W11

Object Tracking in Video

Ref: http://www.robots.ox.ac.uk/~misard/condensation.html

Video Analysis

- Detection of interesting objects
- Tracking such object from frame to frame
- Analyzing the objects tracks

Tracking Methods

- Bottom-up
  - Segmentation-based
- Top-down
  - Model-based

Tracking a Leaf

http://www.robots.ox.ac.uk/~misard/condensation.html

Girl Dancing Vigorously

http://www.robots.ox.ac.uk/~misard/condensation.html

Tracking Finger of Violin Player

Tracking in Difficult Scenarios

Robust Density Comparison for Visual Tracking (BMVC 2009)

Can you use object detection for tracking?

Additional Difficulties in Object Tracking

- Image noise/clutter
- Illumination changes
- Complex object motion
- Partial and full occlusion

Main Steps

- Object Representation
- Feature Selection
- Object Description
- Correspondence across frames

Object Representation

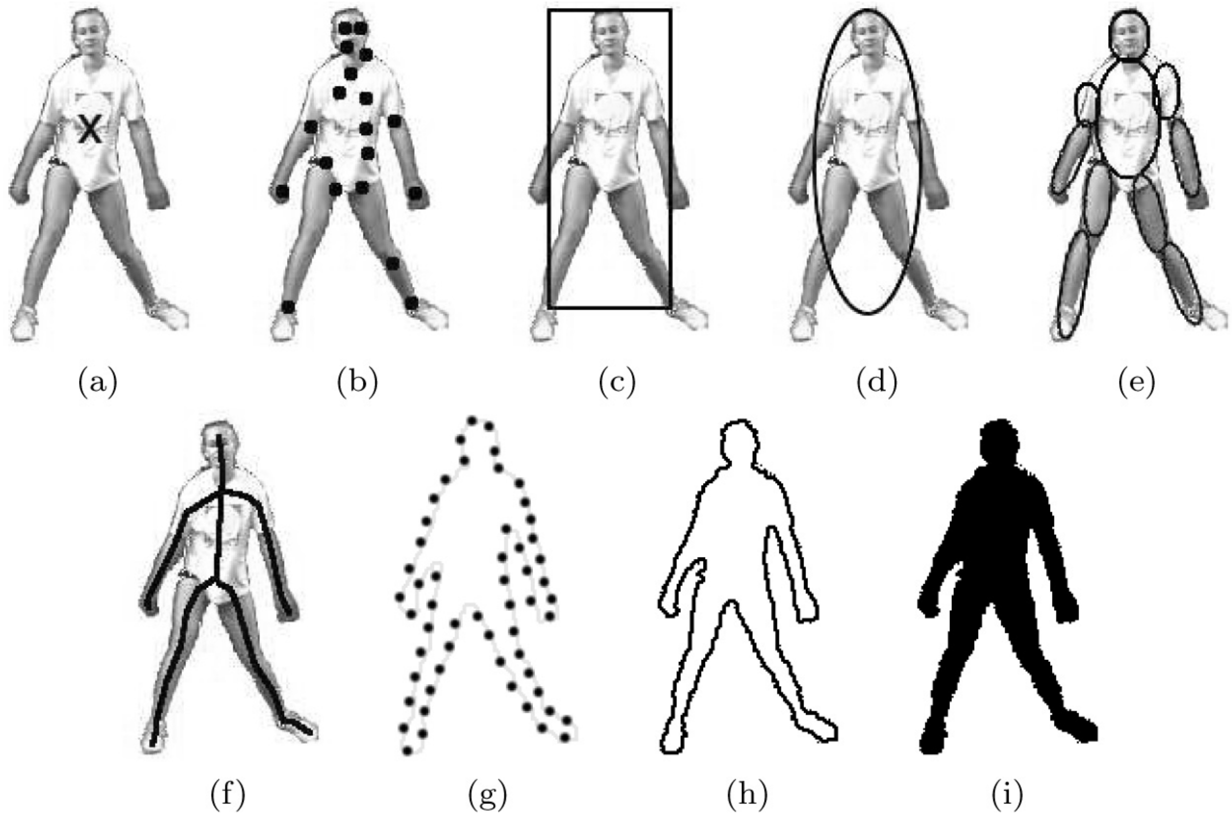


Image: Yilmaz, A., Javed, O., and Shah, M. 2006. Object tracking: A survey. ACM Comput. Surv. 38, 4, Article 13 (Dec. 2006), 45 pages. DOI = 10.1145/1177352.1177355 http://doi.acm.org/10.1145/1177352.1177355

Feature Selection

- Color
- Edges
- HoG
- And more…

Can we use HoG to build object template?

