Neurons and Robots
Using Networks for Control and Learning to Behave

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Old Man of Storr (Isle of Skye)
The great divide:

„Neural“ Networks are (still) no neural networks.

Real Networks are adaptive controllers

Brain

Learning

Sensor → Motor

The World
Networks and Control

  - Learning to avoid a reflex

- AMOS W6, a six-legged robot (2010)
  - Deterministic Chaos and its control
  - Demonstration of a large behavioral repertoire

- Learning Goal directed manipulation actions (2015)
  - Memory in behaving networks
RunBot, the Reflex Machine

15 Sensors, 5 DOF (constrained), 19 neurons

PLoS CB, 2007
RunBot: Learning to walk up a slope

BBC, July 07
Mumbai Mirror July 07
New York Times July 07
AAAS Sci Update July 07

PLoS CB, 2007
What happens here?

Cerebellar Reflex
Avoidance Learning (abstracted)

Look $\rightarrow$ Move

instead of

Ouch $\rightarrow$ Move
How to control Chaos in networks

>30 Sensors, 19 DOF
71 neurons
Two neurons suffice to create a large behavioural repertoire

The bad news is: these circuits almost always produce chaotic outputs (Pasemann)

\[ w_{11} < 0 \quad w_{12} > 0 \quad w_{21} < 0 \]
Chaos control can be used to create periodic outputs
The robot has to learn to rotate and translate the object into the box. Thereby, both movements are learned independently from each other (alternating).

Camera as sensor, 7 DOF, >1000 neurons
Growing a behavior-control network

Neuronal network (schematic)

Growing (non-static) Network

Error [Errormax]

Number of strong synapses in the network [%]

Nature Scientific Reports 2015
Self Organized Network Formation

The combination of Hebbian Learning with Synaptic Scaling allows input driven self-structuring of large networks into many small but powerful Reservoirs.

Growing (non-static) Network
Robotic Arm Movement with Reservoir Cell Assemblies

Before Learning of Cell Assemblies

After Learning of Cell Assemblies
One decade of raising the complexity of neural control and self-organization

- Tao Geng
- Poramate Manoonpong
- Christian Tetzlaff
- Tomas Kulvicius
- Sakya Dasgupta
- Minija Tamosiunaite
- And many others

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