# CV Assignment 6, Condensation Tracker

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***Implementation Idea***

color_histogram: for this method, we first make sure that we correct the bounding box passed so that it lies entirely inside the frame, which can help make sure that the distribution is well-defined and comparable to those of other bounding boxes (this step is necssary because the source code contains a call which can potentially pass out-of-bound boxes). Then we iterate over all pixels inside of the box and calculate its binned RGB values and increment the corresponding value in the slot. Finally, the histogram is normalized by dividing the number of pixels.

propogate: we first derive the formula for the matrix A. According to the handout, we either have a fixed position bounding box with noise or a bounding box with constant velocity and noise. So denote $A,\ A'$ as the matrices for the case where we do not have velocity and the case where we have constant velocity:

$$[x,\ y] = A\begin{bmatrix} x \\ y \end{bmatrix}, [x+\dot{x}, y+\dot{y}, \dot{x}, \dot{y}] = A'\begin{bmatrix} x \\ y \\ \dot{x} \\ \dot{y} \end{bmatrix}$$

Therefore we can see that $A = I_{2x2},\ A' = \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$. We can define the matrix A based on the shape of the particles and the parameter model. The noise is of the same shape of particles which are first initialized as independent standard gaussians and then scaled with sigma_pos and sigma_velocity. In order to make the tracking more stable, we chose to recalculate the particles (use a newly sampled noise) when they do not lie within the picture frame. At the end, all particles should be within the picture frame with the transformation $p' = Ap + B\epsilon$ where $p'$ is the propagated particle, $p$ the original particle, $B$ the sigma parameter, and $\epsilon$ the standard gaussian noise.

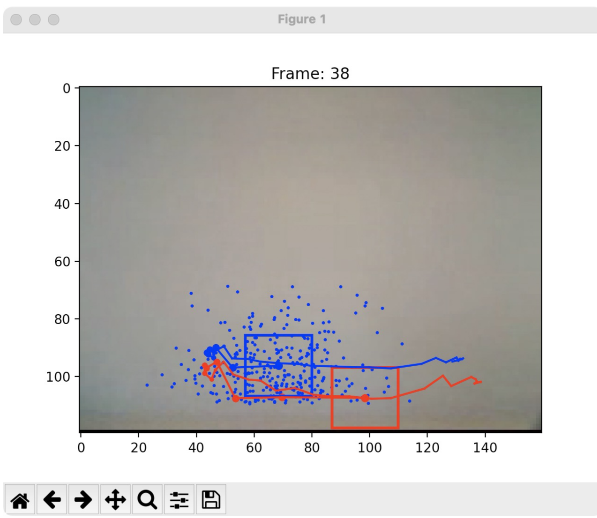
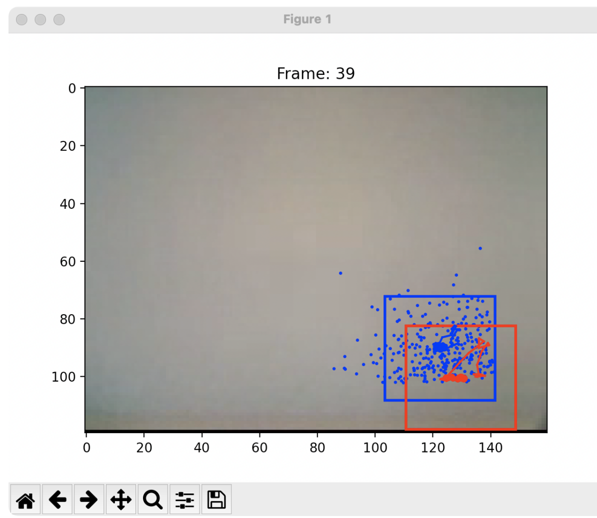
estimate: this is simply implemented as the weighted average.

observe: we iterate over all particles and for each one, we calculate the color histogram corresponding to the bounding box centered at the particle position. Then the chi squared distance is calculated between the histogram and the target histogram provided. This cost is then used to find the gaussian pdf with standard deviation being sigma_observe. Finally, we use the pdf as the unnormalized weights, and normalize them by their sum.

