Internship
Implementation and test of a neuro-inspired navigation system on the PR2 robot.

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DEA de Sciences Cognitives
Ingénieur à l'ENSIIE

Objective

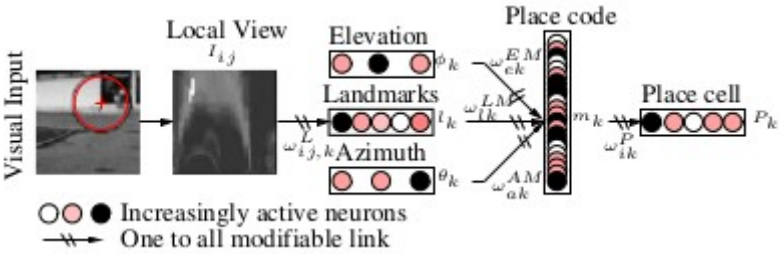
- Biomimetic Navigation System

Basis

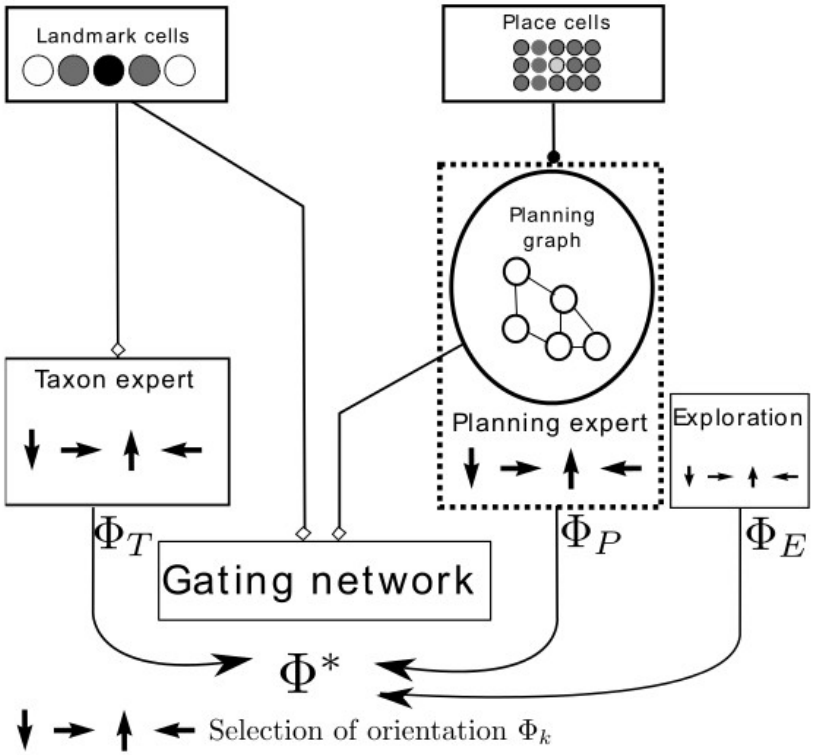
- (Dollé et al. 2010) Animal Model
- (Caluwaerts et al. 2012) Robotic Implementation
- (Giovannangeli & Gaussier 2008) Robust Place Cell Model

Models

Giovannangeli & Gaussier

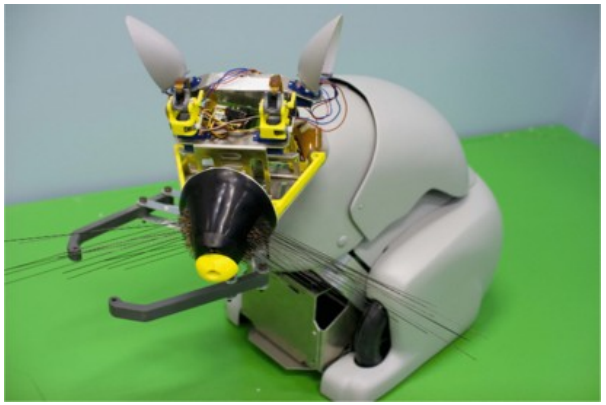


Dollé 2010

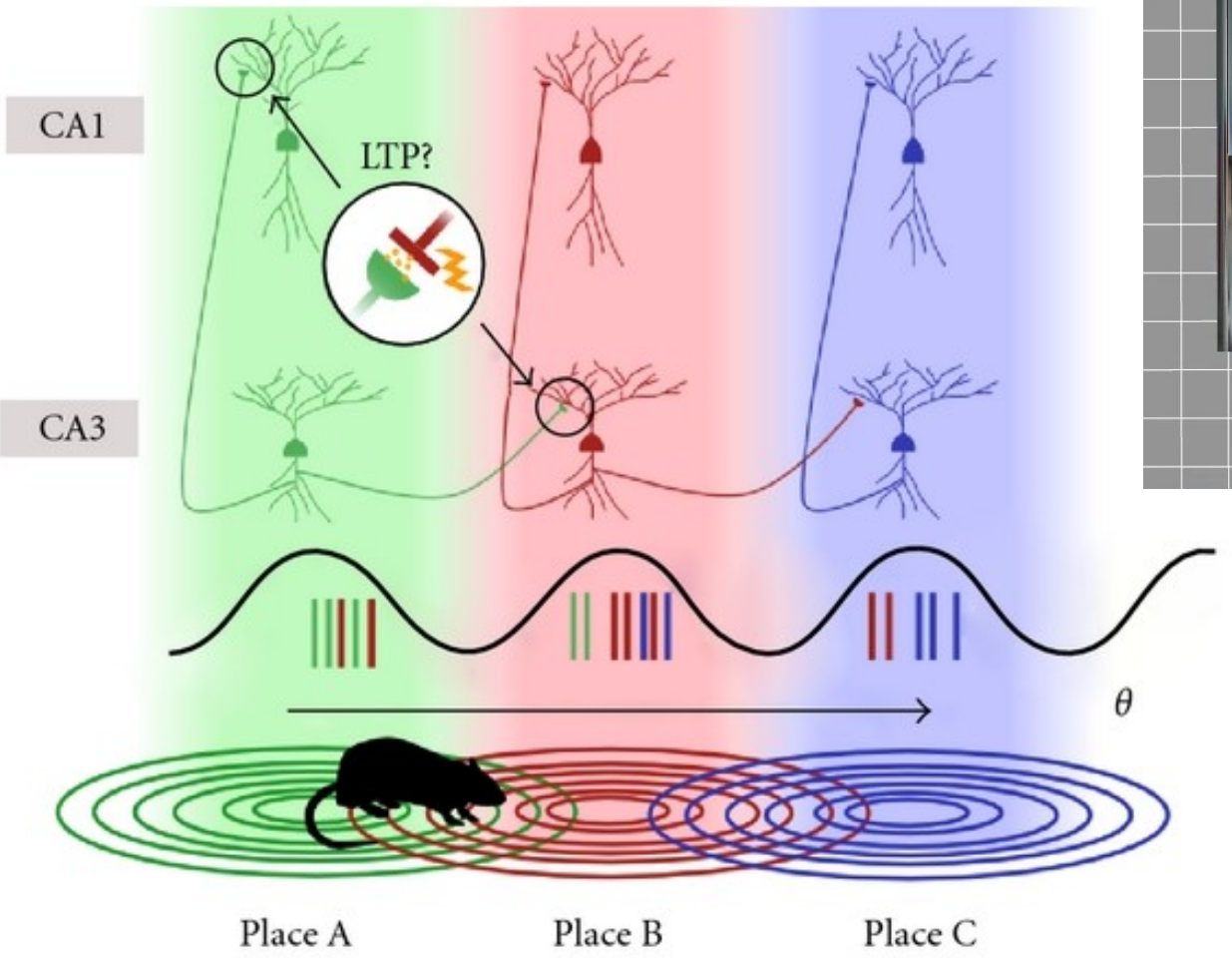


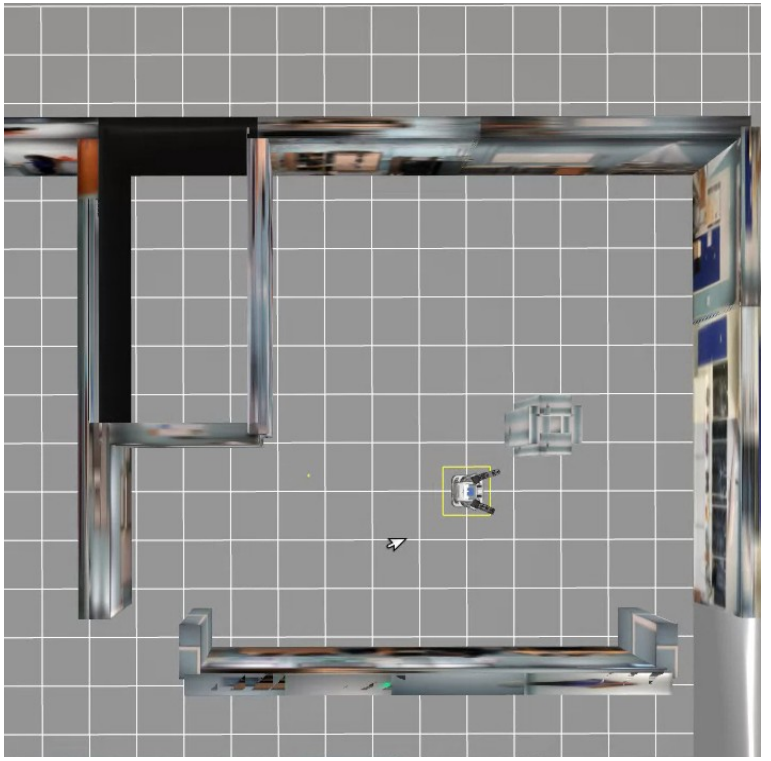
Implemented in

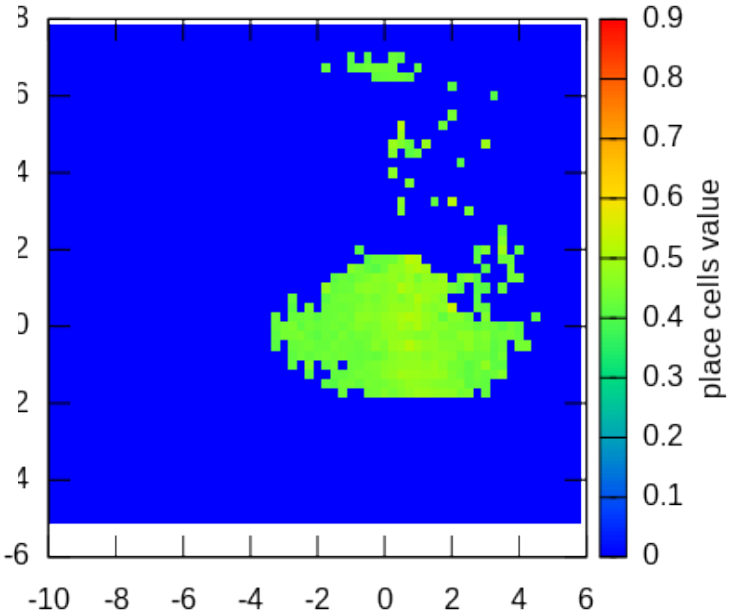
Caluwaerts 2012



Place Cell


CA1
LTP?
CA3
θ
Place A
Place B
Place C




3
5
4
2
0
2
4
-6
-10
-8
-6
-4
-2
0
2
4
6
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
place cells value

