Reactive Behaviour

IAR Lecture 2

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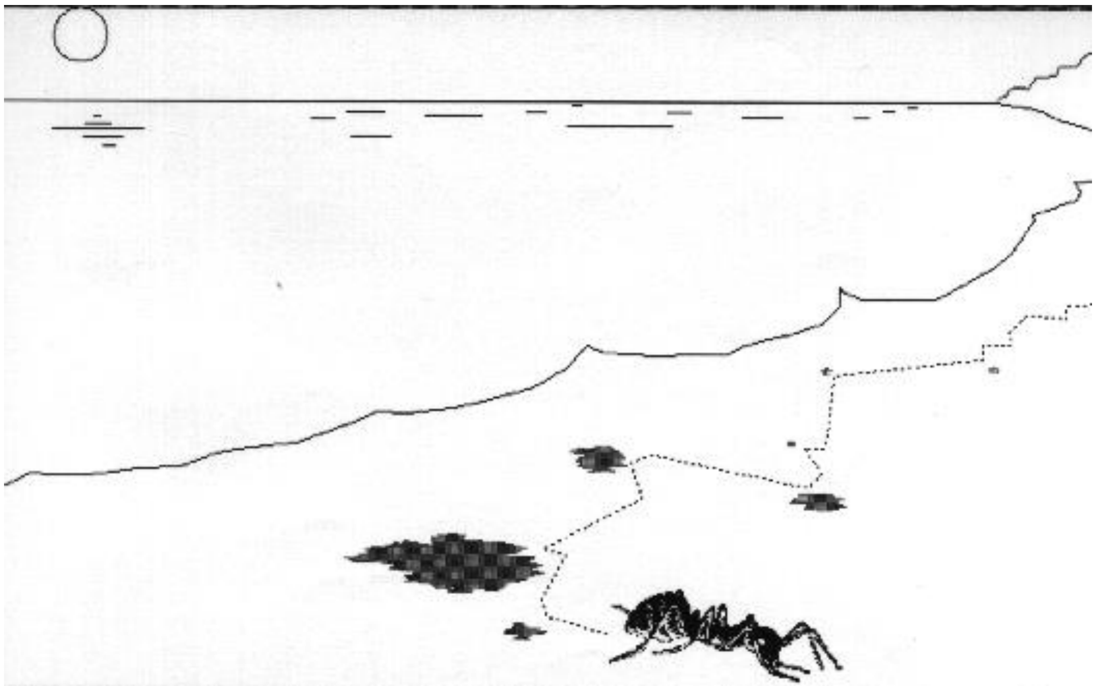
Principle:

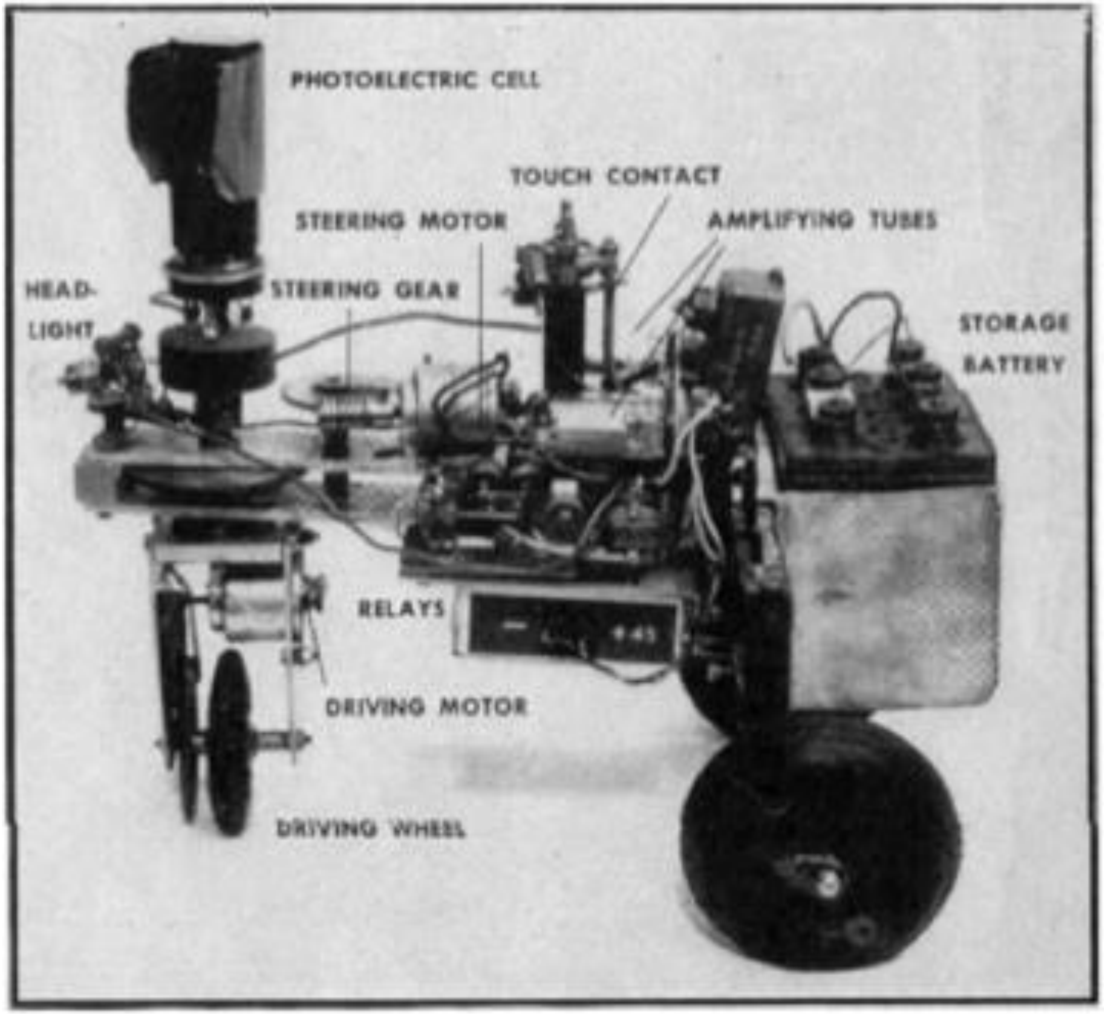
- Complex behaviour may reflect simple system in complex world – e.g. Simon’s ant

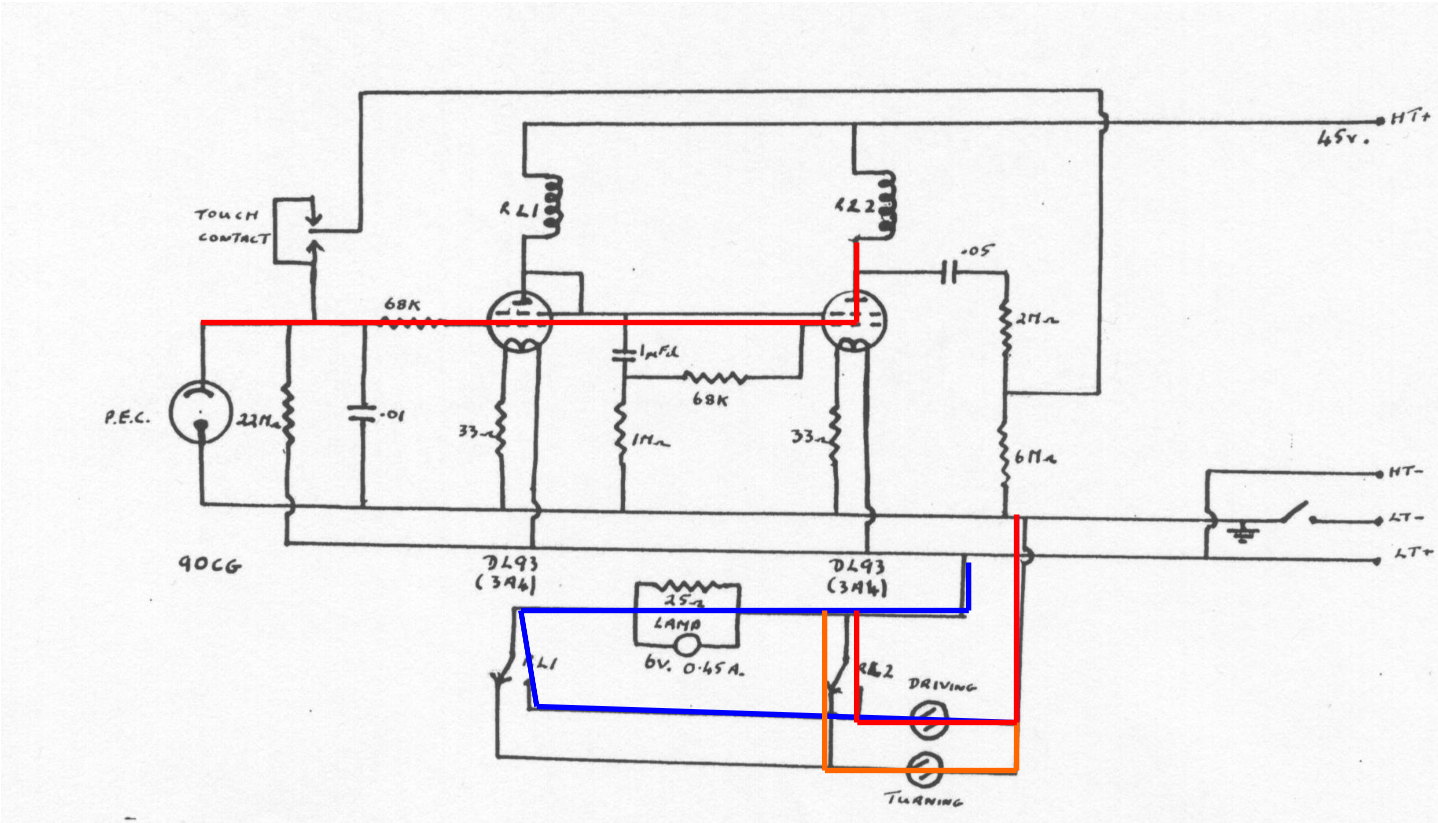


Applied to robotics:

Can get surprising capability from a couple of vacuum tubes and relays…

Grey Walter's 'tortoise' 1950

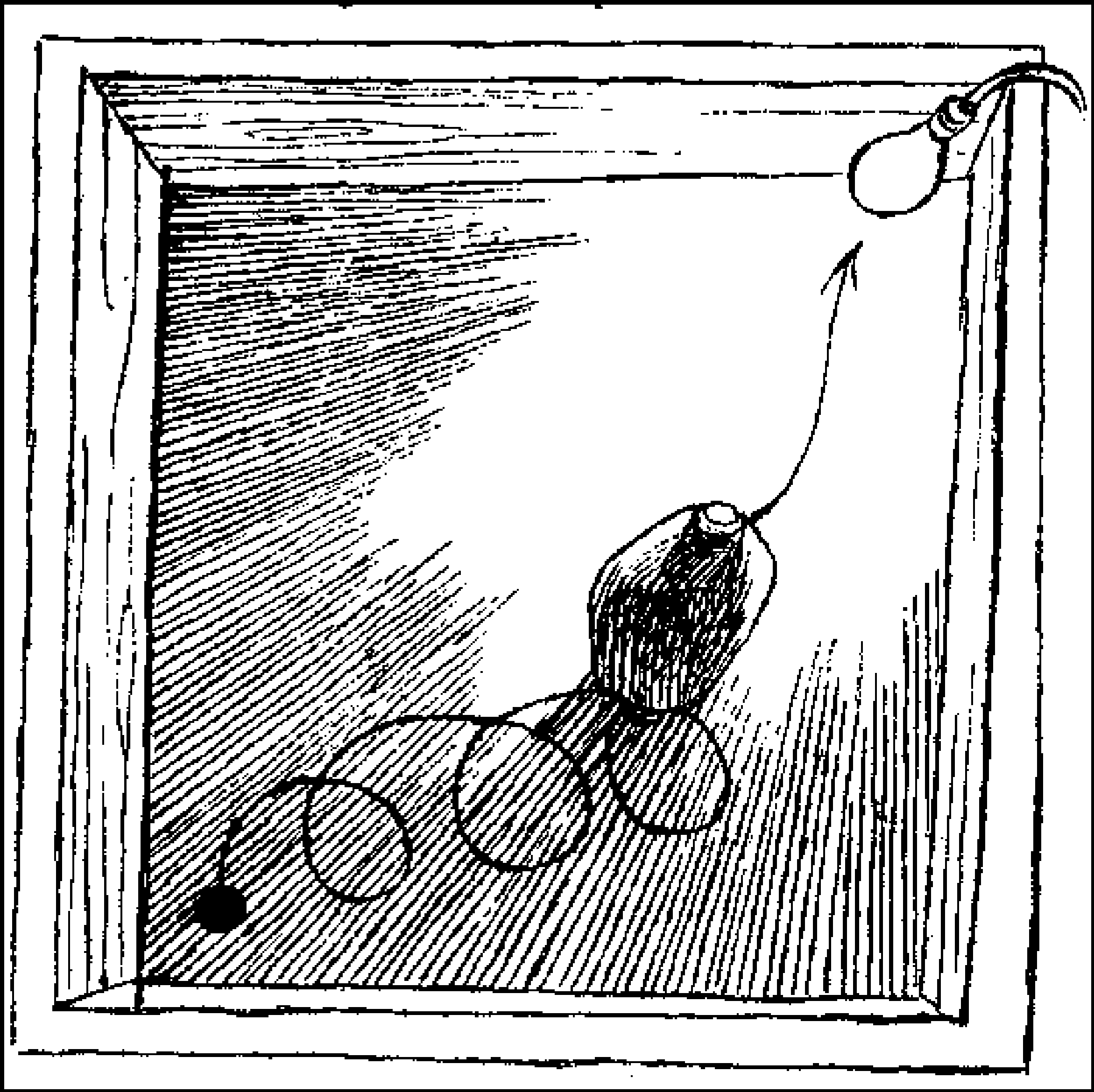


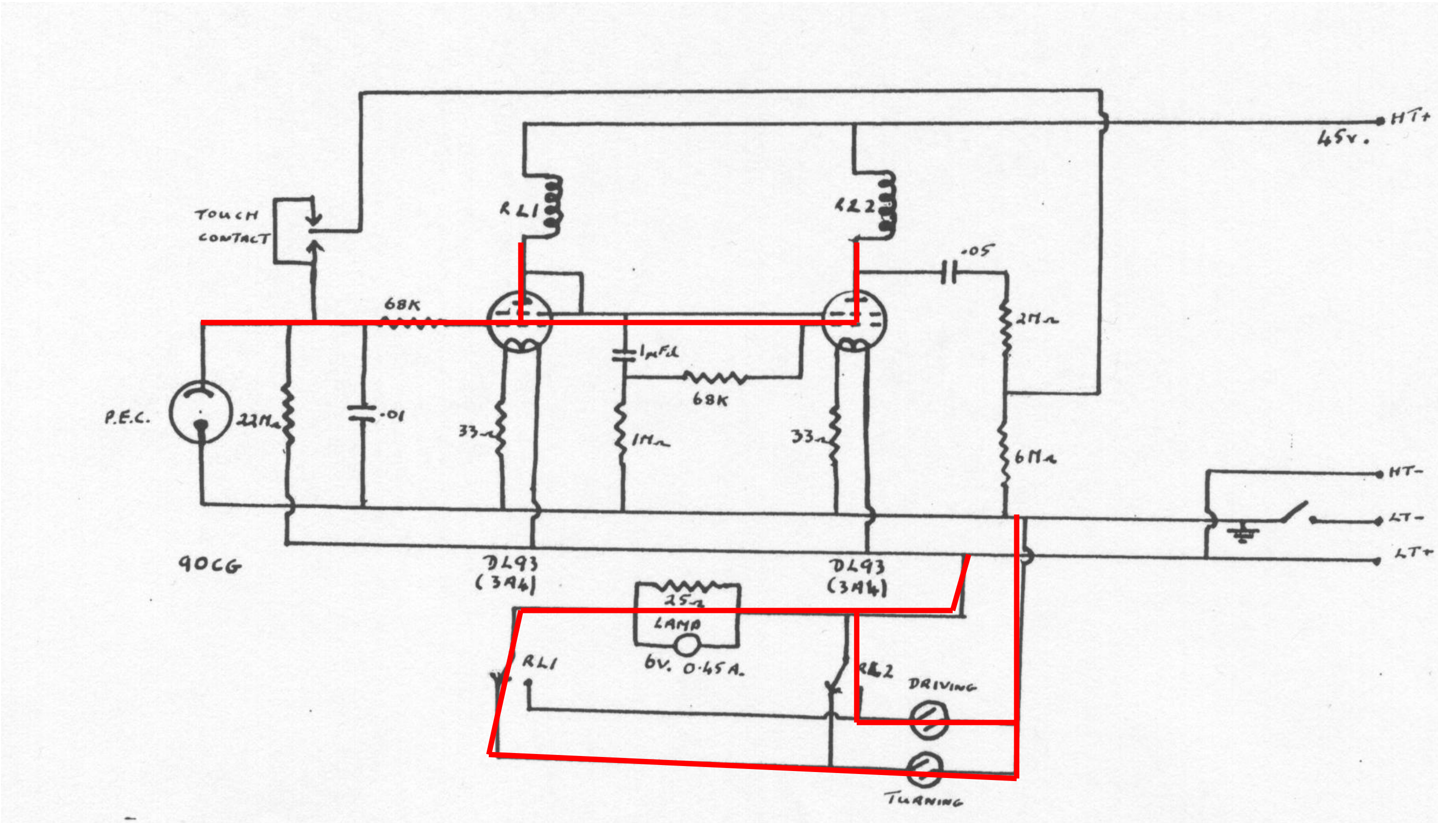


Starts with: drive motor in series with lamp and turning motor full on; get cycloid movement that scans for light.

Light input: passes through two amplifiers, switching relay 2, short circuit; so stops turning and drives double speed to light.

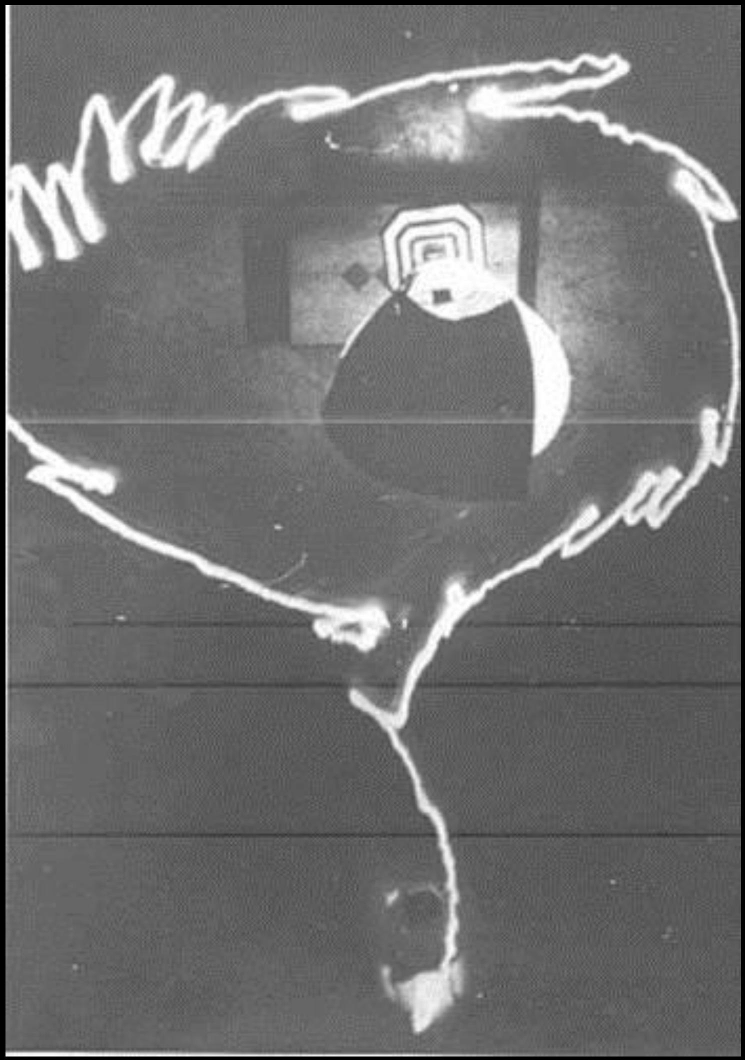
Steers at increasingly shallow angle towards light source



