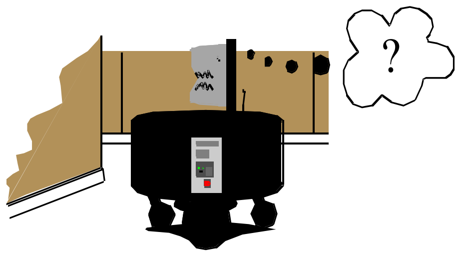
Localization
where am I?



Bookkeeping

- Quiz 3 – short review
- Assignment 3: How Thursday will work
- Next Reading: SNS 5.5 – 5.6.4
- Today
  - Scheduling for demos & presentations
  - Localization

Quiz 3: Manipulators

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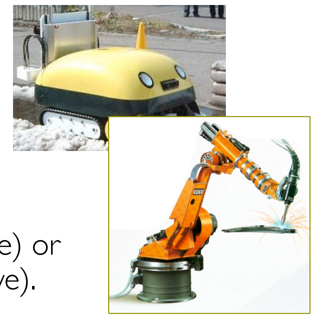

- Which of the following statements is ***true*** of a manipulator?
  - Synonymous with robot arm.
  - Has *grippers* to grasp or move things.
  - Has six degrees of freedom.
  - Can interact with the world (exteroceptive) or remain passive in the world (proprioceptive).
  - *Can* mark all false
    - Since many people didn't, ungraded question
- An open-chain manipulator is modeled as a series of rigid links connected by joints, starting at the base.

Quiz 3: Manipulators

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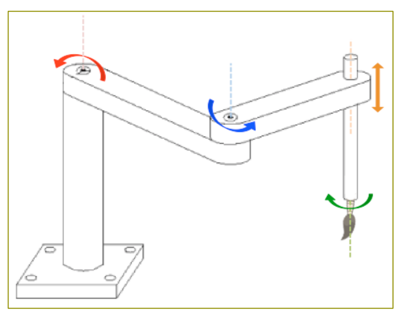

- Where is first joint?
- How many degrees of freedom?
- Is this manipulator's motion
  - Revolute
  - Prismatic
  - Both
- Can paintbrush take any position or orientation in workspace?
- Paintbrush is: end effector

Quiz 3: Manipulators

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- Which of these is a *gripper*?
  - Bending 'fingers' that close around an object.
  - Sliding surfaces that pinch an object in between them.
  - A contact switch that clicks closed when pressed against an object.
  - A vacuum nozzle that seals against the surface of an object.
  - A nozzle that dispenses glue between two objects, adhering them together.
  - Needles that pierce a piece of cloth on two sides to lift it.

Quiz 3: Manipulators

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Quiz 3: Manipulators

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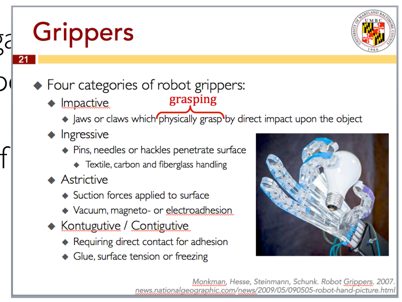
Grippers

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- Four categories of robot grippers:
  - Impactive
    - Jaws or claws which physically grasp by direct impact upon the object
  - Ingressive
    - Pins, needles or hackles penetrate surface
      - Textile, carbon and fiberglass handling
  - Astrictive
    - Suction forces applied to surface
    - Vacuum, magneto- or electroadhesion
  - Kontugutive / Contigutive
    - Requiring direct contact for adhesion
    - Glue, surface tension or freezing

grasping

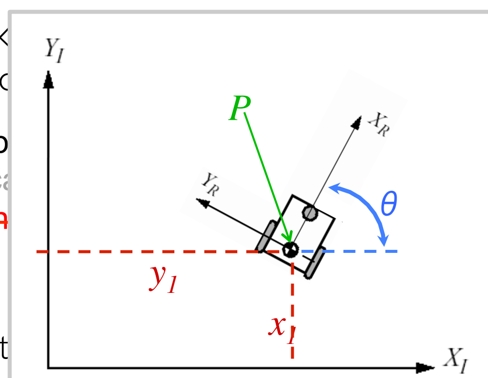
Monkman, Hesse, Steinmann, Schunk. Robot Grippers. 2007.
news.nationalgeographic.com/news/2009/05/090505-robot-hand-picture.html