Implementation in Caluwaerts 2012

Exploration

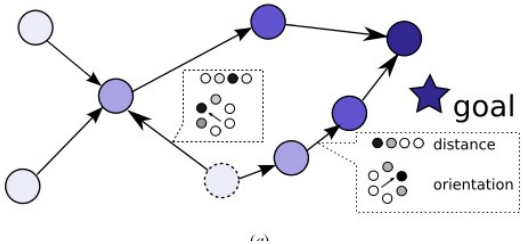
Random movements

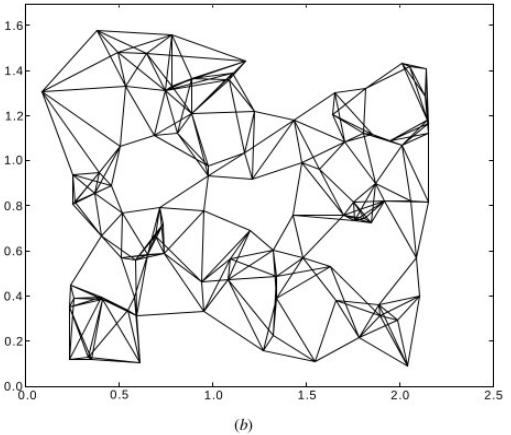
Taxon Expert

Association of Visual Cues with actions
Q-Learning

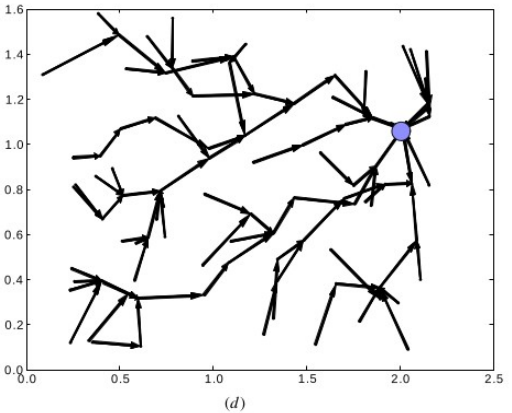
Planning Expert

Topological Map





(b)



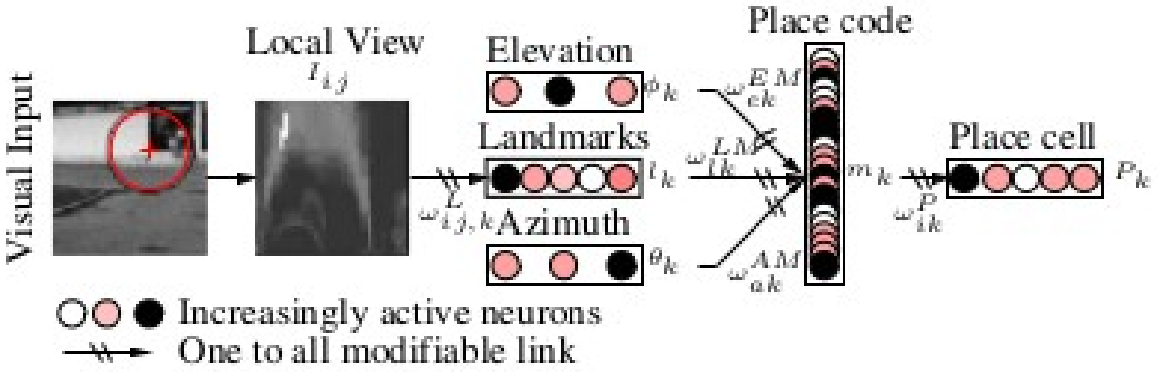
(d)

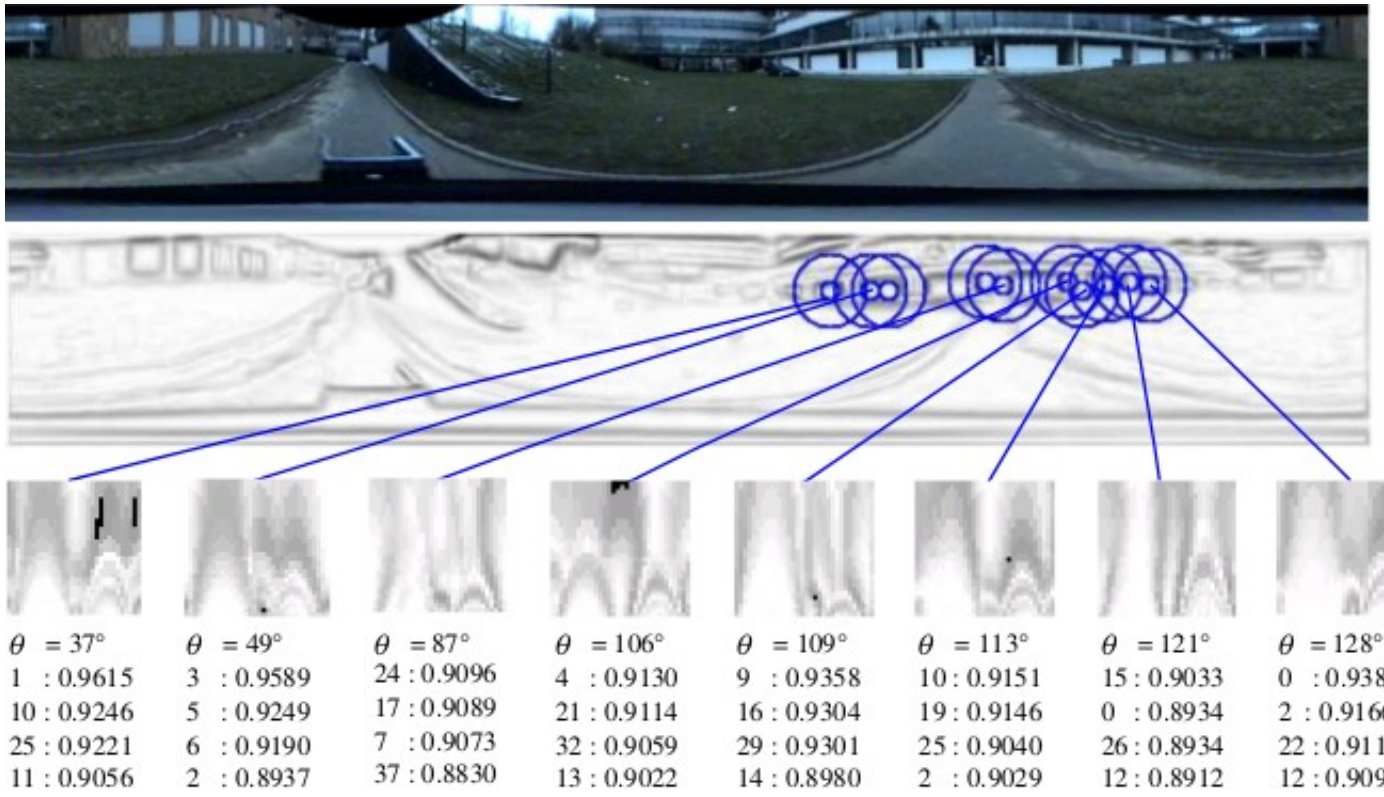
Gating Network

Evaluation of Strategies

Giovannangeli – Gaussier 2008

Generation of Place Cells

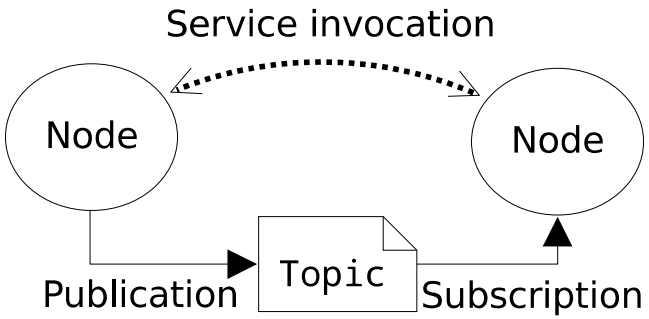




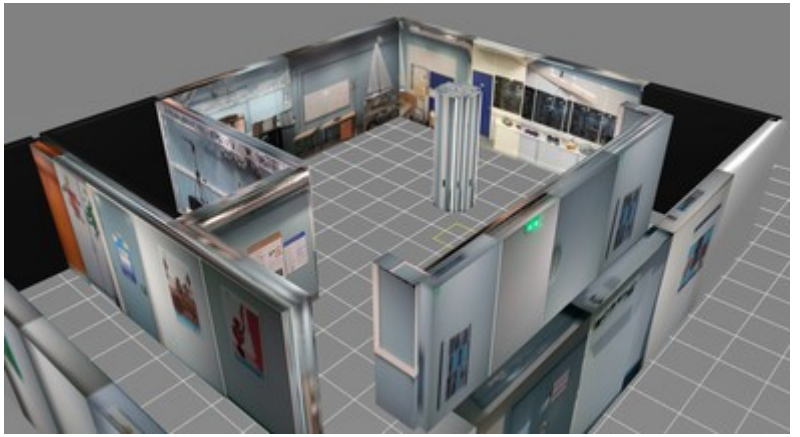
θ = 37°	θ = 49°	θ = 87°	θ = 106°	θ = 109°	θ = 113°	θ = 121°	θ = 128°
1 : 0.9615	3 : 0.9589	24 : 0.9096	4 : 0.9130	9 : 0.9358	10 : 0.9151	15 : 0.9033	0 : 0.9382
10 : 0.9246	5 : 0.9249	17 : 0.9089	21 : 0.9114	16 : 0.9304	19 : 0.9146	0 : 0.8934	2 : 0.9166
25 : 0.9221	6 : 0.9190	7 : 0.9073	32 : 0.9059	29 : 0.9301	25 : 0.9040	26 : 0.8934	22 : 0.9116
11 : 0.9056	2 : 0.8937	37 : 0.8830	13 : 0.9022	14 : 0.8980	2 : 0.9029	12 : 0.8912	12 : 0.9096

