DALHOUSIE
COMPUTATIONAL NEUROSCIENCE GROUP
Studying Minds

Learning robots:

a small step for you
but a large step for neuroscience!

Thomas Trappenberg
&
the Hallab

Brain and Behaviour

Neuromorphic Robotics

- Robotics solutions inspired by biology

Cognitive Robotics

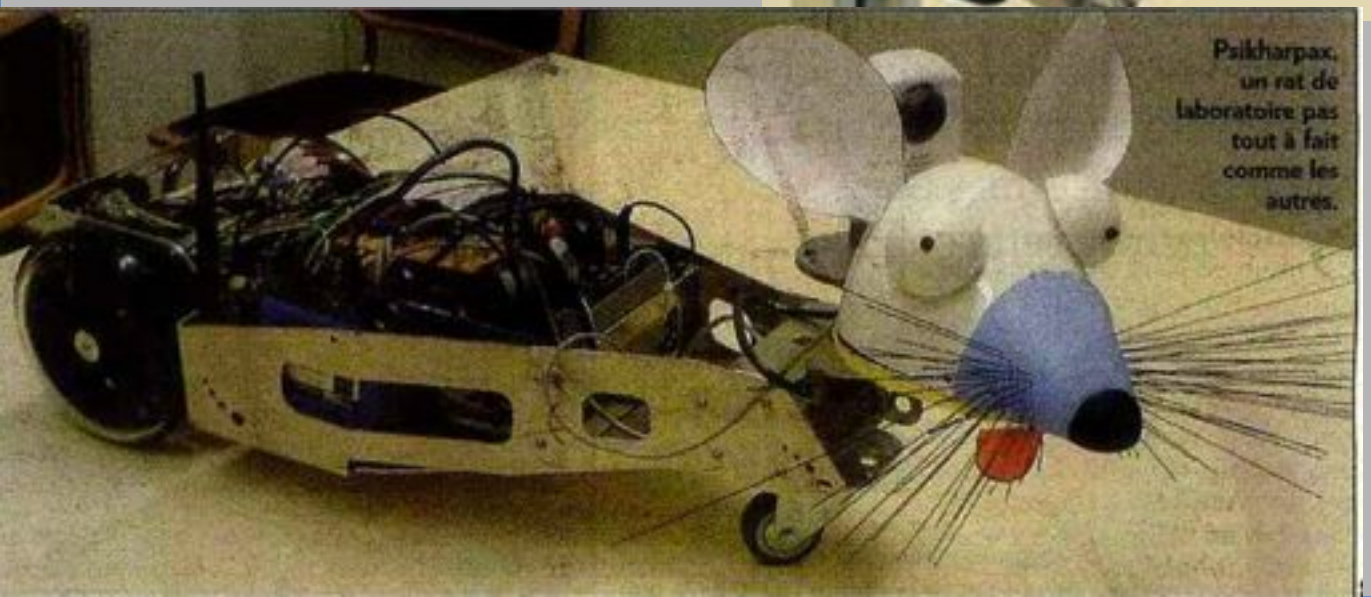
- Robots with Human-like behaviour
- Embodied system

