人工智能 The ShanghAI Lectures 上海授课

Video clips, demonstrations

- **Video: Nao Babbling + pointing**
- **Video: iCub attention**
- **Video: Festo BHA**
- **Video: Playground experiment**

The ShanghAI Lectures on Embodied AI

Today from **Humboldt-Universität zu Berlin**, Germany

host:

Verena Hafner
Adaptive Systems Group, Department of Computer Science
Humboldt-Universität zu Berlin, Germany


DEM DEUTSCHEN VOLKE


U
Alexanderplatz


Breshnew
Honecker
CCCP/SU
TRABI


BERLIN

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Today’s schedule

9:00 - 9:15 Short intro + remaining site presentations (Osaka, Pisa, Madrid) + student presentation on framsticks (TU Poznan, PL)

9:15 - 10:00 Lecture 5:
Developmental Robotics (Verena Hafner, HU Berlin)

10:00 Discussion and Coffee break

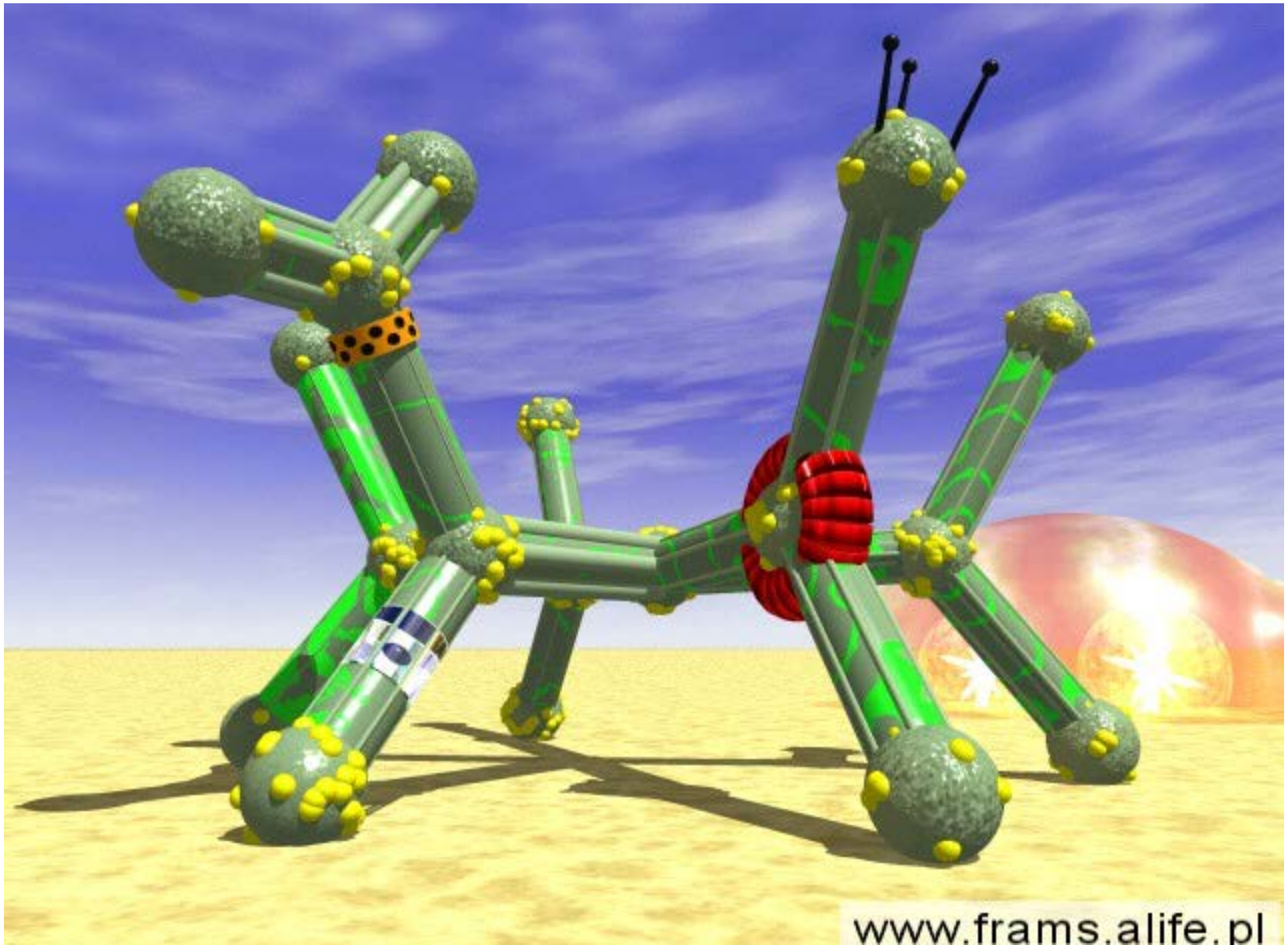
10:15 Guest lecture "Robotics in the Human Brain Project" by Florian Röhrbein, TU Munich

11:00 Wrap up

11:15 End

framsticks

short presentation from TU Poznan, PL

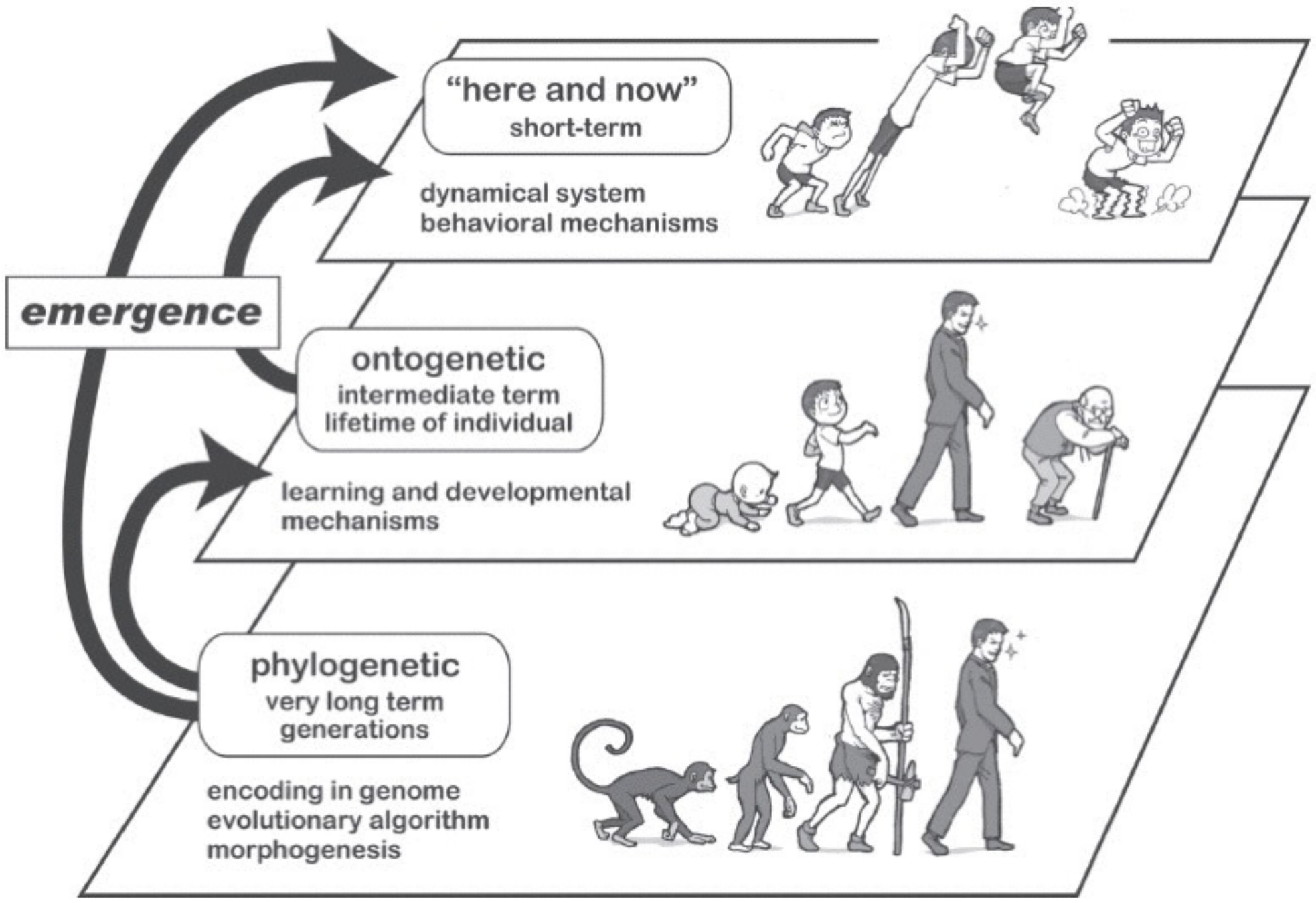


Lecture 5

Developmental Robotics

12th November 2015

Time perspectives



Time perspectives in understanding and design

state-oriented
“hand design”

“here and now” perspective

learning and development
initial conditions, learning and developmental processes

