# Computer Vision Assignment Eleven @ ETH Zurich

Condensation Tracker

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## 1 Color Histograms

A color histogram is created for each of the three channels in the specified bounding box depending on the number of histogram bins.

## 2 Derive Matrix A

We consider two prediction models in this project; for the first prediction model (no motion at all), just noise for the position x and y.

$A = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

for the second prediction model (constant velocity motion model), adding velocity component of each state to its current location.

$A = \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \end{bmatrix}$

# 3 Propagation

For propagation phase, random noise for position is generated for each of the particles and a check is made if the new particle position lies outside the frame or inside; if it lies outside the frame, a new random noise is generated and tested again. Also, in case of mode 1; the velocity is also changed accordingly by using the sigma provided for the velocity's noise component.

# 4 Observation

For the observation section, a color histogram is generated for every bounding box with the particle in its center, then distance is calculated between this histogram and the traget histogram using chi2sqaure; using the calculated distance, the weight of each particle is calculated according to equation (6). Note: weights are normalized at the end before returning the resulting weights.

# 5 Estimation

In the estimation part, the weighted average is computed of all particles using the caclulated weights.

# 6 Resampling

A new sample is generated using the weights of the particles as a probability distribution.

# 7 Experiments

For the first video, different parameters were used for experimentation. When using mode 0 (no motion model), the tracker loses track of the hand and tracks part of the arm. If using mode 0 was complemented by using a larger sigma position, then the apriori estiamtion gets better. However the posterior estimation remains the same. When using mode 1; sometimes the tracker loses track of the fingers and tracks the lower part of the hand; this might be caused by the inaccurate initial velocity model.