1. HoG is for a class of objects not a specific object
2. Colors are more specific to the objects

Object Description

1. Object is specified in the first frame of video (e.g. rectangle)
2. Object is detected in video (e.g. humans)
3. Obtain a template of the object (e.g. color histogram)

Objective: Given object location in the fist frame, find object locations in the subsequent frames!

Correspondence across frames

- Kalman filter
- Mean-shift filter
- Particle filter

Particle Filters

- Also known as Condensation Algorithm
- A kind of genetic algorithm

Genetic algorithms follow "survival of the fittest"

- Individuals compete for resources and mates
- The strong ones will succeed and produce more offspring
- The good "genes" propagate from parents to the child
- Over time, generations become more suited to the environment

Particles are position and shape

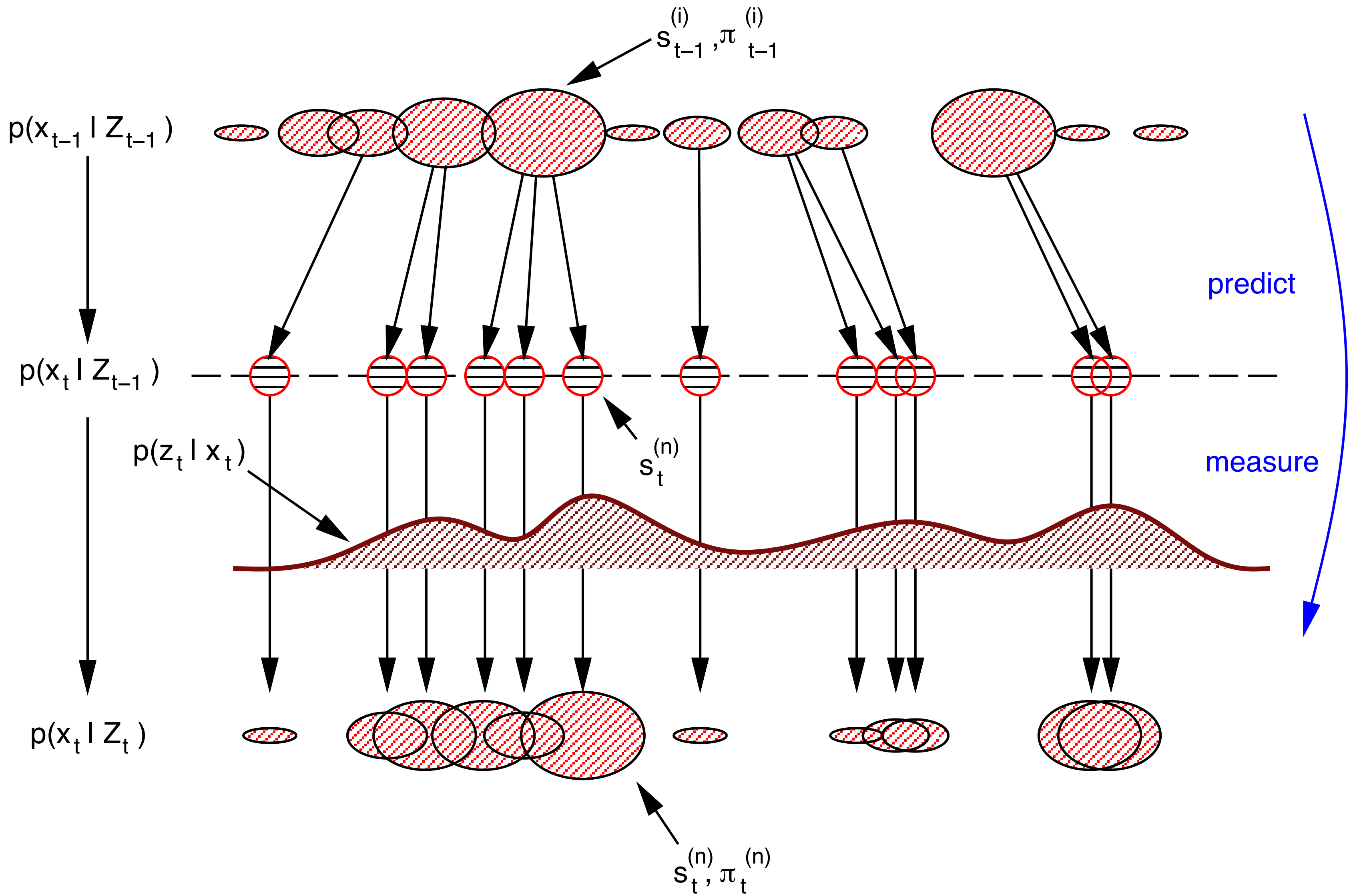
Example: (X, Y, Width, Length)

