Brain-IT

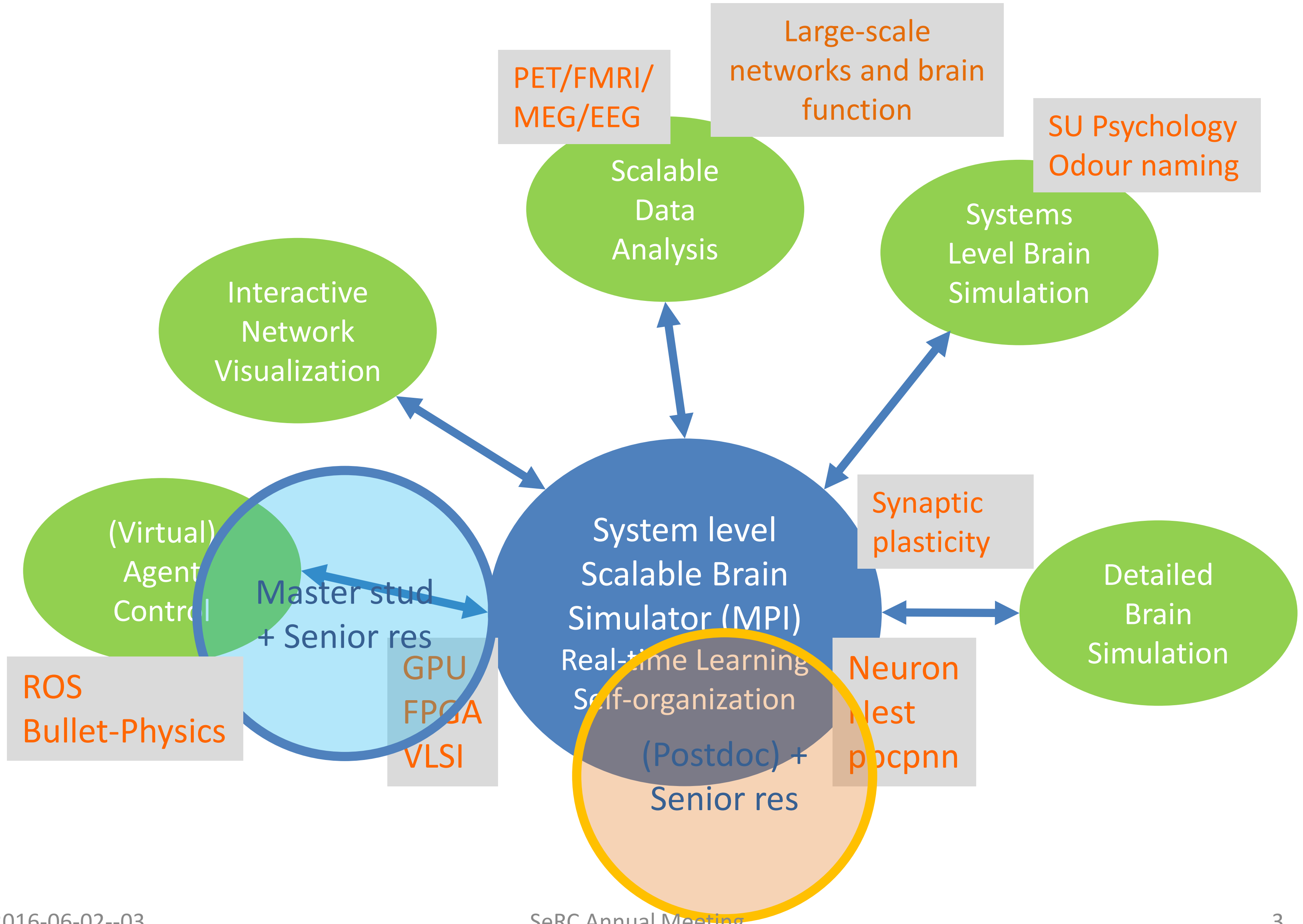
Brain simulation and Brain-like computing

Anders Lansner, SU (and KTH)

Origins of SeRC/Brain-IT

- Computational neuroscience, neuroinformatics at KTH
  - Understanding the brain
- KTH Brain-IT → SeRC Brain-IT community
  - Workshops, meetings
  - 20+ participants, KTH, SU, KI
  - Steering group, plan to recruit Coordinator
- SeRC Brain-IT MCP
  - Jeanette Hellgren Kotaleski (KI, SU)
    - Synaptic plasticity, learning
  - Anders Lansner (SU)
    - ”Brain simulation and Brain-like computing”
      - Large-scale, complex, neural networks that learn and behave
  - Peter Fransson (KI)
    - Dynamics of large-scale human brain networks

