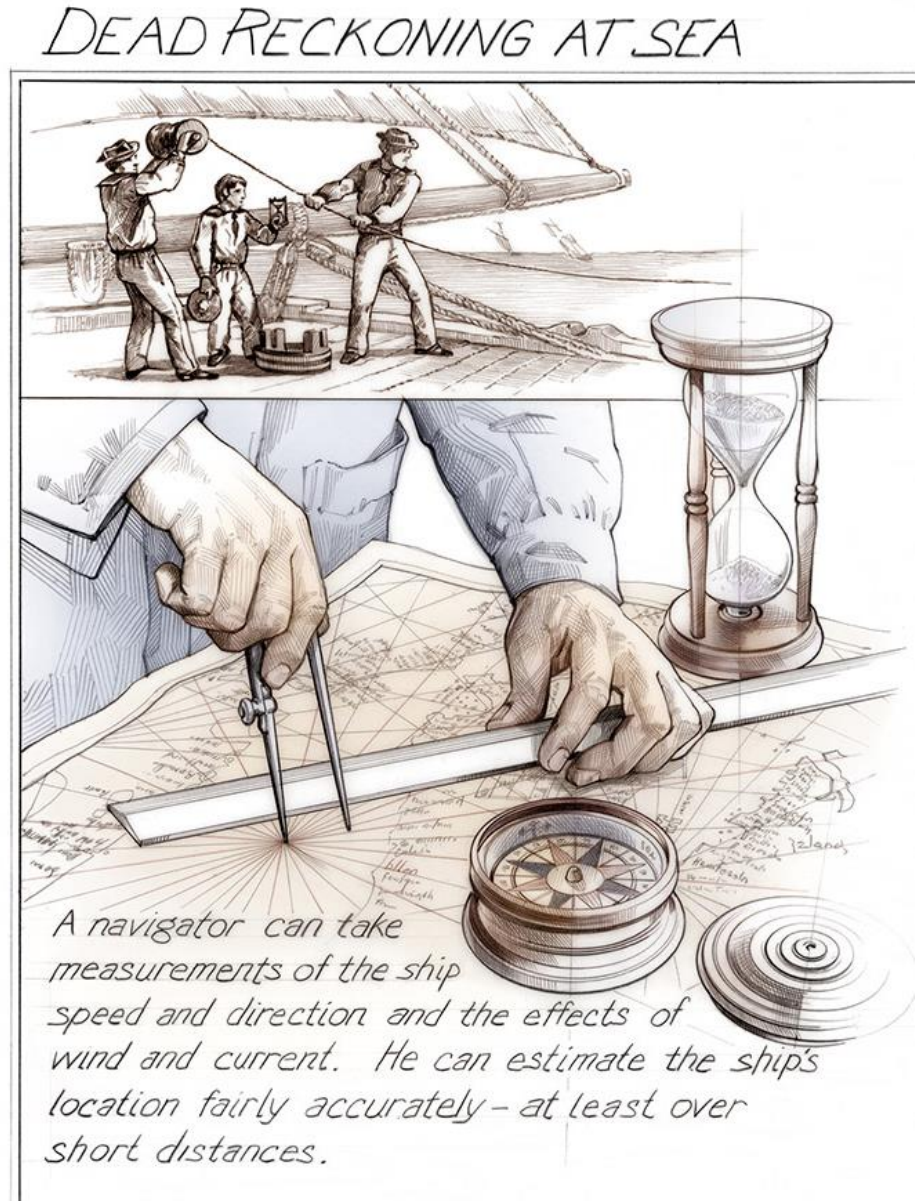
Dead Reckoning

aka Odometry,
Position Integration

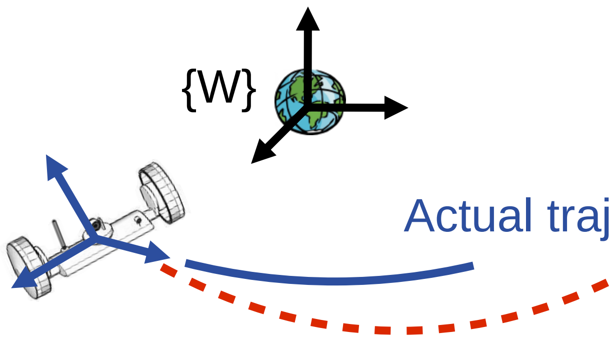


Curious about the origin of the term?
https://www.straightdope.com/columns/read/2053/is-dead-reckoning-short-for-deduced-reckoning/

Computing the pose of a mobile robot

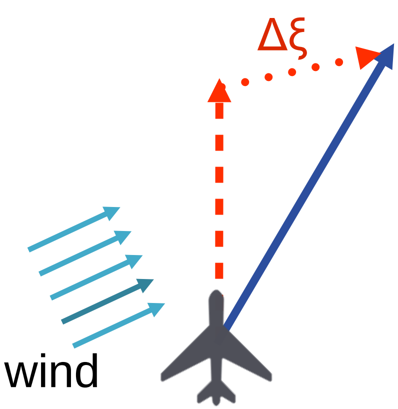
What is robot's *pose* in {W} after moving at a velocity **(v,ω),** for 1 minute?

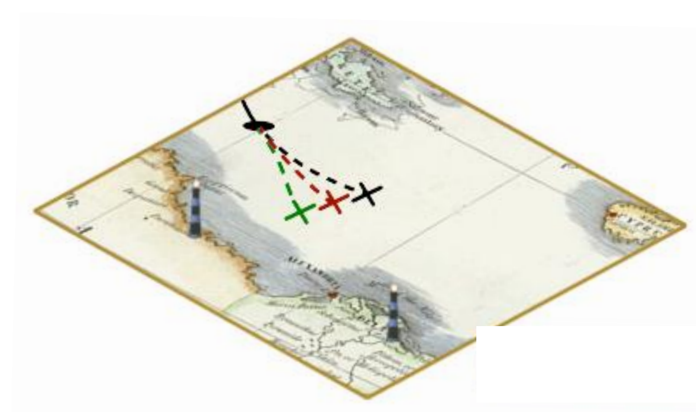
$\Delta\xi(t)$?



Actual trajectory $\xi(t) = [x(t)\ y(t)\ \theta(t)]$

Target trajectory $\xi_d(t) = [x_d(t)\ y_d(t)\ \theta_d(t)]$





Dead (= Deduced) Reckoning

In absence of an external infrastructure (e.g., GPS + Filters + Cameras) able to track the pose of the robot, numerical integration can be used, based on the kinematic model of the robot and on the knowledge of the evolution of the issued velocity commands [$v(t)$ $\omega(t)$]

→ Incrementally evolve the state using on-board information

Deduced reckoning: The process of (incrementally, at discrete time steps) determining its own position based on the knowledge of some reference point (a fix) and the knowledge or the estimate of the velocities (speeds and headings) actuated over time. Data related to exogenous and endogenous disturbances can be included.

reckoning *noun*

reck·on·ing | \ ˈre-kə-niŋ, ˈrek-niŋ\

Definition of *reckoning*

1 : the act or an instance of reckoning: such as

- **a** : ACCOUNT, BILL
- **b** : COMPUTATION
- **c** : calculation of a ship's position

Dead Reckoning (originally from navigation)