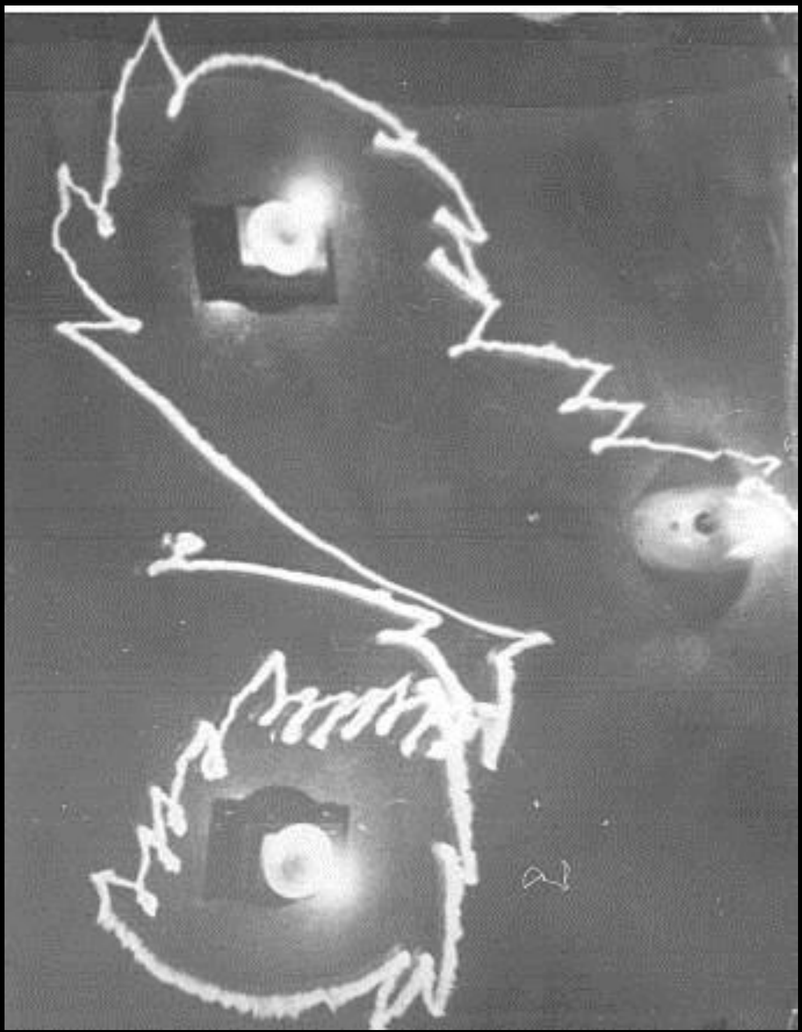


Strong light: switches relay 1, turning motor in series with lamp; turns smoothly away from light.

Approaches then circles light



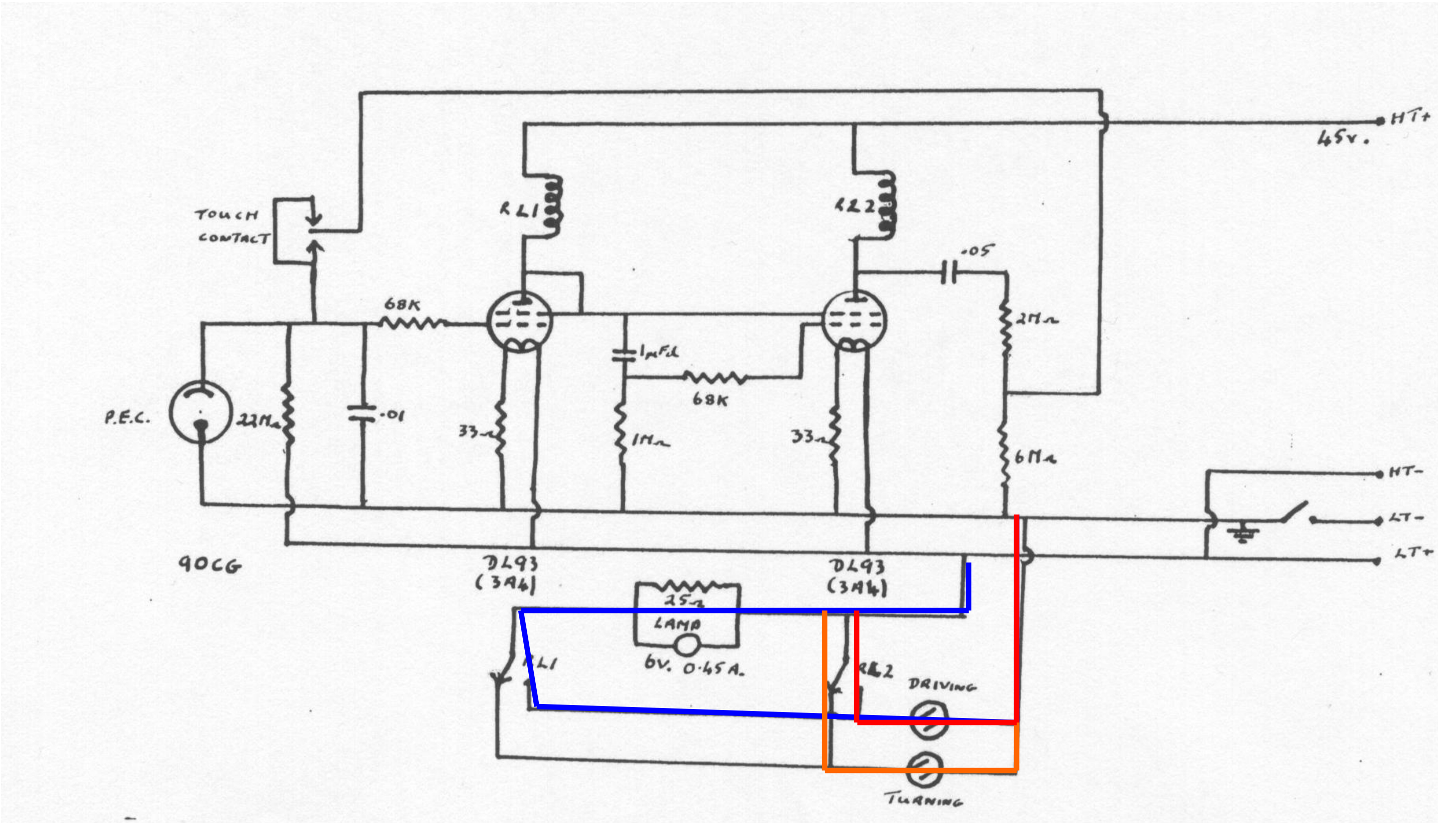
Inspects different light sources



If battery low: won’t reach threshold to turn away from light, so enters hutch to recharge.

Replica tortoise (original hutch)

