Online reinforcement learning by a spiking network model of the basal ganglia

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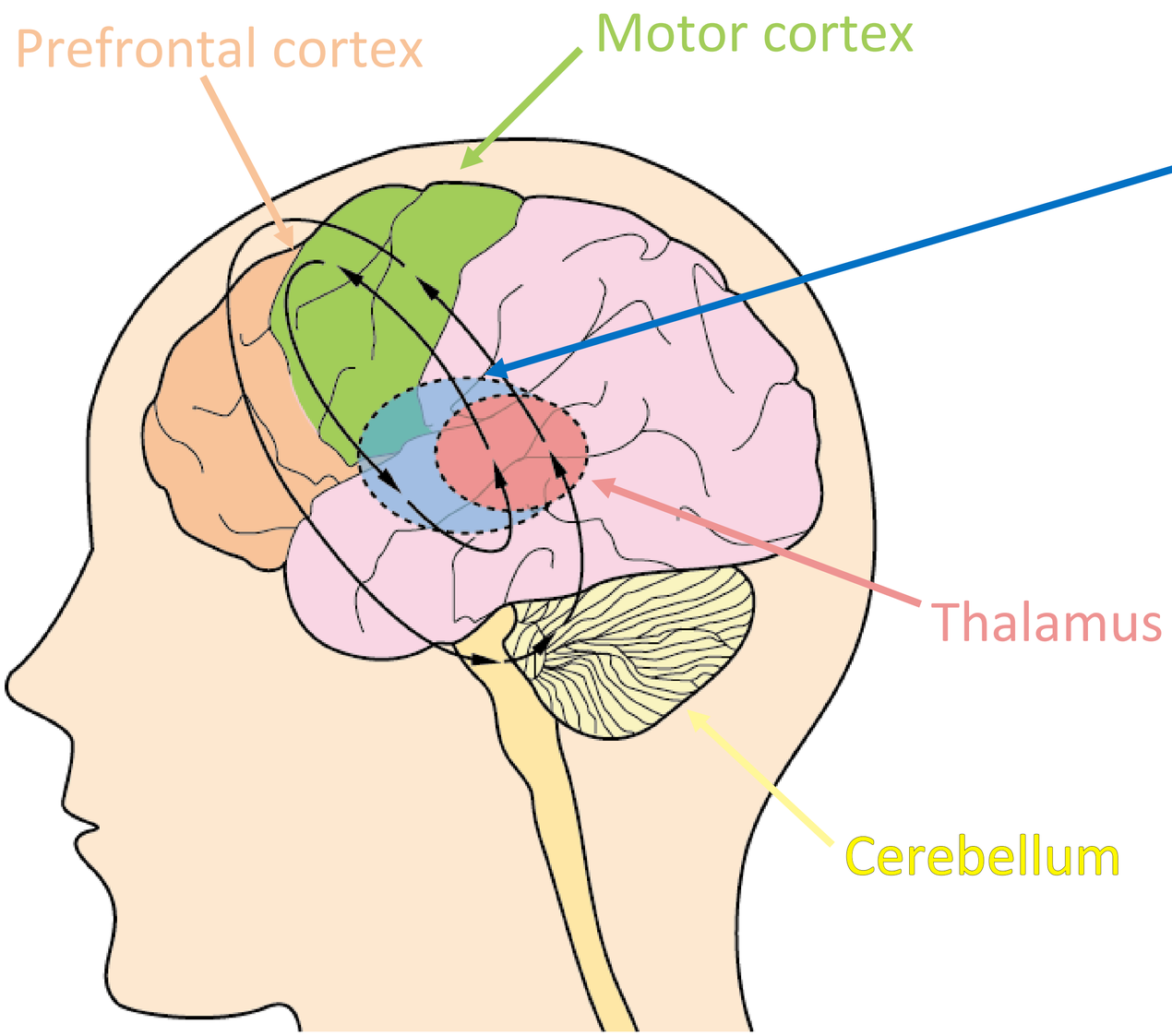
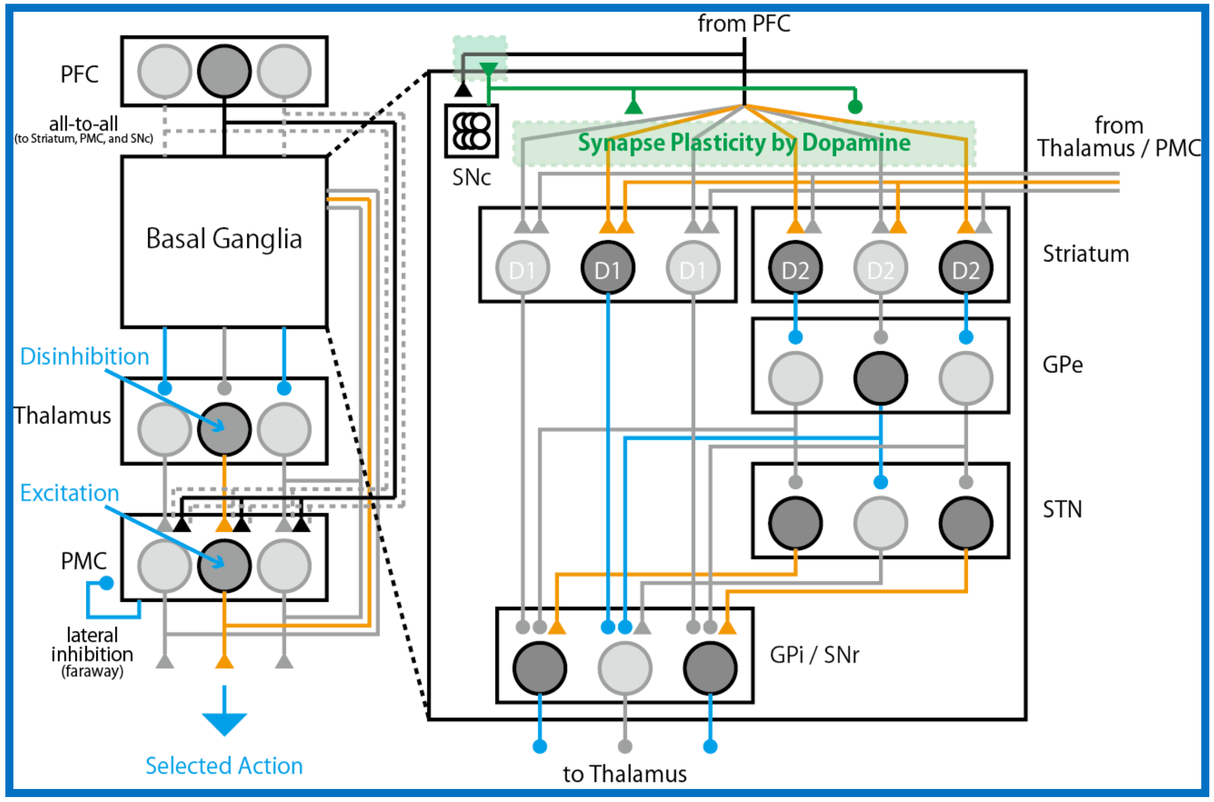
What is a killer app for neuromorphic chips?