SeRC Brain-IT projects



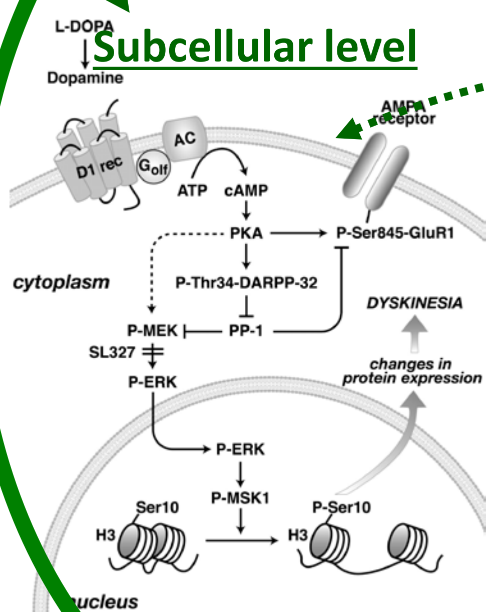
Jeanette Hellgren Kotaleski, Olivia Eriksson et al. (KTH, SU and KI)
Framework for *in silico* experiments on learning in the basal ganglia

In particular: **learning and** decision making **in the basal ganglia**

Neuromodulatory control of plasticity

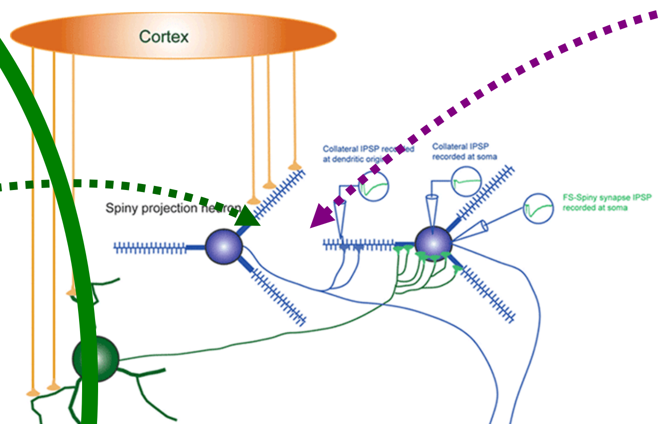
Here: Identify and investigate rules for learning by modeling receptor induced pathways

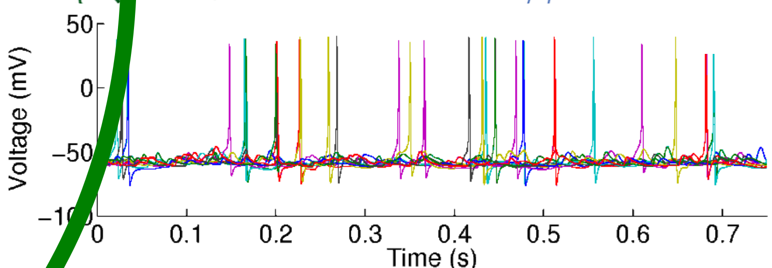
Subcellular level



This level also is a bridge over to 'systems biology' and links to drug discovery...

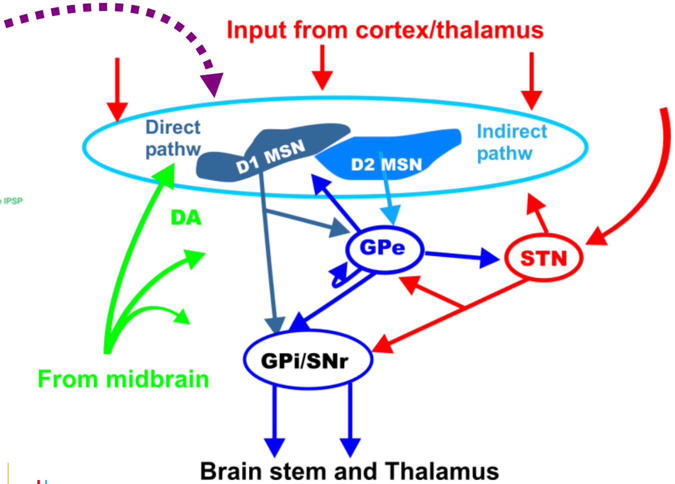
Microcircuit level





Biophysically detailed models to identify role of membrane and synaptic properties on the local network, for input integration, etc