Robotic Neurocognition

- Testing brain theories

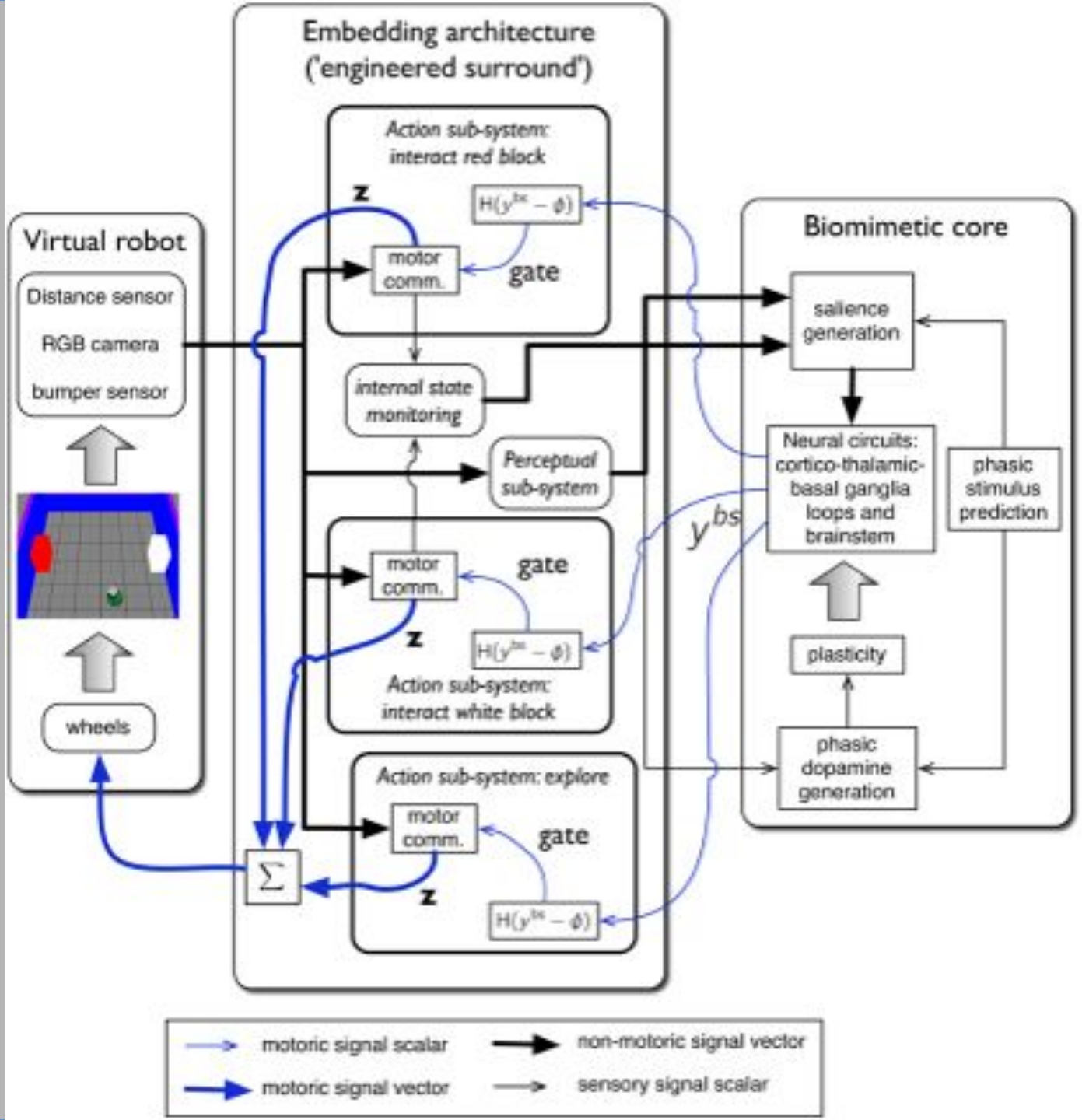
Philippe Gaussier

Cergy-Pontoise University
France



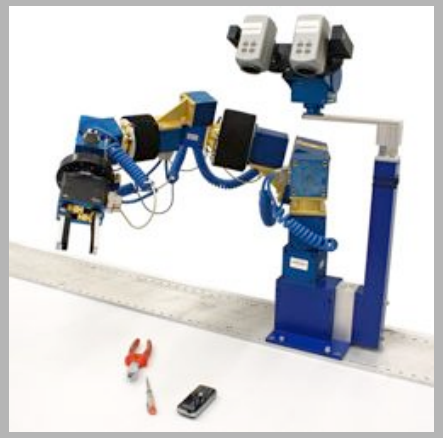
Kevin Gurney

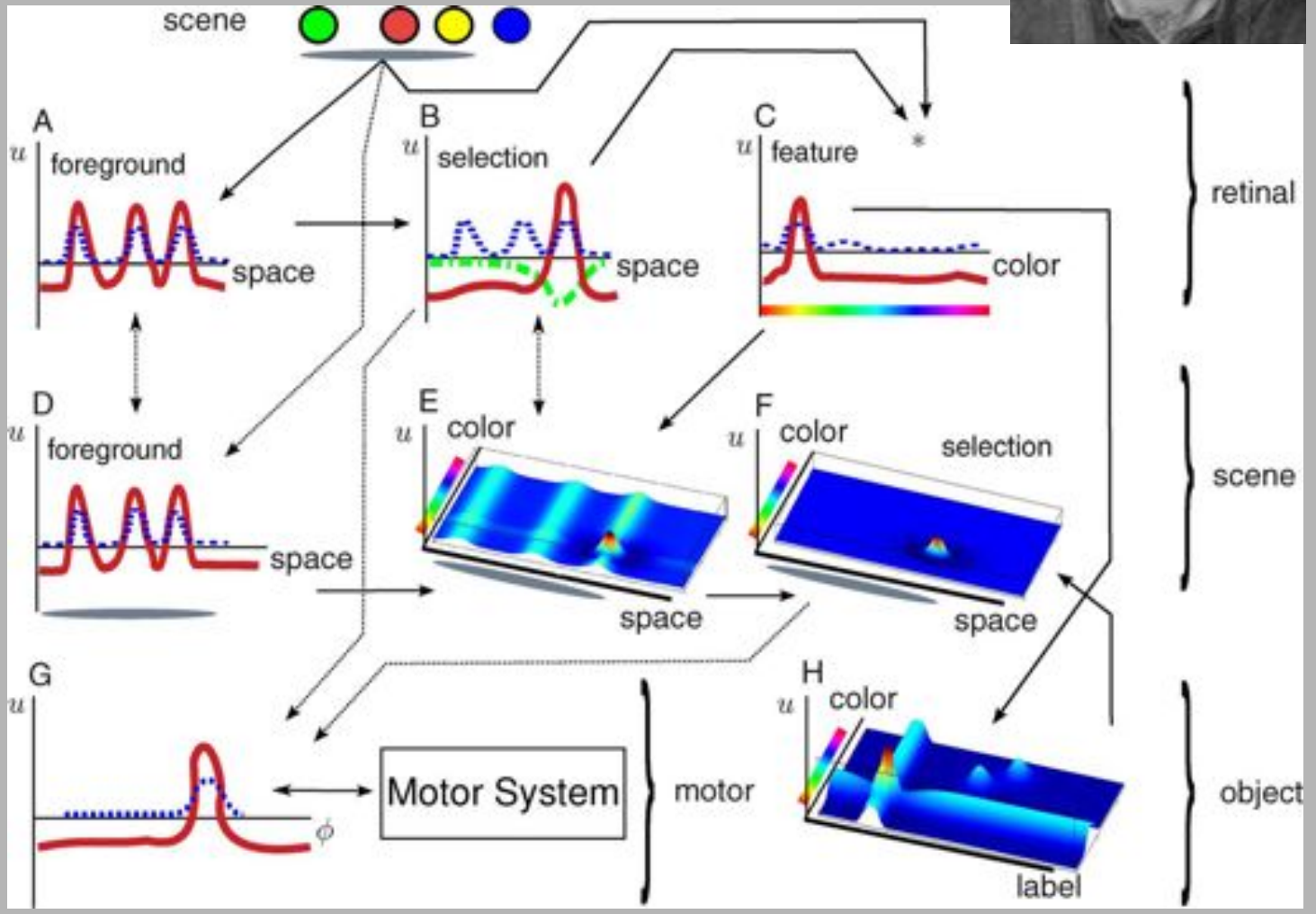
University of Sheffield, UK



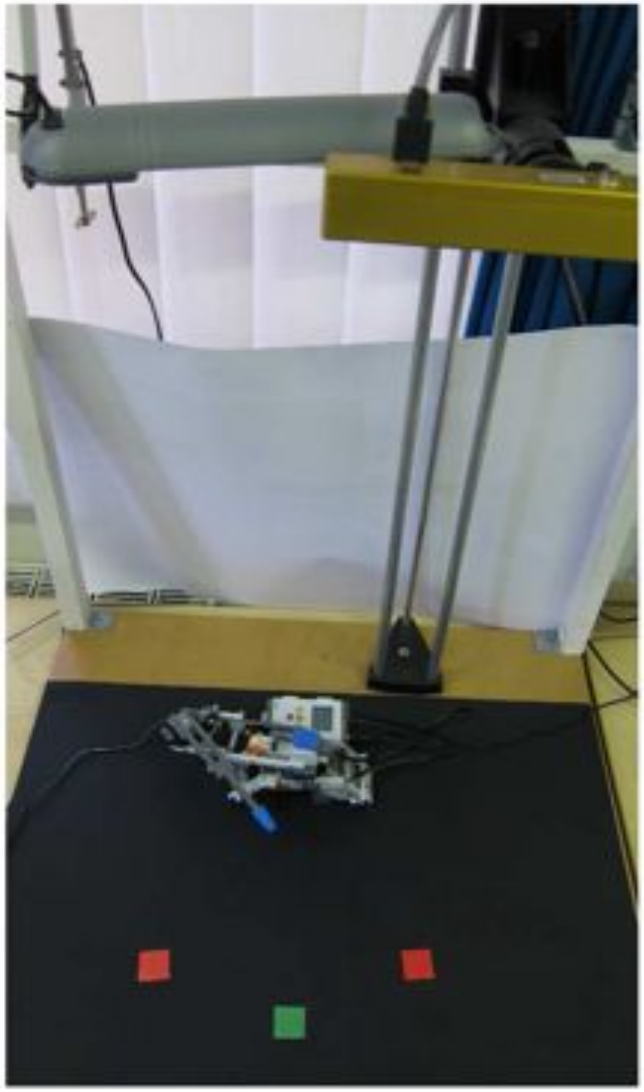
Schoener et al. (Bochum, Germany):

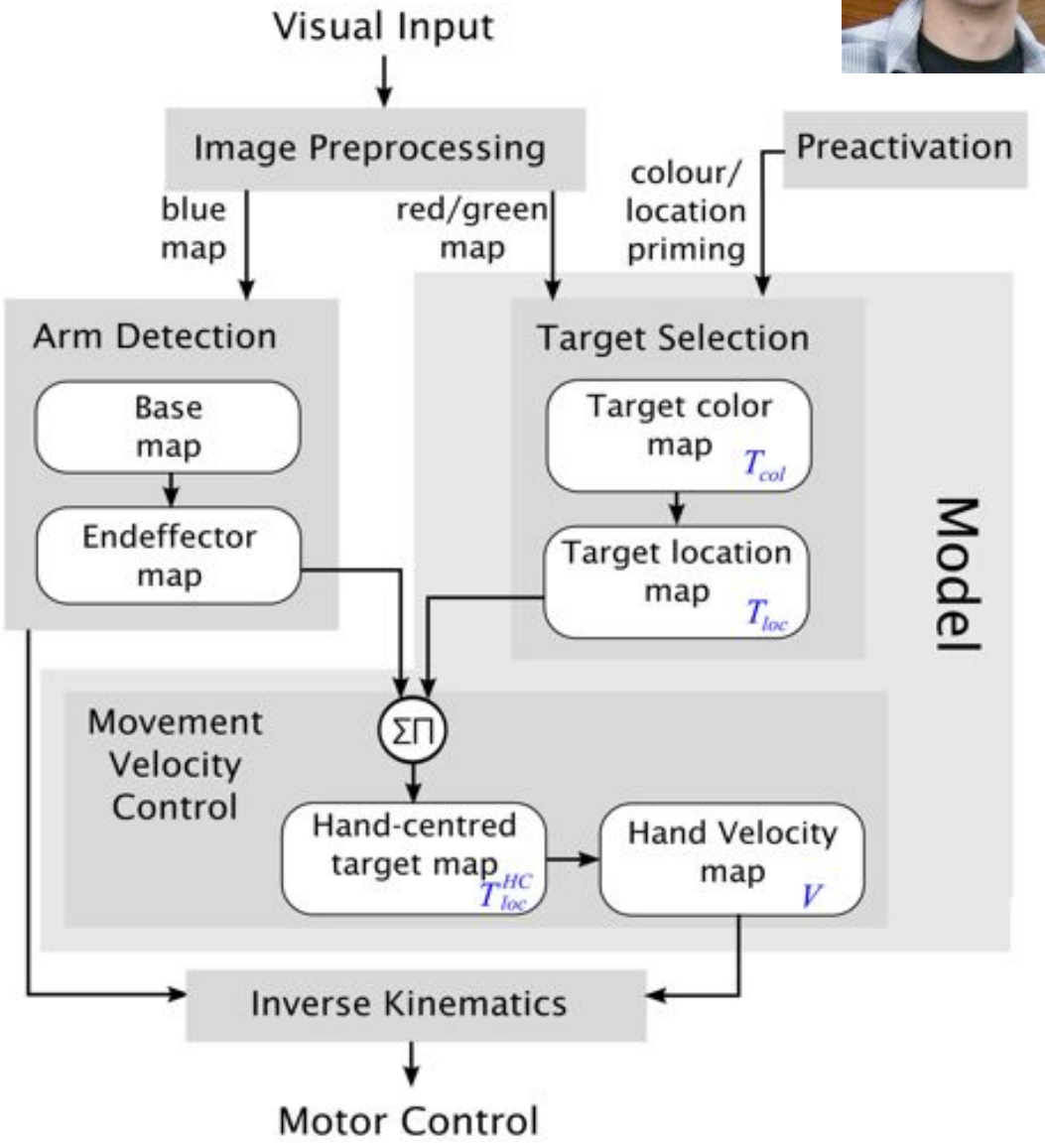
embedded cognitive computing, DNF





Soeren Strauss and Dietmar Heinke, Frontiers in Psychology, 2012

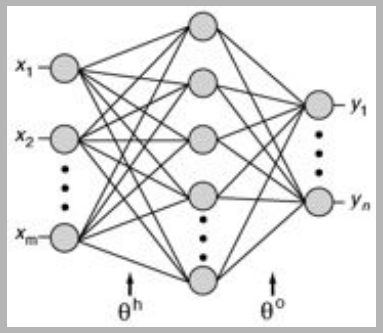


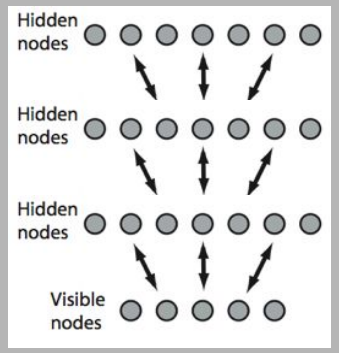


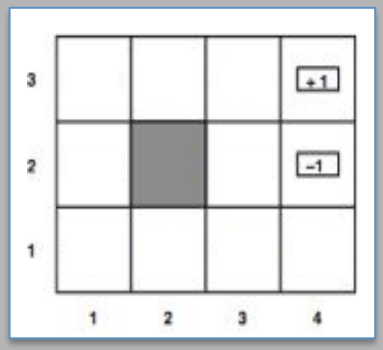

Machine Learning

Machine Learning Domains

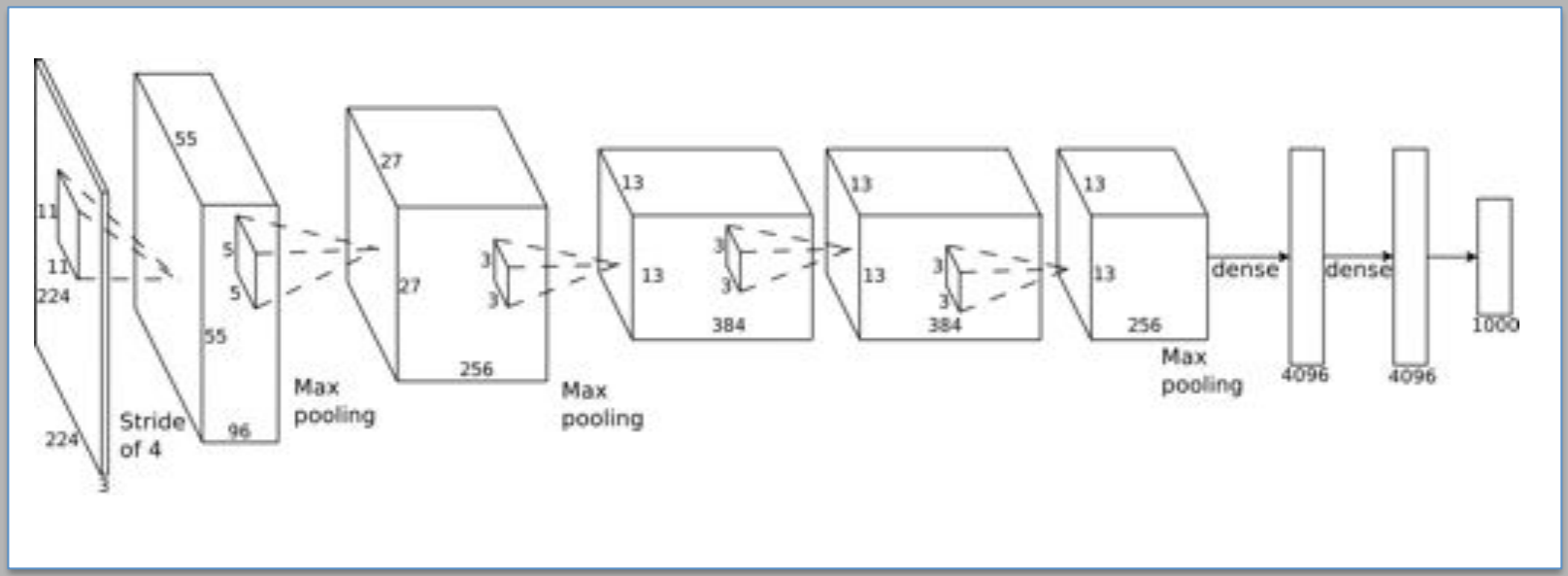
- Supervised
- Unsupervised
- Reinforcement



