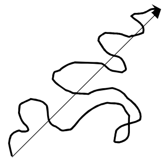
Navigation 3: Path integration

Relative position calculation

- Simple concept: by integrating velocity over time, should be able to keep track of current position relative to starting position.



e.g.

$x(t+\Delta t)=x(t)+\cos(\theta(t))s(t)\Delta t$

$y(t+\Delta t)=y(t)+\sin(\theta(t))s(t)\Delta t$

Where

Δt is the time step, $\theta(t)$ the heading angle and $s(t)$ the speed during that time step.

Relative position calculation

Dead reckoning: general term, sometimes taken to mean making the calculation from motor commands only (i.e. not measuring actual motion).

Odometry: implies use of proprioception (usually wheel encoders) to provide the motion signal for integration. Usually, without external reference.

Path integration: term most commonly used in biology. May involve external reference for heading and/or distance measurement (e.g. compass).

Path integration in robots

Requires information on heading and speed:
e.g. for dual-drive robot with wheel encoders can approximate by:

$s=(s_R+s_L)/2 \qquad \theta=(s_R-s_L)/base$

- Generally cheap and simple to implement
- Important component in more complex systems, e.g. for extending vision-based homing, or SLAM.
- Main problem is cumulative errors, either systematic (e.g. different wheels, limited resolution) or unsystematic (e.g. wheel slip)

Path integration in robots

Various methods to address the error problem:

- improve the sensors, e.g. separate odometry wheels, higher resolution optical encoders
- calibrate the system to reduce systematic error
- use more predictable motion, such as straight lines and fixed turn sizes
- maintain an error estimate along with the location estimate
- combine several sensory devices using sensor fusion methods
- use an external reference to measure direction

Polarised light compass

Desert ants (and many other animals) have visual receptors tuned to the polarisation plane of light.

Skylight has a natural polarisation pattern

The receptors are tuned in orthogonal directions, and opponent processing by ‘POL-neurons’ produces an intensity-independent response.

Polarised light compass

This mechanism has been replicated on the Sahabot. Uses three pairs of sensors oriented at 60 degree axes.

Can create lookup table to determine direction indicated by output ratios of the three sensors. 180 degree ambiguity resolved by sensing sun direction.

Results of path integration using polarised light compass : much more accurate than odometry

Measuring velocity

Path integration requires estimate of speed as well as direction.

Ants do not have wheel-encoders, so how do they measure their speed?

- Counting steps?
- Measure energy expenditure?
- Use optical flow?

Strong evidence from bees that optic flow is important:

Optical flow for robot odometry

Campbell et al 2004

- Assume camera is at fixed angle
- Assume flat ground
- Calibrate to horizon
- Extract flow above horizon for rotation estimate.
- Extract flow below horizon, convert to ground plane, and use for translation estimate

Optical flow for robot odometry

Outdoors:

- rotation error reduced (high contrast, distant horizon)
- translation error increased (glare, undulations, texture above ground plane)

Combining vectors and landmarks

- ‘Home vector’ from path integration can get insect close enough to goal to use visual homing for final approach.
- Potential to construct series of snapshots and vectors into a route.
- Several intersecting routes start to resemble a map…
- Do animals have maps, and do robots need them?

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