Sensing self motion

Key points:

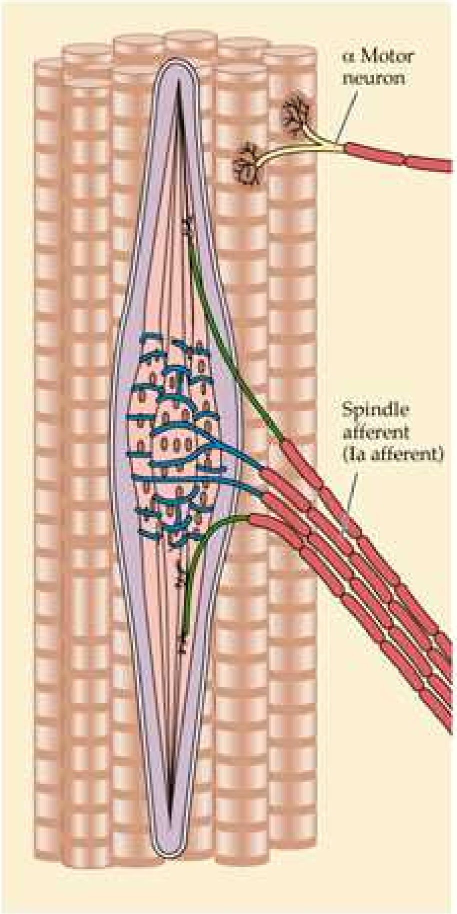
- Why robots need self-sensing
- Sensors for proprioception
  - in biological systems
  - in robot systems
    - Position sensing
    - Velocity and acceleration sensing
    - Force sensing
- Vision based proprioception

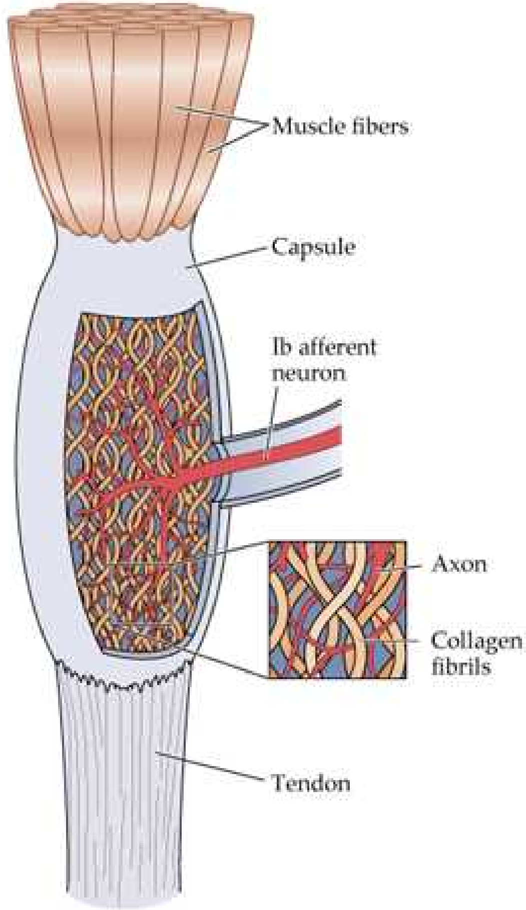
Why robots need self-sensing

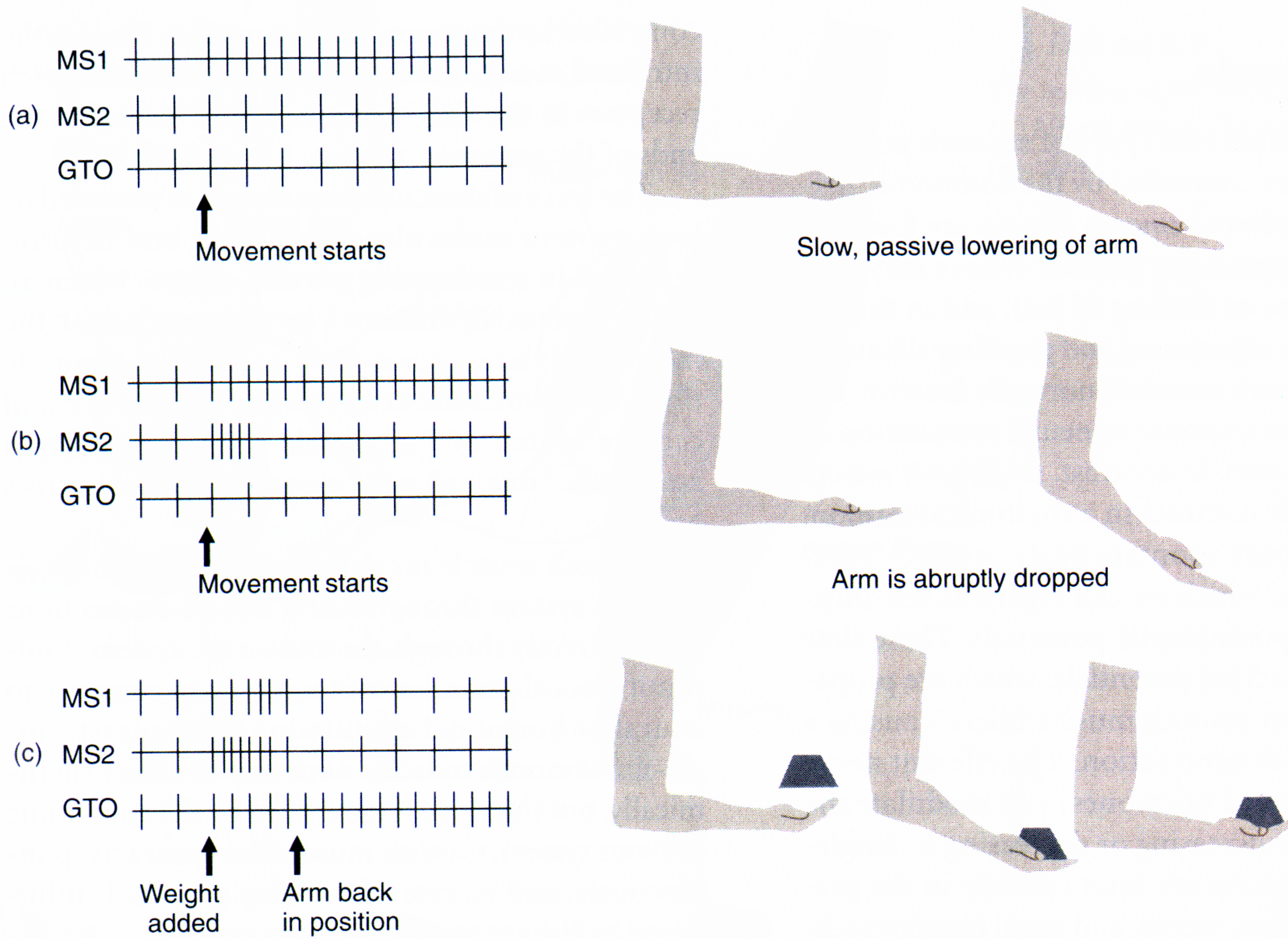
- For a robot to act successfully in the real world it needs to be able to perceive the world, and itself in the world.
- In particular, to control its own actions, it needs information about the position and movement of its body and parts.
- Our body contains at least as many sensors for our own movement as it does for signals from the world.