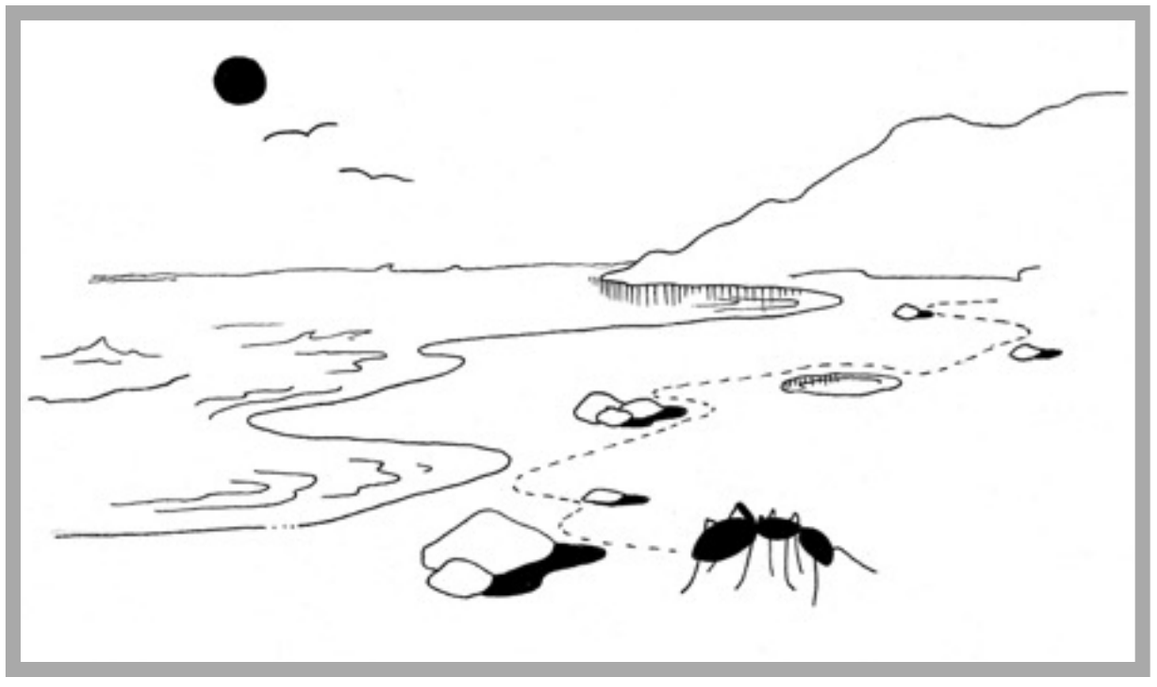
“ontogenetic” perspective

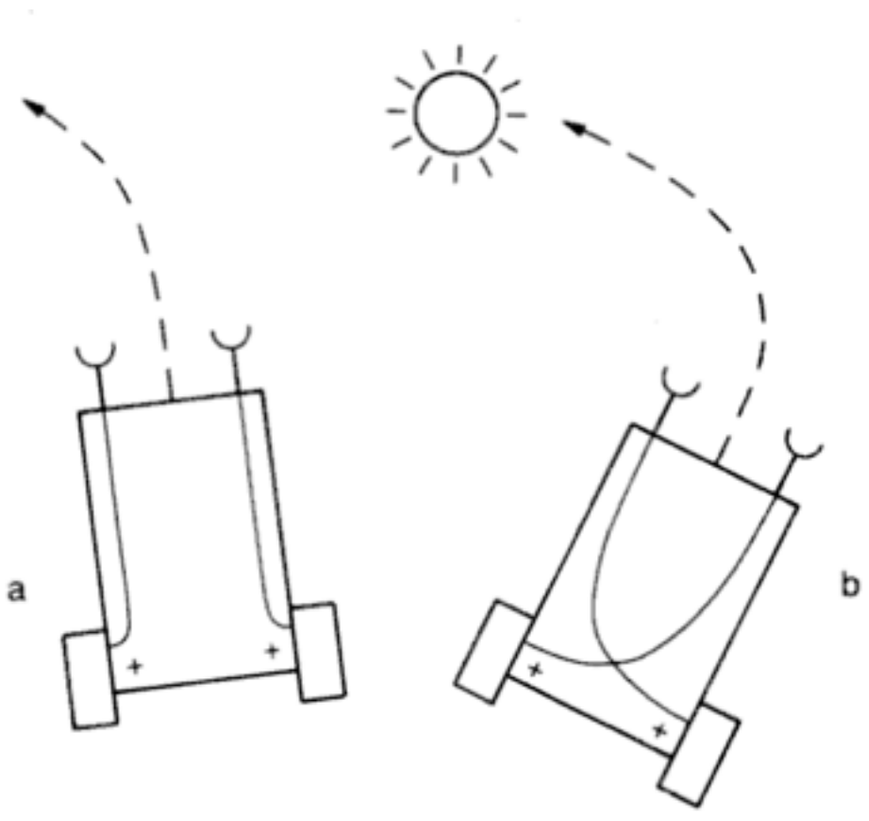
evolutionary
evolutionary algorithms, morphogenesis

“phylogenetic” perspective

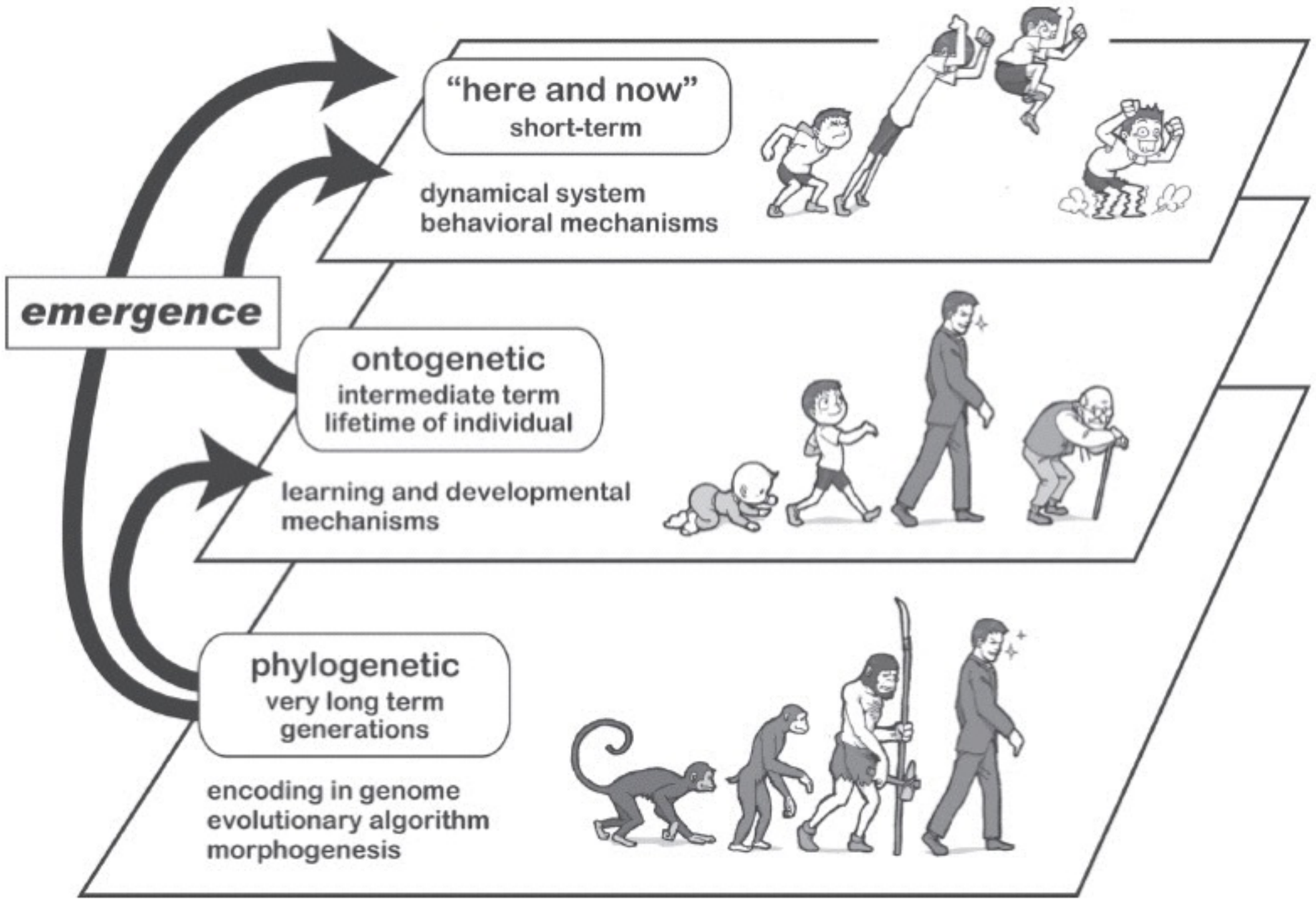
Understanding: **all three perspectives required**
Design: **level of designer commitments, relation to autonomy**

