TECHNISCHE UNIVERSITÄT DARMSTADT

NEURONALE MOTORSTEUERUNG

Rico Möckel

3M-Seminar

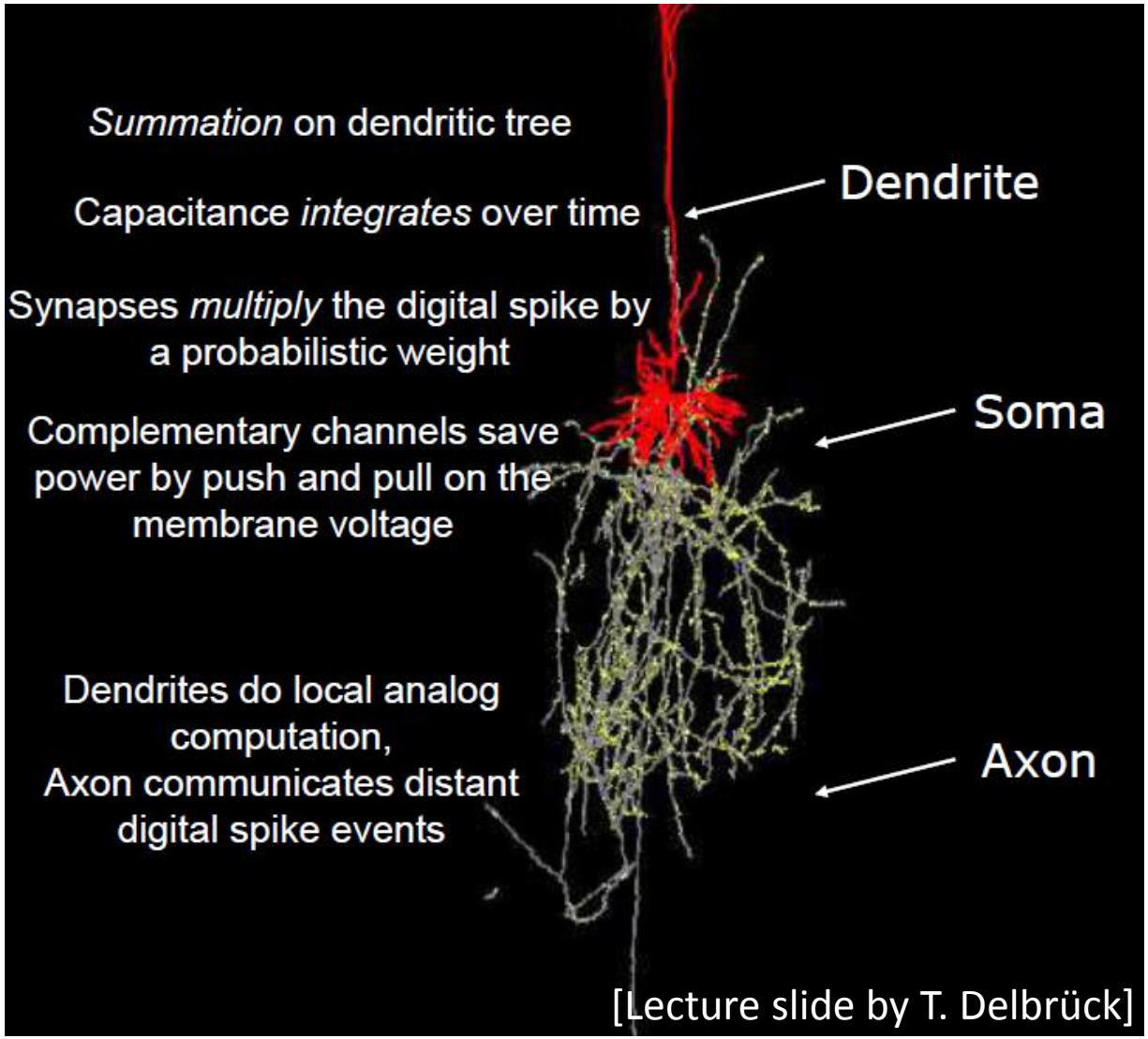
24.05.2014

Overview

- Grundlagen der neuronalen Informationsverarbeitung (zur Motorsteuerung)
- Steuerung mit Zentralen Mustergeneratoren
- Mögliche Gruppenaufgaben – CPG-Netzwerke in Simulink