Hands-On

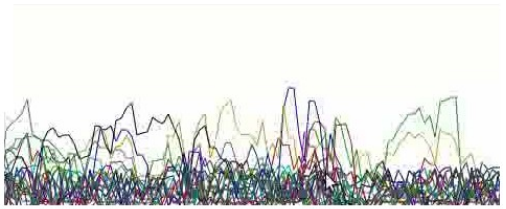
ROS

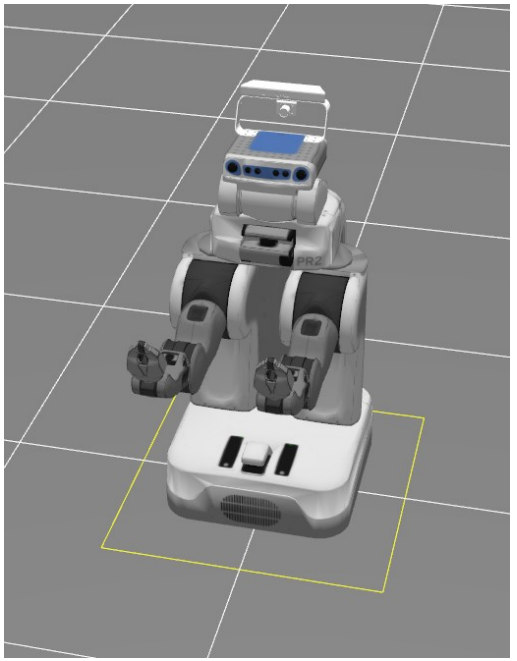


Gazebo & PR2

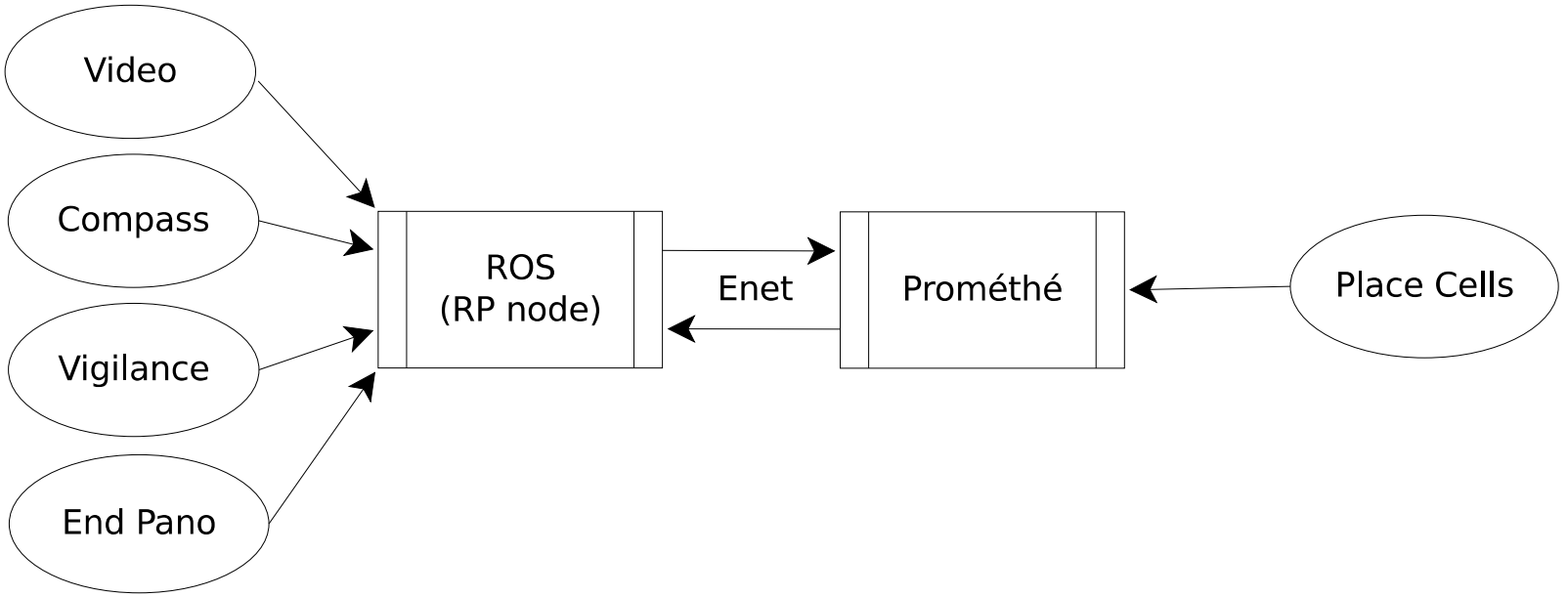


Prométhé

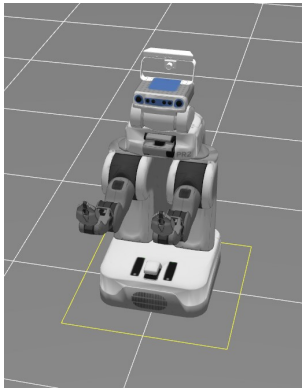




Hands-On: ROS - Prométhé



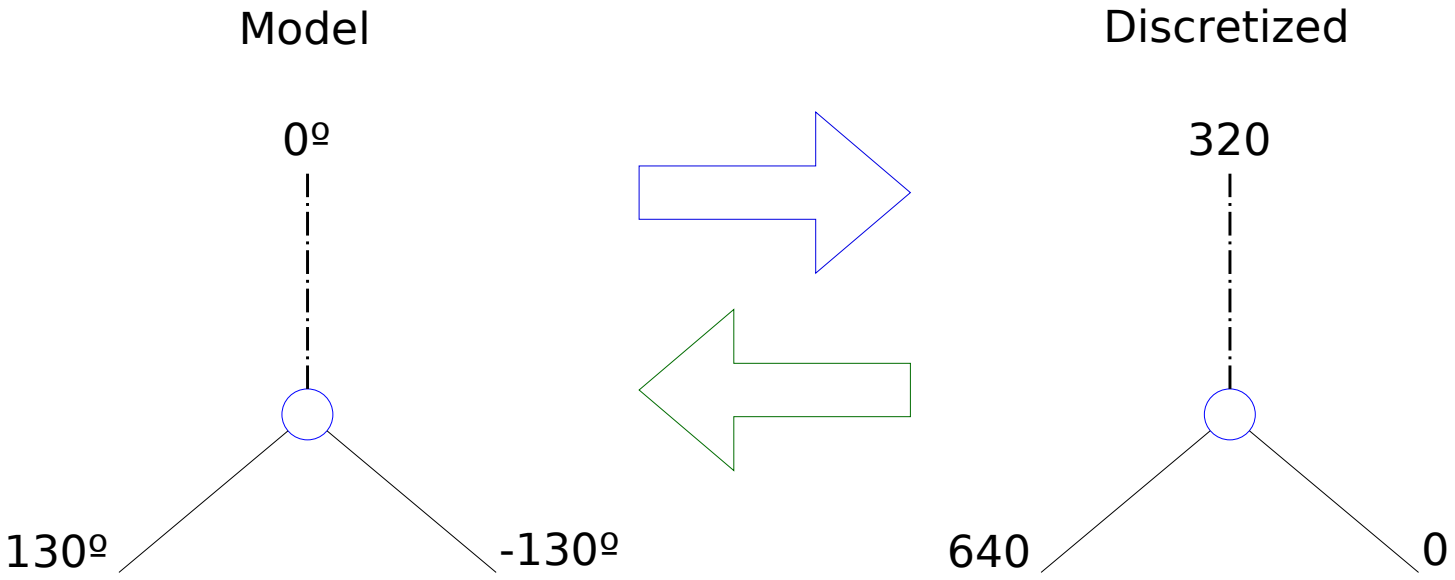
PR2



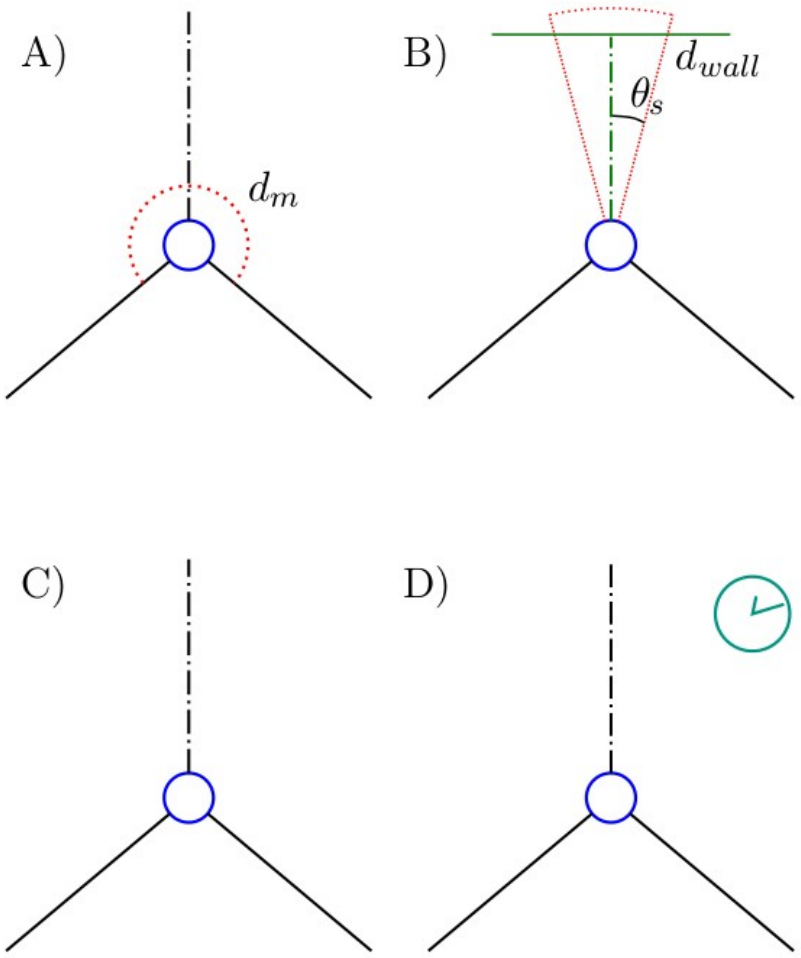
Base controls

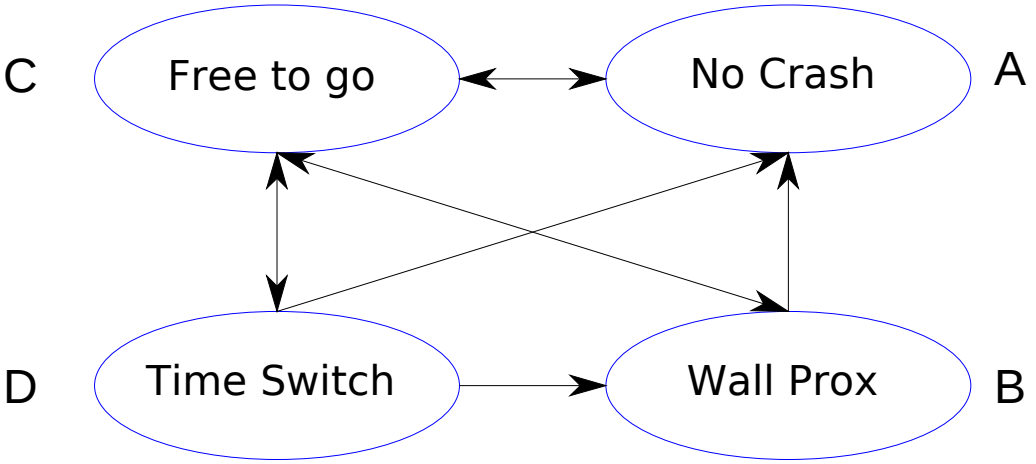
$$\begin{bmatrix} v_x \\ v_y \\ \omega \end{bmatrix} \rightarrow \begin{bmatrix} v_x \\ \omega \end{bmatrix}$$

Laser Scanner

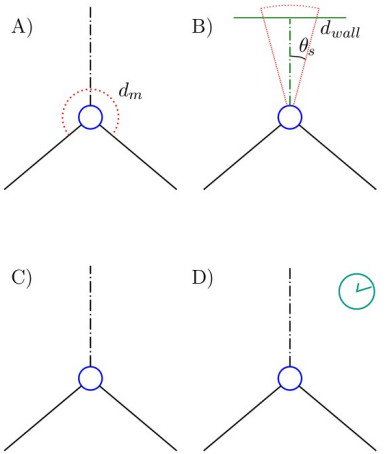


Exploration





Exploration



if $\min(d_\Theta) < d_m$ **then**

$\omega_{t+1} = \omega_t + (1 - [d - d_m]k)k_{nc\omega} sign(-\min(\Theta))$;

$v_{t+1} = v_t + (1 - [d - d_m]k)k_{ncv} f(min(\theta))$

else if $\mu_{\theta_i} < d_w$ **then**

$\omega_{t+1} = \omega_t + setDirection(P(\Lambda_l|d_\Theta)) * k_{wp\omega}$; /* State B */

