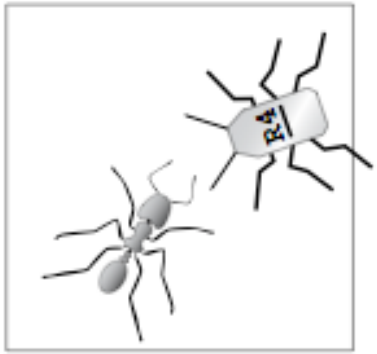
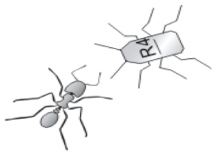
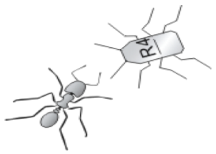
Evolutionary Robotics
Part 2



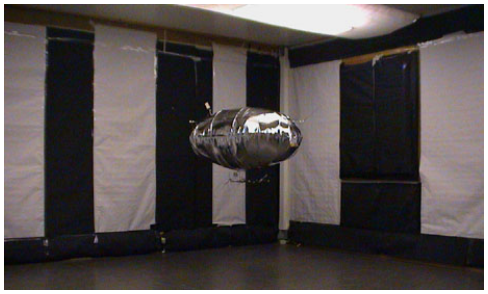


What you will learn in this class

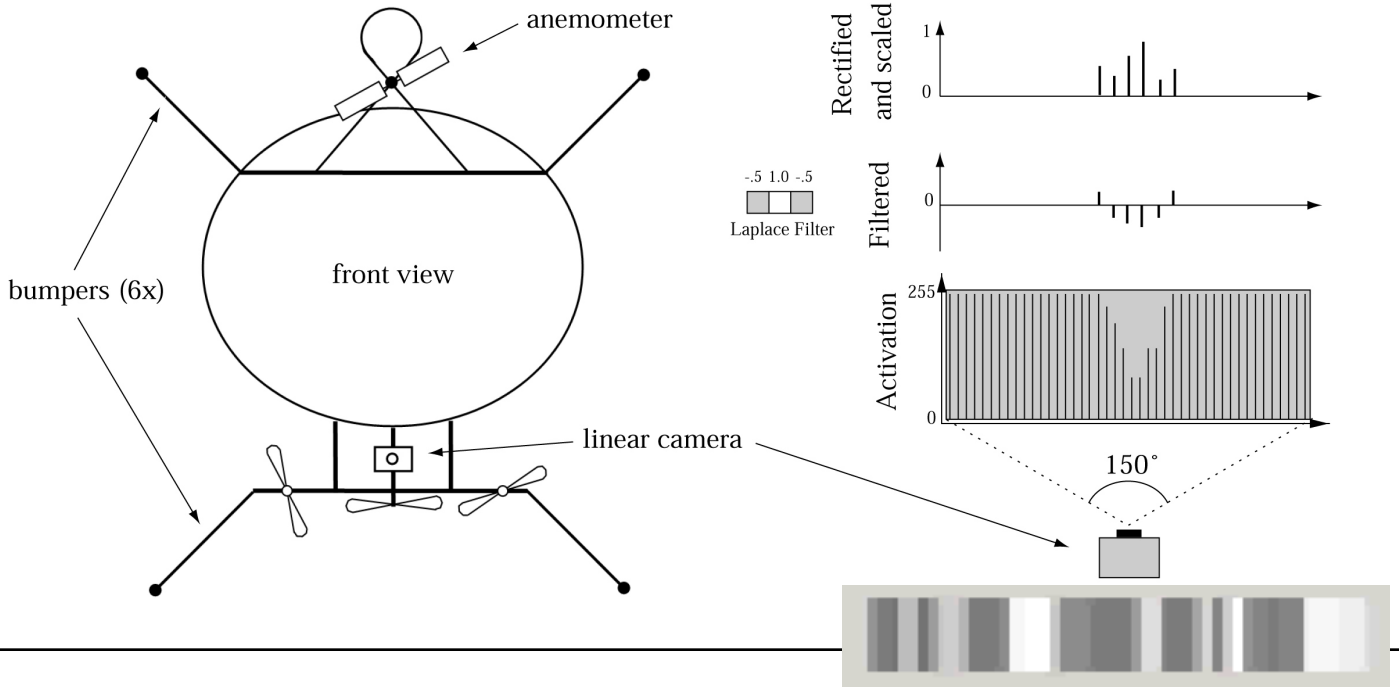
- Evolution of vision-based neuro-controllers
- Analysis of evolved spiking neural networks
- Feature detection and active vision for neural controllers
- Comparing fitness functions: The Fitness Design Space