GRUNDLAGEN DER NEURONALEN INFORMATIONSVERARBEITUNG (ZUR MOTORSTEUERUNG)

Neural computation

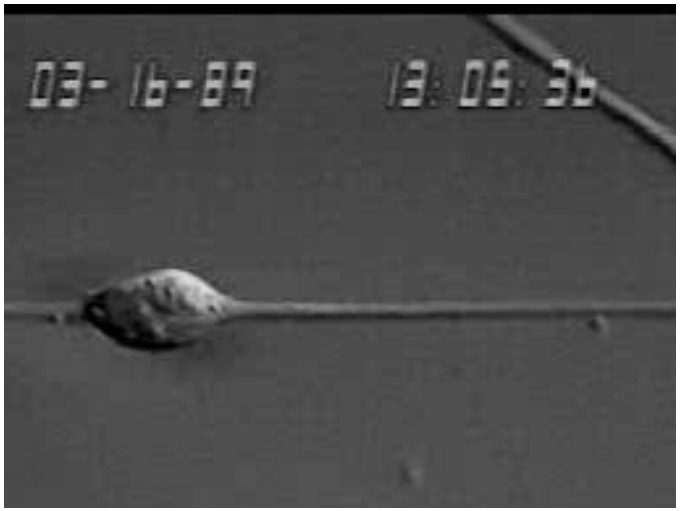


[Lecture slide by T. Delbrück]

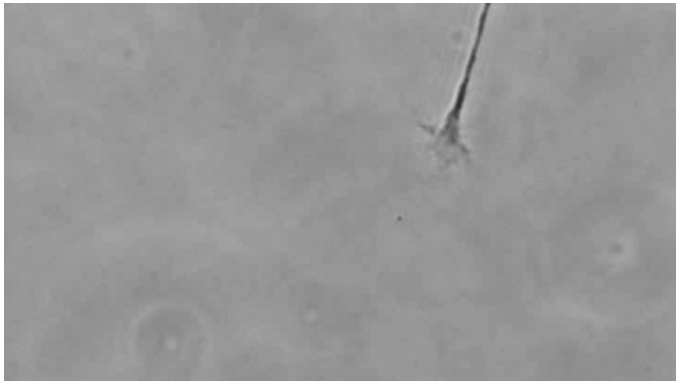
Neuronale Datenverarbeitung is fundamental anders als in künstlich hergestellten Prozessoren

- Analoge Datenverarbeitung
- Keine Taktrate
- Verteilte Datenverarbeitung
- Zufallsverteilte Kommunikation
- Rechner und Speicher lokal im Neuron
- Physische Struktur des Prozessors ändert sich über den Zeitverlauf

