Introduction to Robotics

Lecture 13

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Technical Aspects of Multimodal Systems

July 08, 2016

Outline

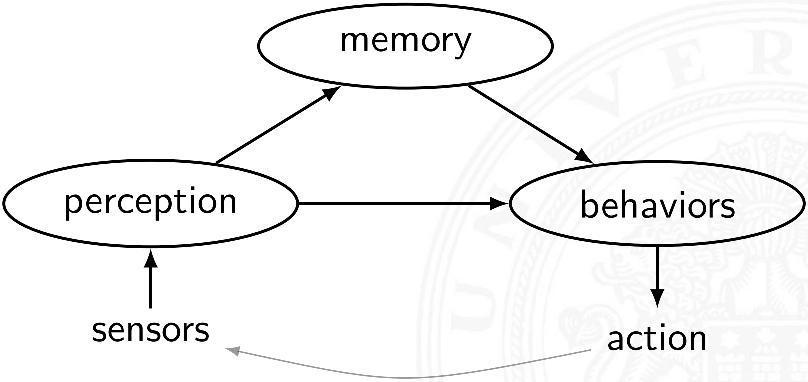
Outline (cont.)

Architectures of Sensor-based Intelligent Systems

Overview

- Basic behavior
- Behavior fusion
- Subsumption
- Hierarchical architectures
- Interactive architectures

The Perception-Action-Model with Memory



CMAC-Model

CMAC: `Cerebellar Model Articulation Controller`

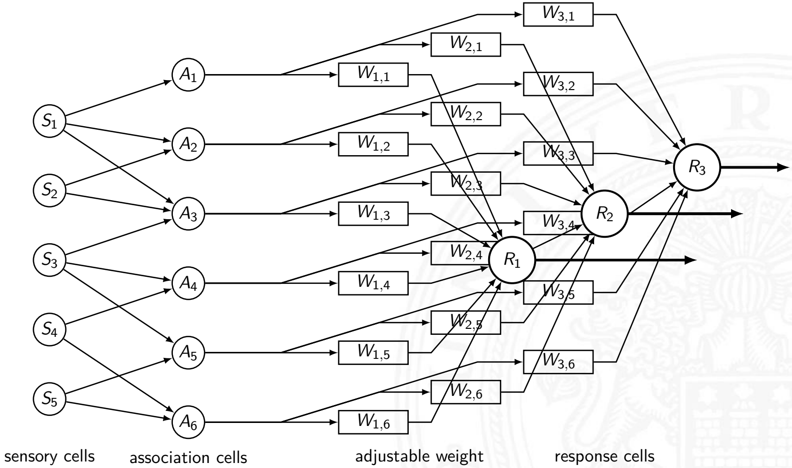
- **S** sensory input vectors (firing cell patterns)
- **A** association vector (cell pattern combination)
- **P** response output vector ($\mathbf{A} \cdot W$)
- W weight matrix

The CMAC model can be viewed as two mappings:

$$f : \mathbf{S} \longrightarrow \mathbf{A}$$

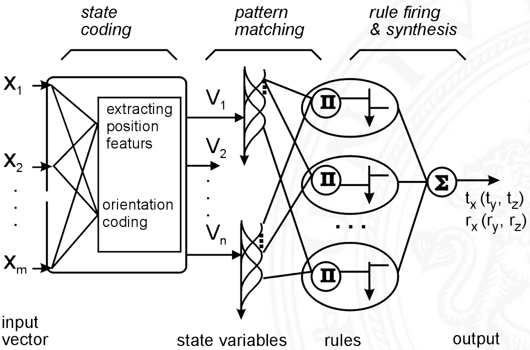
$$g : \mathbf{A} \xrightarrow{W} \mathbf{P}$$

CMAC-Model (cont.)