Particle filter has three main phases:

1. Sample
2. Predict
3. Update

Sample step

a new set of particles is chosen so that each particle survives in proportion to its weight

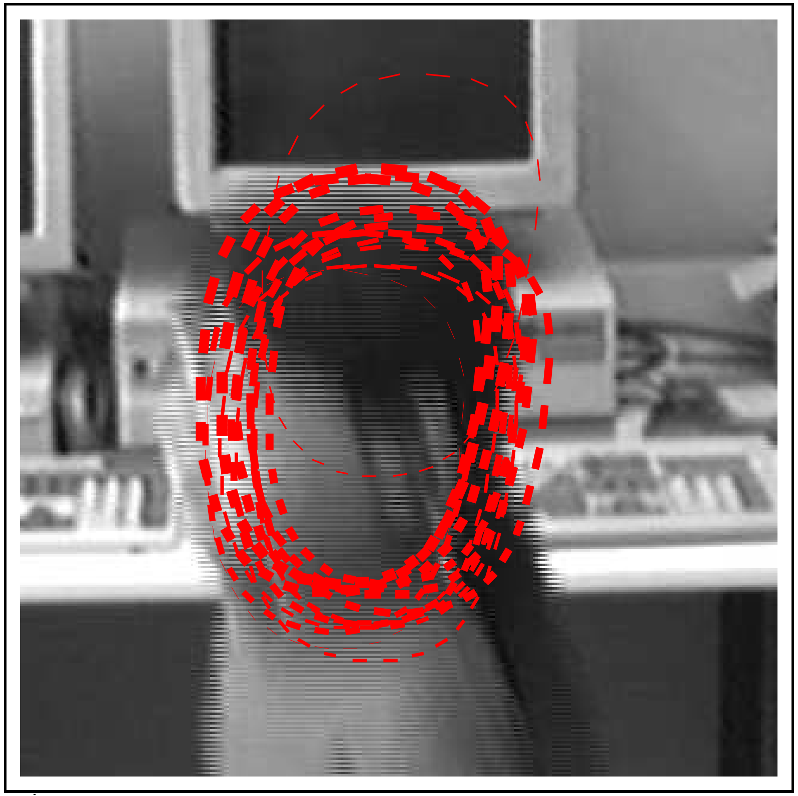


$s_{t-1}^{(i)}, \pi_{t-1}^{(i)}$
$p(x_{t-1} | Z_{t-1})$
$p(x_t | Z_{t-1})$
predict
$p(z_t | x_t)$
$s_t^{(n)}$
measure
$p(x_t | Z_t)$
$s_t^{(n)}, \pi_t^{(n)}$