Systems level

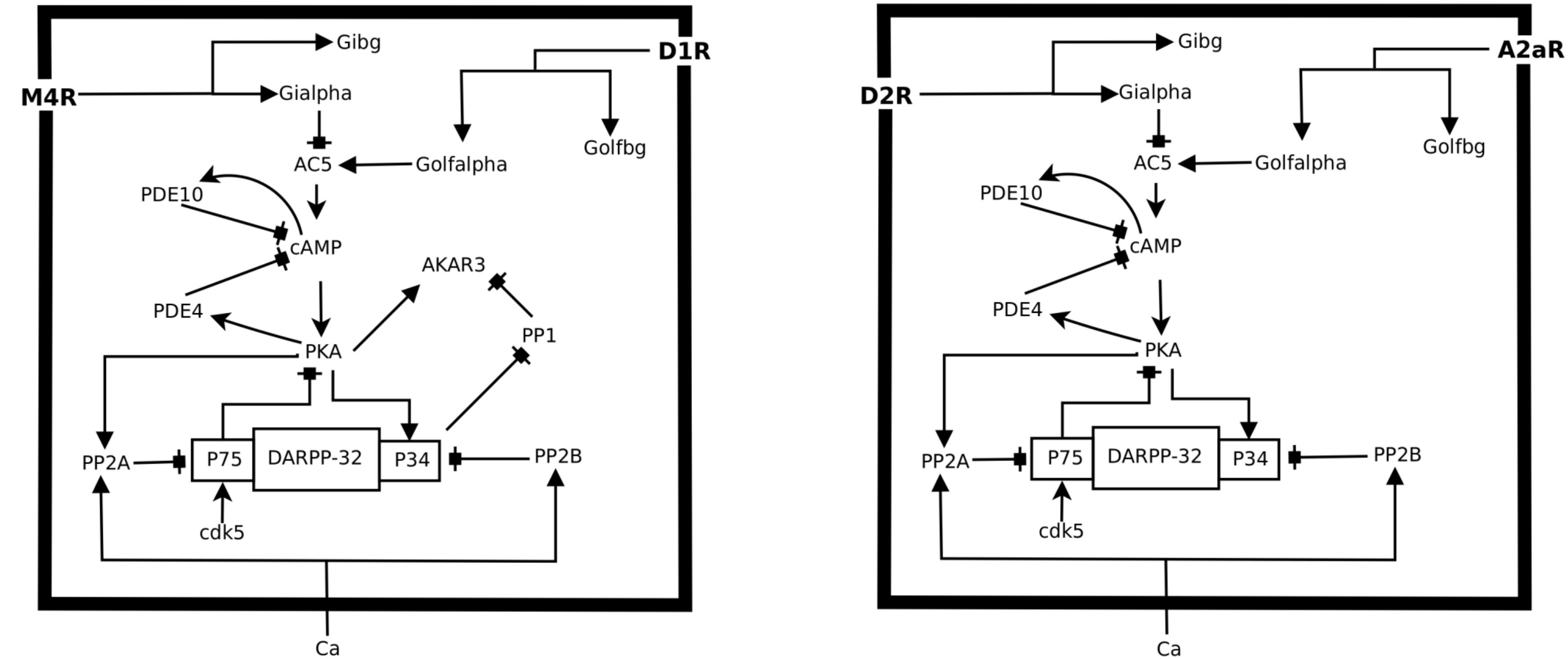


Often somewhat 'reduced', or abstract, models to study e.g.: selection of behaviour, and reward dependent learning, control of motor behaviour via brain stem and spinal cord, etc