Name	Compute	Products	Killer app
AI accelerator	Tensor calculation	TPU2, Tensor core, Movidius, MN-2, ...	Deep learning
Annealer	Simulated annealing	D-Wave, Hitachi CMOS, Fujitsu digital, ...	Combinatorial optimization
Neuromorphic	Spiking neural network	Loihi, TrueNorth, SpiNNaker, BrainScaleS, ...	?

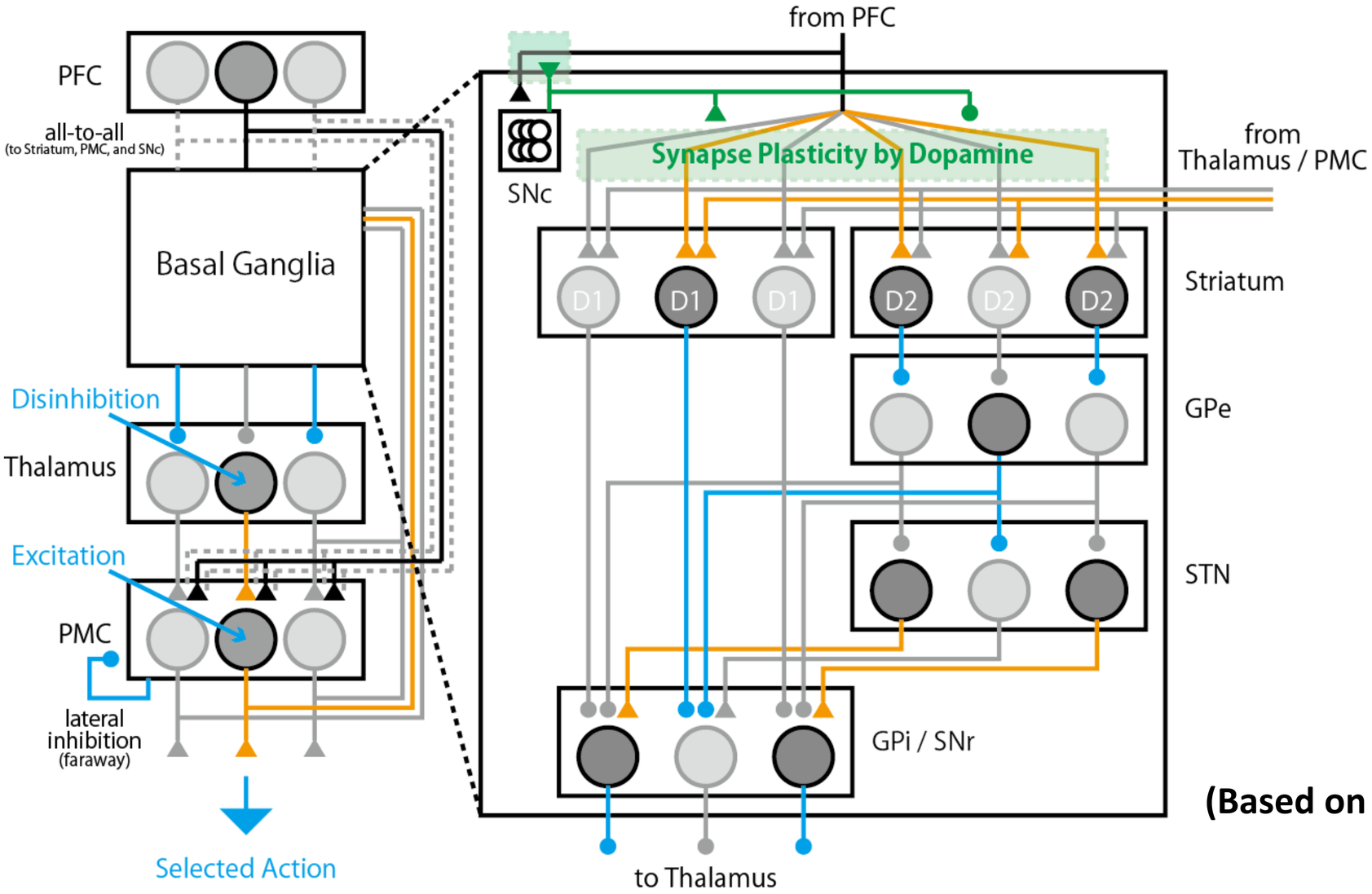
(Deep) Reinforcement learning

Basal ganglia is a site for RL in the brain





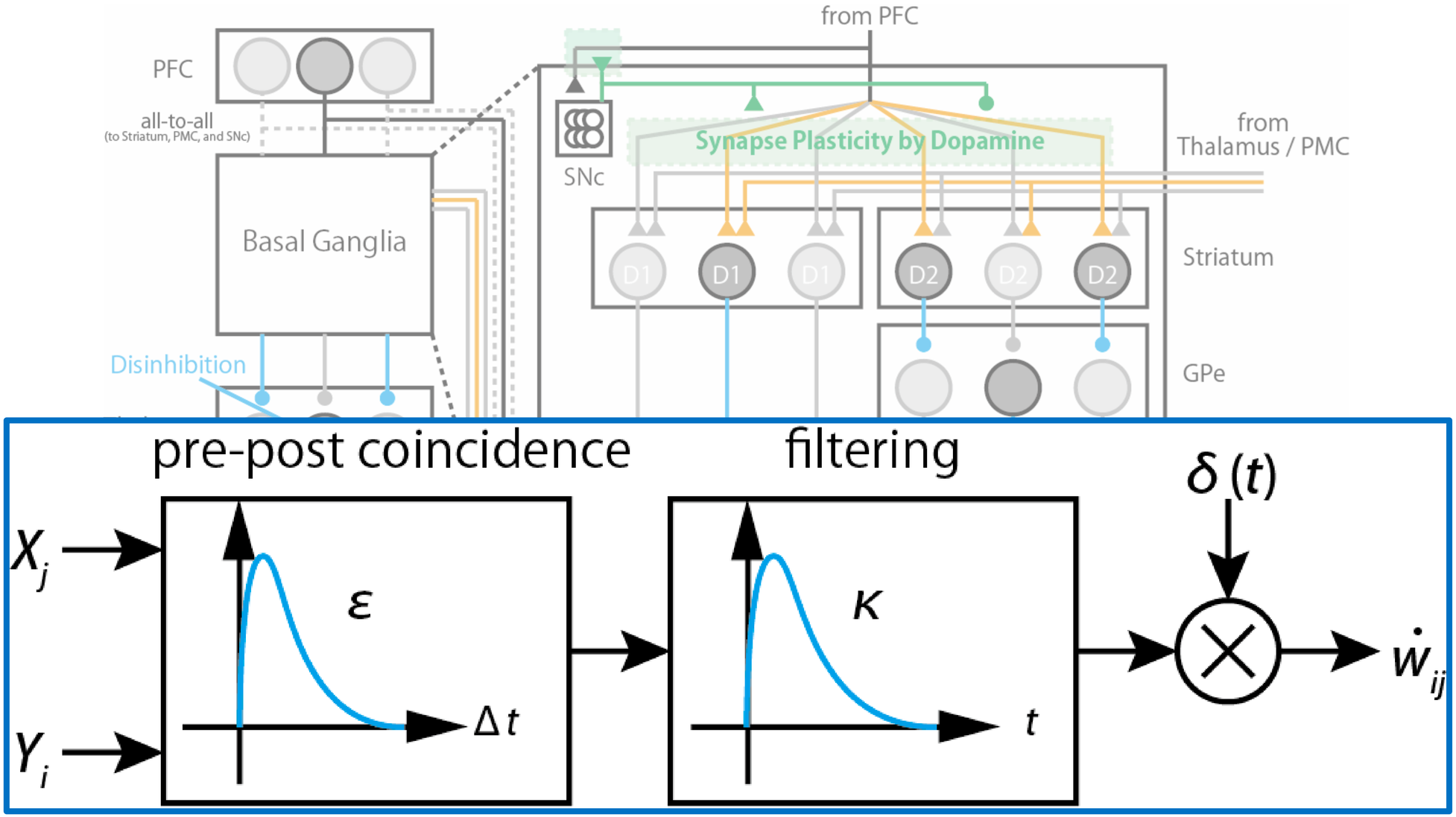
Model anatomical structure



(Based on Kim et al. 2017)

