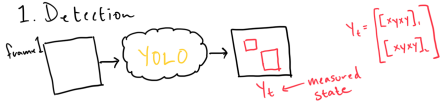


**Kalman Filtering (handwritten)**

SORT: Kalman filtering & Hungarian alg (cost matrix)

- 4 steps:   
 1. Detection - Yolo   
 2. Estimation - Kalman   
 3. Association - Hungarian   
 4. Creation - Threshold   
 } Kalman Steps



2. Estimation

GOAL "True" state  $X_{t+1} = F X_t + U, v \sim N(0, P)$

Measurement  $Y_t = H X_t + v, v \sim N(0, Q)$

Assuming a linear system, matrices  $F$  &  $H$  are assumed to be constant. They are found through hyper-parameters for true.

Estimated state  $\hat{X}_{t+1} = F \hat{X}_t + \hat{U}$

Transition matrix  $\hat{Y}_{t+1} = H \hat{X}_{t+1} + v$

Kalman Ratio  $K_x = \frac{\sum_{xx}}{\sum_{xx} + Q_{xx}}$

uncertainty of estimated position

uncertainty of measurement

new

$X_{t+1} = \hat{X}_{t+1} + K_x \Delta Y_t$

$\Delta Y = Y_{t+1} - \hat{Y}_{t+1} = Y_{t+1} - (H \hat{X}_{t+1} + v)$

Two estimates

- $\sum_{xx} = 0$ :  $X_{t+1} = \hat{X}_{t+1}$
- $Q_{xx} = 0$ :  $X_{t+1} = \hat{X}_{t+1} + \Delta Y = \hat{X}_{t+1} + Y_t - \hat{Y}_t$  (measurement correct)

Kalman filters make estimations about a system's next state based on constant transition matrix & process noise. This is then used to also predict the value of the next measurement.

Finally, when the next measurement is made, the Kalman filter updates its estimation to include info on the predicted measurement as true.

Outputs are estimated positions of targets w/ some information about how much previous est. (pos & measure) were off by.

3. Association

- We have:
- targets: est. detections thanks to Kalman
  - detections: new detections for this frame

Cost matrix containing I.O.U for all targets & estimates

det \ est	d1	d2	d3
t1	0.9	0.8	0.0
t2	0.0	0.2	0.6

assignments: (d1, t1) (d3, t2) (d2, new)   
 If above IOUmin, accepted, otherwise reject.   
 (d2, new) ← see step 4

4. Creation & Deletion

- For assignments in step 3:
- d1 likely same as t1
  - d2 likely new, untracked object
  - d3 could be t2 or not, depending on IOUmin   
 ↳ if IOUmin > 0.6 then, d3 is a new, untracked obj
  - tracks not apart of an assignment are terminated (if they've been missing detections for T\_max frame (if they reappear, they get new id))