Model of the receptor induced cascades controlling cAMP-PKA

A Direct pathway MSN

B Indirect pathway MSN



M4R, D2R, A2aR tonically active; D1R not so active at rest

1) Build reaction network

$$A + B \underset{k_r}{\overset{k_f}{\rightleftharpoons}} AB$$

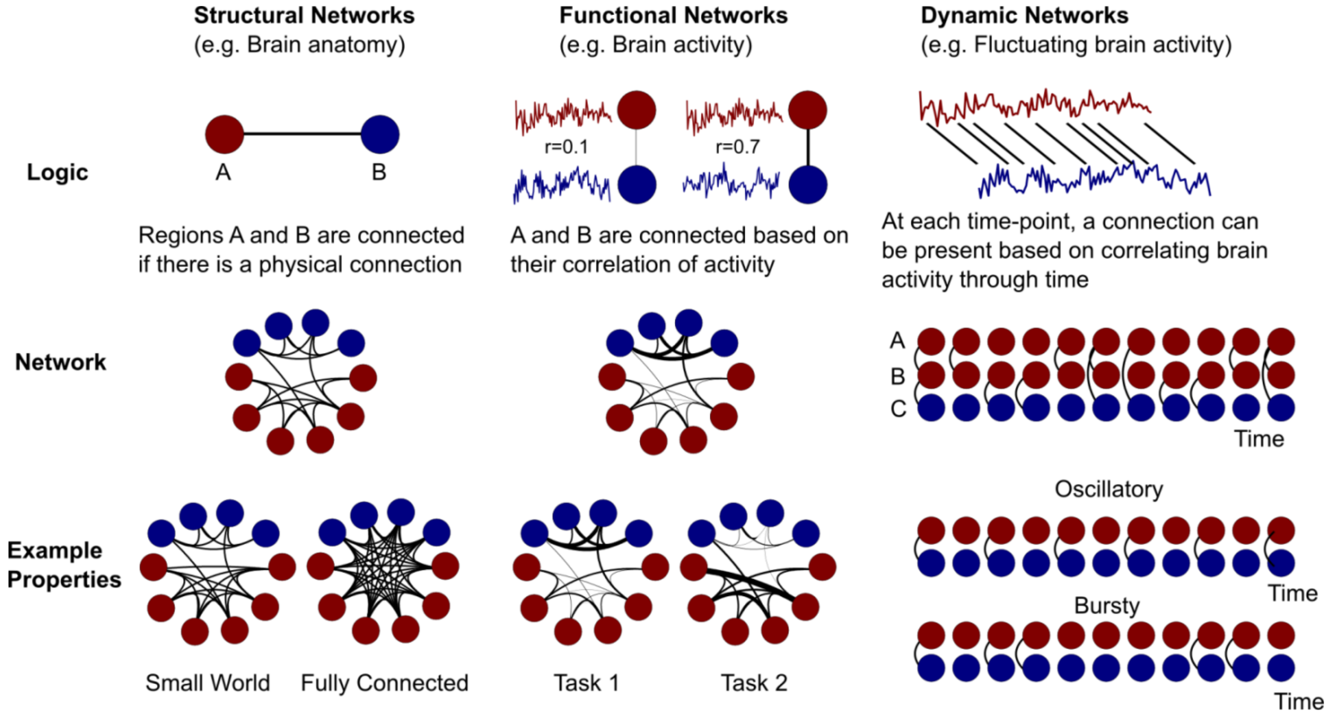
2) Convert it to ODEs

$$\frac{d[AB]}{dt} = k_f \cdot [A] \cdot [B] - k_r \cdot [AB]$$

3) Fit model to data

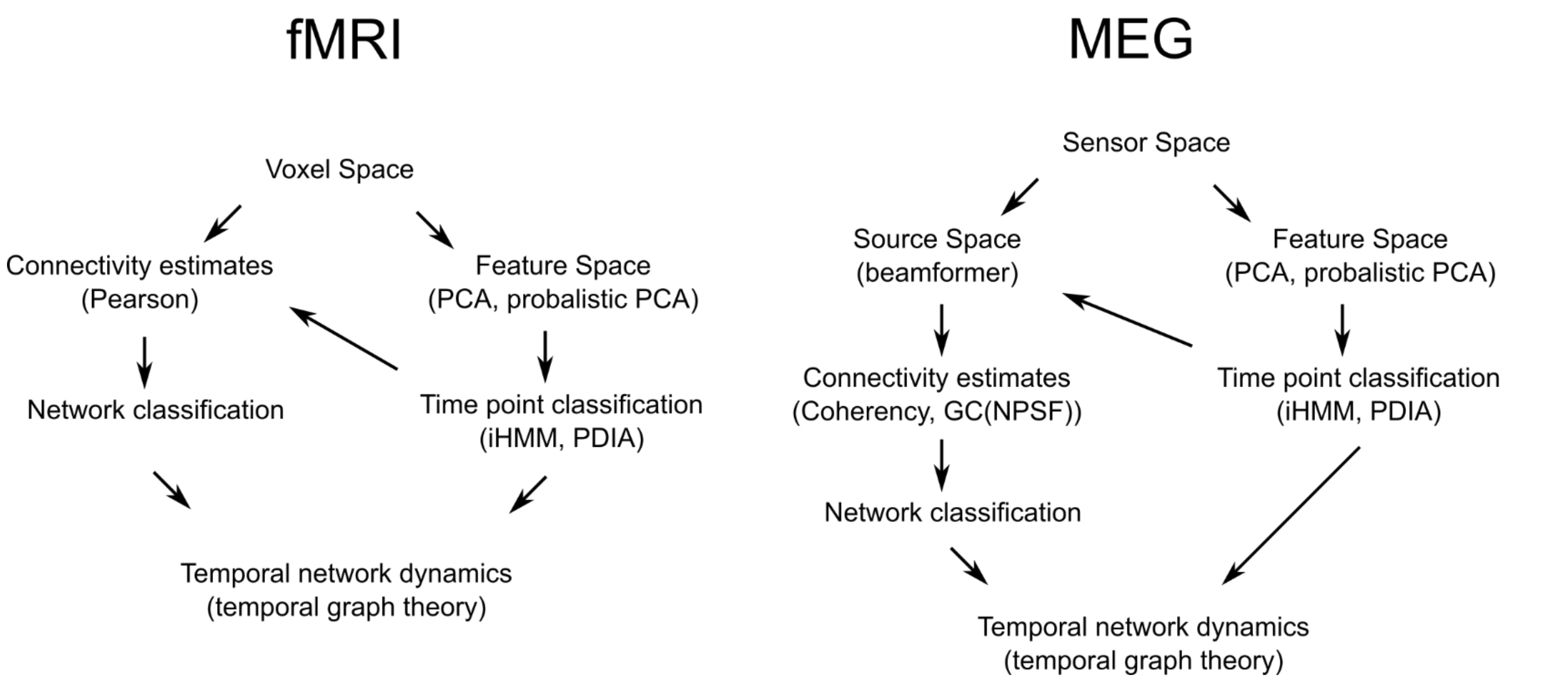
P Fransson et al. (KI, Clinical neuroscience): Dynamics of the large-scale human brain networks

- Aim: to develop, validate and assess novel methods to detect, characterize and visualize fast, dynamic changes in brain network connectivity (fMRI and MEG data).



- Allows for testing hypotheses regarding integration of brain activity. For example, does communication between large-scale networks occur in the form of bursts of activity?