Quiz 3: Kinematics

8

- Solving kinematics and IK two *frames of reference*, c

Global	Rob
Initial	Loca
Cartesian	~~Join~~
Plane	
World	



- How many parameters t mobile robot, and what are they?
  - If you put {x,y,z}, r/p/y, since I didn't specify wheeled, okay

$$\xi_I = \begin{bmatrix} x \\ y \\ \theta \end{bmatrix}$$

Quiz 3: Kinematics

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- Forward or Inverse?
  - We know where everything in the room is from a ceiling cam
  - Robot needs charging
  - Trying to decide what commands to send its actuators
  - What kind of kinematics problem do we need to solve?
- Kinematic models of wheels
  - Rolling: all motion accompanied by wheel spin
    - No skidding front to back
  - Sliding: wheel can move only in its plane of rotation
    - No skidding side to side
  - Single point of contact

Quiz 3: Grasping

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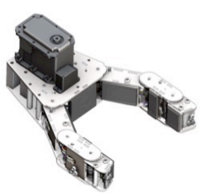

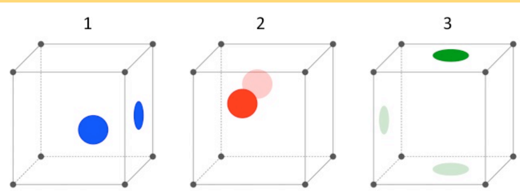

- Which grasp is best? Why?
  - Note: *grasps* are independent of *pickup action*
- Grading
  - Correct cube –*or*– something about using the back of the hand
  - Otherwise, only -1 if something reasonable

Assignment 3

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- Recommendation: read the assignment
  - Build LED circuit
    - Breadboard-based circuit building
    - Everyone/each pair should have 2 AA batteries
  - Build motor
    - Very simple conceptually
  - Writeup
    - Circuit diagram, explanations of current, efficiency of motor
    - 1-1.5 pages
  - In-class workshop
    - 12th November: demonstrate stuff working, seek help
  - Then: projects time

Why do I have 2 LEDs? (use provided parts ≠ use ALL provided parts)

Resistors

How can I make a switch? (it will have moving parts!)

Localization

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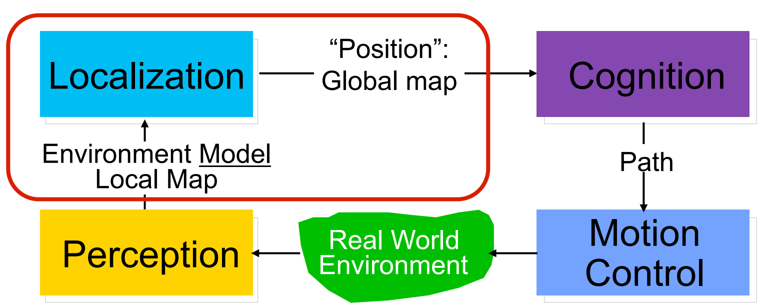
- Where am I (in a model of the environment)?



Sensor Aliasing

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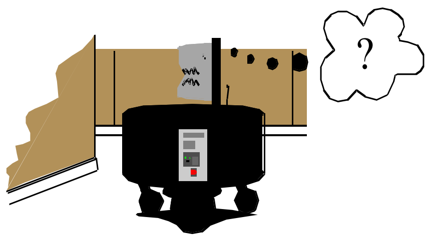
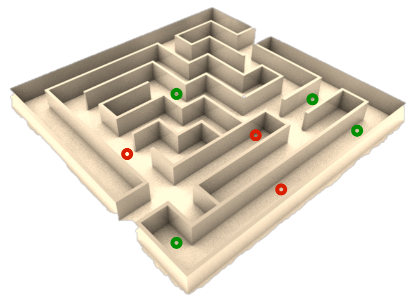
- Robots: non-uniqueness of sensors readings is the norm
- Many-to-one mapping from environmental states to robot's perceptual inputs





- Not NO information

Odometry & Dead Reckoning

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- Position update is based on proprioceptive sensors
  - Odometry: uses …
  - Dead reckoning: uses …
- How?
  - Sense movement
  - Integrate that into map model to get the position
- Extra sensors **reduce** accumulated errors
  - Same problem
- Effectors introduce uncertainty about future state

