last time

Abstract Sensing Models

Configuration spaces

$\mathbb{R}^2 \times S^1 \cong SE(2)$

today

State space concepts

Define some sensors

tomorrow

Time

History-based sensors

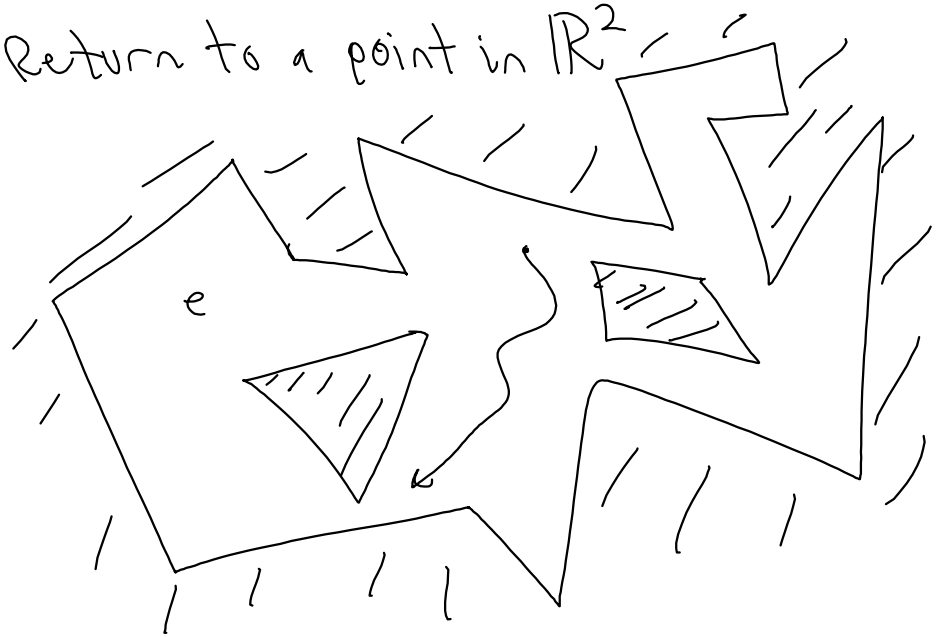
Observation histories

Configuration spaces

0) Rigid body, 2D
1) Multiple moving bodies
2) Discrete
3) 3D
4) Obstructions
5) Attached bodies

4) Obstructions (Obstacles)

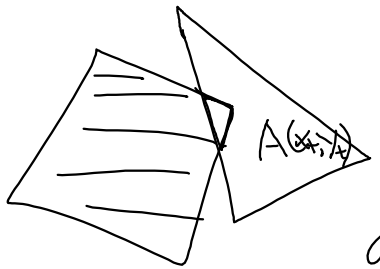
Return to a point in $\mathbb{R}^2$



$\underline{e \subset \mathbb{R}^2}$

Consider rigid body, A

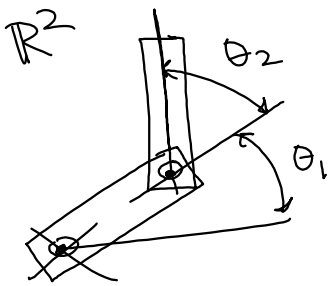
$A(x_t, y_t)$



Which configurations are prohibited?

- Avoid configurations that cause collision
- If $\mathcal{C} = \mathbb{R}^2 \times S^1$, then with obstacles, we restrict to some $F \subset \mathbb{R}^2 \times S^1$
- How to determine F? See, LaValle, 4.3
- Basis of motion planning $\longrightarrow$ LaValle, Ch. 5, 6, 7
  (Piano mover's problem)

5) Attached bodies (LaValle 3.3)



2 d.o.f.