- To optimize the analysis pipeline of MEG and fMRI data including feature space selection, time point classification, connectivity and coherencey estimates, network classification and temporal graph network theory.



- To integrate results obtained with the theoretical and computational work on brain dynamics carried out within the SeRC Brain-IT community

Brain simulation and Brain-like computing

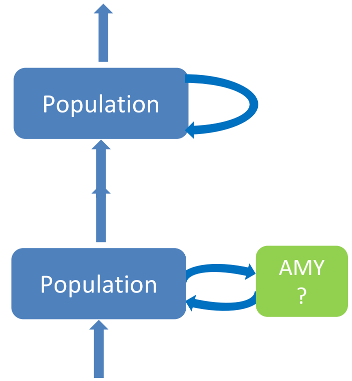
- Started Jan 2016
- Approach: Brain model → Brain computation
  - Detailed brain network models & simulations
    - ODE:s, signal transmission, learning; Event based communiction
    - Locomotion, Memory (LTM & WM), Reinforcement learning, Vision; BCPNN learning rule

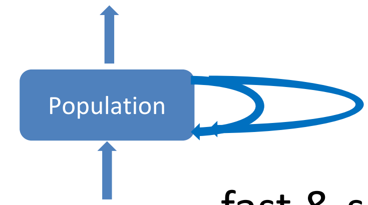
→Abstraction → (FPGA/VLSI design) → Applications

- Modular, weak scaling, small→large brain

”Functional network motifs”

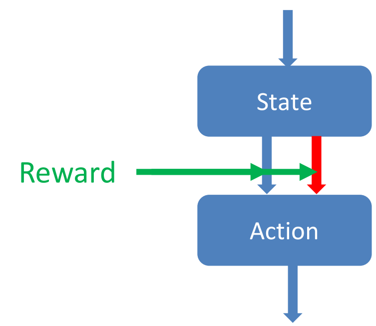
- Attractor memory
  - Long-term, short-term
  - Sequence learning
  - Attentional gating
  - Cortex, Amygdala, ...