here&now Perspective



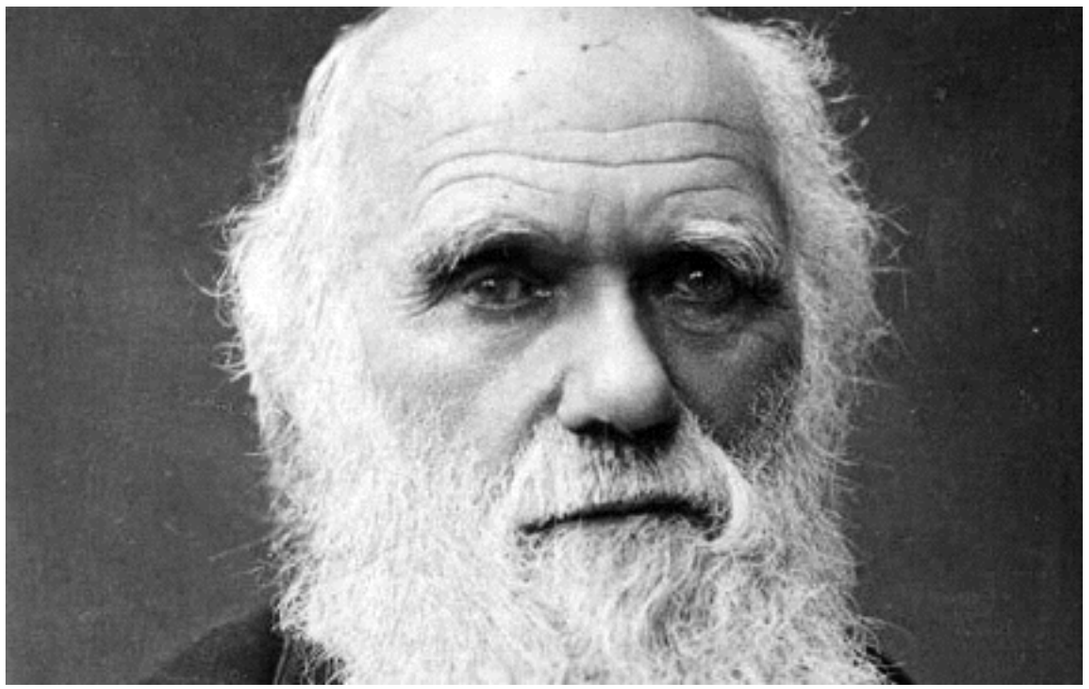


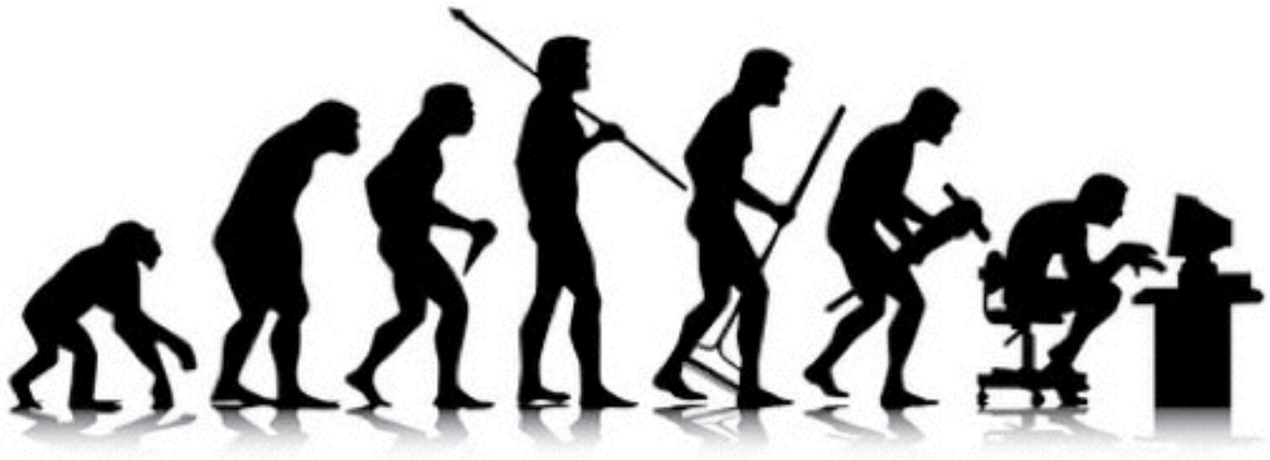
Time perspectives



Phylogenetic Perspective

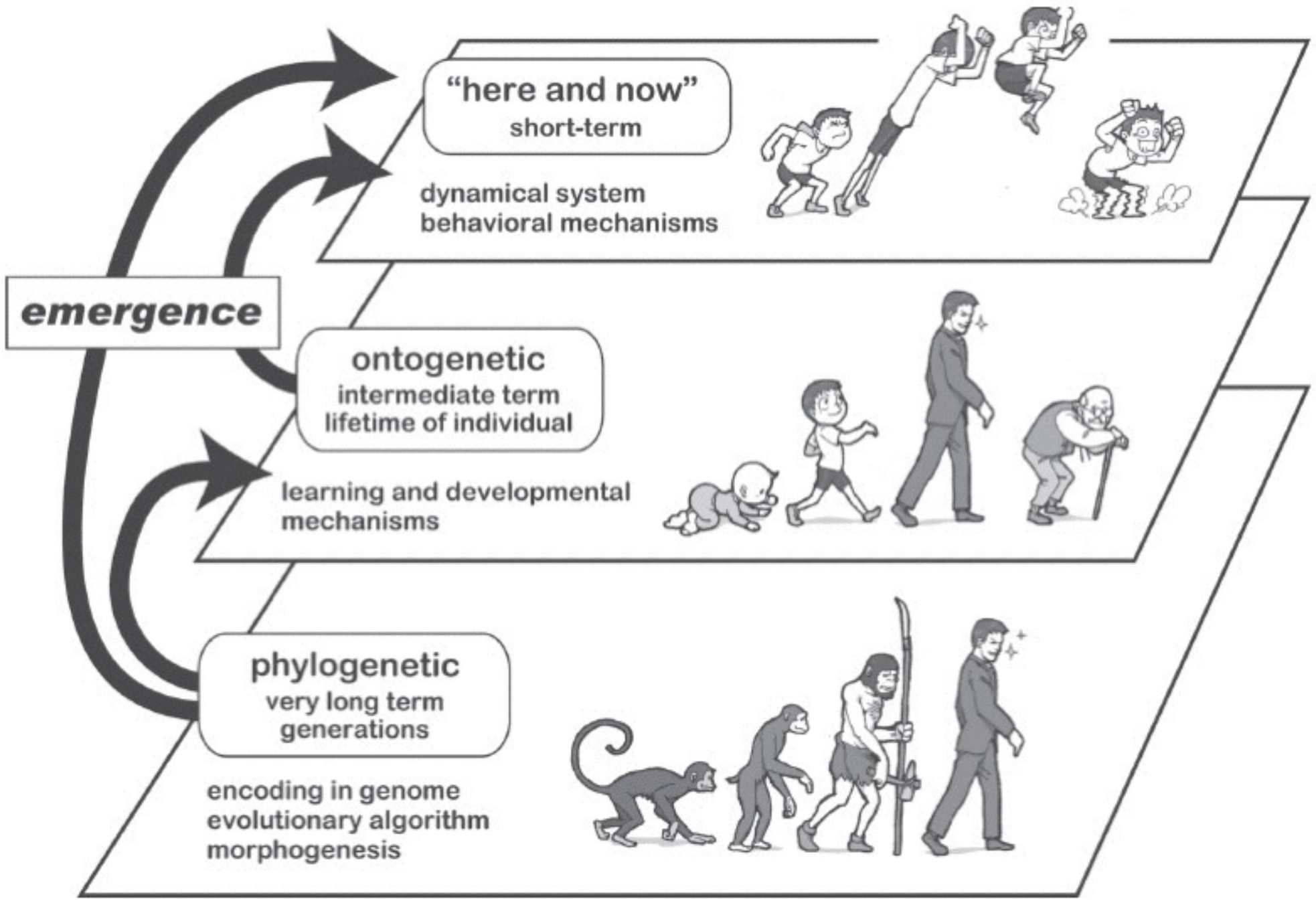
Evolution



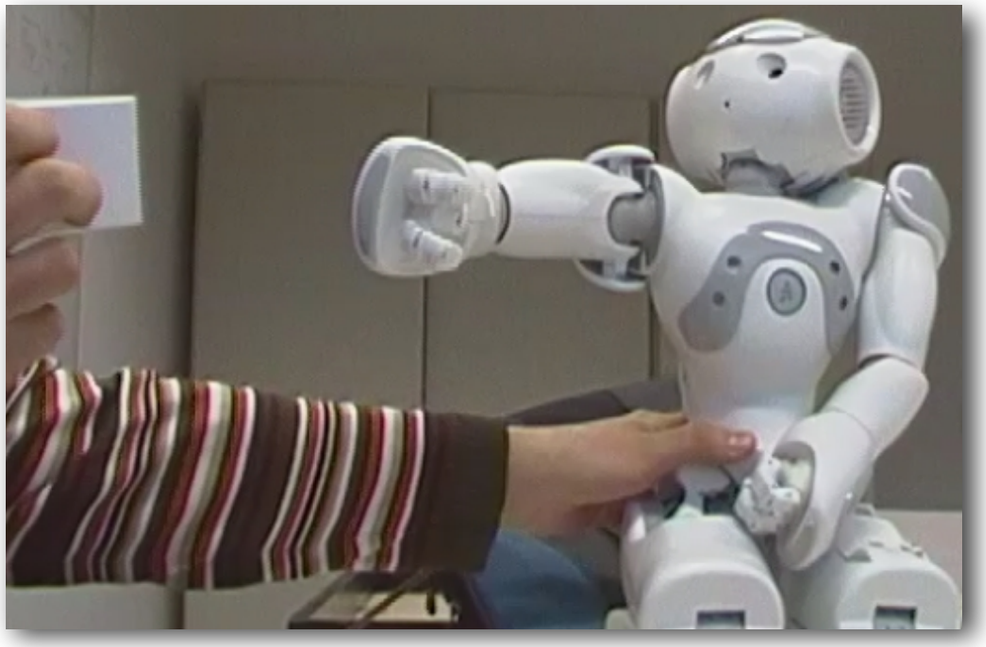


Charles Darwin

Time perspectives

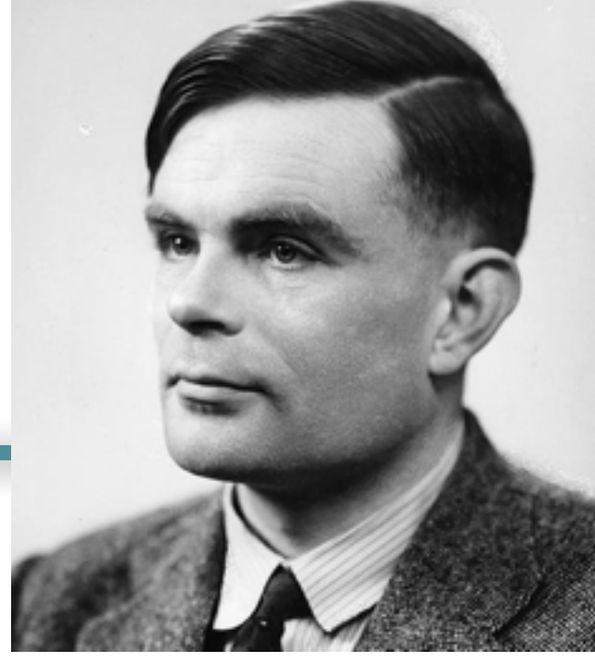


Ontogenetic Perspective



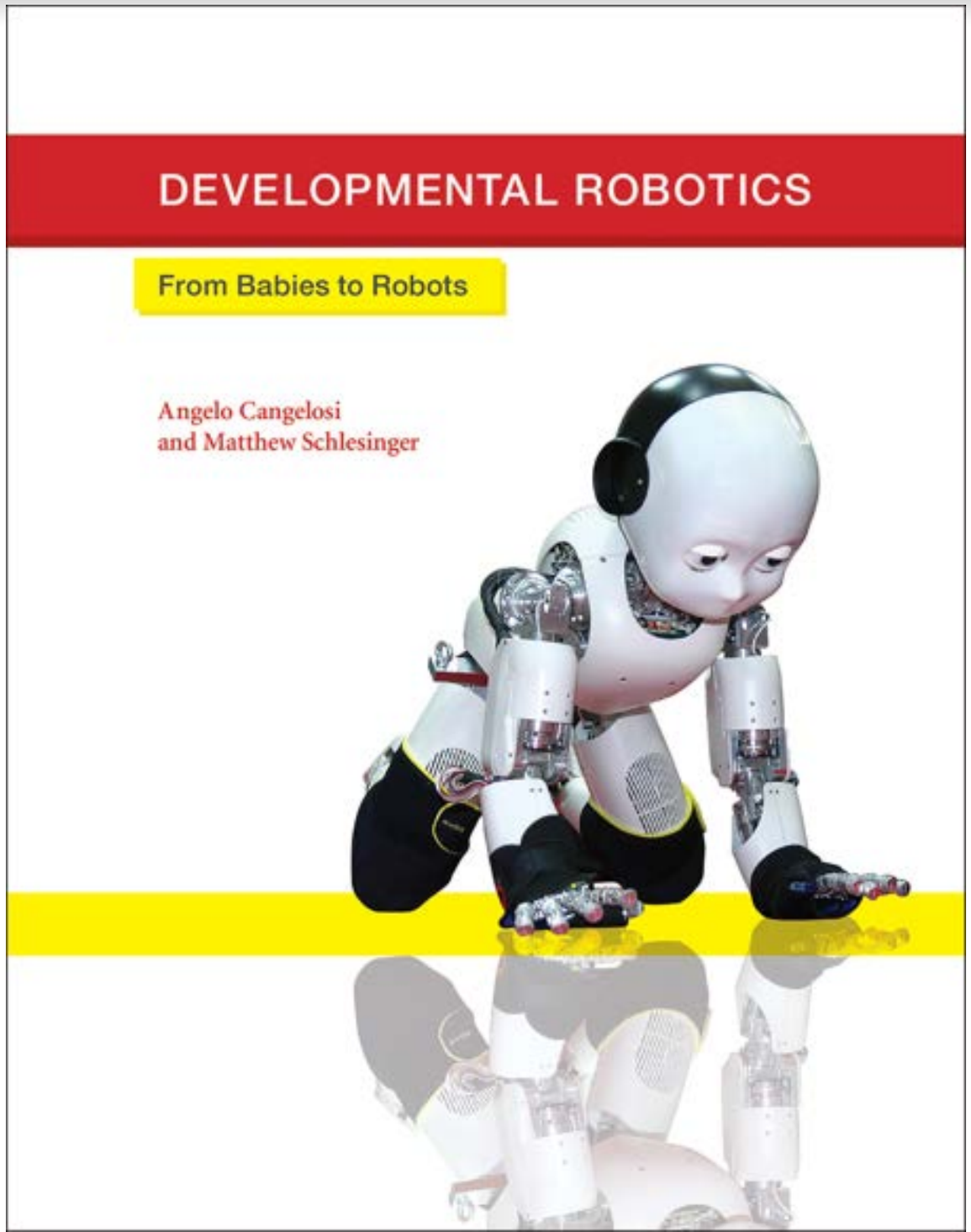
Hafner, V.V. and Schillaci, G. (2011), From field of view to field of reach - could pointing emerge from the development of grasping? *Frontiers in Computational Neuroscience, Conference Abstract: IEEE ICDL-EPIROB 2011.*

Alan Turing, 1950



“Instead of trying to produce a programme to simulate the adult mind, why not rather try to produce one which simulates the child's? If this were then subjected to an appropriate course of education, one would obtain the adult brain [...]
Our hope is that there is so little mechanism in the child brain that something like it can be easily programmed. The amount of work in the education we can assume, as a first approximation, to be much the same as for the human child.”

Ontogenetic Perspective



International Conference on Epigenetic Robotics

IEEE
ICDL - EPIROB
2013

The Third Joint IEEE International Conference on Development and Learning and on Epigenetic Robotics

Osaka City Central Public Hall, Osaka, Japan, August 18-22, 2013

IEEE ICDL-EPIROB 2015

The Fifth Joint IEEE International Conference on Development and Learning and on Epigenetic Robotics

Brown University, Providence, Rhode Island, USA, August 13-16 2015

IEEE
ICDL - EPIROB
2014

The Fourth Joint IEEE International Conference on Development and Learning and on Epigenetic Robotics

Palazzo Ducale, Genoa, Italy
October 13-16, 2014

IEEE - ICDL EPIROB 2016

The Sixth joint IEEE International Conference

Development, Learning and Epignentic Robotics

Cergy-Pontoise

Ontogenetic Perspective

Developmental Robotics / Epigenetic Robotics

- relationship between evolution and development
- aspects of human infant development
- sensorimotor learning
- learning of social skills
- e.g. imitation learning, joint attention

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

Nagai, Y., Hosoda, K., Morita, A., and Asada, M. (2003). A constructive model for the development of joint attention. Connection Science, 15(4):211–229.

