Robot attentional models for intuitive HRI.

Verena Vanessa Hafner
Kognitive Robotik, Institut für Informatik, Humboldt-Universität zu Berlin
WS Attention Models in Robotics: Visual Systems for Better HRI, HRI 2014, March 3, 2014

Overview

- Introduction & Motivation
- Joint Attention
- Robot Attentional Models
- Summary & Discussion

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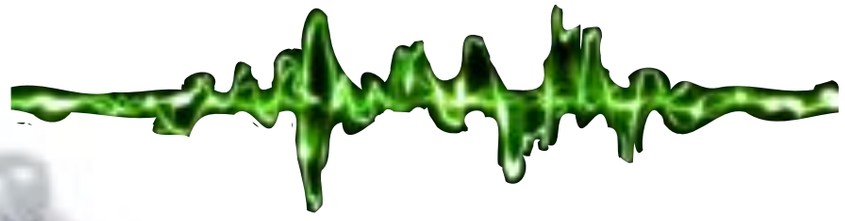
Embodied Cognition

embodiment hypothesis

intelligence emerges from the **interaction** of an agent with an environment and as a result of sensorimotor activity.

"Lara, 9 Monate, verschmiert Karottenbrei" (Foto: Peez, idw)

Visual & auditory attention



EU project EARS on Embodied Audition for RobotS, 2014-2017, FP7 STREP

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Joint Attention

- Strong interest in the robotics community (HRI & devrob)
- Joint Attention skills are important for:
  - Imitation
  - Social Cognition
  - Development of Language
  - Intuitive Interaction

Kaplan, F. and **Hafner, V. V.** (2006), The Challenges of Joint Attention, Interaction Studies, 7:2, pp. 135-169

First Approaches

- Gaze detection between a robot and a human
  (Nagai et al. 2002+2003, Scassellati,1999, Carlson and Triesch, 2003)

- Pointing and gaze detection between a robot and a human (Imai et al. 2001, Kozima et al. 2000)

- Pointing detection between two robots
  (**Hafner**, Kaplan 2005)

What is Attention?

Process whereby an agent concentrates on some features of the environment to the (relative) exclusion of others.

- **Passive attention**: a salient event automatically triggers the attention of the agent.
- **Active attention**: the agent is involved in an intentionally directed process and must actively select particular features of its environment.

Attention by Sound Cue / Attention by Visual Cue

Defining Joint Attention: What Joint Attention is **NOT**

Joint Attention is **more** than simultaneous looking

Two robots look at the same things but do not share attention

Defining Joint Attention

1. Joint Attention is **more** than simultaneous looking

2. Joint Attention is more than attention detection, attention manipulation and social coordination

3. Joint Attention is mainly about intentional understanding

Prerequisites of Joint Attention

- Attention Detection
- Attention Manipulation
- Social Coordination
- Intentional Understanding

Human Developmental Timelines

T1 Attention detection

0-3m	Mutual gaze
6m	Discrimination of left/right
12m	Gaze angle detection, interpretation of pointing
15m	Gaze following and pointing detection toward object outside the field of view

T2 Attention manipulation

9m	Imperative pointing as a request for reaching an object
12m	Declarative pointing, attention manipulation using gestures
13m	Referential words

T3 Social coordination

0-3m	Protoconversation, simple rhythmic interaction including turn-taking mediated by the caregiver
6m	Shared games, conventional routines established between child and caregivers
9m	Simple immediate imitation
18m	Complex imitative games

T4 Intentional understanding

0-3m	Early identification with other persons
6m	Distinction between animate and inanimate entities
9m	First goal-directed behaviour
12m	Behavioural understanding of observed behaviour, intentional understanding of produced behaviour
18m	Intentional understanding of observed behaviour

Pointing in Human Infants

Imperative pointing (9 months)

Drawing attention as a request for reaching an object,
attention not monitored,
origin: grasping?