$v_{t+1} = v_t - k_{wpv}$

else if *FlagFunction()* **then**

$\omega_{t+1} = \omega_t + k_{ts\omega}$; /* State D */

$v_{t+1} = v_t$

else

setParamsFlagFunction() ; /* State C */

$\omega_{t+1} = \omega_t - sign(\omega_t)\alpha_v k_{ftg\omega}$

$v_{t+1} = v_t + \alpha_v k_{ftgv}$

end

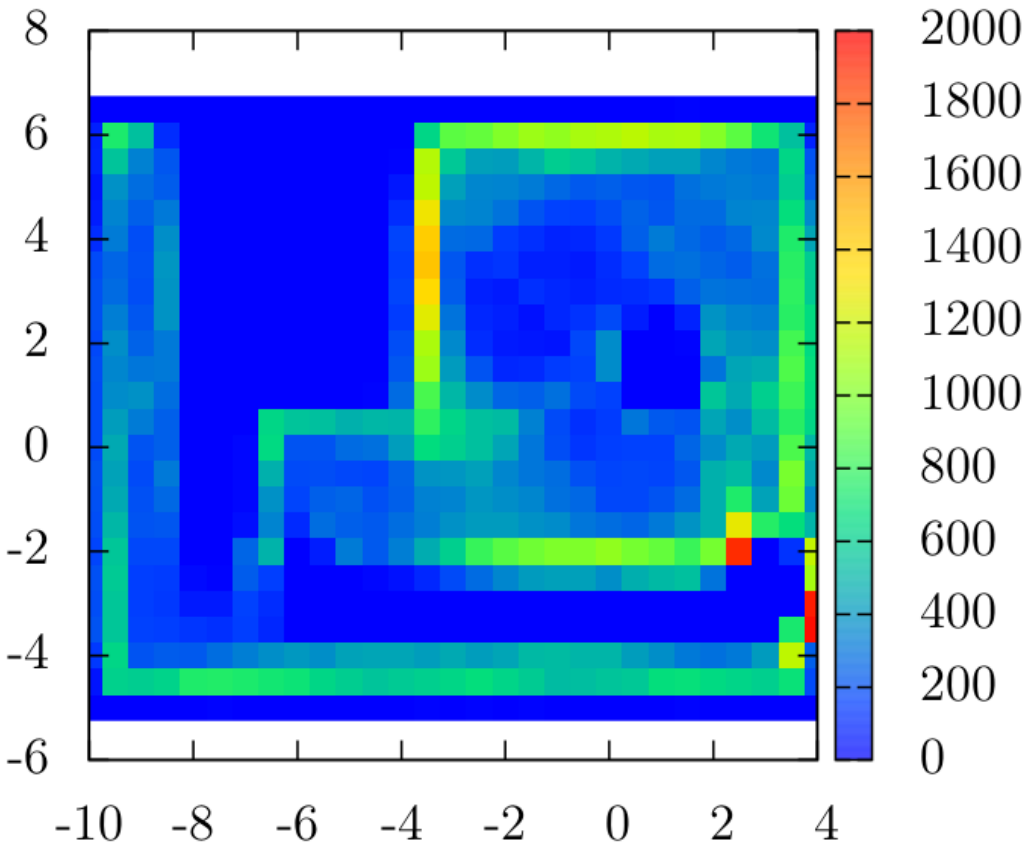
/* State A */

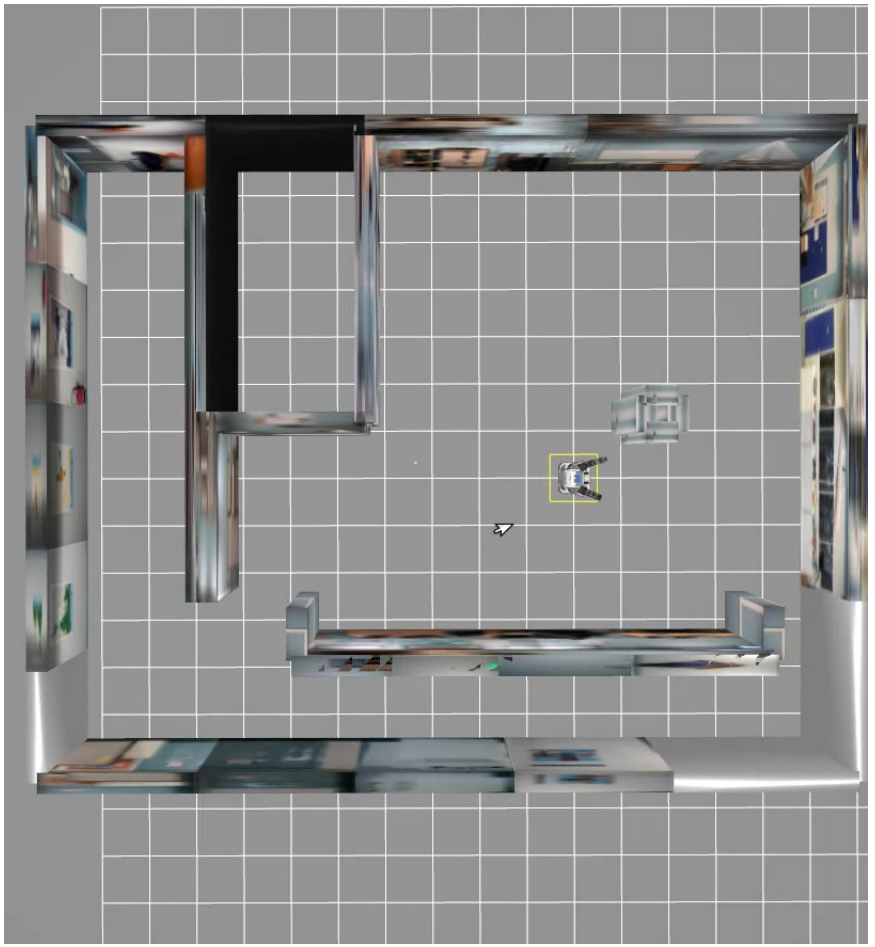
$$d_\Theta = [d_{\theta_1}, d_{\theta_2}, \ldots, d_{\theta_i}]$$

$$\mu_{\theta_i} = \frac{1}{2\theta_s} \sum_{j=k-\theta_s}^{k+\theta_s} d_{\theta_j}$$

$$P(\Lambda_l|d_\Theta) = \frac{\sum_r d_{\theta_i}}{\sum_r d_{\theta_i} + \sum_l d_{\theta_j}}$$