Intelligenz im Gehirn ist eingebettet in die biologischen Strukturen

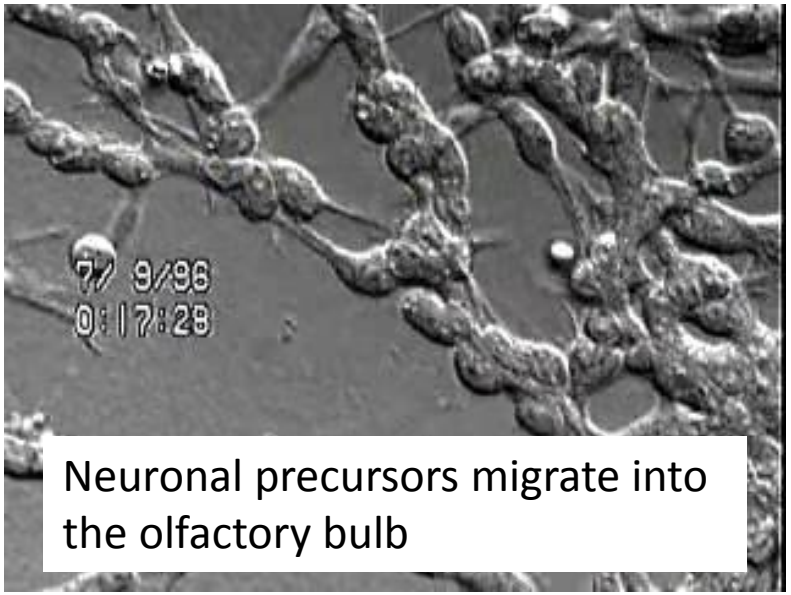


Granule cell migrate along radial glial

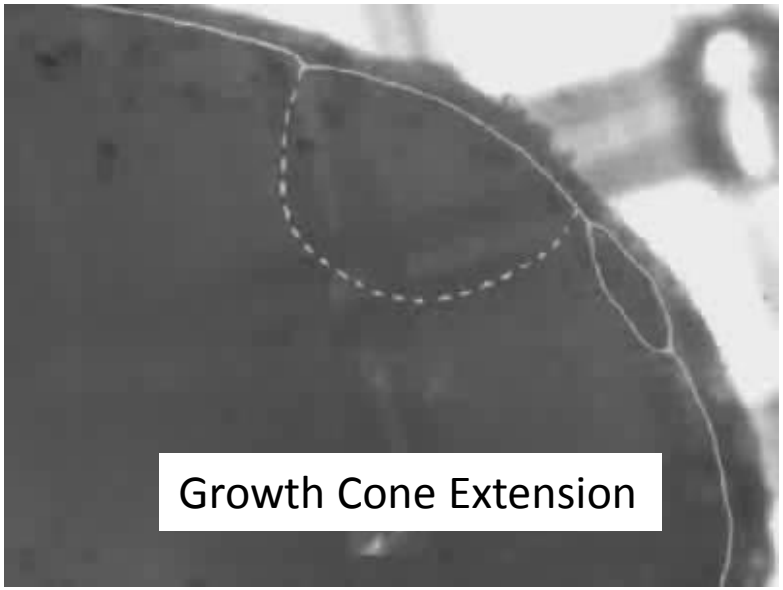


Granule cell migrate along radial glial

???



Neuronal precursors migrate into the olfactory bulb



Growth Cone Extension

STEUERUNG MIT ZENTRALEN MUSTERGENERATOREN

Work at

EPFL Biorobotics Laborators,

headed by Professor Auke Jan Ijspeert

The BIOROB modular robotics team


Stéphane Bonardi


Massimo Vespignani


Soha Pouya


Jesse van den Kieboom


Alexander Spröwitz


Rico Möckel


Yura Perov


Nguyen The Anh


Frédéric Wilhelm

Biorobotics Laboratory EPFL


Professor
Auke Jan Ijspeert

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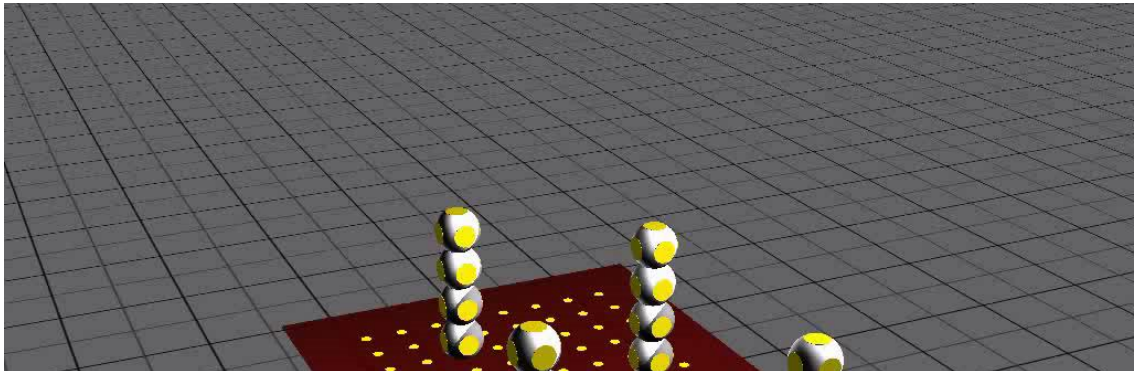
- The Swiss National Science Foundation financing the National Centre of Competence in Research Robotics
- The European Community's Seventh Framework Programme financing the project LOCOMORPH (www.locomorph.eu)