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

Developmental Robotics

major role of Embodied AI

intelligence: learned experience from interaction in the real world

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

Embodied Cognition

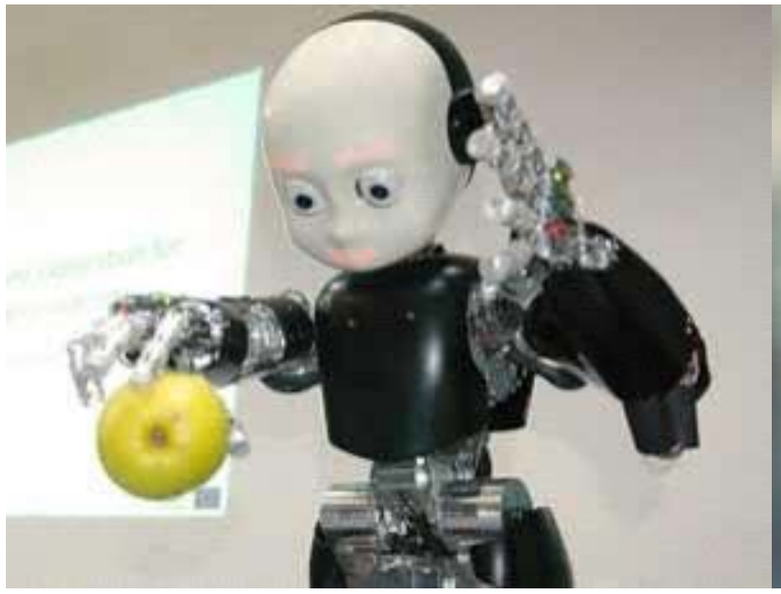
embodiment hypothesis

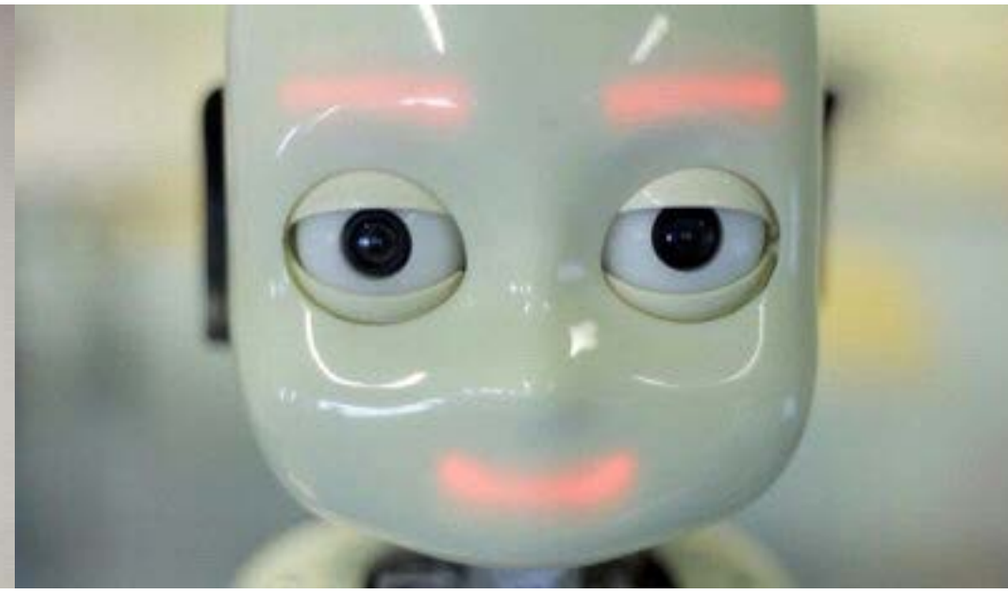
intelligence emerges from the **interaction** of an agent with an environment and as a result of sensorimotor activity.

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

(humanoid) platforms

- iCub

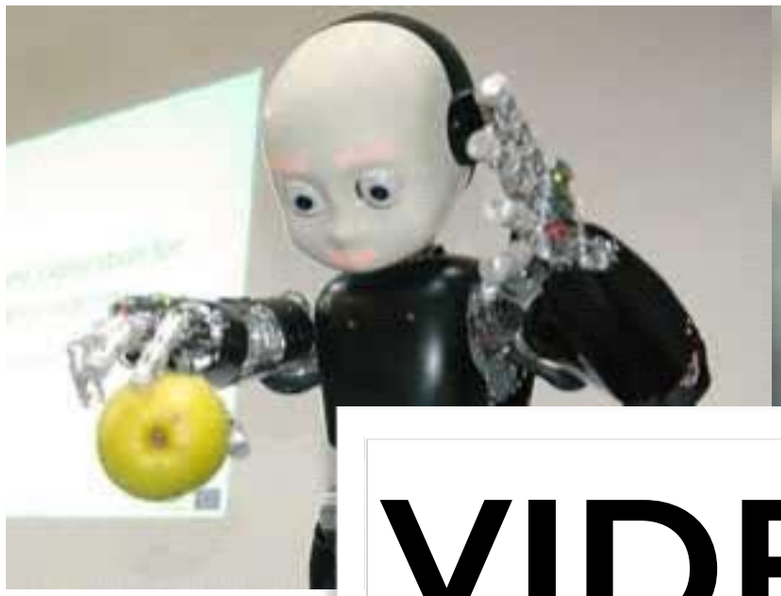


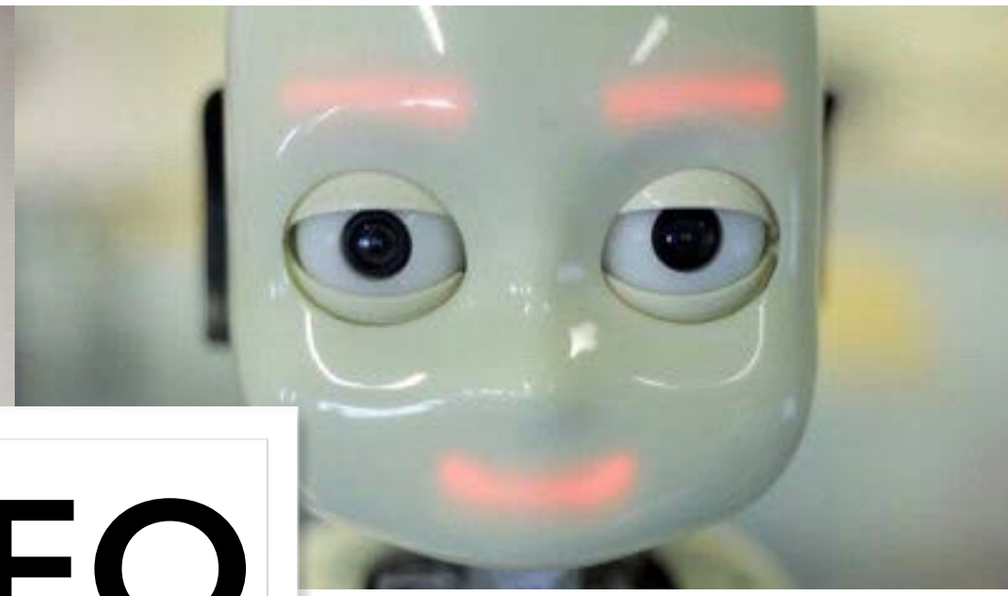


- Nao

(humanoid) platforms

- iCub



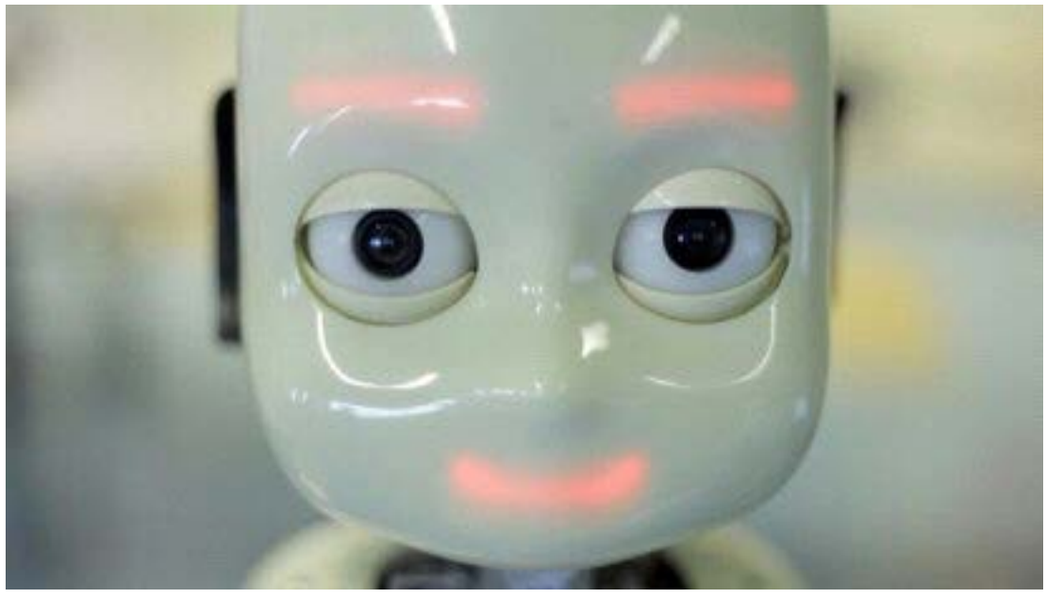


VIDEO

- Nao

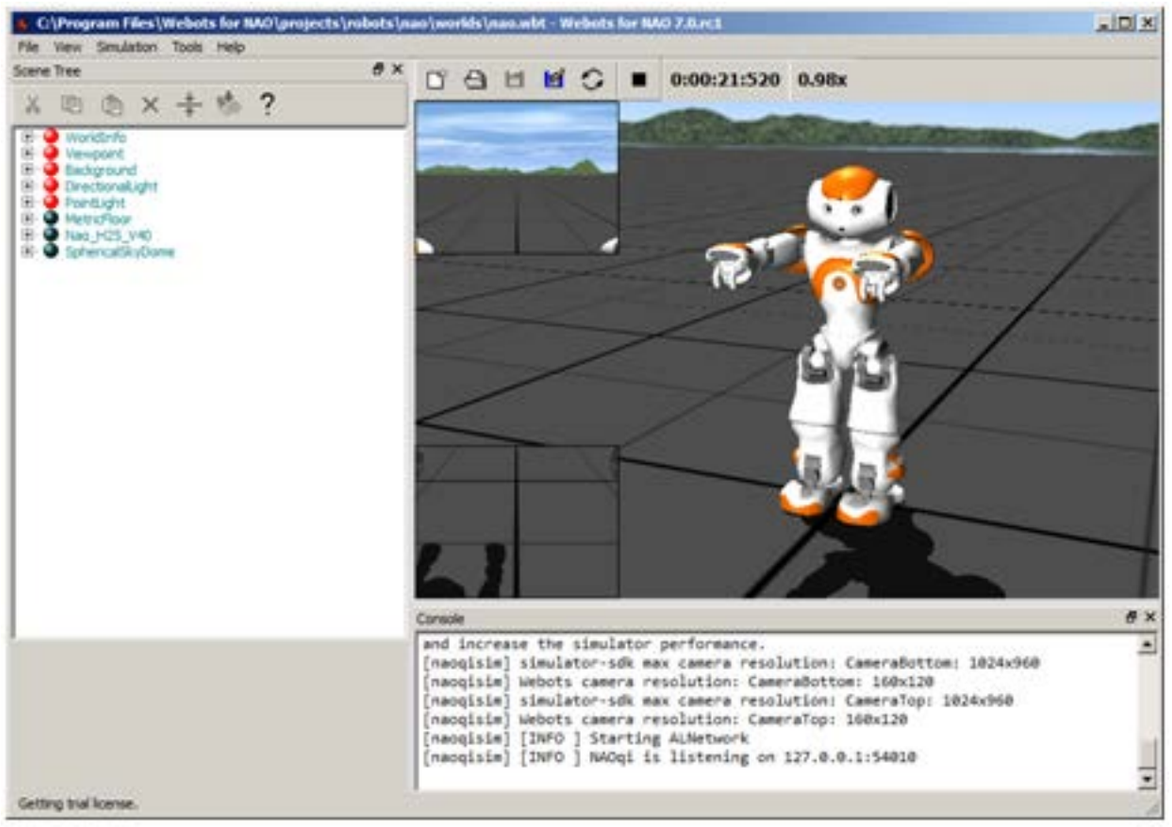
iCub attention

- Prerequisites for attention behaviour in a robot
- Purpose?
- F-O-R?



Schillaci, G., Bodiroza, 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.

