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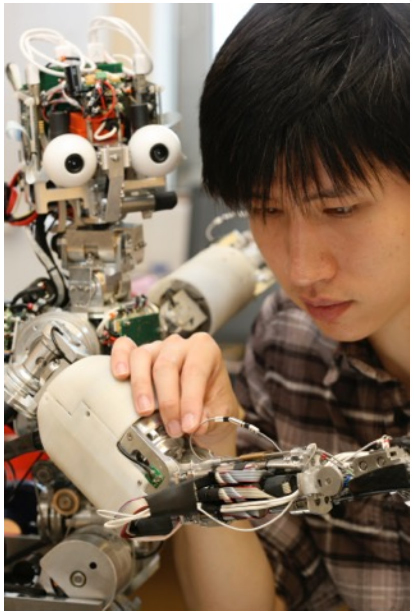

HUMAN-ROBOT COLLABORATION - PERSONALISATION AND DEVELOPMENTAL ISSUES

Yiannis Demiris

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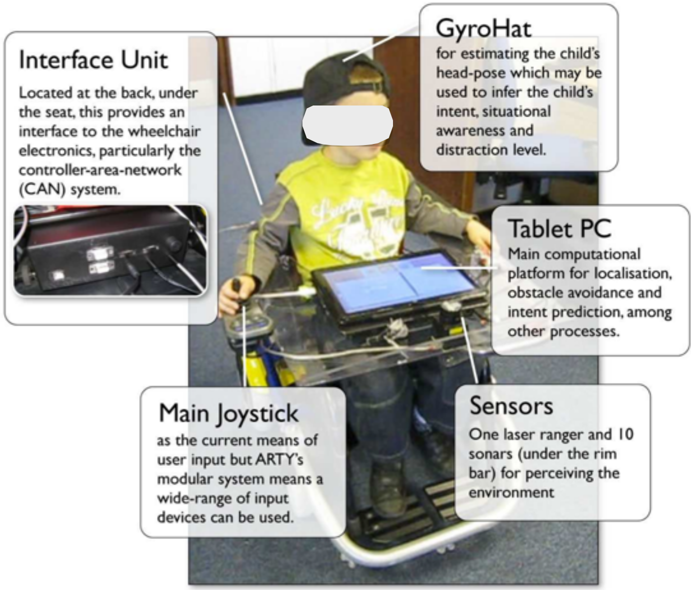
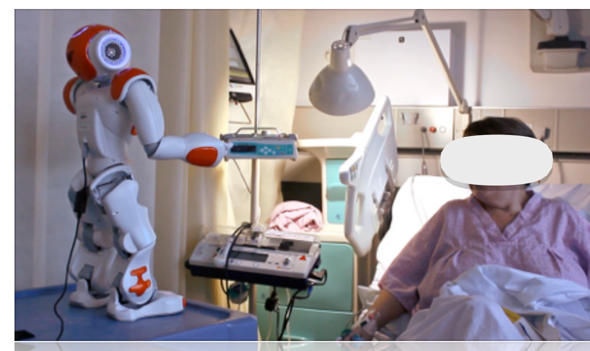
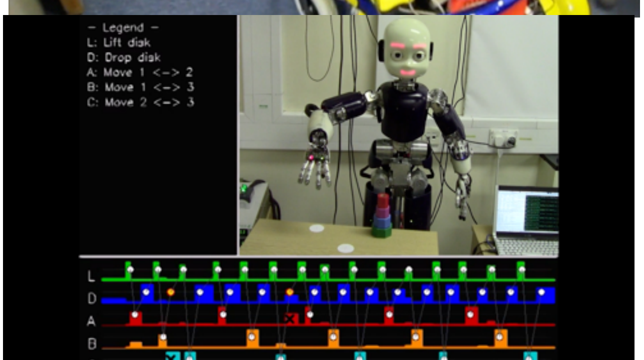
http://www.imperial.ac.uk/PersonalRobotics

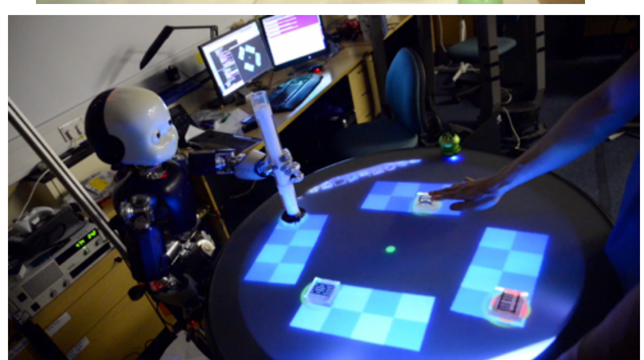


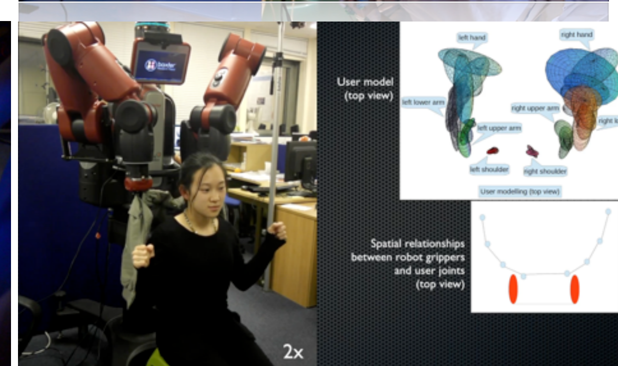
Cognitive Robot Systems that *learn* *to:*

- **Perceive** the world & users through sensors
- **Model** users, learn their skills and preferences, predict intentions
- **Collaborate** with the users to maximize learning outcomes
- Interaction over **extended** periods of time





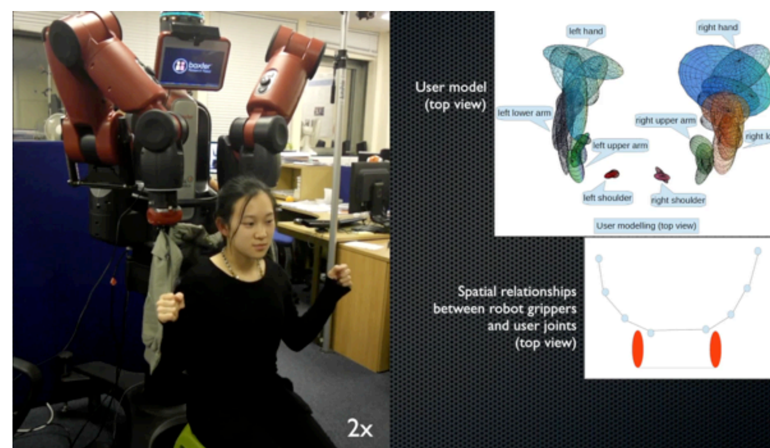




Joint actions and tasks: key issues

- **Personalisation:**
  - Participants explicitly model their partner's parameters (skills, preferences, …) and adjust their behaviour based on the internal models; prediction a key element
  - Hierarchical partner modelling using ensembles of inverse and forward models at increasing levels of abstraction

- **Lifelong joint action constraints:**
  - Includes developmental aspects: in our domain outcome is improvement of one or more of the partners, not only success of an external temporary goal



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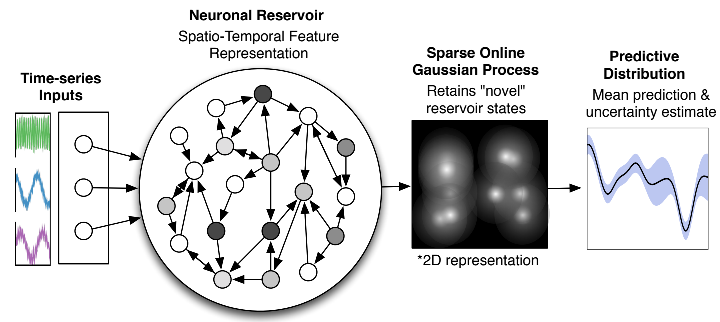
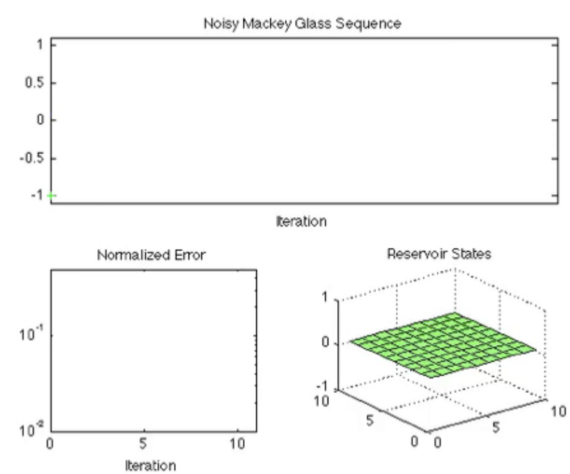
Continuous (lifelong) Interactive Learning Cycle

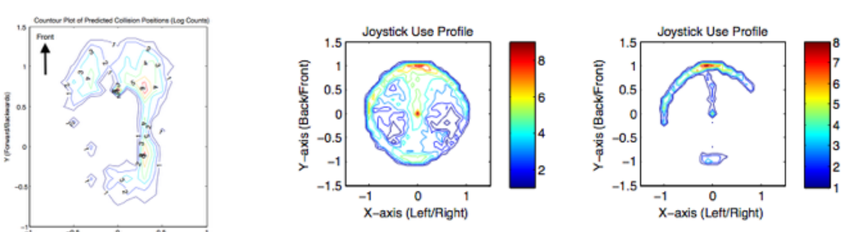
1. Perceive partner's actions

2. Use machine learning algorithms to build hierarchical user models





3. Predict required levels of assistance / collaborative control



(a) C (b) Reference

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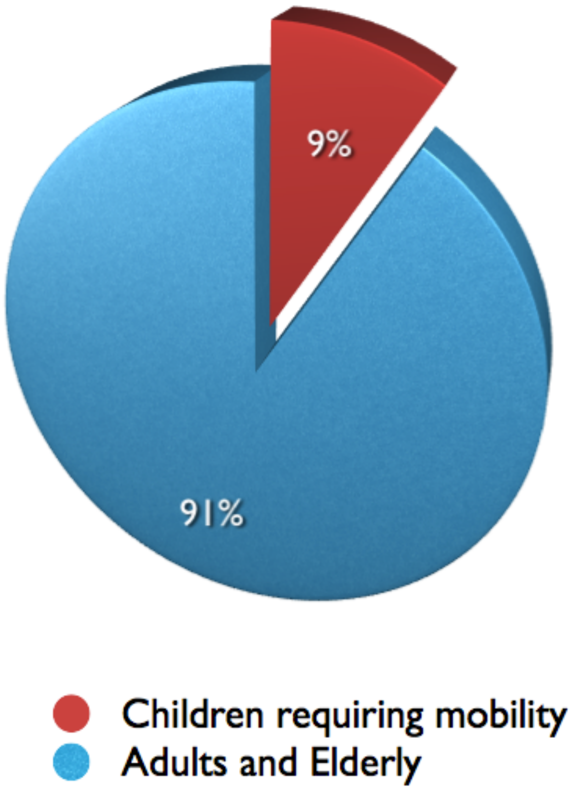
Disabled children in the UK