$\mathcal{C} = S^1 \times S^1$

Unattached

$(\mathbb{R}^2 \times S^1) \times (\mathbb{R}^2 \times S^1) =$

$\mathbb{R}^4 \times S^1 \times S^1$

suppose the ~~fins~~ lower body is not attached

$\mathcal{C} = \mathbb{R}^2 \times S^1 \times S^1$

Sweden 2

Finland 1

For everything so far, the state becomes the the configuration space: $X = \mathcal{C}$

$$h: X \to Y$$

However, for many problems, this is insufficient

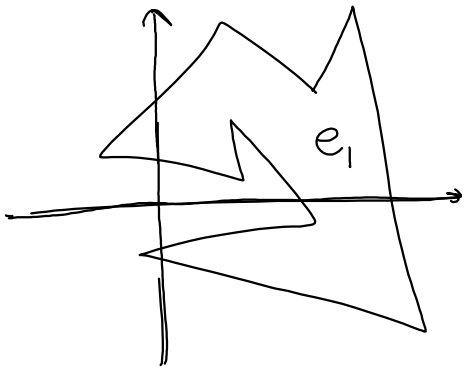
Additional information/complications:

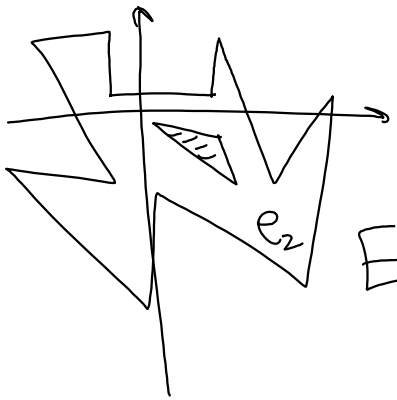
1) Unknown environments
2) Keep track of velocities
3) Additional fields
4) Discrete modes

1) Unknown environments (2D)

Suppose we are in a <u>bounded, polygonal environment</u>

Let e_i be an exact description of the set of available points in $\mathbb{R}^2$





$E = \{e_1, e_2\}$

Each e_i is called an <u>environment</u>

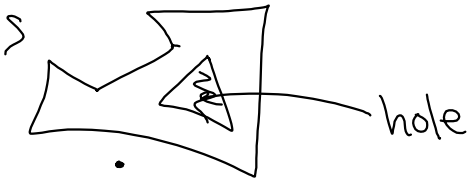
Let E be the set of possible environments, called <u>the environment space</u>

Note: E may be infinite

Ex Let $\underline{E}$ be the set of all bounded, simply connected, polygonal subsets of $\mathbb{R}^2$

no holes

Note: E is HUGE! → no problem



The state space becomes $X = \mathcal{C} \times \underline{E}$ $\mathcal{C}_e$

$\mathcal{C}$ = whatever configuration space

E = set of environments

$h: X \to Y$ $y = h(q, e)$

conf.

$x = (\ldots)$

$(\underline{p_1, p_2, \theta}, e)$

2) Velocities

Sensor readings may depend on velocity (linear or angular)

Translation-only case in $\mathbb{R}^2$

$\mathcal{C} = \mathbb{R}^2$ $\quad (x_t, y_t) \in \mathcal{C}$

$\frac{dx_t}{dt} = \dot{x}_t \quad \dot{y}_t$

velocity vector

$(\dot{x}_t, \dot{y}_t)$

$h: X \to Y$

State: $x = (x_t, y_t, \underline{\dot{x}_t, \dot{y}_t})$

State space: $X = \mathbb{R}^4$ (phase space - in physics
state space - in control theory

3) Fields

At each point in the environment, associate a vector (or scalar)

<u>Ex</u> Electromagnetic field $\mathcal{C} = \mathbb{R}^2$

<u>Ex</u> Signal intensity state: (x_t, y_t, v_1, v_2) in which $\vec{v} = (v_1, v_2)$ is the field vector

$\downarrow$

(x_t, y_t, σ)

State space: $X = \mathbb{R}^4$

$h: X \to Y$