Holland, 1995

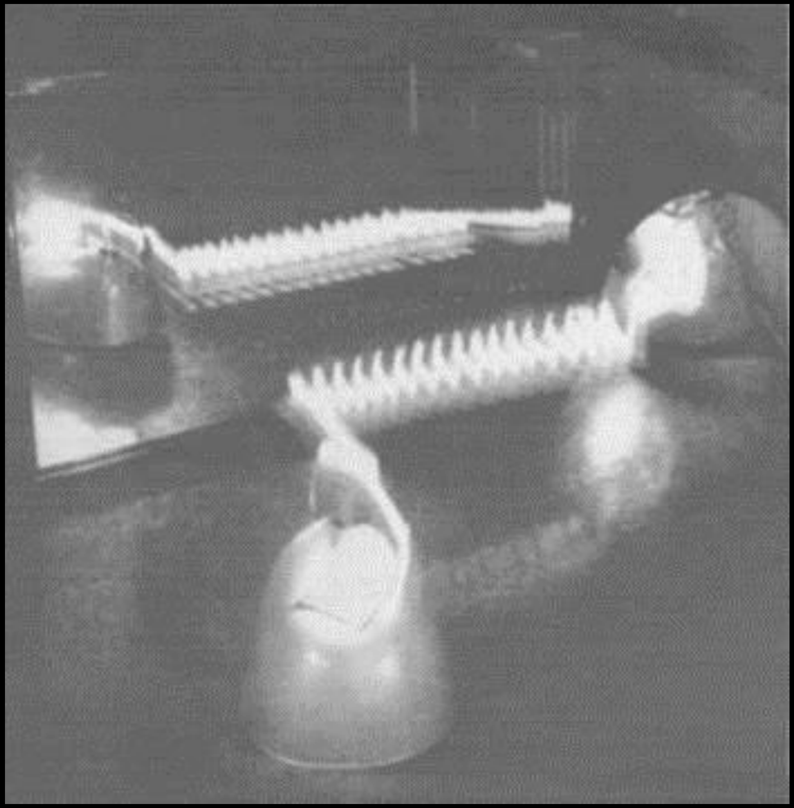


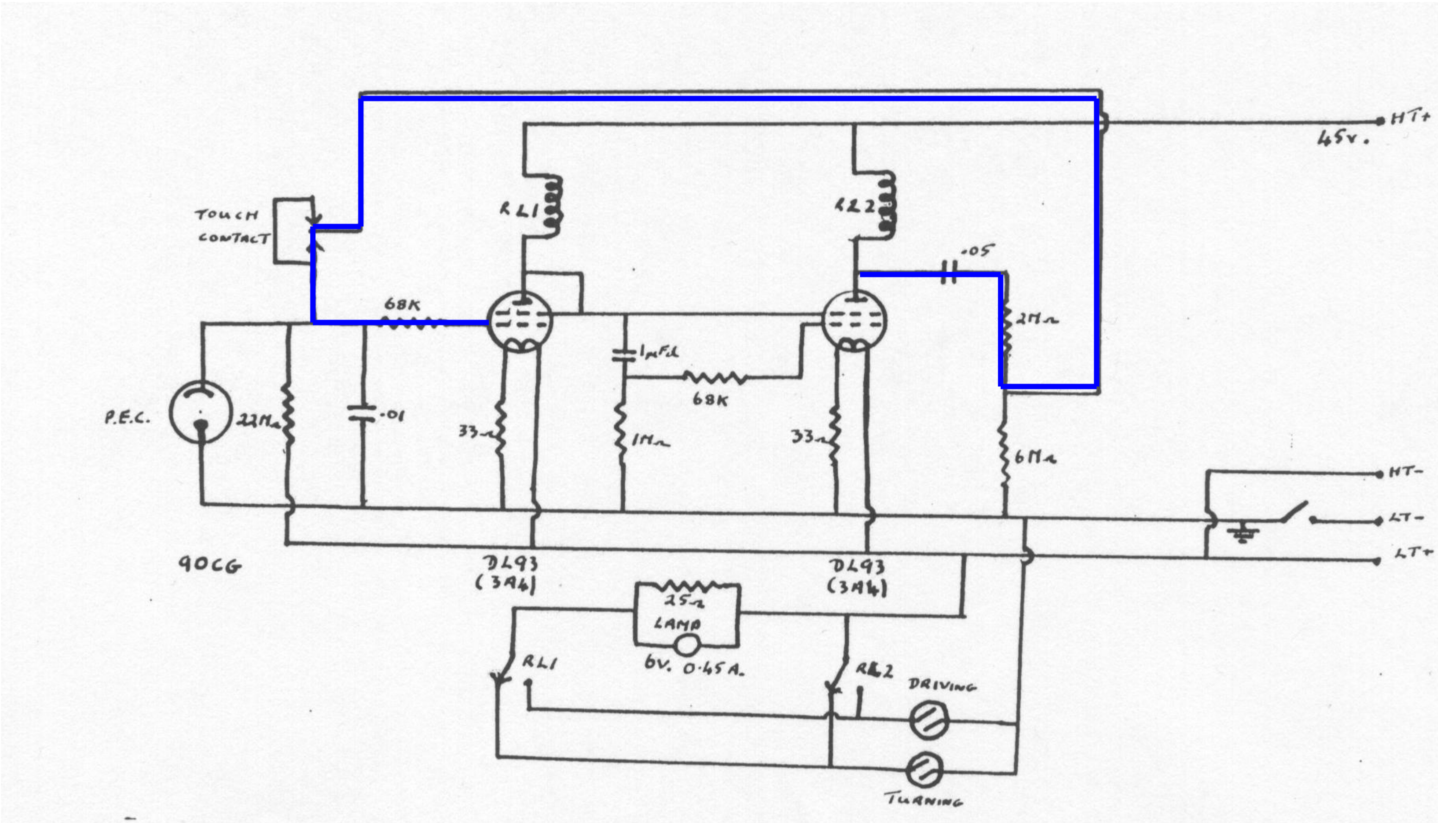
During scanning for light, own lamp is on.

When moving to light, own lamp is off.

Complex interactions of two robots

‘Recognises’ self in mirror and ‘dances’



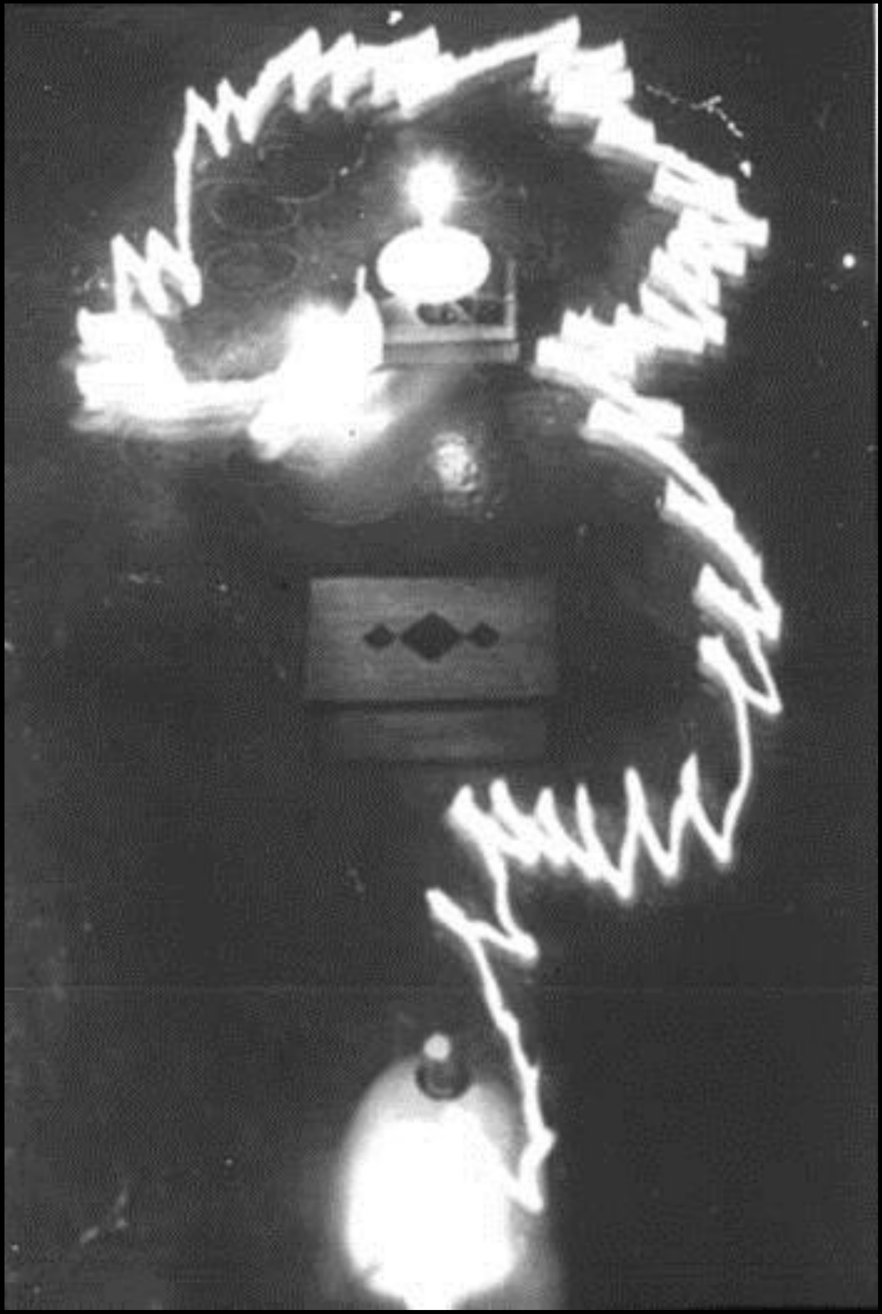


Shell collision: closes touch contact, output of amplifier 2 becomes input to amplifier 1; produces oscillator, switching relays.

Rapidly alternates driving and turning speeds, overriding effects of light input, till clear of obstacle.

Can get round obstacles to find light.

Also tends to push small obstacles out of the way, gradually clearing the area.



- Reactive behaviour: direct mapping from current sensor input to motor output.
  - Strict definition: no internal state or memory.
  - Loose definition: no deliberation or use of internal models.
- Physical design of sensor (see lecture 3) to match the task will make this easier
- Example: sound localisation

