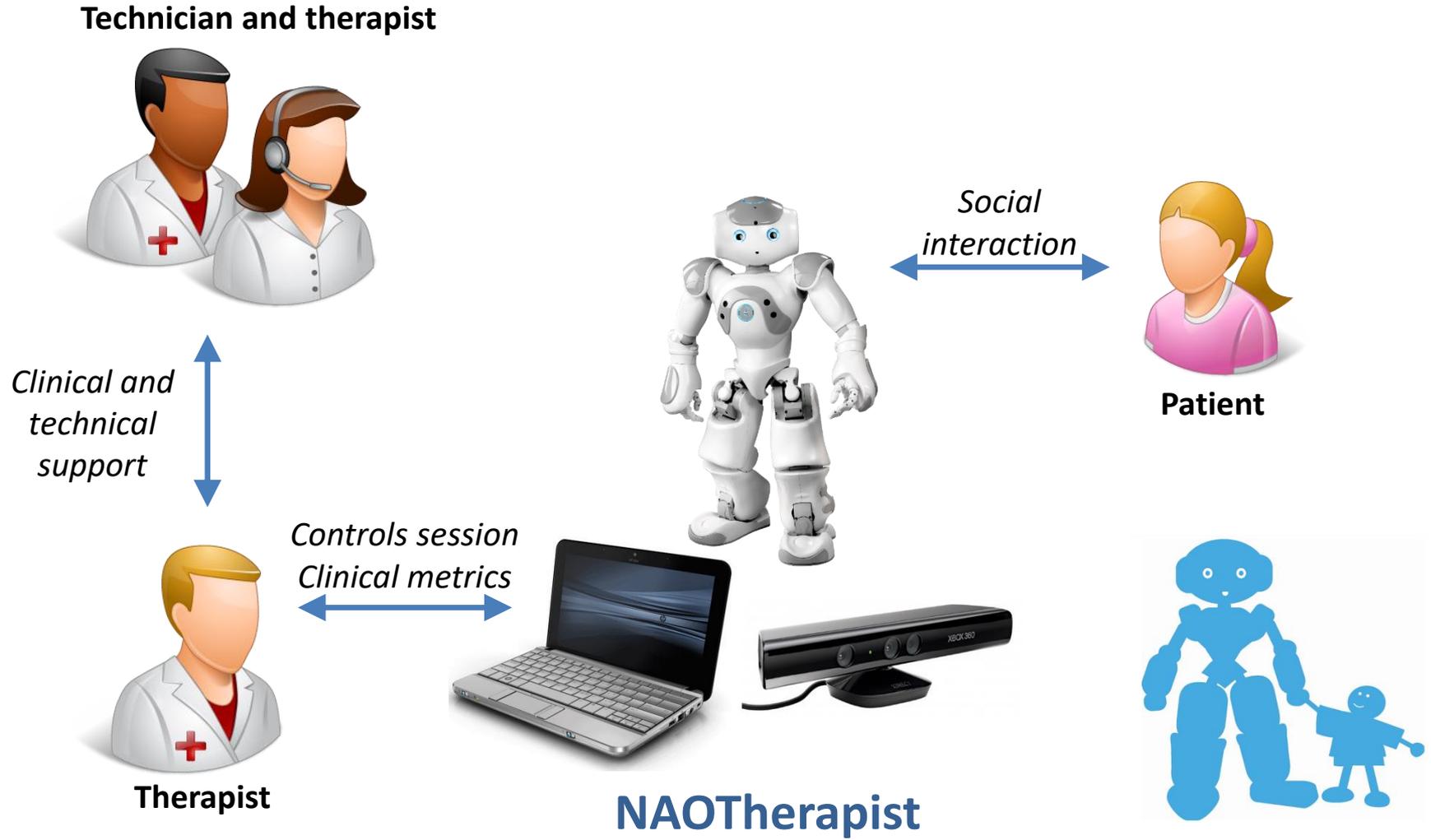


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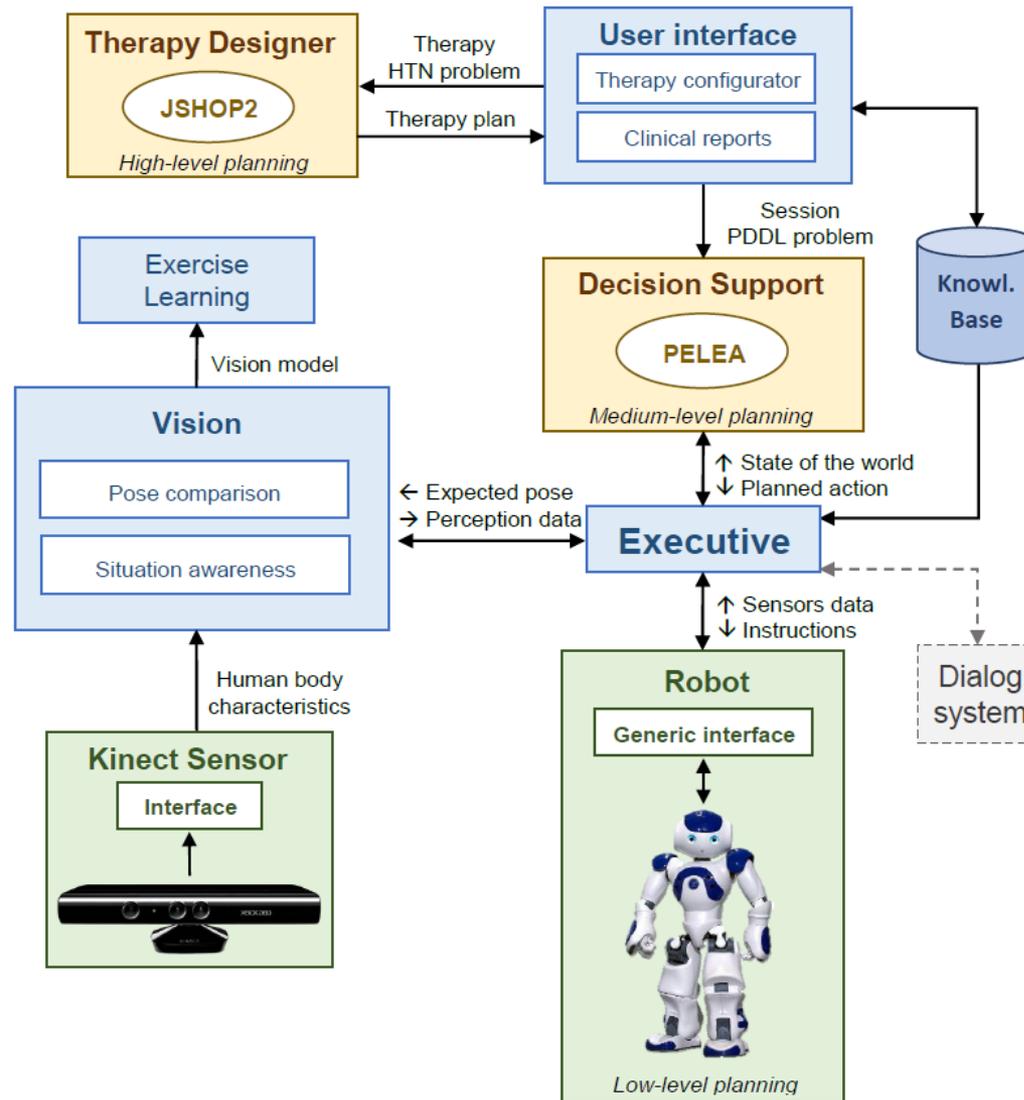
Thank you for your attention

- **Cerebral palsy and brachial plexus palsy**
 - Children with upper-limb impairments
 - They improve with rehabilitation
- **Very long and repetitive sessions**
 - Patients may lose interest
 - A lot of time for clinicians
- **Autonomous social therapeutic robots**
 - Motivate patients
 - Can capture clinical metrics on the fly





NAOTherapist Architecture



- Modular
- Distributed
- Reusable

- **Replanning** mechanism
 - Mature planning framework
 - Modular
 - Check the actual effects in the environment
 - Planner as a black box
- **Receives** world states
 - Transformed to full high-level states
- **Plans** every deliberative low-level action
 - Plans at high level
 - High->Low-level action set