Project goals: Study self-reconfiguration and locomotion with modular robots

- Create cellular robots that can organize themselves into bigger structures and learn autonomously

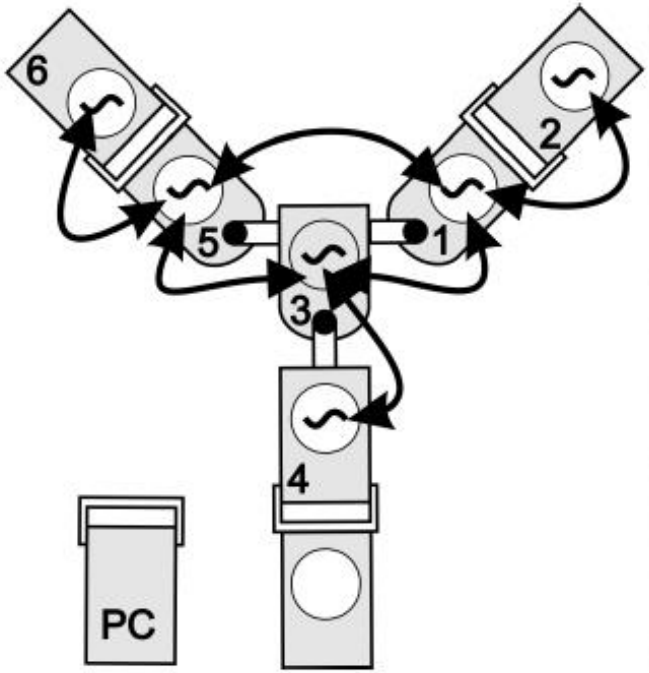


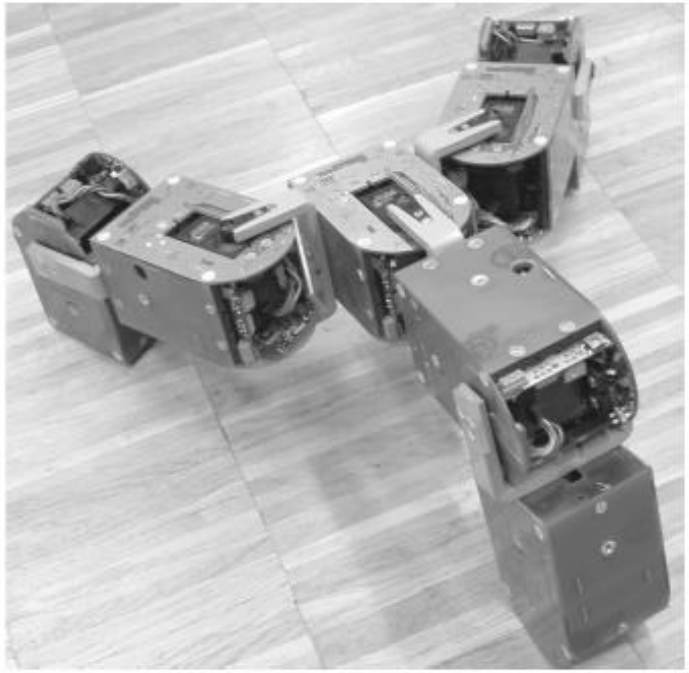
We want to be able to throw a bunch of robot modules into some unknown environment and they should be able to structure themselves and perform locomotion autonomously

[Spröwitz, Moeckel et al., IEEE Computational Intelligence Magazine 2010]