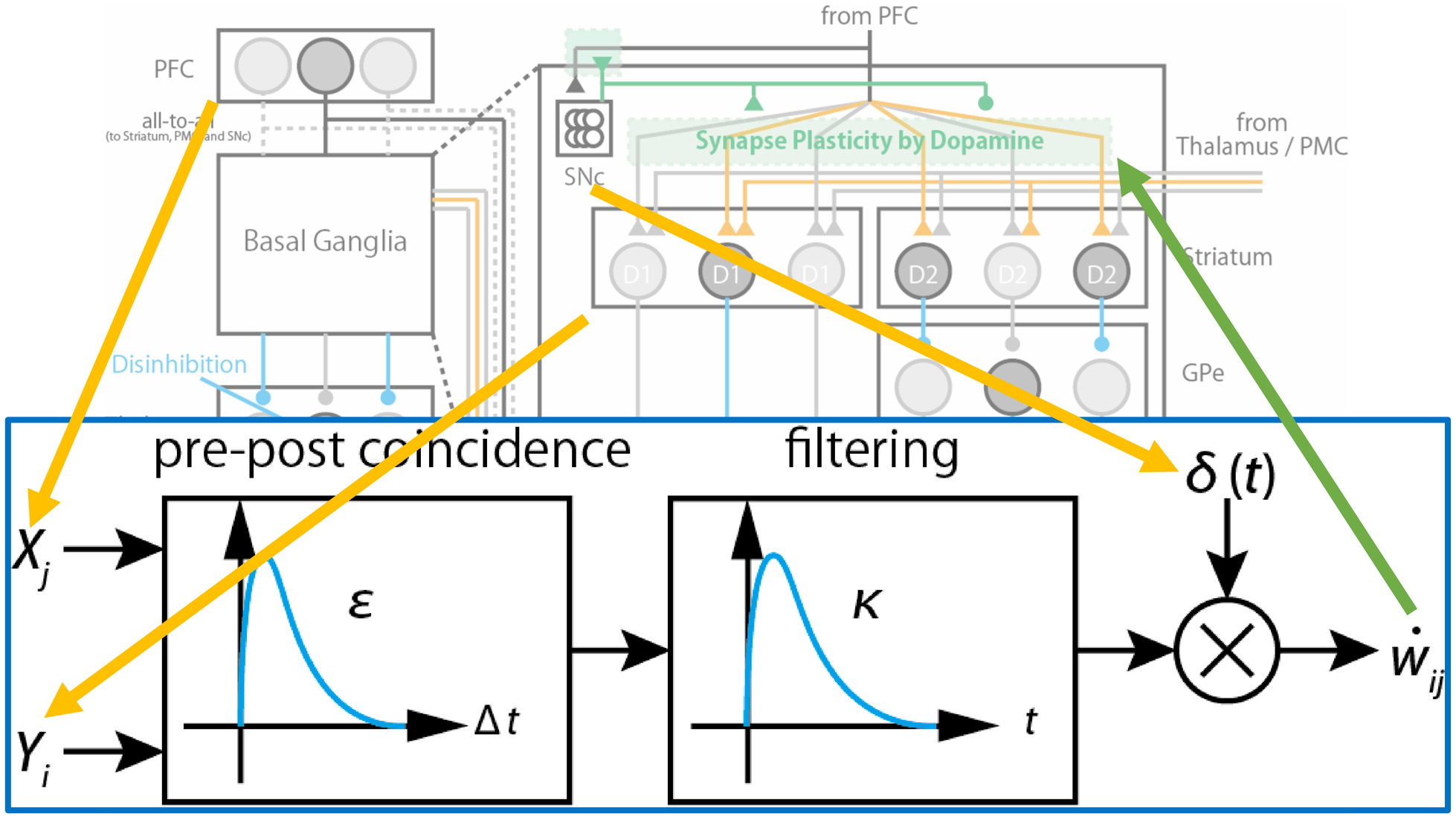
900 spike response model (SRM0) neurons

Learning rule



Spike timing-based learning rule (TD-LTP) **(Frémaux et al. 2013)**

Learning rule



Spike timing-based learning rule (TD-LTP) **(Frémaux et al. 2013)**

Implementation

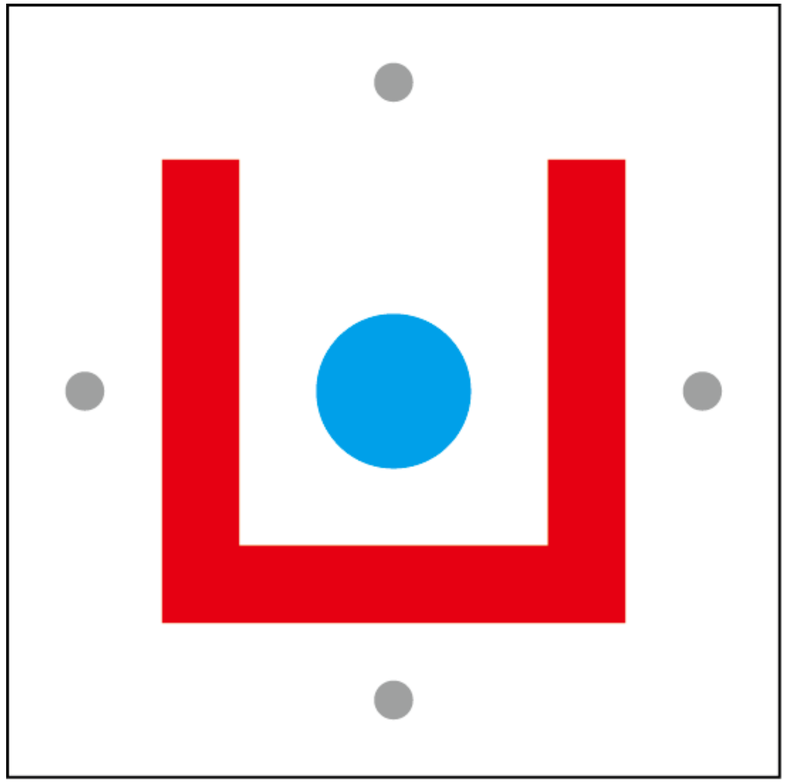
- C++ and CUDA
- Explicit Euler method with dt = 1 ms