Simulators



Webots

Casparo -

an opera on developmental robotics

Luc Steels (music) &
Oscar Vilarroya (libretto)

This is the story of a humanoid robot called Casparo who is bought by the greedy Graziano against the wishes of his wife Rosalinda.
To Graziano's disappointment, Casparo turns out to be a **developmental robot** that needs to be taught everything, even how to walk or speak.
Moreover Casparo has become imprinted on Rosalinda and consequently does not want to listen to Graziano. Graziano looses patience, becomes angry, and wants to reduce Casparo to a scrap of metal. But Rosalinda comes to Casparo's rescue and the story ends in harmony.

https://www.youtube.com/watch?v=4upV519Uu1Q

Casparo -

an opera on developmental robotics

https://www.youtube.com/watch?v=4upV519Uu1Q

Ontogenetic Perspective

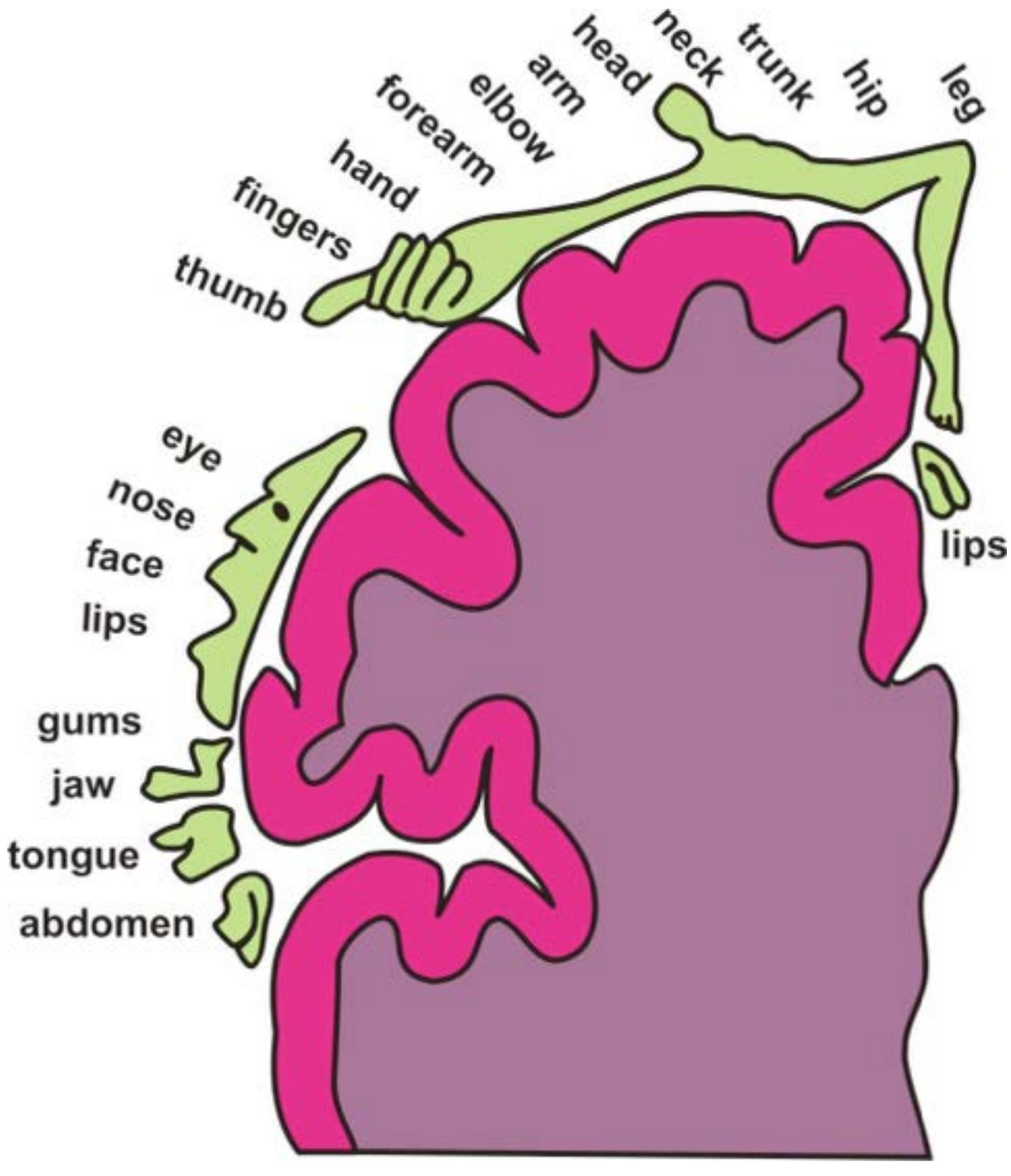
Developmental Robotics / Epigenetic Robotics

some examples on body maps, sensorimotor exploration and learning

Body maps

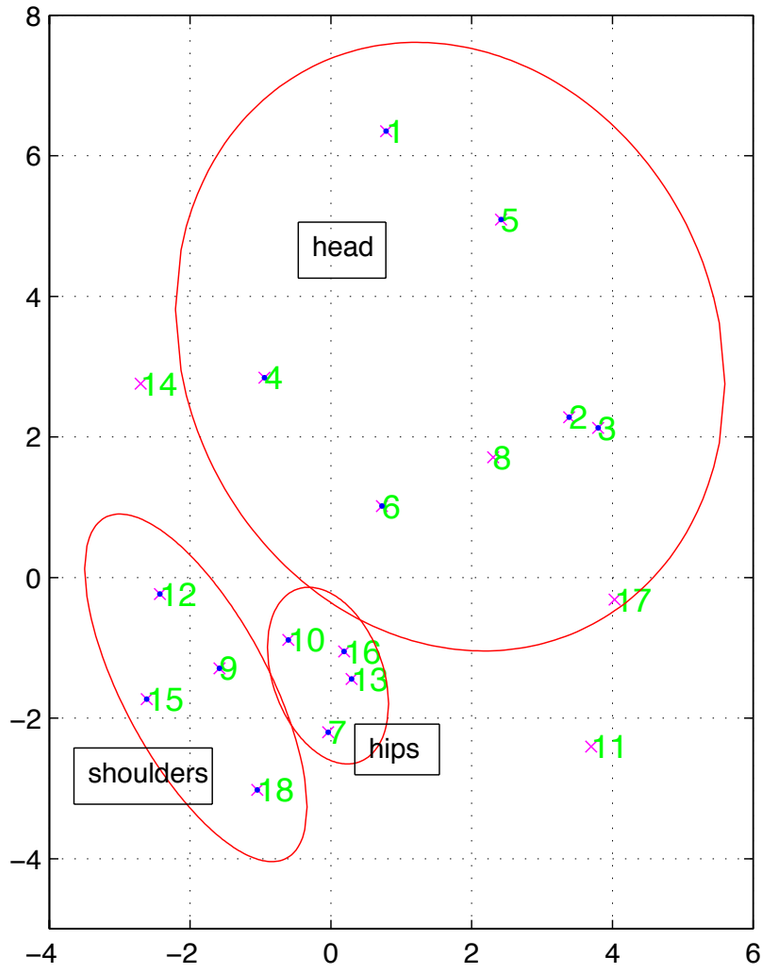
- inspired by somato-sensory maps in human cortex

- dynamic and short term representation of body and behaviour



Maps based on Information Distances

- informationally close sensors are also close on the map
- maps function as body schema



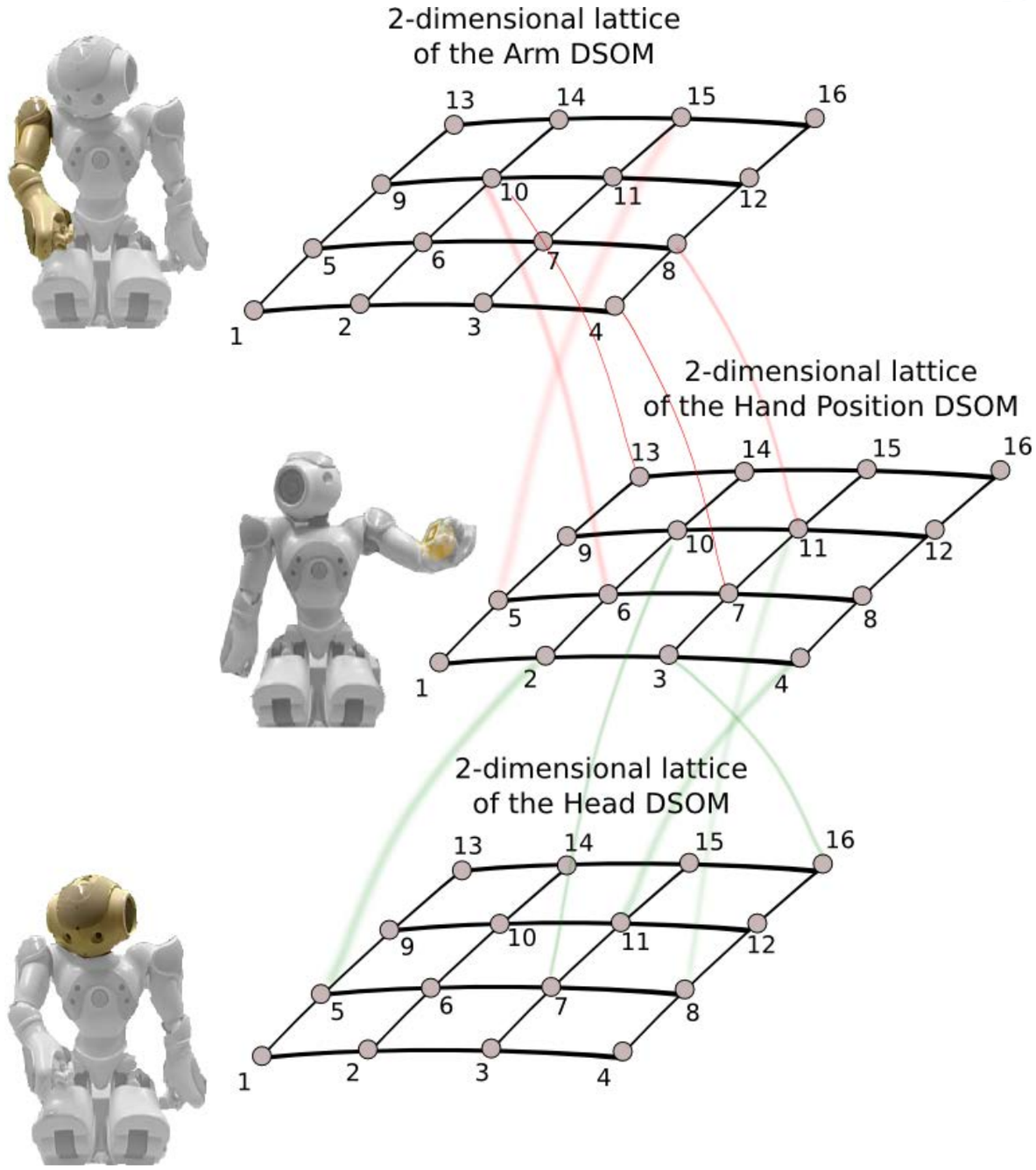
Hafner, V.V. and Kaplan, F. (2008), Interpersonal Maps: How to Map Affordances for Interaction Behaviour, *In: E. Rome et al. (Eds.): Affordance-Based Robot Control, LNAI 4760, pp. 1-15, Springer-Verlag Berlin Heidelberg*

ERA

- A. Morse, J. de Greeff, T. Belpaeme, and A. Cangelosi, "Epigenetic robotics architecture (era)," Autonomous Mental Development, IEEE Transactions on, vol. 2, no. 4, pp. 325–339, 2010.