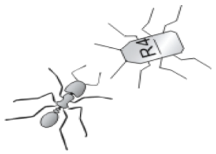


Vision-based flight of a blimp

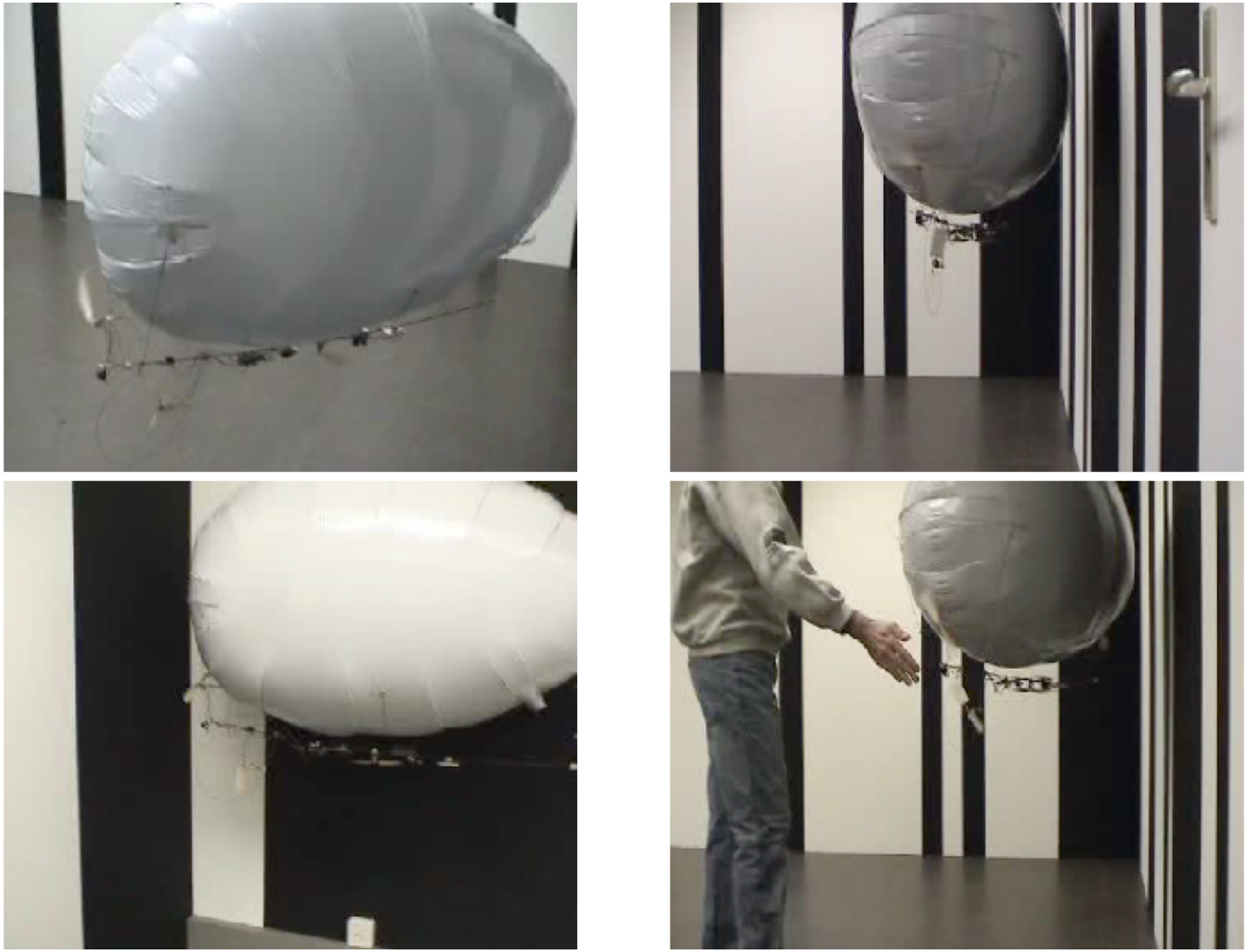


- 5 x 5 room, random size stripes
- Fitness = forward motion (anemometer)
- 2 trials, 2 minutes each
- Evolution + network activation on PC
- Sensory pre-processing on microcontroller