- Realtime simulation

  1 s simualtion completes in 0.61 s

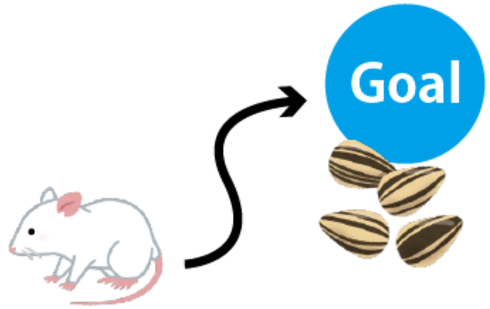
  → Allowing online RL

Experiment Environment: NVIDIA GeForce GTX TITAN Z, Intel Core i7-4960X, 64GB RAM

Example 1: Water maze task



Goal area
Starting point
Obstacle

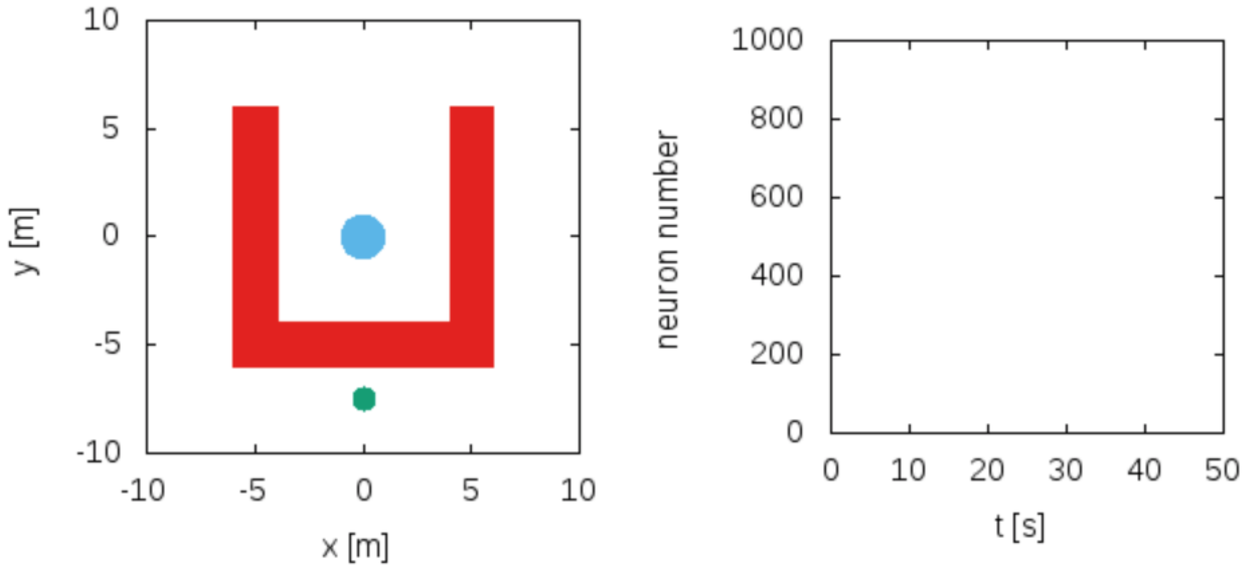


Obtain reward
(positive reward)