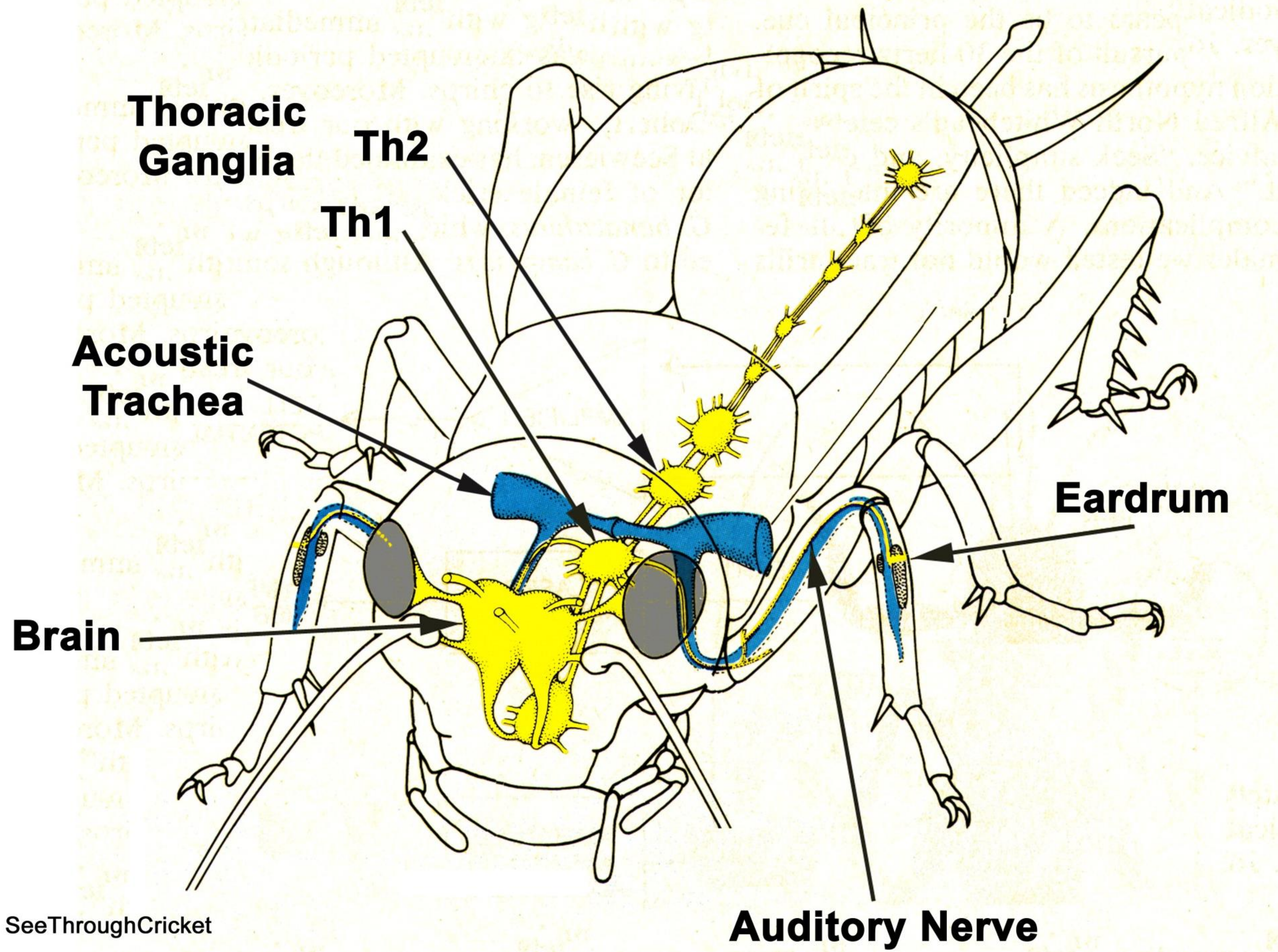
Sound localisation

- How do humans localise sounds?

Sound localisation

- How do humans localise sounds?
- Why might a small (and small-brained) cricket localising sound (of a wavelength larger than itself) have problems using the same solution as humans?

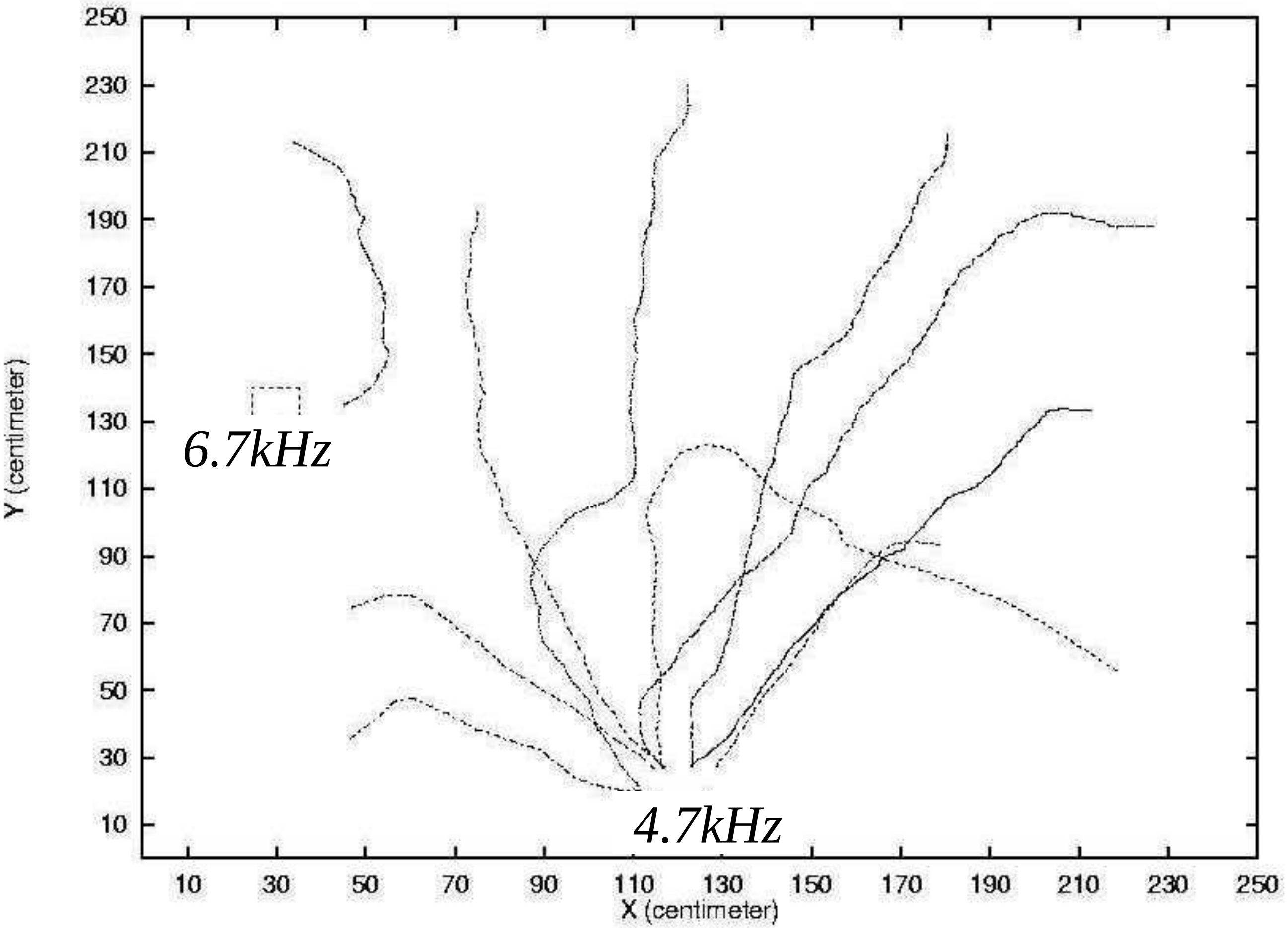
Cricket CNS and Auditory Pathway



Huber and Thorson, Sci.Am.

In free movement will chose between sounds,

- preferring correct carrier frequency



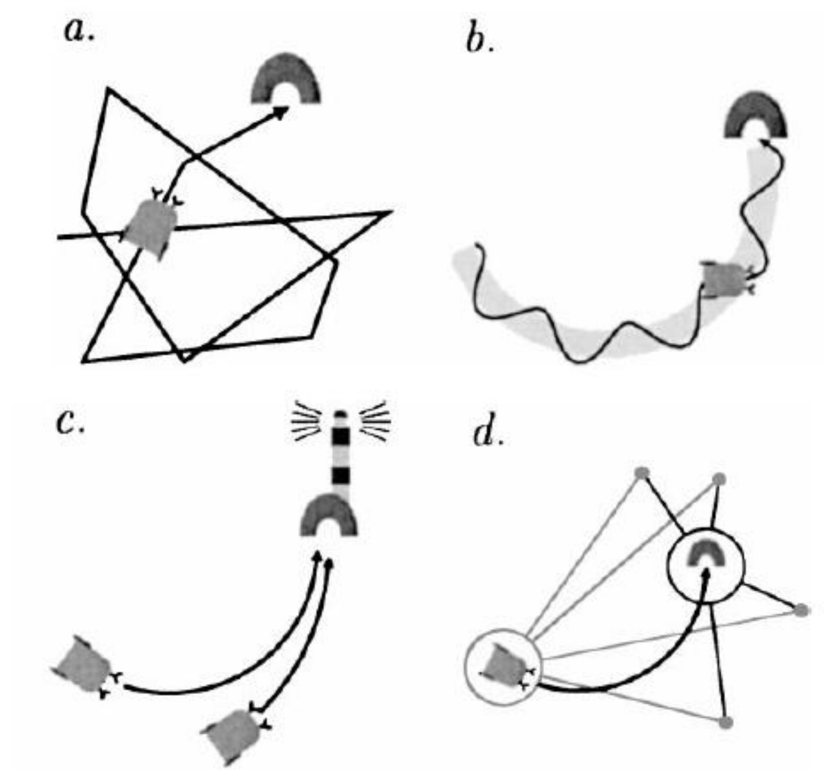
Reactive navigation

- Traditional navigation says robot must determine -
  - a) “Where am I”?
  - b) “Where is the goal with respect to me?”
  - c) “How do I get there from here?”

- by locating itself with respect to a map and inferring a navigable path

- But it is not evident that answering a) or b) is necessary to answer c)

- Wider definition: (Franz & Mallot, via Gallistel): *"Navigation is the process of determining or maintaining a course or trajectory to a goal location"* which could include following reactive strategies:
- a) <u>search</u>: can move, and can recognise arrival at the goal.
- b) <u>direction following</u>, e.g. compass direction, or trail following: can find goal from one direction.
- c) <u>aiming</u>, e.g. taxis to source, using landmarks: can find a salient goal from a catchment area
- d) <u>guidance</u> by surroundings



