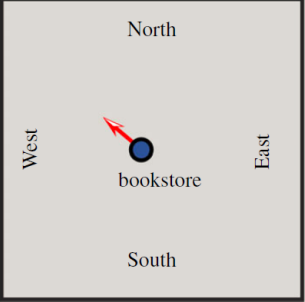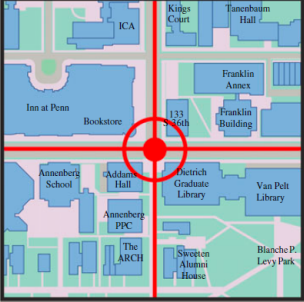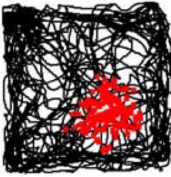# Spatial Navigation in Machines

➡️ Recap *division of labor* suggested by neuroscience
- role of different brain areas: PPA, RSC, MTL
- different cell types: place, grid, boundary,
  head direction

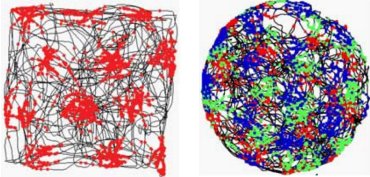RatSLAM *biologically inspired* navigation system
- mapping the environment for navigation
- mobile robots and autonomous vehicles

Para-hippocampal place area	**Retrosplenial complex**	**Medial temporal lobe Hippocampus**
PPA	RSC	MTL

Identifies landmarks	**Uses landmarks to determine the current location and direction**	**Encodes a cognitive map that represents landmarks and goals in terms of coordinates in allocentric space**

Can we build a navigation system for a mobile robot
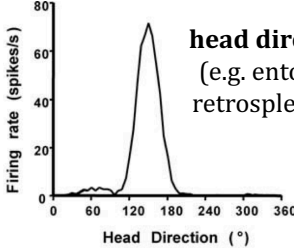or autonomous vehicle that embodies similar roles?
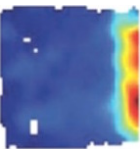
place cells
(hippocampus)

grid cells
(entorhinal cortex)

head direction cells
(e.g. entorhinal and retrosplenial cortex)

boundary cells
(e.g. entorhinal cortex)

Can we build a navigation system for a mobile robot or autonomous vehicle that uses analogous units?

3

Spatial Navigation in Machines

Recap *division of labor* suggested by neuroscience
- role of different brain areas: PPA, RSC, MTL
- different cell types: place, grid, boundary, head direction

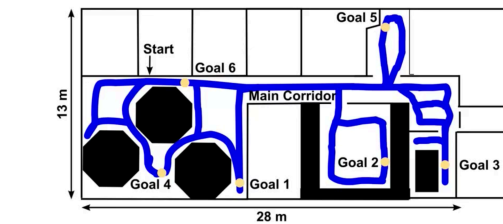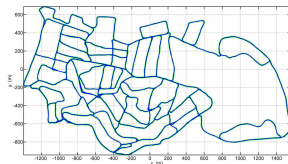➡ RatSLAM *biologically inspired* navigation system
- mapping the environment for navigation
- mobile robots and autonomous vehicles

RatSLAM *biologically inspired* navigation system
Milford & Wyeth

SLAM = **S**imultaneous **L**ocalization **A**nd **M**apping

At a large scale, over long time, in a changing environment

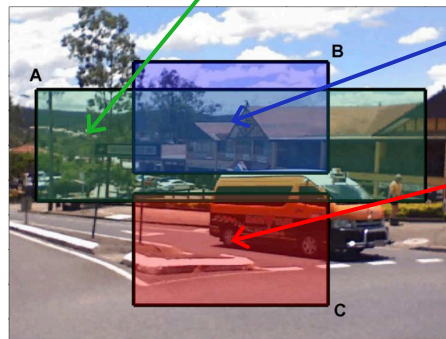https://www.youtube.com/watch?v=-0XSUi69Yvs