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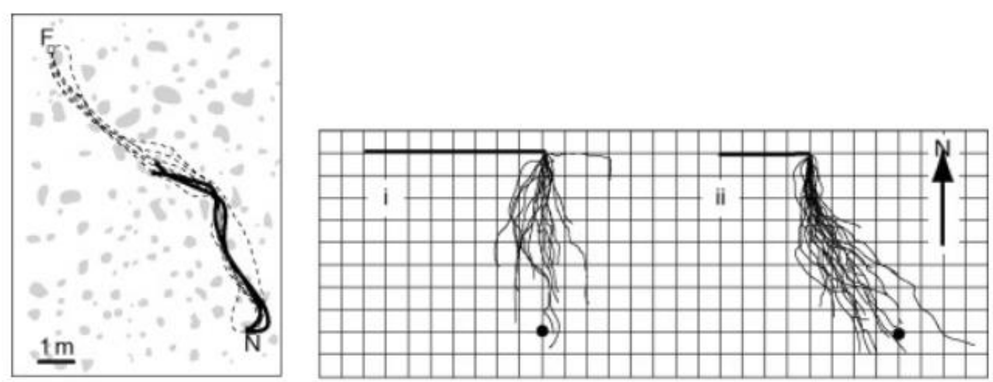
Odometry

=

Path Integration (neuroscience/biology/etology)

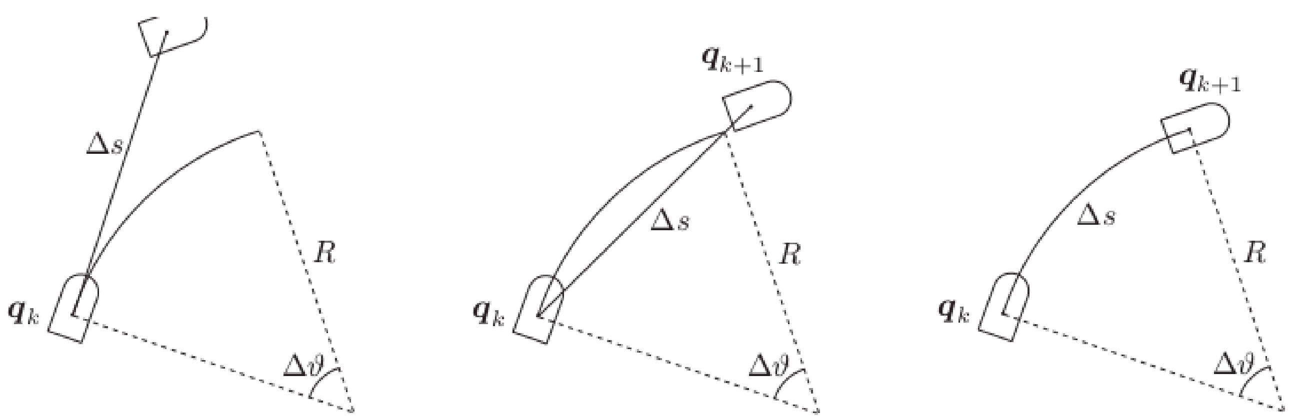


(a) (b)