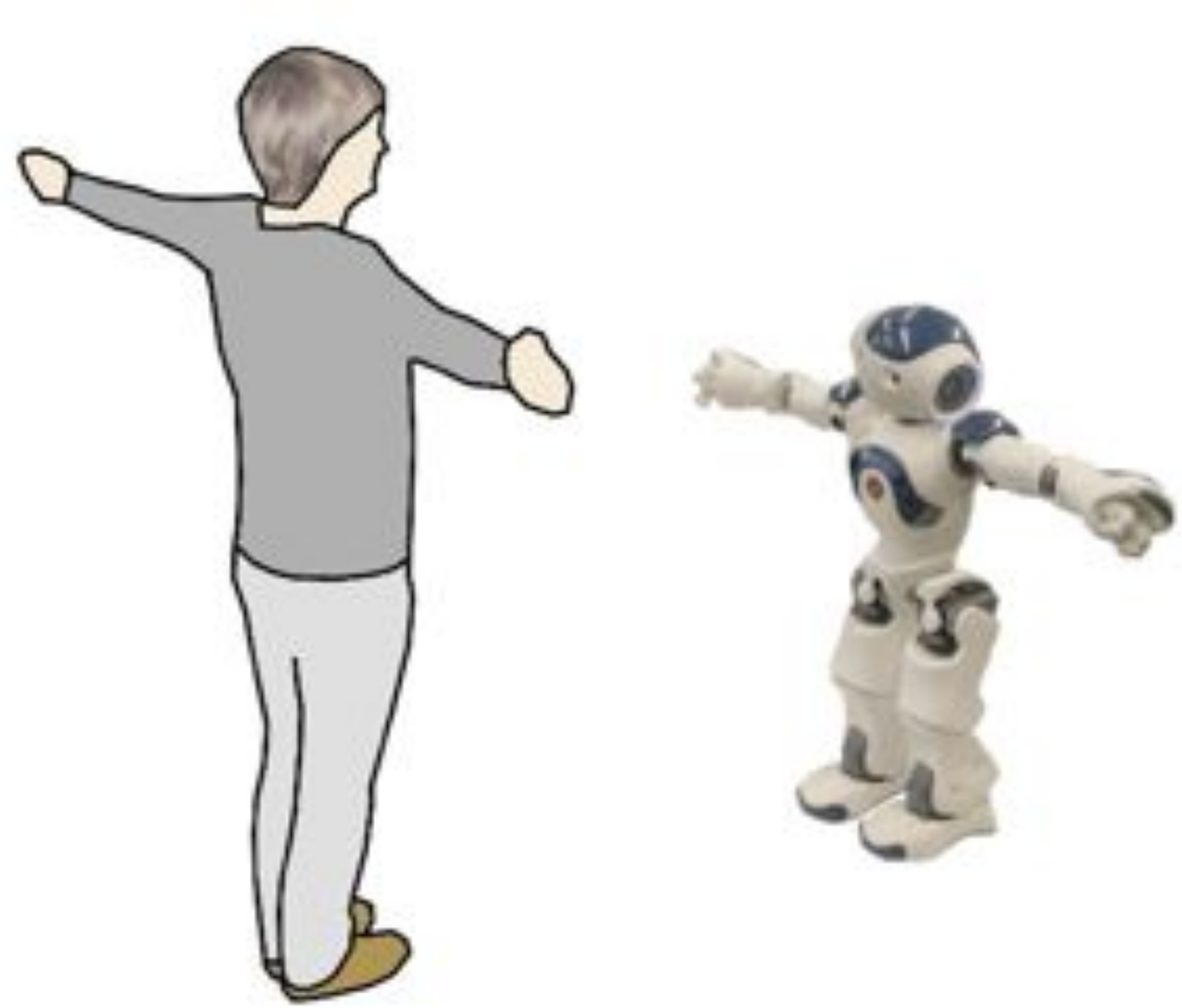
Declarative pointing (12 months)

Drawing attention using gestures

Interaction Game

However, intentional understanding is still difficult

(Joint) Attention in HRI



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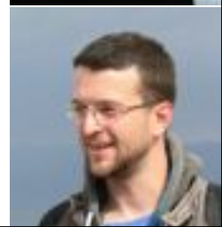
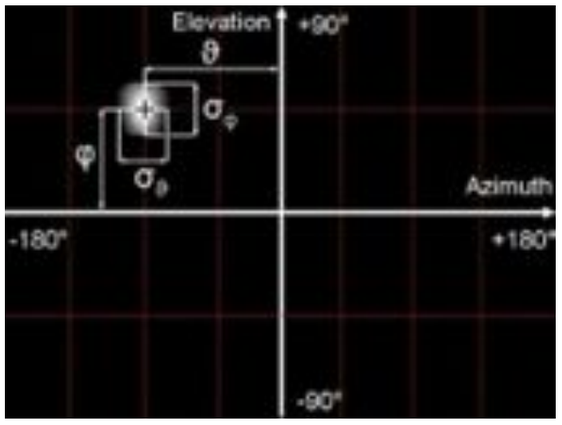
Visual Attention and Attention Manipulation

