Computer Vision
and Geometry Lab

Computer Vision

Exercise Session 9 – Condensation Tracker

Assignment Tasks

1. Condensation tracker with color histogram observations
2. Experiment with the condensation tracker

Task 1

- Track an object through an image sequence

- State space: **X**

- Time t ⟶ $\mathbf{x}_t$

General Tracking Framework

1. **Prediction**, based on **system model**

$$x_t = f_{t-1}(x_{t-1}, w_{t-1})$$

f = system transition function

2. **Update**, based on **measurement model**

$$z_t = h_t(x_t, v_t)$$

h = measurement function

$Z_t = (z_1, \ldots, z_t)$ is the history of observations

Recursive Bayesian Filter

Object not treated as a single state but as a probability distribution:

1. Prediction

$$p(x_t \mid Z_{t-1}) = \int p(x_t \mid x_{t-1})\, p(x_{t-1} \mid Z_{t-1})\, dx_{t-1}$$

2. Update

$$p(x_t \mid Z_t) = \frac{p(z_t \mid x_t)\, p(x_t \mid Z_{t-1})}{p(z_t \mid Z_{t-1})}$$

normalization factor

Recursive Bayesian Filter - Bottleneck

- Calculating $p(x_t \mid Z_{t-1}) = \int p(x_t \mid x_{t-1})\, p(x_{t-1} \mid Z_{t-1})\, dx_{t-1}$ numerically is very time consuming, and the probability distributions have to be known…
- Analytic solutions are only available for the simplest of cases, e.g. when distributions are Gaussian and the system and measurement models are linear…*(Kalman filter, 1960)*
- That's where CONDENSATION comes in, acronym for CONditional DENSity propagATION

Condensation Tracker

- The probability distribution is represented by a sample set S

$$S = \left\{ \left(s^{(n)}, \pi^{(n)} \right) \mid n = 1 \ldots N \right\}$$

- π - weights giving the sampling probability

Condensation Tracker

1. Prediction

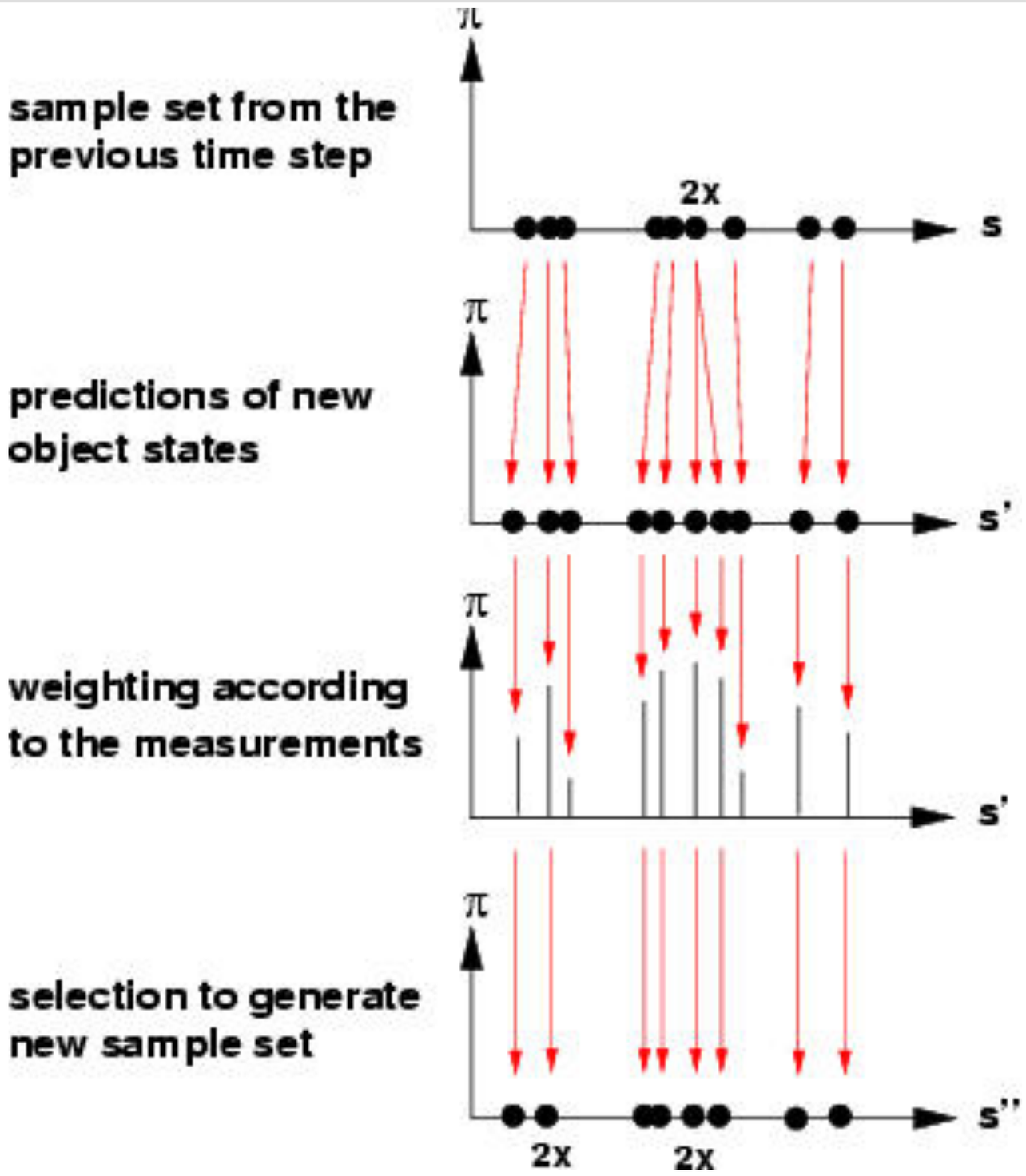
Start with S_{t-1} , the sample set of the previous step, and apply the system model to each sample, yielding predicted samples $s_t^{'(n)}$