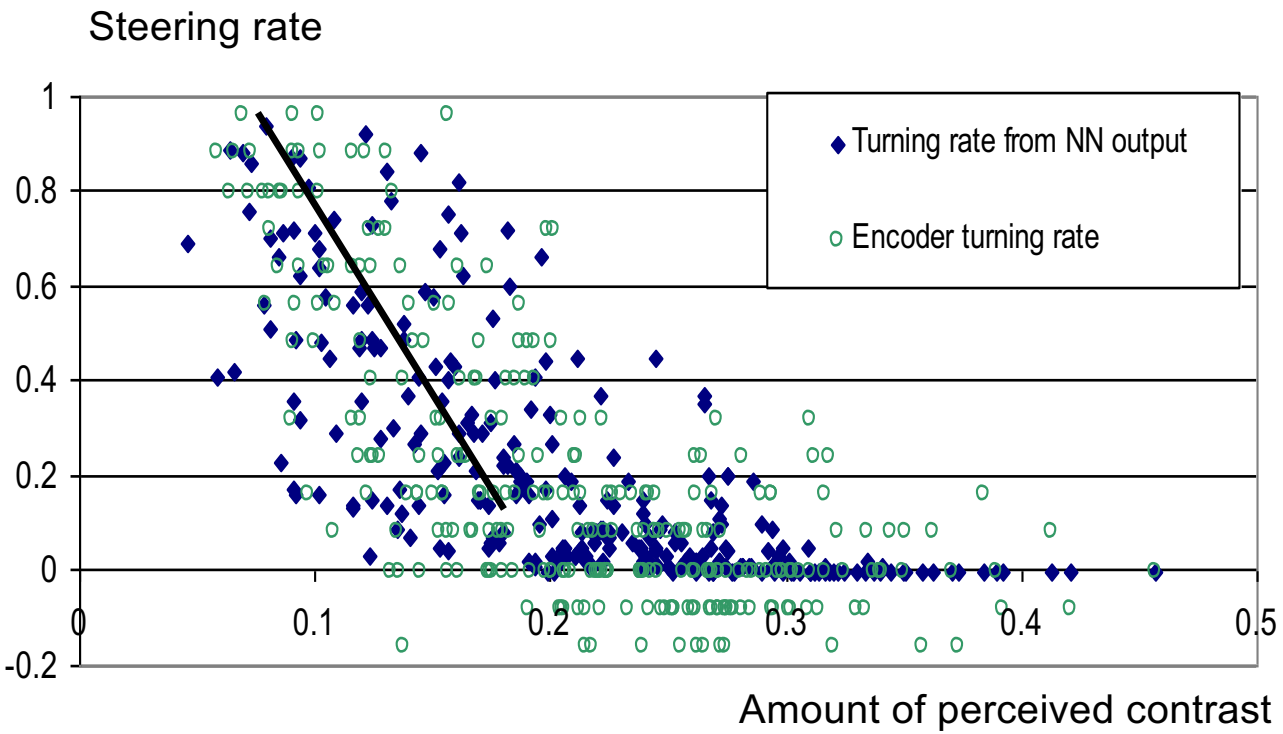


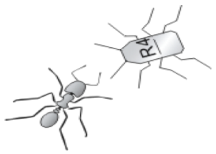


After 50 generations on the real blimp

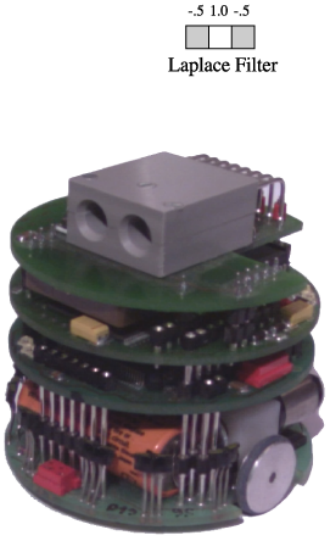


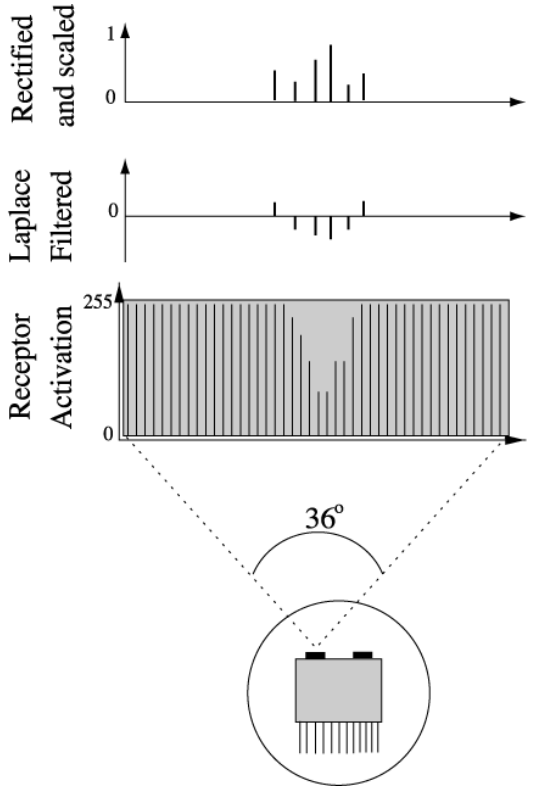
Evolution is opportunistic!





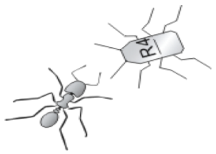
Vision-based navigation with spiking neurons