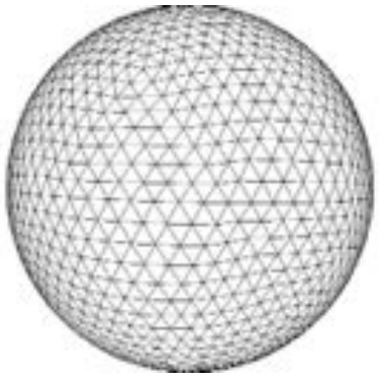
Schillaci, G., Bodiroža, S. and **Hafner, V.V.** (2013), Evaluating the Effect of Saliency Detection and Attention Manipulation in Human-Robot Interaction, *International Journal of Social Robotics, Springer, Volume 5, Issue 1 (2013), pages 139-152, OPEN ACCESS.*

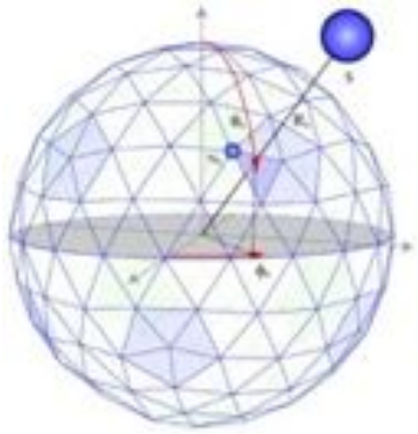
Bodiroža, S., Schillaci, G. and **Hafner, V.V.** (2011), Robot Ego-sphere: An Approach for Saliency Detection and Attention Manipulation in Humanoid Robots for Intuitive Interaction, *Proceedings of the 11th IEEE-RAS International Conference on Humanoid Robots (Humanoids 2011), pp. 689–694, Bled, Slovenia.*



Robot Ego-Sphere







- Saliency detection
- Multi-modal salient ego-sphere
- (tesselated sphere)

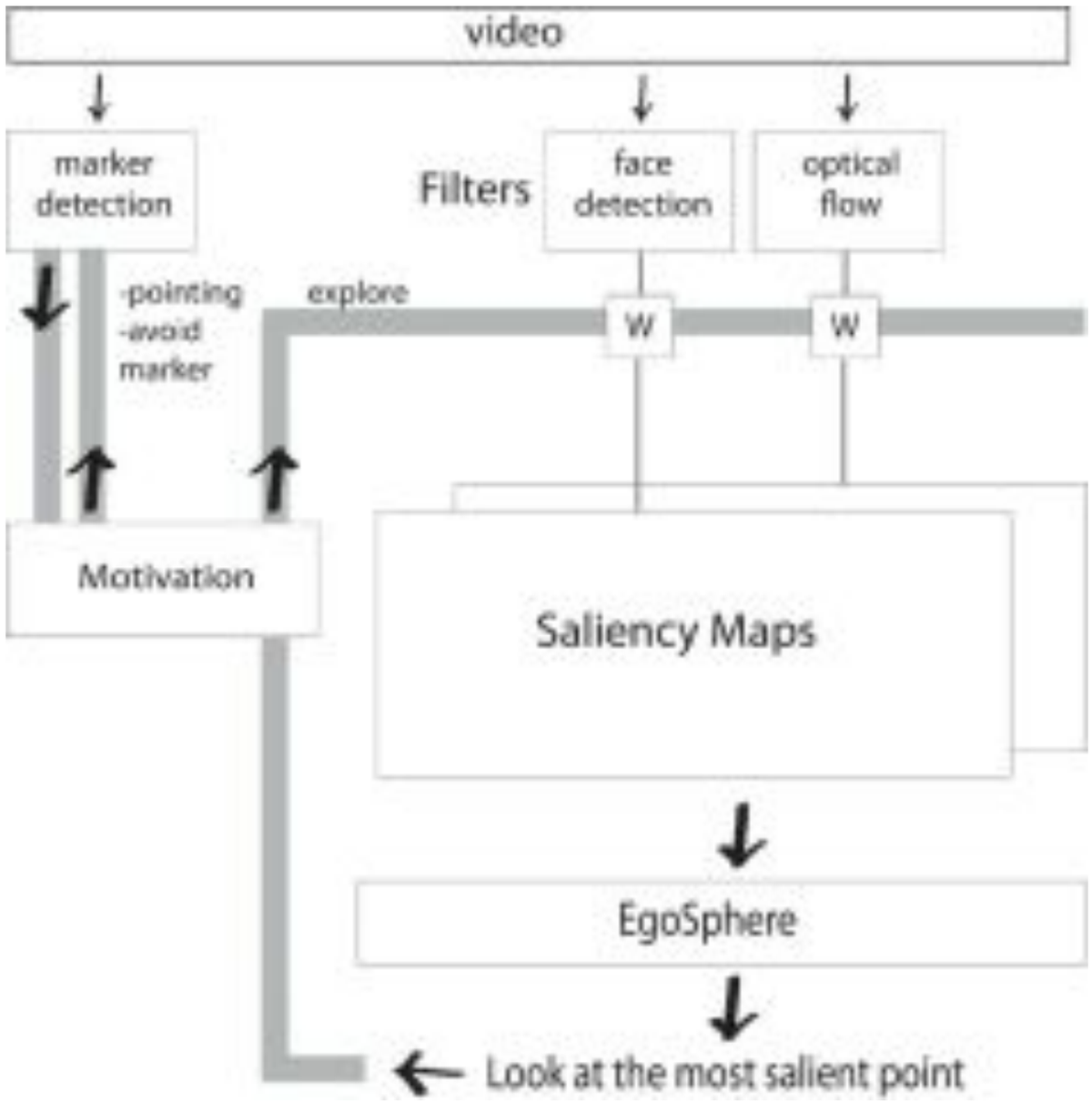
J. Ruesch, M. Lopes, A. Bernardino, J. Hornstein, J. Santos-Victor, and R. Pfeifer, “Multimodal saliency-based bottom-up attention a framework for the humanoid robot iCub,” in *Proceedings of the IEEE International Conference on Robotics and Automation 2008 (ICRA 2008)*, 2008, pp. 962–967.