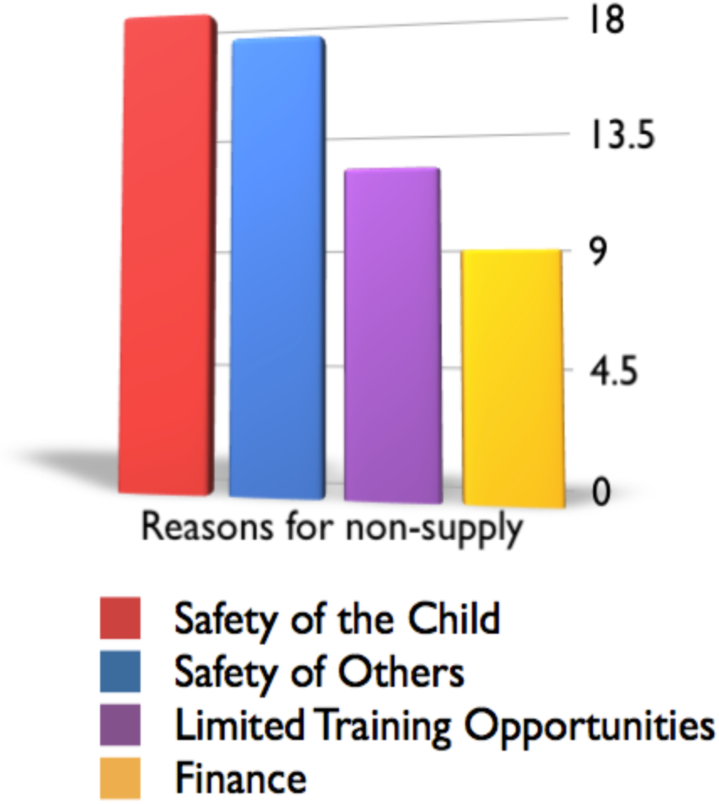


- **~54,000** children require wheelchairs [1,2]
- **33%** cannot navigate independently [3]
- **Safety** concerns **limits wheelchair provision** by NHS [4]

[1] Audit Commission, 2000

Limited Provision of Powered Wheelchairs

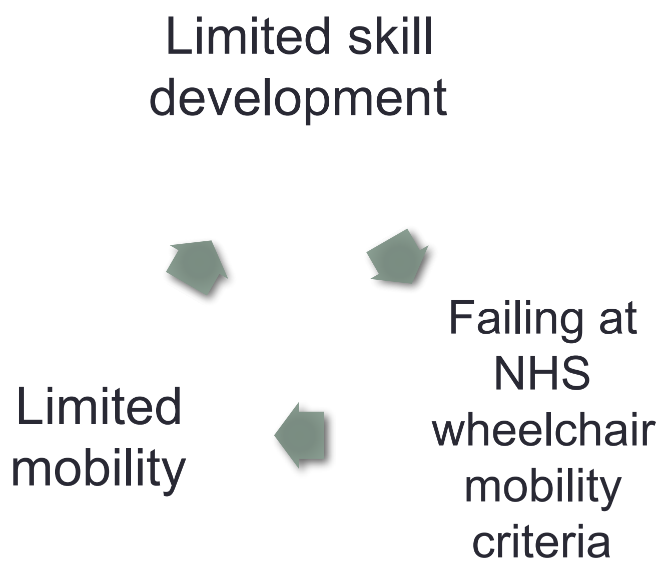
- Nicholson and Bonsall Survey of 139 NHS Wheelchair Services [4].
- Of 97 respondents, **50** (51%) did not supply wheelchairs for children (< 5 years).
- Why? ***Safety concerns.***

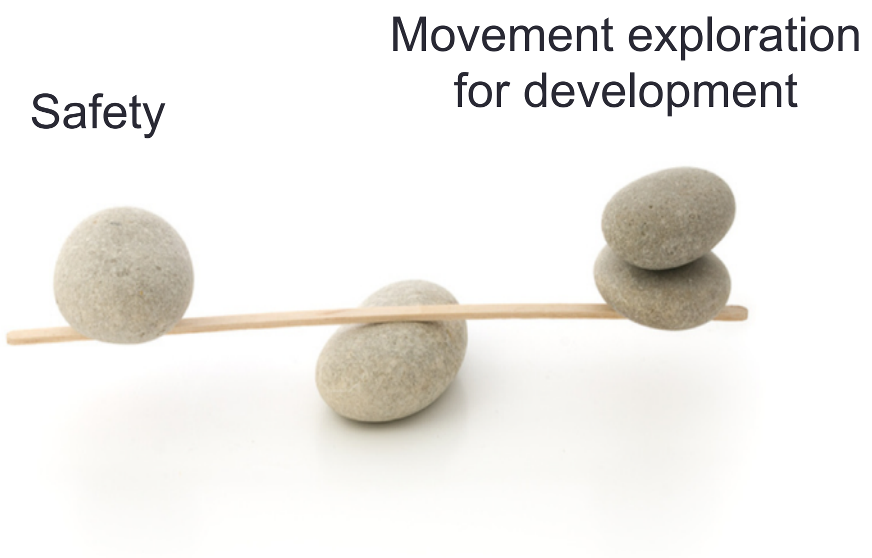


Providing safe exploration opportunities

- In the development-critical years below 5, deprivation of movement leads to "learned helplessness"

- Vicious cycle:



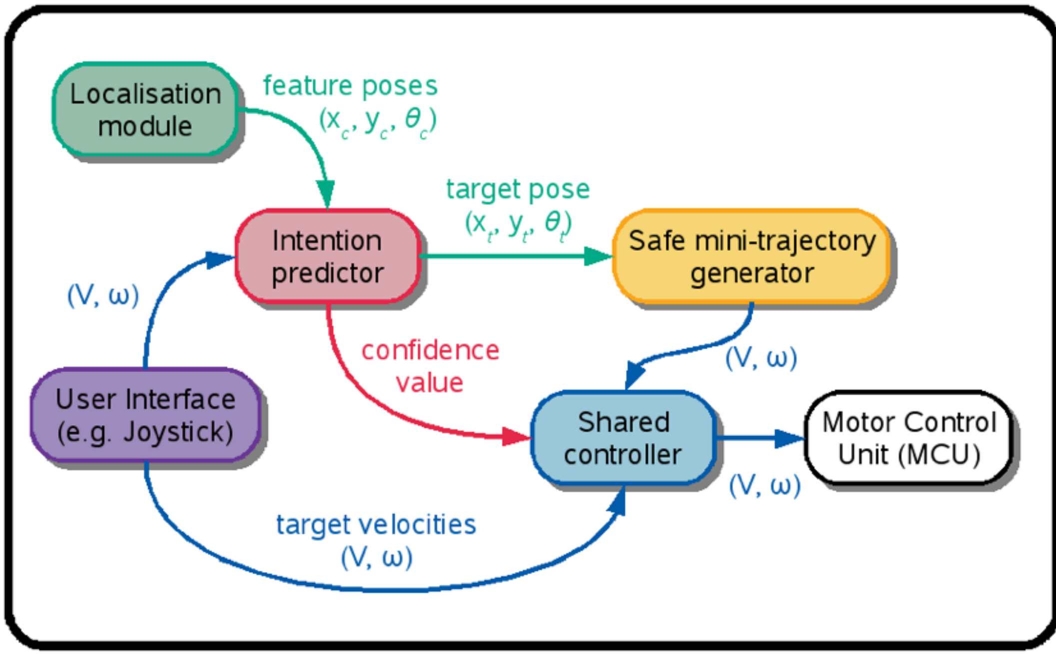


Our approach: adaptive collaborative control with intelligent robotic wheelchairs

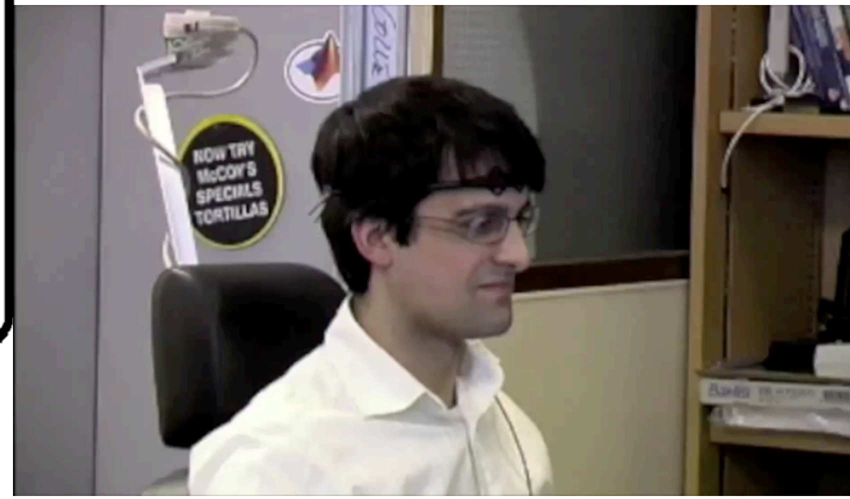
(and humanoid robot assistants)

Prediction of intention during collaborative task execution

Assisting only when needed



Haptic Joystick based control

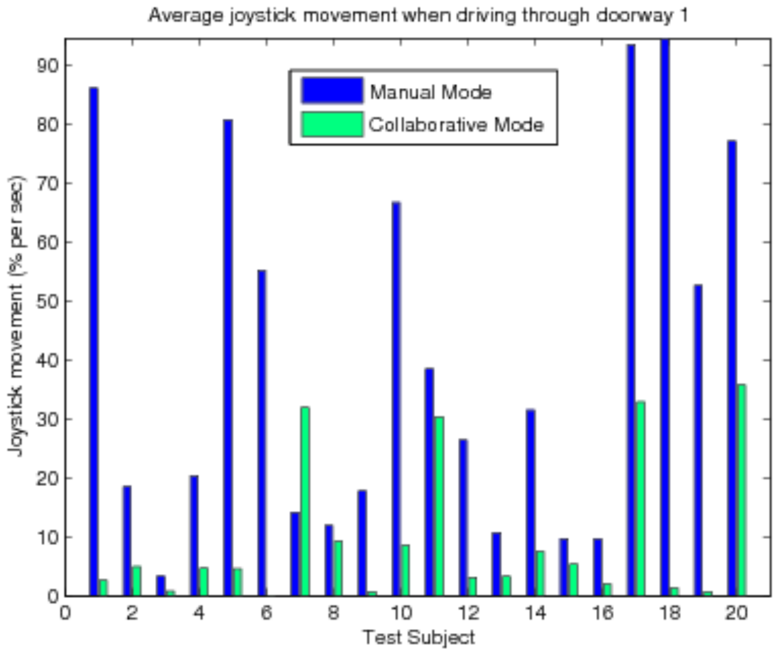


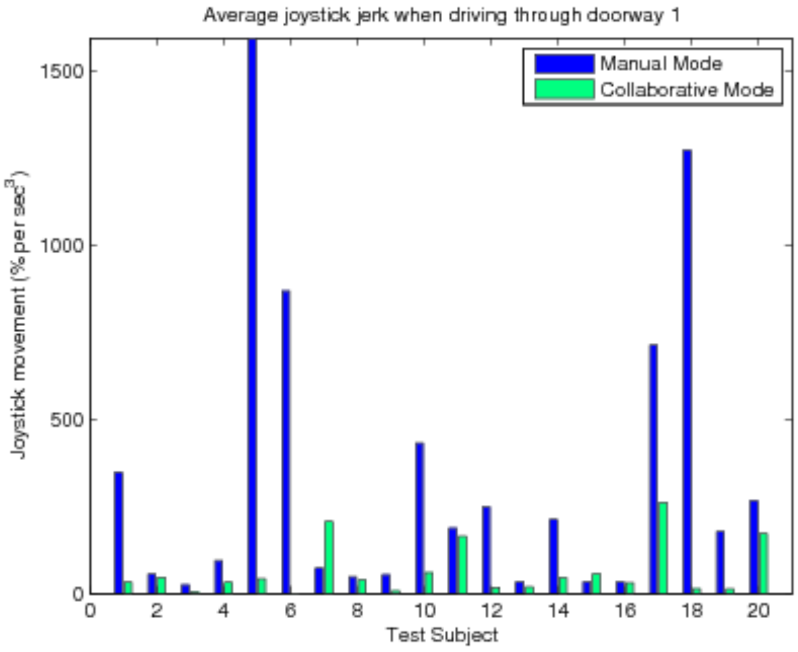
Electromyograph-based (EMG) control

- [T. Carlson and Y. Demiris, IEEE ICRA-2008 & IEEE Transactions SMC-B 2012, H Soh and Y Demiris, JHRI 2015]

Human evaluations

reduction of joystick movements and jerk





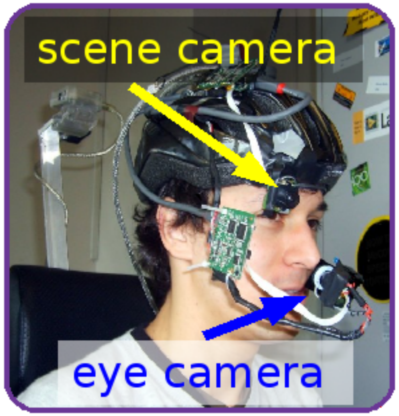
- 81.7% reduction of joystick movements ($p < 0.001$)

75% of cases reduction of jerk (movement smoothness)

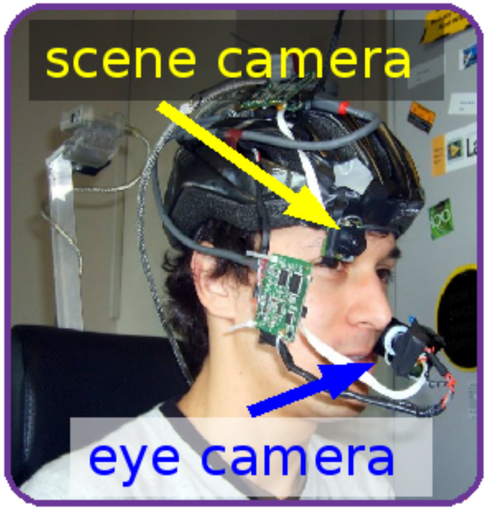
But not everyone benefited!