Proprioception: detecting our own movements

- To control our limbs we need feedback.
- Muscle spindles
  - * where: length
  - * how fast: rate of stretch
- Golgi tendon organ
  - * how hard: force



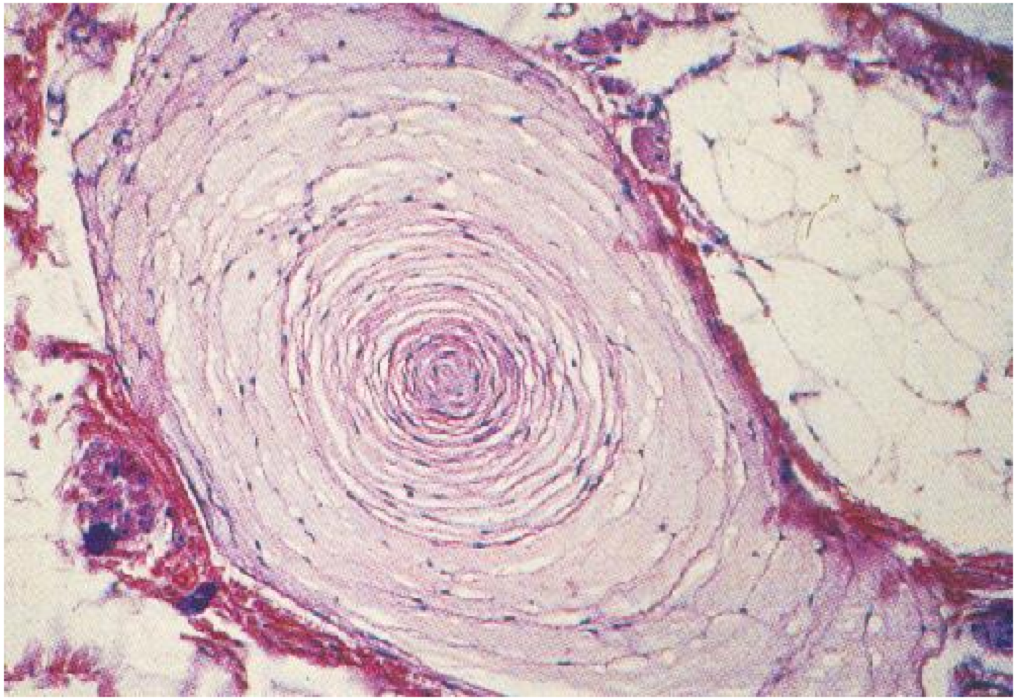




MS1
(a) MS2
GTO
Movement starts
Slow, passive lowering of arm
MS1
(b) MS2
GTO
Movement starts
Arm is abruptly dropped
MS1
(c) MS2
GTO
Weight added
Arm back in position

Proprioception: detecting our own movements

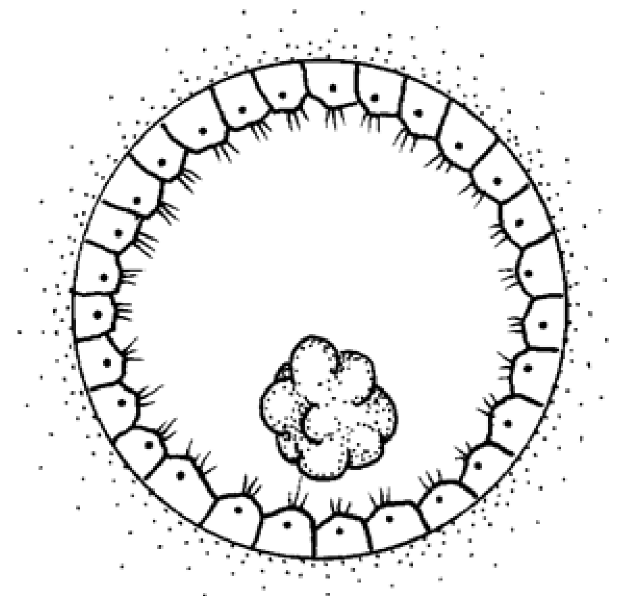
- To control our limbs we need feedback on where they are.
- Muscle spindles
- Golgi tendon organ
- Pressure sensors in skin



Pacinian corpuscle –
transient pressure response

Proprioception (cont.)