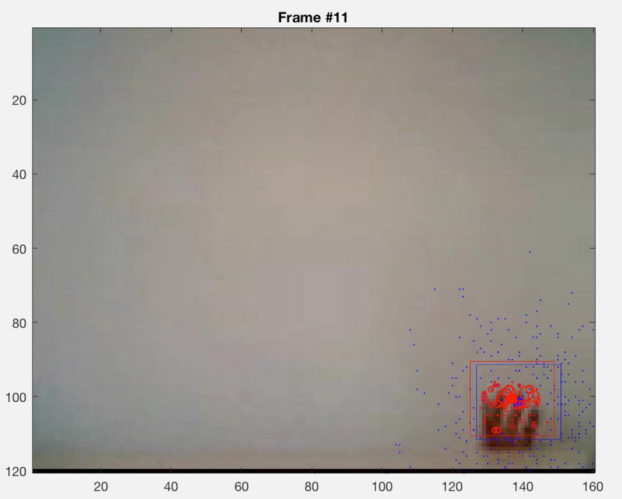


**Figure 1:** Video 1

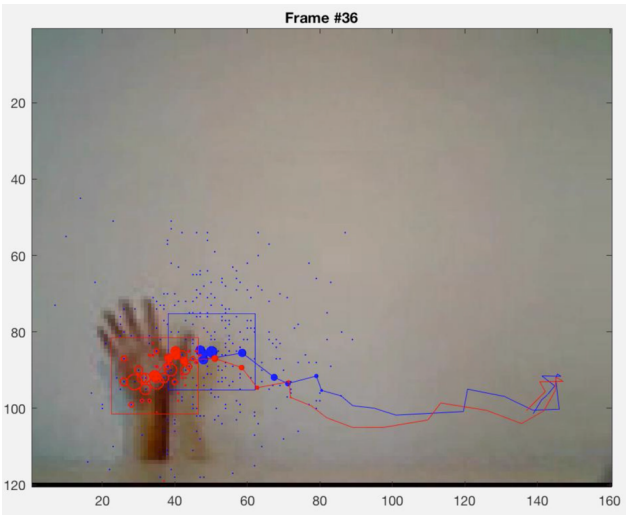


**Figure 2:** Video 1

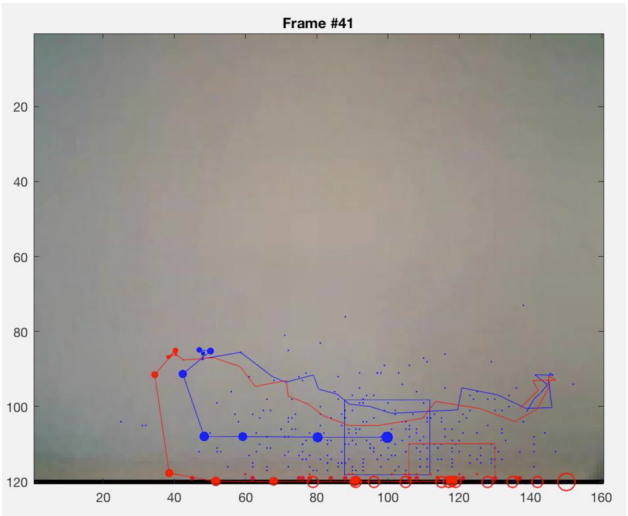


**Figure 3:** Video 1

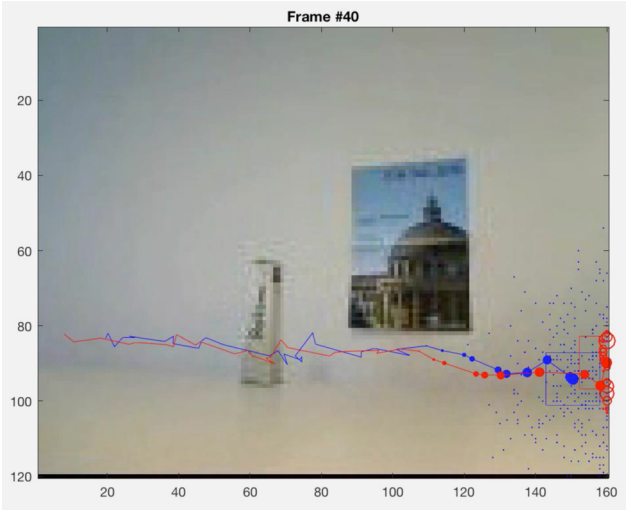


**Figure 4:** Video 2

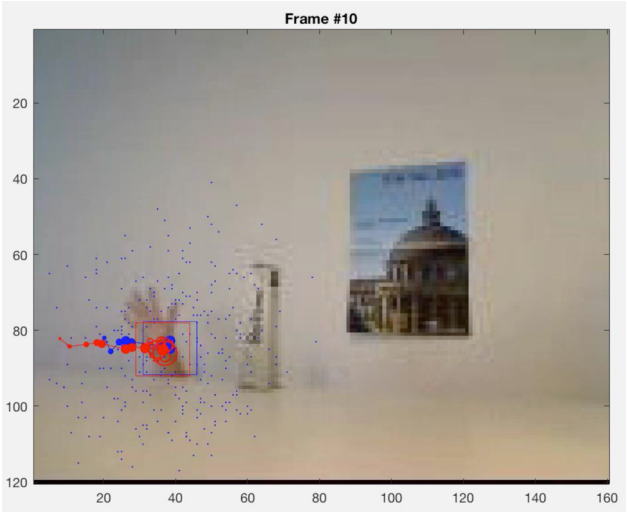


**Figure 5:** Video 2

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

For the second video, different parameters were used for experimentation. When using mode 0 (no motion model), the tracker loses track of the hand and tracks part of the arm; in this case I think occlusion is the main reason behind the failure in tracking the hand. When using mode 1 (motion model with constant velocity); the tracker successfully tracks the hand even when it goes into

occlusion.

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

The increased system noise helps the tracker in recovering from losing track of the hand in couple of consecutive frames.

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

Increasing the measurment noise has the same effect as increasing system noise, it helps recovering from a failure in tracking the object for couple of consecutive frames, since it brings more randomness to setting the particle weights. Increasing the randomness in setting particle weights is evedinetly better in cases of clutter in the background where the histogram distance will give us false (unreliable) information to hypothesis on the current position of the object.