2. Update

Sample from the predicted set, where samples are drawn with replacement with probability $\pi^{(n)} = p(z_t \mid s_t^{'(n)})$ (using measurement model)

Condensation Tracker

Samples may be drawn multiple times, but noise will yield different predictions



Condensation Tracker with Color Histograms

- Track objects – bounding-boxes
- Samples = particles = bounding-boxes
- State =
- Initialization: user interaction – provide bounding box
- Use color histogram in the measurement model

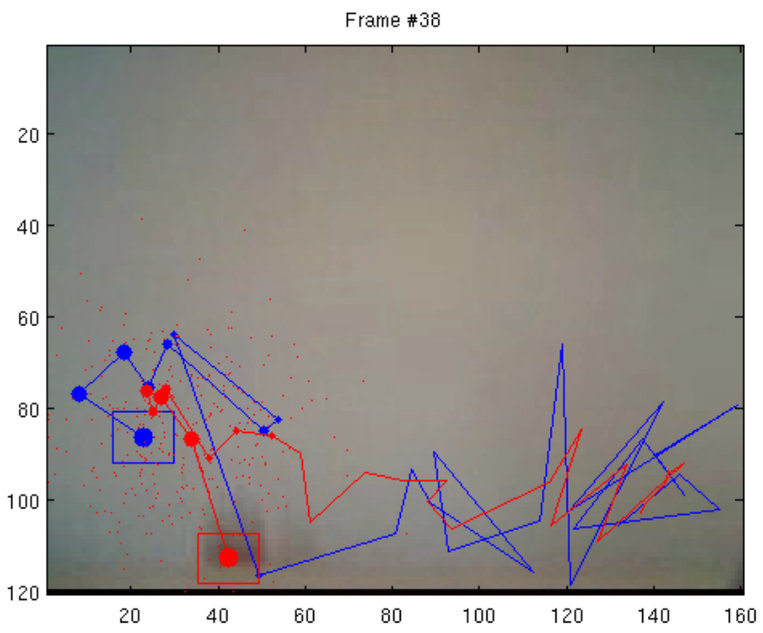
Task 2:
Experiment with the Condensation Tracker