SOMs

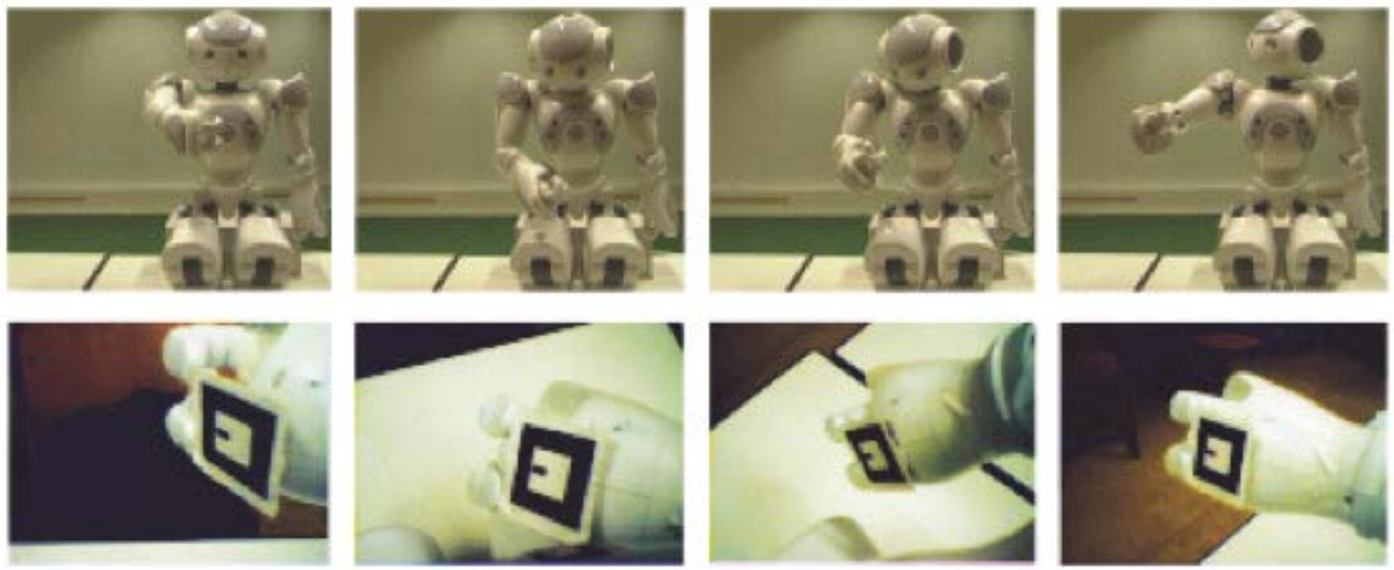
- Self-organising maps based on acquired data
- Framework supports easy inclusion of different modalities, including auditory



Schillaci, G., **Hafner, V.V.**, Lara, B. (2014), Online Learning of Visuo-Motor Coordination in a Humanoid Robot. A Biologically Inspired Model, 4th International Conference on Development and Learning and on Epigenetic Robotics (ICDL-EpiRob 2014), pp. 145-151, Genova, Italy.

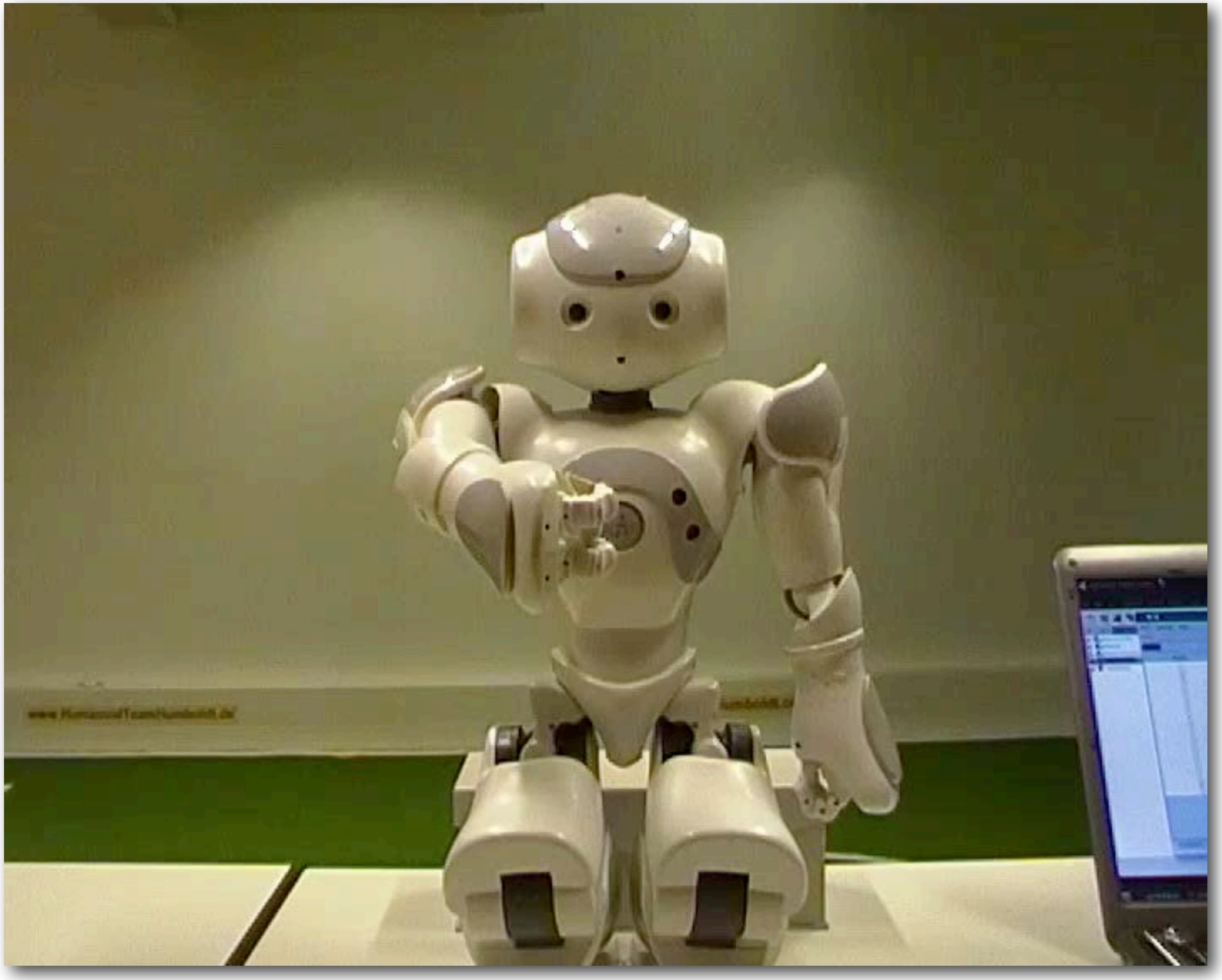
Experiments on Motor Babbling

exploration strategies

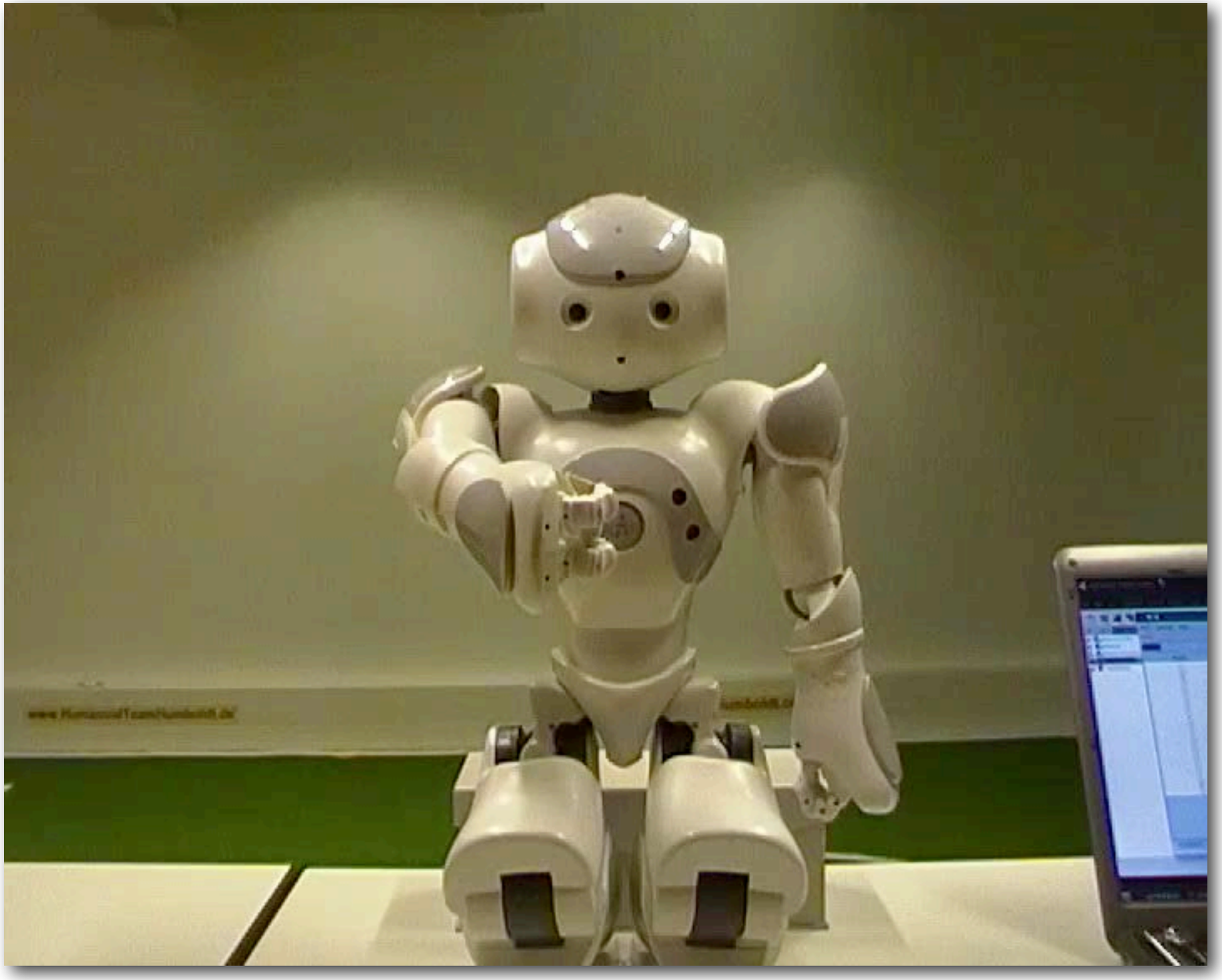


Schillaci, G. and **Hafner, V.V.** (2011), Random Movement Strategies in Self-Exploration for a Humanoid Robot, Proceedings of the 6th ACM/IEEE International Conference on Human-Robot Interaction (HRI 2011), pp. 245-246, Lausanne, Switzerland.

Motor Babbling



Motor Babbling



Exploration Strategies

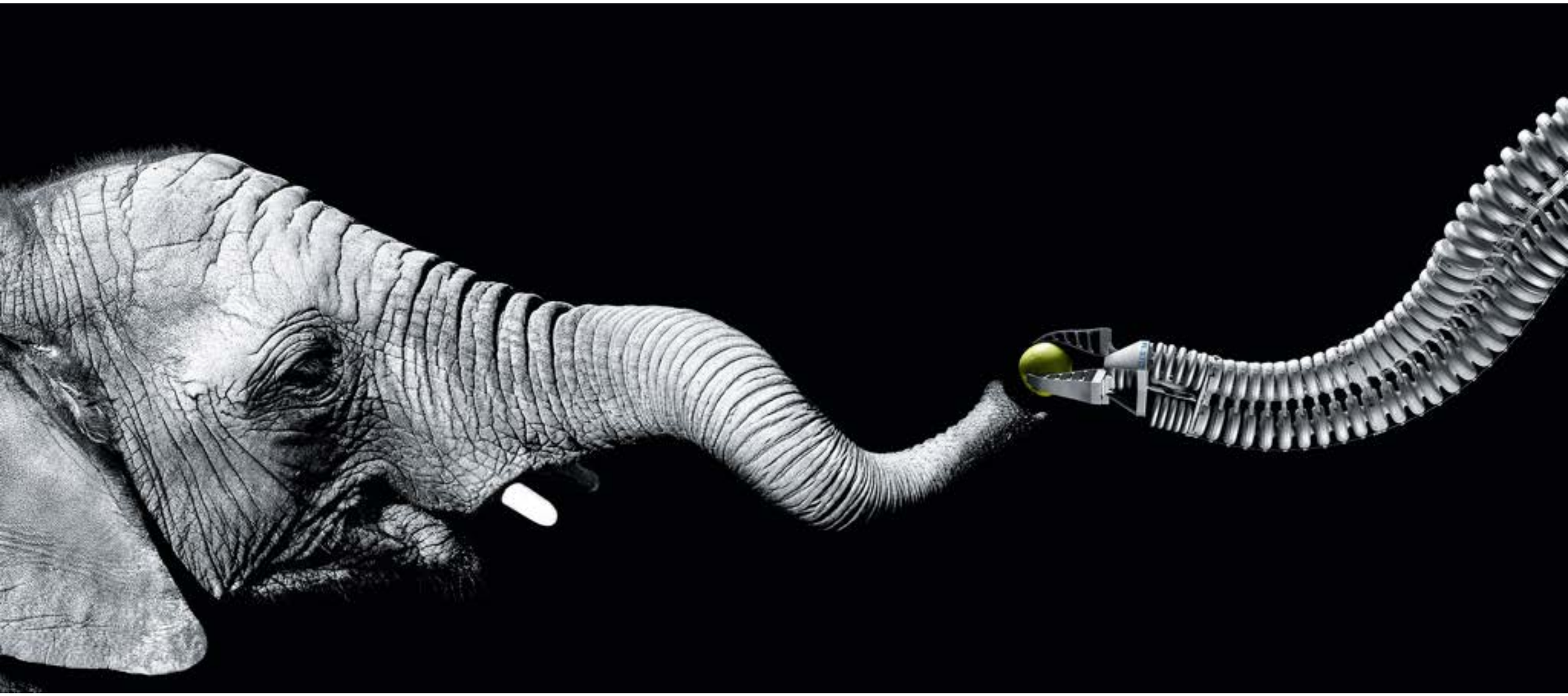
- Random motor babbling
- Goal-directed
- Intrinsic motivation

Rolf, M., and M. Asada, "Autonomous Development of Goals: From Generic Rewards to Goal and Self Detection", IEEE Int. Conf. Development and Learning and on Epigenetic Robotics, Genoa, 10/2014.