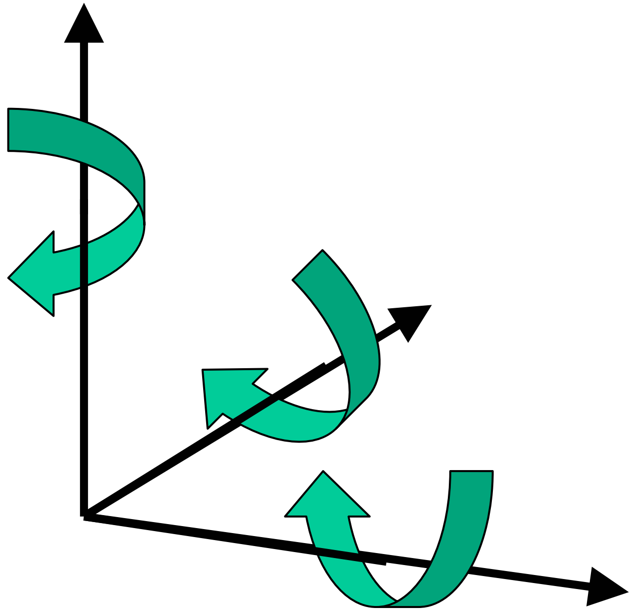
- To detect the motion of our whole body have vestibular system based on statocyst
- Statolith (calcium nodule) affected by gravity (or inertia during motion) causes deflection of hair cells that activate neurons

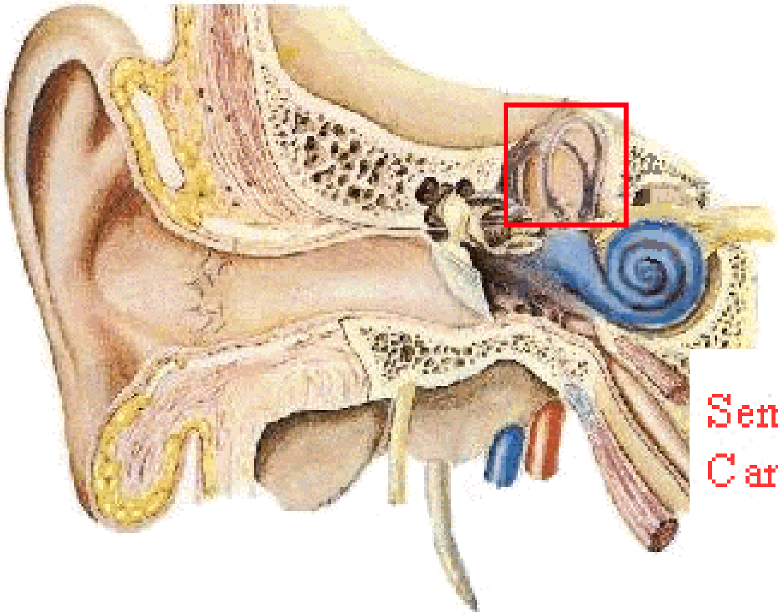


Describing movement of body

Requires:

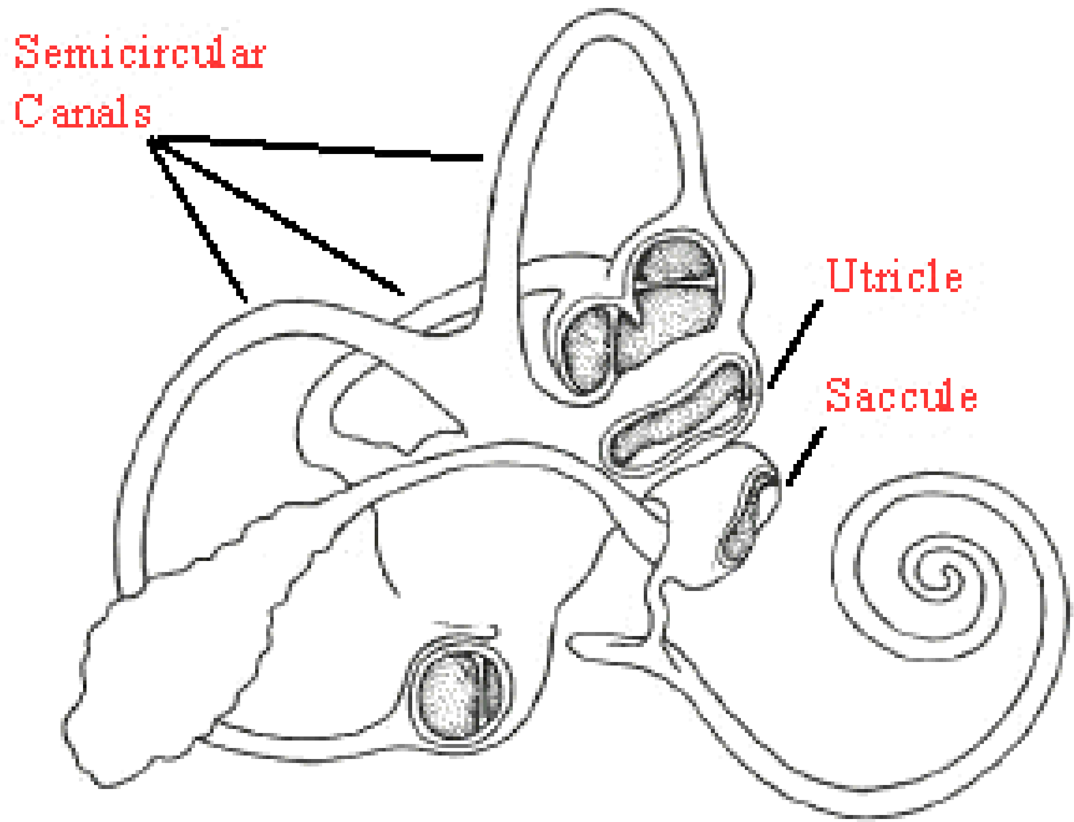
- Three translation components
- Three rotatory components





Vestibular System

Utricle and Saccule detect linear acceleration.

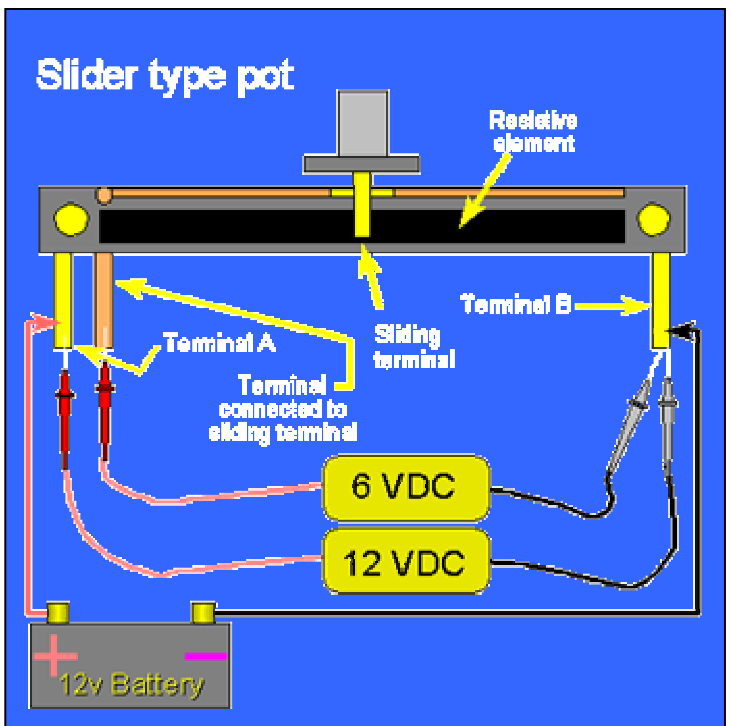


Semicircular canals detect rotary acceleration in three orthogonal axes

Fast vestibular-ocular reflex for eye stabilisation

For a robot:

- Need to sense motor/joint positions with e.g.:
  - Potentiometer (variable current control thru 6V)
  - Optical encoder (counts axis turning)



For a robot:

- Velocity by position change over time or other direct measurement - tachometer
- E.g. using principal of dc motor in reverse: voltage output proportional to rotation speed

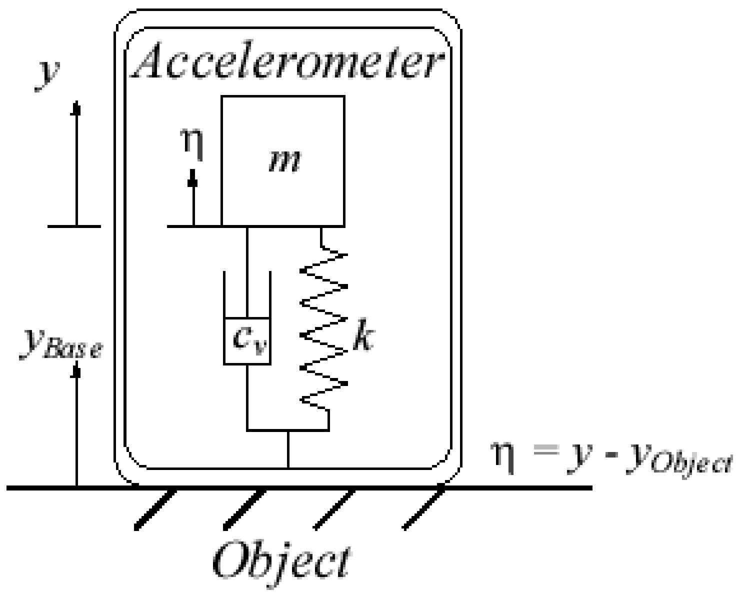
(Why not use input to estimate output…?)

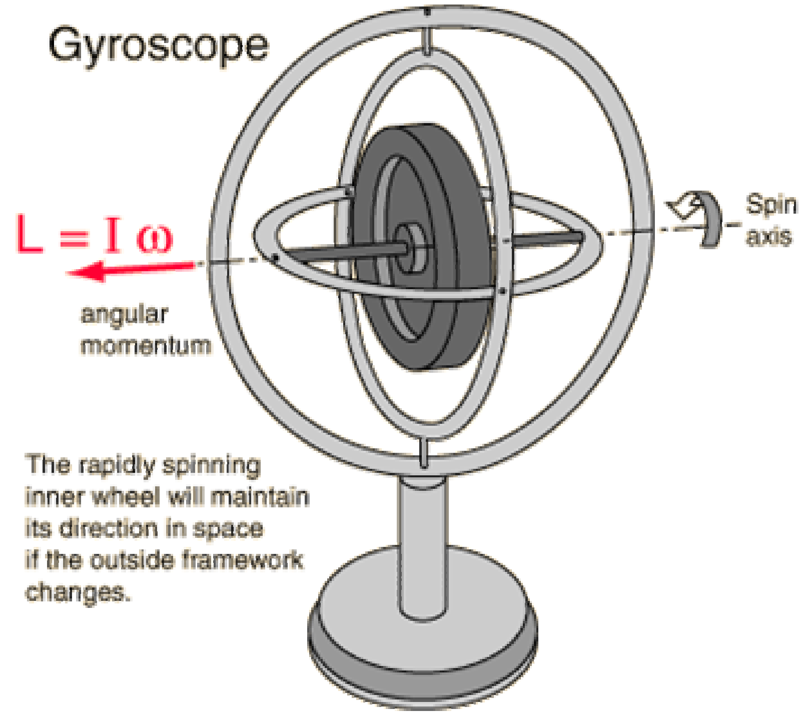
- Acceleration: could use velocity over time, but more commonly, sense movement or force created when known mass accelerates
- I.e. similar to statocyst

Accelerometer:

measures displacement of weight due to inertia

Gyroscope: uses conservation of angular momentum





There are many alternative forms of these devices, allowing high accuracy and miniaturisation

Inertial Navigation System (INS)

- Three accelerometers for linear axes
- Three gyroscopes for rotational axes (or to stabilise platform for accelerometers)

- By integrating over time can track exact spatial position
- Viable in real time with fast computers
- But potential for cumulative error

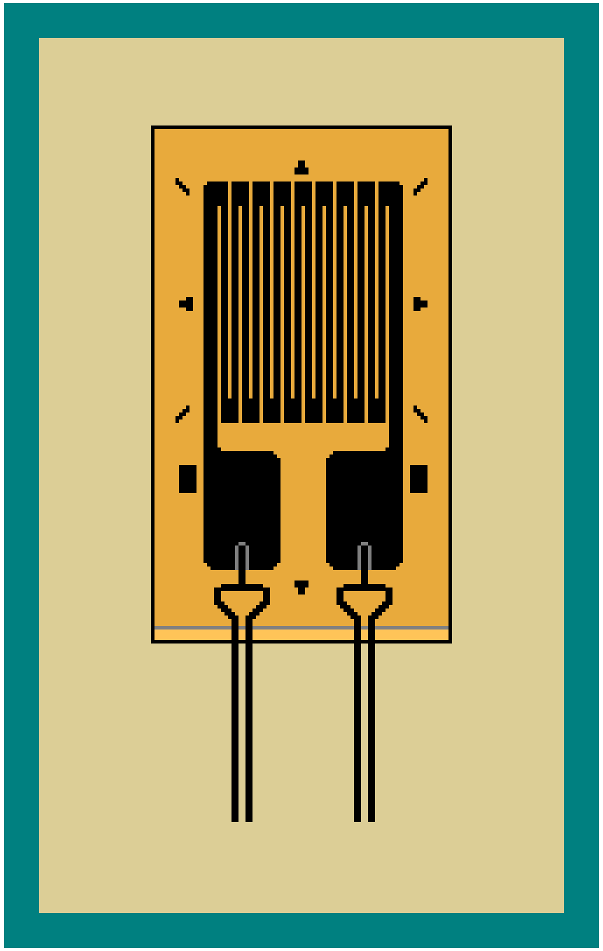
For a robot:

Also want to sense force:

e.g.

