Exercise 4: Advanced tracking

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I. Introduction

In this paper, we present Kalman filtering method using motion models. We also implement trackers, using those motion models. We tried different parameters and report performance changes. The best results were obtained using $q = 100, r = 0.0001$.

II. Experiments

In the first part, we ran Kalman filtering method on a spiral curve using RW, NCV and NCA motion models and different values of parameters q and r. In Figure 1, we can see resuts. First column is from RW, second fro NCV and third from NVA. In first row we used $q = 1, r = 0.1$, in second $q = 1, r = 1$ and $q = 0.1, r = 0.1$ in the last one.

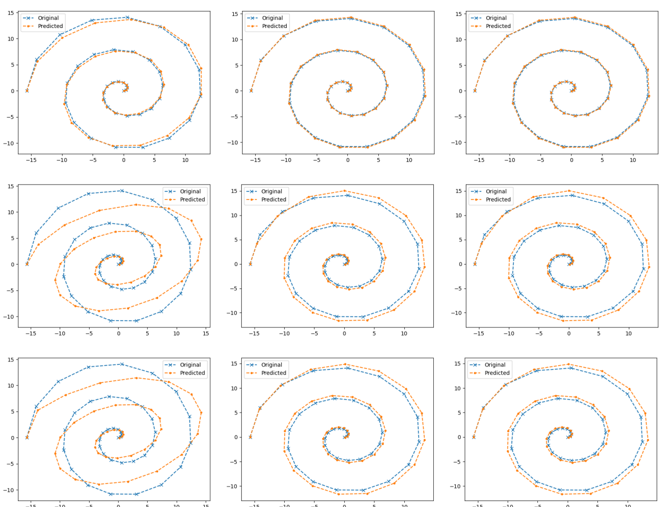

Figure 1. Comparison between models and parameters.

After that, we implemented particle filter tracker using color histogram as a visual model and NCV as a motion model. We tested tracker on whole VOT14 dataset and obtain accuracy of 43% and robustness of 58%.

Next, we tried our Kalman filtering method on two other functions, shown in Figure 2. First, a sine wave (first row), second, a cubic function (second row). For both, we tried all three motion models, as in the first paragraph. Parameters for all examples were $q = 1, r = 0.1$.

In addition to NCV model, we also tested NCA model when tracking. Both were tested on the whole VOT14 dataset. Comparison can be seen in Figure 4. There is no significant difference overall, NCV is slightly more robust. Parameters $q = 100, r = 0.0001$ were used.

Lastly, we tried a different number of particles, to see performance changes of a tracker, using color histogram and NCV. More particles used, slower the tracker. Having a few particles result in faster tracker, but accuracy drops significantly. Using more particles result in better accuracy, but having too many, may also result in dropped accuracy (on top of being really slow). We can see results in Table **??**. Parameters $q = 100, r = 0.0001$ were used. We can see how accuracy and robustness grows with greater number of particles, but the difference is not significant. On the other hand, speed is falling exponentially.

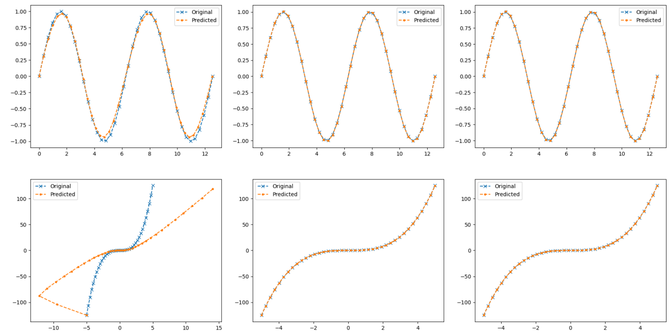

Figure 2. Comparison between models on sine wave and cubic function.