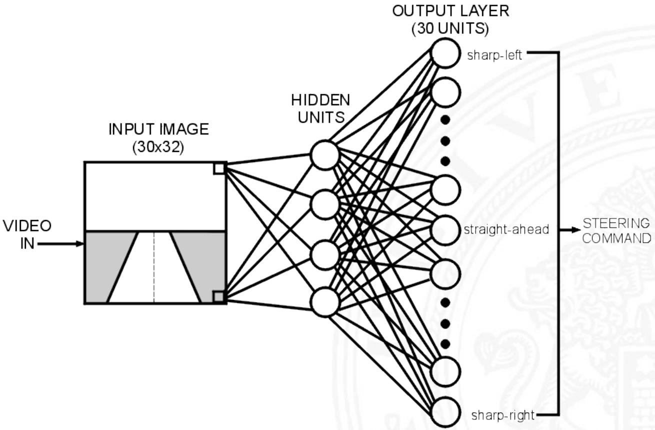


B-Spline-Model

The B-Spline model is an ideal implementation of the CMAC-Model. The CMAC model provides an neurophysiological interpretation of the B-Spline model.

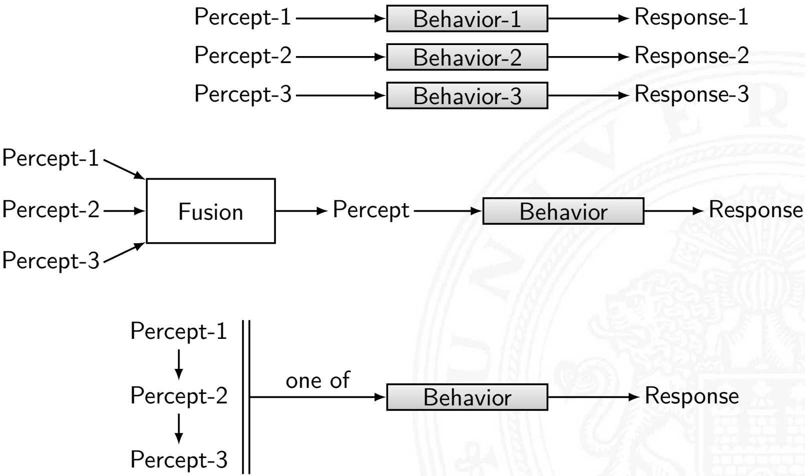


Alvinn – Visual Navigation



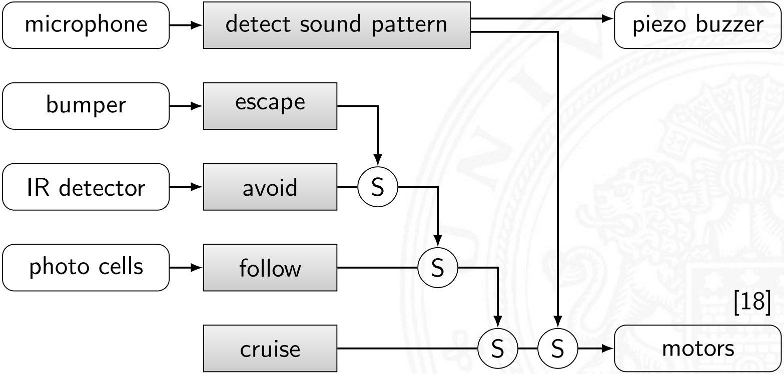
CMU – Carnegie Mellon University

Action-oriented Perception



The Subsumption Architecture

- hierarchical structure of behavior
- higher level behaviors subsumpt lower level behaviors



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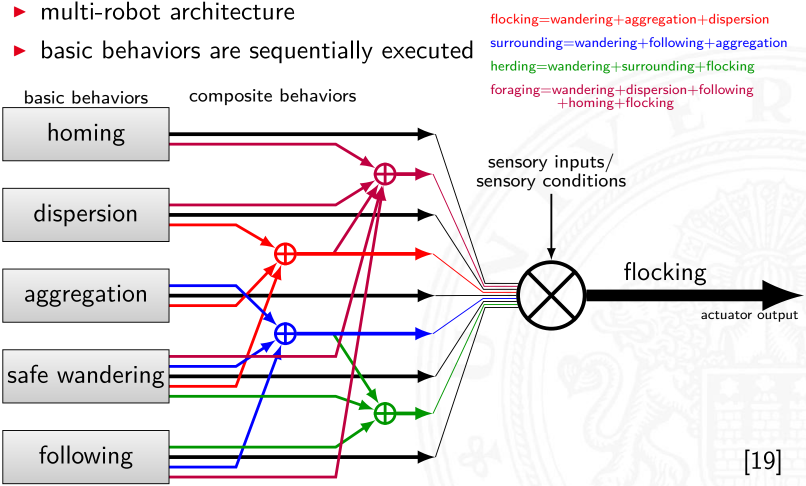
Foraging and Flocking