Robot control with central pattern generators

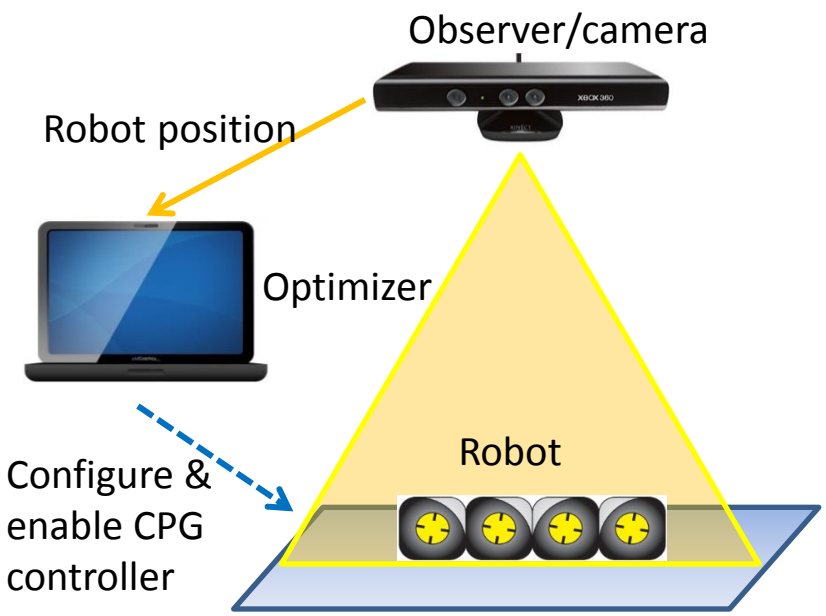
Central Pattern Generators (CPG): networks of coupled nonlinear oscillators found in spinal cord of vertebrates





[Sproewitz, Moeckel, et al., IJRR 2008.]

Optimization of locomotion in hardware and software



Experimental setup for optimization

Learning optimal gaits in simulation

[Movie by Soha Pouya and Jesse van den Kieboom]

Locomotion control with YaMoR - Yet another Modular Robot

- Locomotion gaits found with online optimization

Single YaMoR module
Fully distributed control: each module is running own controller, coupling through Bluetooth

[Moeckel et al., 2006; Sproewitz, Moeckel, et al., IJRR 2008.]

Central Pattern Generators

$$\dot{\Phi}_i = 2\pi f \sum_i w_{ij}\, r_i\, sin(\Phi_j - \Phi_i - \psi_{ij})$$

$$\dot{r}_i = a_i(R_i - r_i)$$

$$\Theta_i = r_i \cdot sin(\Phi_i) + X_i$$

Variables	
Φ_i	Phase
Θ_i	Output driving a DOF
r_i	Amplitude

Controls	
X_i	Offset
ψ_{ij}	Phase bias
R_i	Target amplitude
f	Frequency

Advantages of Central Pattern Generators (CPG)

- Synchronization behavior between different DOFs
- Well suited for tight coupling (entrainment) and distributed control
- Smooth trajectory modulation
- A few high-level parameters for control and optimization

[A. J. Ijspeert, “Central pattern generators for locomotion control in animals and robots: A review,” Neural Networks, vol. 21, no. 4, pp. 642–653, 2008.]