Evaluation II

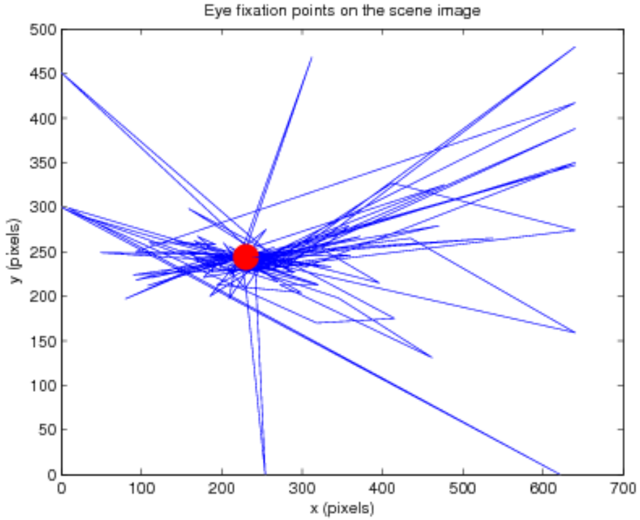
Gaze tracking

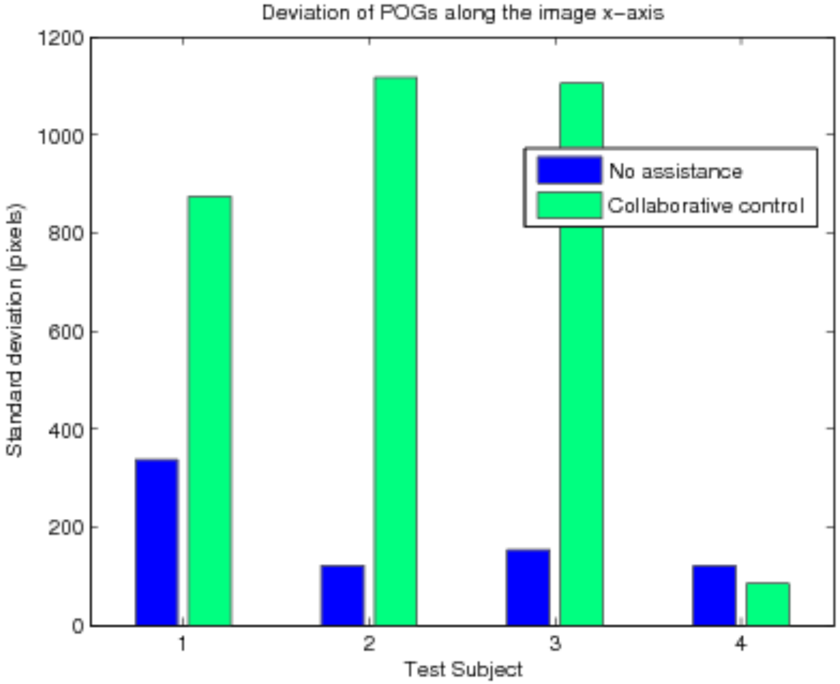


Evaluation II: Gaze Tracking [2]



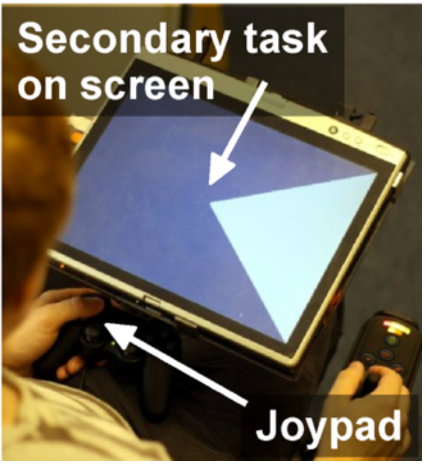
- For more experienced users, saccadic eye movements became more erratic when assisted
- Shared control disturbs the user's forward model

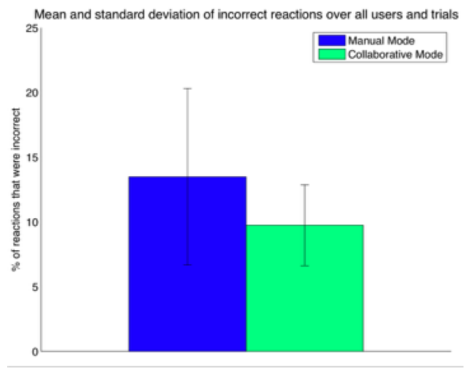


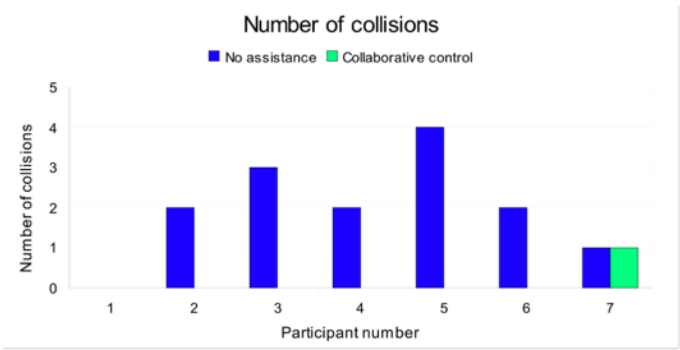


Evaluation III: Secondary task

Clear advantage for when the user is preoccupied with other activities







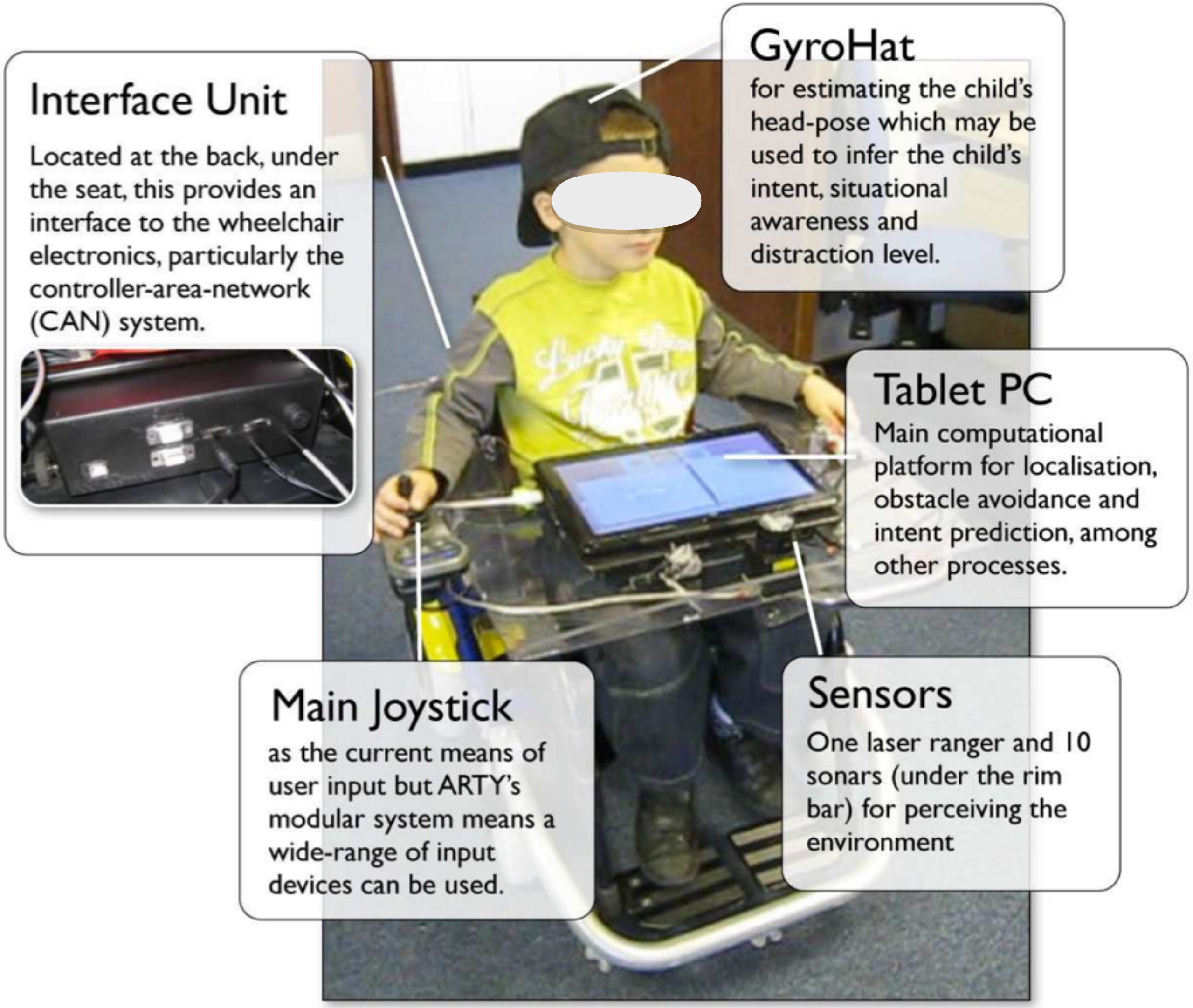
First conclusions: need for personalisation in human-robot collaboration

- One size does not fit all
- Assistance is not always needed/wanted
  - Must determine conditions under which joint action is desirable, and assistance is needed.
  - Need for lifelong user modeling of sensorimotor and cognitive skills
    - A decent amount of work in the fields of computer-aided learning, intelligent tutoring…
    - **Very little work in sensorimotor domains**