- multi-robot architecture
- basic behaviors are sequentially executed



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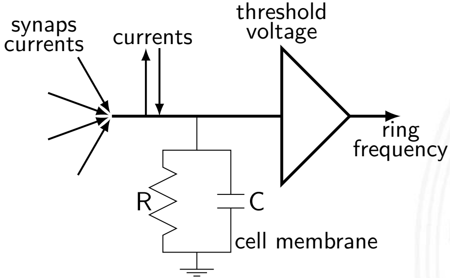
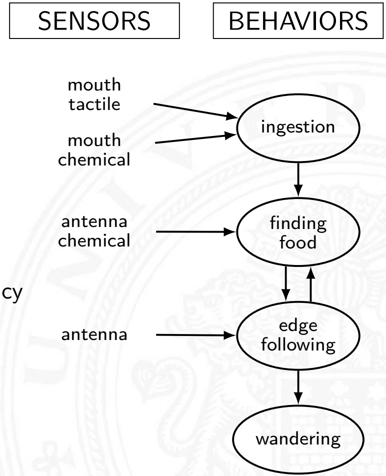
Cockroach Neuron / Behaviors





Control Architecture of a Fish

Control and information flow in artificial fish

Perception sensors, focuser, filter

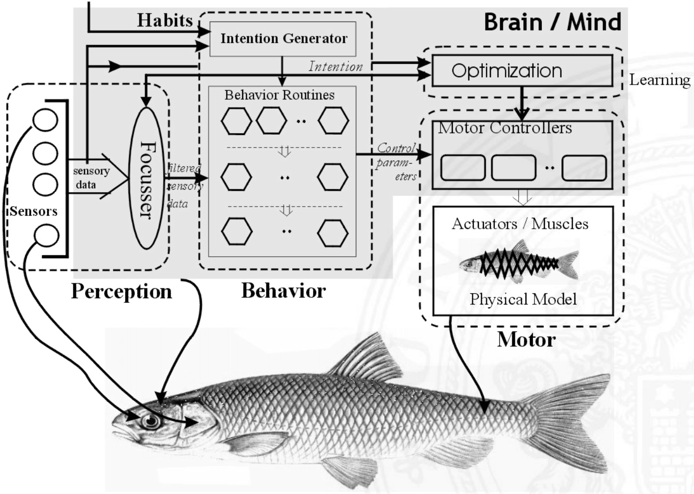
Behaviors behavior routines

Brain/mind habits, intention generator

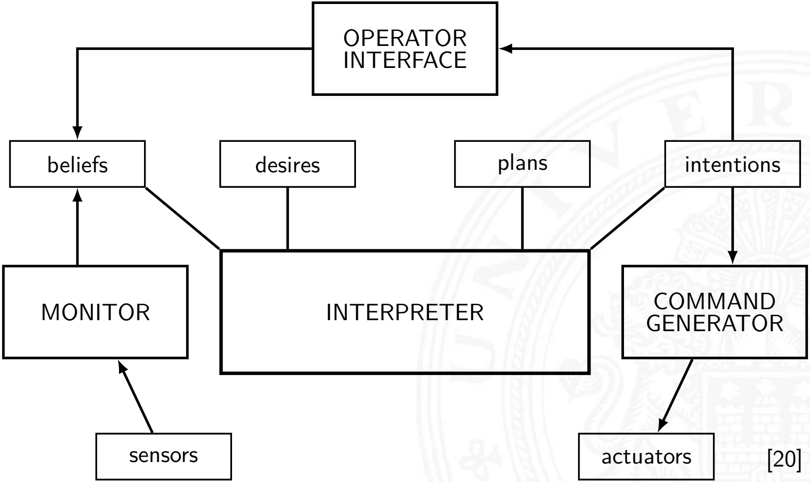
Learning optimization

Motor motor controllers, actuators/muscles

Control Architecture of a Fish (cont.)