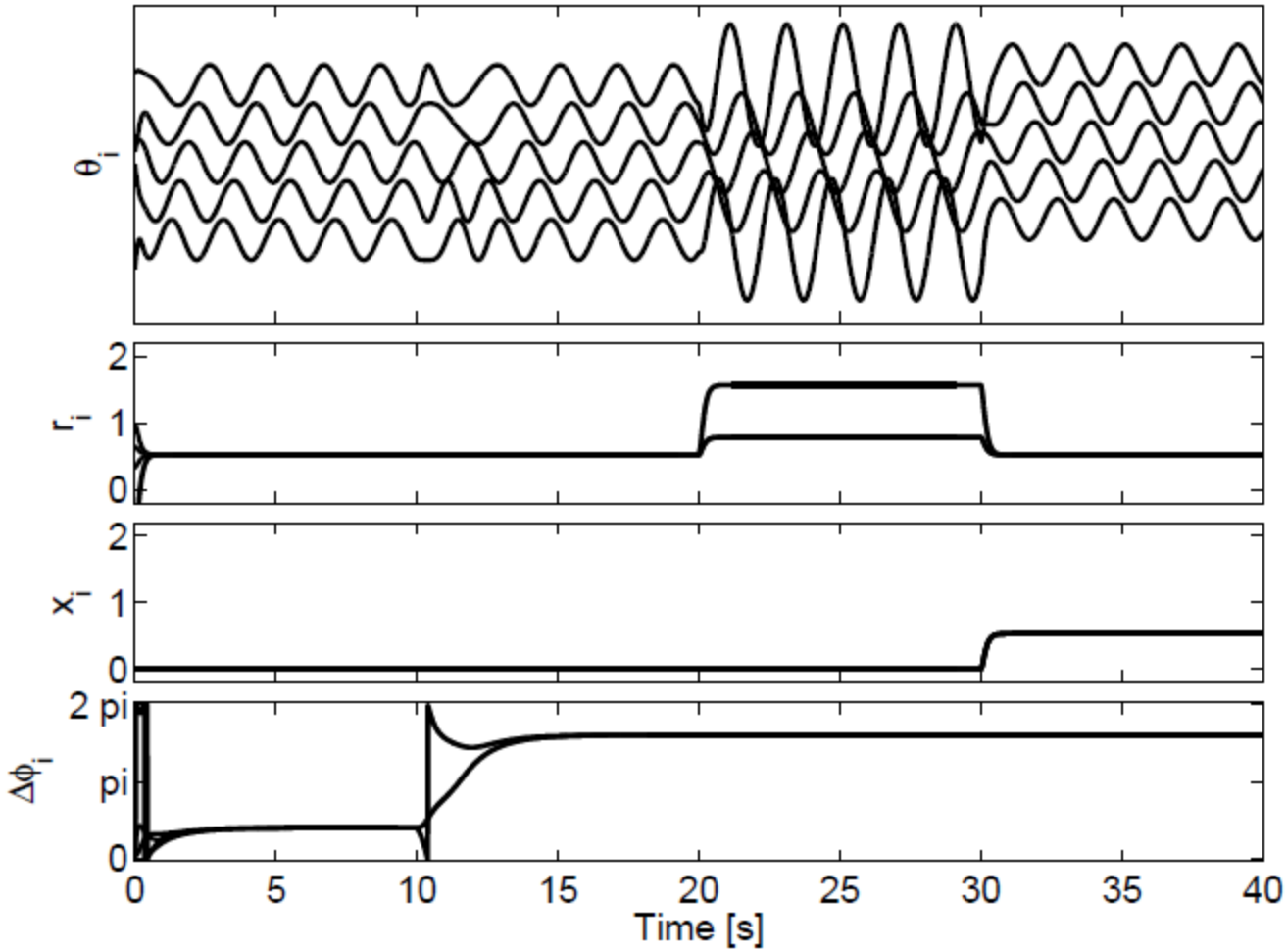
Smooth control with central pattern generators