E.g. Navigate to Appleton Tower

Search with visual recognition

Visual aiming to landmark

Visual homing using surrounding landmarks

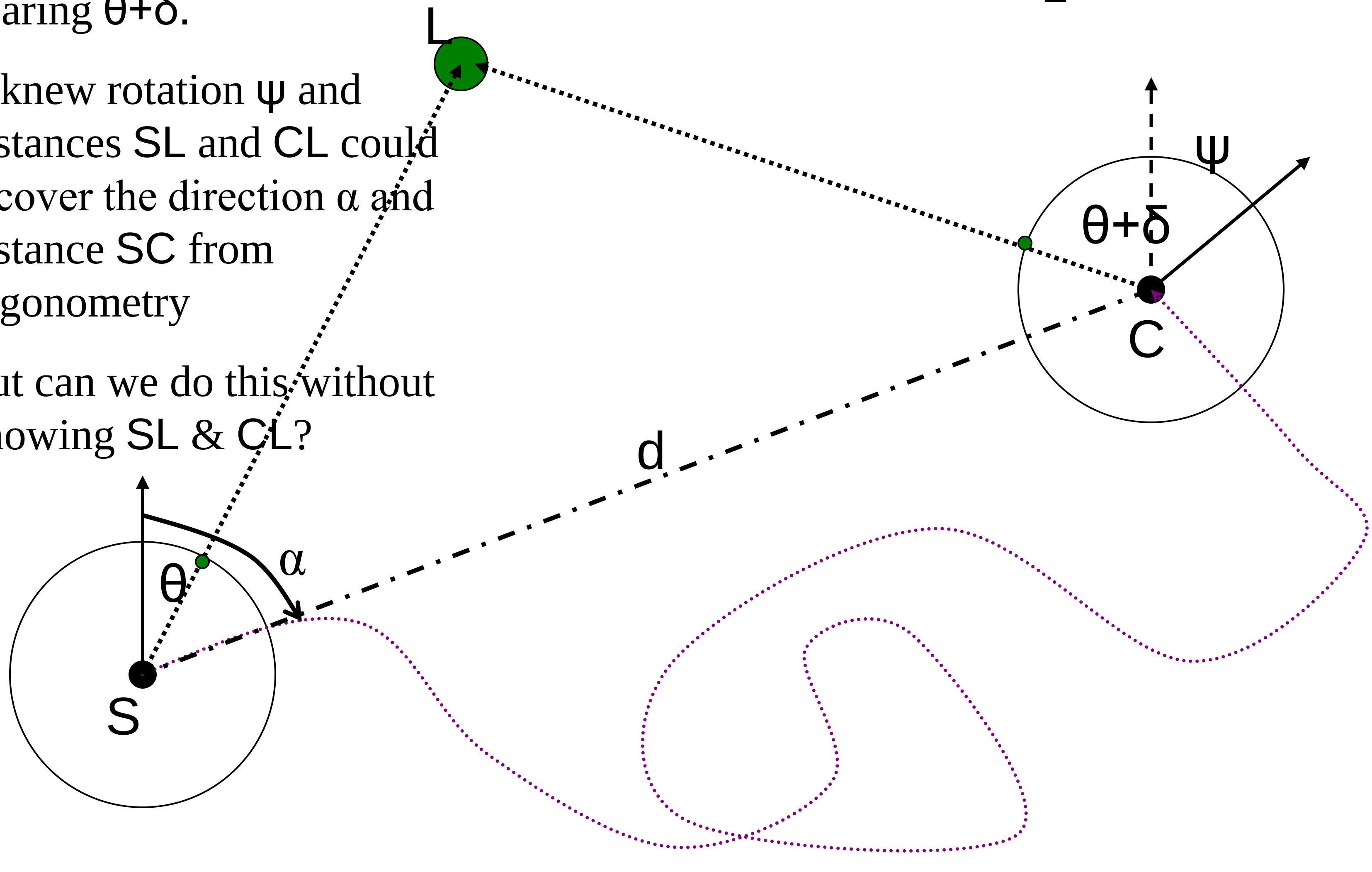
Visual homing: statement of problem

Starting at S, with landmark at bearing θ.

Move to C, landmark at bearing θ+δ.

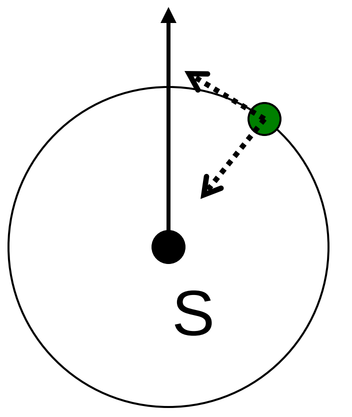
If knew rotation ψ and distances SL and CL could recover the direction α and distance SC from trigonometry

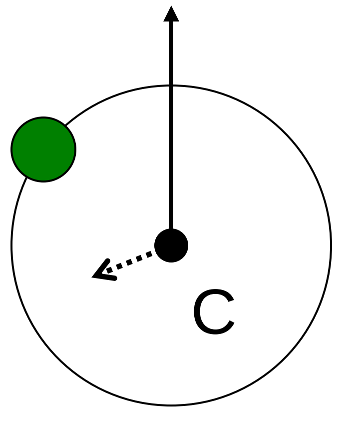
But can we do this without knowing SL & CL?



The snapshot model

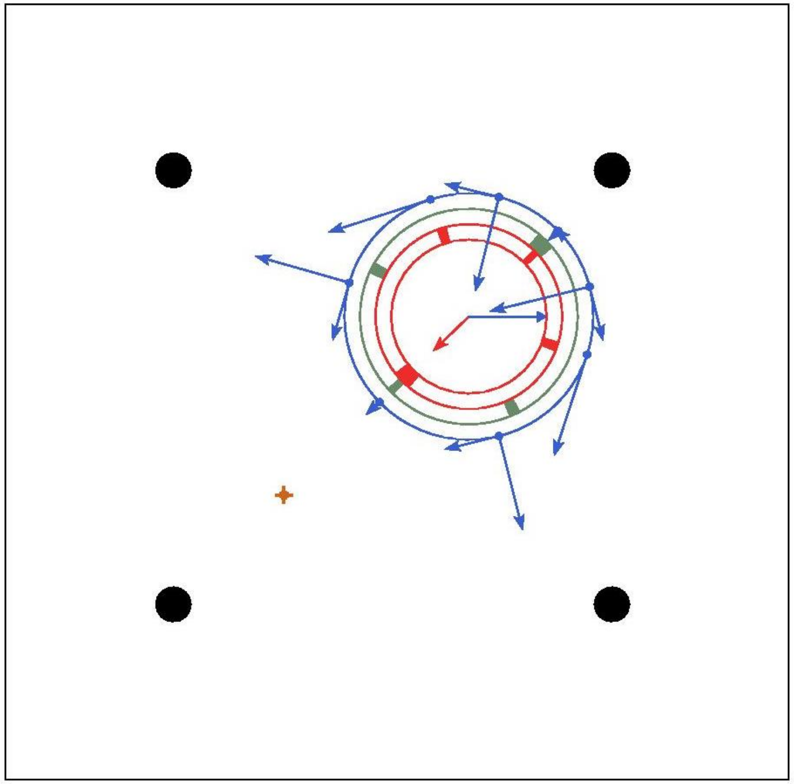
- Cartwright & Collett (1983)
- Store 360° 1-D image at home location
- In new location, assume the agent can rotate itself (or the current image) to the home orientation (using compass sense).
- Should move in direction that reduces landmark bearing and size discrepancy
- Iterate to return to home