Strain gauge – resistance change with deformation

Piezoelectric - charge created by deformation of quartz crystal (n.b. this is transient)



For a robot:

Various other sensors may be used to measure the robot's position and movement, e.g.:

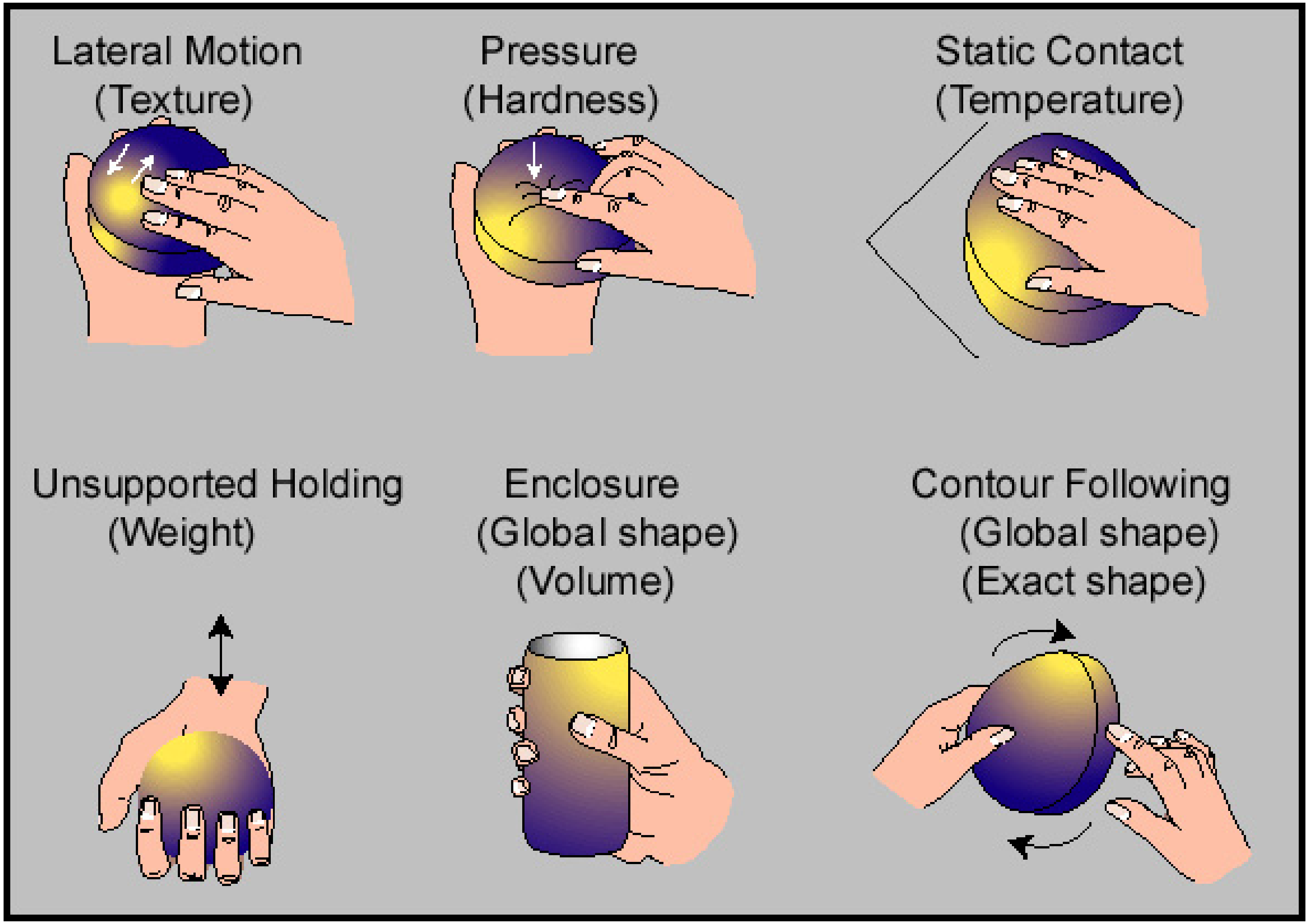
- Tilt sensors
- Compass
- GPS

May use external measures e.g. camera tracking of limb or robot position.