Designing for children

Children Robotic wheelchairs

Supporting the development of young disabled children



Case study: Children Robotic wheelchairs

Supporting the development of young disabled children

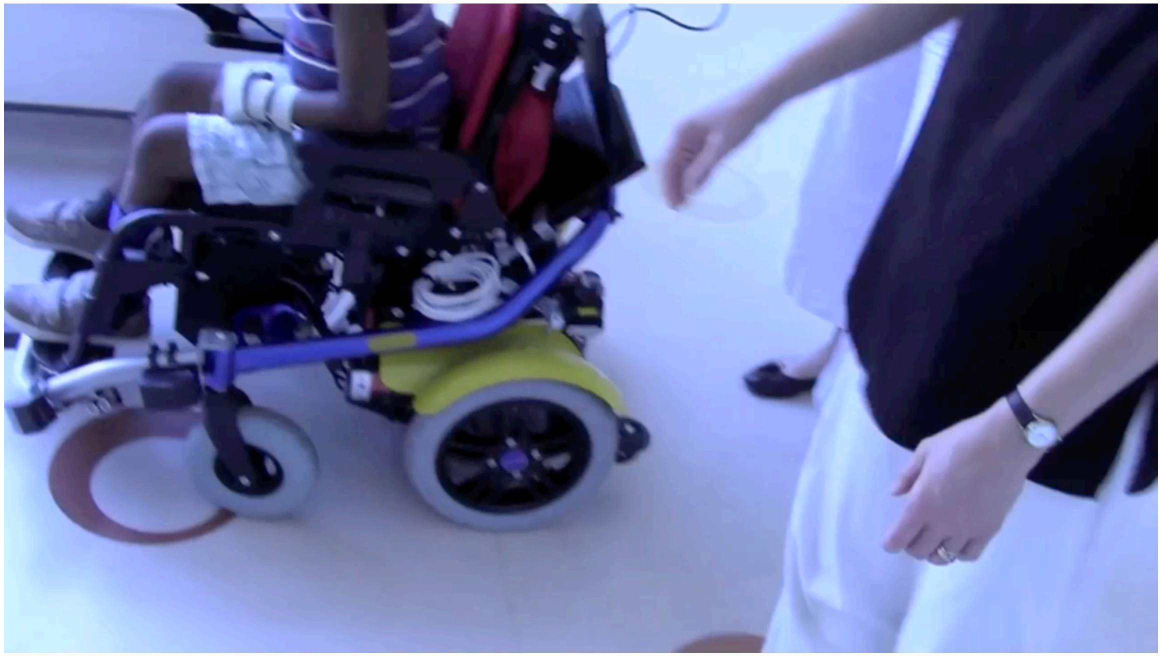
Soh and Demiris, IEEE Trans. NNLS 2015, & J Human Robot Interaction 2015

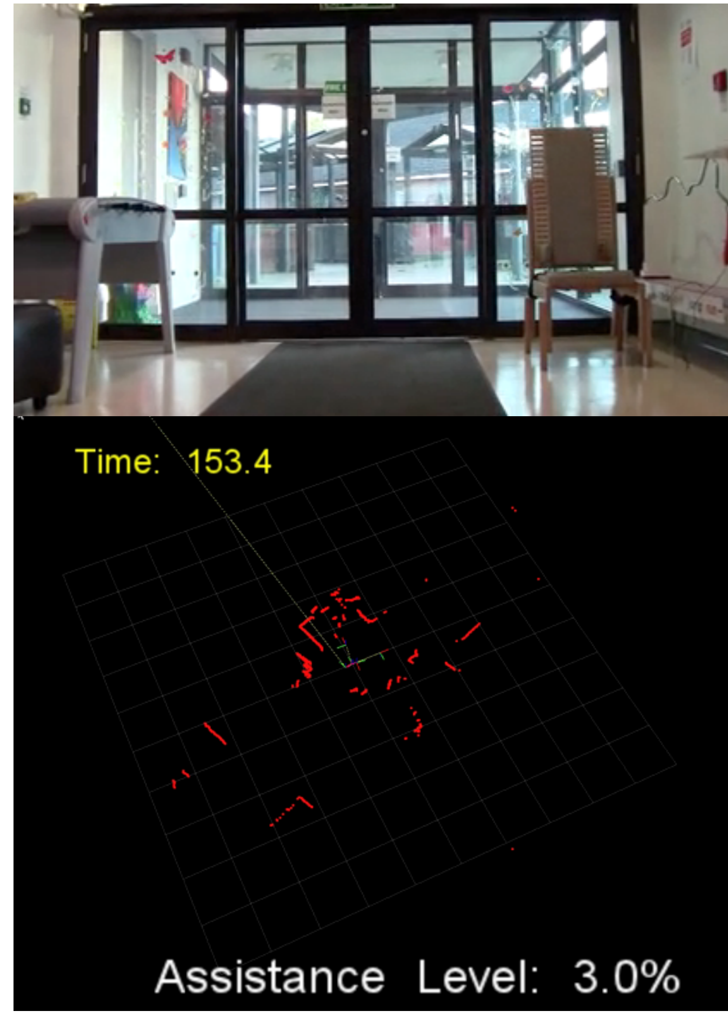
Case study(2): Children Robotic wheelchairs

Supporting the development of young disabled children

Hospital trials

User trials with brain injured children



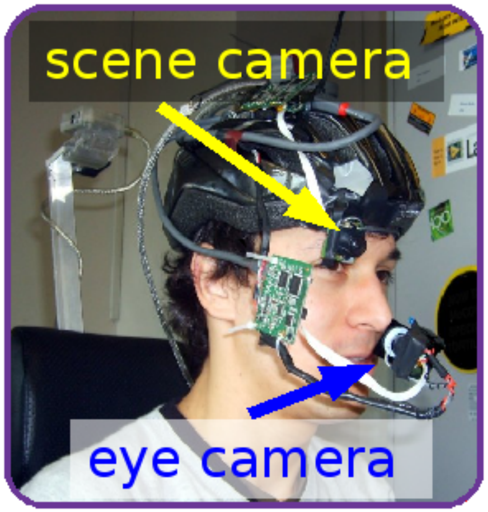


Doubled training time tolerance

Improved accessibility to new environments (eg. the hospital's gardens)

Soh and Demiris, IEEE Trans. NNLS 2015, & J Human Robot Interaction 2015

Recall importance for participants for understanding why a partner's action was performed in a certain way



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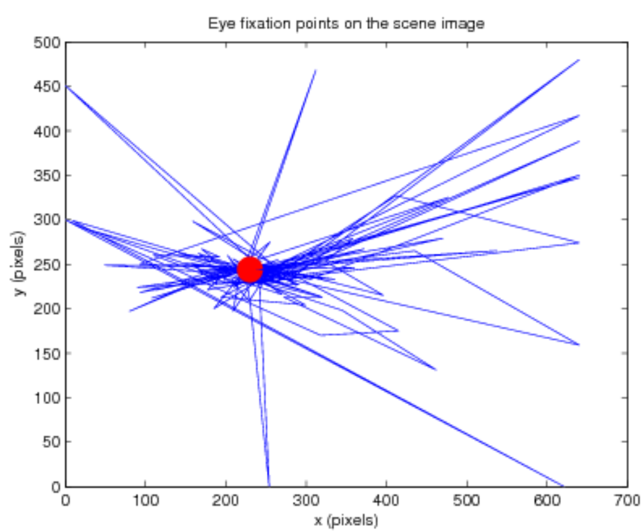
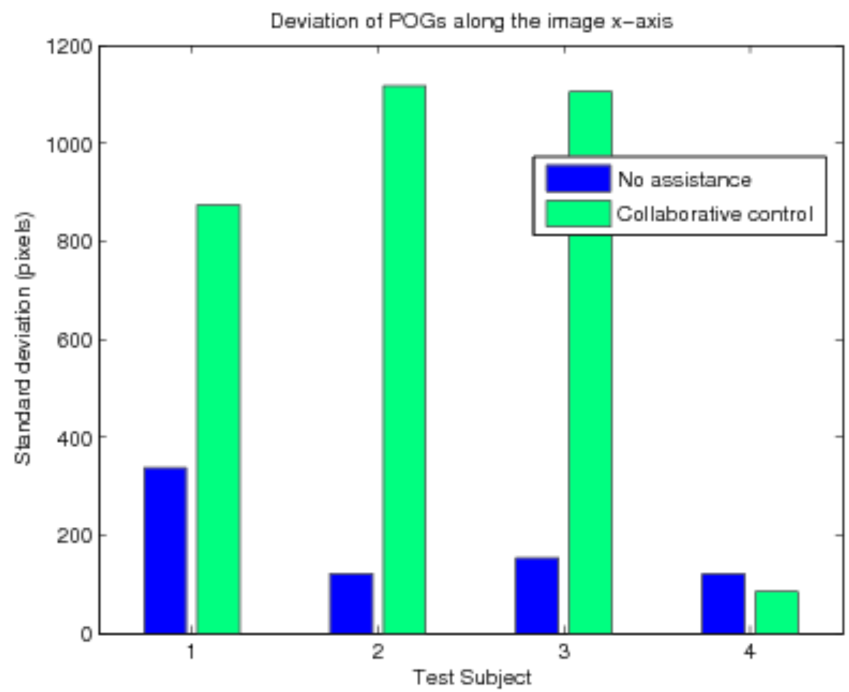




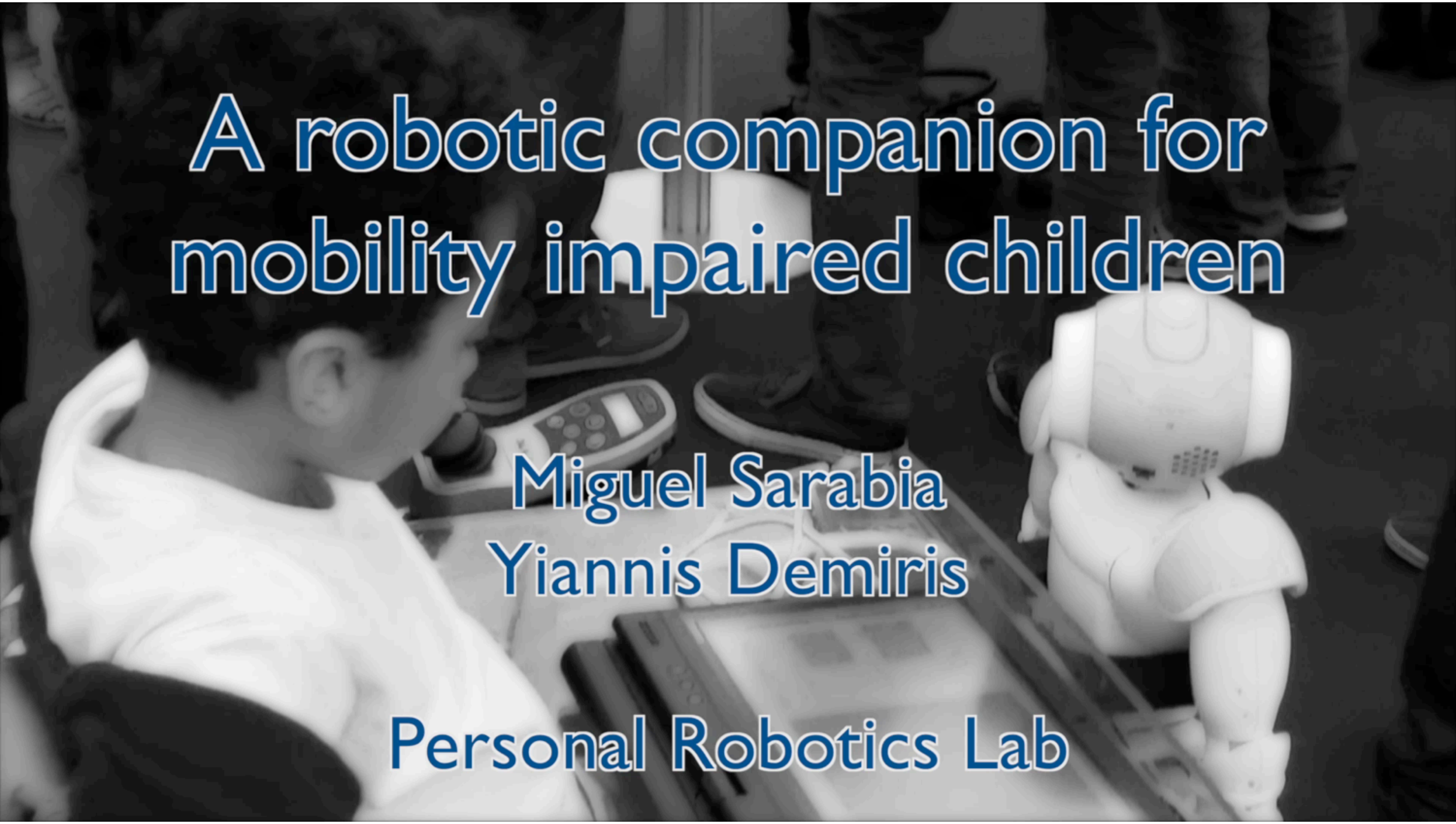
Humanoid Companion for a Paediatric Wheelchair