Fitness proportional to amount of forward translation over 2 mins

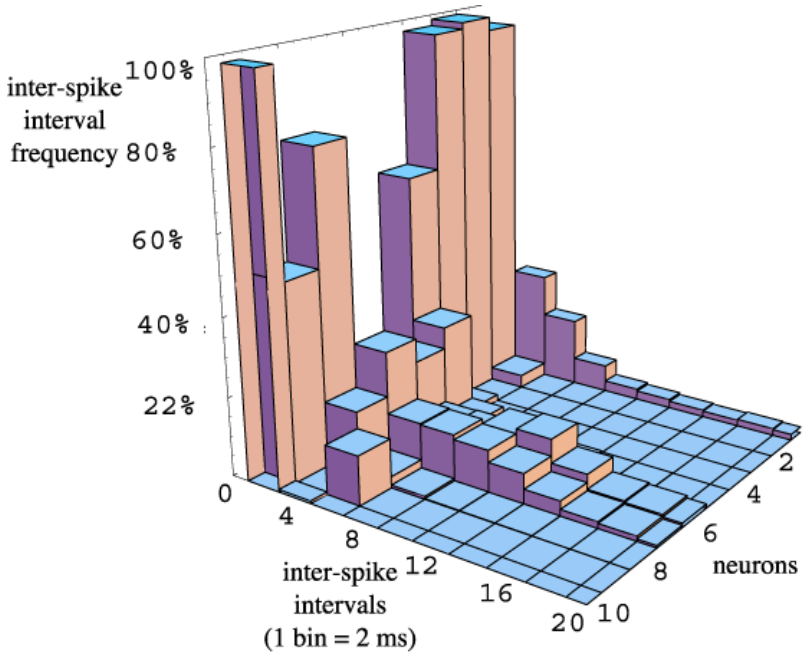
After 30 generations



Robot neuroethology

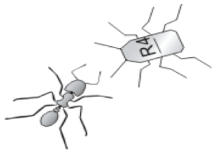
Neuron #

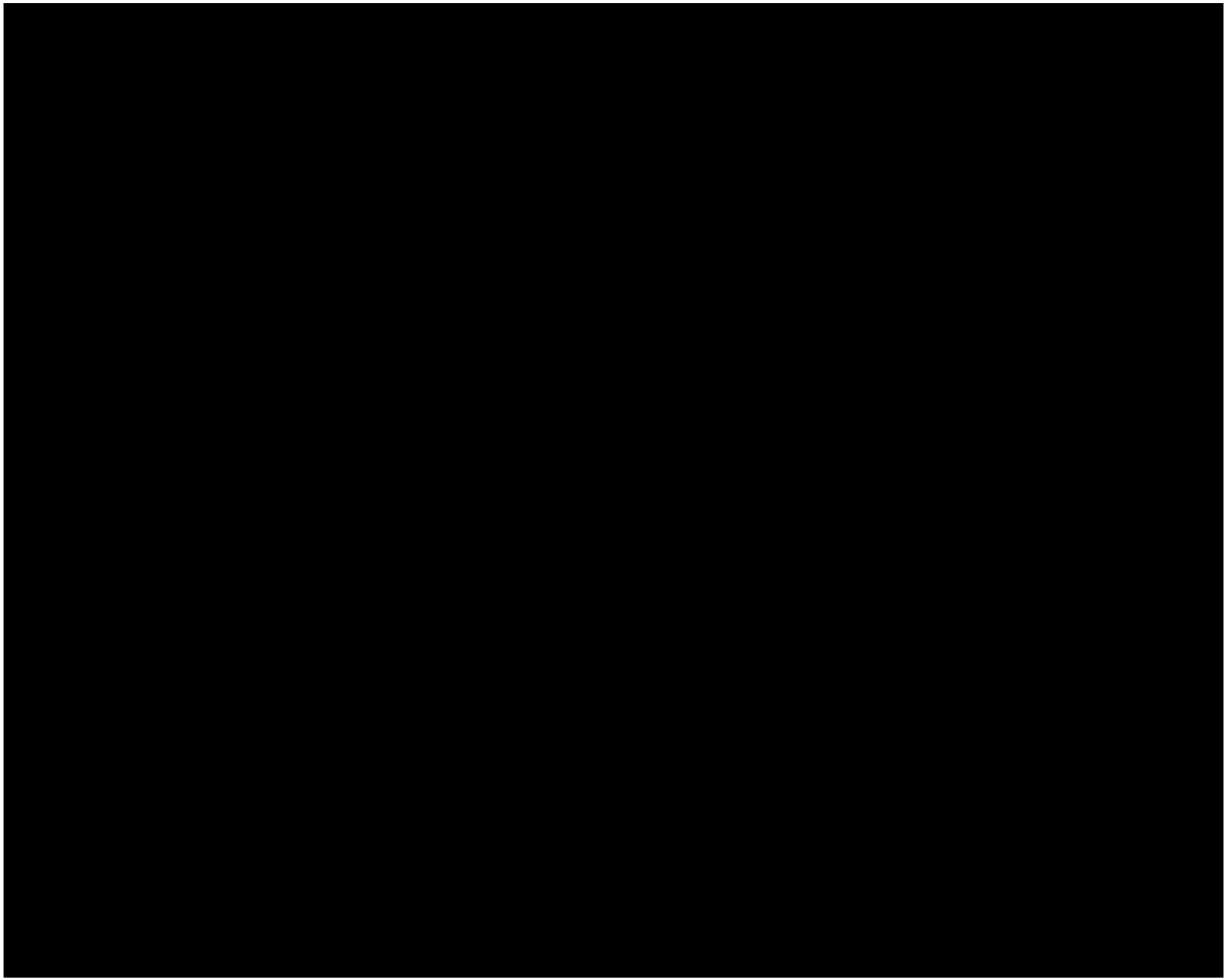
	1	2	3	4	5	6	7	8	9	10
spikes/s	9	445	453	450	330	40	129	363	0	452



- Removing any single neuron (except # 9) decreases the robot's performance
- Removing any neuron pair decreases even further robot's performance
- but… removing neurons 1, 5, 6 has no effect on performance

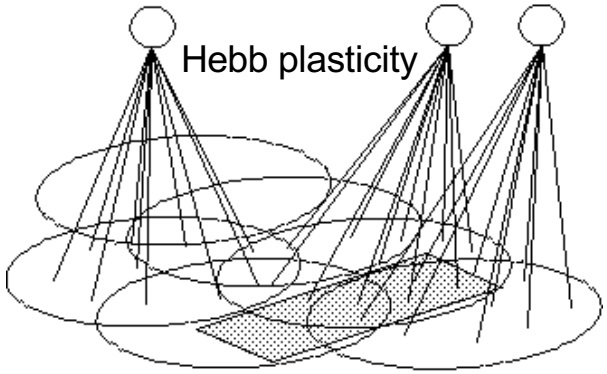
-> we infer that evolved neurons use time difference of incoming signals, not only total signal intensity



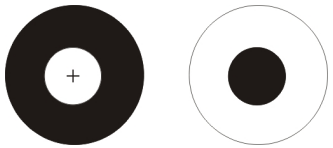


Visual feature detection

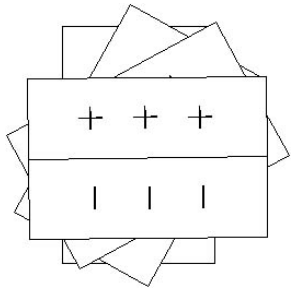
Process whereby visual neurons become sensitive to certain sensory patterns (features) during the developmental process (Hubel & Wiesel, 1959)

