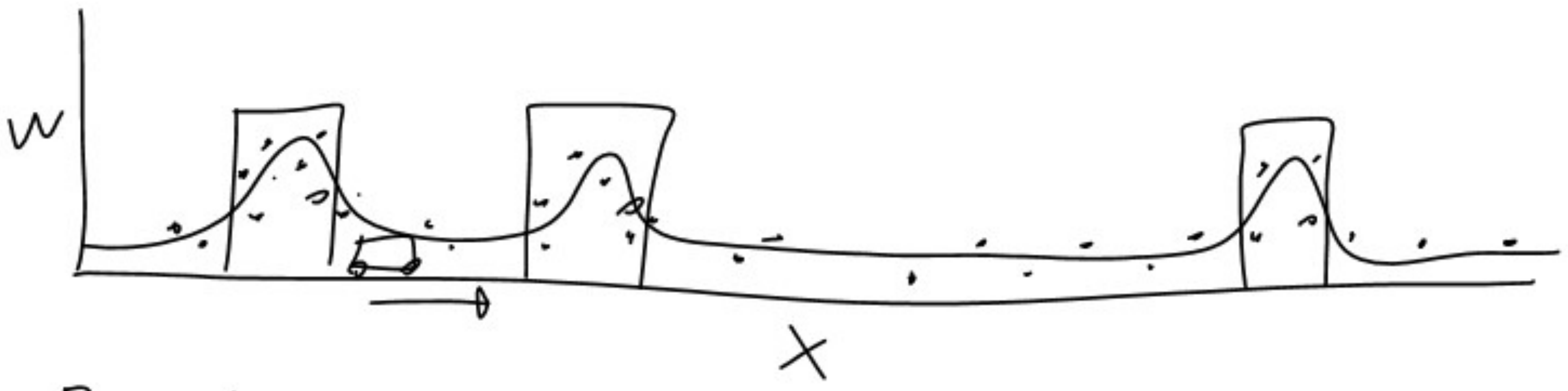
Markov Localization	Kalman Filter	Extended Kalman Filter	Particle Filte
multimodal PDF	uimodal PDF	unimodal PDF	multimodal PDF
nonlinear	linear	nonlinear	nonlinear
limited	scalable	scalable	scalable



Particle

Predict: move particles and add noise

$$x_t \sim p(x_t | x_{t-1}, u_t)$$

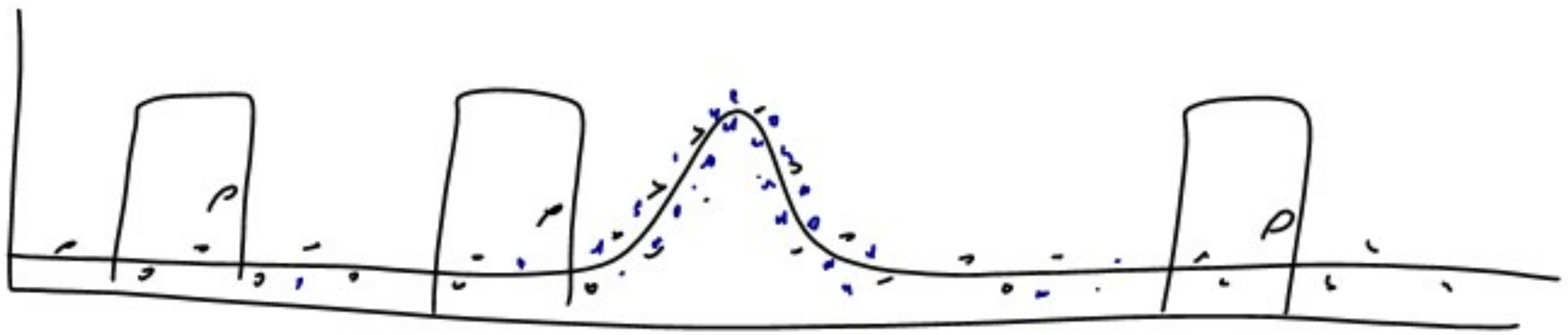
sampling from motion model

Update:

importance factors or weights

$$w = p(x_t | z_t)$$

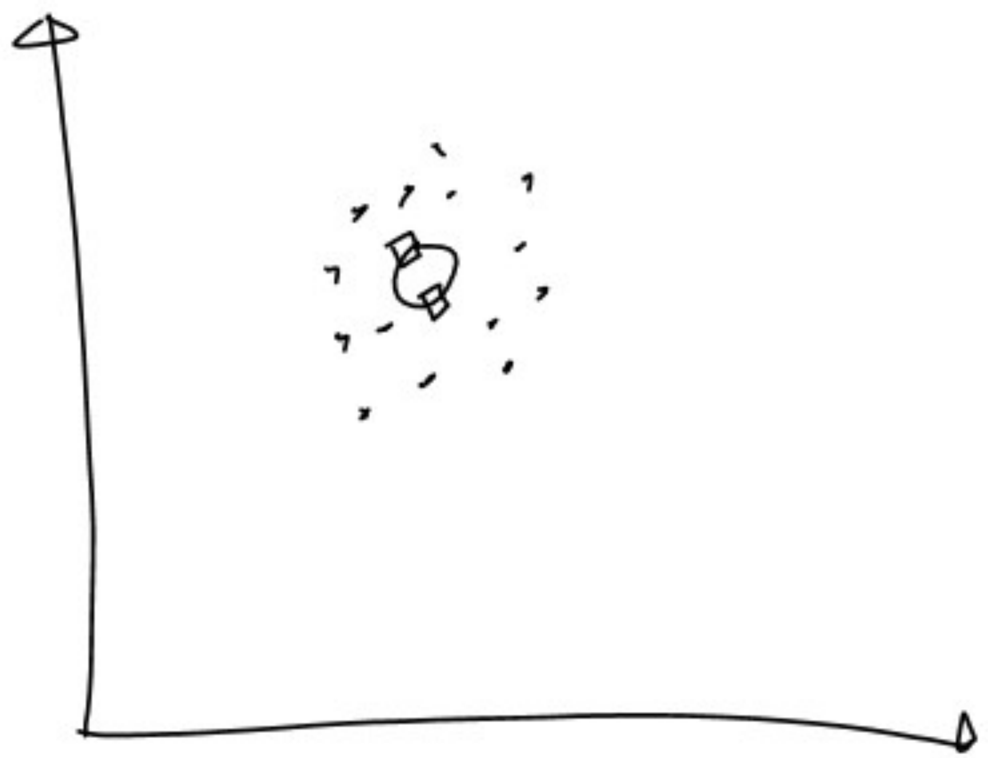
Resampling



Mean

normalize weights

$$E[X] = \sum_i w_i x_i$$



Algorithm Particle_filter($\mathcal{X}_{t-1}, u_t, z_t$)**:**

$\bar{\mathcal{X}}_t = \mathcal{X}_t = \emptyset$

for $m = 1$ *to* M *do*

sample $x_t^{[m]} \sim p(x_t \mid u_t, x_{t-1}^{[m]})$ predict

$w_t^{[m]} = p(z_t \mid x_t^{[m]})$ update

$\bar{\mathcal{X}}_t = \bar{\mathcal{X}}_t + \langle x_t^{[m]}, w_t^{[m]} \rangle$