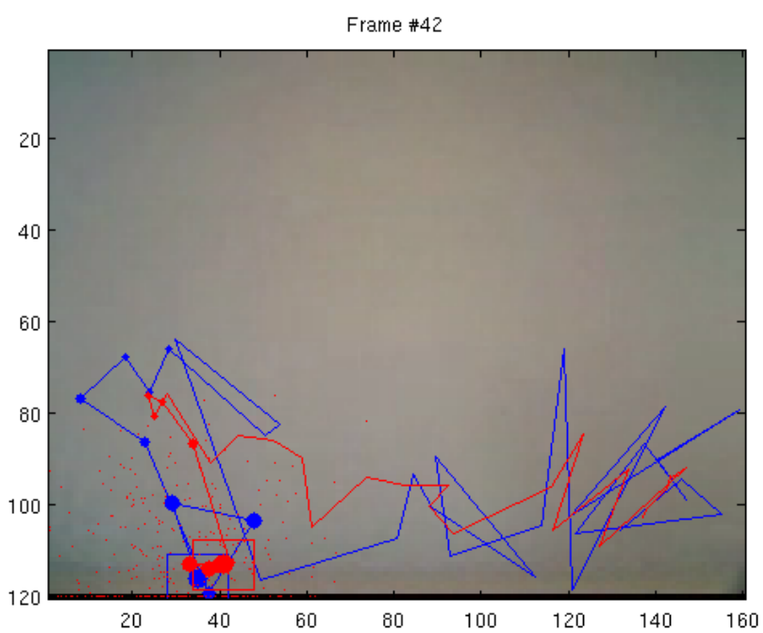
- Moving hand
- Uniform background

- Moving hand
- Clutter
- Occlusions

- Ball bouncing
- Motion model

Video 1: Hand, uniform background

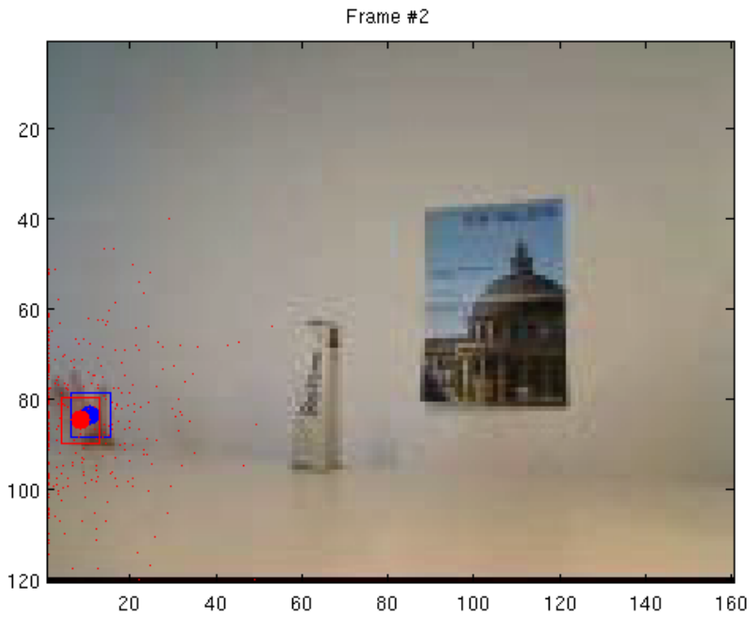


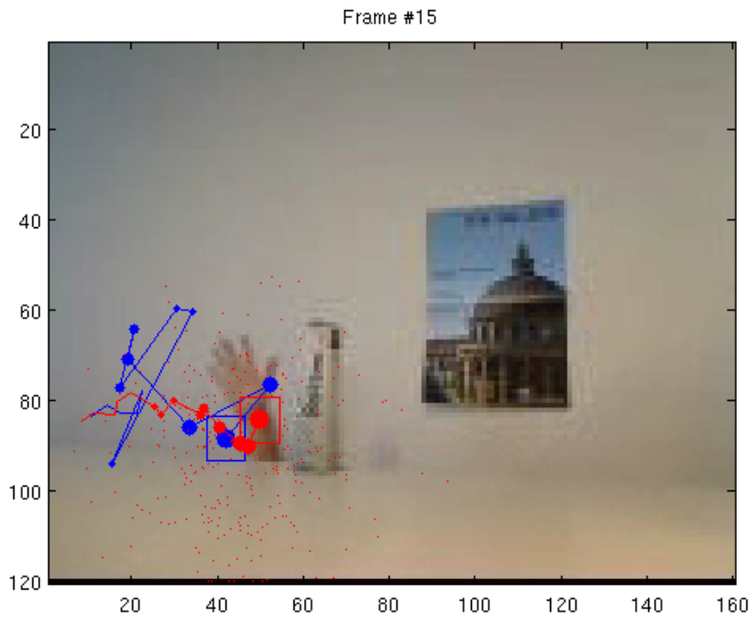


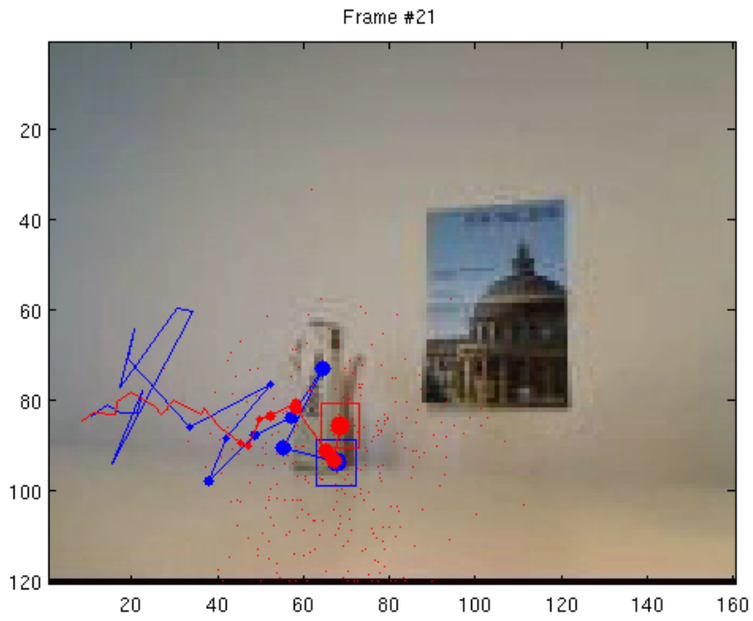
a priori mean state

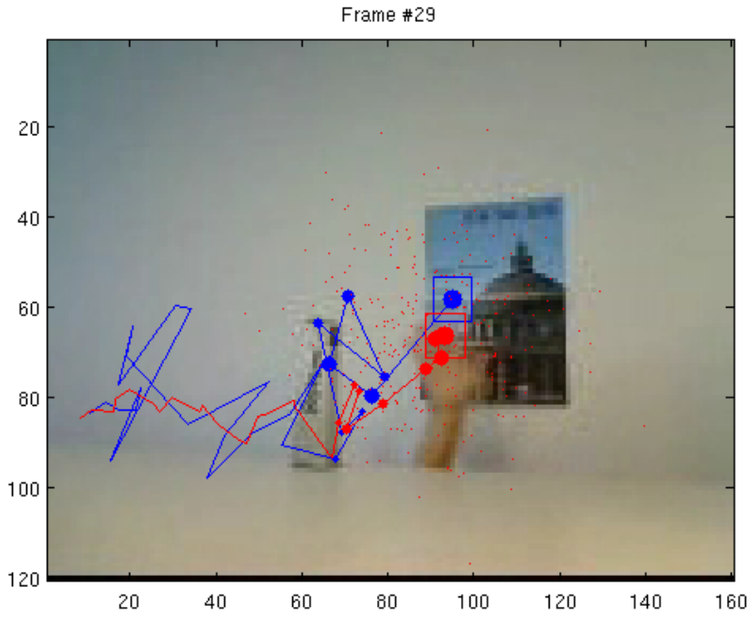
a posteriori mean state