Procedural Reasoning System



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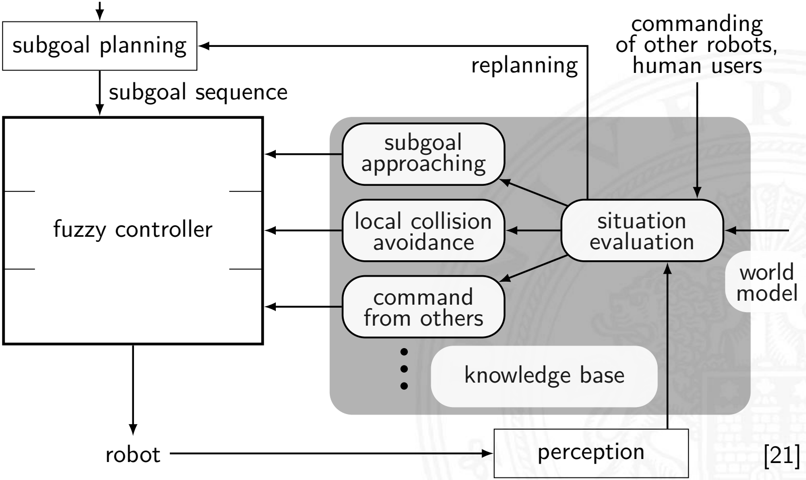
Hierarchical Fuzzy-Control of a Robot



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Behavior Fusion

Fuzzy rules evaluate current situation.

Situation evaluation determines 3 fuzzy-parameters

- the priority K of the LCA rule base
- the replanning selector
- `NextSubgoal` (whether a subgoal has been reached)

Typical rule IF ($SL85$ IS HIGH) AND ($SL45$ IS VL) AND ($SLR0$ IS VL) AND ($SR45$ IS VL) AND ($SR85$ IS VL) THEN ($Speed$ IS LOW) AND ($Steer$ IS PM) K IS HIGH AND $Replan$ IS LOW

Translation If the leftmost proximity sensor detects an obstacle which is near and the other sensors detect no obstacle at all, then steer halfway to the right at low speed. Mainly perform obstacle avoidance. No re-planning required.

Coordination of multiple rule bases

$$Speed = Speed_{LCA} \cdot K + Speed_{SA} \cdot (1 - K)$$

Hierarchy

Real-Time Control System (RCS)

- RCS reference model is an architecture for intelligent systems.
- Processing modes are organized such that the BG (Behavior Generation) modules form a command tree.
- Information in the knowledge database is shared between WM (World Model) modules in nodes within the same subtree.

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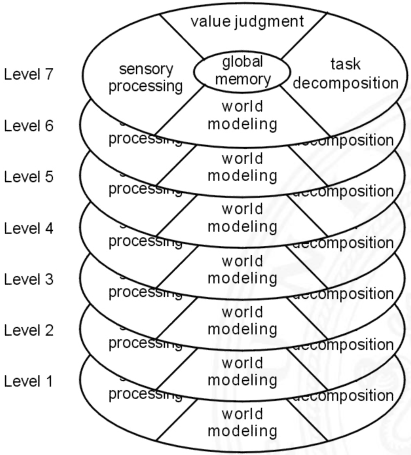
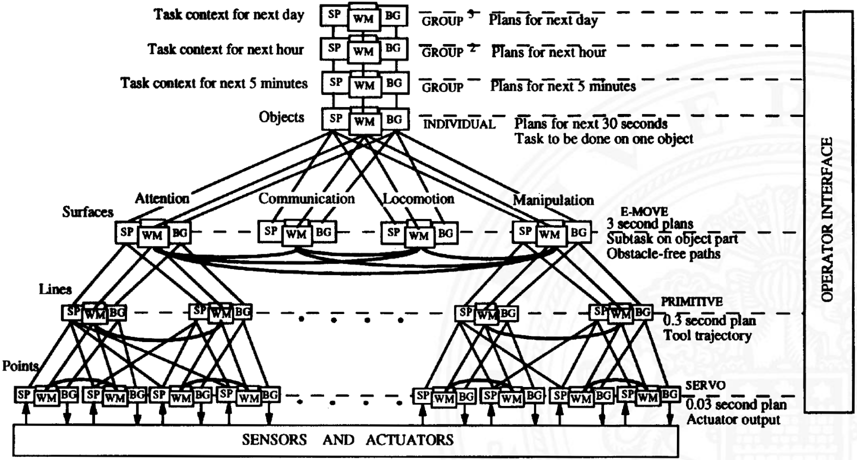
Examples of functional characteristics of the BG and WM modules:

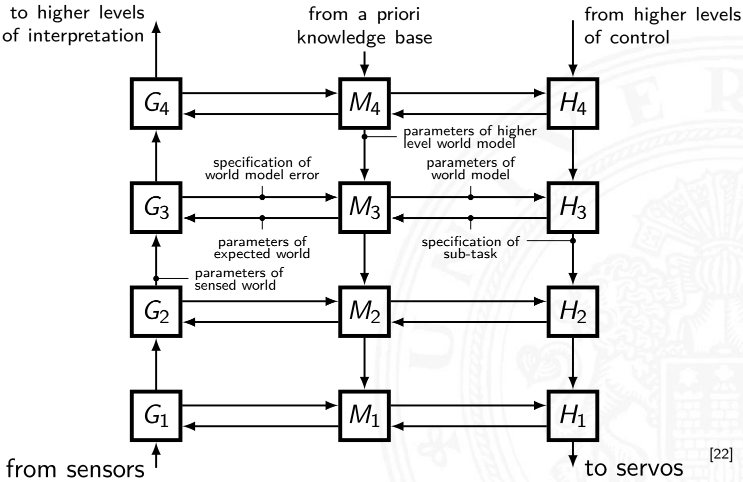
Hierarchy (cont.)



Hierarchy (cont.)



Hierarchy (cont.)



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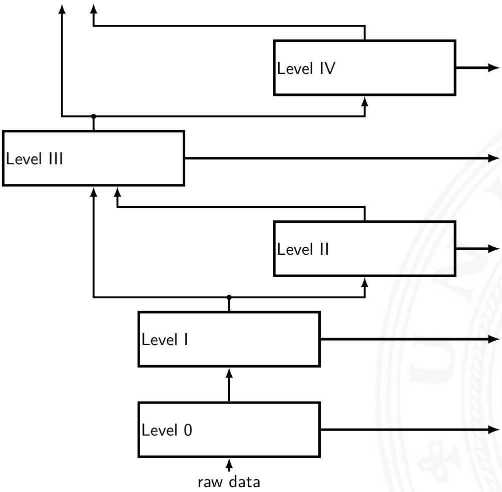
Sensor-Hierarchy



Recognition of relations of objects

Descriptions of relations of objects or unrecognized aggregates

Recognition of aggregates of features (objects)

Descriptions of aggregates of points and their features (object elements)

Properties of points in space

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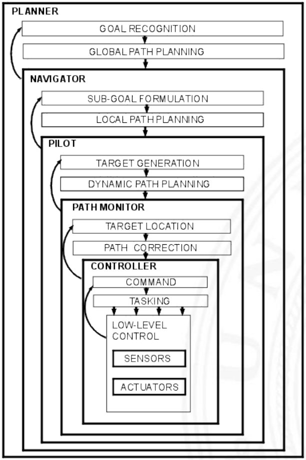
Other examples



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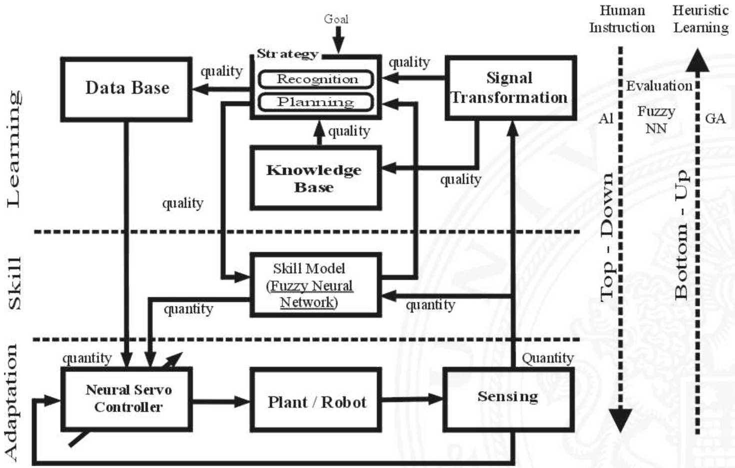
An Architecture for Learning Robots