Ego-sphere as a short-term memory

- habituation, inhibition and forgetting
- different for motion and face detection
- saliency decays over time

R. A. Peters, K. E. Hambuchen, K. Kawamura, and D. M. Wilkes, “The sensory ego-sphere as a short-term memory for humanoids,” in *Proceedings of the IEEE-RAS Conference on Humanoid Robots, 2001, pp. 451–460.*

Robot Attentional System

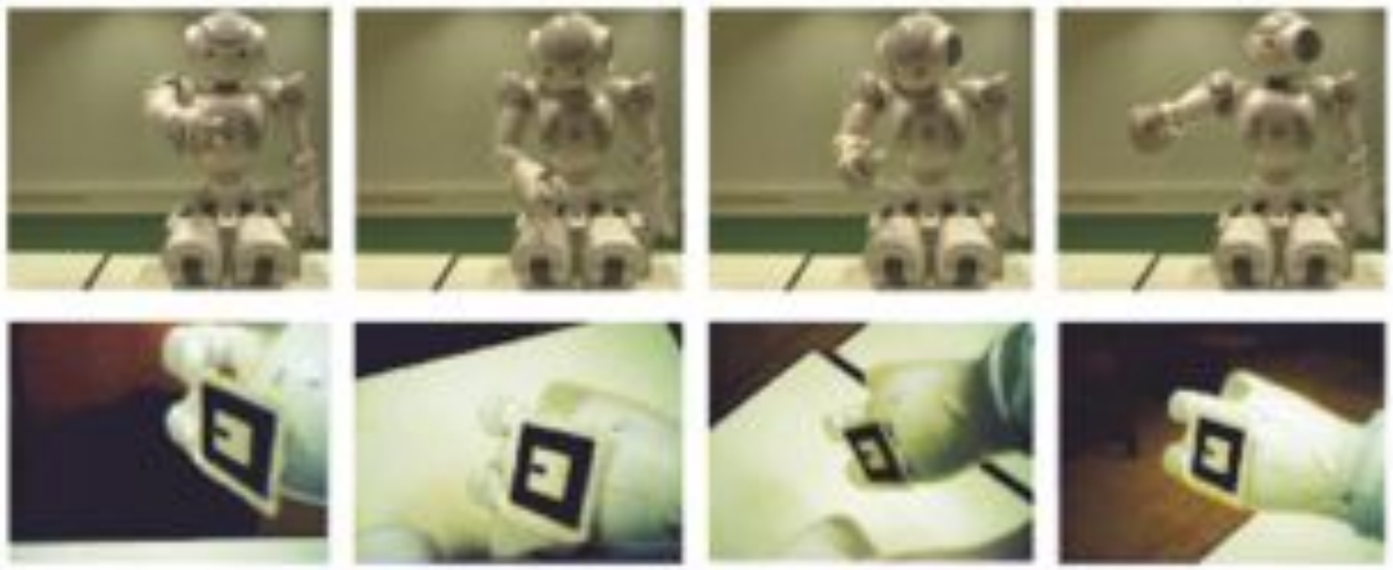


Robot Attention Manipulation

pointing

Experiments on Motor Babbling

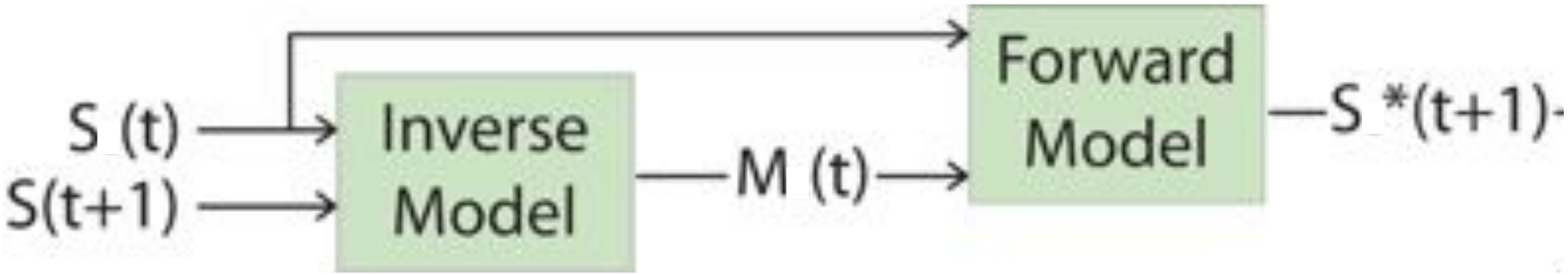
exploration strategies



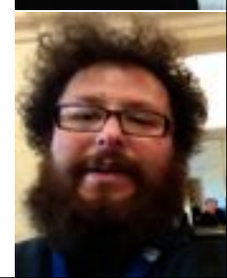
Schillaci, G. and **Hafner, V.V.** (2011), Random Movement Strategies in Self-Exploration for a Humanoid Robot, *Proceedings of the 6th ACM/IEEE International Conference on Human-Robot Interaction (HRI 2011), pp. 245-246, Lausanne, Switzerland.*