Predict step

take each particle and add a random sample from the motion model

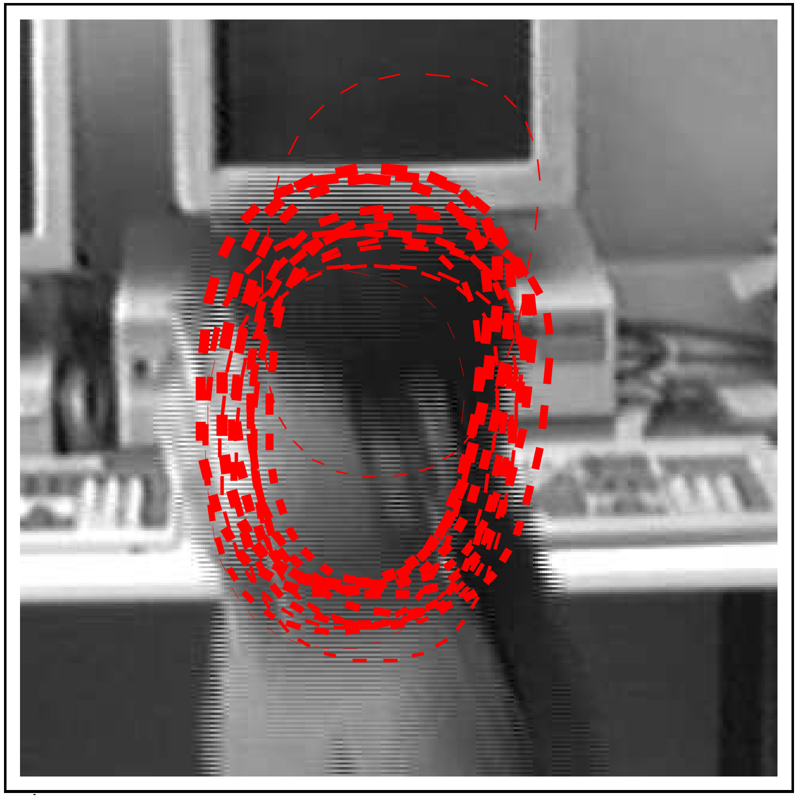
Sample-set representation



Update step

calculate weight of each particle as probability of observing that particle given the template