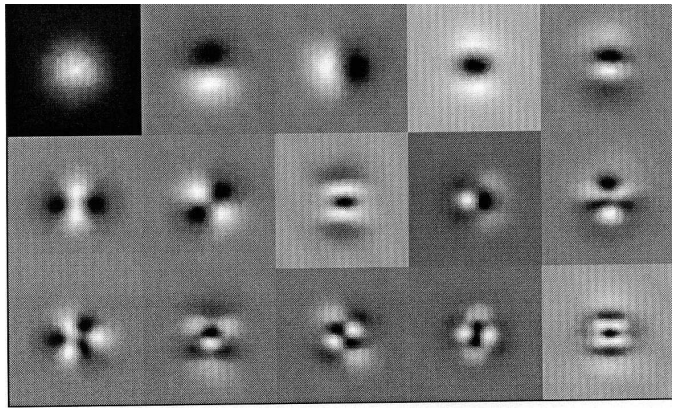


Center-Surround



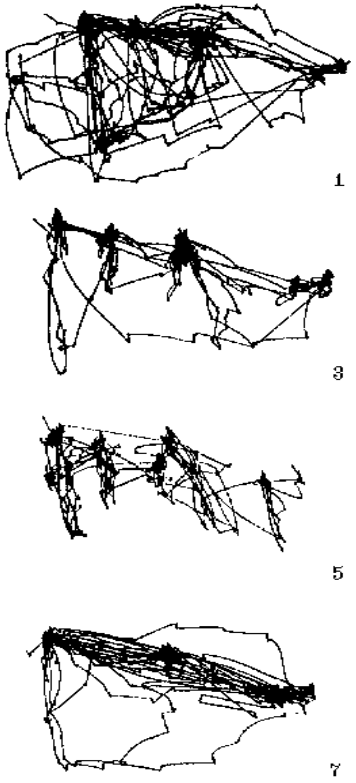
Oriented Edges



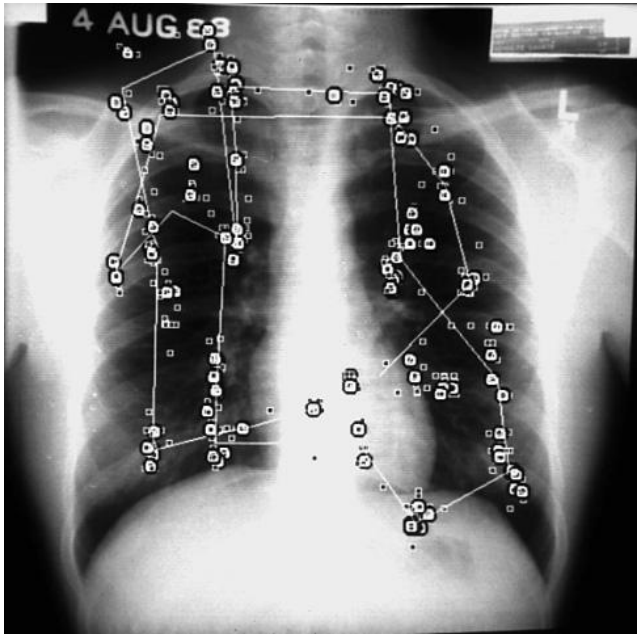


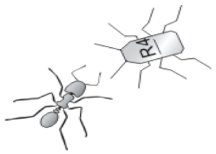
Active vision

Yarbus, 1967



Process of selecting by motor actions sensory patterns (features) that make discrimination easier (Bajcsy, 1988)

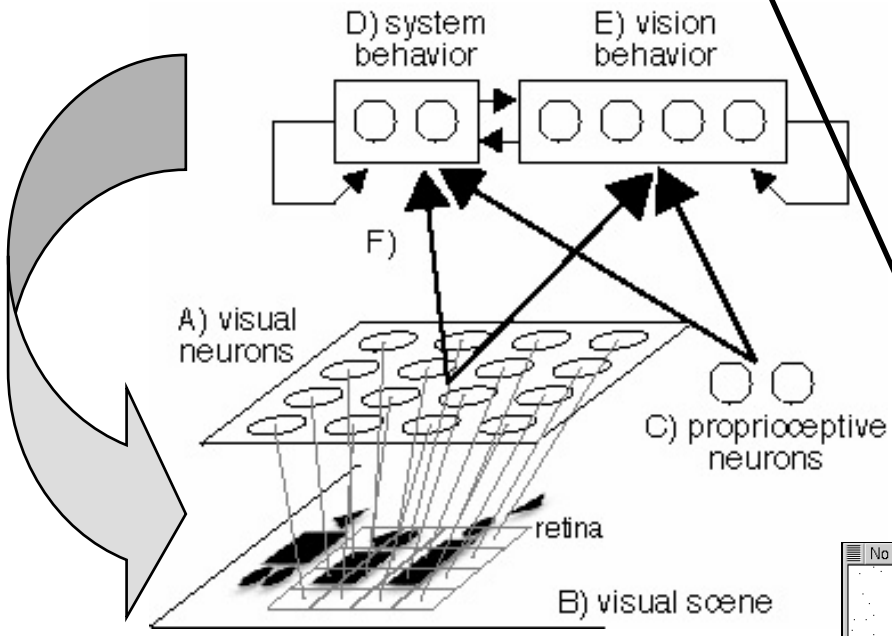


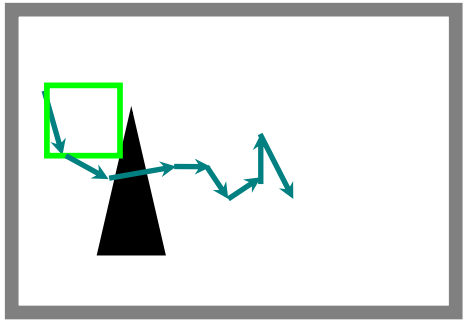


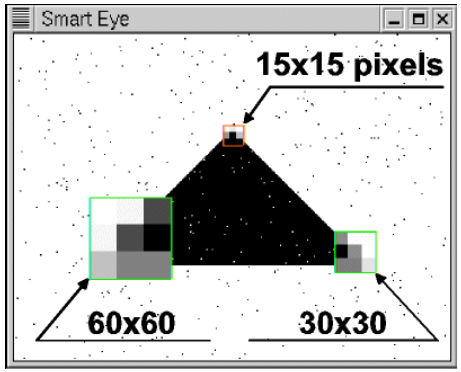
Neural architecture for active vision

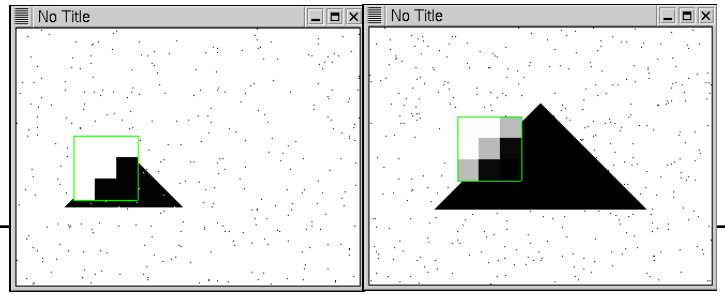
shape discrimination
robot control
car driving

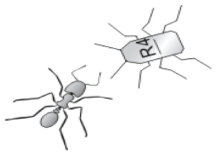
retina movement
zooming factor
filter type