Miguel Sarabia
Yiannis Demiris

Personal Robotics Lab

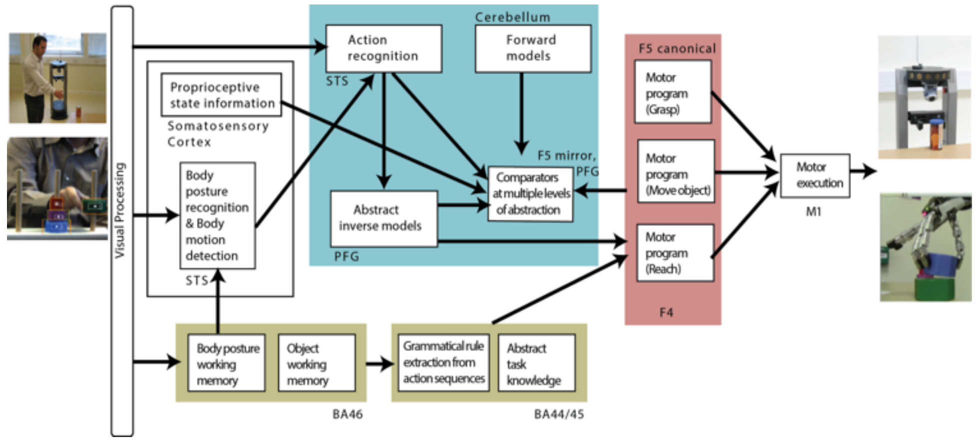
Sarabia and Demiris, Int Conf Social Robotics, 2013

Robotic companion for disabled children

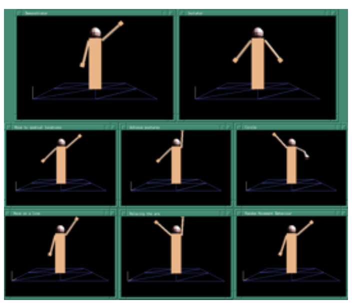


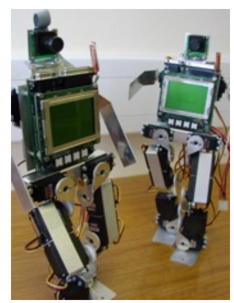
Sarabia and Demiris, Int Conf Social Robotics, 2013

HIERARCHICAL ATTENTIVE MULTIPLE MODELS FOR EXECUTION AND RECOGNITION (HAMMER)



Demiris, Aziz-Zadeh and Bonaiuto, Neuronformatics 2014



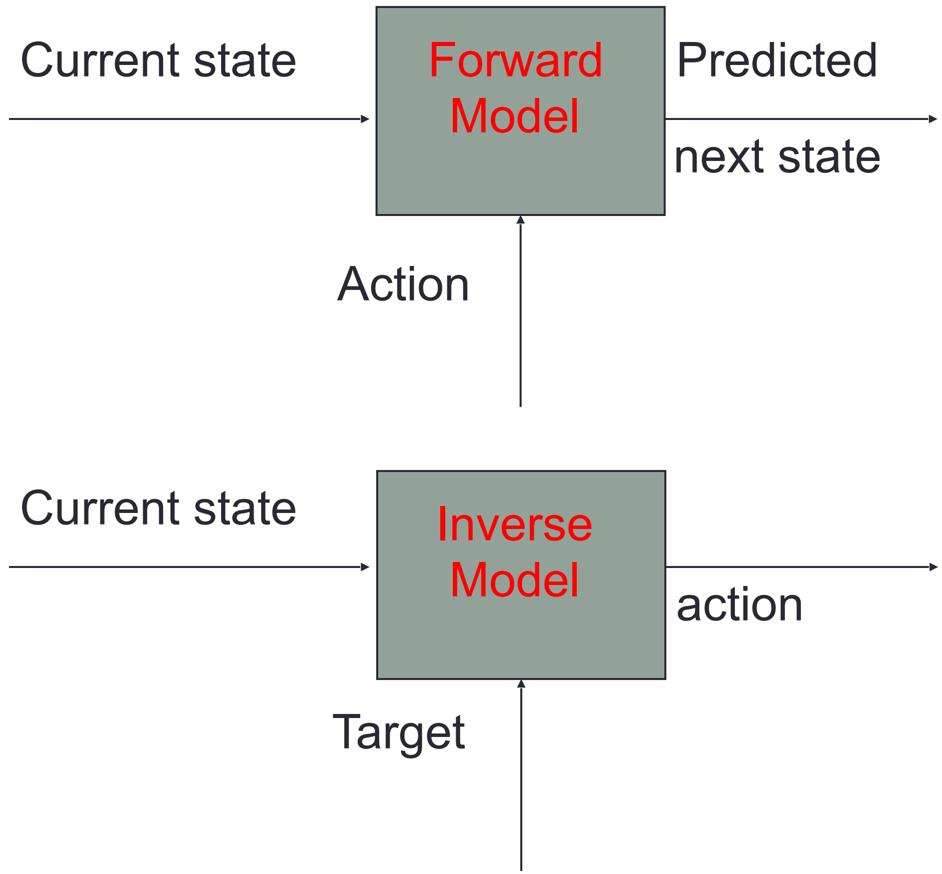


Several learning algorithms working at multiple levels :

- Learning human representations
- Learning at trajectory level *[Gaussian Processes, Quantum Mixtures, Recurrent Neural Nets]*
- Learning at action sequence and symbolic level *[Context-free stochastic grammars]*
- Auto- and hetero-biographcial memory for storing and revisiting memories

HAMMER Architecture (1)

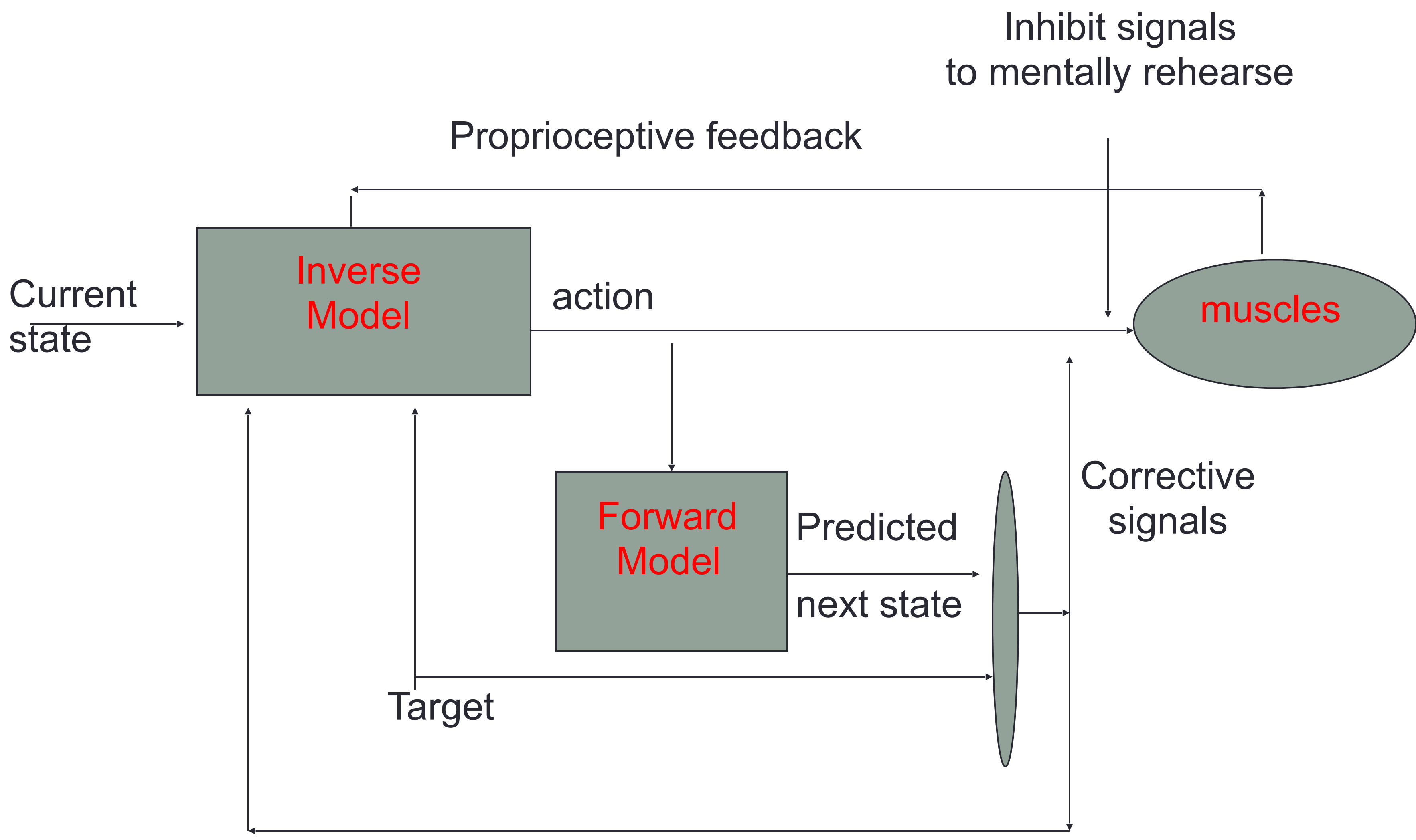
The Basic Building Blocks



Demiris and Khadhouri, Robotics and Autonomous Systems, 54:361-369, 2006

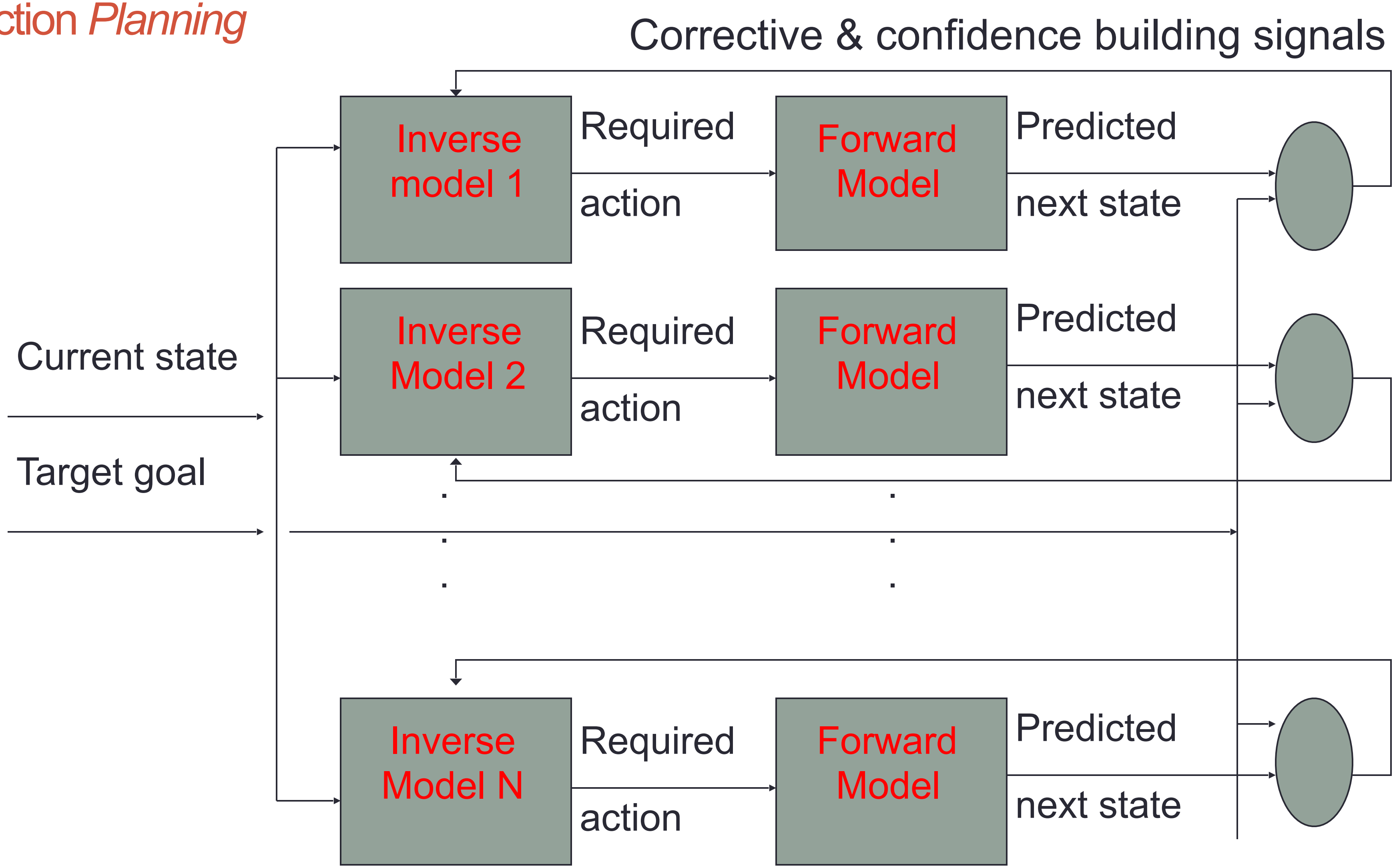
HAMMER Architecture (2)