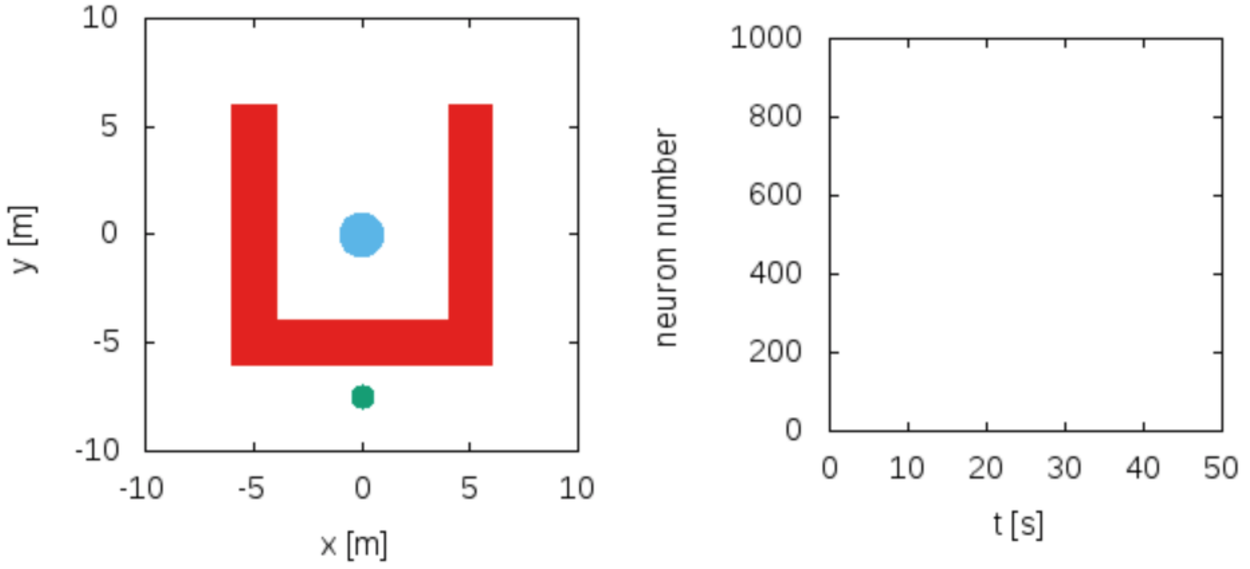
Given punishment
(negative reward)

Example 1: Water maze task

Before learning



After learning



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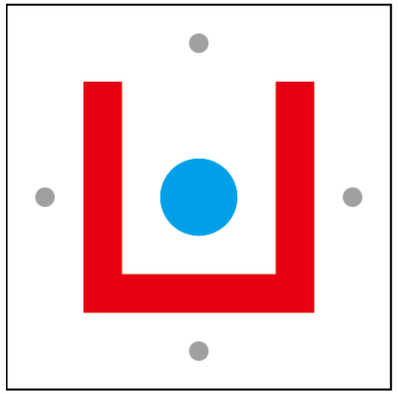

Goal area

Starting point

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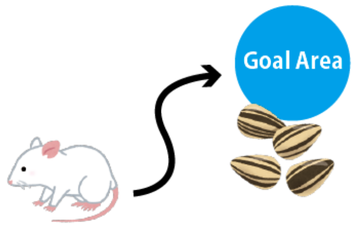