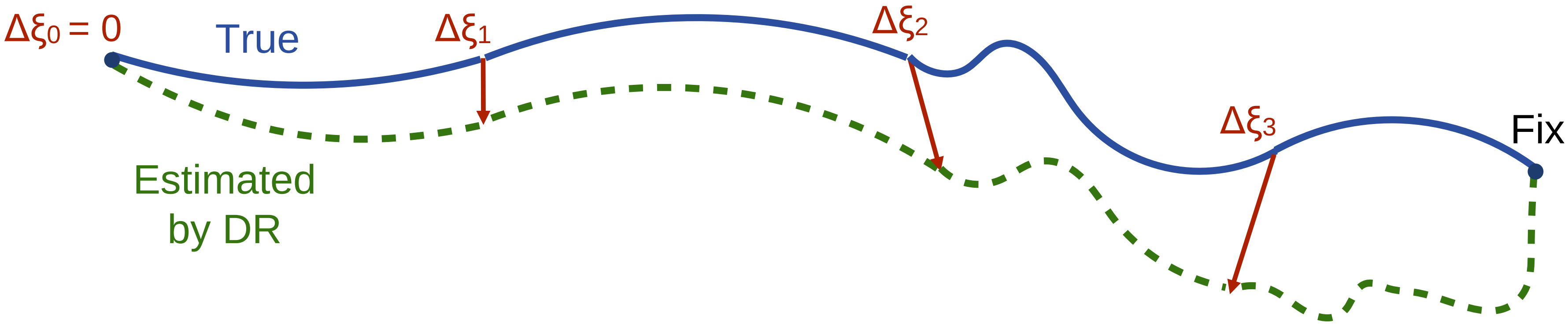
Approach

- Time is discretized in short intervals of length Δt
- When used online, a numeric integration is performed at each time step
- During a time interval $[t_k, t_{k+1}]$, the velocity inputs v_k and ω_k are assumed to be constant and the robot moves along a circle of radius v_k / ω_k centered at the ICR(t), or moves along a segment if $\omega_k = 0$
- At step k, robot's pose ξ_k and its velocities are assumed to be known and are used to compute ξ_{k+1} by integration of the kinematic model over $[t_k, t_{k+1}]$

Euler | Runge-Kutta | Exact

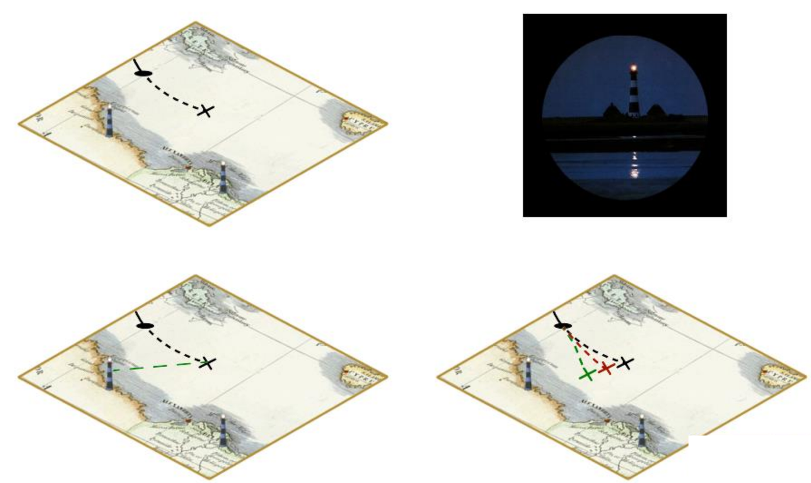


Problem: odometry drift



The uncertainty of dead reckoning / odometry increases over time
➔ A new fix is intermittently needed to determine a more reliable position from which a new dead reckoning process (i.e., integration) can be restarted

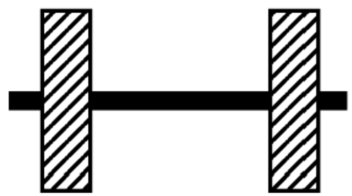
In navigation lighthouses and/or celestial observations were used to get a new fix



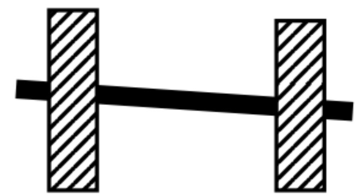
Sources of error

- Numerical integration errors (approximations, floating point rounding, ….)
- Error readings from the wheel encoders
- Wheel slippage (friction issues, uneven ground, …)
- Inaccurate measurement or calibration of wheel and chassis parameters, that are reflected in inaccuracies in the results from the kinematic model