Exploration

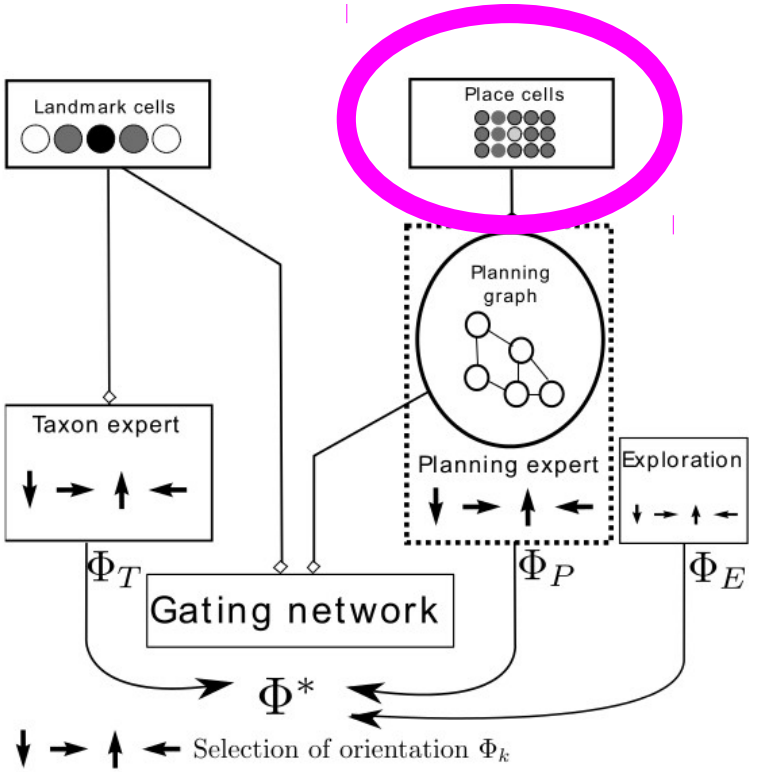




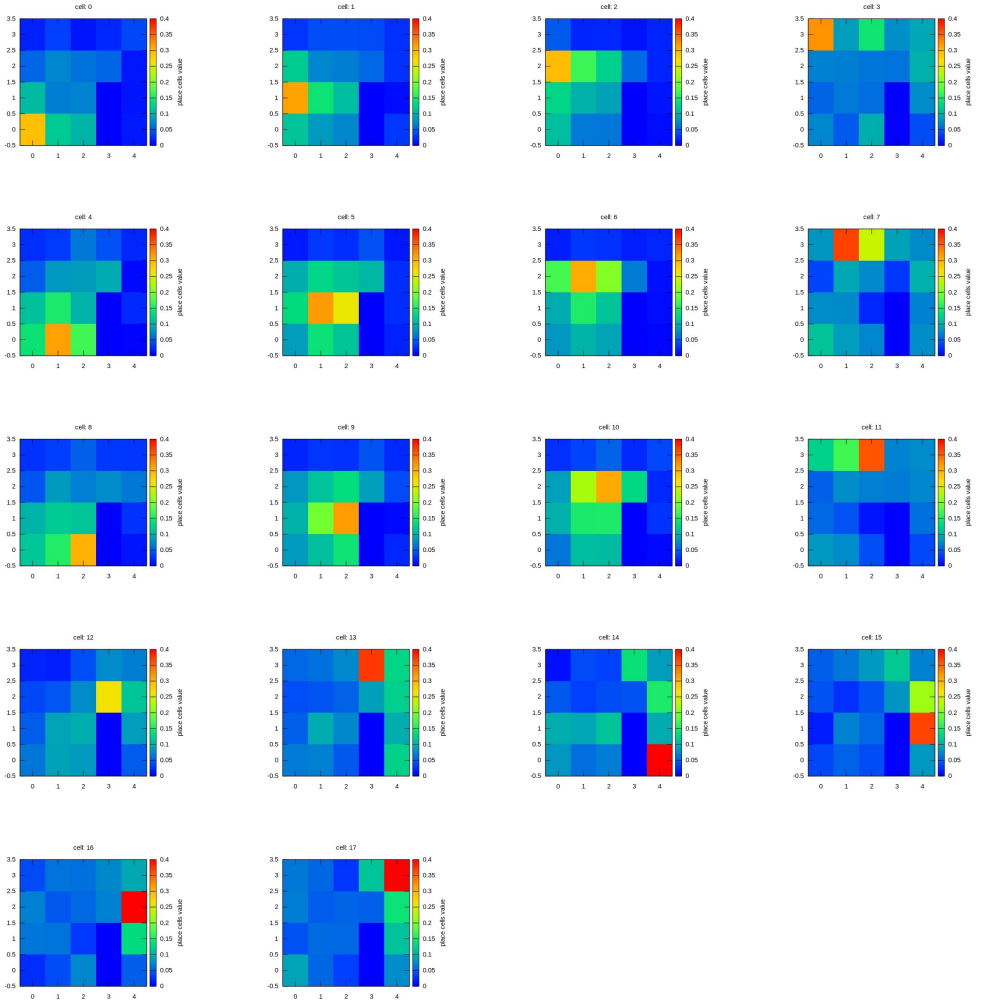
27 hours of simulation time

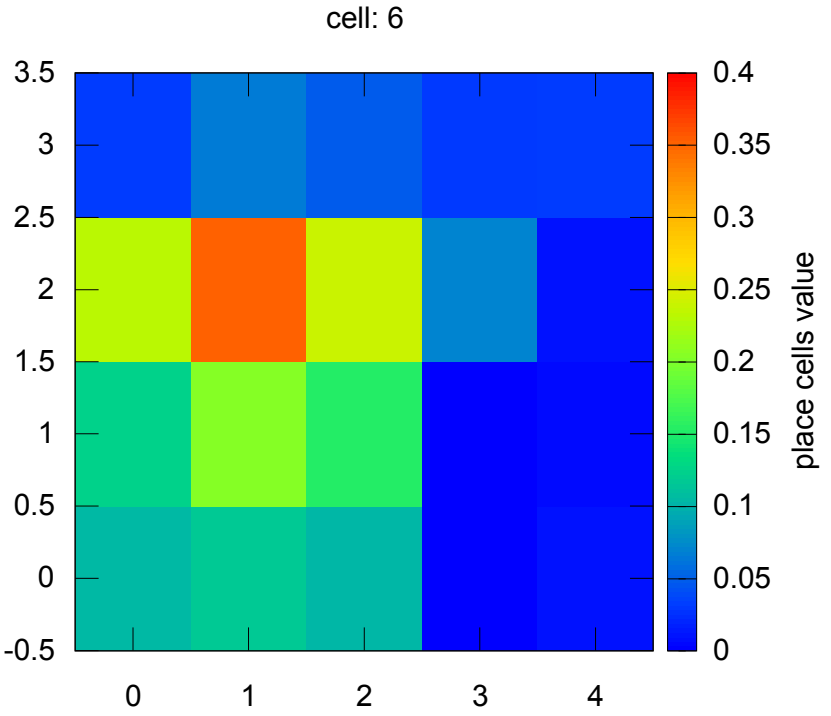
Place Cells

- Performance in Positions
- Performance in Angles
- Recognition Thresholds: Performance during Exploration Expert



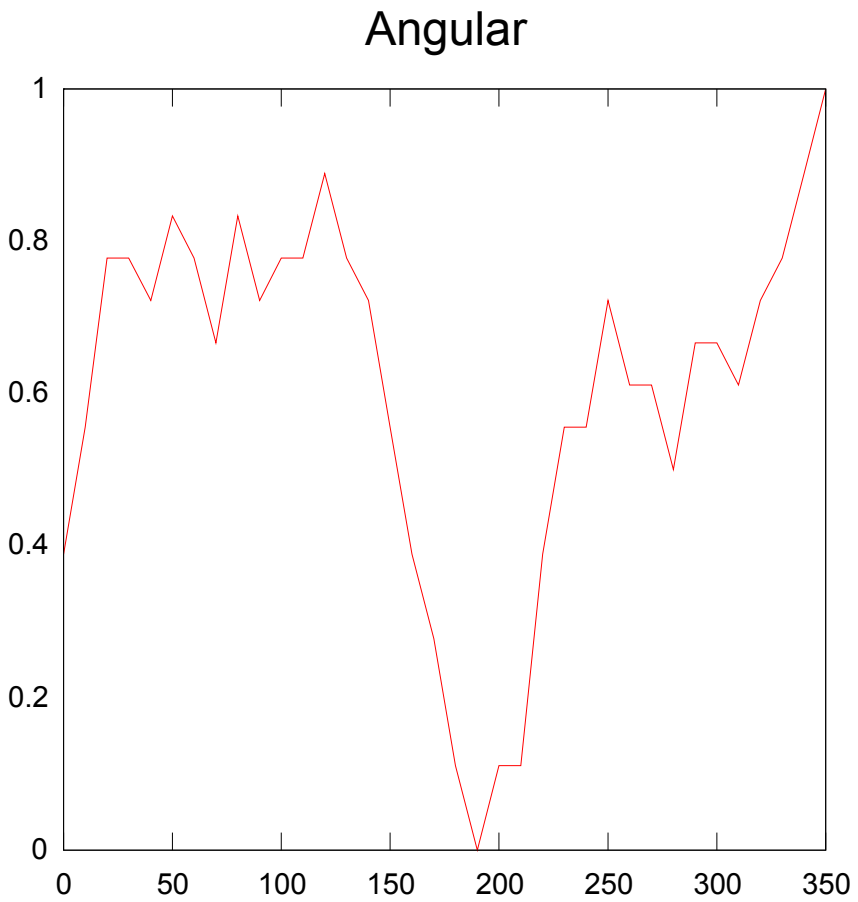
Place Cells: Positions

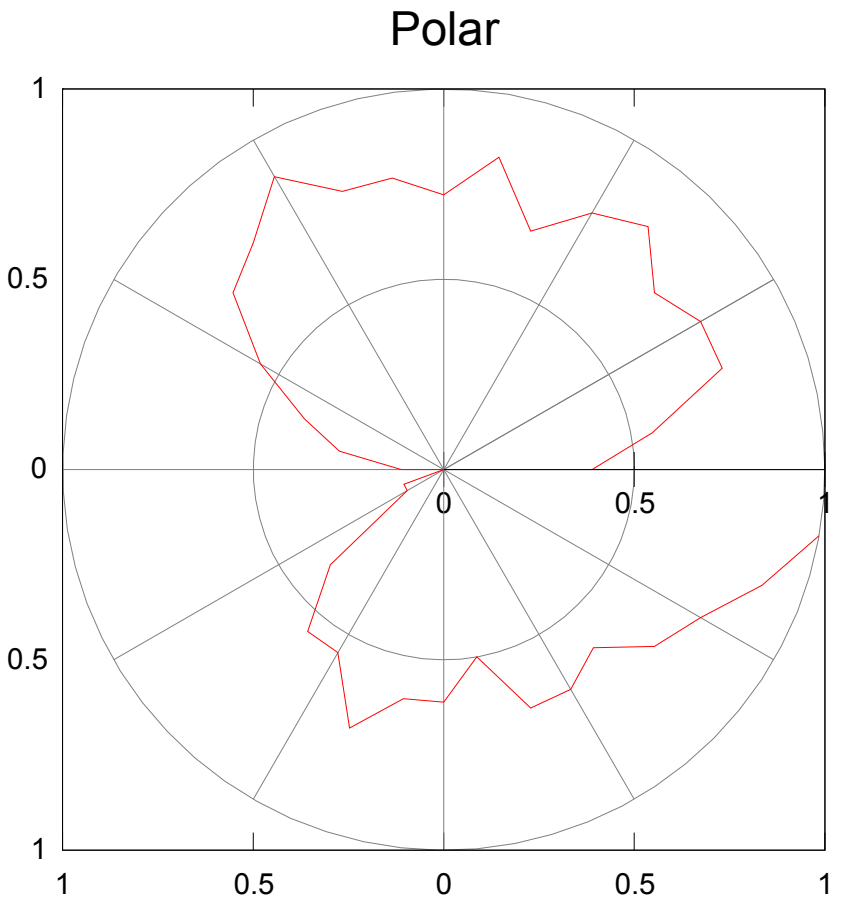




$$\mu_j^i = \frac{1}{\alpha_{max}} \sum_{\alpha=0}^{\alpha_{max}} \iota_{j_\alpha}^i$$

Place Cells: Angular



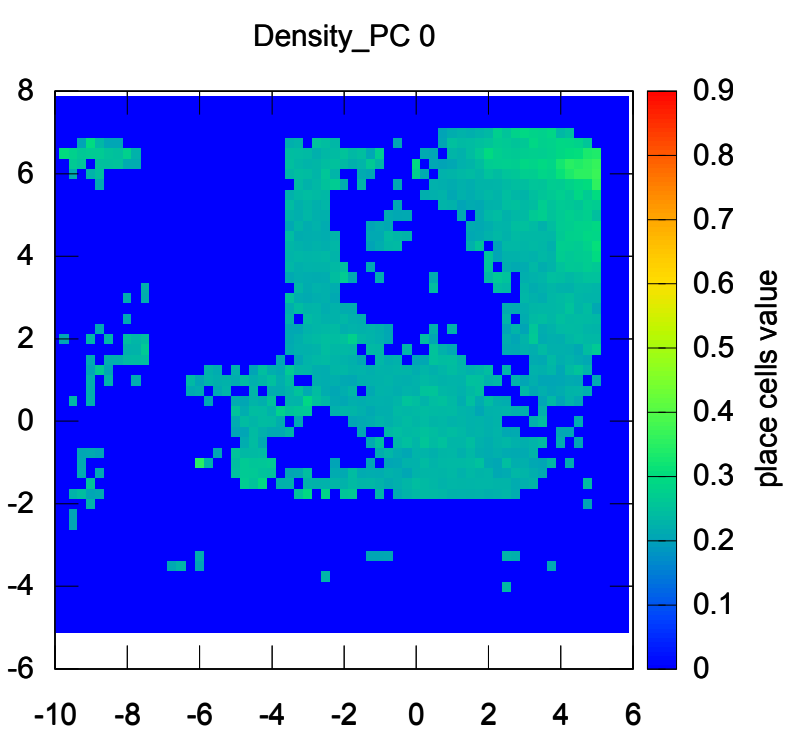


$$\mu^{\theta} = \frac{1}{N_{PC}} \sum_{j=0}^{N_{PC}} \iota_j^{\theta_i}$$

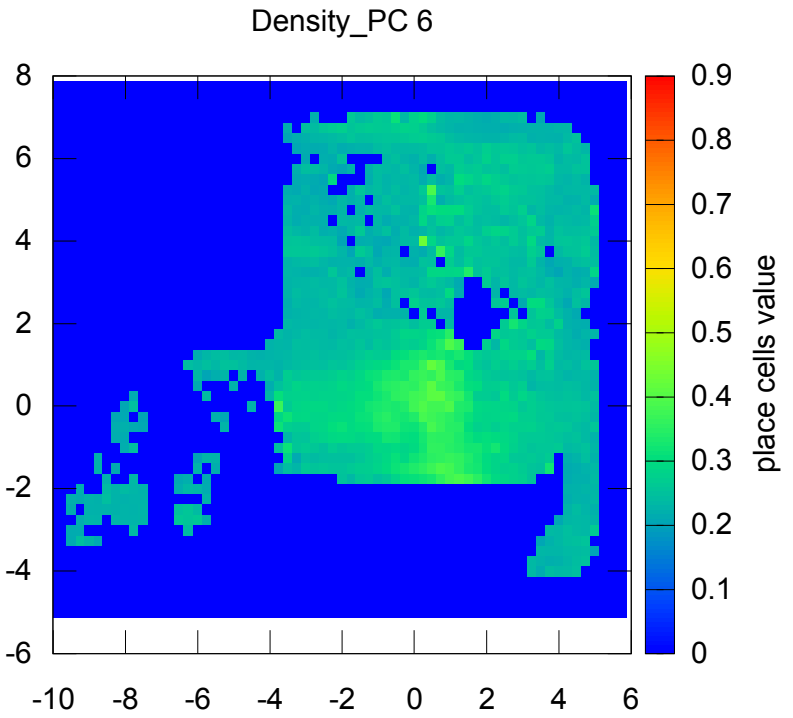
Place Cells: Recognition Thresholds

$$\beta = 0.2$$

Simulation time: 16.6 hours



(4,6)