Rolf, M. and Steil, J.J. (2014), Explorative learning of inverse models: a theoretical perspective, Neurocomputing, vol. 131, pp. 2–14

Oudeyer, P.-Y., Kaplan, F., **Hafner, V.V.** (2007), Intrinsic Motivation Systems for Autonomous Mental Development, IEEE Transactions on Evolutionary Computation, Special Issue on Autonomous Mental Development, 11:2, pp. 265-286

soft robotics



Festo: Bionic handling assistant

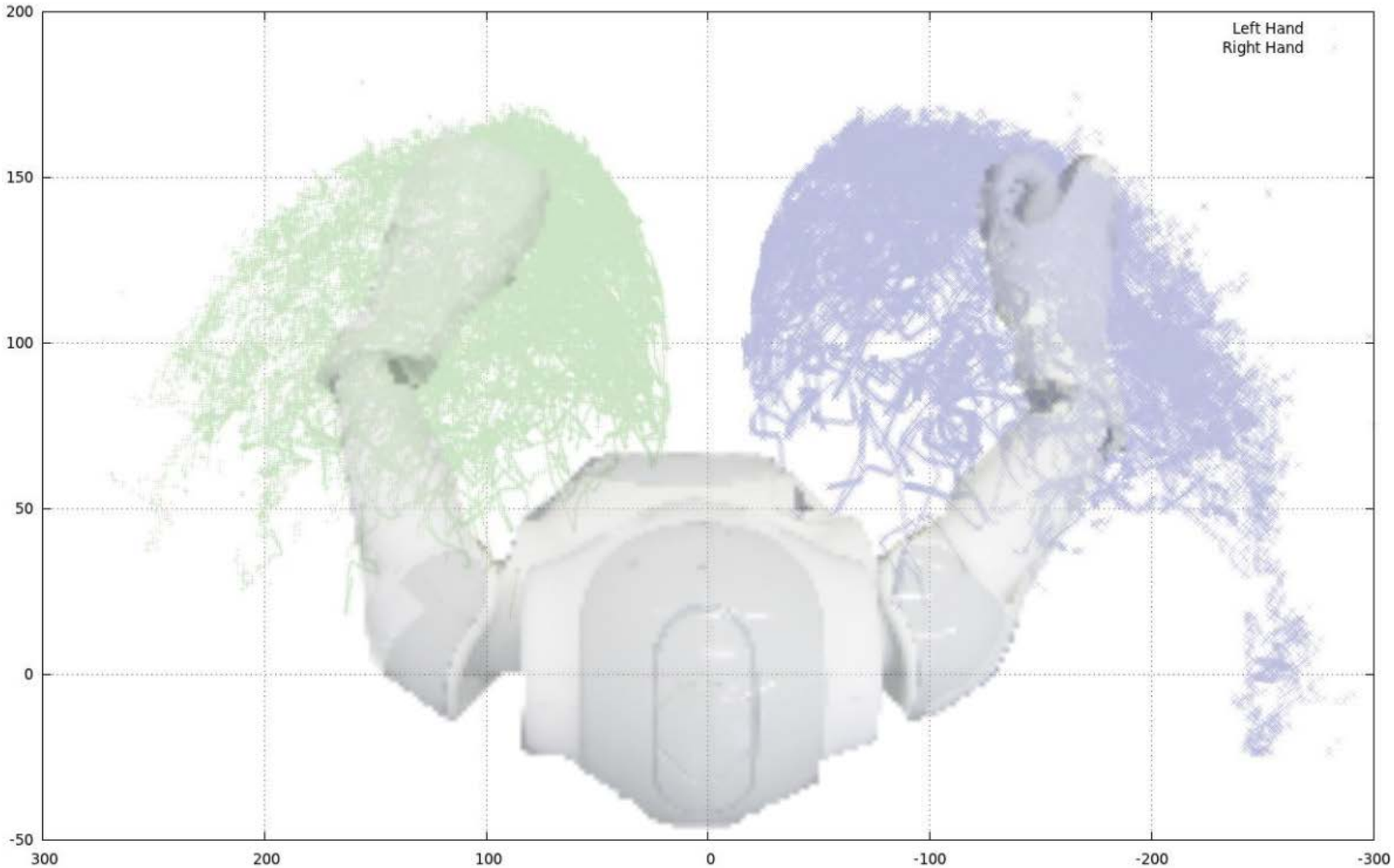
Exploration Strategies

The Playground Experiment (intrinsic motivation, maximise learning progress)

https://www.youtube.com/watch?v=Ltl9vC2t_vU

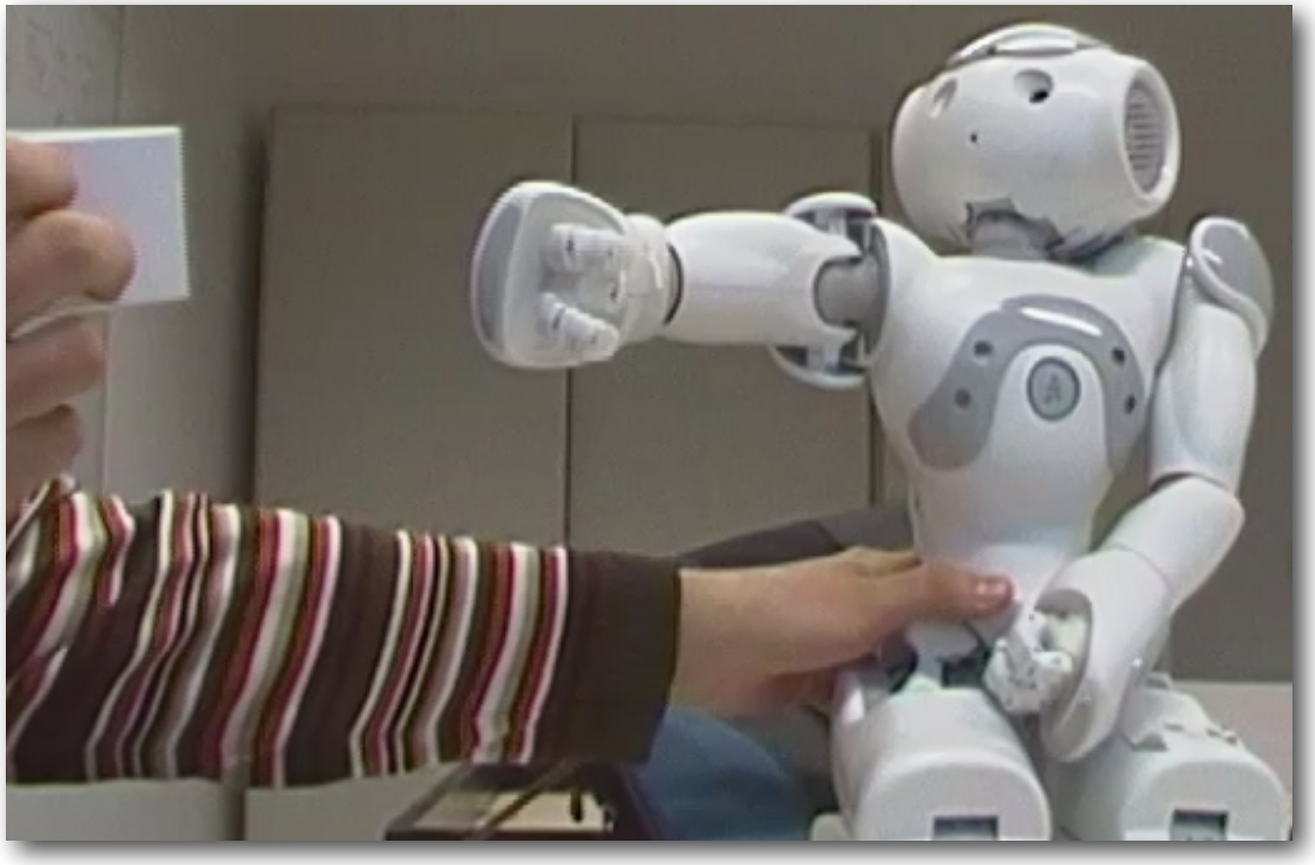
Oudeyer, P.-Y., Kaplan, F., **Hafner, V.V.** (2007), Intrinsic Motivation Systems for Autonomous Mental Development, IEEE Transactions on Evolutionary Computation, Special Issue on Autonomous Mental Development, 11:2, pp. 265-286

Sensorimotor Exploration



action spaces on a Nao robot

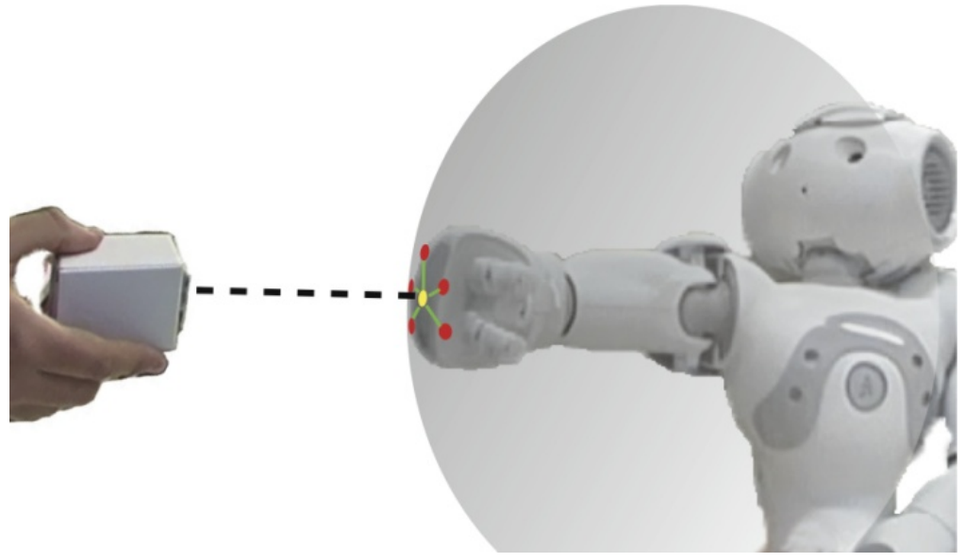
Could pointing emerge from grasping?