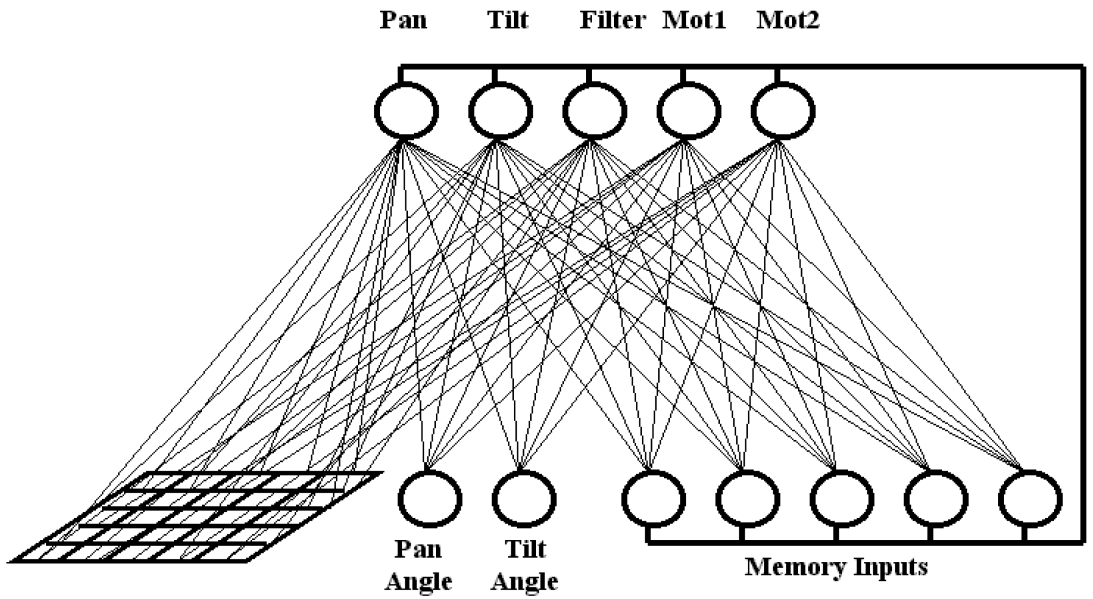


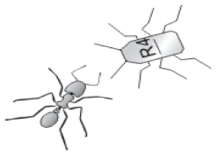


Robot navigation with active vision architecture

Goal: Evolve collision-free navigation using only vision information from a pan/tilt camera.

Output of vision system is movement of camera (pan/tilt) and of robot wheels (mot1/mot2). Filter as before.

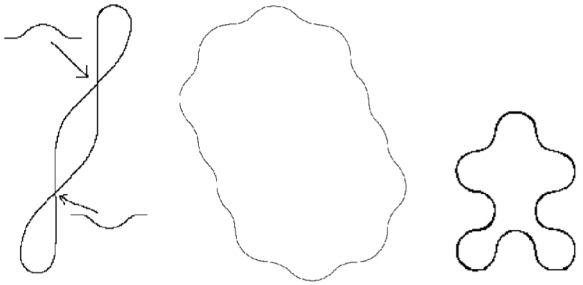




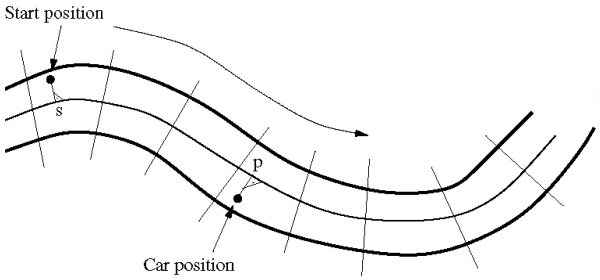

Environment

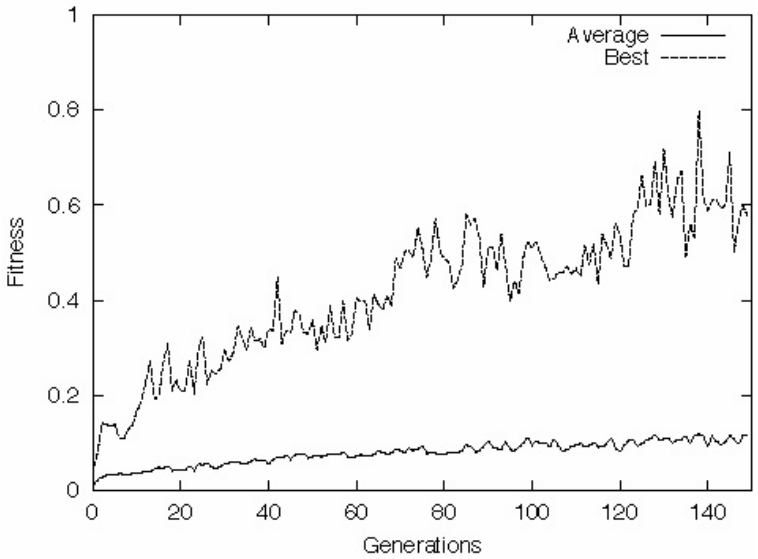
Active Vision for Car Driving

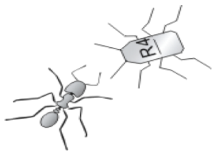
Fitness = percentage of covered distance D in R races on M circuits (limited time for each race).