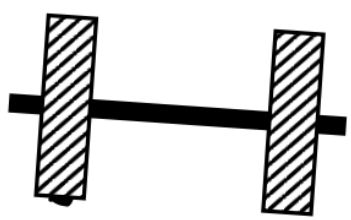
E.g. for wheeled robots



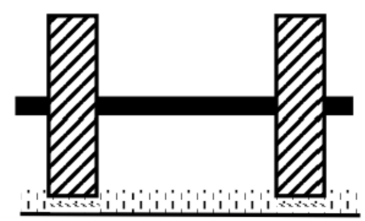
ideal case



different wheel diameters

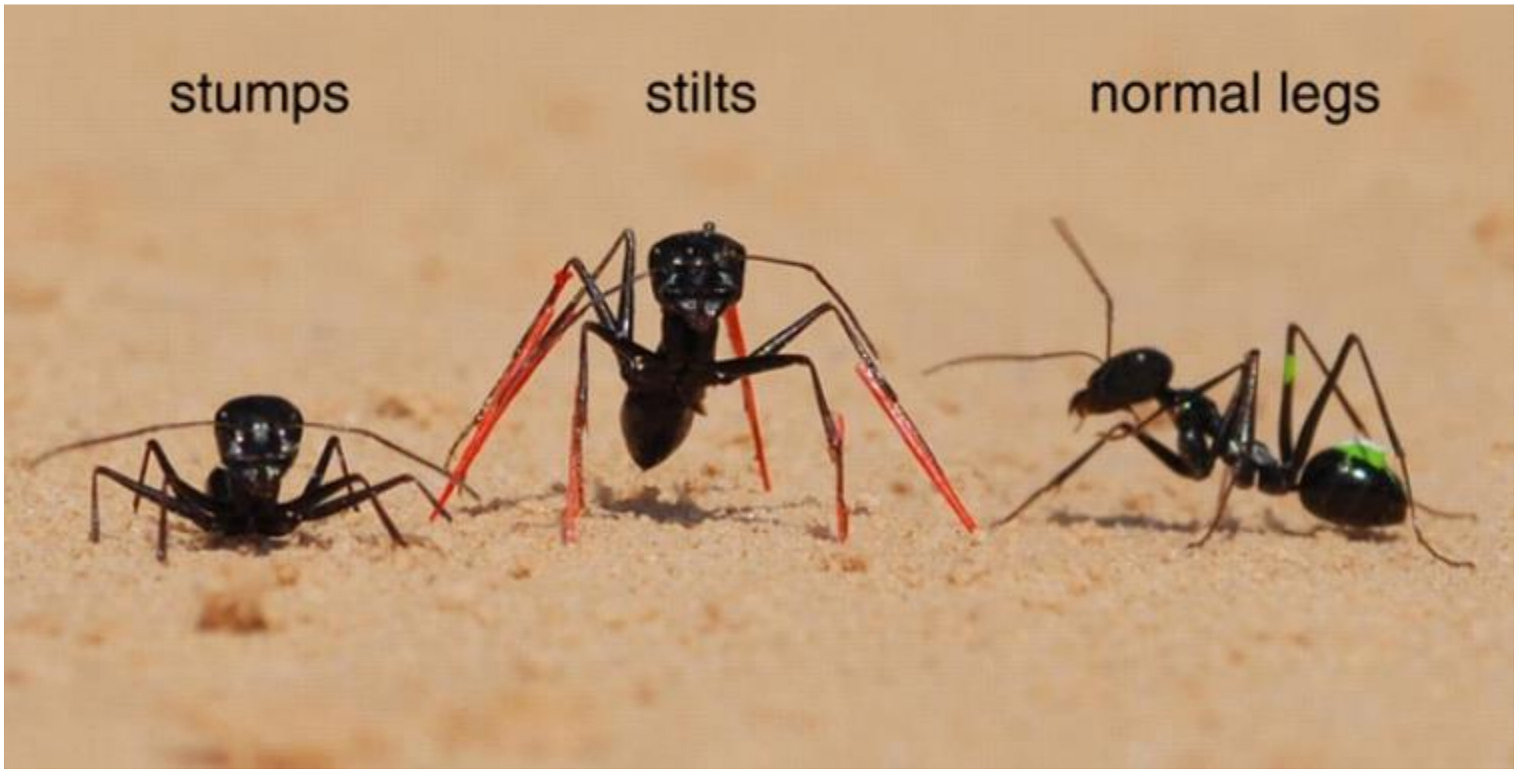


bump



carpet

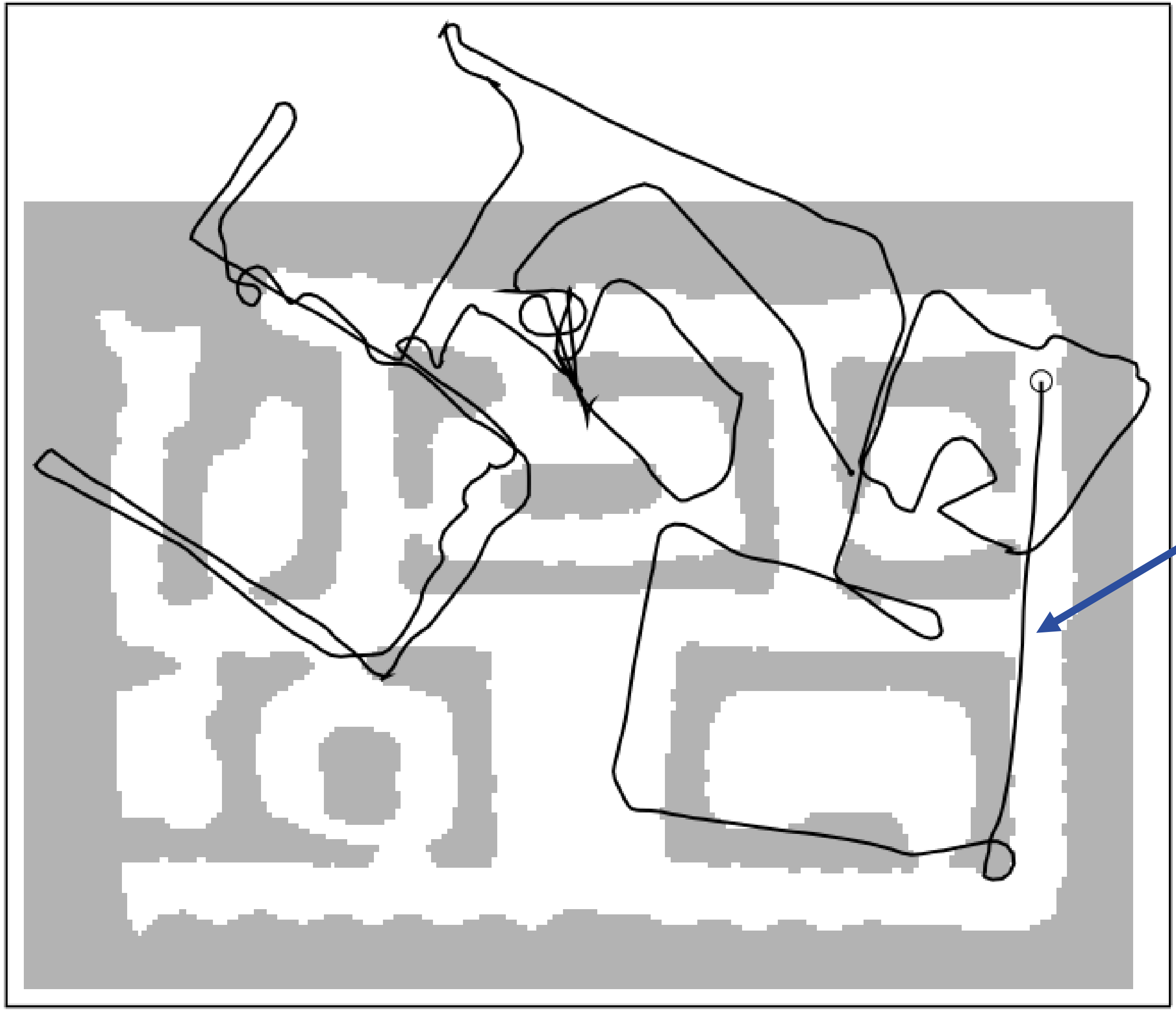
E.g. for ants (!)