Some issues for sensors

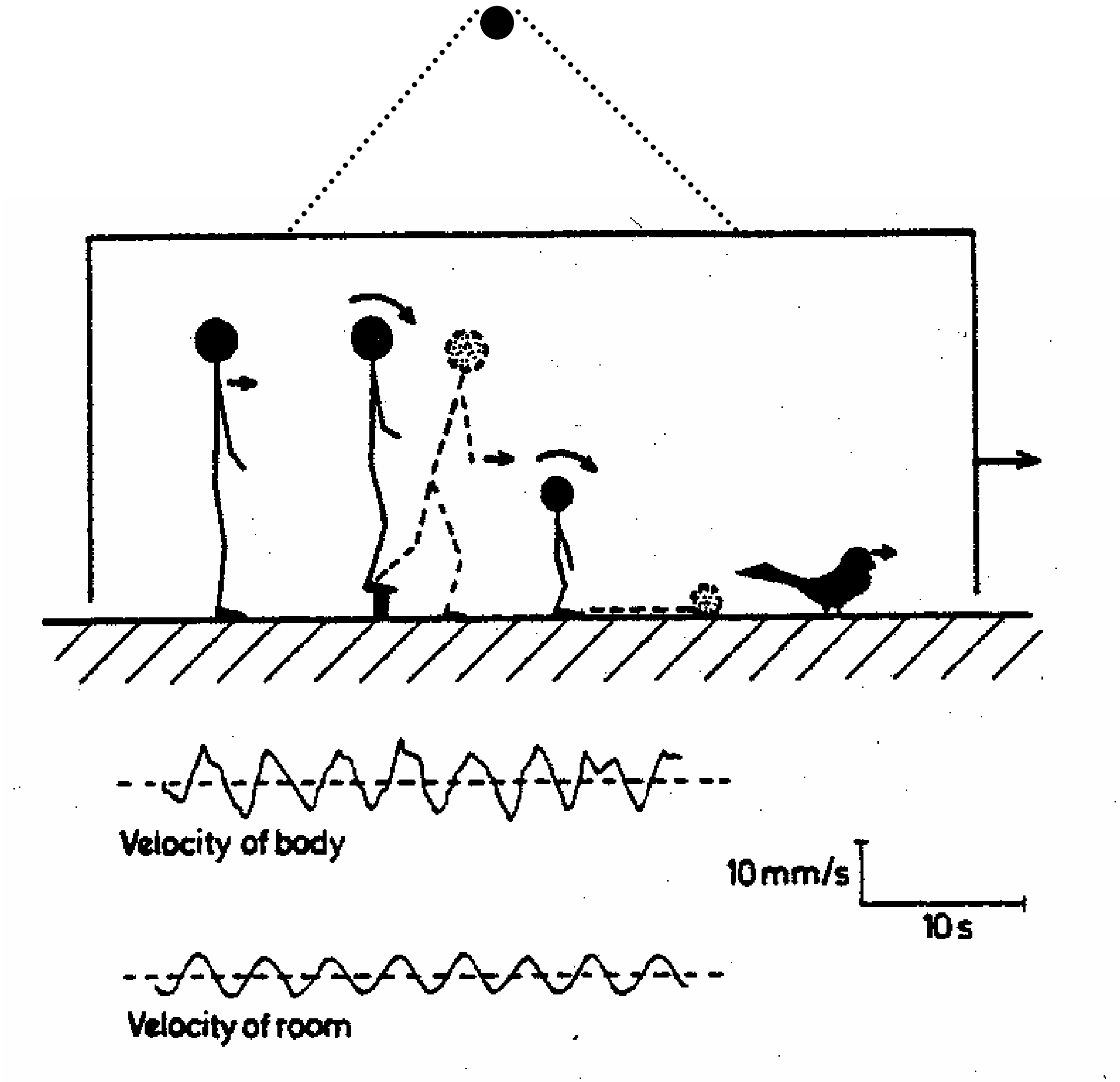
- What range, resolution and accuracy are required? How easy to calibrate?
- What speed (i.e. what delay is acceptable) and what frequency of sampling?
- How many sensors? Positioned where?
- Is information used locally or centrally?
- Does it need to be combined?

e.g. Haptic perception – combines muscle & touch sense



Vision as proprioception?

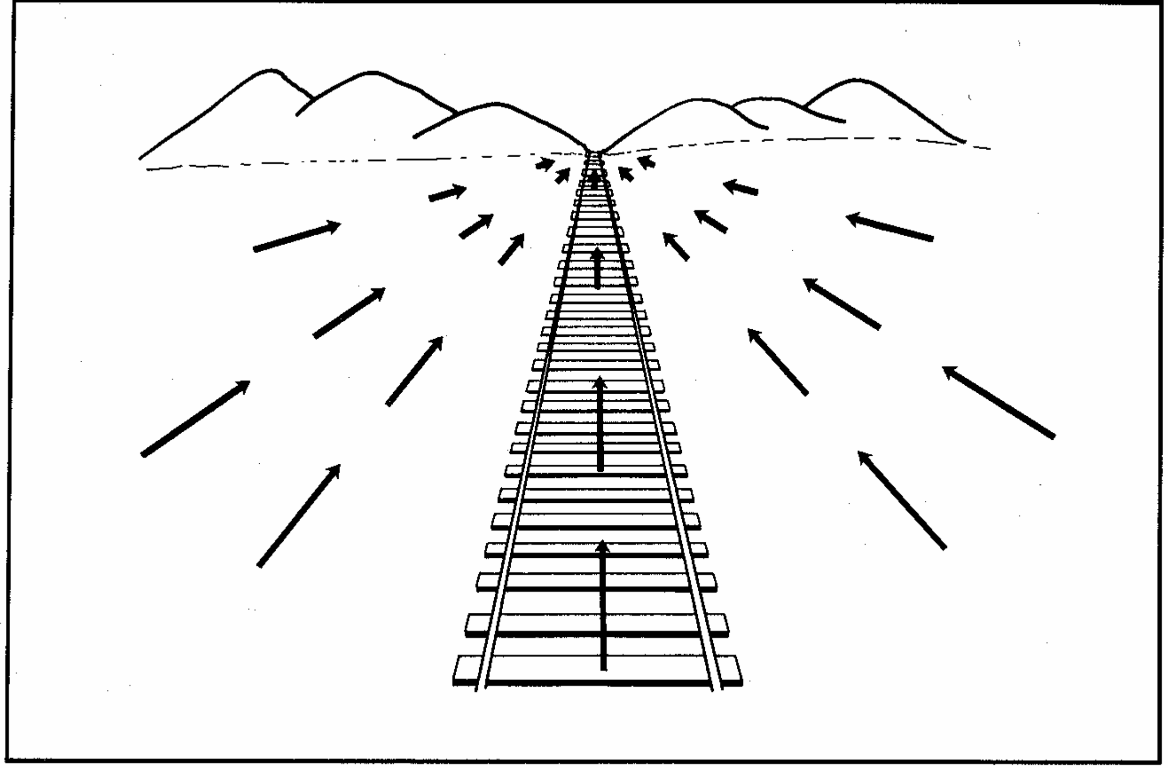
- An important function of vision is direct control of motor actions
- e.g. simply standing up...



