

# Computer Vision

## Exercise 3: Tracking

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**Due date: Monday February 25th at noon**

### 1 Programming exercises

This week we will look into implementing a probabilistic tracker based on particle filter. Consider the case where we are interested in locating the position of a fixed size object in a video, thus our state  $\mathbf{x} = (u, v)$  is 2D and contains the image coordinates of the center of the target. Implement the condensation algorithm in slide 52, lecture10, with brownian motion as dynamics, and normalize cross-correlation as likelihood. Implement resampling when necessary. Create your own video where given an existing video you superpose a template that has a parabolic motion (from one side of the image to the other). Show plots (as in page 55, lecture 10) as a function of time. Select a video where you think this algorithm will succeed, as well as one where it will failed. Run it and say whether your prediction was right. You should submit the videos, the code and a script to generate the plots and the results.

### 2 Critic reading exercise

This week assignment is the condensation algorithm [1]

### 3 Problem Sets

**Kalman filter:** Assume that the state and the observations are Gauss linear as follows

$$\begin{aligned}\mathbf{x}_t &= \mathbf{A}\mathbf{x}_{t-1} + \eta_x & \eta_x &\sim \mathcal{N}(0, \Sigma_x) \\ \mathbf{z}_t &= \mathbf{B}\mathbf{x}_{t-1} + \eta_z & \eta_z &\sim \mathcal{N}(0, \Sigma_z)\end{aligned}$$

Show that the prediction distribution has the form

$$p(\mathbf{x}_t | \mathbf{z}_{1:t-1}) = \mathcal{N}(\mathbf{x}_t | \mu_t^-, \Sigma_t^-)$$

with  $\mu_t^- = \mathbf{A}\mu_{t-1}^+$  and  $\Sigma_t^- = \mathbf{A}\Sigma_{t-1}^+ \mathbf{A}^T + \Sigma_x$ . Show also that the posterior has the form

$$p(\mathbf{x}_t | \mathbf{z}_{1:t}) = \mathcal{N}(\mathbf{x}_t | \mu_t^+, \Sigma_t^+)$$

with  $\mu_t^+$  and  $\Sigma_t^+$  defined as in lecture 10, slide 39.

**Hint:** Use the matrix inversion lemma and/or other useful identities.

**Smoothing distribution:** Show that the smoothing distribution is

$$p(\mathbf{x}_\tau | \mathbf{z}_{1:t}) \propto \frac{p(\mathbf{z}_\tau | \mathbf{x}_\tau) p(\mathbf{x}_\tau | \mathbf{z}_{1:\tau-1}) p(\mathbf{x}_\tau | \mathbf{z}_{\tau+1:t})}{p(\mathbf{x}_\tau)}$$

## References

- [1] M. Isard and M. Black. Condensation- conditional density propagation for visual tracking. In *IJCV*, 1998.