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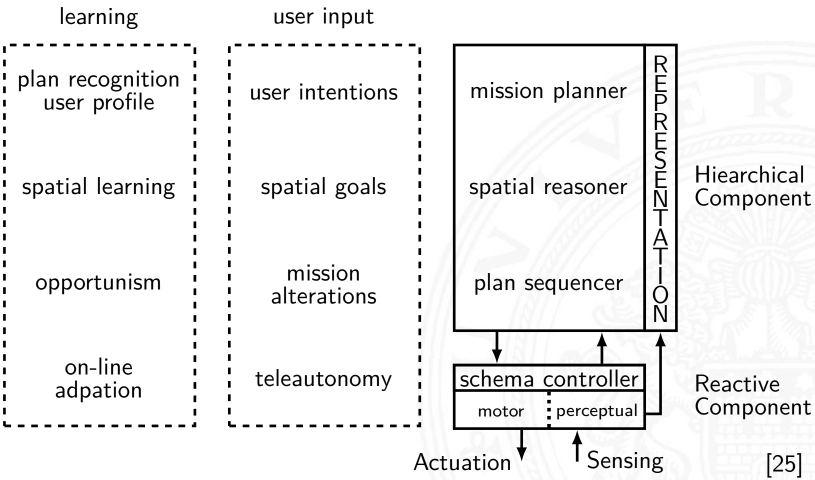
AuRA Architecture



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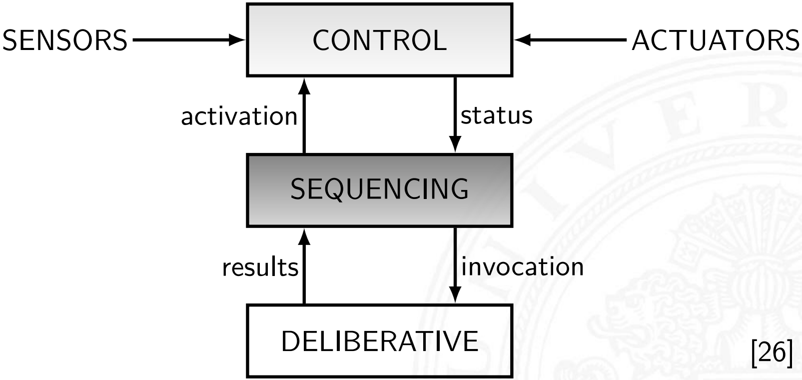
Atlantis Architecture



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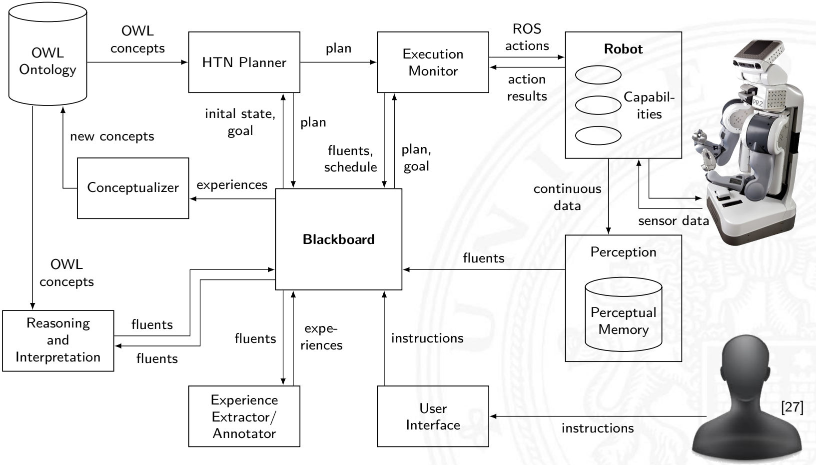
RACE

Robustness by Autonomous Competence Enhancement



[1] K. Fu, R. González, and C. Lee, *Robotics: Control, Sensing, Vision, and Intelligence*.
McGraw-Hill series in CAD/CAM robotics and computer vision, McGraw-Hill, 1987.

[2] R. Paul, *Robot Manipulators: Mathematics, Programming, and Control : the Computer Control of Robot Manipulators*.
Artificial Intelligence Series, MIT Press, 1981.

[3] J. Craig, *Introduction to Robotics: Pearson New International Edition: Mechanics and Control*.
Always learning, Pearson Education, Limited, 2013.

[4] J. F. Engelberger, *Robotics in service*.
MIT Press, 1989.

[5] W. Böhm, G. Farin, and J. Kahmann, "A Survey of Curve and Surface Methods in CAGD," *Comput. Aided Geom. Des.*, vol. 1, pp. 1–60, July 1984.