endfor

for $m = 1$ *to* M *do*

draw i with probability $\propto w_t^{[i]}$

add $x_t^{[i]}$ to $\mathcal{X}_t$

endfor

return $\mathcal{X}_t$

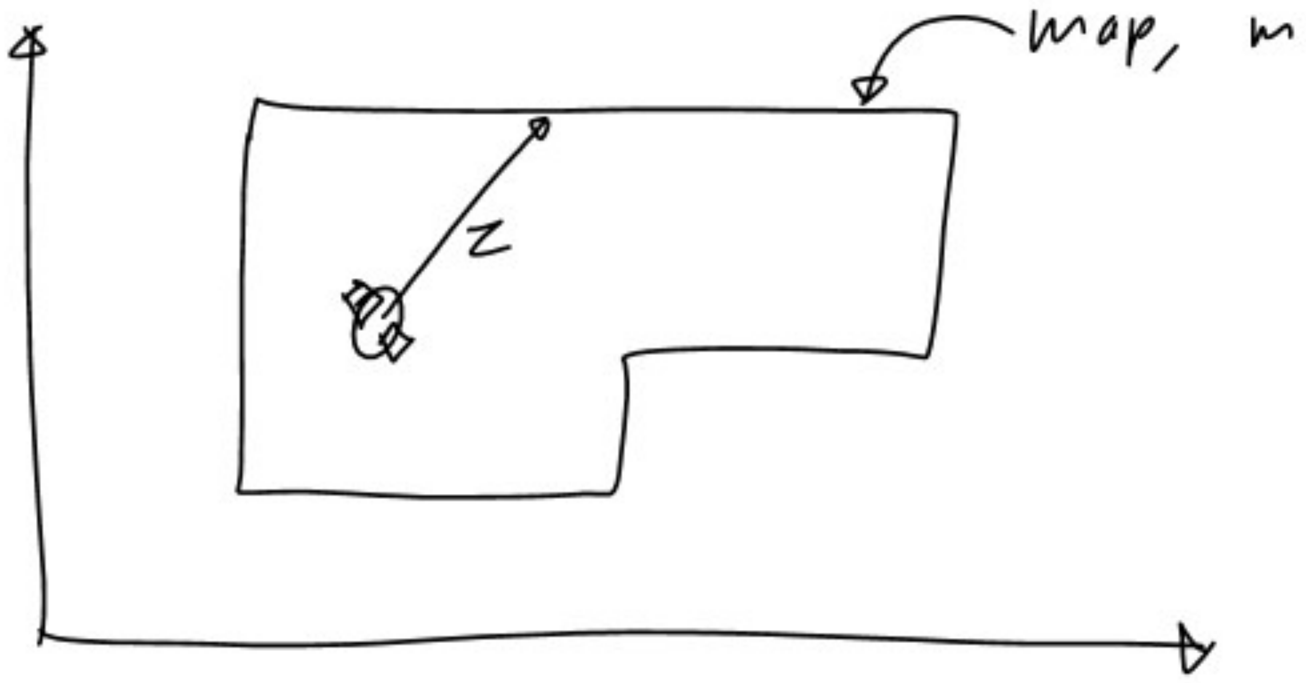
resample

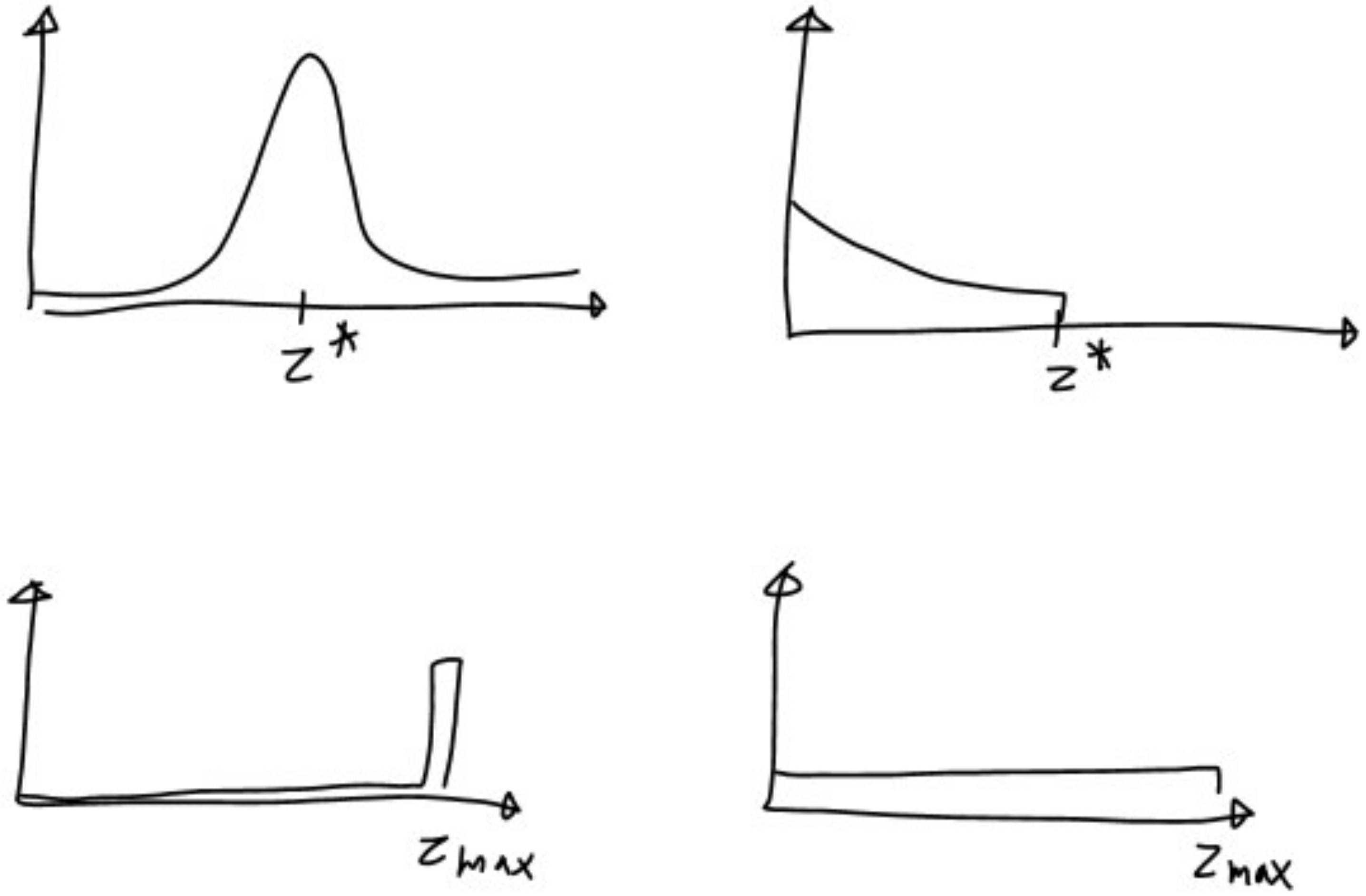
Measurement Models

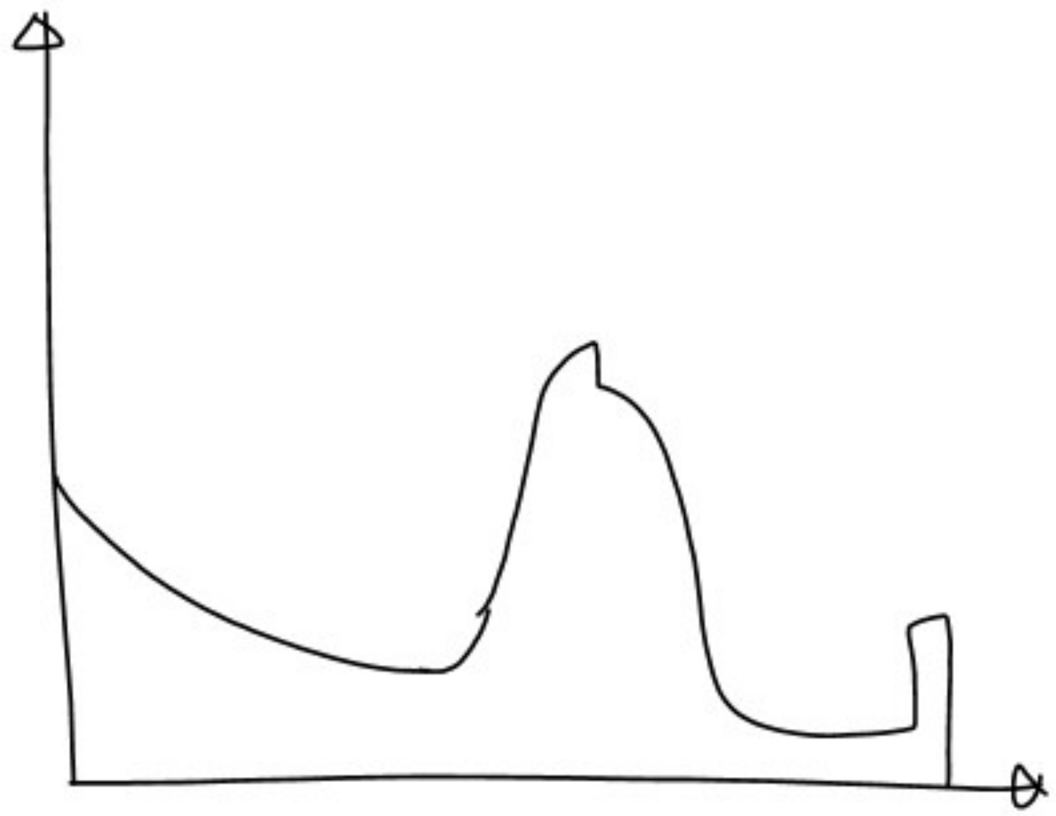