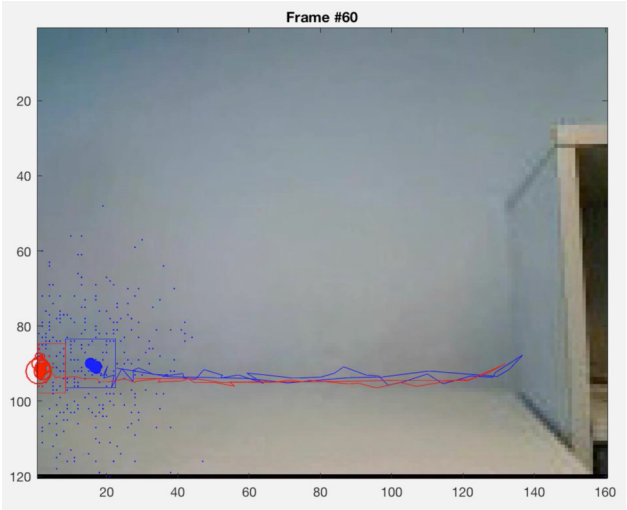


**Figure 6:** Video 3

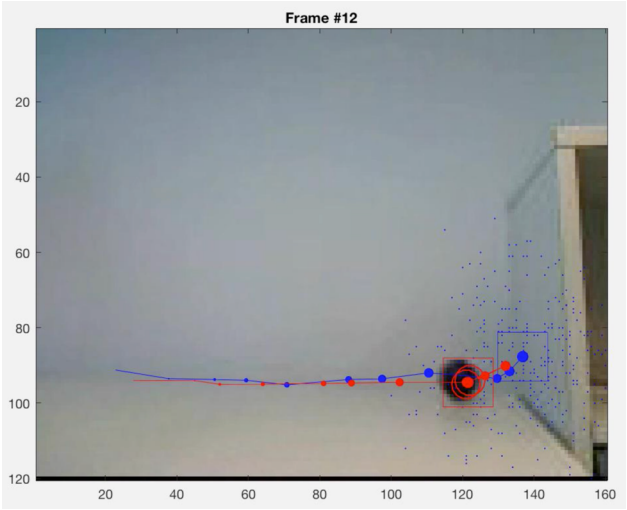


**Figure 7:** Video 3

Using the best parameters of video 2 for video 3 failed as expected since we are dealing here with a different movement situation (bouncing ball hitting the wall and moving in the reverse direction afterwards.). After increasing the sigma velocity, increasing the measurment noise and decreasing the postion noise, I was able to track the ball seamlessly as shown above.

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

The effect of using a velocity motion model in the video is very important since the ball moves in different directions with high speed, which makes it hard to capture the movement with just a no motion model (noise only)

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

The increased system noise helps the tracker in recovering from losing track of the ball in couple of consecutive frames. However after a certain point increasing the system noise would help the tracker in losing track of the ball, specifically when hitting the wall and bouncing back.

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

Increasing the measurment noise has the same effect as increasing system noise, it helps recovering from a failure in tracking the object for couple of consecutive frames, since it brings more randomness to setting the particle weights. In the case of this video, slight differences were noticed when increasing/decreasing the measurment noise; since the ball's color is very different than the background of the video.

What is the effect of using more or fewer particles?

The more particles we use; the higher the risk that the good estimate particles will be dropped in the resampling phase. On the other hand, if we use a small number of particles, then if the tracker loses track of the object in couple of consecutive frames then it will be harder to recover and there will be bias towards to the current estimated bounding box.

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

Too few bins for the histogram has a disadvantage of providing misleading information in case of a cluttered background since a lot of the histograms will be close to each other when measured by the chi2sqaure distance. More histogram bins will increase the precision but too many bins will lead to not identifying the close histograms to each other which will mislead the tracker in hypothesising that no bounding box contains the close histogram color with high particle weight.

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

This will be useful in helping the tracker in case of illumination changes and appearance changes. But it shouldn't be very often since there is a big risk of

losing the original model after couple of updates (and once the tracker loses the original model it will be very hard to track the original object again.)

# 8 Bonus

**Figure 8:** Bonus Video


**Figure 9:** Bonus Video

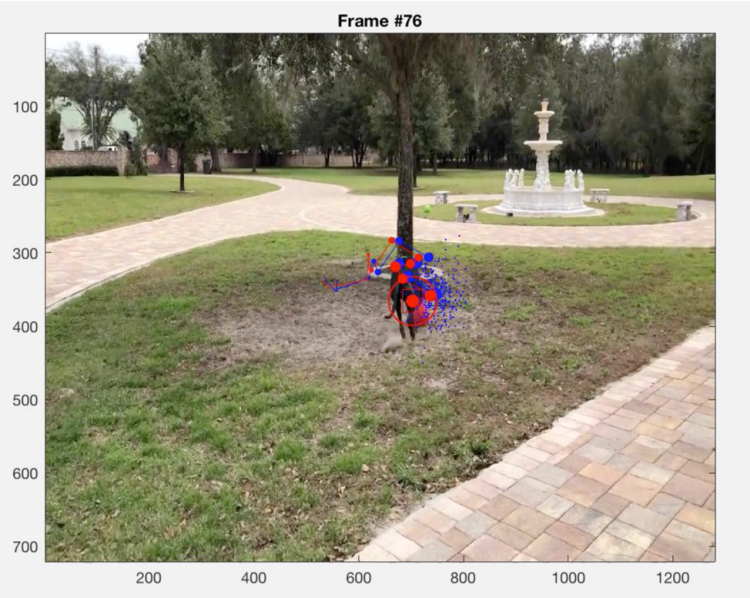


**Figure 10:** Bonus Video

The video shown above is about a dog holding a ball with his mouth and playing with it and moving it around. Several occlusions are witnessed while the dog is running as well as some scale changes. The challenging part in this video that the first frame had already occlusions to the target object (the ball was occluded by the dog's leg). Surprisingly after tuning the parameters and increasing the position sigma and velocity sigma as well as the observation noise, the algorithm worked quite well and tracked the object for a short time horizon (since the video is lengthy). One of the suggested improvments that can be taken in account is trying to recover the original target if the tracker losed it for n consecutive frames by increasing the system noise and the measurment noise for one step only not every time. so adapting the noise according to the average chi2square dist.


**Figure 11:** Bonus Video Failure Case