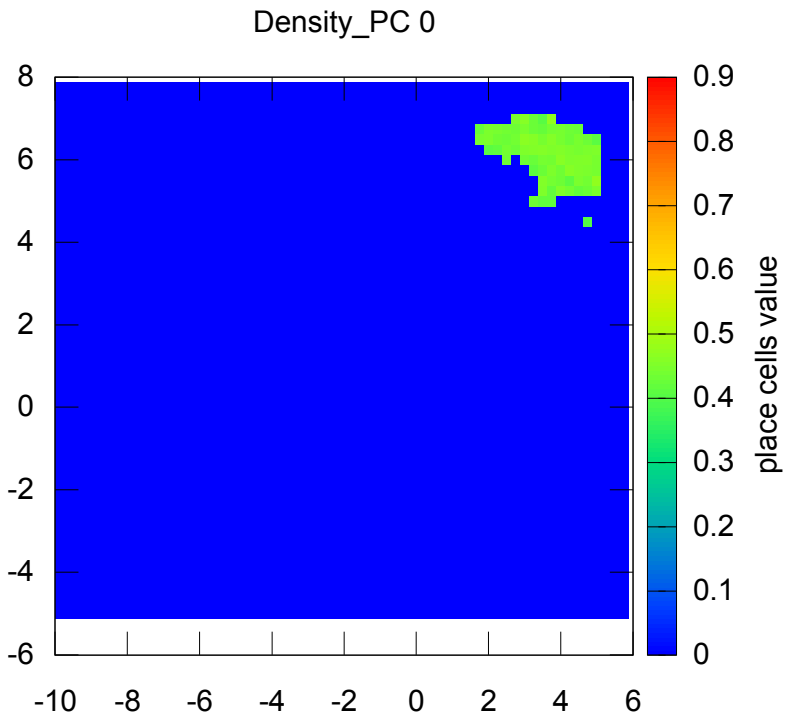


(0,0)

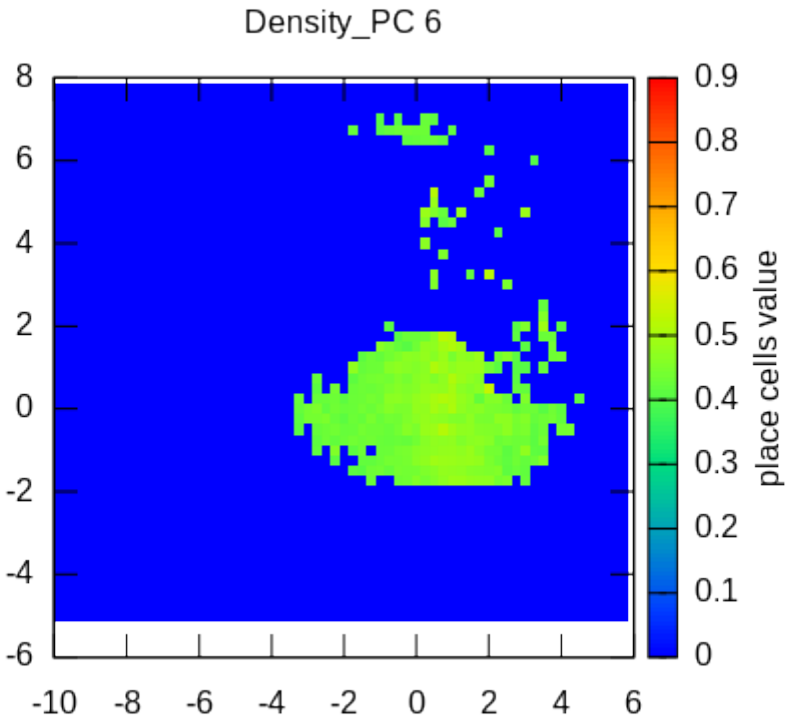
Place Cells: Recognition Thresholds

$$\beta = 0.4$$

Simulation time: 16.6 hours



(4,6)

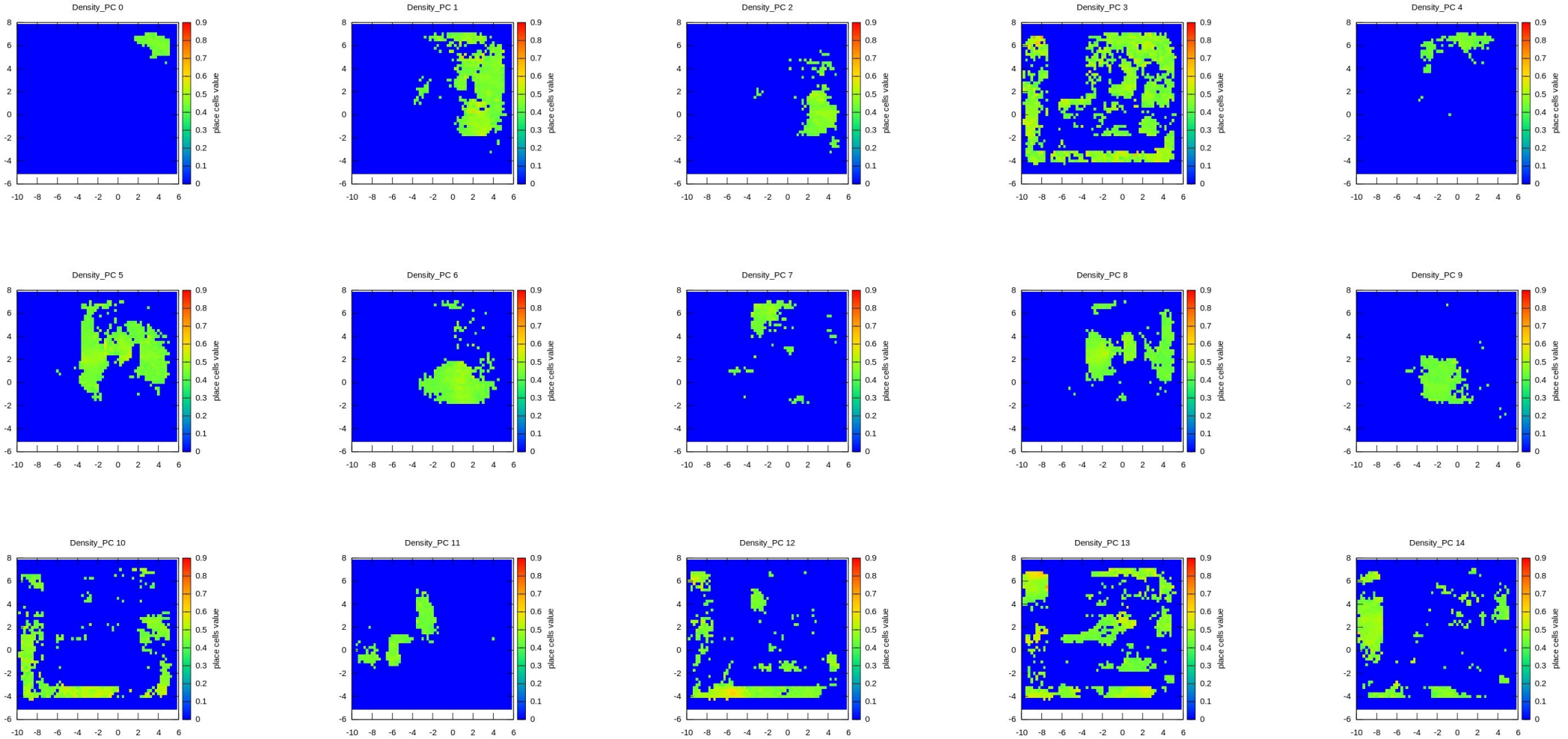


(0,0)

Planning Expert (PE): Analysis

- Definition of change of state
- Oscillations and Iterations
- Learning and Forgetting Positions
- Distance between neurons
- Moving from point to point

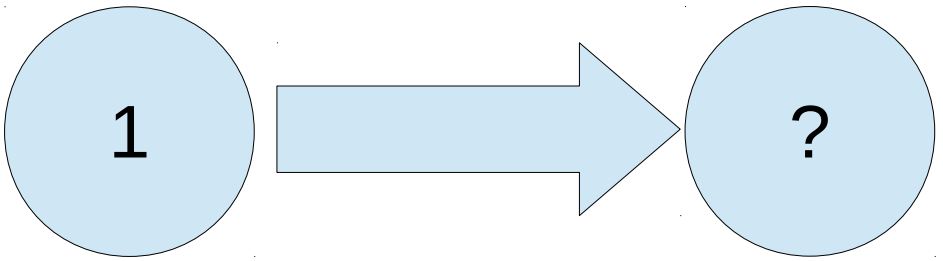
PE: Place Cell Positions



Simulation time: 16.6 hours

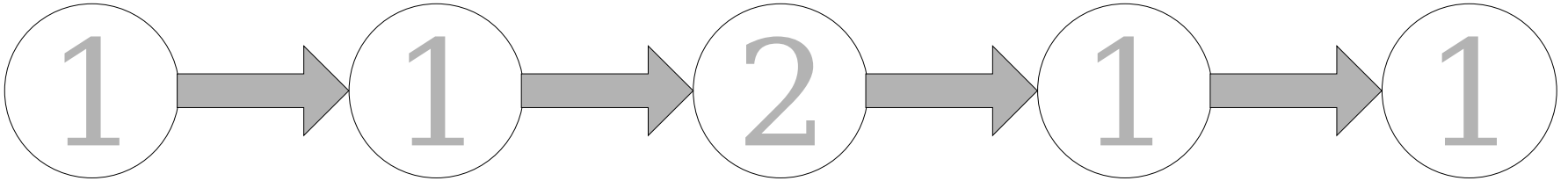
PE: Change of State

$$\Delta s = (1 - \delta_{k,l}) H(n^l_{trust} - \beta) H(n_{iters} - \eta)$$

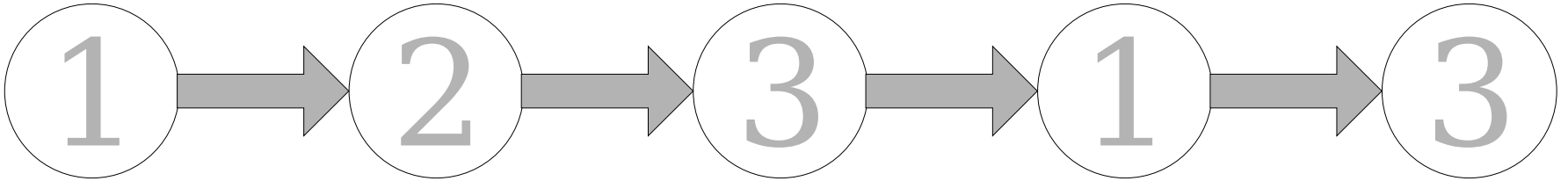


PE: Oscillations and Iterations

A)