Motor Babbling

Internal Models

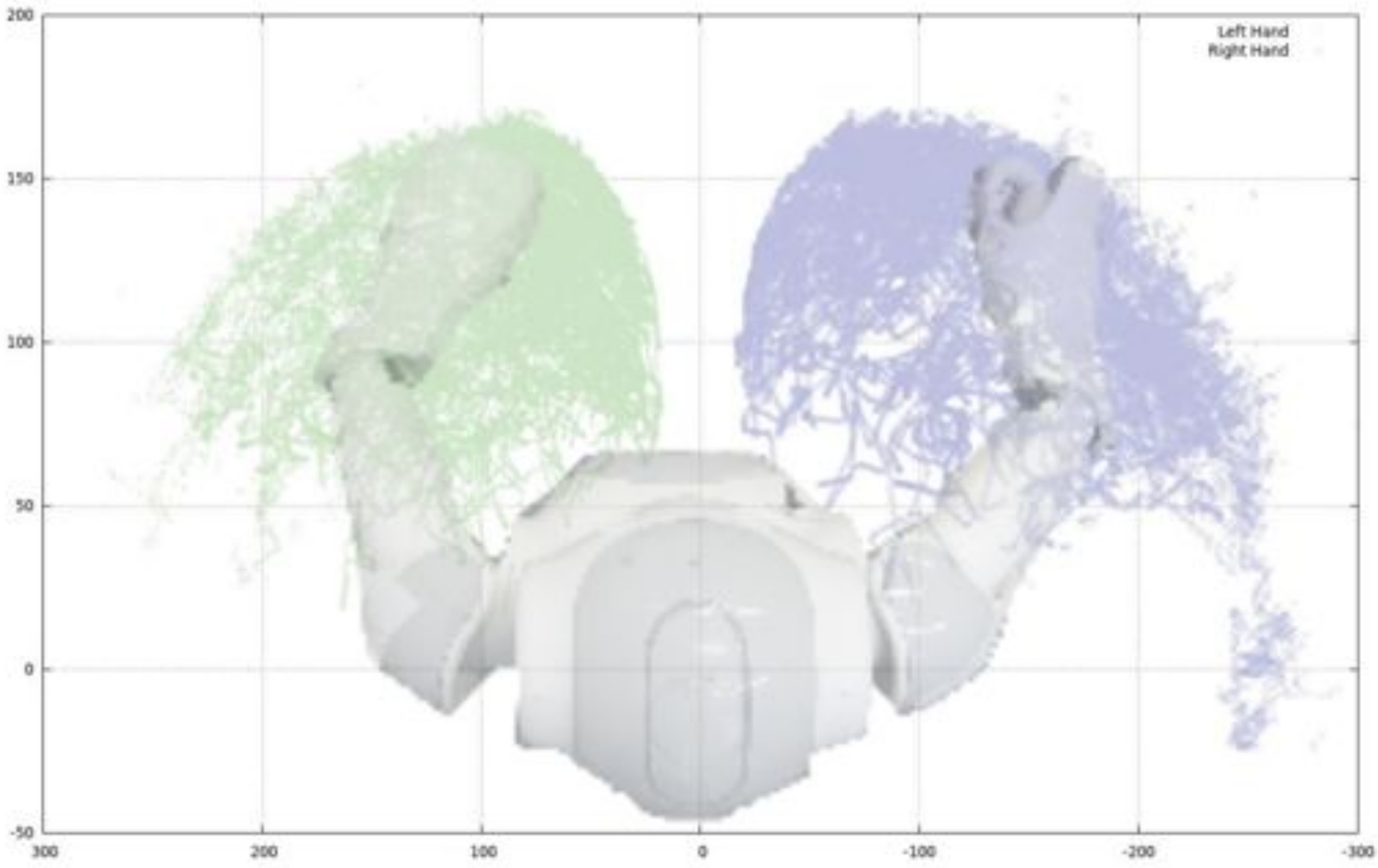


(controller) (predictor)



Schillaci, G., **Hafner, V.V.**, Lara, B. (2012), Coupled Inverse-Forward Models for Action Execution Leading to Tool-Use in a Humanoid Robot, *Proceedings of the 7th