Odometry & Diff. Drive

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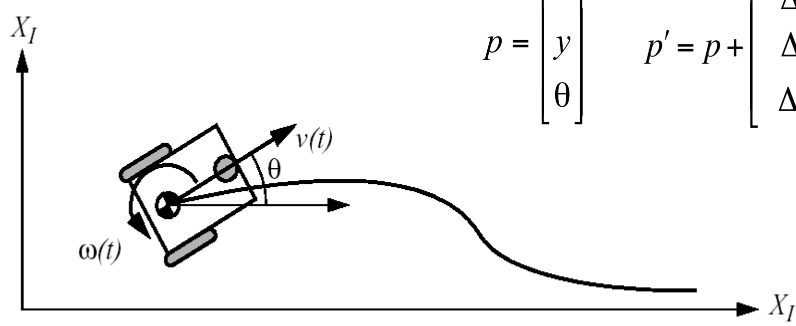
- Given a discrete sampling rate Δt
- And motion Δs_r, Δs_l = right wheel, left wheel distance travelled
- Changes in pose are Δx, Δy, $\Delta\theta$
- Distance between wheels is b

$$p = \begin{bmatrix} x \\ y \\ \theta \end{bmatrix} \qquad p' = p + \begin{bmatrix} \Delta x \\ \Delta y \\ \Delta\theta \end{bmatrix}$$



Odometry & Diff. Drive

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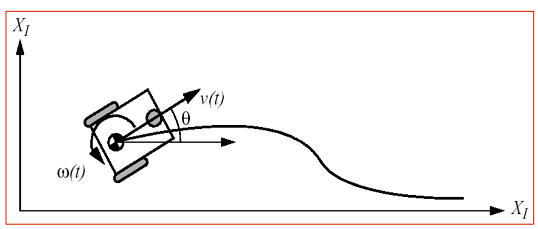
- Kinematics



$$\Delta x = \Delta s \cos(\theta + \Delta\theta/2)$$

$$\Delta y = \Delta s \sin(\theta + \Delta\theta/2)$$

$$\Delta\theta = \frac{\Delta s_r - \Delta s_l}{b}$$

$$\Delta s = \frac{\Delta s_r + \Delta s_l}{2}$$

$$p' = f(x, y, \theta, \Delta s_r, \Delta s_l) = \begin{bmatrix} x \\ y \\ \theta \end{bmatrix} + \begin{bmatrix} \frac{\Delta s_r + \Delta s_l}{2} \cos\left(\theta + \frac{\Delta s_r - \Delta s_l}{2b}\right) \\ \frac{\Delta s_r + \Delta s_l}{2} \sin\left(\theta + \frac{\Delta s_r - \Delta s_l}{2b}\right) \\ \frac{\Delta s_r - \Delta s_l}{b} \end{bmatrix}$$

Odometry & Diff. Drive

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- Error model – represent uncertainty of location over time in covariance matrix
- Σ_p is initial matrix
- Errors of 2 wheels independent
- Variance of error $\propto \Delta s_r, \Delta s_l$

$$\Sigma_\Delta = covar(\Delta s_r, \Delta s_l) = \begin{bmatrix} k_r|\Delta s_r| & 0 \\ 0 & k_l|\Delta s_l| \end{bmatrix}$$

$$\Sigma_{p'} = \nabla_p f \cdot \Sigma_p \cdot \nabla_p f^T + \nabla_{\Delta_{rl}} f \cdot \Sigma_\Delta \cdot \nabla_{\Delta_{rl}} f^T$$

$$F_p = \nabla_p f = \nabla_p (f^T) = \begin{bmatrix} \frac{\partial f}{\partial x} & \frac{\partial f}{\partial y} & \frac{\partial f}{\partial \theta} \end{bmatrix} = \begin{bmatrix} 1 & 0 & -\Delta s \sin(\theta + \Delta\theta/2) \\ 0 & 1 & \Delta s \cos(\theta + \Delta\theta/2) \\ 0 & 0 & 1 \end{bmatrix}$$

$$F_{\Delta_{rl}} = \begin{bmatrix} \frac{1}{2}\cos\left(\theta + \frac{\Delta\theta}{2}\right) - \frac{\Delta s}{2b}\sin\left(\theta + \frac{\Delta\theta}{2}\right) & \frac{1}{2}\cos\left(\theta + \frac{\Delta\theta}{2}\right) + \frac{\Delta s}{2b}\sin\left(\theta + \frac{\Delta\theta}{2}\right) \\ \frac{1}{2}\sin\left(\theta + \frac{\Delta\theta}{2}\right) + \frac{\Delta s}{2b}\cos\left(\theta + \frac{\Delta\theta}{2}\right) & \frac{1}{2}\sin\left(\theta + \frac{\Delta\theta}{2}\right) - \frac{\Delta s}{2b}\cos\left(\theta + \frac{\Delta\theta}{2}\right) \\ \frac{1}{b} & -\frac{1}{b} \end{bmatrix}$$