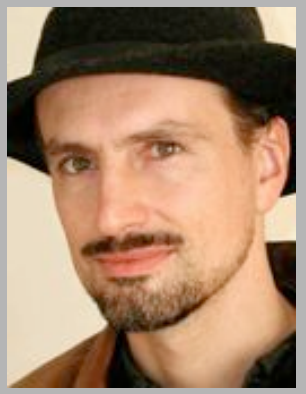




lates buzz: Deep Learning finally works!!!!



Geoff Hinton
Toronto



Juergen Schmidhuber
Lugano

Yoshua Bengio
Montreal

Yann LeCun
New York

Much recent progress in autonomous robotics

Google Self-driving car

DARPA urban challenge 2007

Machine Learning & Probabilistic Inference

A central problem in Robotics is localization (pose estimation):

Pose: $l(x,y,\theta)$

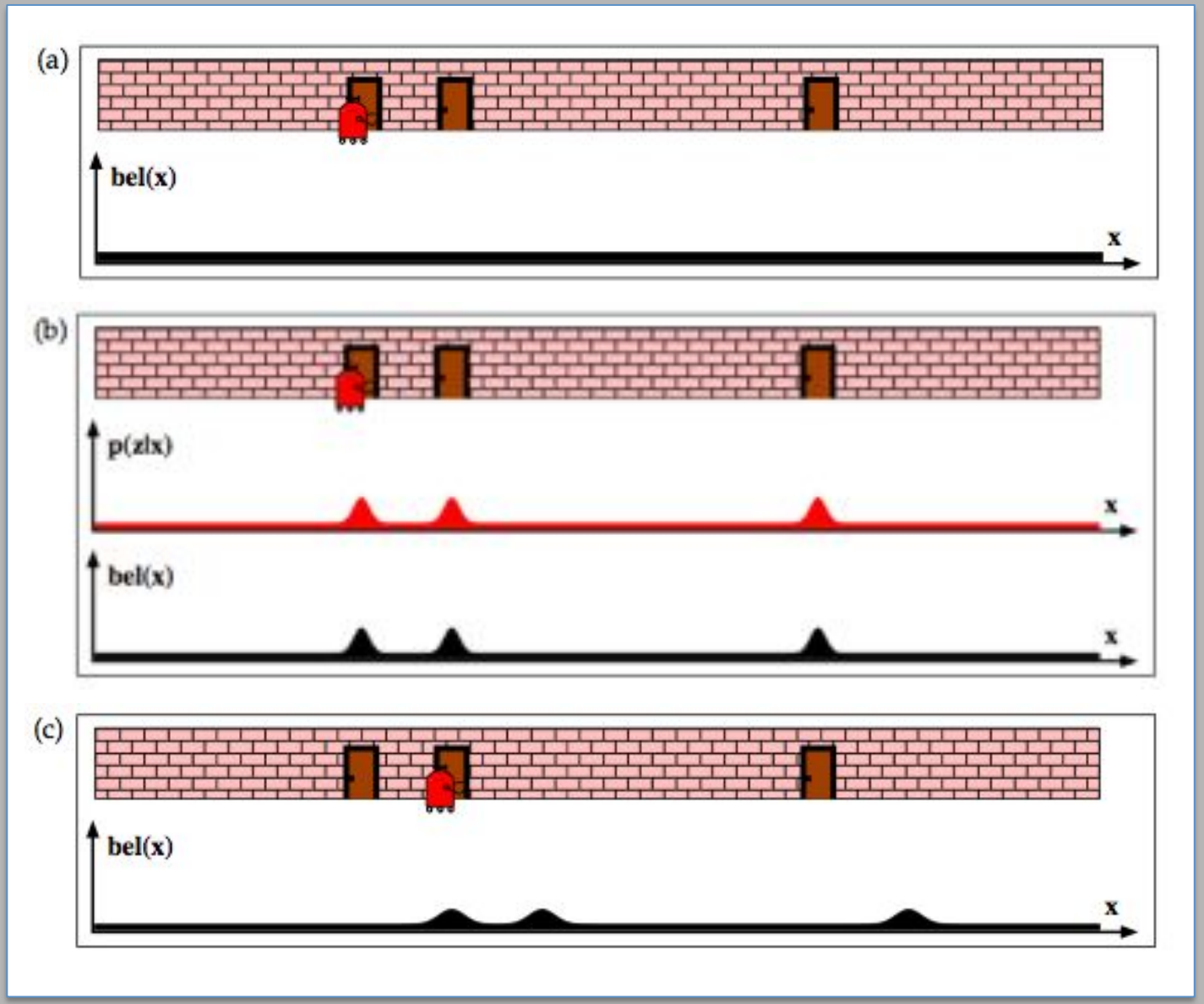
More important for advanced reasoning:

Uncertain world → $p(L=l)=p(X=x,Y=y,\Theta=\theta)$

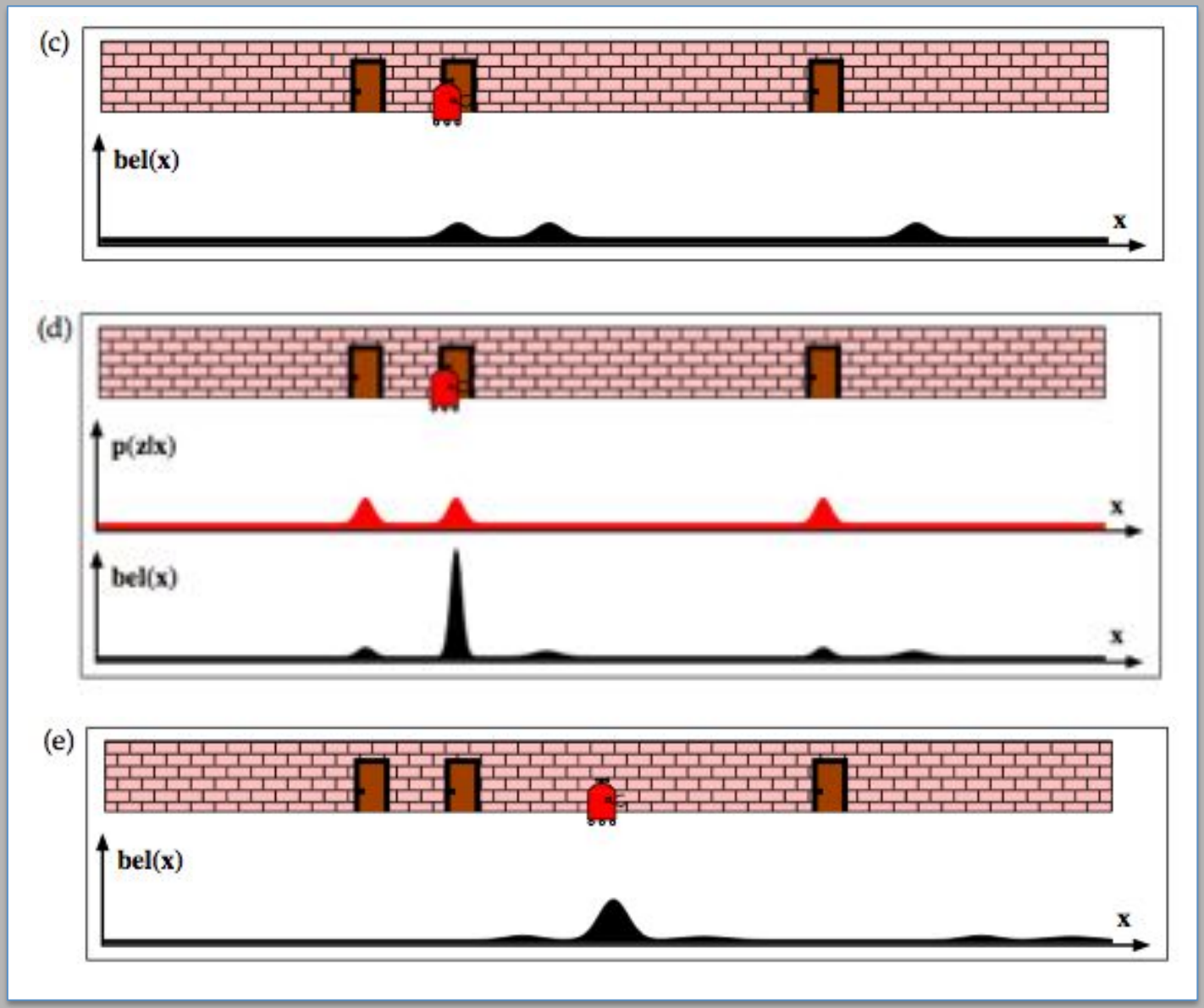
How to combine sensory information with internal predictions?

Bayes Filters!!

Markov Localization



From Thrun et al.