$p(z \mid x, m)$

z^* true measurement

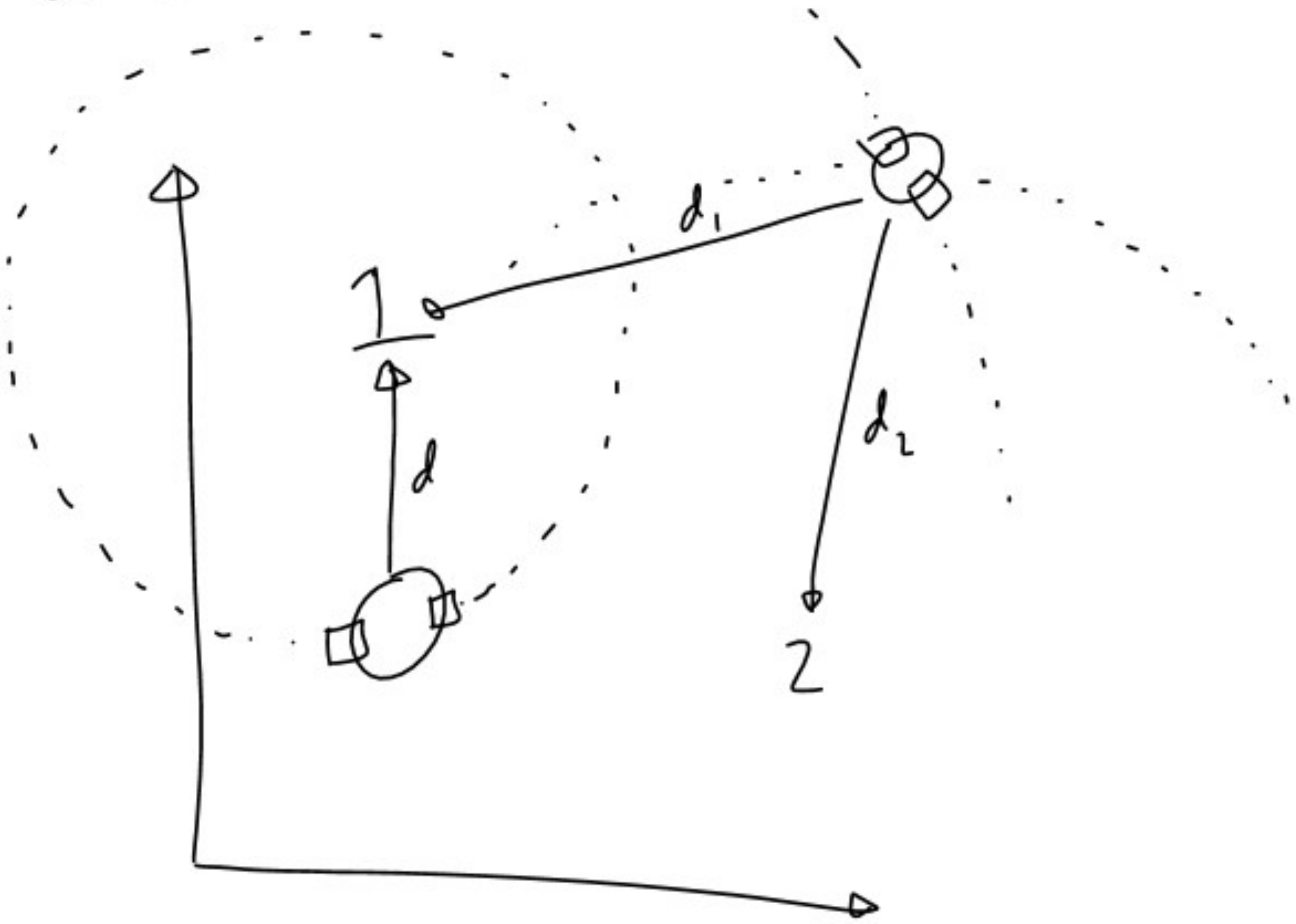
Ray Sensor







Lab 3: Feature Based Localization



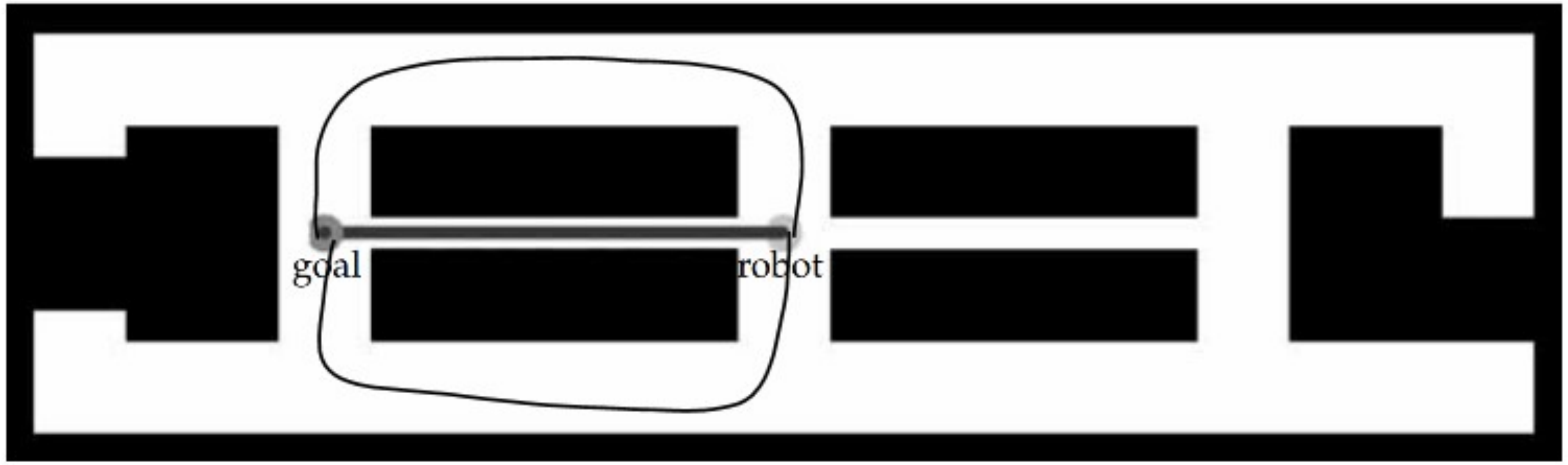
Fiducials

April Tags

Known Correspondence

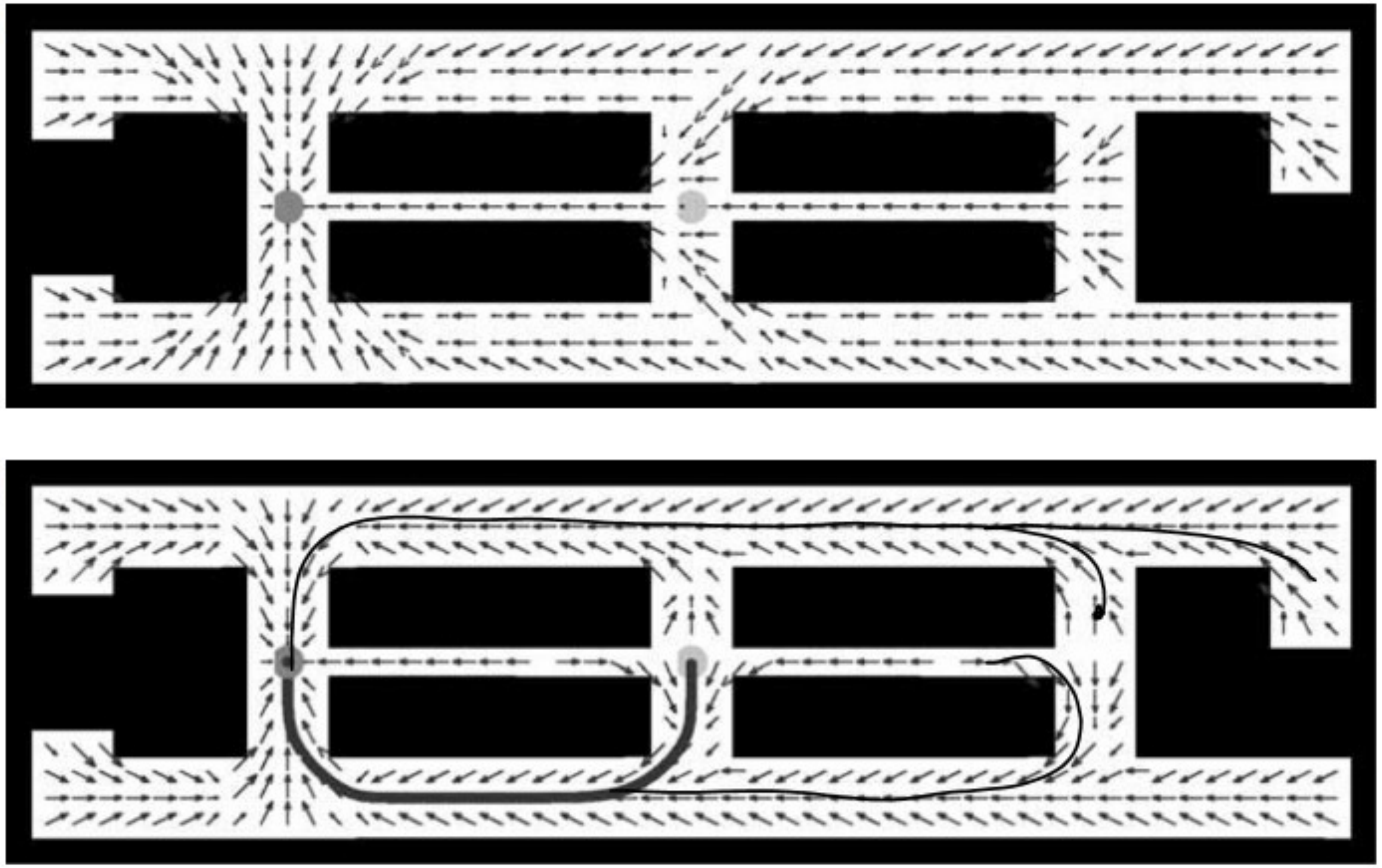
Path Planning

Markov Decision Process