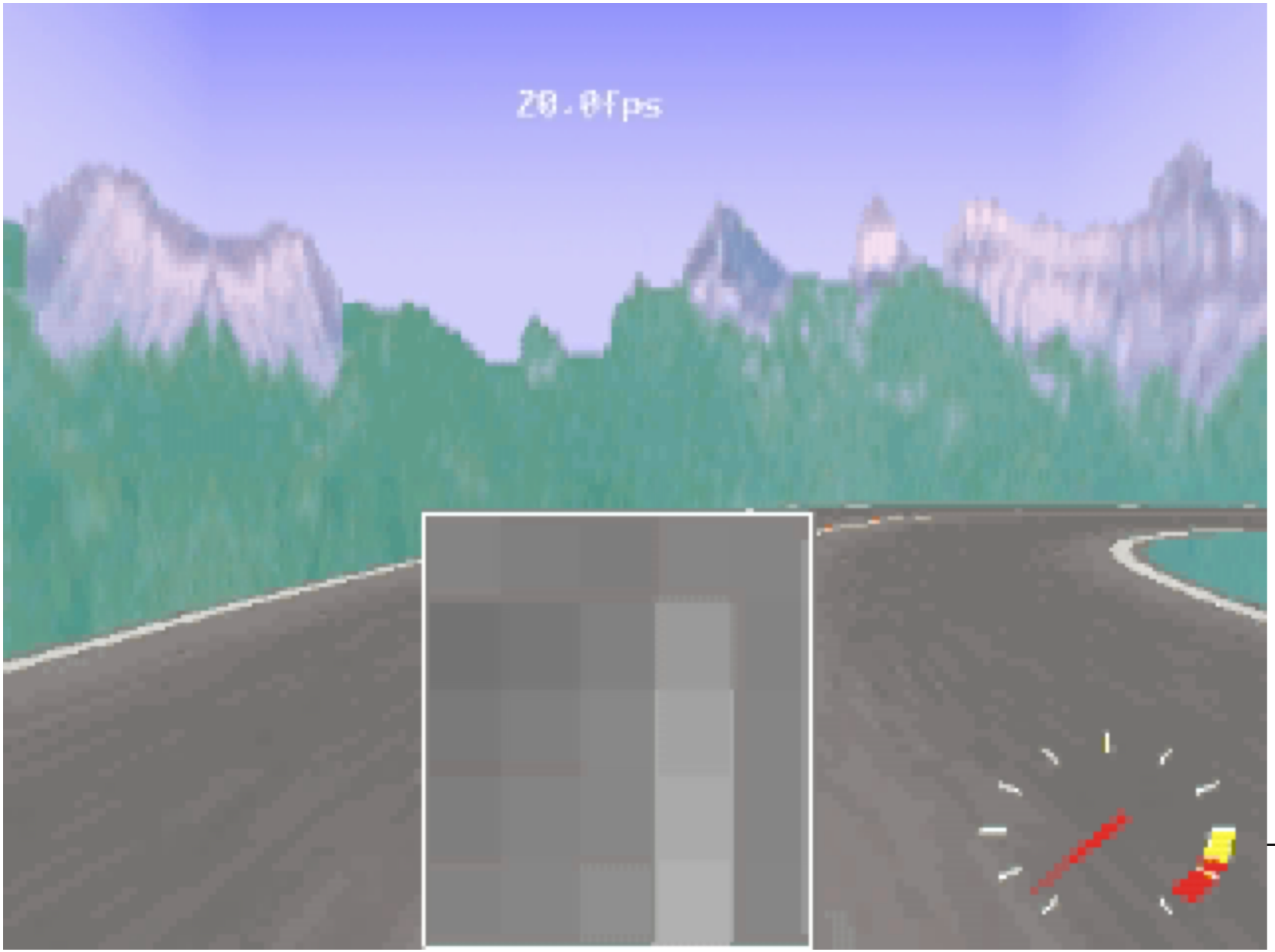


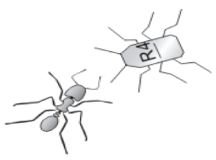
$$F = \frac{1}{R * M} \sum_{r=1}^{R} \sum_{m=1}^{M} D_{r,m}$$