ACM/IEEE International Conference on Human-Robot Interaction (HRI 2012), pp. 231-232, Boston, USA.*

Motor Babbling



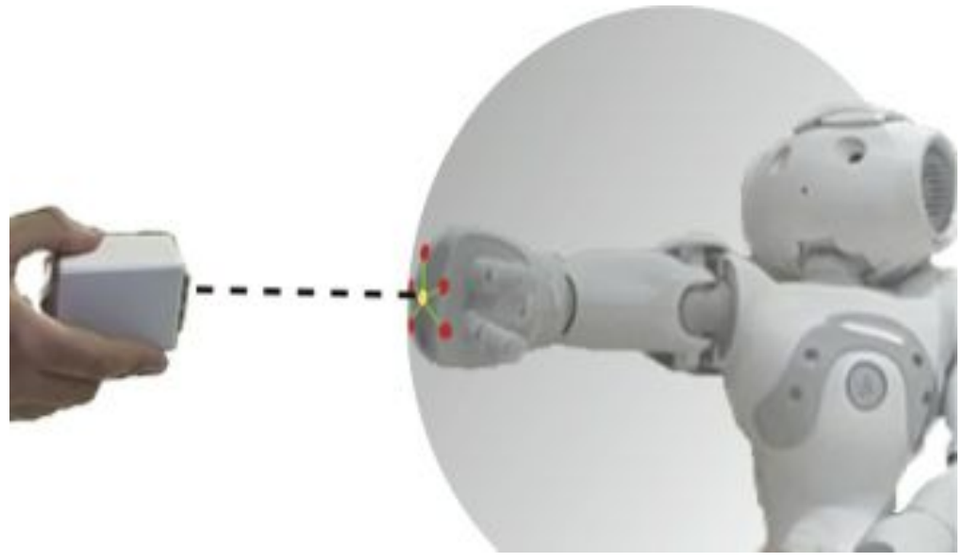
action spaces on a Nao robot

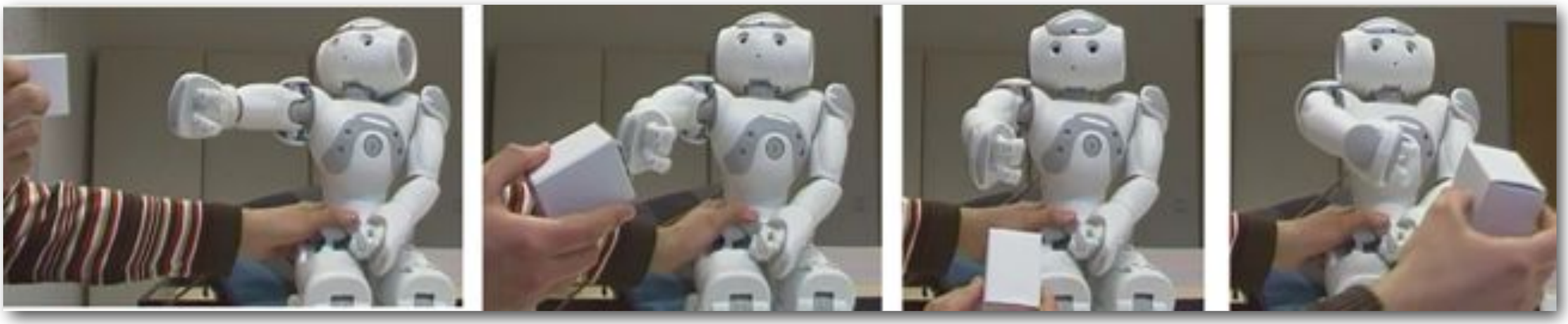
Could pointing emerge from grasping?

