# Driving a car with low dimensional input features

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## PROBLEM

The motivation for this project is a robotics competition in which autonomous cars race against each other around a small circuit. The challenge is keep the car within the track boundaries knowing only the distance driven, the heading and the color of the track under the car.

## MODEL

This problem can be posed as a partially observable Markov decision process (POMDP).

### State Space

$$s = \{x_m, y_m, \theta, \kappa, p, v, c_b\} \in S$$

### Observation Space

$$o = \{d, \hat{\theta}, \kappa, \hat{v}, c_b\} \in \Omega$$

### Action Space

$$A = A_s \times A_p \text{ with}$$

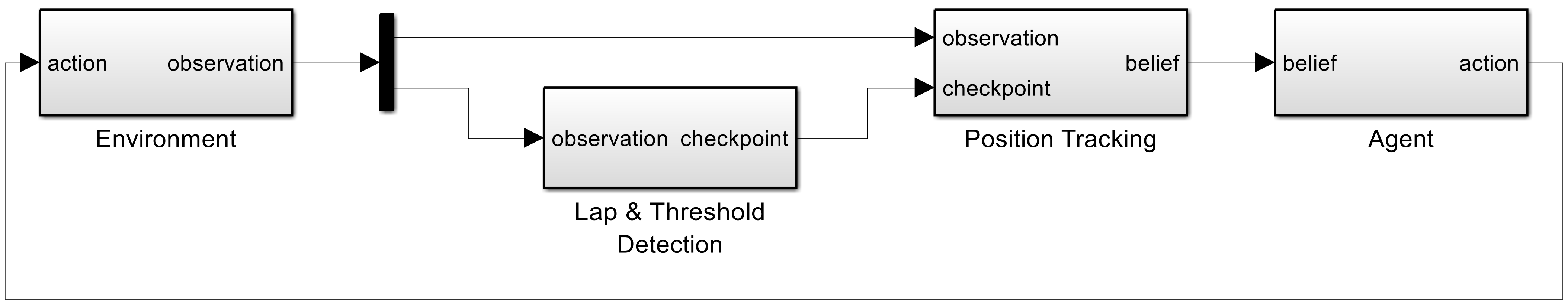
$$A_s = \{nothing, steer\ left, steer\ right\}$$
$$A_p = \{nothing, throttle\ up, throttle\ down\}$$

### Reward

$$R(s) = v \cdot \Delta t \cdot \cos\big(\theta - h(x_m)\big)$$

Where $\Delta t$ is the time step and $h(x_m)$ is the tangent of the track median line at distance $x_m$.

## PIPELINE




### Belief State Space

$$b = \{\hat{x}_m, \hat{y}_m, \hat{\theta}, \kappa, \hat{v}\} \in B$$

$$\hat{x}_m^{(t_2)} = \int_{t=t_1}^{t_2} \hat{v}\cos\Big(\hat{\theta} - h(\hat{x}_m)\Big)\,dt$$

$$\hat{y}_m^{(t_2)} = \int_{t=t_1}^{t_2} \hat{v}\sin\Big(\hat{\theta} - h(\hat{x}_m)\Big)\,dt$$

When $c_b > 0$

$$\hat{y}_m^{(t_2)} = \operatorname{sign} \hat{y}_m^{(t_1)}\left(\frac{1}{2}w_a + c_b w_b\right)$$

Lap or checkpoint:

set $\hat{x}_m$ to 0 or $-1$.

## Q-LEARNING

$$\hat{Q}^*(b,a) \leftarrow r(s) + \gamma \max_{a \in A} \tilde{Q}^*(b', a')$$

$$a = \operatorname{argmax}_a \hat{Q}^*(b,a)$$

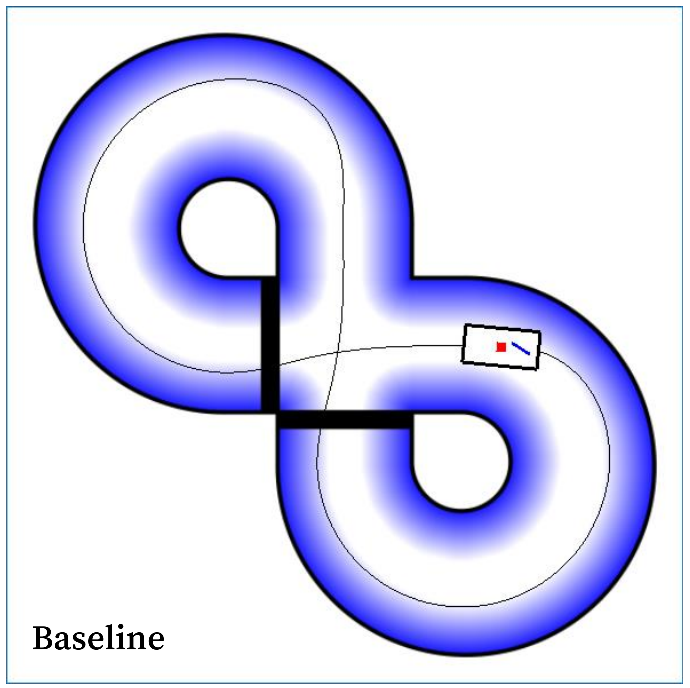
## BASELINE

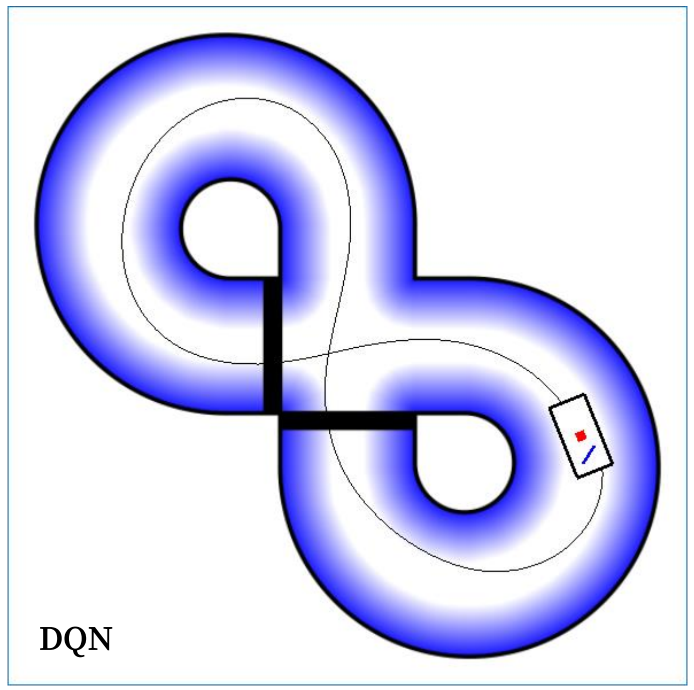
A simple PD controller on belief $\hat{y}_m$

$$f(s) = \kappa + k_p y_m + k_d \dot{y}_m$$

$$a = \begin{cases} steer\_left & \text{if } f(s) < -\epsilon \\ steer\_right & \text{if } f(s) > \epsilon \\ do\_nothing & \text{otherwise} \end{cases}$$

| 100 episodes | Score | Crashes |
|---|---|---|
| Baseline 75% throttle | 16.0 | 0 |
| Baseline 100% throttle | 12.9 | 35 |
| DQN | 22.1 | 0 |


Baseline


DQN