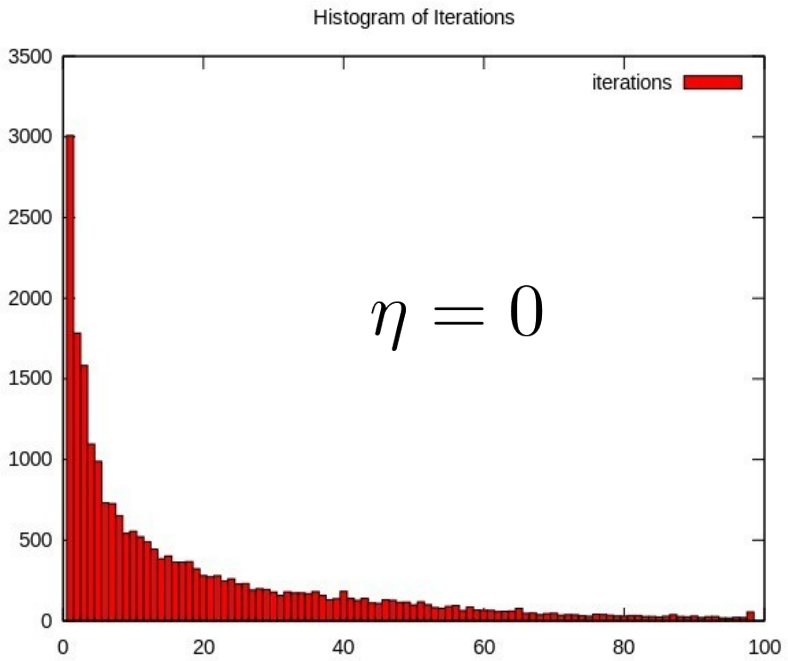


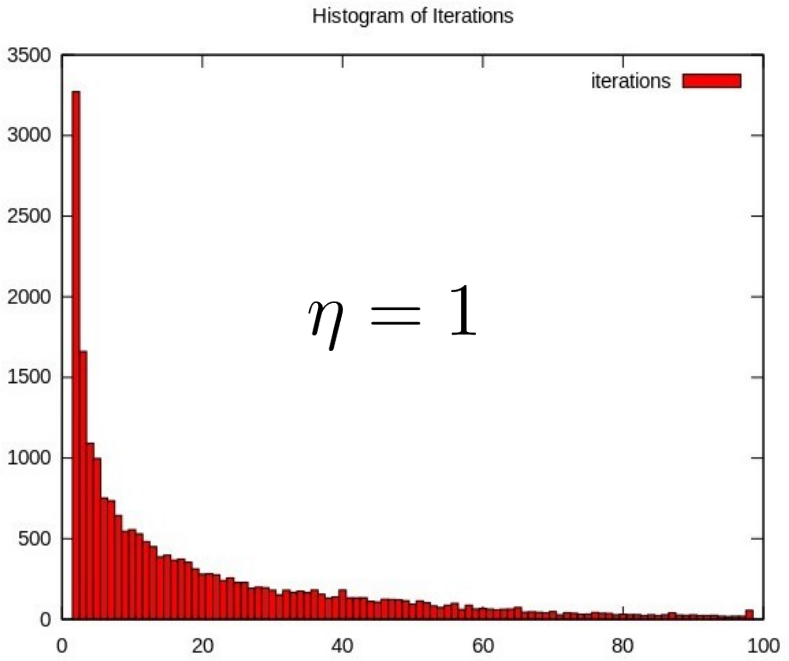
B)

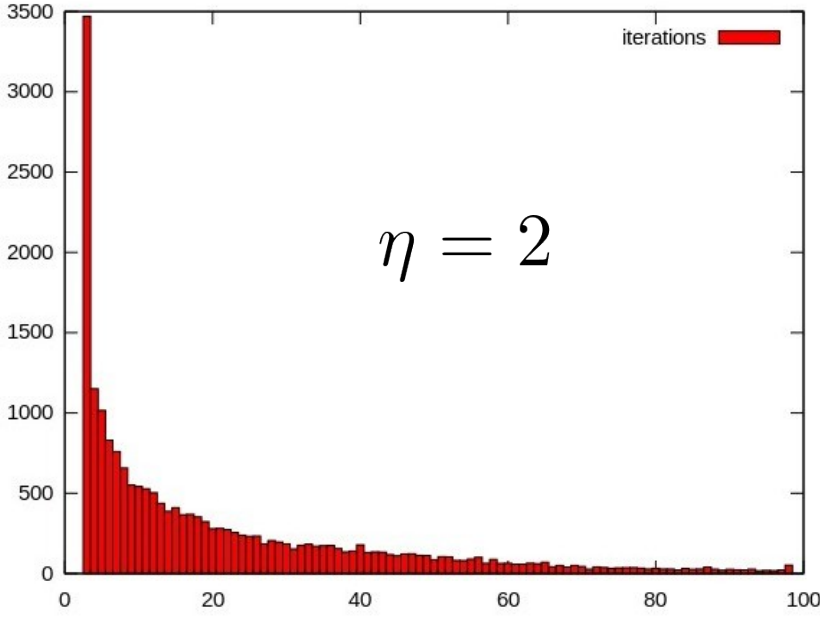


$$\Delta s = (1 - \delta_{k,l}) H(n^{l}_{trust} - \beta) H(n_{iters} - \eta)$$

PE: Oscillations and Iterations

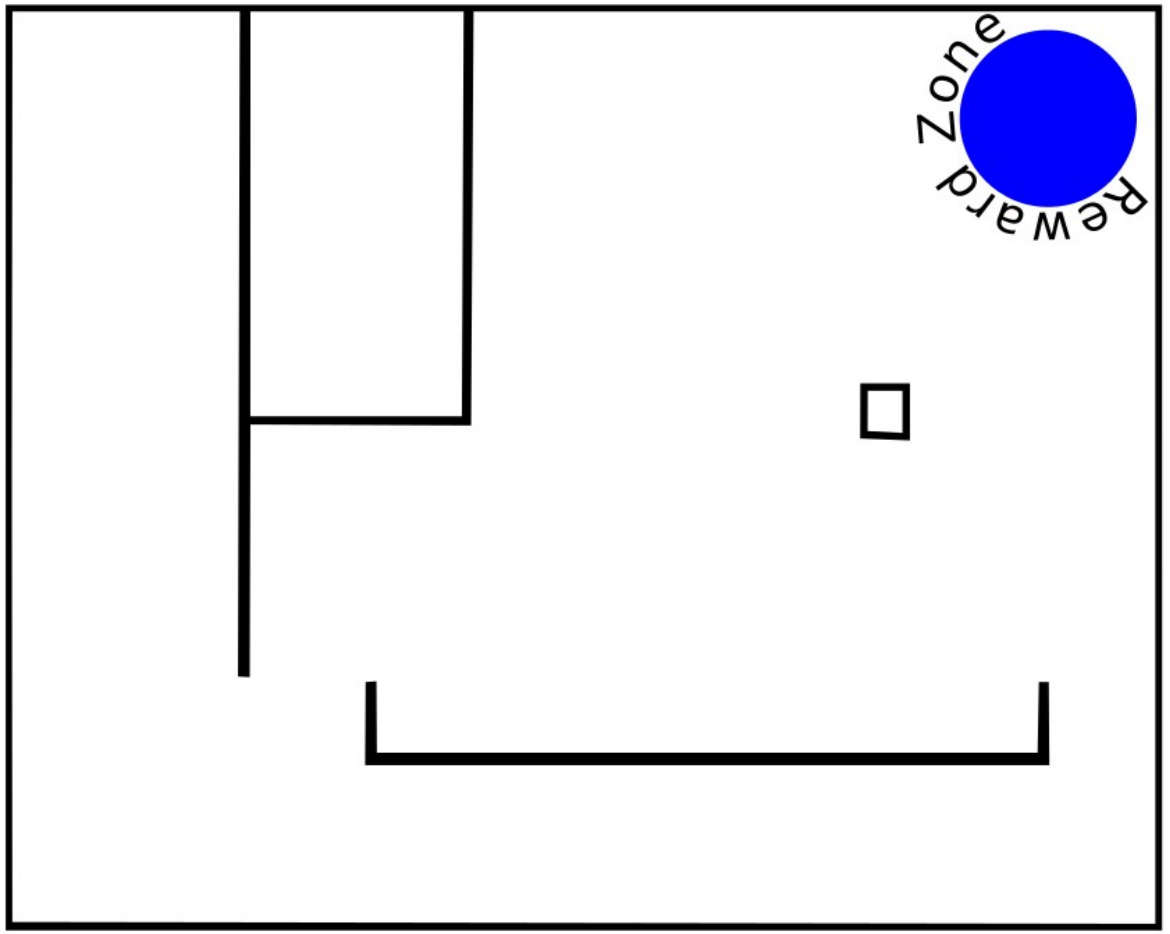


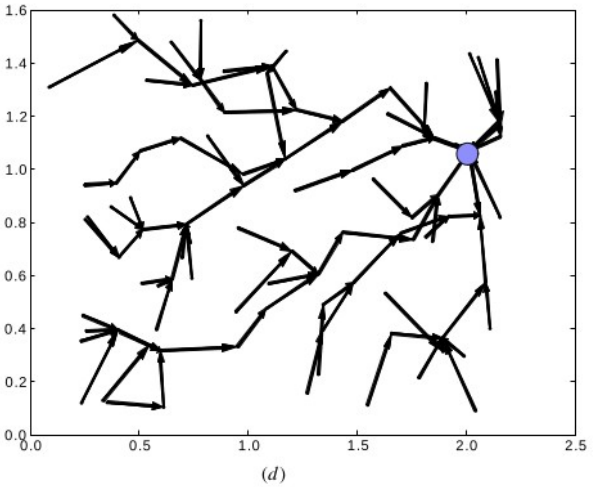




Simulation time: 16.6h

PE: Learning and Forgetting



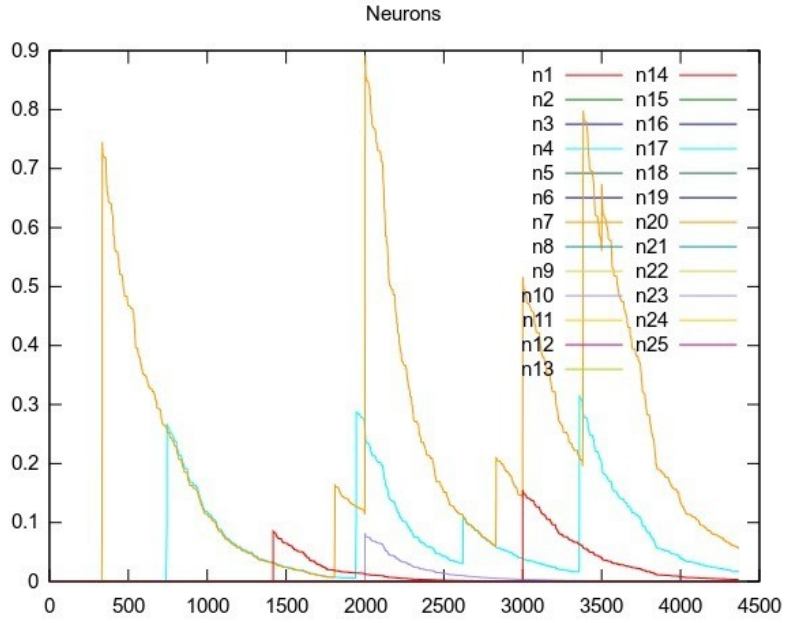


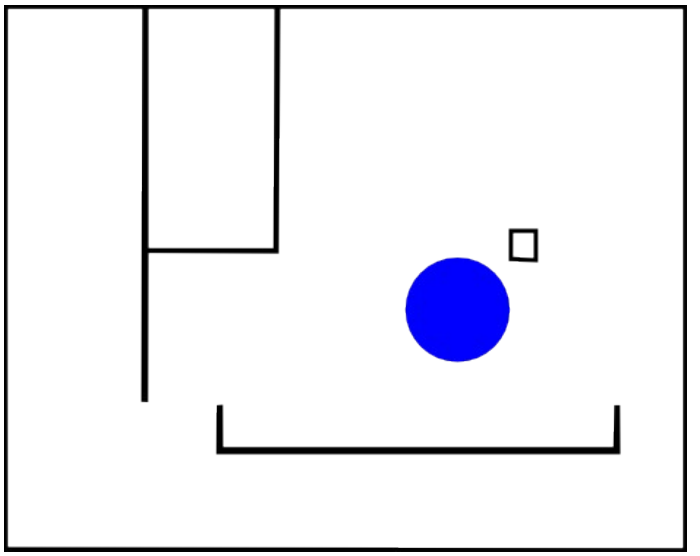
$$g_j(t+1) = g_j(t)(1 - \tau_{forget})$$

$$g_j(t+1) = g_j(t)(1 - \tau_{learn} n^{PFC}_{winner}(t)) + \tau_{learn} n^{PFC}_{winner}(t) R(t)$$