[6] J. Zhang and A. Knoll, "Constructing fuzzy controllers with B-spline models-principles and applications," *International Journal of Intelligent Systems*, vol. 13, no. 2-3, pp. 257–285, 1998.

[7] M. Eck and H. Hoppe, "Automatic reconstruction of b-spline surfaces of arbitrary topological type," in *Proceedings of the 23rd Annual Conference on Computer Graphics and Interactive Techniques*, SIGGRAPH '96, (New York, NY, USA), pp. 325–334, ACM, 1996.

[8] M. C. Ferch, *Lernen von Montagestrategien in einer verteilten Multiroboterumgebung*.
PhD thesis, Bielefeld University, 2001.

[9] N. J. Nilsson, "A mobile automaton: An application of artificial intelligence techniques," tech. rep., DTIC Document, 1969.

[10] J. H. Reif, "Complexity of the mover's problem and generalizations extended abstract," *Proceedings of the 20th Annual IEEE*

Conference on Foundations of Computer Science, pp. 421–427, 1979.

[11] J. T. Schwartz and M. Sharir, "A survey of motion planning and related geometric algorithms," *Artificial Intelligence*, vol. 37, no. 1, pp. 157–169, 1988.

[12] J. Canny, *The complexity of robot motion planning*. MIT press, 1988.

[13] T. Lozano-Pérez, J. L. Jones, P. A. O'Donnell, and E. Mazer, *Handey: A Robot Task Planner*. Cambridge, MA, USA: MIT Press, 1992.

[14] O. Khatib, "The potential field approach and operational space formulation in robot control," in *Adaptive and Learning Systems*, pp. 367–377, Springer, 1986.

[15] J. Barraquand, L. Kavraki, R. Motwani, J.-C. Latombe, T.-Y. Li, and P. Raghavan, "A random sampling scheme for path planning,"

in *Robotics Research* (G. Giralt and G. Hirzinger, eds.), pp. 249–264, Springer London, 1996.

[16] R. Geraerts and M. H. Overmars, "A comparative study of probabilistic roadmap planners," in *Algorithmic Foundations of Robotics V*, pp. 43–57, Springer, 2004.

[17] K. Nishiwaki, J. Kuffner, S. Kagami, M. Inaba, and H. Inoue, "The experimental humanoid robot h7: a research platform for autonomous behaviour," *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences*, vol. 365, no. 1850, pp. 79–107, 2007.

[18] R. Brooks, "A robust layered control system for a mobile robot," *Robotics and Automation, IEEE Journal of*, vol. 2, pp. 14–23, Mar 1986.

[19] M. J. Mataric, "Interaction and intelligent behavior.," tech. rep., DTIC Document, 1994.

[20] M. P. Georgeff and A. L. Lansky, "Reactive reasoning and planning.," in *AAAI*, vol. 87, pp. 677–682, 1987.

[21] J. Zhang and A. Knoll, *Integrating Deliberative and Reactive Strategies via Fuzzy Modular Control*, pp. 367–385. Heidelberg: Physica-Verlag HD, 2001.

[22] J. S. Albus, "The nist real-time control system (rcs): an approach to intelligent systems research," *Journal of Experimental & Theoretical Artificial Intelligence*, vol. 9, no. 2-3, pp. 157–174, 1997.

[23] A. Meystel, "Nested hierarchical control," 1993.

[24] T. Fukuda and T. Shibata, "Hierarchical intelligent control for robotic motion by using fuzzy, artificial intelligence, and neural network," in *Neural Networks, 1992. IJCNN., International Joint Conference on*, vol. 1, pp. 269–274 vol.1, Jun 1992.

[25] R. C. Arkin and T. Balch, "Aura: principles and practice in review," *Journal of Experimental & Theoretical Artificial Intelligence*, vol. 9, no. 2-3, pp. 175–189, 1997.

[26] E. Gat, "Integrating reaction and planning in a heterogeneous asynchronous architecture for mobile robot navigation," *ACM SIGART Bulletin*, vol. 2, no. 4, pp. 70–74, 1991.

[27] L. Einig, *Hierarchical Plan Generation and Selection for Shortest Plans based on Experienced Execution Duration.*
Master thesis, Universität Hamburg, 2015.