(c)
bel(x)
x
(d)
p(z|x)
x
bel(x)
x
(e)
bel(x)
x

- Prediction

$$\overline{bel}(x_t) = \int p(x_t \mid u_t, x_{t-1})\, bel(x_{t-1})\, dx_{t-1}$$

- Correction

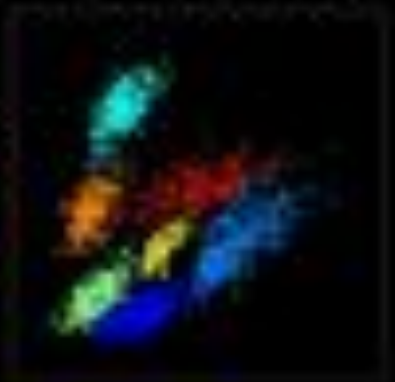
$$bel(x_t) = \eta\, p(z_t \mid x_t)\, \overline{bel}(x_t)$$

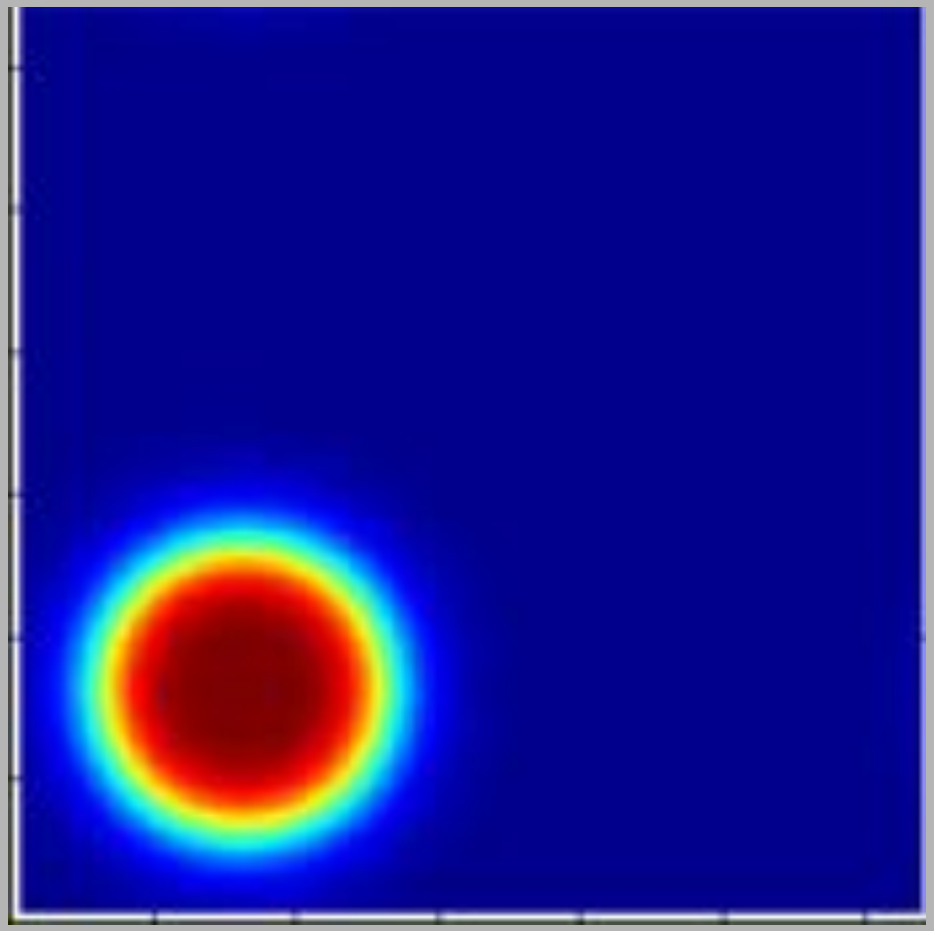
cell activity

behavior

overall

ongoing

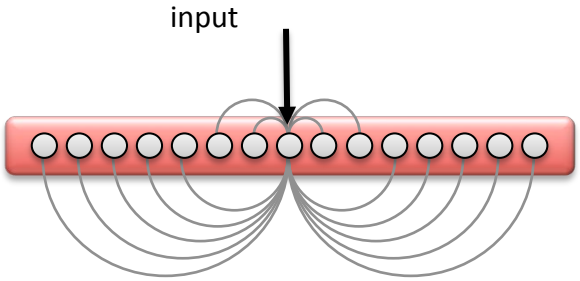


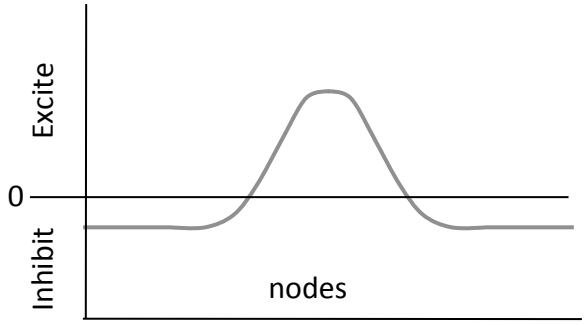


Dynamic Neural Fields (DNF)

Wilson & Cowan 1972/3
Amari 1977

- **Weights**

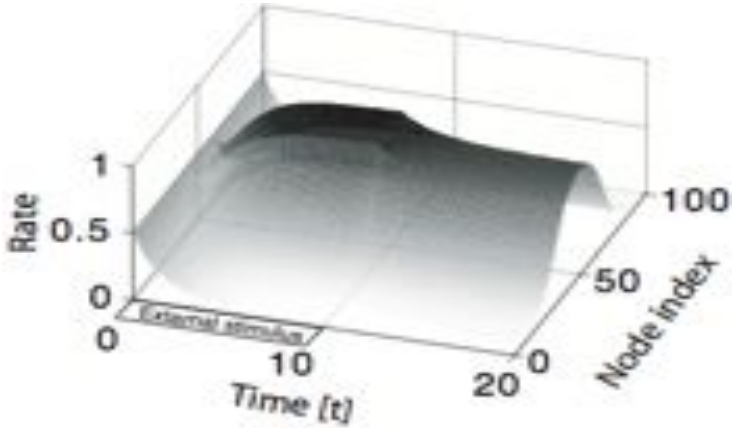




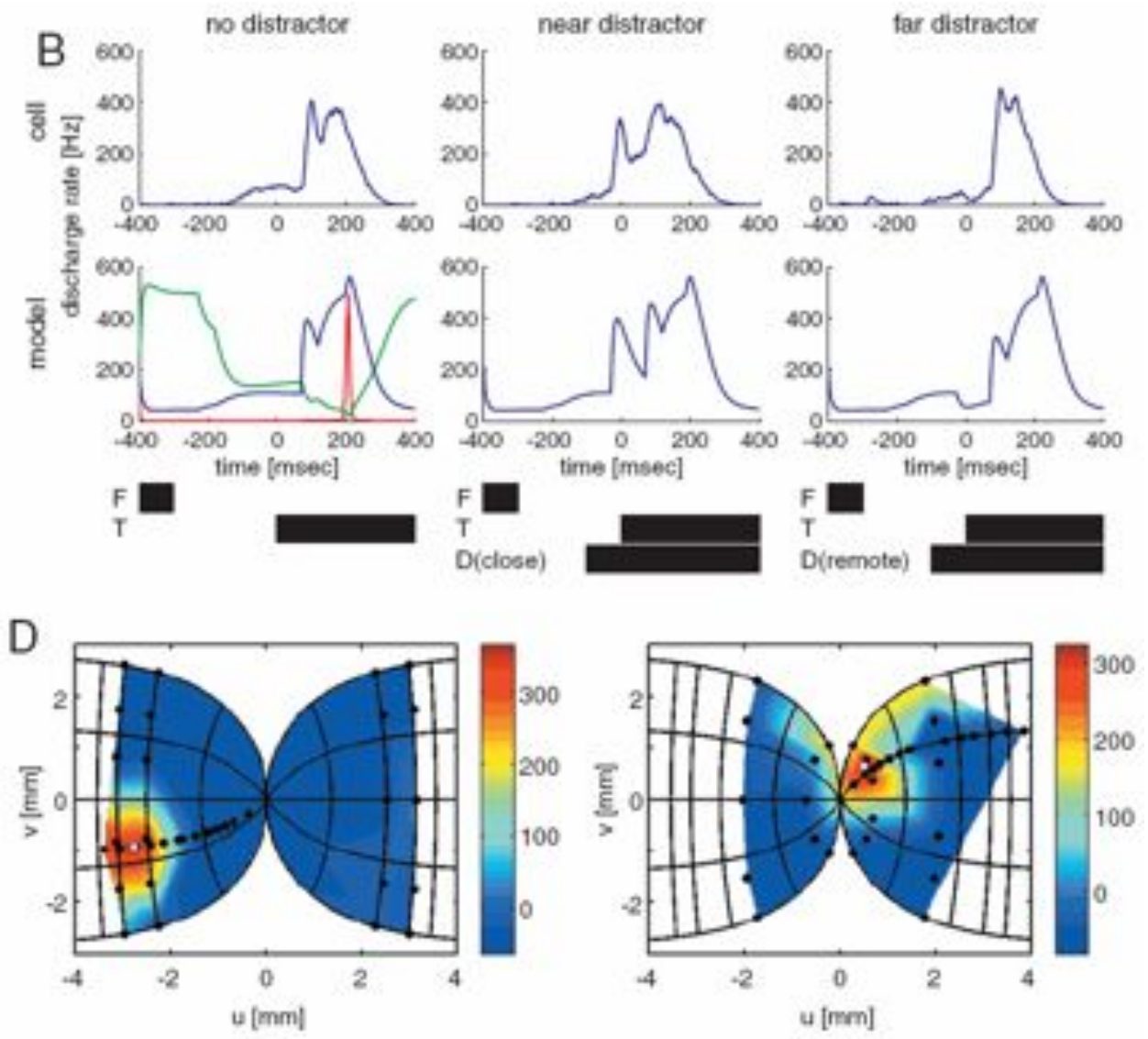
(can be acquired with Hebbian learning $w_{ij} \propto \sum_\mu r_i^\mu r_j^\mu$ **)**