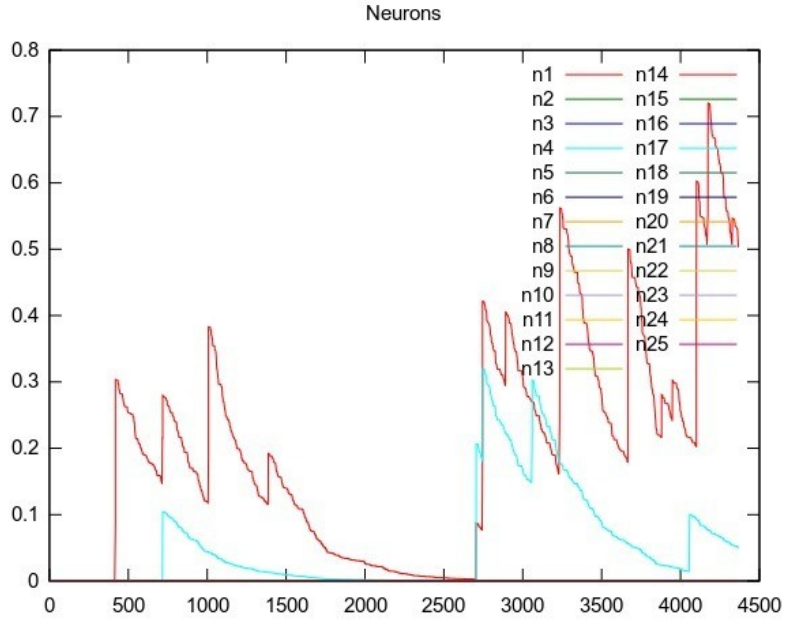
PE: Learning and Forgetting

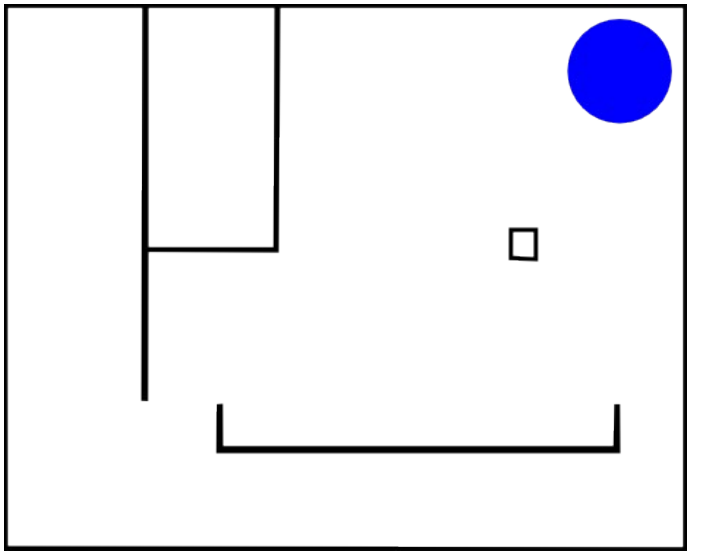
(0,0)





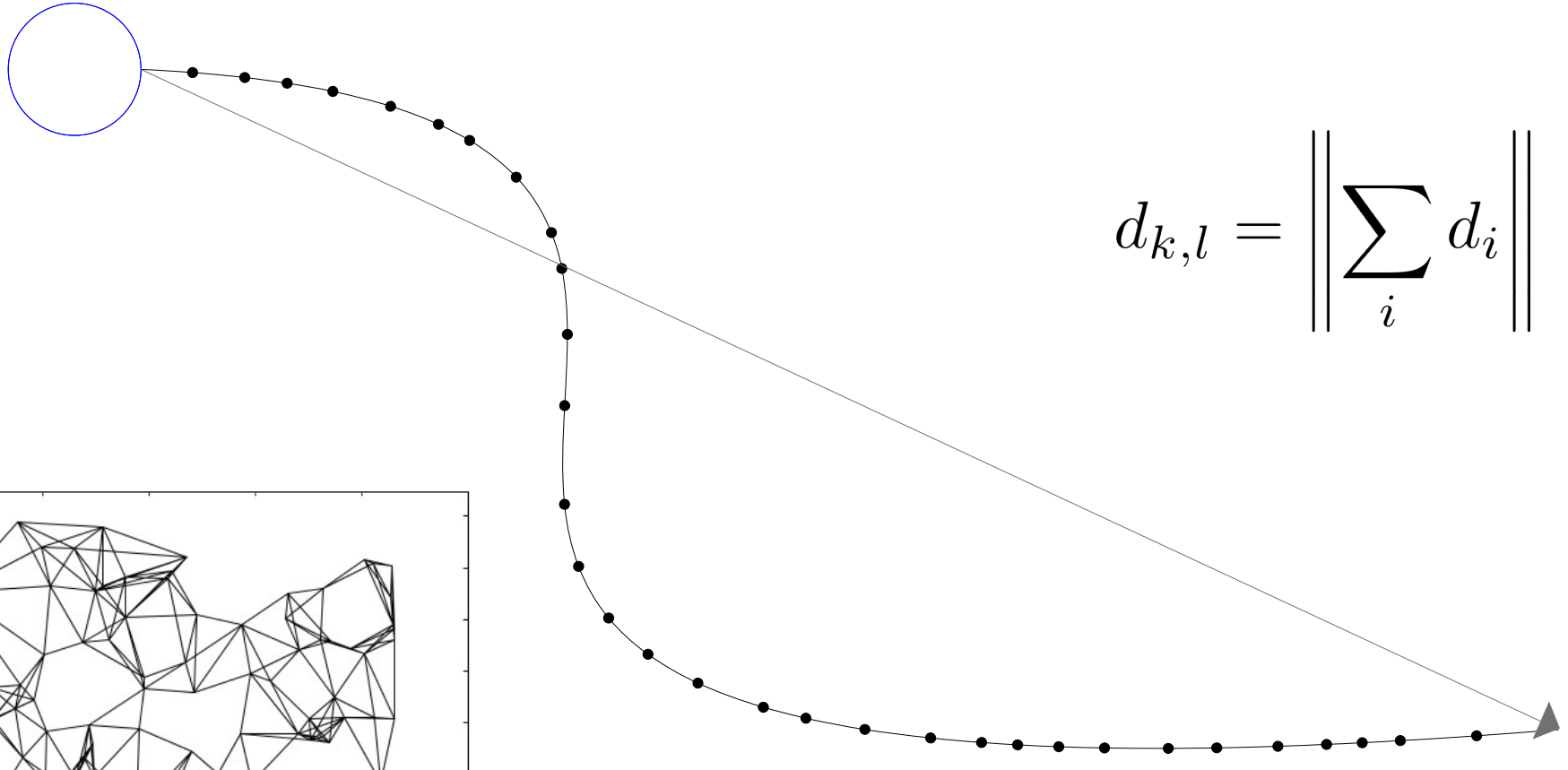
(4,6)



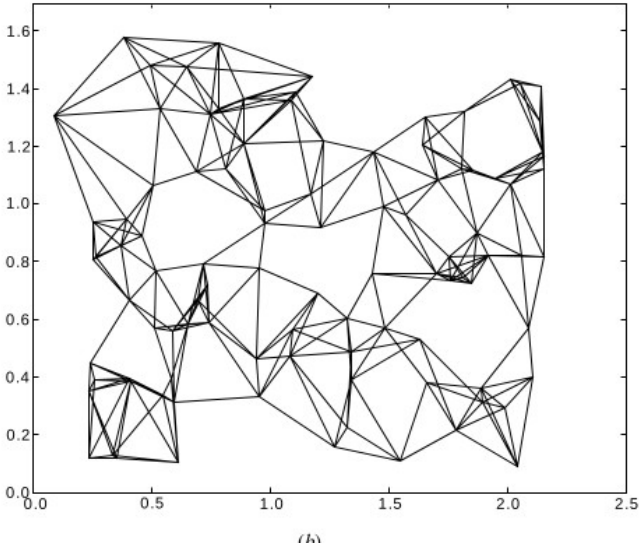


Simulation time: 1.2h

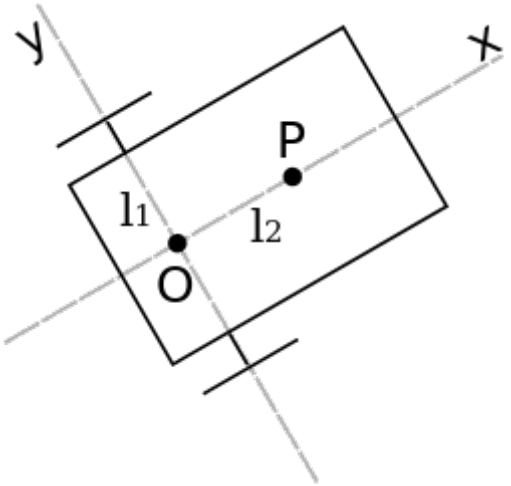
PE: Distance between neurons



$$d_{k,l} = \left\| \sum_i d_i \right\|$$



PE: Moving From Point To Point



$$e = \begin{bmatrix} e_x \\ e_y \end{bmatrix} = \begin{bmatrix} x_P - x_g \\ y_P - y_g \end{bmatrix}$$

$$\begin{cases} v = -k_{vp} e_x - k_{vd} \dot{e}_x \\ \omega = -k_{\omega p} e_y - k_{\omega d} \dot{e}_y \end{cases}$$

$$\begin{cases} \dot{x} = v\cos(\theta) \\ \dot{y} = v\sin(\theta) \\ \dot{\theta} = \omega \end{cases}$$

$$\begin{cases} v = -k_{vp} e_{x(t)} - k_{vd} \frac{e_{x(t)} - e_{x(t-1)}}{dt} \\ \omega = -k_{\omega p} e_{y(t)} - k_{\omega d} \frac{e_{y(t)} - e_{y(t-1)}}{dt} \end{cases}$$

$$\begin{bmatrix} \dot{x}_P \\ \dot{y}_P \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} 1 & -l_2 \\ 0 & l_1 \end{bmatrix} \begin{bmatrix} v \\ \omega \end{bmatrix}$$

Summary

- Exploration: Ok
- Planning
  - Place Cells Interconnection: Ok
  - Change of State: Pending
  - Place Associations: Pending
  - Path Integration: Pending

Perspectives

- Change of State Filter
- Integration of Planning Elements
- Others

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