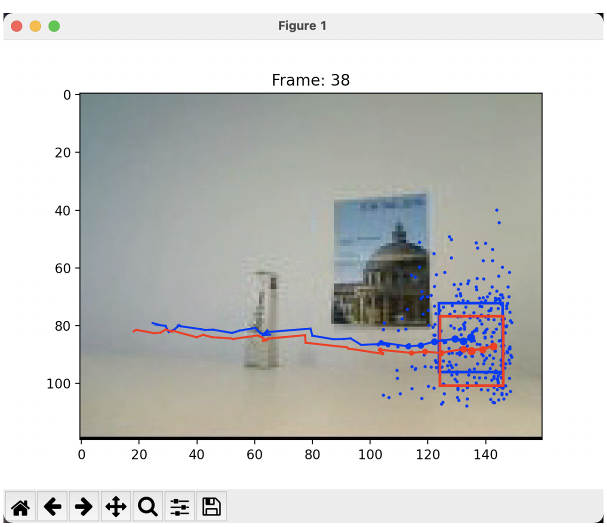
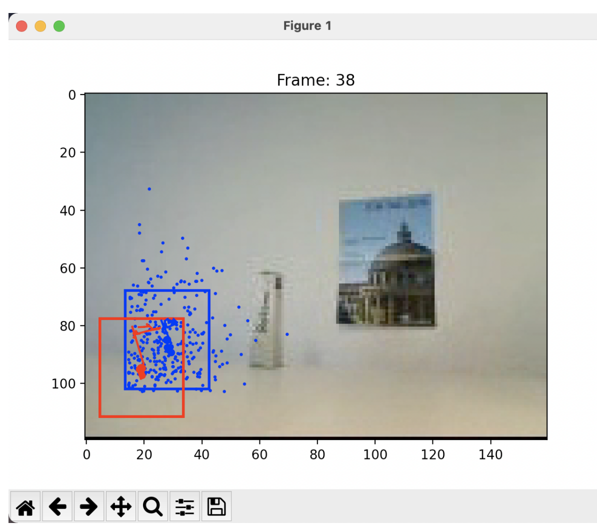
resample: in this function, we sample with replacement the indices of the particles based on the weights. And we return the particles based on these indices. The weights are set to be $1/N$ where $N$ is the number of particles. In this case, the resampled buffer represents the empirical distribution of the posterior distribution.

## ***Experiments***

* Video1

| Successful | Unsuccessful |
| --- | --- |
|  |  |

* Video2

| Successful | Unsuccessful |
| --- | --- |
|  |  |

• What is the effect of using a constant velocity motion model?

When we have a constant velocity model, our particles will have a tendency of propogating towards this direction. And if the object is indeed moving along the same direction, the tracking will be easier than just replying on noises. Especially when the hand moves passing through the obstacle (occluded), using a constant velocity along the right direction can help losing the target.

• What is the effect of assuming decreased/increased system noise?

If we have large system noise, the particles are more spreaded out after propagation. And the prior would be a little bit far away from the posterior. But it will also work in this case with other parameters fixed except that it is not as robust.

If we have small system noise, the particles are more concentrated. The prior and posterior are more aligned, which makes the trajectory smoother. However, when the object moves too fast, the particles can not follow it as much without the velocity model, the tracking will fail as the target moves out side of the range covered by the particles.