Hafner, V.V. and Schillaci, G. (2011), From field of view to field of reach - could pointing emerge from the development of grasping? *Frontiers in Computational Neuroscience, Conference Abstract: IEEE ICDL-EPIROB 2011*.

Resulting Behaviour

object outside the field of grasp





HRI
Robot Behaviours

- Exploration
- Interaction
- Interaction Avoidance
- Full Interaction (combination)

Robot Ego-sphere: An Approach for Saliency Detection and Attention Manipulation in Humanoid Robots for Intuitive Interaction

Sasa Bodiroza Guido Schillaci Verena V. Hafner

Cognitive Robotics Group
Department of Computer Science
Humboldt-Universitaet zu Berlin
Berlin, Germany

Evaluation

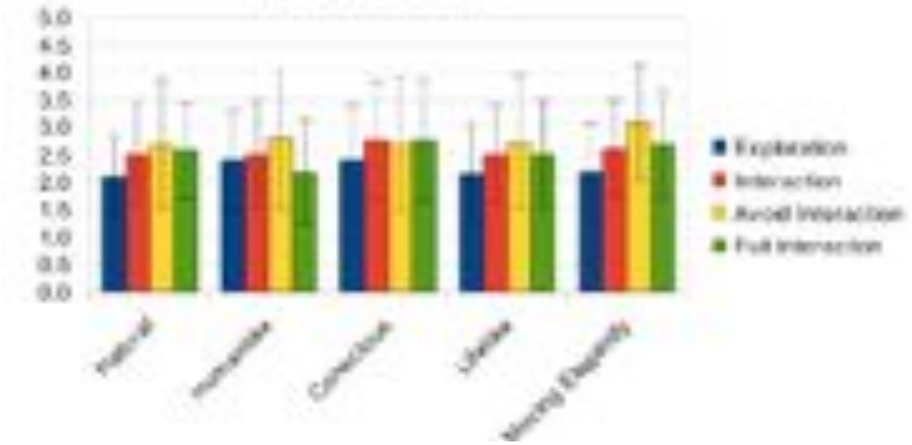
- Questionnaires (Godspeed) (N = 28) Anthropomorphism, Animacy, Likeability, Perceived Intelligence, Perceived Safety, User Satisfaction
- Confirmed reliability and internal consistency – all questionnaires have high Cronbach's alpha ($\alpha > 0.7$)
- Proxemics

C.Bartneck, E.Croft, and D.Kulic, "Measurement Instruments for the Anthropomorphism, Animacy, Likeability, Perceived Intelligence, and Perceived Safety of Robots," *International Journal of Social Robots, vol. 1, 2009, pp. 71-81.*

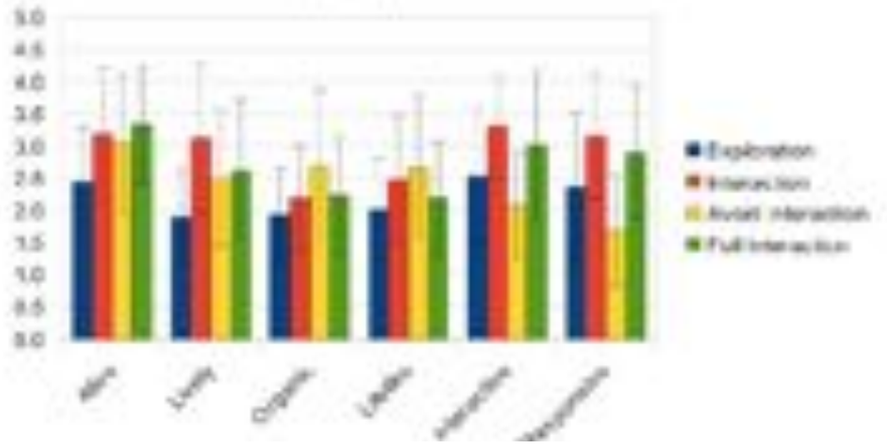
Proxemics

- personal spheres
- boundaries can be identified by factors like gender, age and culture
- 4 spheres: Intimate Distance (0 to 45cm)
  Personal Distance (45 to 120 cm)
  Social Distance (1.2 to 3.6 m)
  Public Distance (more than 3.6 m)