(a)

(b)



Payoff Function

$$r(x, u) = \begin{cases} 100 & \text{if } x \text{ is goal} \\ -1 & \text{otherwise} \end{cases}$$

$$R_T = \sum_{\tau=1}^{T} \gamma^{\tau} r_{t+\tau}$$

γ discount factor

Greedy $T=1$

Finite horizon $1 < T < \infty$

Infinite horizon $T = \infty$ $0 < \gamma < 1$

Value Function

$$V_1(x) = \gamma \max_u r(x, u)$$

$$V_2(x) = \gamma \max_u r(x, u) + \int V_1(x') \, p(x' \mid u, x) \, dx'$$

$$V_T(x) = \gamma \max_u r(x, u) + \int V_{T-1}(x') \, p(x' \mid u, x) \, dx'$$

```
Algorithm MDP_discrete_value_iteration( ):
    for i = 1 to N do
        V̂(x_i) = r_min
    endfor
    repeat until convergence
        for i = 1 to N do
            V̂(x_i) = γ max_u [ r(x_i, u) + Σ_{j=1}^{N} V̂(x_j) p(x_j | u, x_i) ]
        endfor
    endrepeat
    return V̂
```

$$\hat{V}(x_i) = \gamma \max_u \left[r(x_i, u) + \sum_{j=1}^{N} \hat{V}(x_j)\, p(x_j \mid u, x_i) \right]$$