Action *Execution*



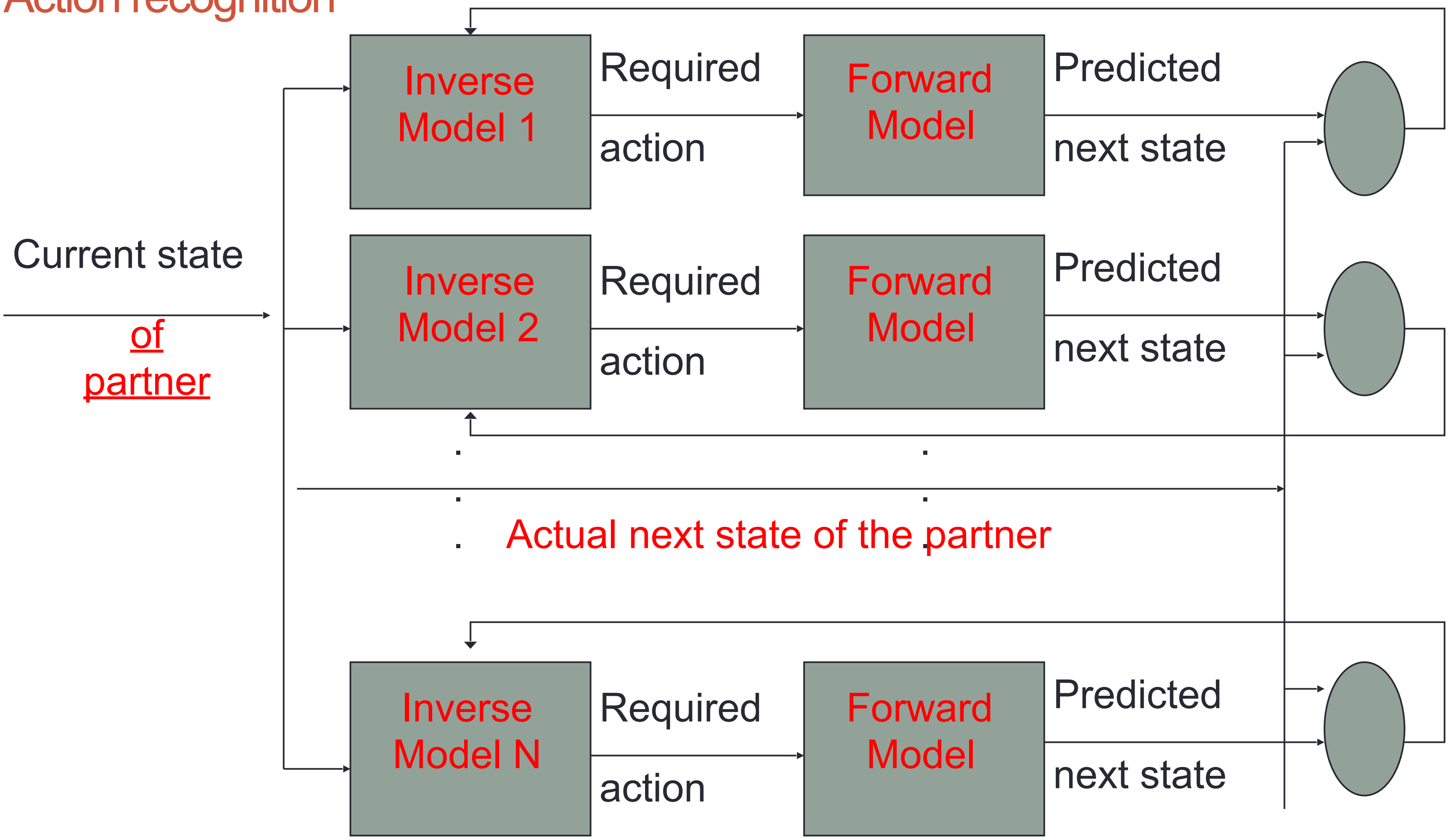
HAMMER Architecture (3)

Action *Planning*



HAMMER Architecture (4)

Action recognition



Demiris, 2007, 'Prediction of intent in robotics and multiagent systems", Cognitive Processing, 2007

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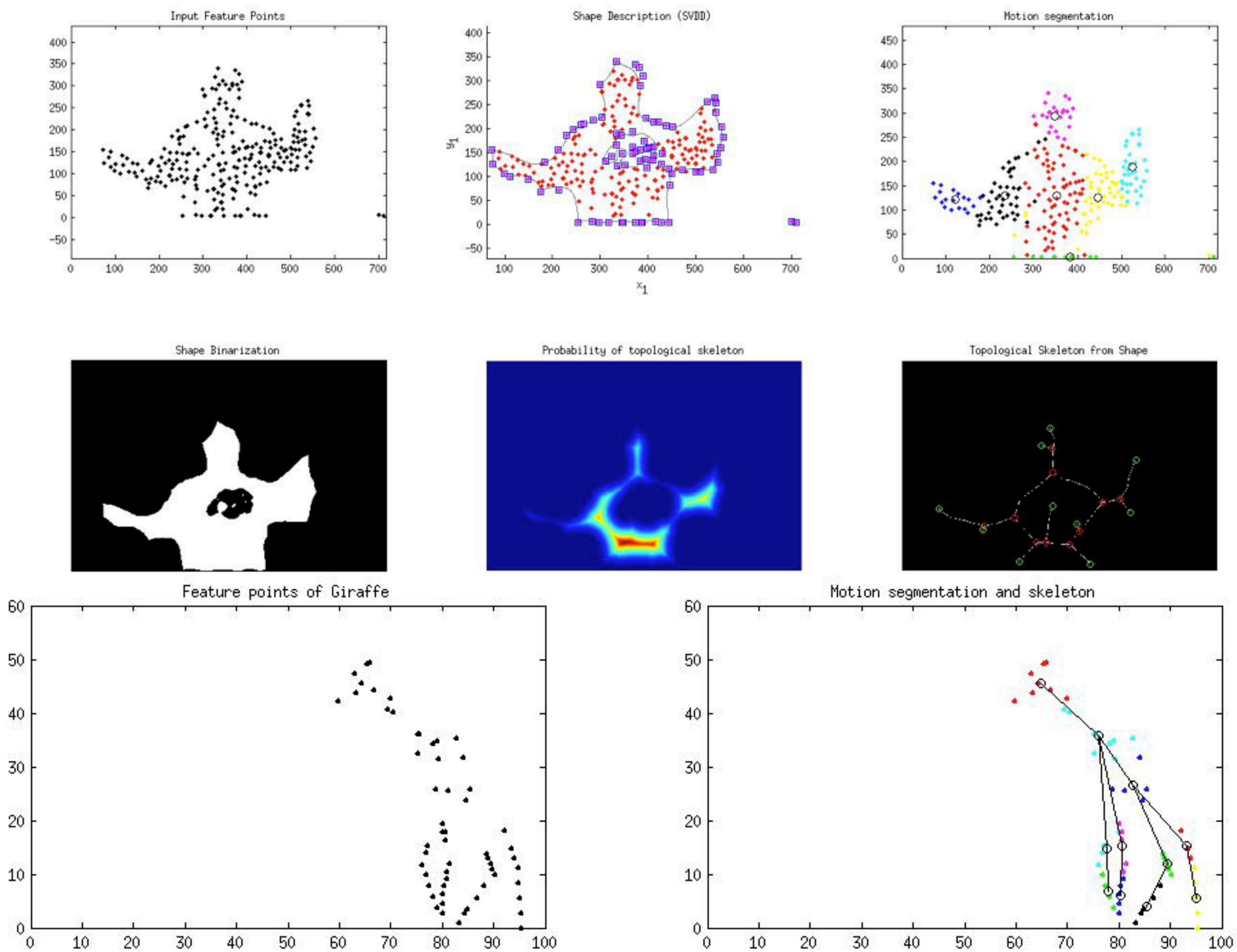
Learning Human Representations

- ***Using computer vision for Latent kinematic structure estimation (combining appearance and movement)***

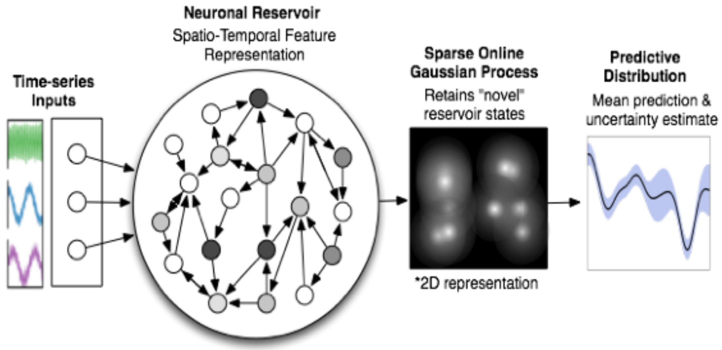


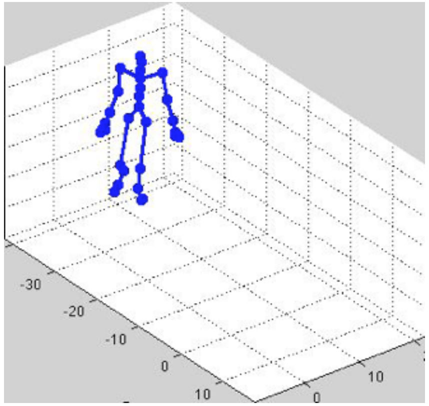
☞ Chang & Demiris, CVPR 2015, 2016

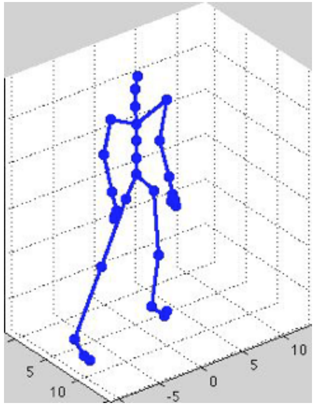
Learning complex spatiotemporal data

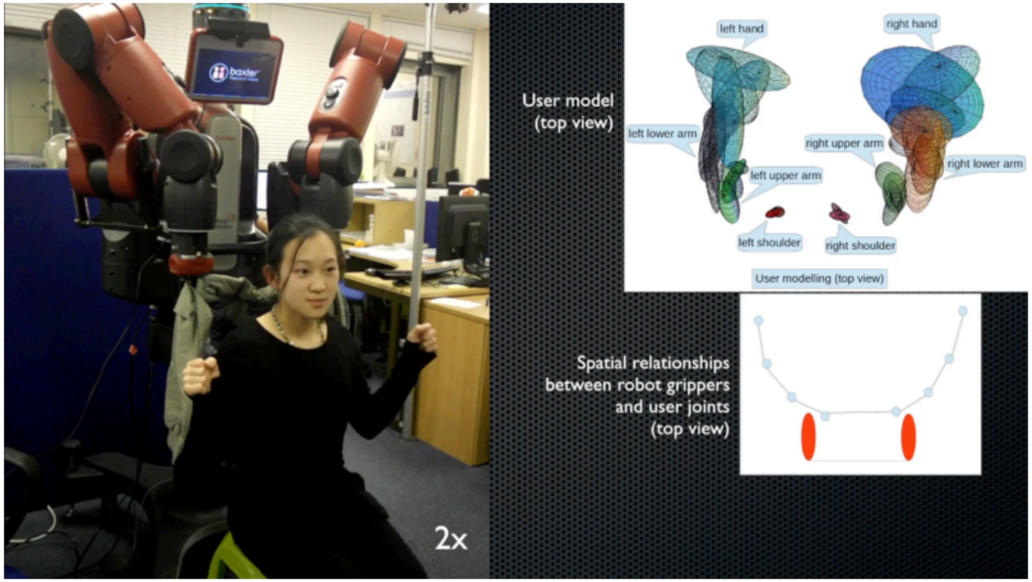
Echo-State Neural Network + Sparse Online Gaussian Process

- Sequential data learning merging **reservoir computing** approaches, and **Bayesian inference** techniques.