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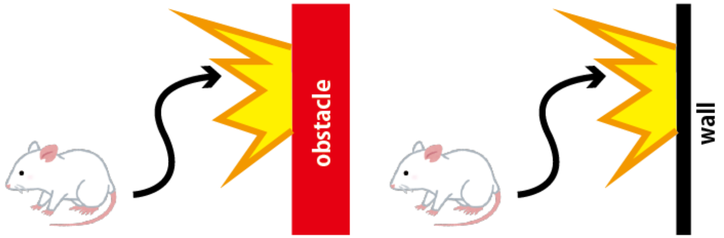
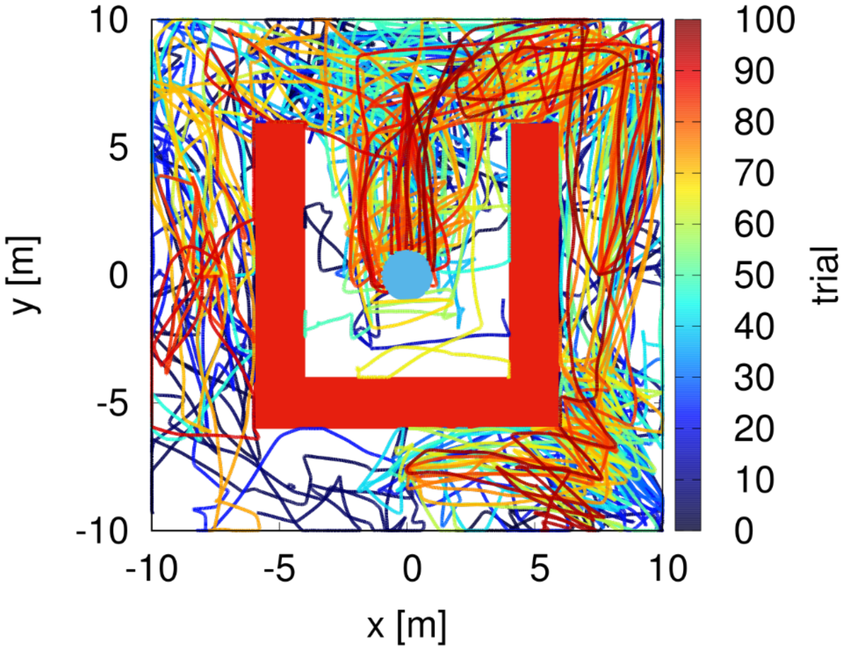
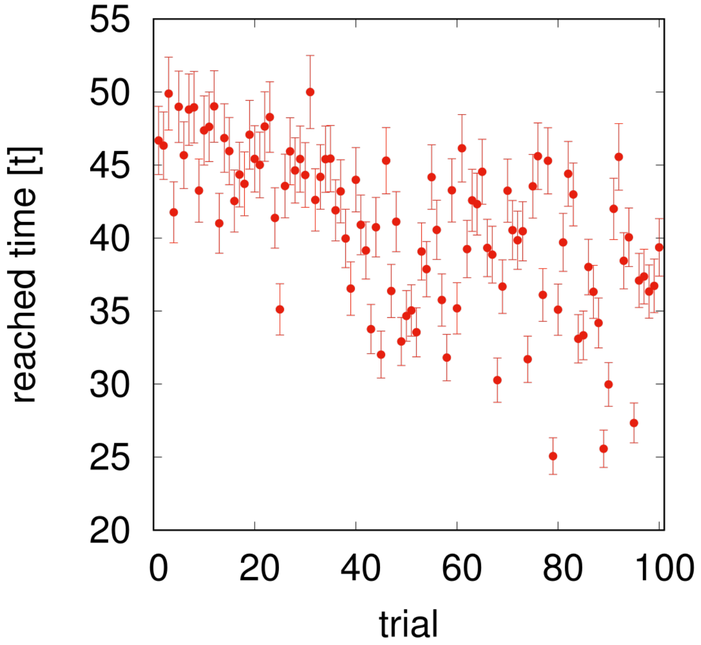


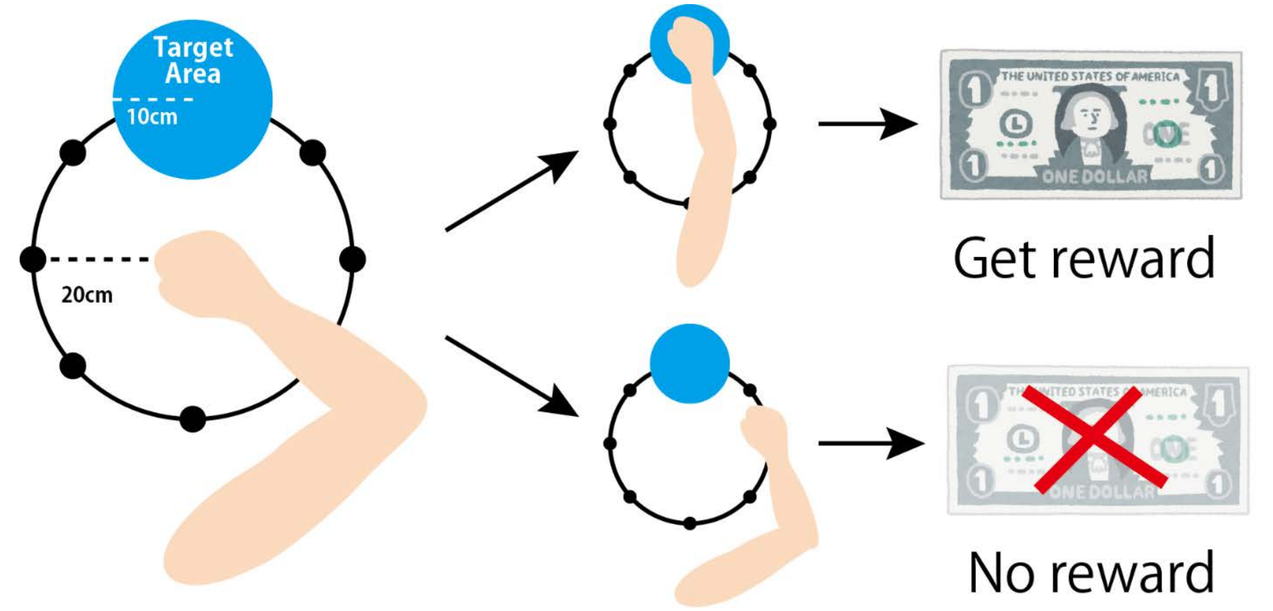
Given punishment
(negative reward)