Sensory input from vision

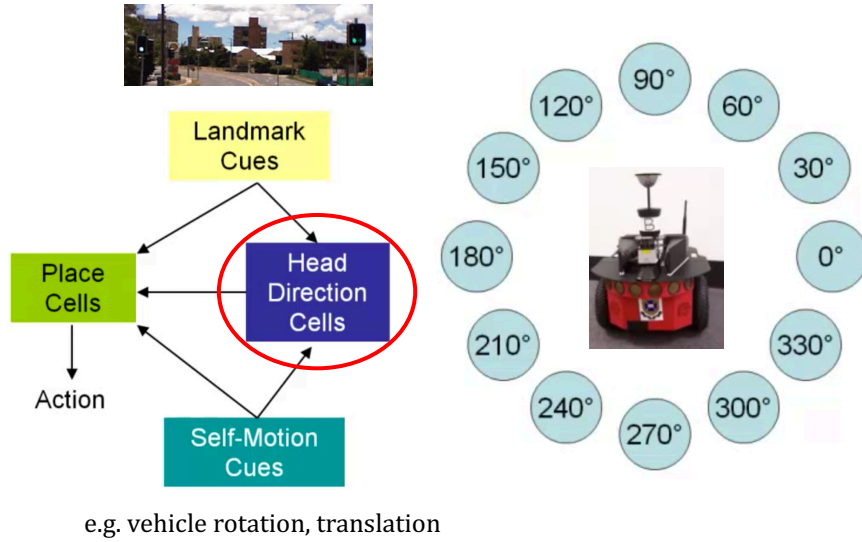**A. Visual landmarks – *local views***

B. Sense *rotation* of car from the shift of visual texture to the left or right
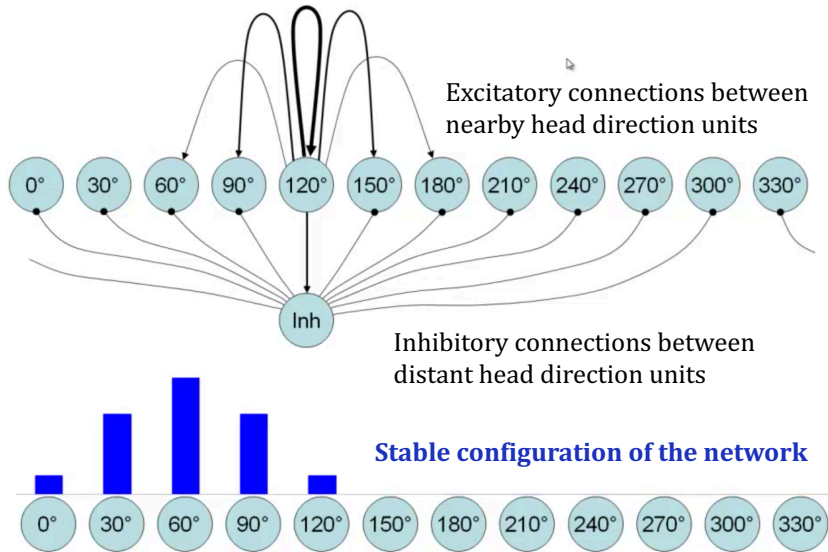
C. Sense *translation* of car from shift of visual texture along ground

Uses methods for measuring image motion and recognizing remembered scenes based on *mean absolute difference*

Representing head direction in RatSLAM v1

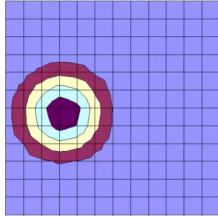

e.g. vehicle rotation, translation

Attractor network of head direction units

Excitatory connections between nearby head direction units

Inhibitory connections between distant head direction units

Stable configuration of the network

Local view (LV) units encode the *head direction* experienced when the scene was viewed previously

Suppose the network *thinks* the head direction is 240° when the system encounters this familiar view…

Updating the head direction network

Local view units increase activity around the head direction associated with previous experience…

… which moves the network toward a new (corrected) head direction

Sensory input indicating rotation of the car also shifts the network activity to new head directions
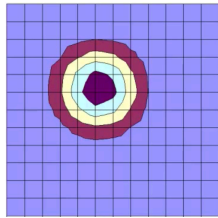
2D attractor network of place units

Each location on the grid represents a *place unit* that is active when the agent is at a particular location on a 2D grid (ground or floor)

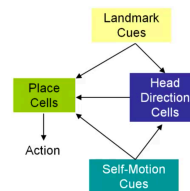Bulls' eye pattern of activation shows a stable state of the place network

Sensory input indicating small translations shifts activity of the network to a new location

Local view (LV) units also encode the *place* experienced when the scene was viewed previously, and inject activity into a new (corrected) place in the network
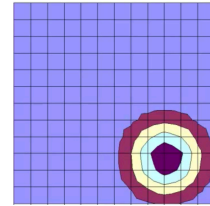
Testing RatSLAM v1

Could robot keep track of its location in a 2m x 2m arena with colored "landmarks"?

(Milford & Wyeth, 2003)

Localization was successful in the short term, but performance of the simple place and head direction networks *failed over the long term*

Why?? stay tuned…