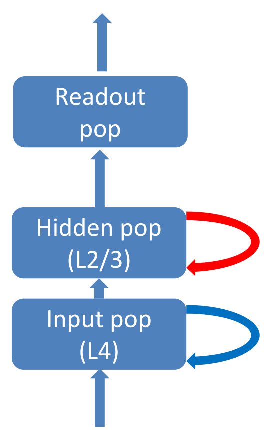


fast & slow τ_{syn}

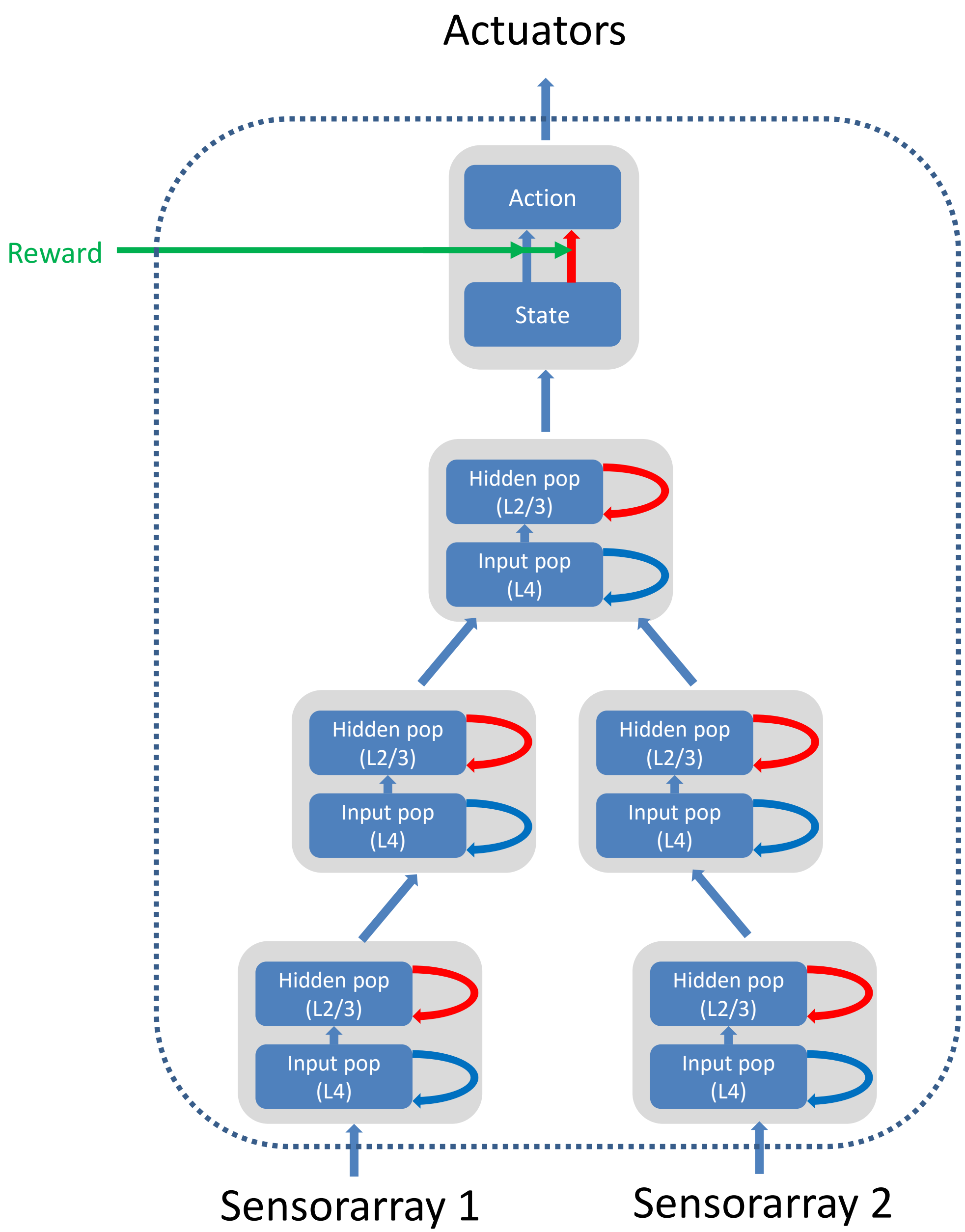
- Reinformement learning
  - Cortex - Basal ganglia