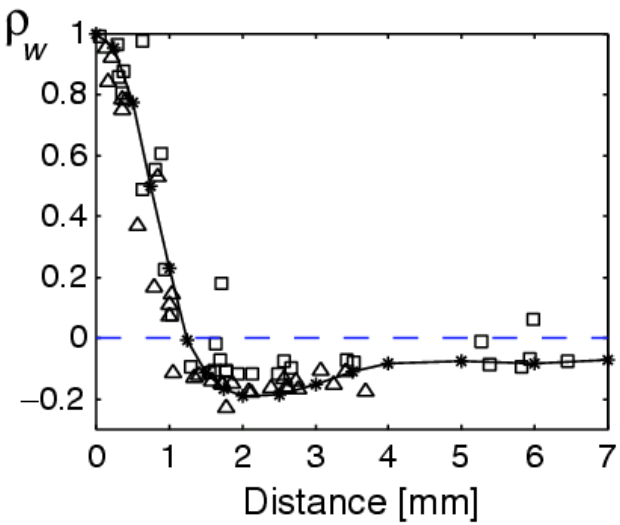
- **Dynamic field equation (updating network states)**

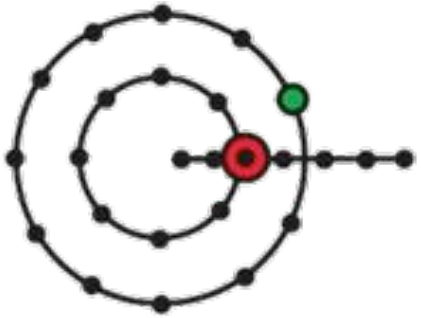
$$\tau \frac{\partial u(x,t)}{\partial t} = -u(x,t) + \int_y w(|x-y|) r(y,t) \mathrm{d}y + I^{\mathrm{ext}}(x,t)$$



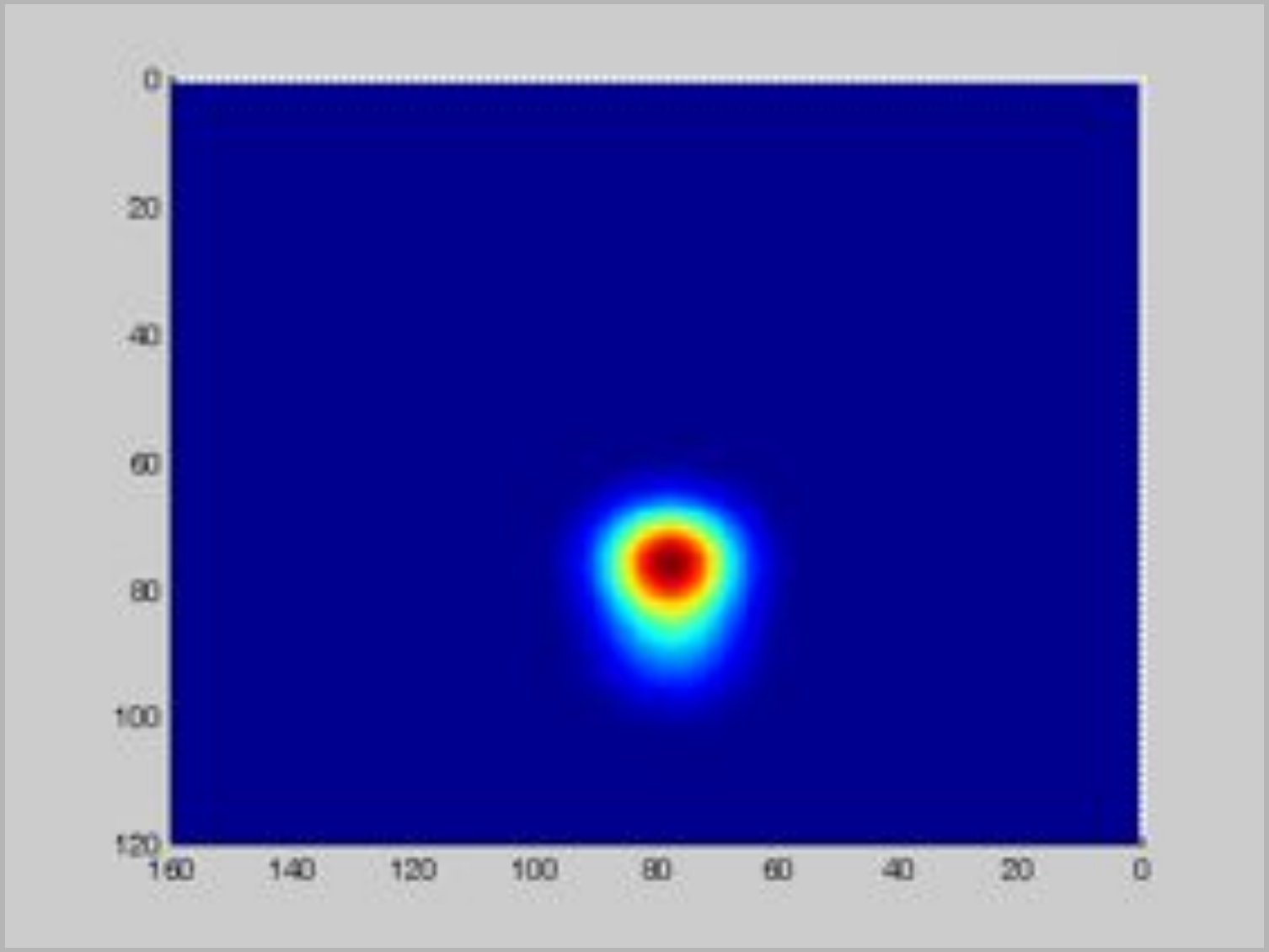
DNF model of the Superior Colliculus







Trappenberg, Dorris, Klein & Munoz, *A model of saccade initiation based on the competitive integration of exogenous and endogenous inputs* J. Cog. Neuro. 13 (2001)


0
20
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60
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120
160
140
120
100
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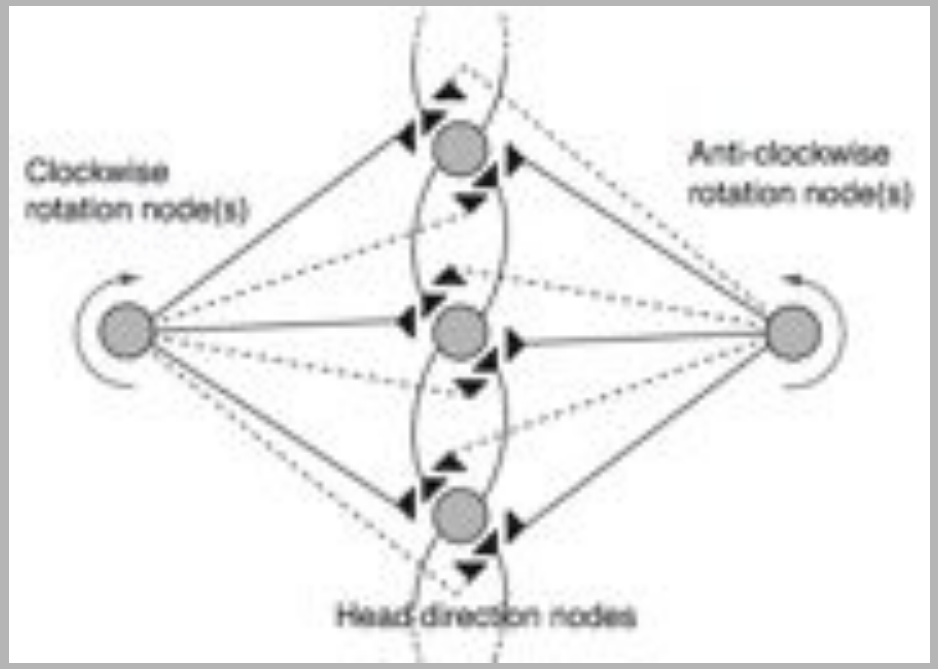
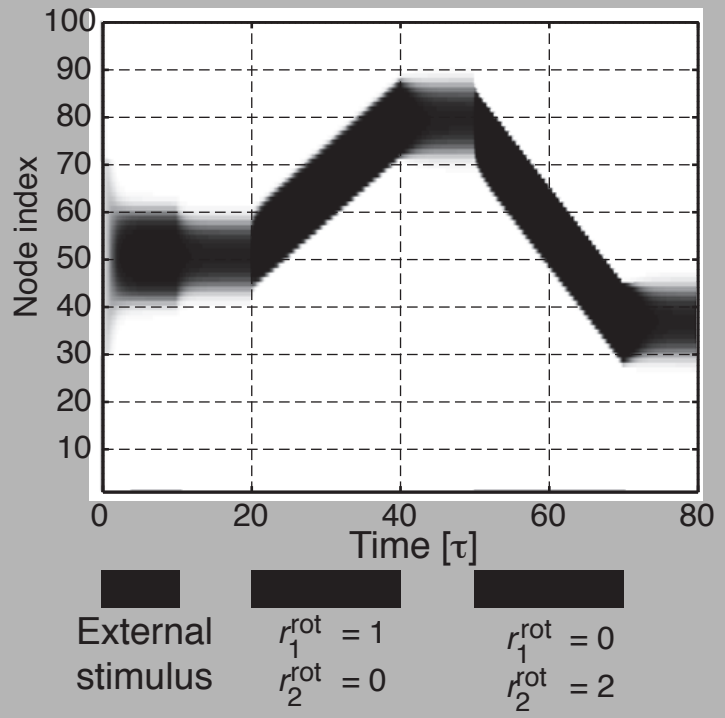
60
40
20
0

Odometry and Path Intergration





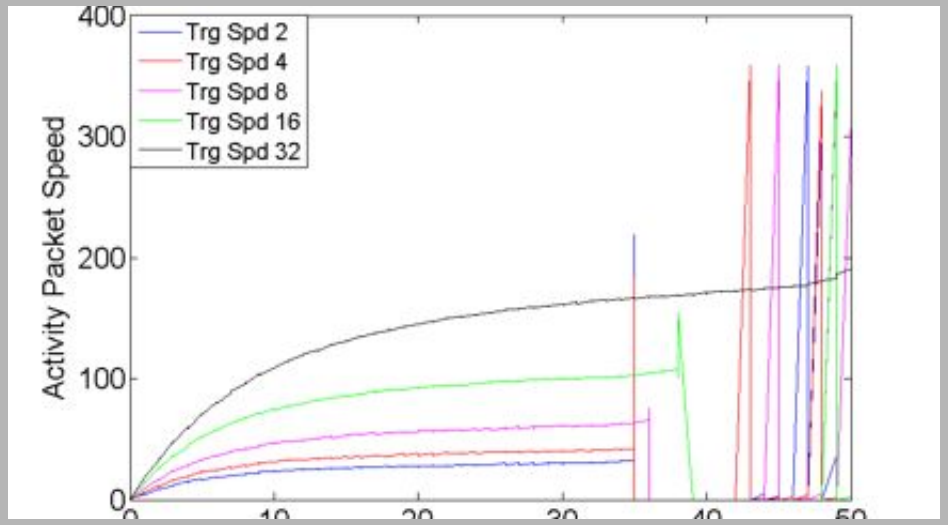
Stringer, Trappenberg, Araujo, Rolls, 2002