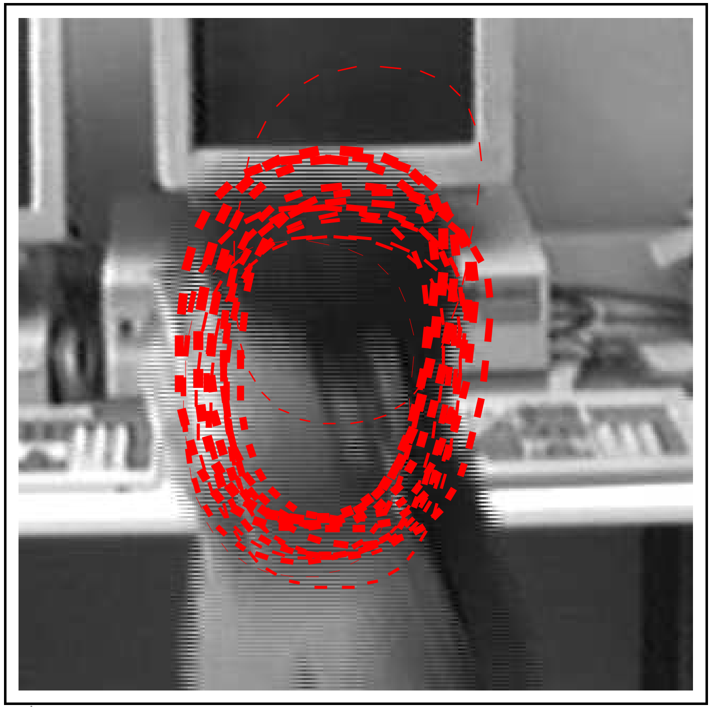
Particles with Weights



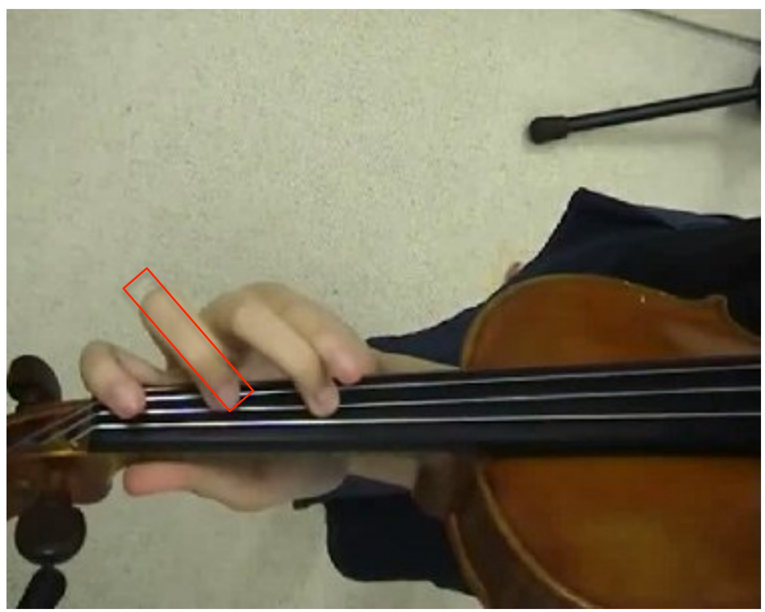
Current State (Location and Shape)

1. Highest weight particle
2. Weighted sum of particles

Current State



Task: Use Particle Filter method to track middle finger of violin player!



Particles

$$S = (L, W, \theta, X, Y)$$

$L =$ Length of rectangle
$W =$ Width
$\theta =$ Angle
$X =$ Row Coordinate
$Y =$ Column Coordinate

Let's assume 100 particles

Initialization

- Initialize all the samples (particles) by actual location and shape of the finger
- Assign weight $\pi_t^n = 1$ to all particles
- Obtain color histogram of the finger

Sampling Step in tth Frame

Re-sampling

- Select 100 samples from the set of samples S'_{t-1} with probability π_t^n
  - Normalize all the weights by dividing each weight sum of weights

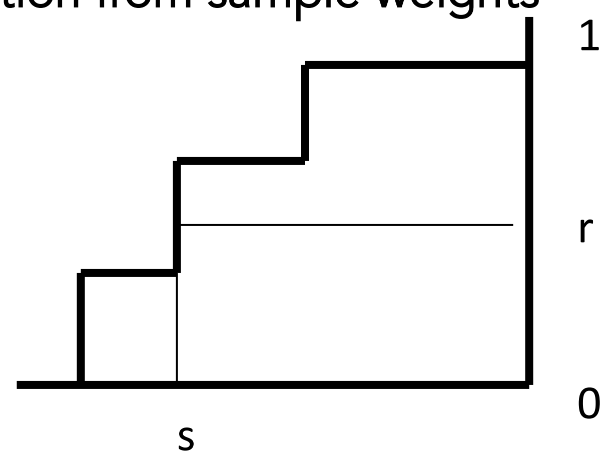
$$\pi_t^{'n} = \frac{\pi_t^n}{\sum_{i=1}^{100} \pi_t^n}$$

  - Calculate the cumulative mass function from sample weights

$$c_t^0 = 0$$

$$c_t^n = c_t^{n-1} + \pi_t^{'n}$$

$$c_t^{100} = 1$$



Prediction Step in tth Frame

- Propagate each sample by adding Gaussian Noise

$$S'^{n}_{t-1} = S^{n}_{t-1} + W^{n}_{t-1}$$

Update by Observing Current Pixels

- Assign weights to the samples based on histogram matching
- Calculate Bhattacharya coefficient and weight

$$bc = \sum_k \left\| h_{itk} . h_{imk} \right\|^{\frac{1}{2}}$$

$$\pi_{it}^{n} = \exp(-(1 - bc) / \sigma 1^2)$$

Current State

- Estimate the current state by taking weighted average of the particles

$$E[S_{it}] = \sum_{n=1}^{100} \pi_{it}^{n} s_{it}^{n}$$

One Finger

Not so good

Four Fingers

Particle Filter Basics

- The basic idea of particle filters is that any pdf can be represented as a set of samples (particles).
- The density of your samples in one area of the state space represents the probability of that region.
- This method can represent any arbitrary distribution, making it good for non-Gaussian, multi-modal pdfs.