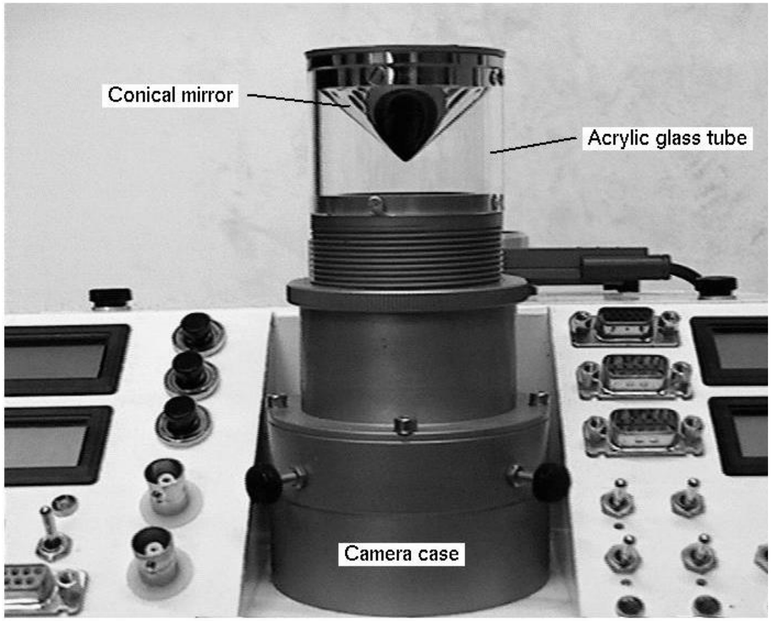


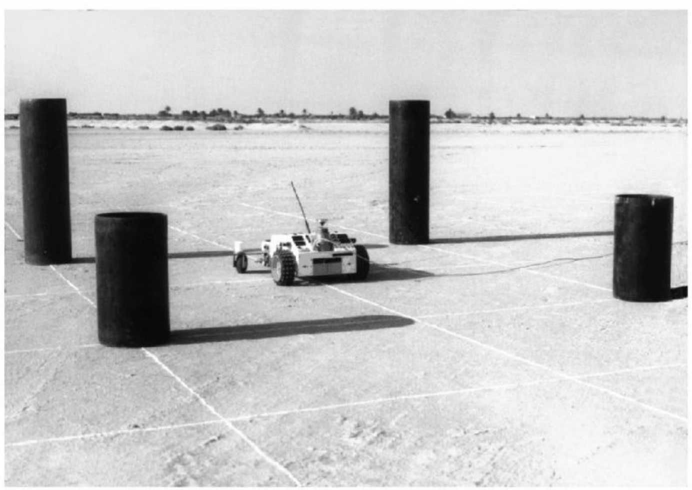
The snapshot model

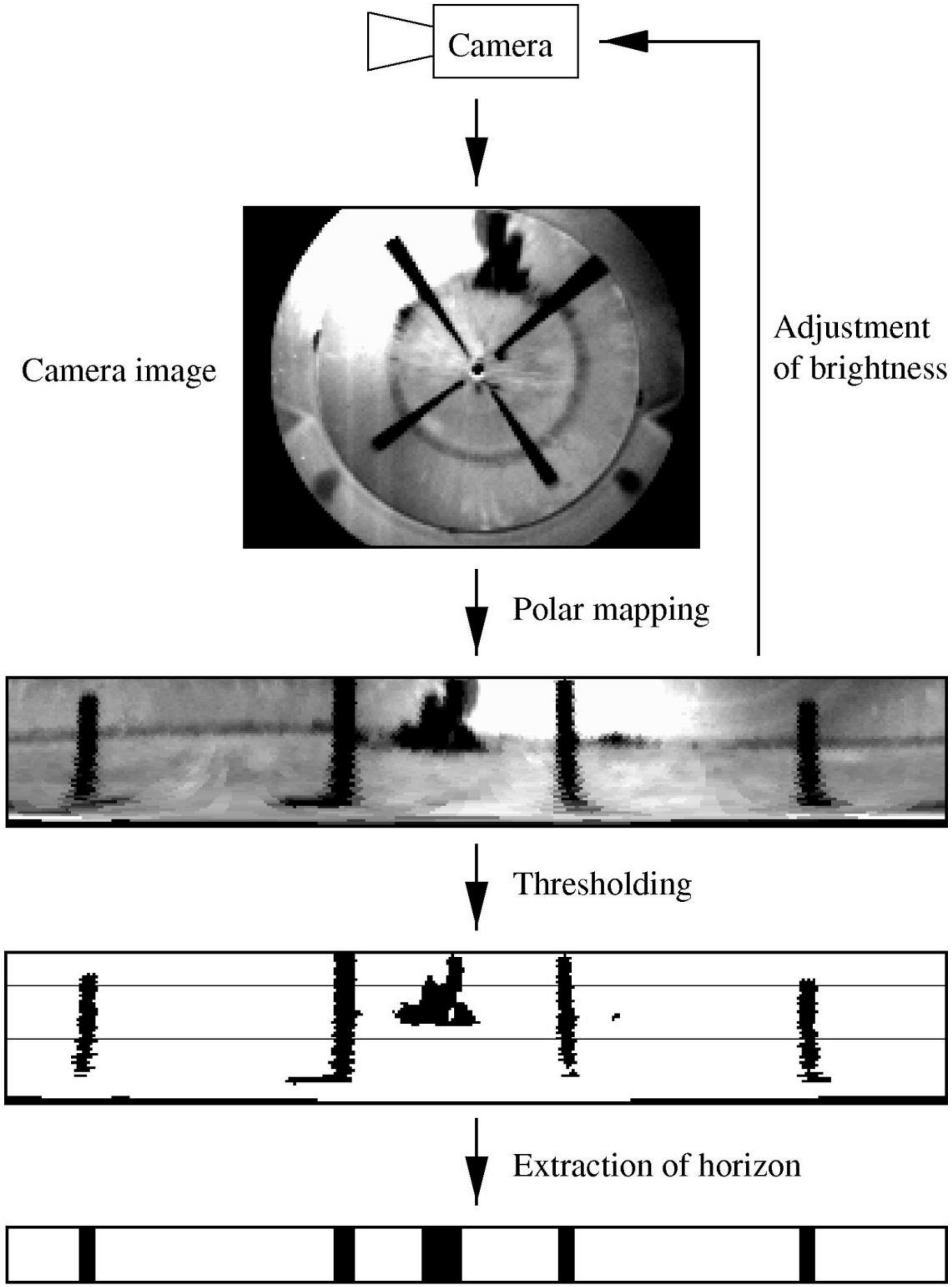
- Use whole image by dividing into segments (landmarks and spaces between them)
- Assume nearest neighbour pairing of segments
- Calculate vectors for each pairing and sum all to generate homing vector
- N.B. original model uses unit vectors, but can make them proportional

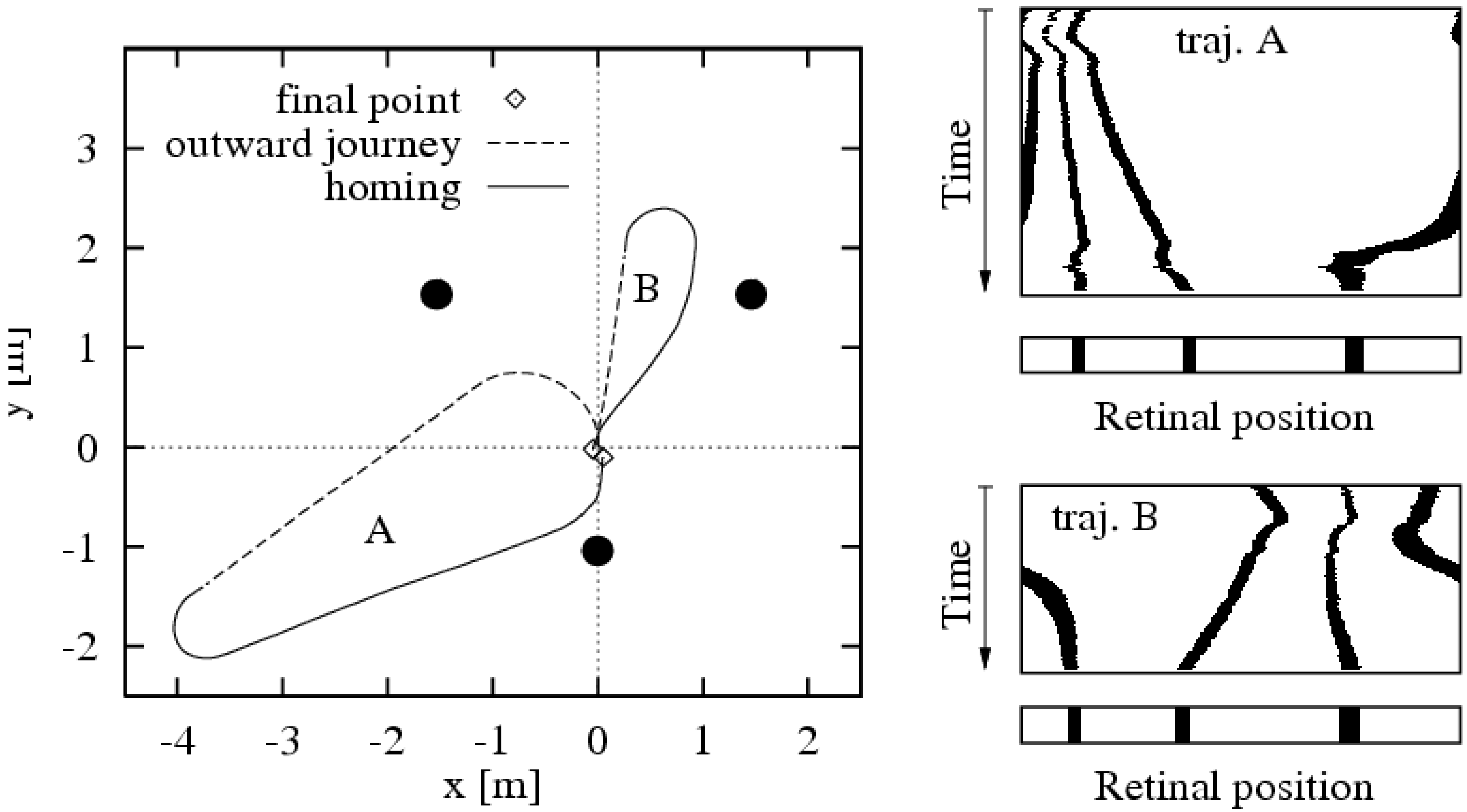


Inner ring is home snapshot, outer ring is current image, vector origins are centred on each inner ring segment and indicate direction and size change of corresponding outer ring segment.


Conical mirror
Acrylic glass tube
Camera case



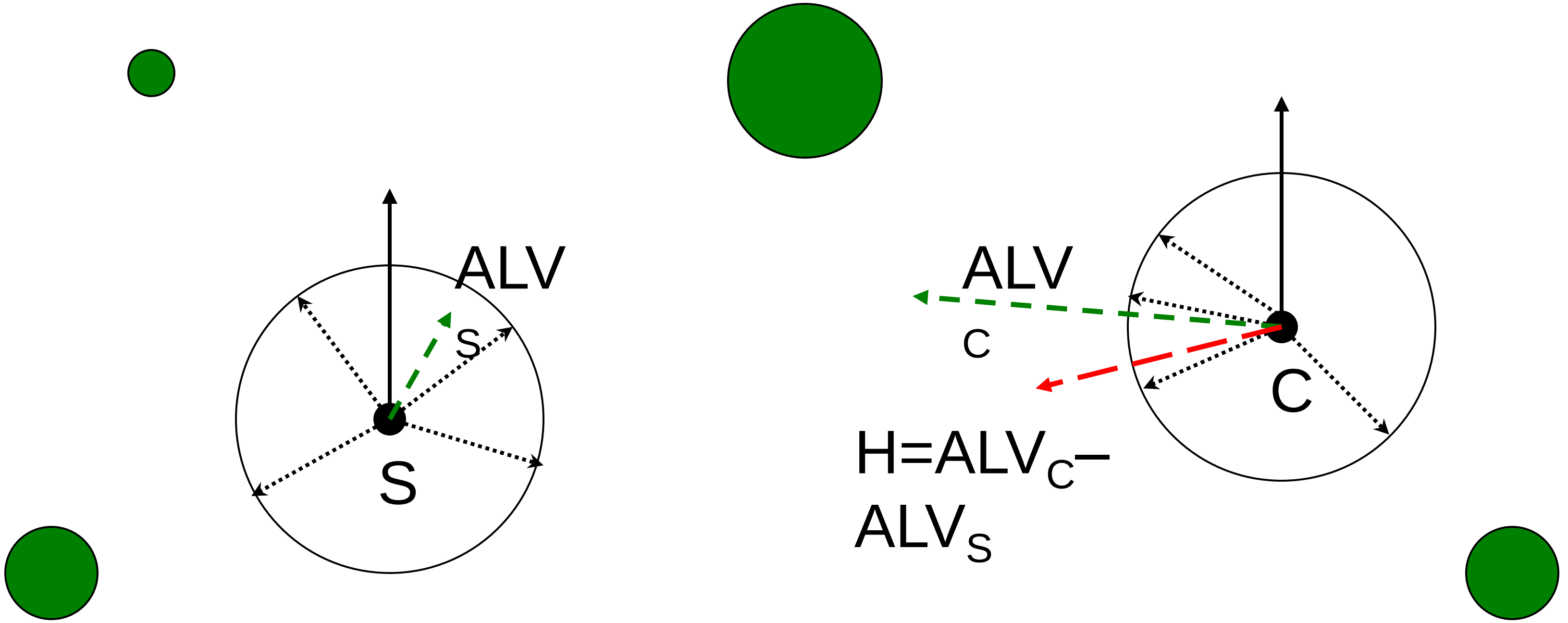

Camera
Camera image
Adjustment of brightness
Polar mapping
Thresholding
Extraction of horizon



Möller et al (2001)