Odometry:

Growth of Pose Uncertainty for Straight Line Movement

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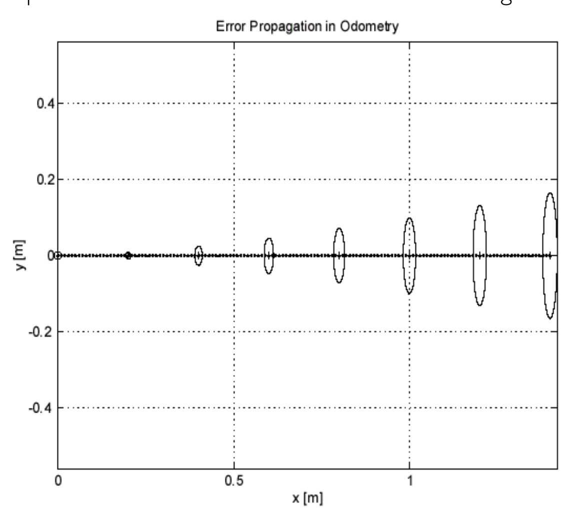
- Note: Errors perpendicular to the direction of movement are growing much faster!

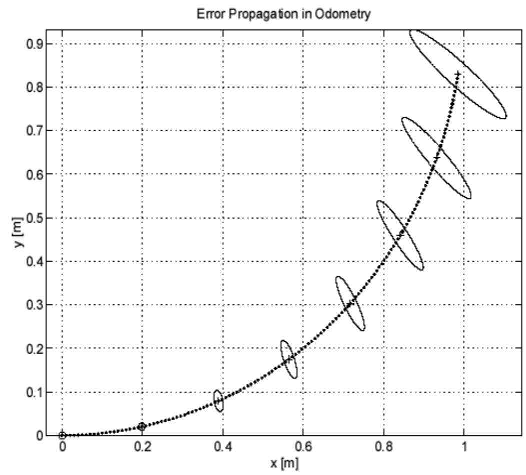


Odometry:

Growth of Pose uncertainty for Movement on a Circle

19

- Note: Errors ellipse in does not remain perpendicular to the direction of movement!



Calibration of Errors

5.2.

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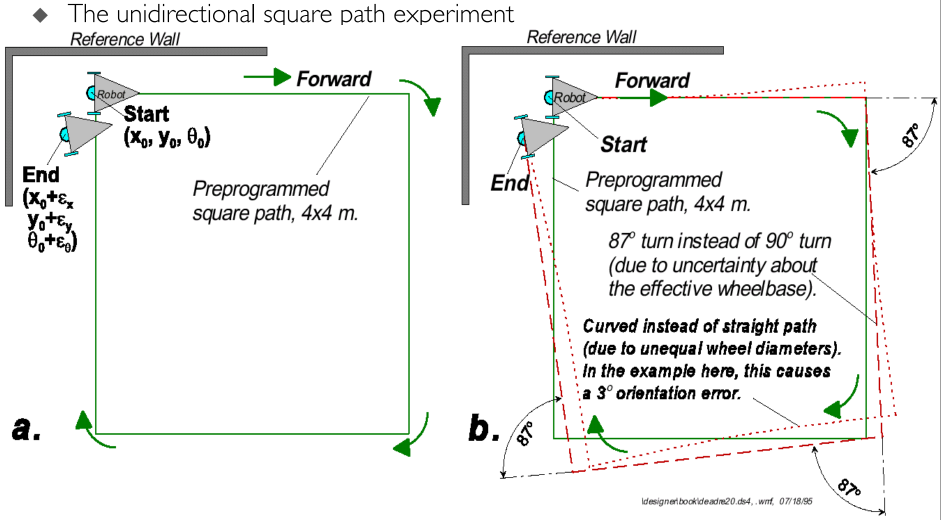
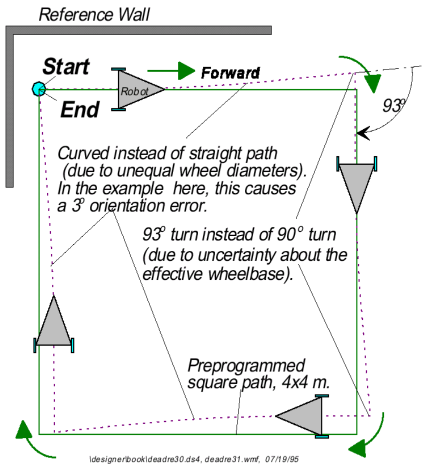
- The unidirectional square path experiment