Recent progress: … with Warren Connors

Cognitive Computation 2013

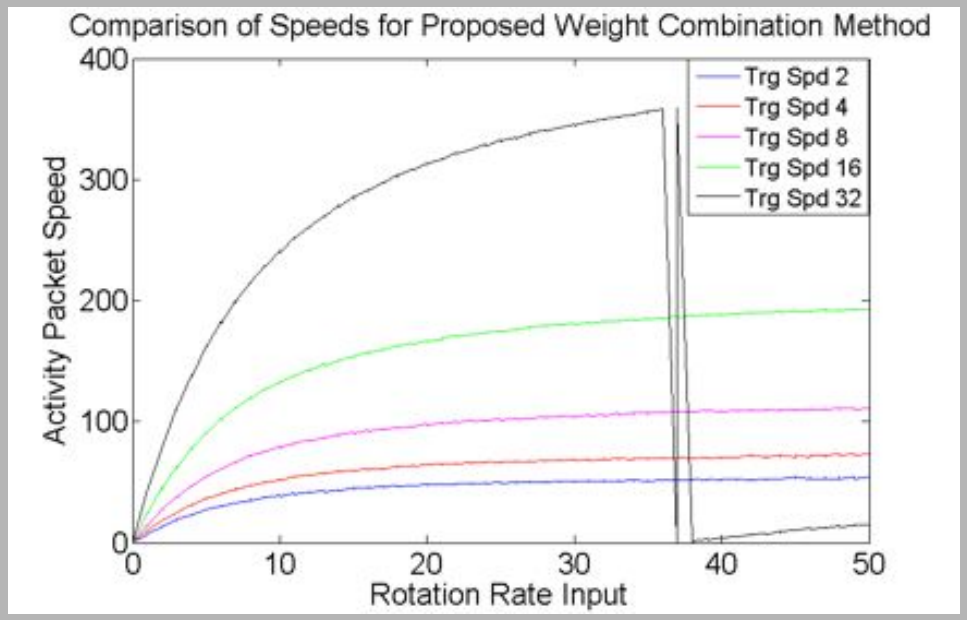
Old:
(Stringer et al.)

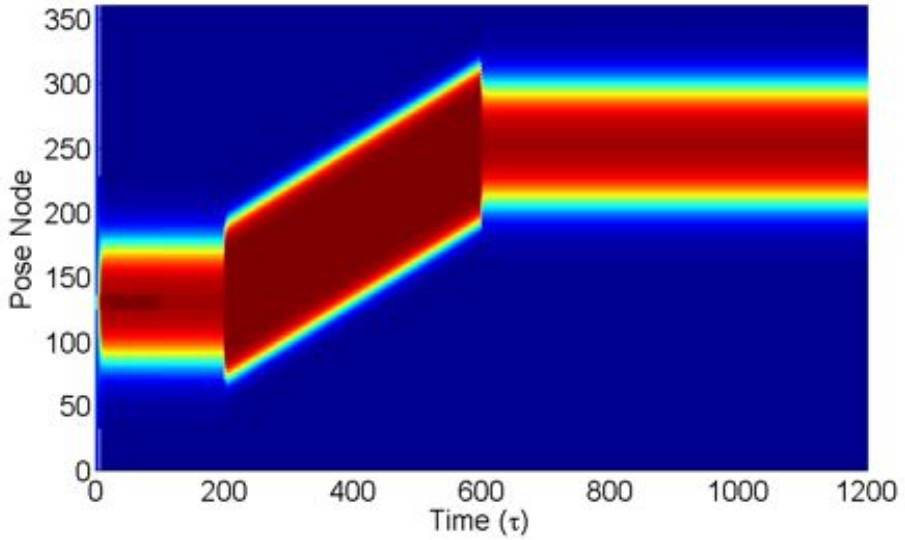
$$w_{ij}^{eff} = w_{ij} \sum_k (1 + w_{ijk}^{rot} r_k^{rot})$$



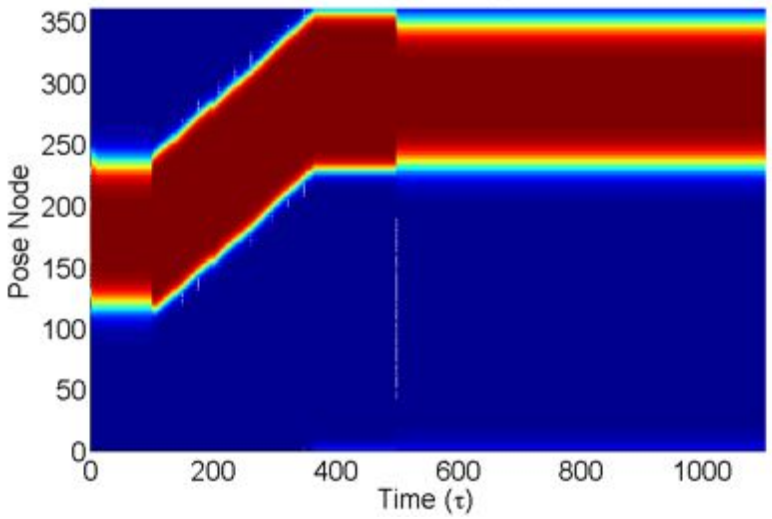
New:
(Connors & TT)

$$w_{ij}^{eff} = w_{ij} + \sum_k (w_{ijk}^{rot} - \mu) r_k^{rot}$$

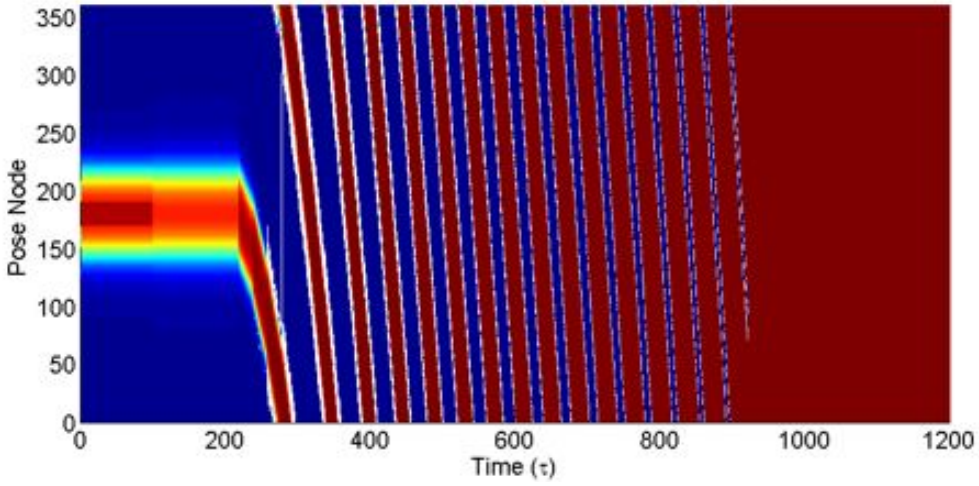




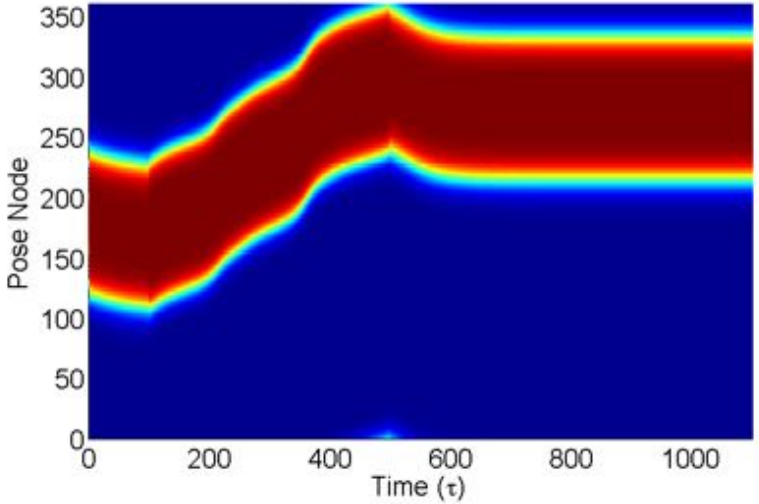
Plot of PI for Noisy Weights Using NMDA Stabilization