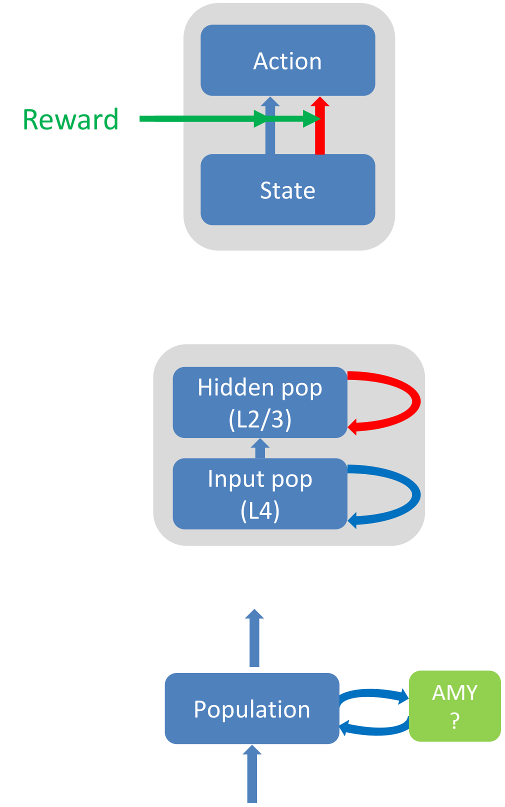


- Perception/Classification
  - Cortex



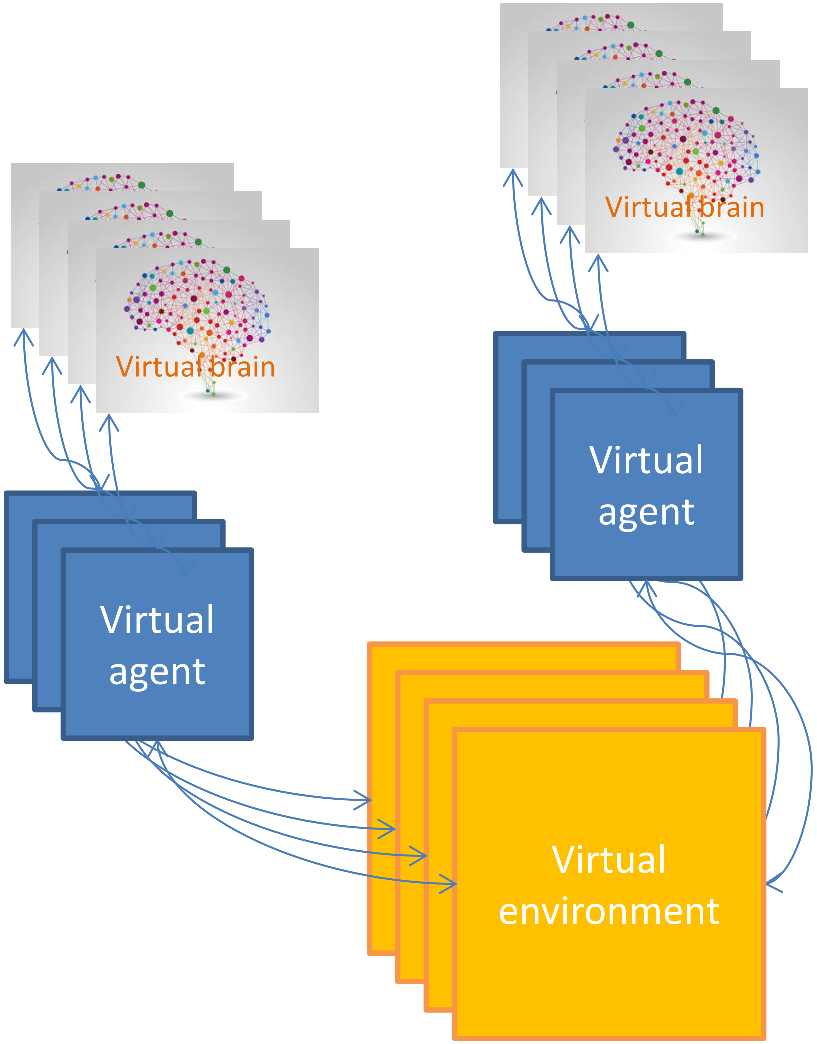
Tools for building and running artificial brains