Calibration of Errors

21

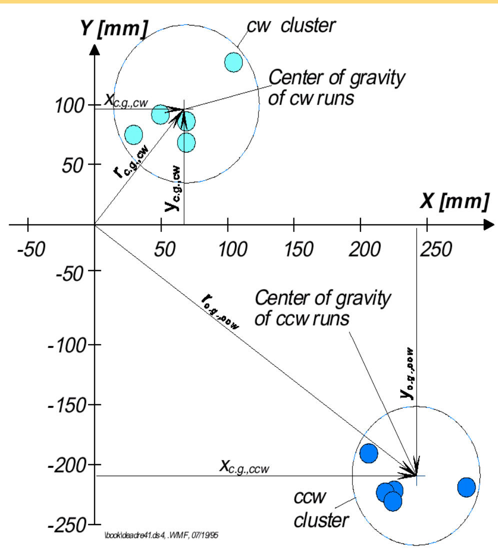
- The bi-directional square path experiment



Calibration of Errors

22

- The deterministic and non-deterministic errors



Localize, Or Not?

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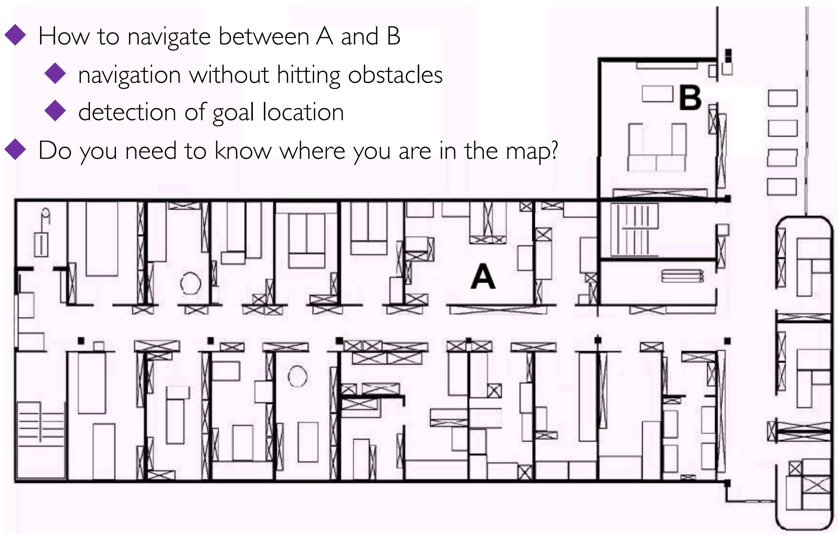
- How to navigate between A and B
  - navigation without hitting obstacles
  - detection of goal location
- Do you need to know where you are in the map?



Behavior Based Navigation

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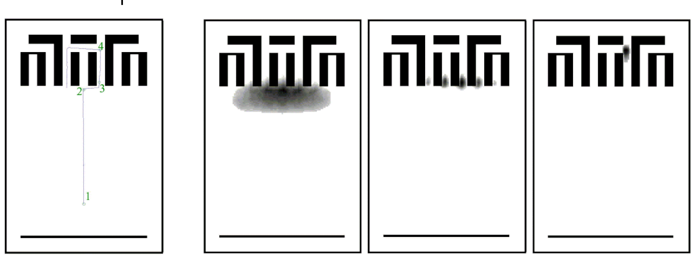
- Fast to implement
- Effective in unchanging environment
- Does not scale to new environments
- Behaviors must be designed and debugged
- Sensor changes change behavior
- Harder to represent to users