The ‘swinging room’ - Lee and Lishman (1975)

Optical flow

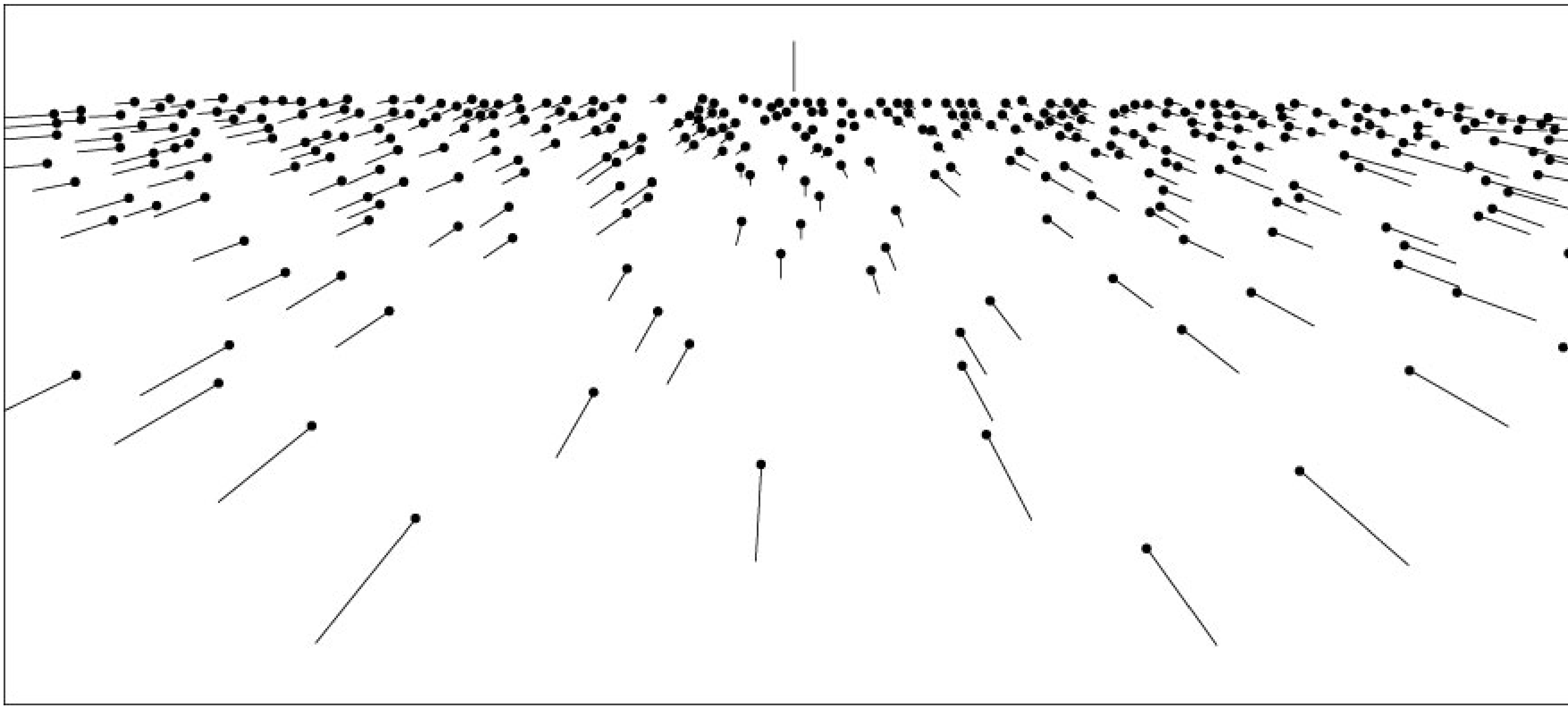
FIGURE 11.7



The optic flow field for a person sitting on the roof of a train, facing backwards.

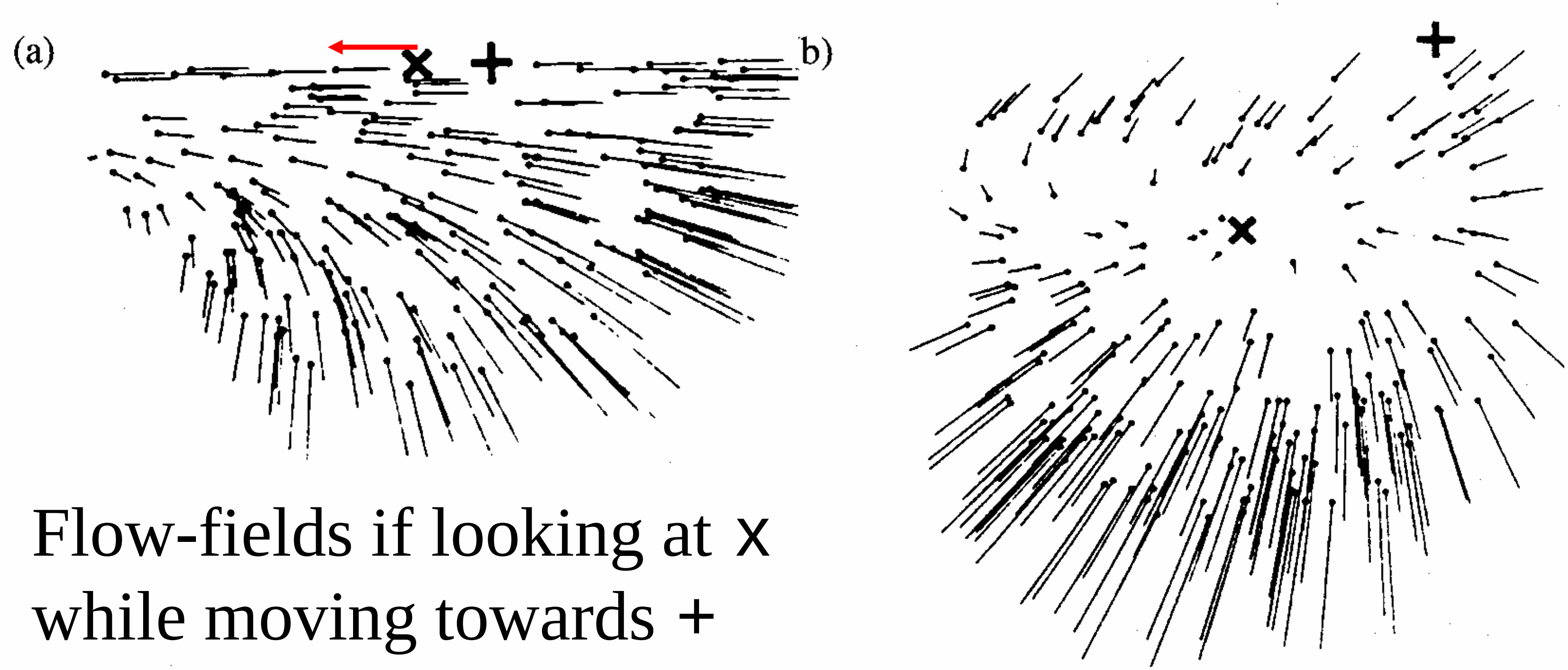
Optical flow:

Heading = focus of expansion



…provided can discount flow caused by eye movements

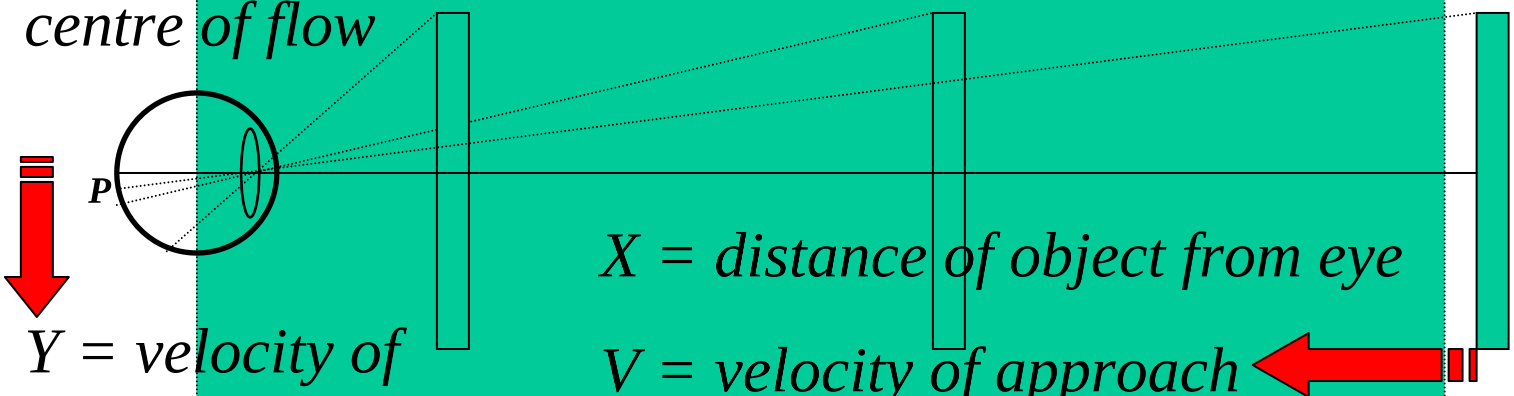
Optical flow:
Flow on retina = forward translation + eye rotation



Flow-fields if looking at x while moving towards +
Bruce et al (op. cit) fig 13.6

t

P = distance of image from centre of flow



X = distance of object from eye

V = velocity of approach

Y = velocity of P on retina

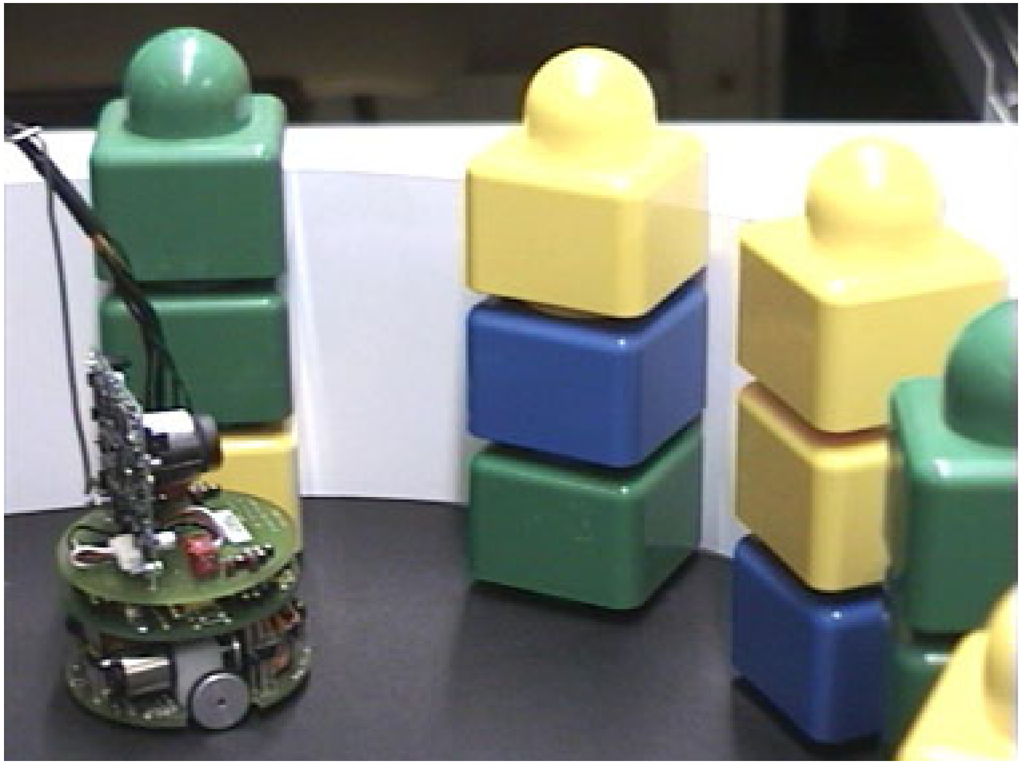
“tau” = P/Y = X/V

rate of image expansion = time to contact

Lee (1980) suggested visual system can detect *tau* directly and use to avoid collisions e.g. correct braking.

Using expansion as a cue to avoid collision is a common principle in animals, and has been used on robots

- E.g. robot controller based on neural processing in locust – Blanchard et. al. (2000)



Summary

- Have discussed a variety of natural and artificial sensors for self motion
- Have hardly discussed how the transduced signal should be processed to use in control for a task.
  - E.g. knowing about muscle and touch sensors doesn’t explain how to manipulate objects