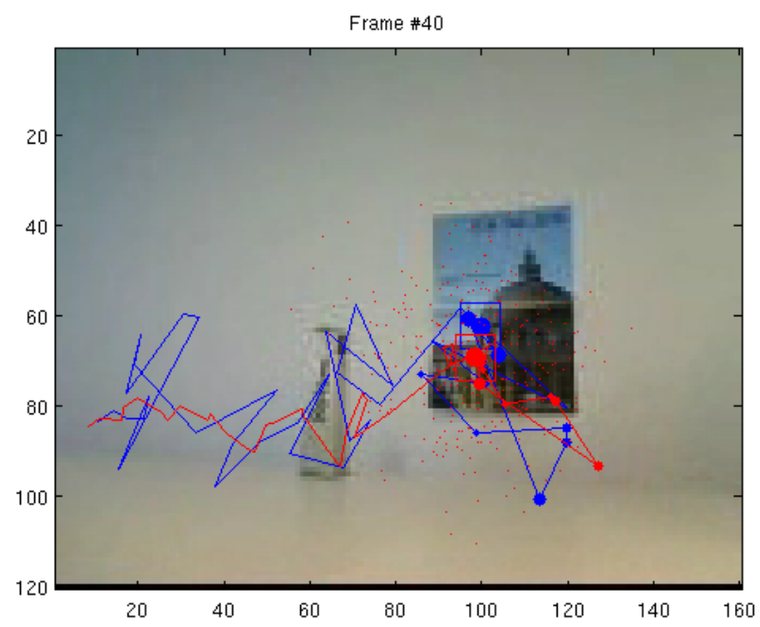
Video 2: Hand, clutter, occlusions







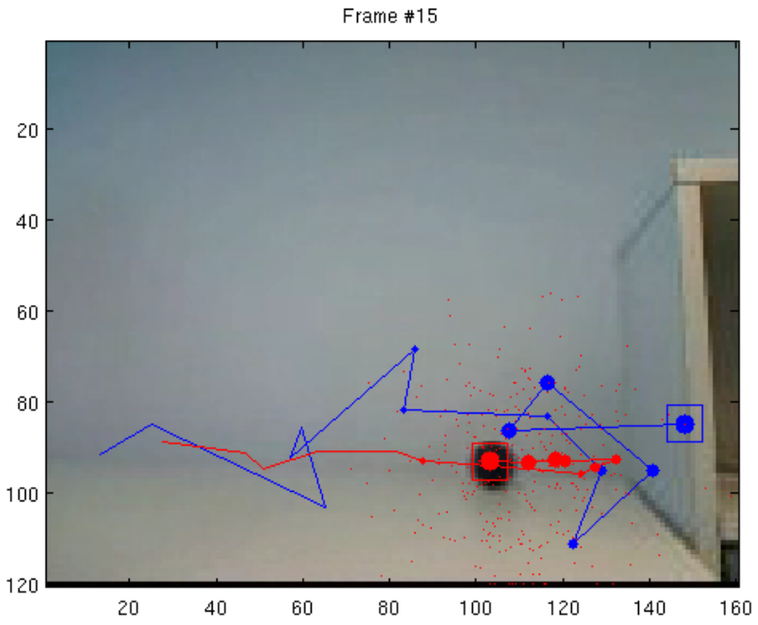


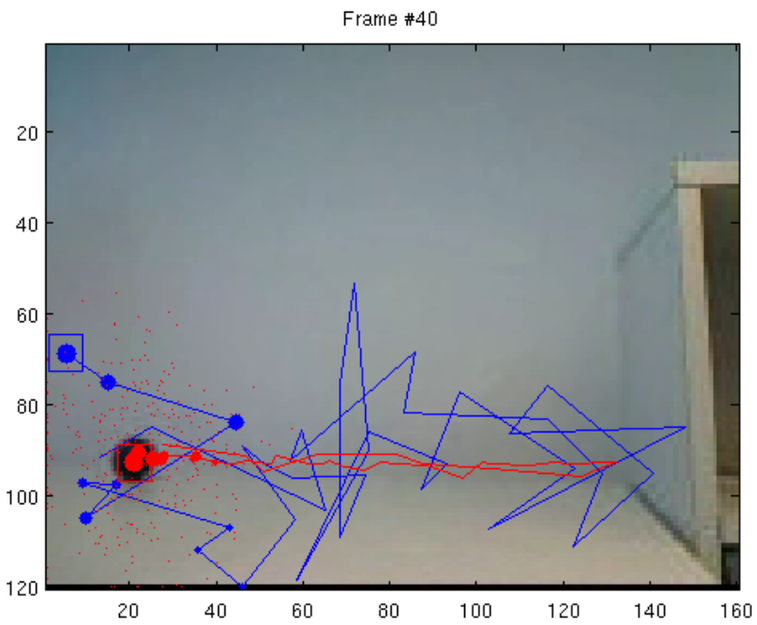


a priori mean state

a posteriori mean state

Video 3: Ball bouncing





a priori mean state

a posteriori mean state

Report

- MATLAB code
  - We provide the overall structure
  - Write the code to perform each step of the CONDENSATION tracker

- Plot the trajectories of the mean state

- Experiment different settings
    - number of particles
    - number of bins for quantization
    - updating appearance model
    - motion model

- Try your own video (bonus)

Hand-in

Hand in by **1pm** on **Thursday 12th December 2013**

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