Path of the robot *Belief states at positions 2, 3 and 4*

Behavior Based Navigation

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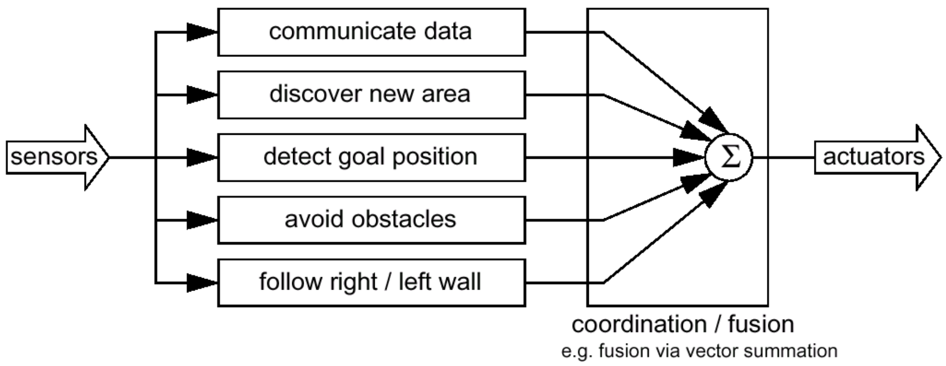

Model Based Navigation

5.3

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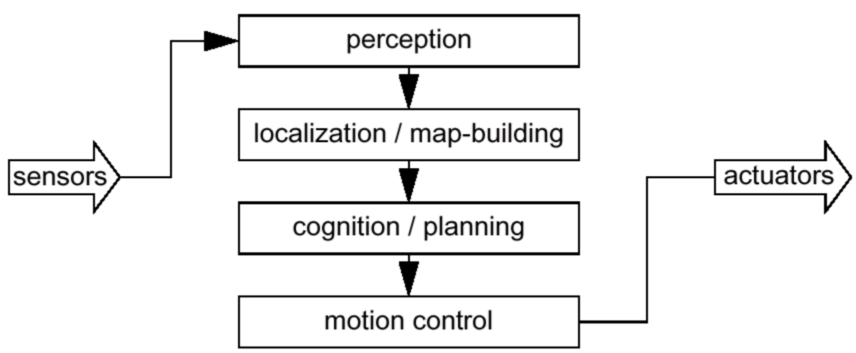

Belief Representation

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- a) Continuous map with *single hypothesis*
- b) Continuous map with *multiple hypothesis*
- d) Discretized map with probability distribution
- d) Discretized topological map with probability distribution

Belief Repr

28

- a) Continuous map with *single hypothesis*
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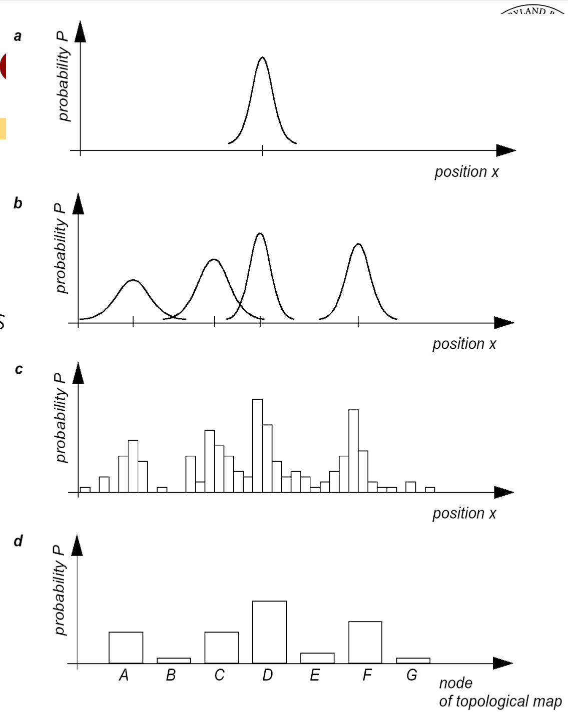
- d) Discretized topological map with probability distribution



Characteristics

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Belief Representation can be…

- Continuous
  - Precision bound by sensor data
  - Typically single hypothesis pose estimate
  - Lost when diverging (for single hypothesis)
  - Compact representation and typically reasonable in processing power.
- Discrete
  - Precision bound by resolution of discretisation
  - Typically multiple hypothesis pose estimate
  - Never lost (when diverges converges to another cell)
  - Important memory and processing power needed. (not the case for topological maps)