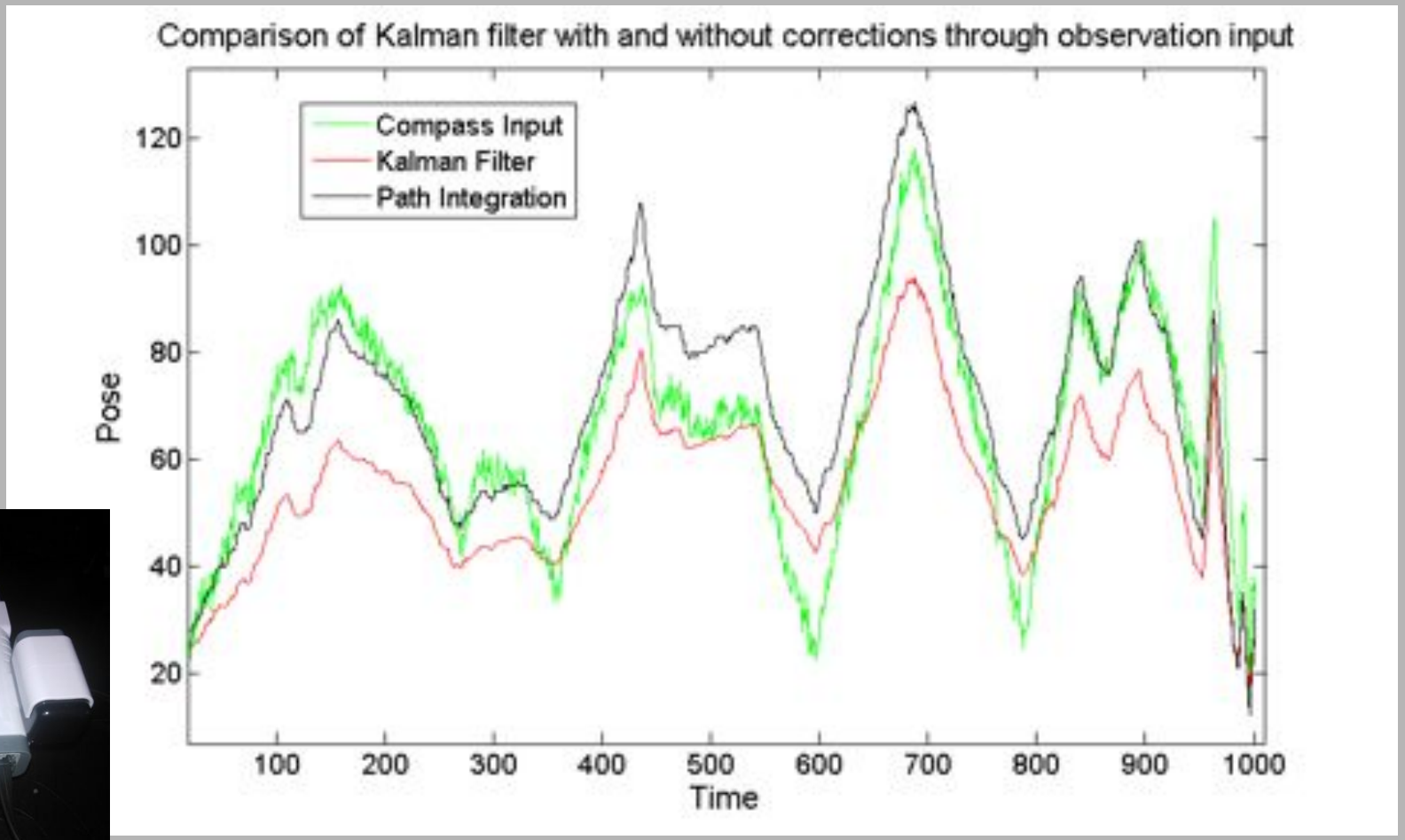
Surface plot of the breakdown of the activity packet.



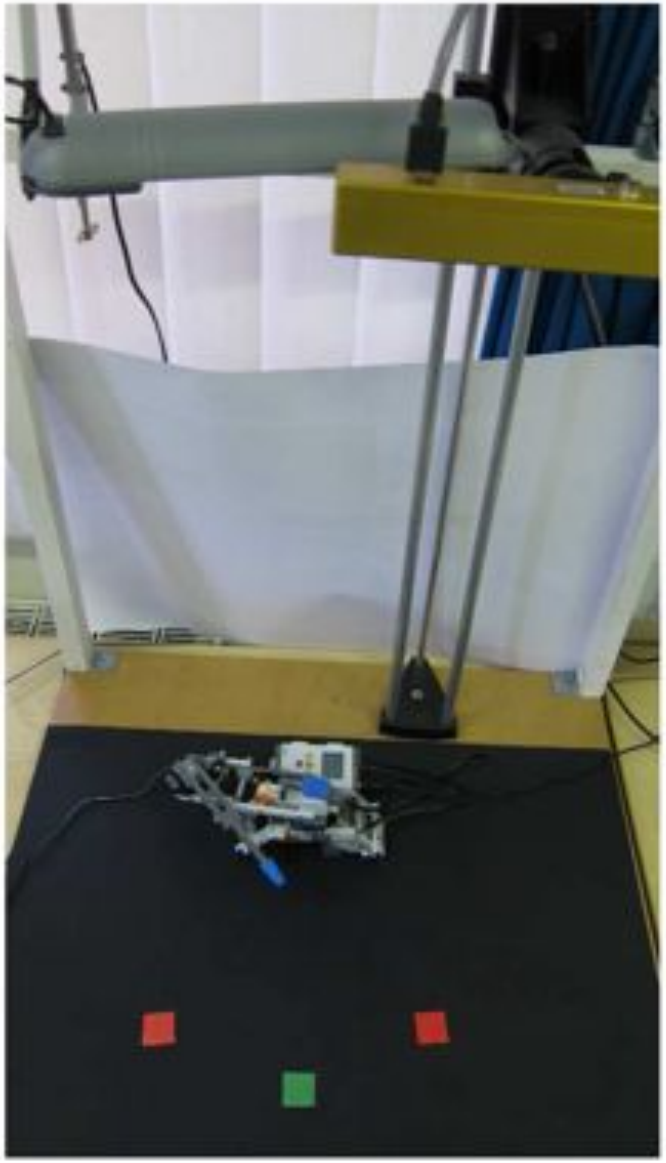
Plot of PI for Noisy Weights Without NMDA Stabilization

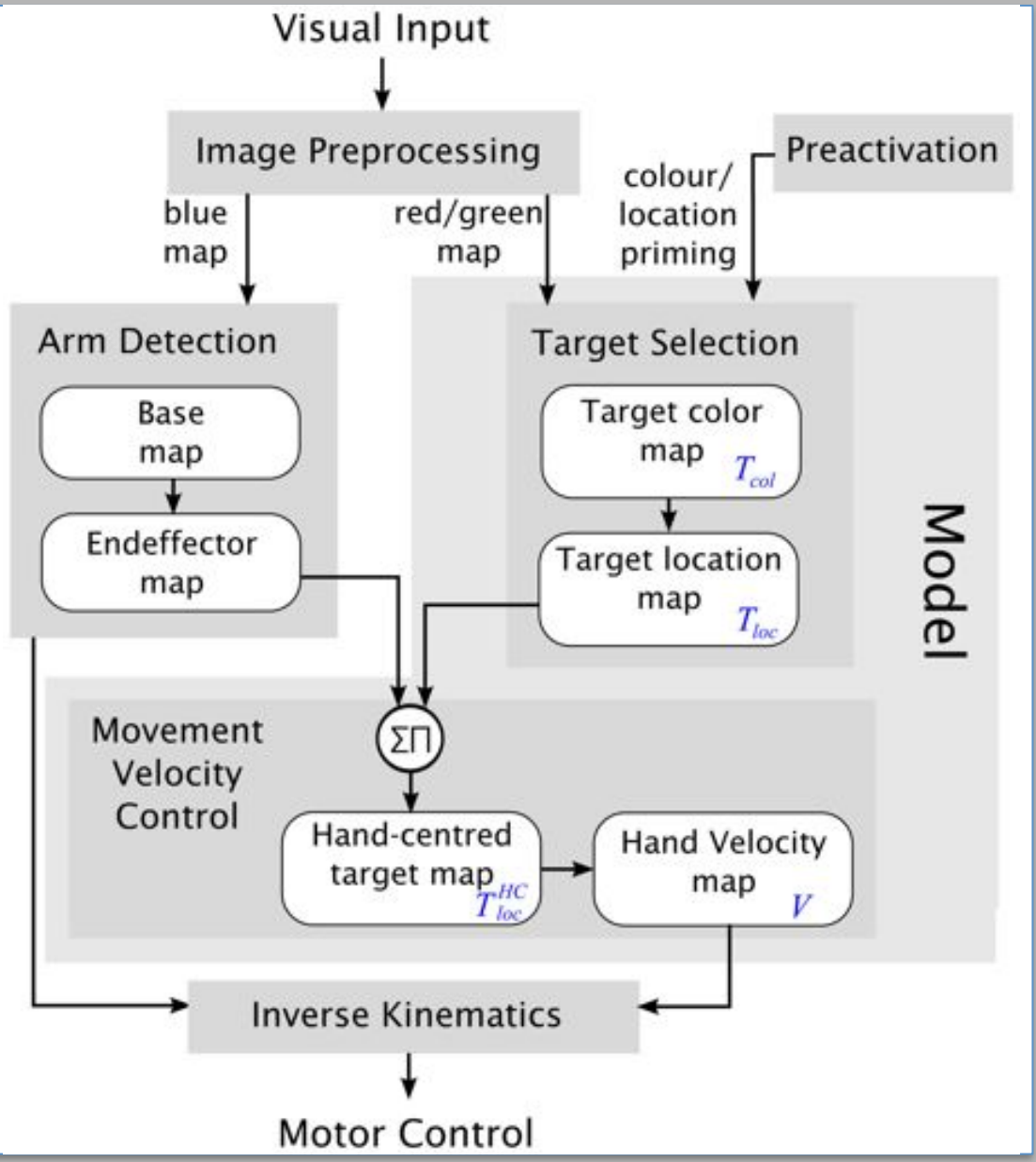


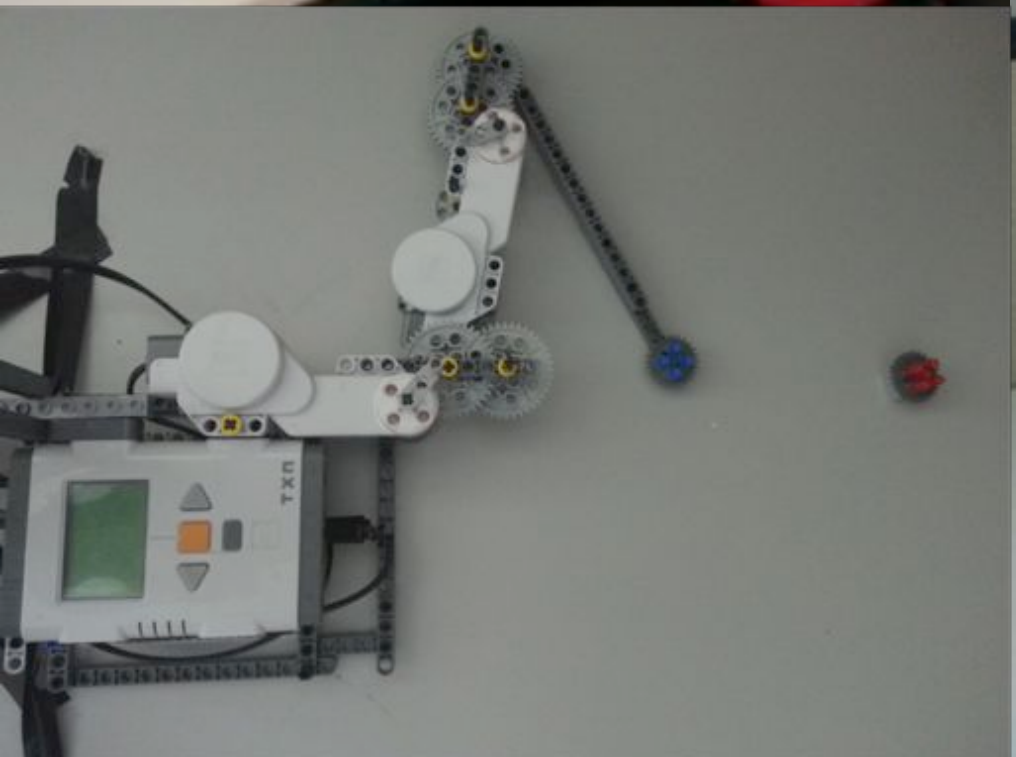
DNF with Path Integration vs Bayes Filters