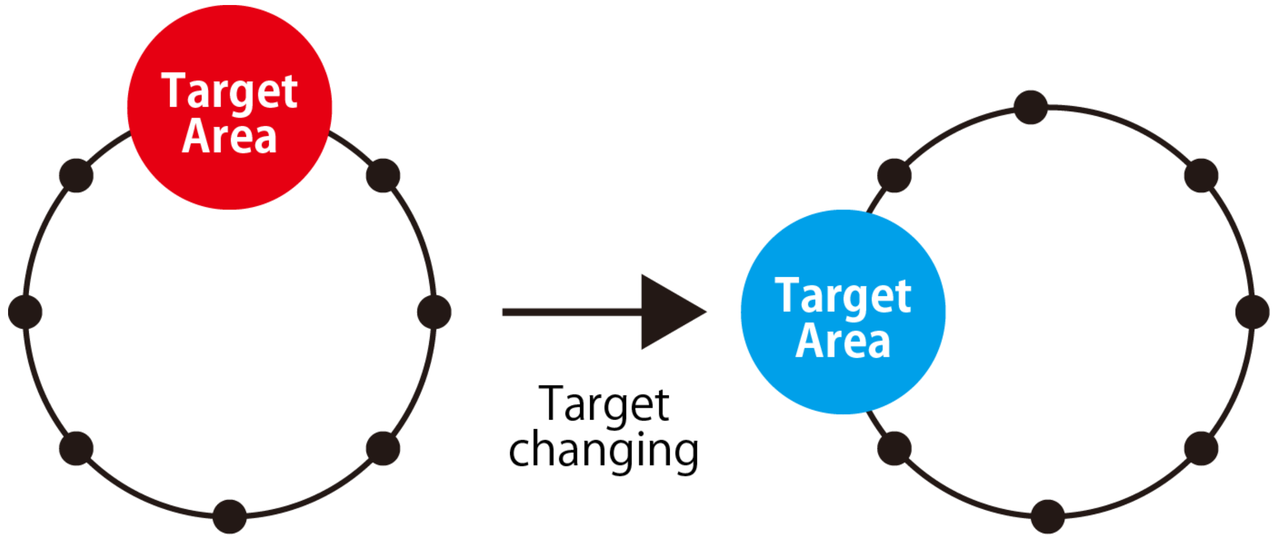




Successfully learned to find the goal

Example 2: Reaching task





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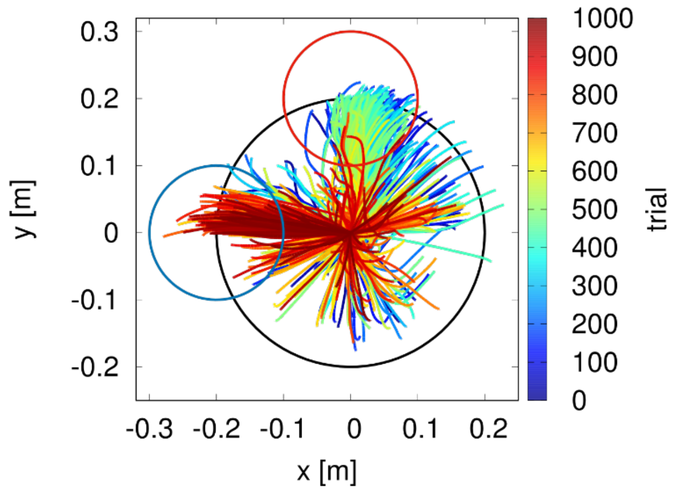

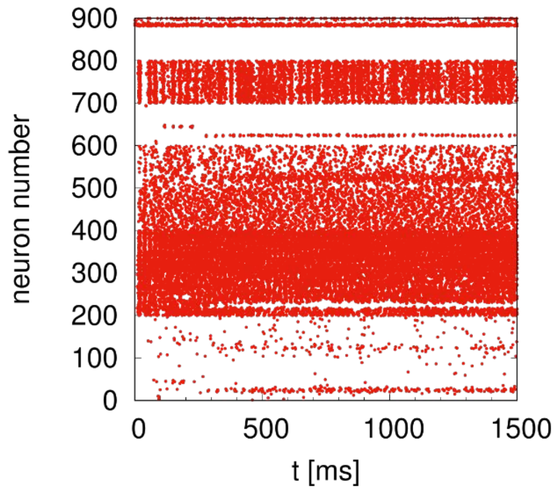

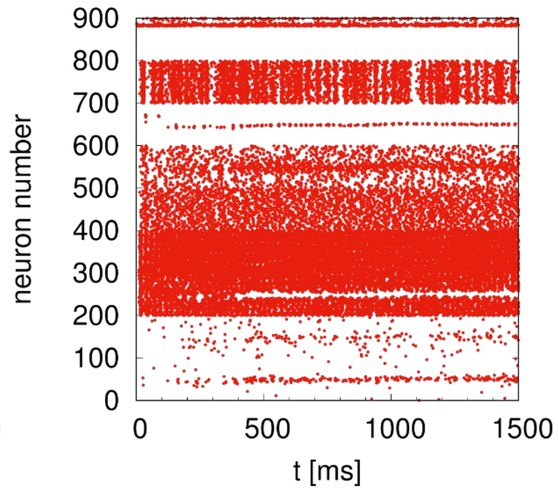

Successfully learned to reach to the given target

Summary

- Built a spiking network model of the basal ganglia
- The model can perform RL
- Realtime simulation → Online RL
- We have a poster!