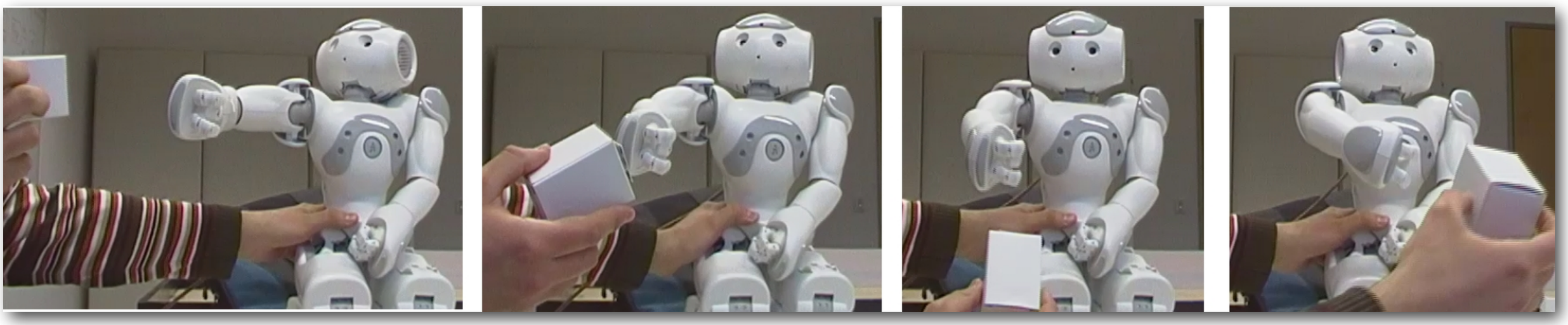


Hafner, V.V. and Schillaci, G. (2011), From field of view to field of reach - could pointing emerge from the development of grasping? *Frontiers in Computational Neuroscience, Conference Abstract: IEEE ICDL-EPIROB 2011.*

Could pointing emerge from grasping?

object outside the field of grasp





future challenges

- Language -> next week's main lecture by Anthony Morse, Univ. Plymouth
- Mathematics -> book by Lakoff

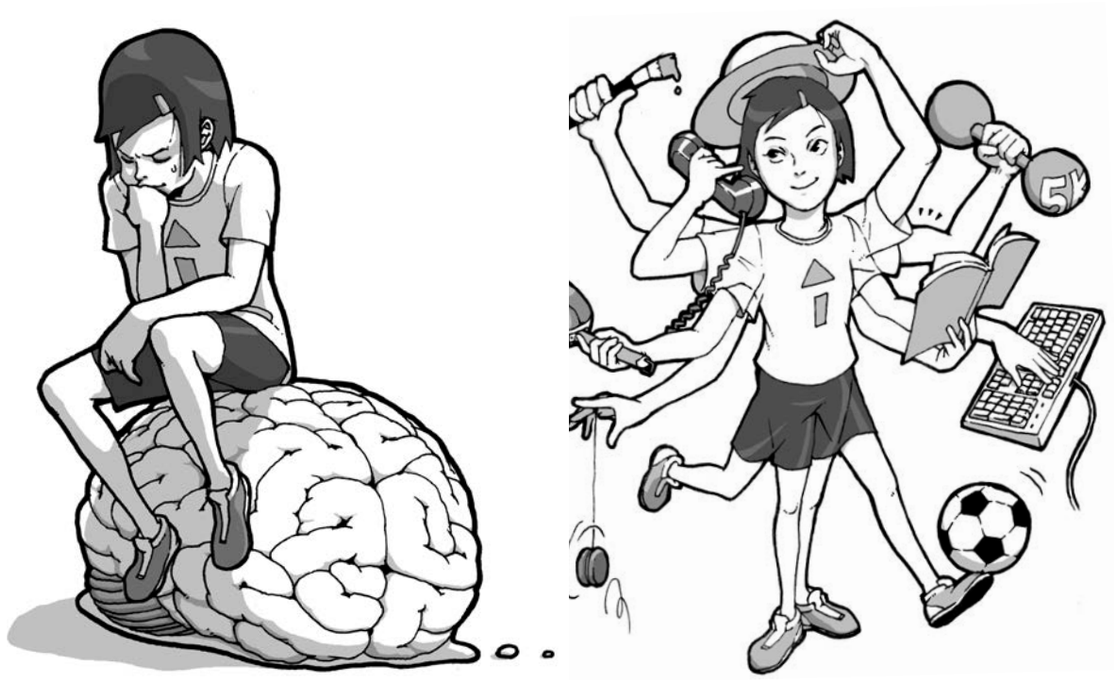
Assignments for next week

- Read chapter 5 of “How the body …”
- Assignments - volunteers?

End of lecture 5

Thank you for your attention!

stay tuned for guest lectures



Lecture 5: Guest speaker

Guest lecture "Robotics in the Human Brain Project" by Florian Röhrbein, TUM

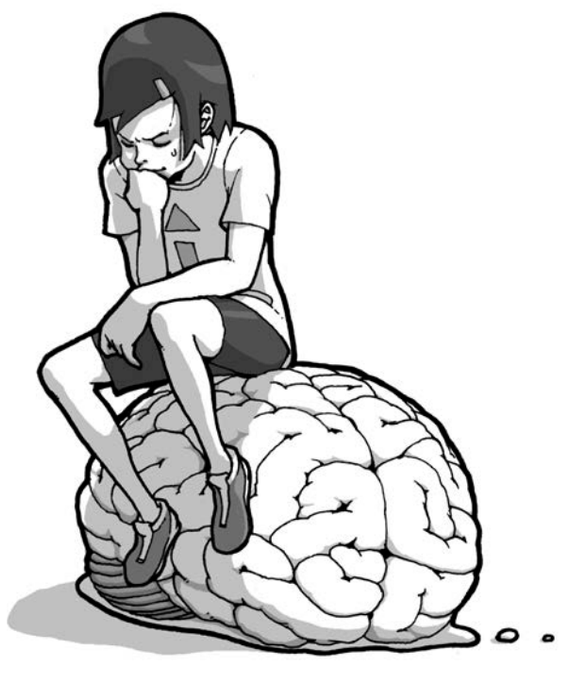
End of lecture 5

Thank you for your attention!

stay tuned for lecture 6

“Developmental Robotics: Language”

(Anthony Morse, Plymouth, UK)



Thank you.

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

Local organisers:

- Andreas Goroncy
- Damien Drix
- Christian Blum

Internal Models

Current sensory state S(t)

Desired sensory state S(t+1)

Inverse Model

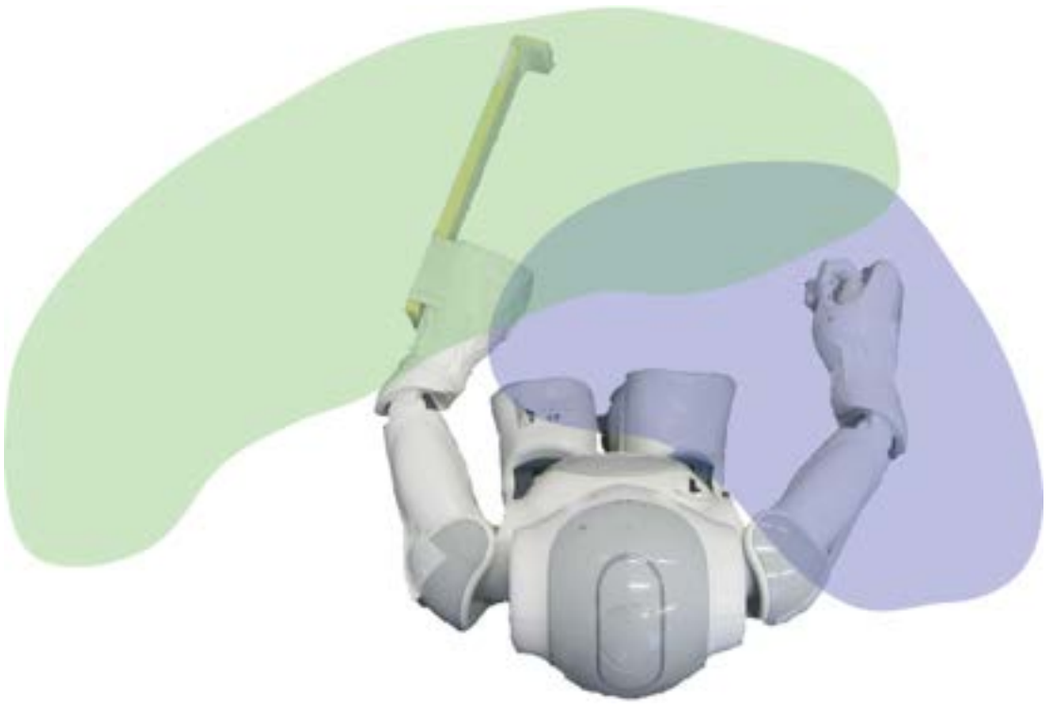
Simulated motor command M*(t)

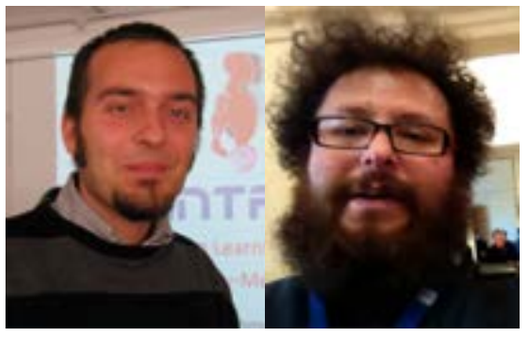
Forward Model

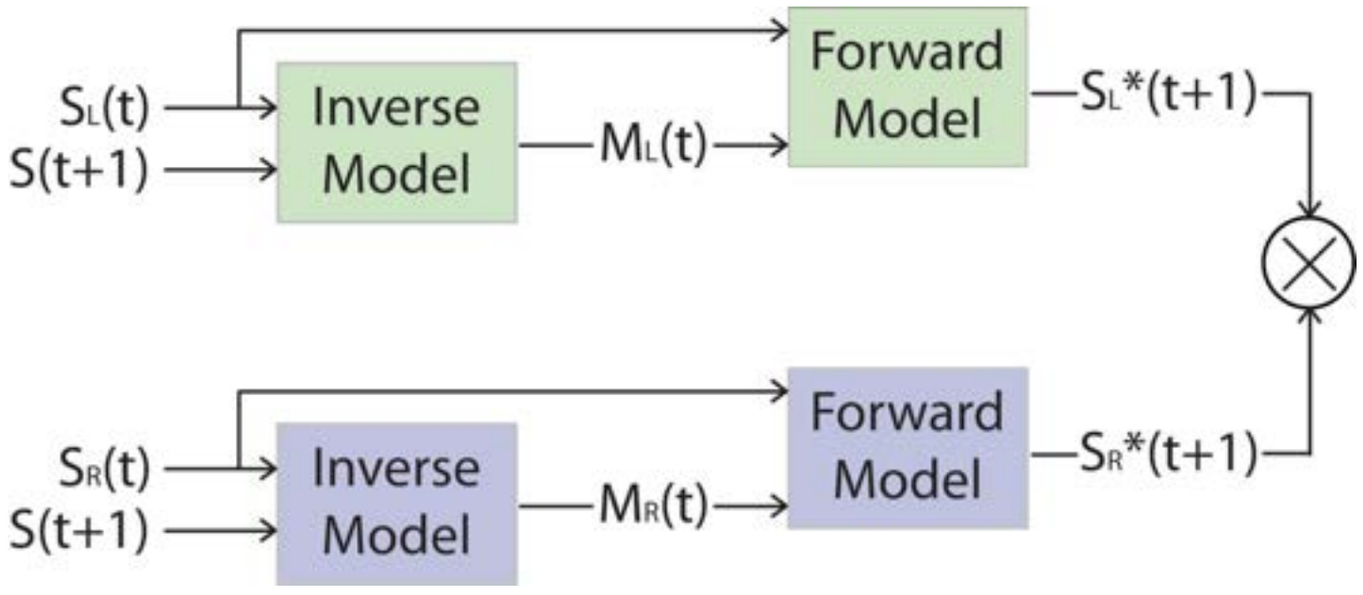
Simulated sensory state S*(t+1)

Predictions of own and others' actions for decision making and action recognition

...Tool-use and Internal Models







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.*