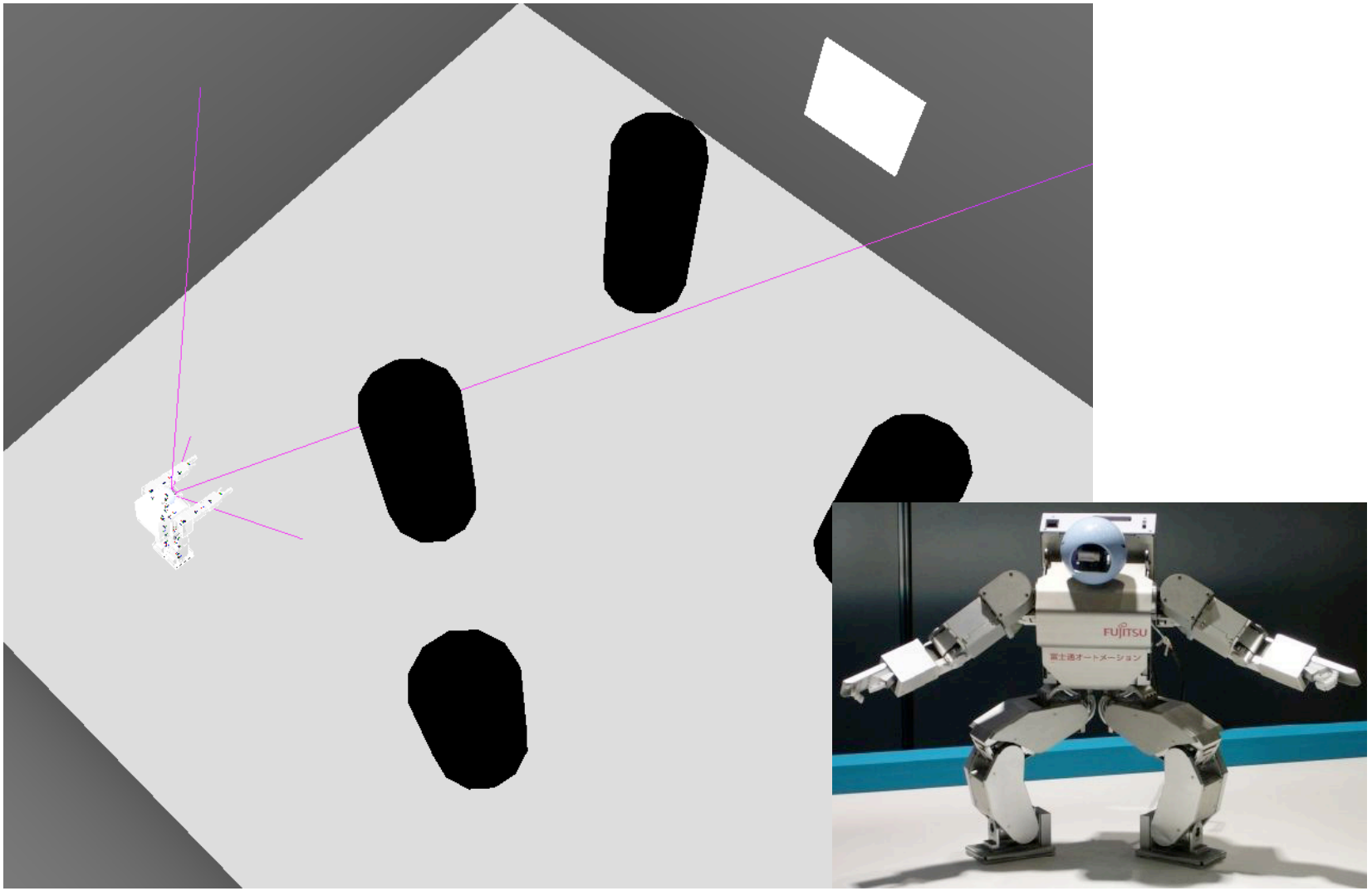


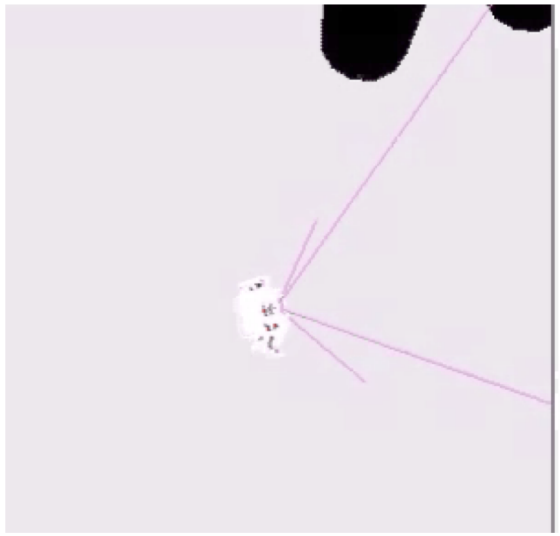
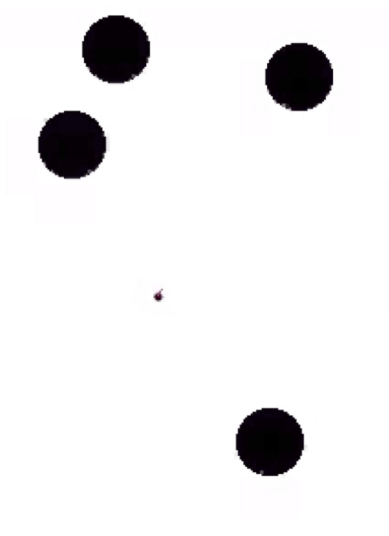


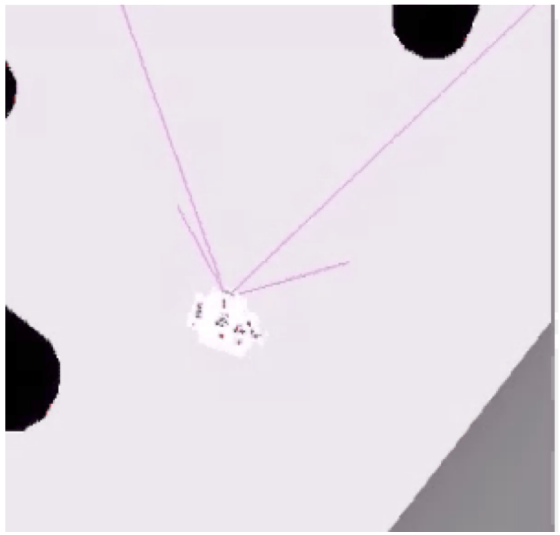
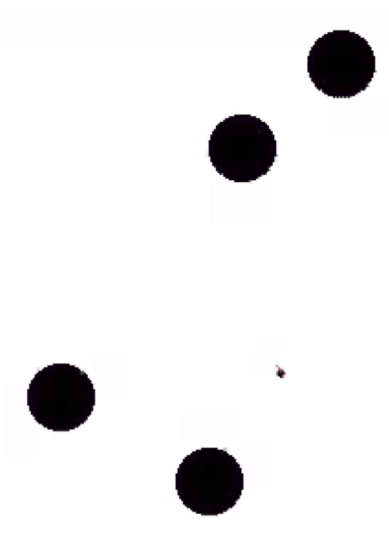
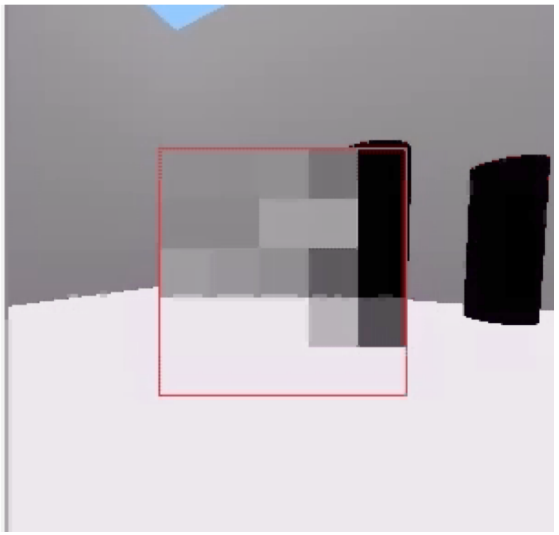
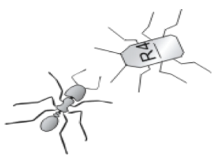

20.0fps



Active Vision for bipedal locomotion



Fitness design space: comparing fitness functions