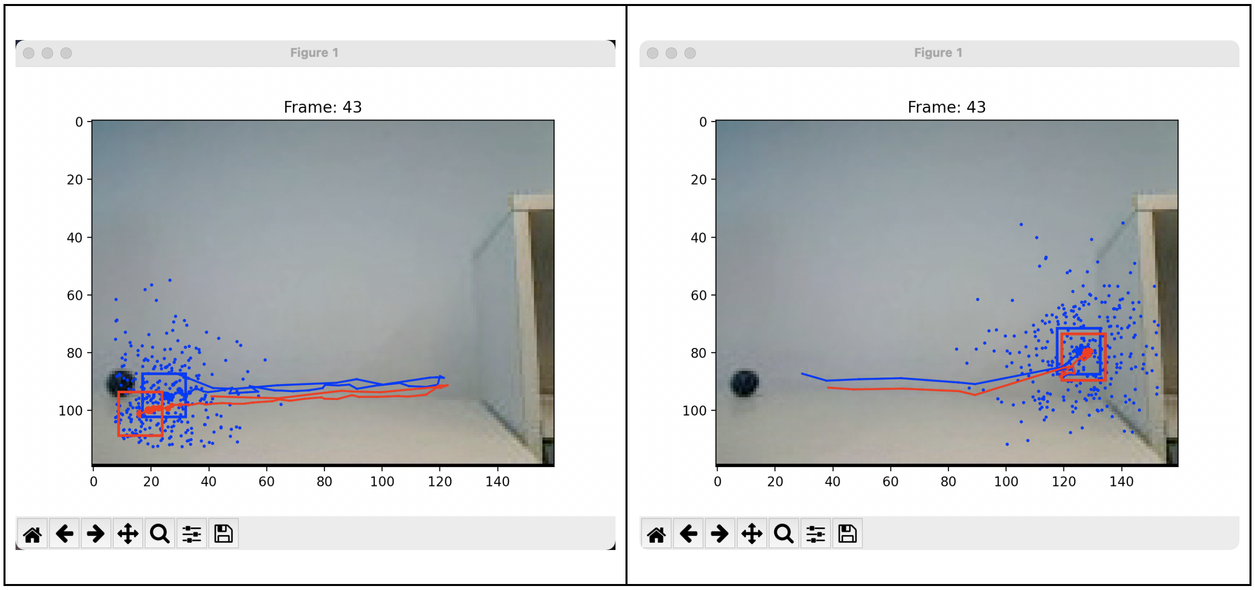
• What is the effect of assuming decreased/increased measurement noise?

If we have large measurement noise, the trajectory will be smoother as more particles are contributing to the mean estimation. However, it is likely to lose the target because the mean estimate can be noisy and inaccurate.

If we have small measurement noise, the mean estimation will be more accurate but at the same time less prone to perturbation or small change of the target. Having too small a measurement noise will also result in loss of the target as the target moves too fast or the color distribution changes too fast than the update frequency.

* Video3

| | |
|---|---|
| Successful | Unsuccessful |




• Use the best parameters for video2.wmv to try to track the ball. Are you able to track the ball? Why or why not?

My specific choice of parameters for video2 did not work for video3. The problem happens when the ball changes its direction. Because I used a very small alpha for video2, once I increased the alpha a little bit (from 0.1 to 0.2) with all others fixed, the tracking became successful.

• What is the effect of using a constant velocity motion model?

In this case, having a constant velocity model in video3 might not be very good as the ball will change its direction rapidly once it reaches the right end. And the model will be an incorrect one which will deviate the tracking.

• What is the effect of assuming decreased/increased system noise?

This will be very similar to the case in video2 according to the experiment.

• What is the effect of assuming decreased/increased measurement noise?

Different from video2, the object in video3 stay relatively similar. Therefore, having a small measurement noise (not too small) will likely to improve the tracking performance.

• What is the effect of using more or fewer particles?

Having more particles will make the approximation to the posterior more accurate (lower variance) although it also creates computation burden. Having fewer particles can make running fast but the trajectory can be very zig-zagging due to high variance of the approximation. And if there are too few particles, chances are that we will lose tracking when the coverage of the particle can not match how fast the object moves.

• What is the effect of using more or fewer bins in the histogram color model?

The more bins we use the more accurate the color histogram approaches the real color distribution (as in 24 bit colors). However, if the object changes fast and the alpha is set low, this will result in loss of tracking. When the object is very flat in color and the background is also flat in color, using fewer bins can be more robust. The general idea is that the more bins we use, the more sentitive the estimation becomes. So the best parameter depends on the object color, the background, the distance metrics, and the update parameter alpha.

• What is the advantage/disadvantage of allowing appearance model updating?

If we do not allow update to the appearance model and the shape of the object can change over time, the tracking is very likely to fail as the original appearance model is no longer accurate enough to keep tracking going. However, having very fast update rate can also be problematic. For example, when some perturbation happens or when the object moves over another object that can occlude the target, the tracking can fail as the appearance update too fast so that the information of target object is lost as well. This can also happen more frequently when we have fewer particles and the mean estimation is noisy.