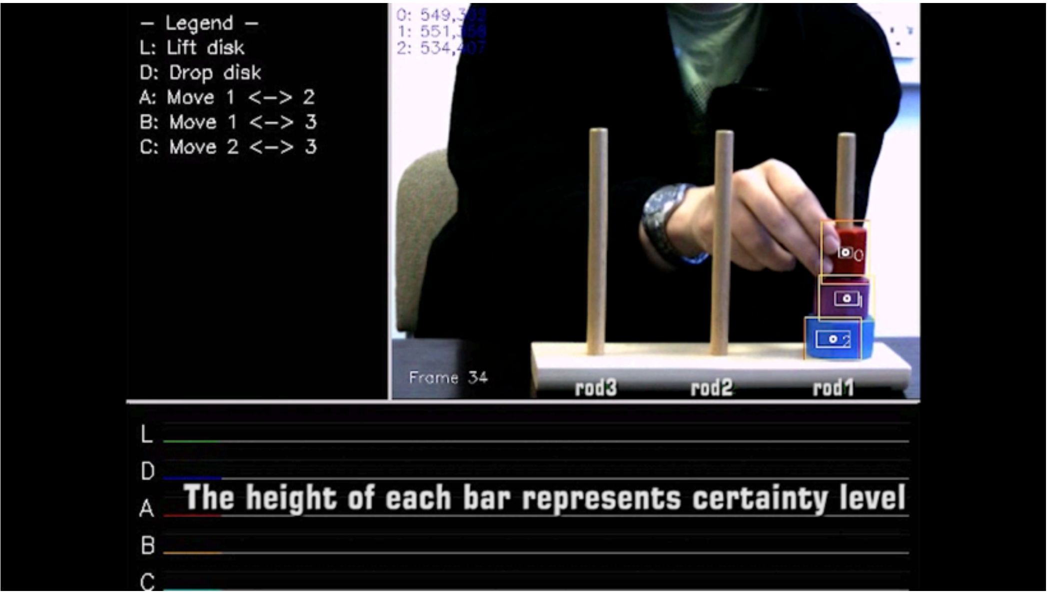


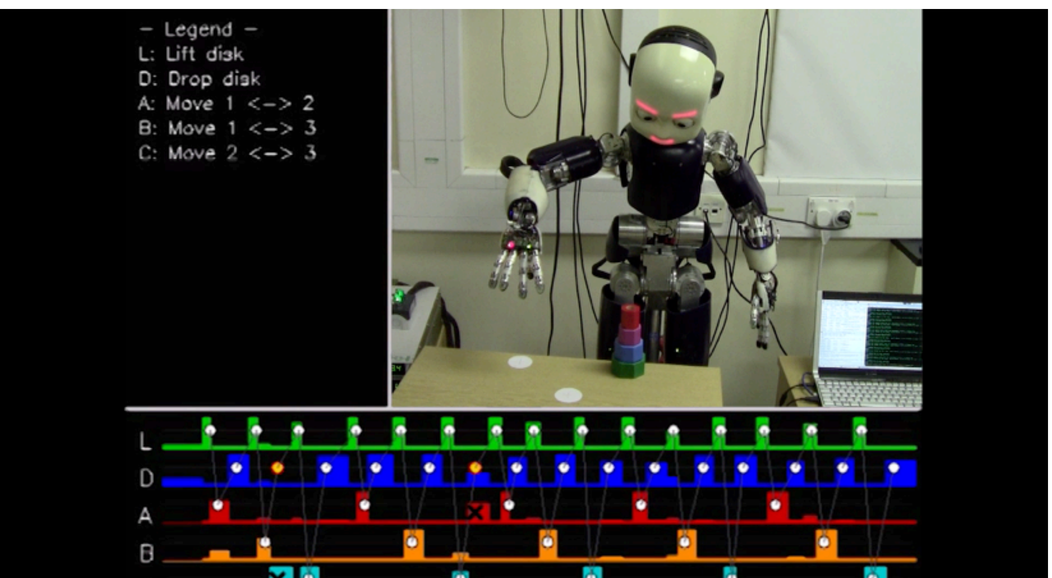
Y. Gao, HJ Chang, and Y Demiris, "User Modelling for Personalised Dressing Assistance by Humanoid Robots", IROS 2015, Hamburg, Germany.

H. Soh and Y. Demiris, "Spatiotemporal learning with the online finite and infinite echo-state Gaussian Process", IEEE Transactions on Neural Networks and Learning Systems, 2015

Stochastic context free grammars for task representations

Using "linguistic" representations for task descriptions – Towers of Hanoi





Action Grammar Rules related to DROP Branch

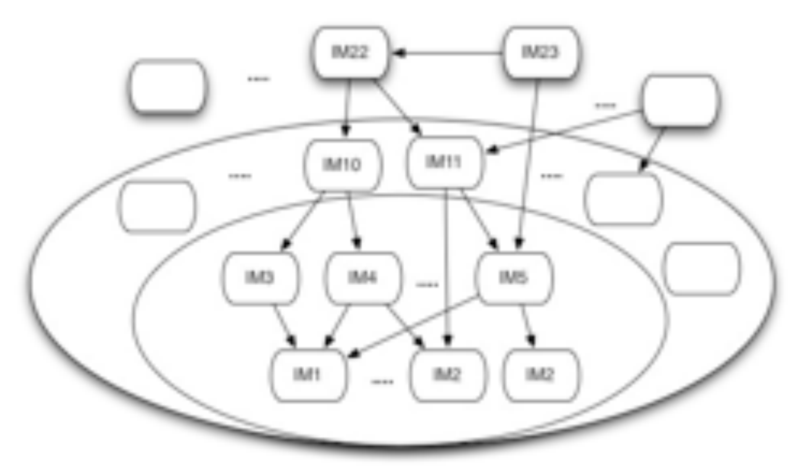
* Naming conventions: OBJ=object, BOX=box, A=approach, L=leave HGONE=hand invisibility, OGONE=object invisibility CONTACT=hand in contact with an object, SKIP=(See Sec.II-D.2)

BEGIN	⇒	NEXTBOX		[0.33]
	|	DROP		[0.33]
	|	PLACE		[0.33]
DROP	⇒	AOBJ CONTACT ABOX LOBJ OGONE		[1.0]
AOBJ	⇒	AOBJ	aobj	[0.5]
	|	aobj		[0.4]
	|	SKIP	aobj	[0.1]
ABOX	⇒	ABOX	abox	[0.5]
	|	abox		[0.4]
	|	SKIP	abox	[0.1]
CONTACT	⇒	CONTACT	contact	[0.5]
	|	contact		[0.4]
	|	SKIP	contact	[0.1]
LOBJ	⇒	LOBJ	lobj	[0.5]
	|	lobj		[0.4]
	|	SKIP	lobj	[0.1]
OGONE	⇒	OGONE	ogone	[0.5]
	|	ogone		[0.4]
	|	SKIP	ogone	[0.1]

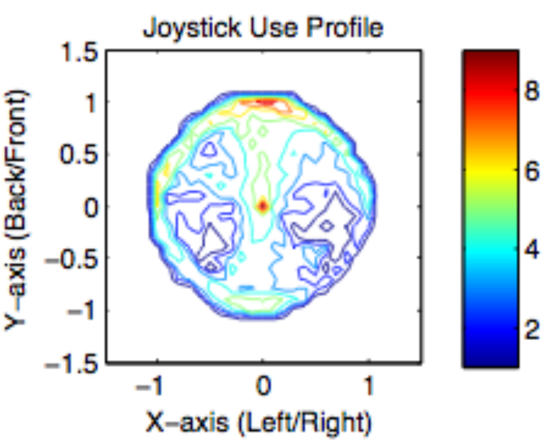
Lee, Su, Kim & Demiris, A syntactic approach to robot imitation learning using probabilistic activity grammars, Robotics & Autonomous Systems, 2013.

Representing human skills (1)

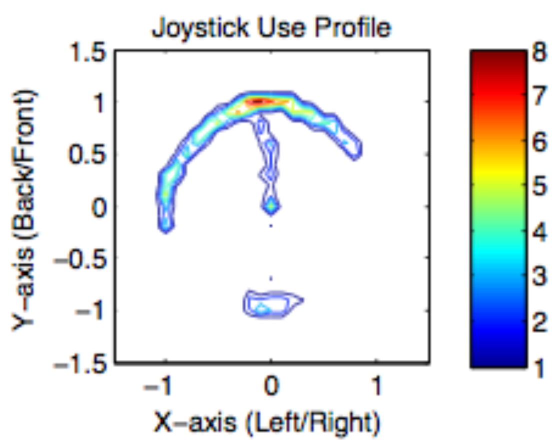
Hierarchical Representations - building the Zone of Proximal Development



- Collect user data for each component inverse model and propagate uncertainties in the hierarchal model
- Predict level of shared control required
    - Attentional and sensorimotor load calculations (Demiris and Khadhouri, Interaction Studies, 2008)



(a) C



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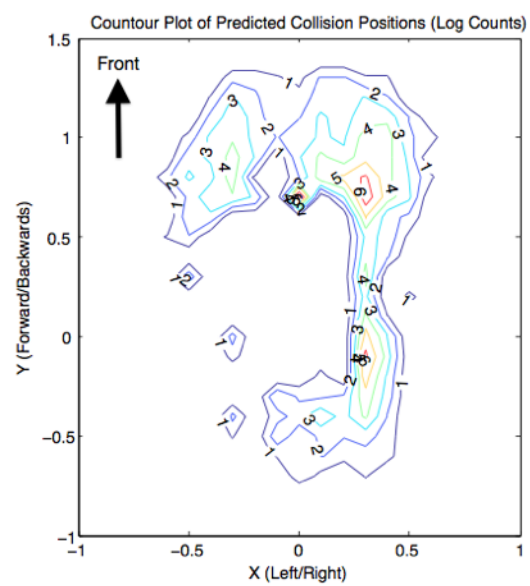
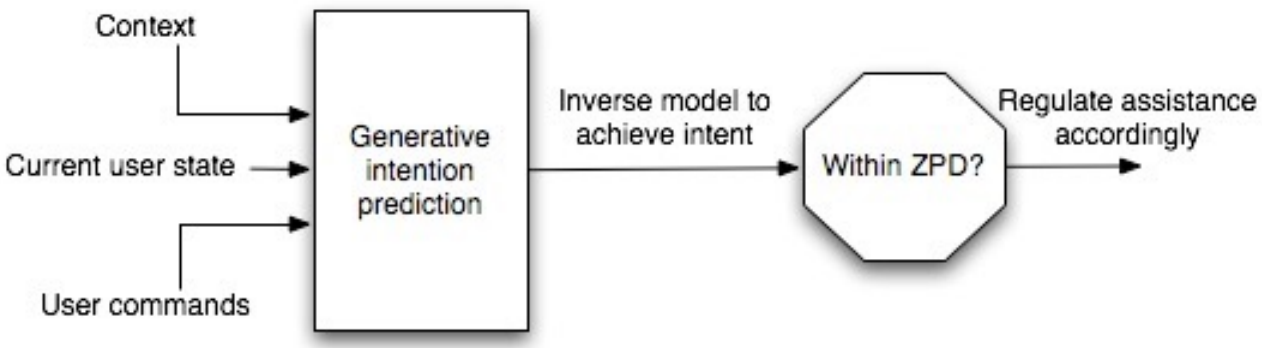
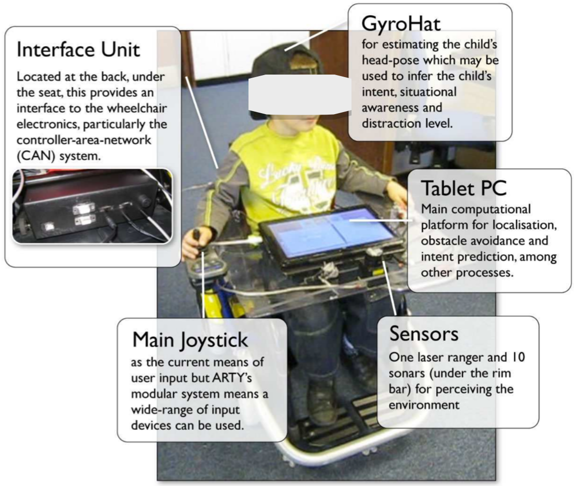