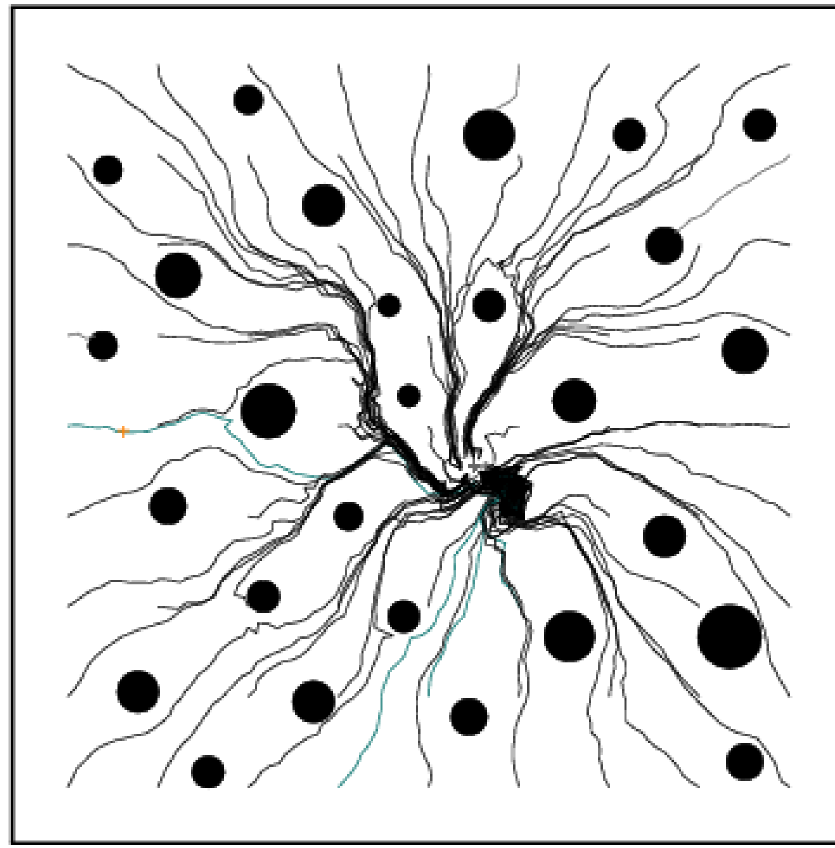
The average landmark vector model

- Möller (1999)
- Store average of unit vectors pointing at landmarks
- Subtract current average vector from stored vector to obtain approximate home vector

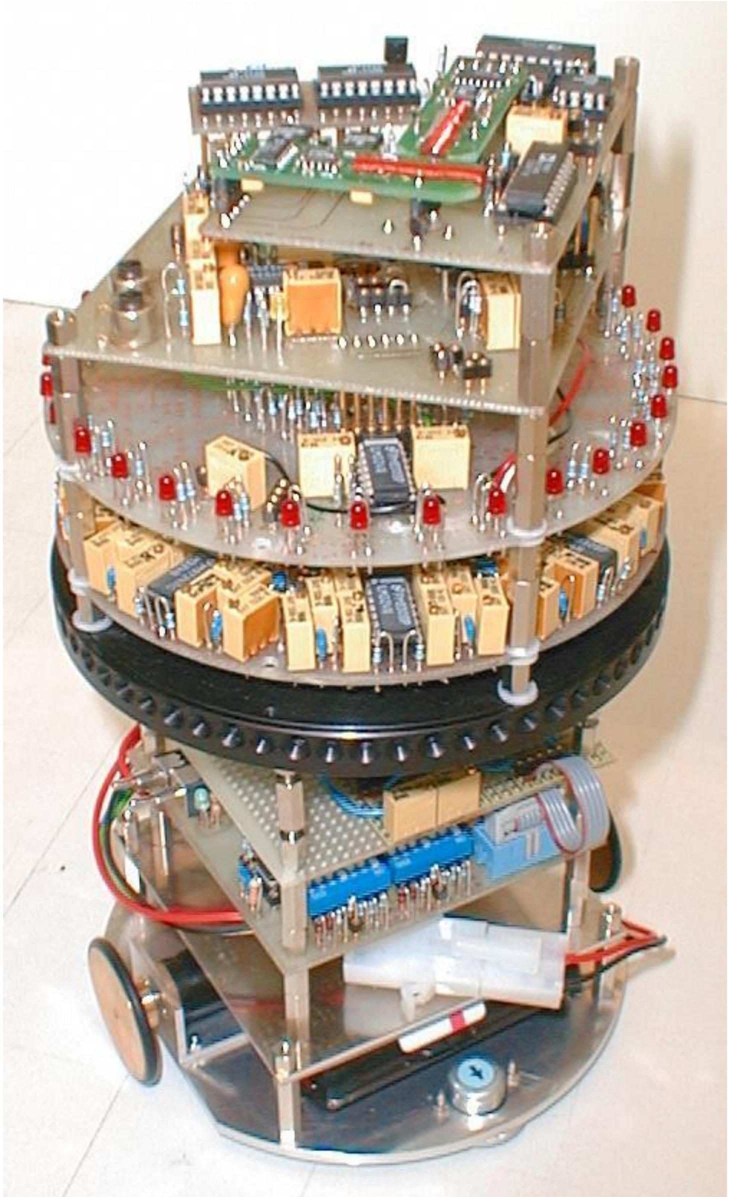


The average landmark vector model

- Reliably returns to S (provably when all landmarks seen at S are seen at C)
- Do not need to match landmarks (though still require separation from background, and compass)
- Only need to store one vector
- Can be efficiently implemented in hardware



Tracks in ALV simulation



Moeller (2001) – analogue robot implementing average landmark vector model

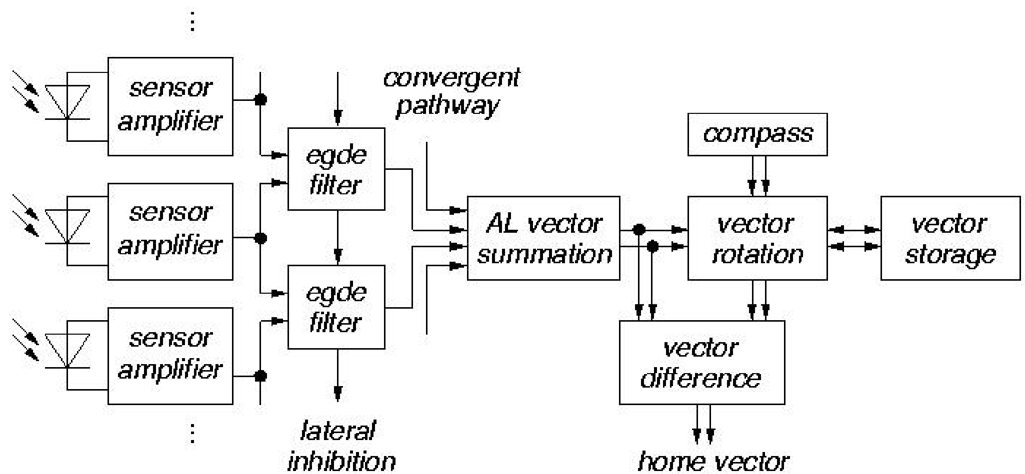


Image difference model

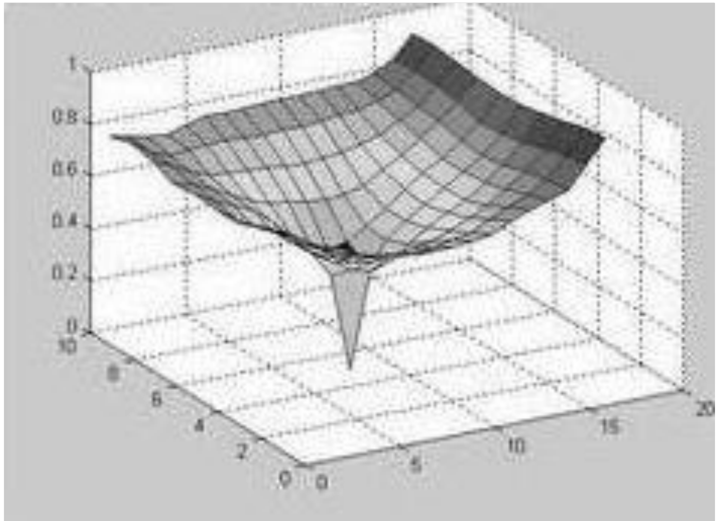
- Zeil et al (2003)

Take snapshot I_1 at home position

For homing, compare with current image I_2

Find the pixel-by-pixel difference of the two images…

$$RMS(I_1, I_2) = \sqrt{\frac{\sum_{i=1}^{n}(I_1(i) - I_2(i))^2}{n}}$$



...which decreases monotonically as robot approaches the home position: can follow gradient home

Summary

- Successful adaptive (intelligent?) behaviour can sometimes be achieved by relatively direct sensorimotor coupling = reactive control
- Complex behaviour can arise through simple interaction with a complex world
- Navigation (finding the way to a goal location) requires deciding where to go, but not necessarily knowing where you are

References

Herbert Simon (1969). *The sciences of the artificial*. Cambridge, Mass.: MIT Press

W. Grey Walter (1950) *An Imitation of Life*, **Scientific American**, May, p42-45 See also: http://www.ias.uwe.ac.uk/Robots/gwonline/gwonline.html

Owen Holland (2003) *Exploration and high adventure: the legacy of Grey Walter*, Philosophical Transactions of the Royal Society, 361:2085-2121

Franz, M.O. & Mallot, H.A. (2000) *Biomimetic robot navigation*. Robotics and Autonomous Systems, 30:133-153

Cartwright, B. and Collett, T. (1983) *Landmark learning in bees*. Journal of Comparative Physiology, 151:521-543

Möller (1999) *Visual homing in analog hardware* Int J Neural Syst. 9(5):383-9.

Zeil J, Hofmann MI, Chahl J (2003) *The catchment areas of panoramic snapshots in outdoor scenes*. Journal of the Optical Society of America A 20: 450 – 469.