Anthropomorphism

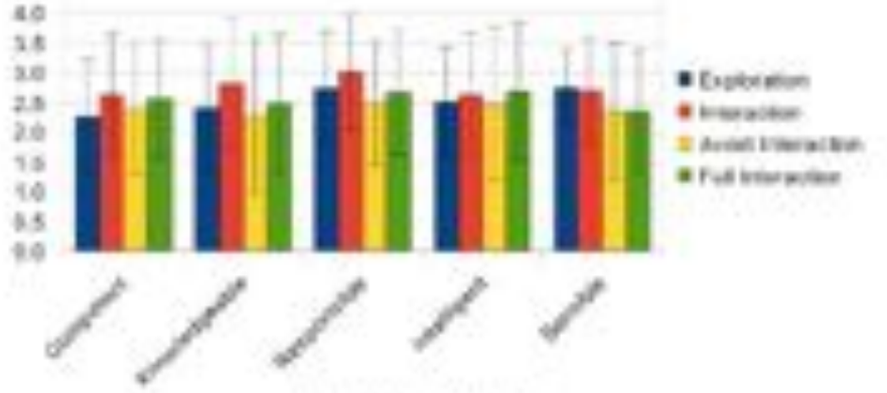


Animacy

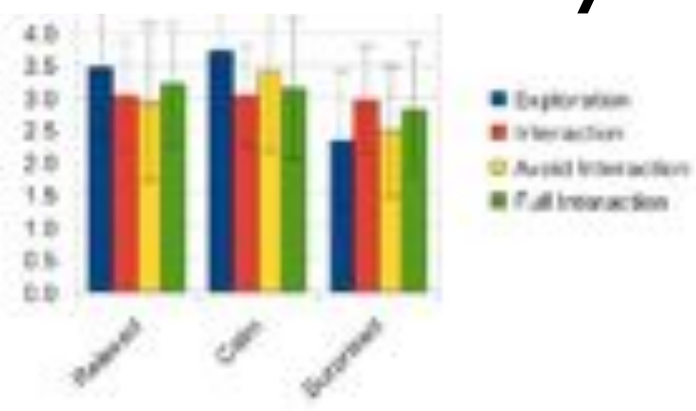


Likeability

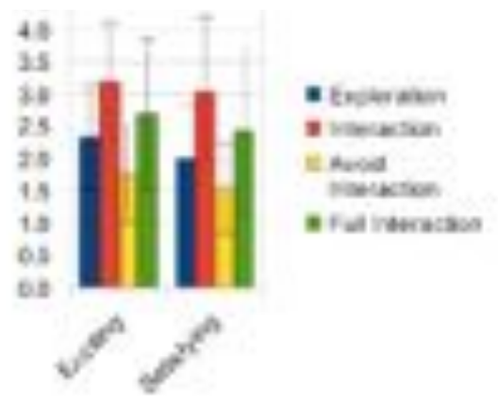
Perceived Intelligence



Perceived Safety



User Satisfaction



Study Results I

- Positive correlation between **anthropomorphic attributes** and **perceived intelligence** (expectations not taken into account)

- **Interactiveness** (exhibited with attentive mechanisms) positively correlated with **excitement, lifelikeness and intelligence**

- **Multi-modal interaction** (interaction and full interaction) increased the level of **interactiveness**

Study Results II

- Negative correlation between:
  - likeness and kindness, and variance of the face-face distance
  - satisfaction and variance of the face-hand distance
- Variance is higher during the interaction avoidance than during the other behaviors

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Summary I

- Intuitive HRI needs **joint attention**
- identified prerequisites
- attention manipulation through **pointing**
- attentional model based on **saliency maps** & robot **ego-sphere**
- setup: human-robot **interaction** game

Summary II

- different **levels of interactiveness** of the robot
- pos. correlated with user experience factors like **excitement** and robot factors like **lifelikeness** and **intelligence**
- robot **feedback** important for intuitive interaction

Acknowledgements

Contributions:
all members and partners of the Cognitive Robotics group at HU Berlin

http://koro.informatik.hu-berlin.de

METRIK – Modellbasierte Entwicklung von Technologien für selbstorganisierende dezentrale Informationssysteme im Katastrophenmanagement

GRK Sensory Computation in Neural Systems

DFG Deutsche Forschungsgemeinschaft

DBU

SEVENTH FRAMEWORK PROGRAMME

MARIE CURIE ACTIONS