Representing human skills (2)

Hierarchical Representations - building the ZPD





- Research challenge – principled methods for determining whether we should help
  - Balancing short and long term benefits

Demiris 2009, "Knowing when to assist: Developmental issues in lifelong assistive robots", IEEE EMBC 2009

Rehabilitation settings 2

Technology challenges

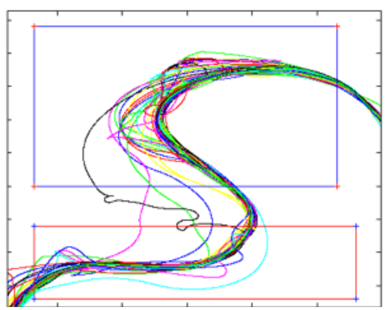
- Lifelong modelling of the *sensorimotor and cognitive* states of a human user
- Formulating a user-specific joint action plan
- Short- and long-term robot response adaptation to a developing system [Demiris, IEEE EBMC 2009]

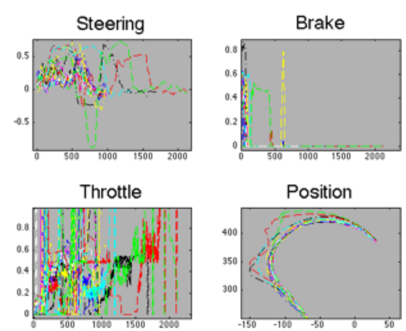
Adaptive Training in high performance scenarios

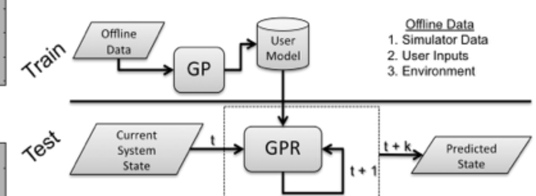
Georgiou and Demiris, "Predicting Car States through Learned Models of Vehicle Dynamics and User Behaviours", **IEEE Intelligent Vehicles 2015, Seoul, Korea.**

USER MODELLING UNDER HIGH PERFORMANCE DRIVING

- **Racing Simulator**
  User races for a certain period on one specific track
- **Personalised User Models**
  User, EEG, Simulator and Environment data are being captured while the user is driving
- **Model Creation**
  Model encapsulates user's habits and behaviour on road paths







Georgiou and Demiris, "Predicting Car States through Learned Models of Vehicle Dynamics and User Behaviours", **IEEE Intelligent Vehicles 2015, Seoul, Korea.**

Attention during action perception

Multi-objective optimisation examining the content of the requests of the multiple models

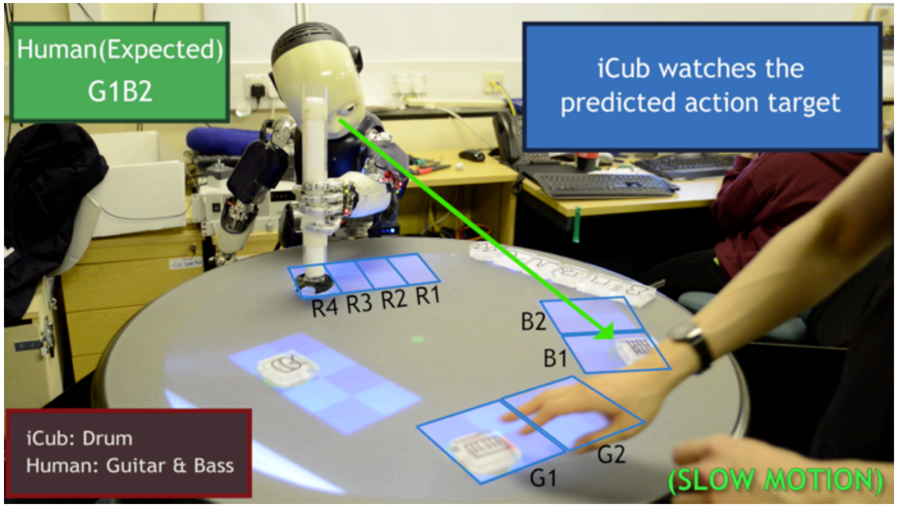
Saliency of request is a function of the confidence of inverse model

Multiple additional criteria:

- Utility of the request

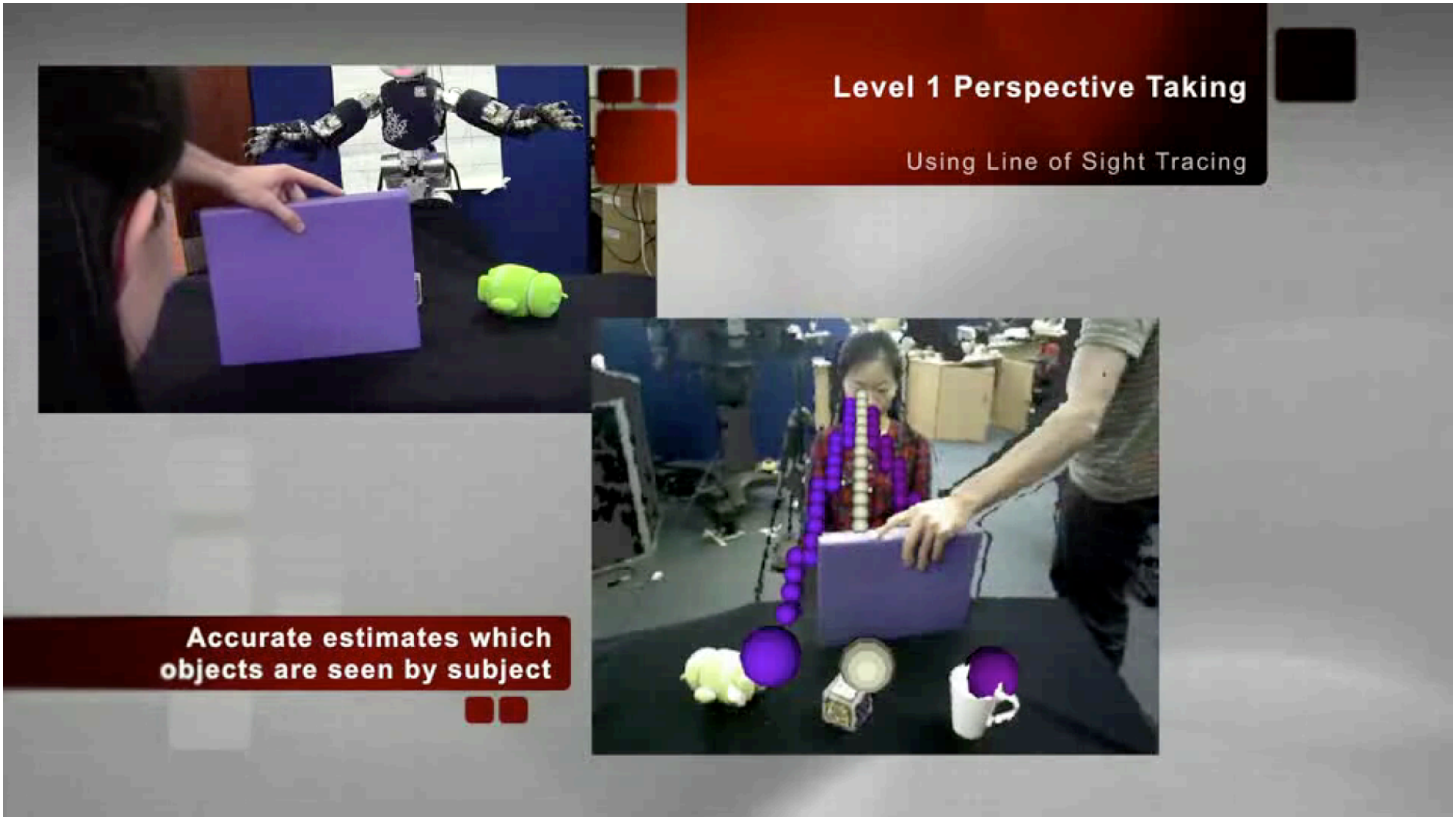
(how many behaviours will be served if this request is serviced?)

- Cost of request (e.g. saccades)
- Current reliability of requested information



Demiris & Khadhouri, Interaction Studies, 2008
Ognibene & Demiris, IJCAI 2013
EU FP7 project WYSIWYD

Perspective Taking



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Fischer T, Demiris Y, Markerless Perspective Taking for Humanoid Robots in Unconstrained Environments, IEEE International Conference on Robotics and Automation, IEEE ICRA 2016

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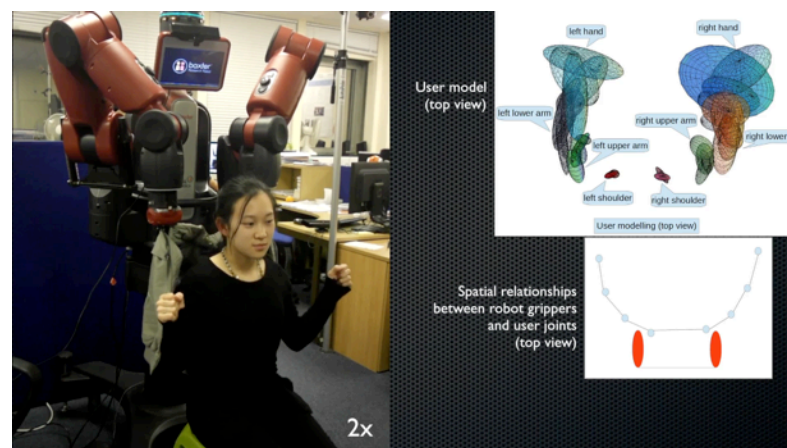
PERSONAL ROBOTICS LABORATORY

Conclusions

- **Personalisation:**
  - Participants explicitly model their partner's parameters (skills, preferences, …) and adjust their behaviour; prediction a key element
  - Hierarchical partner modelling using ensembles of inverse and forward models
- **Lifelong joint action constraints:**
  - Has to include developmental aspects: in our domain outcome is improvement of one or more of the partners, not only success of an external temporary goal



THANKS TO MY TEAM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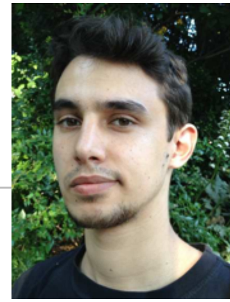
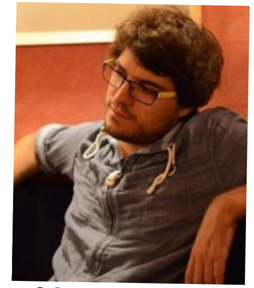

Antoine Cully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