Soeren Strauss and Dietmar Heinke, Frontiers in Psychology, 2012



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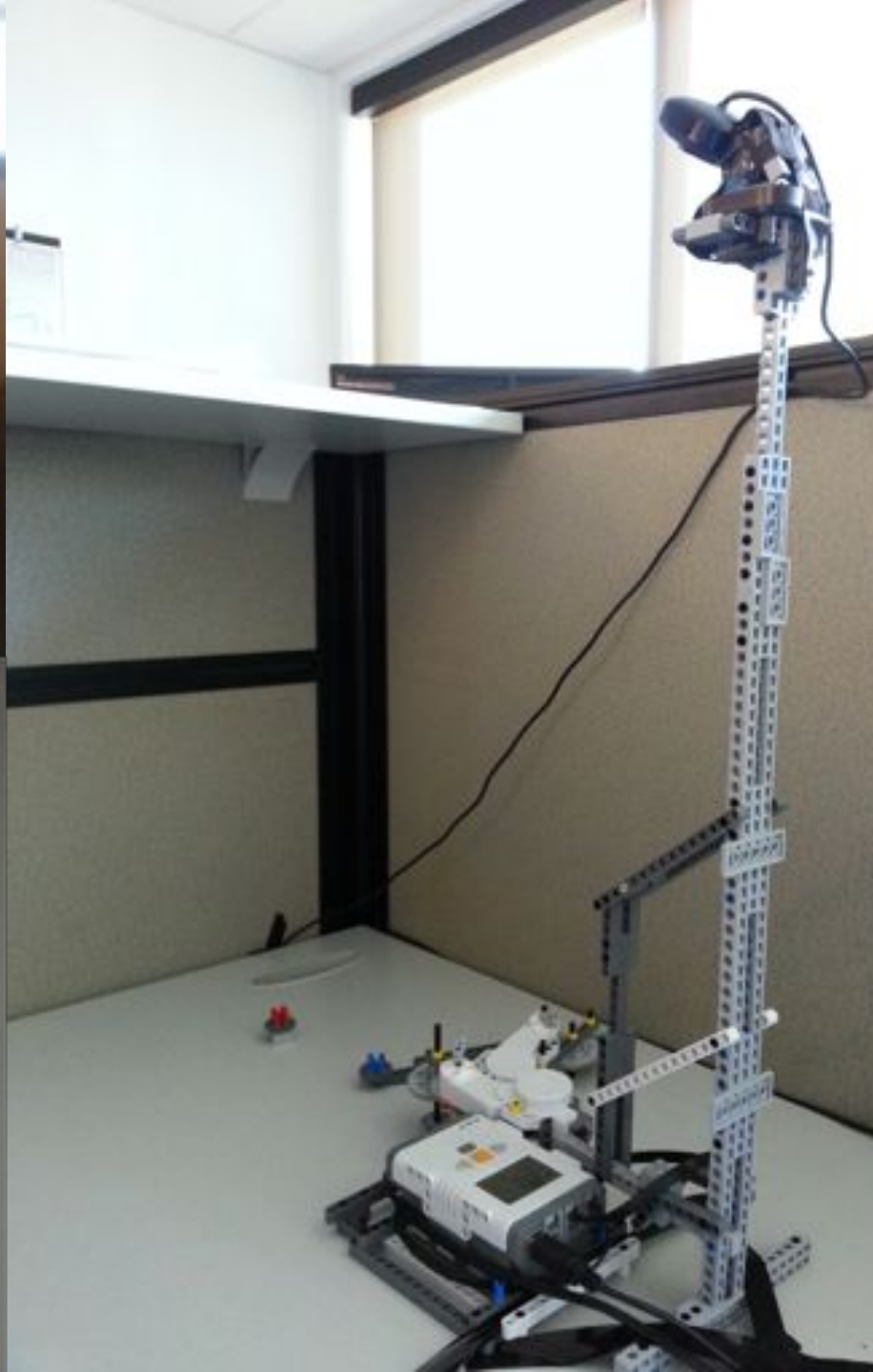

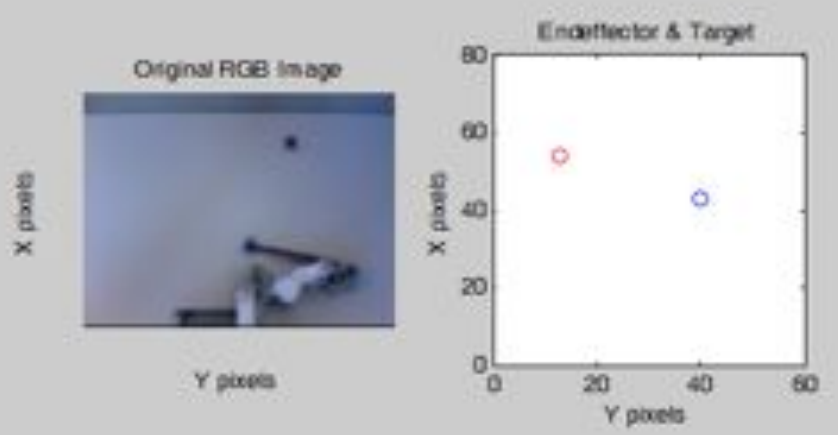
Original RGB Image
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Posts tagged *RatSLAM*

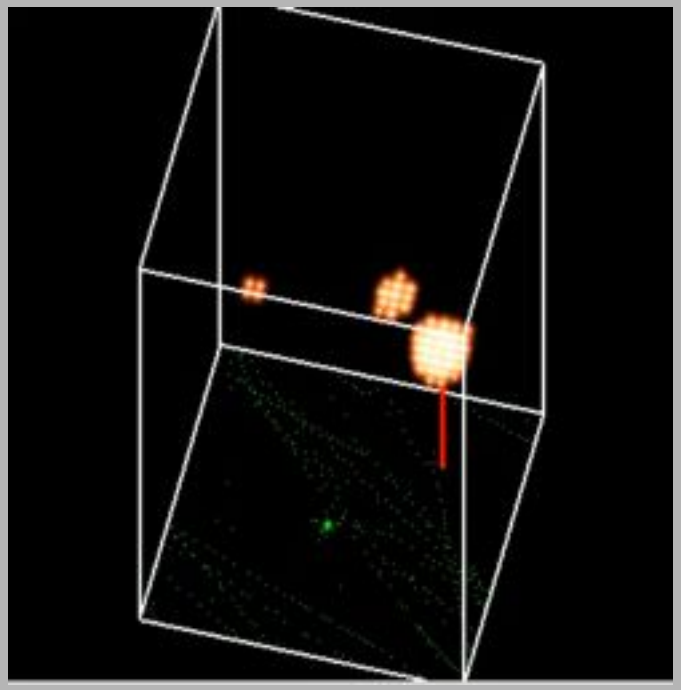
Michael Milford, and Gordon Wyeth

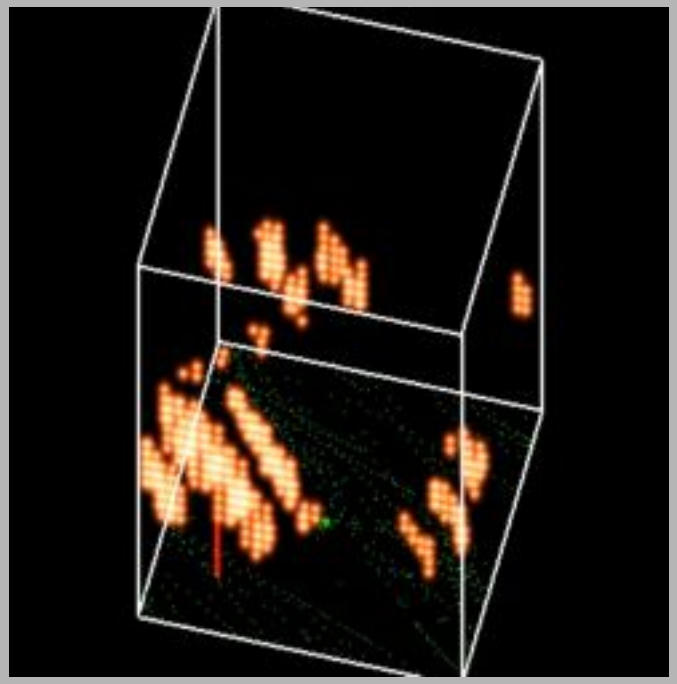
Solving the localization problem by studying the rat's hippocampus

MAR 12TH Posted by Awesome-o in [...] No comments

Neuroscientists at the Department of Physiology and Pharmacology, Robert F. Furchgott Center for Neural and Behavioral Science, State University of New York Downstate Medical Center, New York, U.S., are studying how rats interpret spatial information by analyzing the activity in the hippocampus.

Specifically, Dr. Andre F. Fenton has published a recent article in the latest issue of Science discussing the latest discoveries about how different cells in the rat's hippocampus behave allowing the rodent to identify previously visited areas. For example, activity in specialized neurons called "place cells" reveals that some discharge rapidly when the animal is in a part of the environment that it has visited before. Scientists observed the activity in the hippocampus when the animals were placed in different boxes with shapes varying from a square to a circle.





Summary and Outlook

Machine Learning is a really exciting area:

- Theoretical backdrop for cognitive neuroscience
- Progress in data analysis
- New applications possible (Google, Microsoft, …)
- New era in robotics

We are working on many more application

- Analysis of data:
  - lens-less microscopy
  - EEG
  - Video data
- Neuroscience of plasticity and learning
- Neuroscience of eye and arm movements
- Vision

Specific methodological areas of interest

- Deep learning
- Temporal sequences
- Robotics
- Sensory data