Desert ants, *Cataglyphis*, navigate in their vast desert habitat by path integration. They continuously integrate directions steered (as determined by their celestial compass) and distances traveled, gauged by as-yet-unknown mechanisms. Here we test the hypothesis that navigating ants measure distances traveled by using some kind of step integrator, or “step counter.” We manipulated the lengths of the legs and, hence, the stride lengths, in freely walking ants. Animals with elongated (“stilts”) or shortened legs (“stumps”) take larger or shorter strides, respectively, and concomitantly misgauge travel distance. Travel distance is overestimated by experimental animals walking on stilts and underestimated by animals walking on stumps.

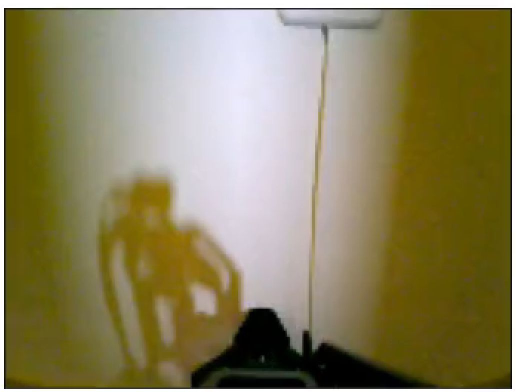
https://science.sciencemag.org/content/312/5782/1965

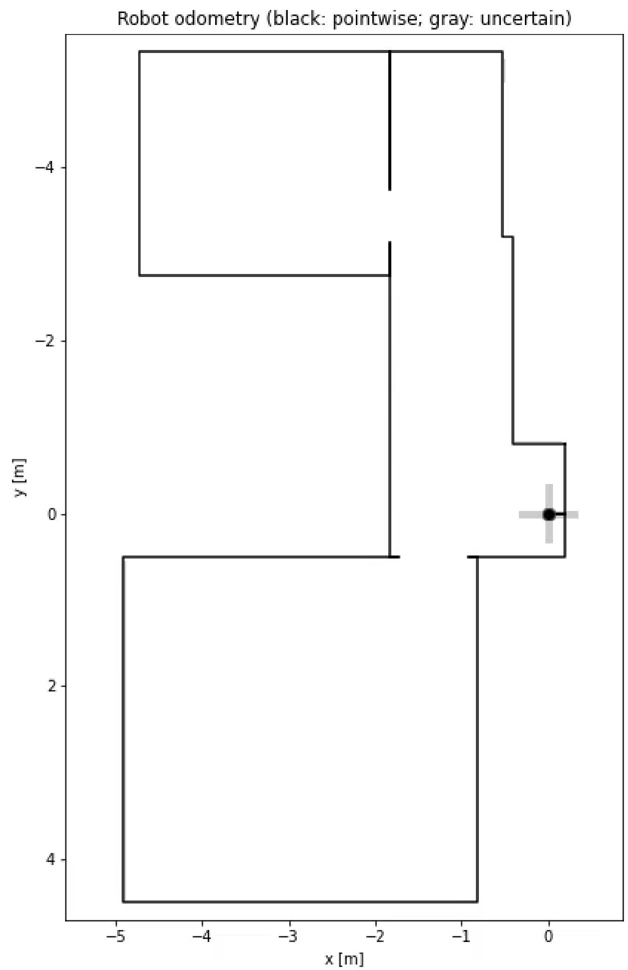
Example



This the path the robot has estimated using odometry measures

Another example





Managing errors

- Rotations usually determine more errors than translations (more slippage)
- Systematic / Deterministic errors can be corrected by a calibration process
- Random / Environment-related errors have to be explicitly modeled, but will inevitably determine uncertain pose estimates
- The additional use of inertial measures (heading, acceleration) can greatly improve accuracy of the whole dead reckoning process