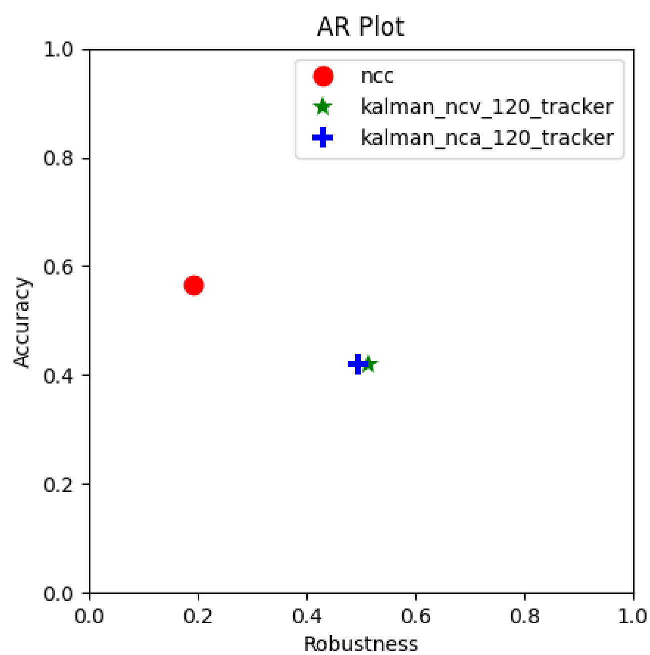

Figure 3. Comparison between trackers accuracy and robustness.

III. Conclusion

Motion model trackers are more advanced, and can provide optimal performance, but only when parameters are set correctly. Finding optimal universal parameters can be quite difficult.

Appendix

(I uploaded this image, because I was having troubles with packages that would allow matrix writing. I am sorry for that).

Random walk (q, r)

$$\Phi = \begin{bmatrix} 1 & \Delta t \\ 0 & 1 \end{bmatrix} \qquad L = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \qquad R = \begin{bmatrix} r & 0 \\ 0 & r \end{bmatrix} \qquad H = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$Q = \begin{bmatrix} \Delta t^3 \cdot \frac{q}{3} + \Delta t \cdot q & \Delta t^2 \cdot \frac{q}{2} \\ \Delta t^2 \cdot \frac{q}{2} & \Delta t \cdot q \end{bmatrix}$$

(state)

$X = [x, y]$

Near Constant velocity (q, r)

$$\Phi = \begin{bmatrix} 1 & 0 & \Delta t & 0 \\ 0 & 1 & 0 & \Delta t \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad L = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 1 & 0 \\ 0 & 1 \end{bmatrix} \qquad H = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \qquad R = \begin{bmatrix} r & 0 \\ 0 & r \end{bmatrix}$$

$$Q = \begin{bmatrix} \Delta t^3 \cdot \frac{q}{3} & 0 & \Delta t^2 \cdot q/2 & 0 \\ 0 & \Delta t^3 \cdot q/3 & 0 & \Delta t^2 \cdot q/2 \\ \Delta t^2 \cdot q/2 & 0 & \Delta t \cdot q & 0 \\ 0 & \Delta t^2 \cdot q/2 & 0 & \Delta t \cdot q \end{bmatrix}$$

$X = [x, y, vx, vy]$

Near Constant acceleration (q, r)

$$\Phi = \begin{bmatrix} 1 & 0 & 0 & 0 & \Delta t & 0 \\ 0 & 1 & 0 & 0 & 0 & \Delta t \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \qquad L = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 1 & 0 \\ 0 & 1 \end{bmatrix} \qquad H = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix} \qquad R = \begin{bmatrix} r & 0 \\ 0 & r \end{bmatrix}$$

$X = [x, y, vx, vy, ax, ay]$

$$Q = \begin{bmatrix} \Delta t^3 \cdot q/3 & 0 & & & \Delta t^2 \cdot q/2 & 0 \\ 0 & \Delta t^3 \cdot q/3 & 0 & 0 & 0 & \Delta t^2 \cdot q/2 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ \Delta t^2 \cdot q/2 & 0 & 0 & 0 & \Delta t \cdot q & 0 \\ 0 & \Delta t^2 \cdot q/2 & 0 & 0 & 0 & \Delta t \cdot q \end{bmatrix}$$