Motor output driving a DOF

Amplitude

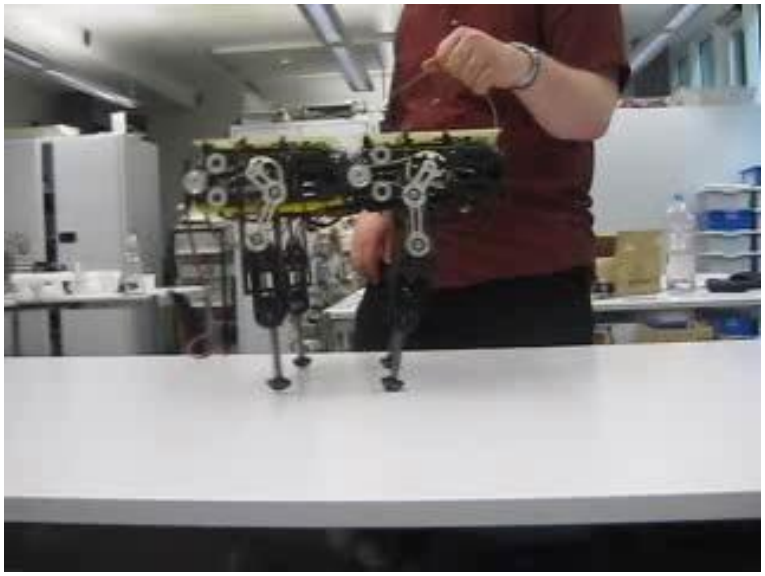
Offset

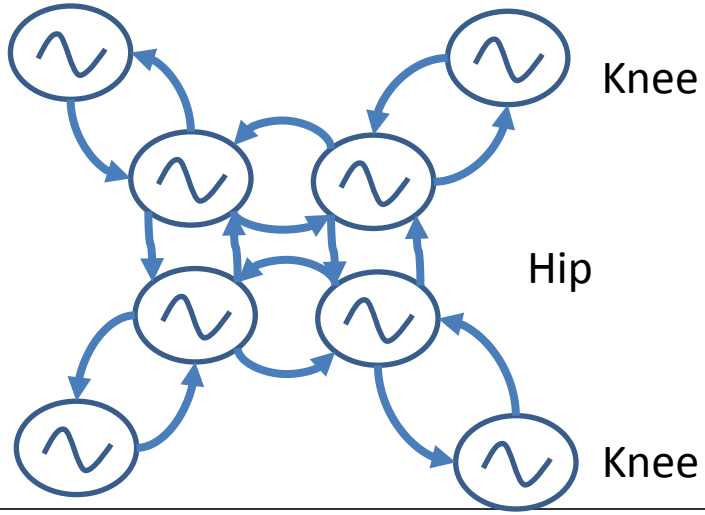
Coupling phase

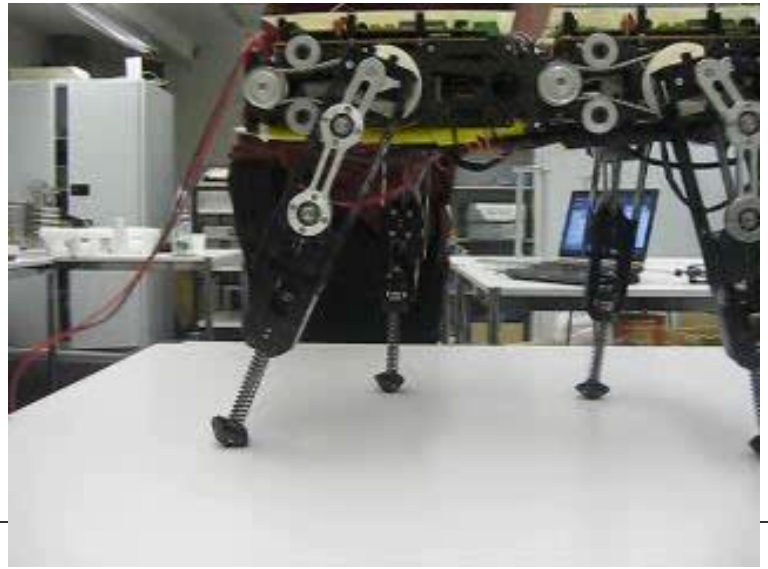


[Sproewitz, Moeckel, et al., IJRR 2008.]

Locomorph modular robotic toolkit for dynamic locomotion







MÖGLICHE GRUPPENAUFGABE: CPG-NETZWERKE IN SIMULINK

CPG-Netzwerke in Simulink

- 3 Paper über CPG und CPG-Kontrolle von Robotern lesen
- Differentialgleichung in Simulink implementieren
- Simulationsexperimente mit CPG-Netzwerken (Phase, Amplitude ändern, verschiedene Netzwerke ausprobieren, Zweibeiner oder Vierbeiner, Gaittransition from Trot to Bound)

- Mögliche Erweiterungen:
  - Einfache Animation eines Zweibeiners
  - Verbindung mit biomechanischem Model
  - Ansteuerung von MYOROBOTICS