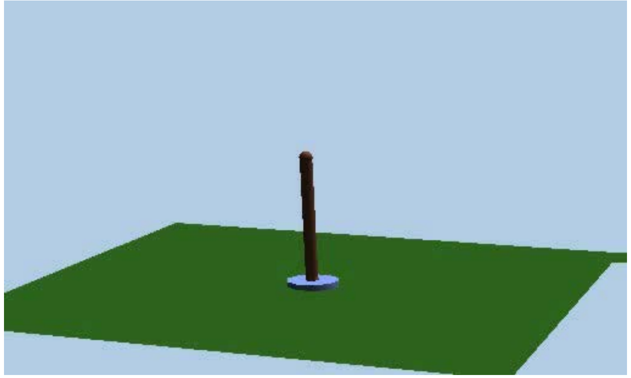
Simulator development (MPI)

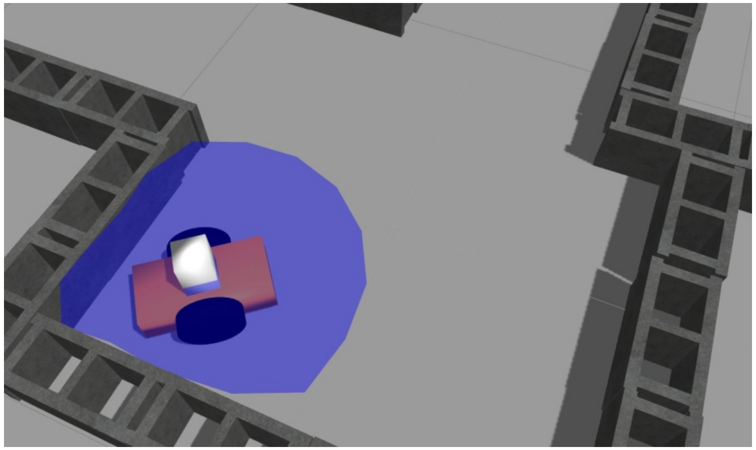
- Extending *pbcpnn* code
- Deep network structure
  - Structural plasticity ("rewiring")
- Evaluation (ML datasets)
  - Wine, RocksAndMines, MNIST
- MUSIC interface
  - KTH developed
  - Event based, continuous



Virtual agent control

- Artificial brain (insect/mouse ...)
- Closed loop (sensors, actuators)
  - Via MUSIC interface, in progress
- Two MPI apps, reinforcement learning

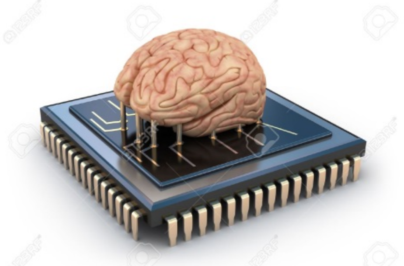




  - Örjan Ekeberg
  - Naresh Balaji Ravichandran (MSc)

GPU implementation, VLSI design

- Aim: real-time, modularity, perfect weak scaling
- GPU implementation
  - Future clusters, MPI + CUDA/OpenCL
  - Research engineer recruited (ICT)
- FPGA, VLSI: KTH ICT Ahmed Hemani
  - (other funding)
  - Based on MPI version
  - Real time or faster
  - eBrain, eBrain++
  - New postdoc recruited
  - Estimate: Embedded mouse brain (22 nm, 2 W)



Summary and Future

- SeRC Community
- SeRC Brain-IT – 3 complementary MCP:s
- Brain simulation and Brain-like computing
  - Scalable simulator, MPI, GPU, FPGA, VLSI
  - Tools for specifying network-of-networks =>
  - Artificial brains for virtual agents
  - Evaluation on pole balancing, collision avoidance, ... more to come
- Future: Migration to real robot with embedded VLSI brain

Thank you!

Questions?