A6

Kalman Filter (Dynamic Bayes) State Estimation

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1. Introduction - Johnny Le

This assignment tracks the movement of projectiles in two instances. The first instance will track the projectile as it moves with zero gravity while the second instance will track the projectile with normal gravity. Normal gravity will be assumed at -9.8 m/s. Both will use a Kalman filter to pull more accurate data and noise will be accounted for.

In addition to the charts plotting the positional changes, another chart plotting the velocities is also displayed.

Questions:

1. How does changing the covariance affect the plot?
2. What impact does the noise have on the plot?
3. How does the projectile chart change with varying initial velocities?

2. Method - Trung Le

The starting point for the Kalman filter experiment was CS4300_Driver. Here, the majority of the statistics and analysis take place. The variables that are passed into CS4300_Driver_Proj and CS4300_Driver_Lin are initialized here. The variables are initialized according to the assignment specifications.

For the linear motion, the variables are instantiated as:

X0 = y0 = 0.

Vx0 = vy0 = 4.

Del_t = 0.05.

Max_time = 20.

For the projectile motion, the variables are instantiated as:

X0 = y0 = 0.

Vxo = vyo = 100.

Del_t = 0.05.

Max_time = 70.

Obs_freq = 0.35.

R = 0.001.

Q = 1.
The linear motion driver and the projectile motion driver are similar with only one difference. The u matrix is instantiated as [0;0] for linear motion and [0;g] for projectile motion, where g = -9.8. These matrices are an essential portion of the formula for positions and velocities. To calculate these values, a function called CS4300_process is utilized in which it takes in the initial variables and will multiply those matrices based on the associated formula.

This will return the ideal state. The next step will create a new variable known as x_noise which uses randn multiplied against the standard deviation. To get the actual state, x_noise gets added to the ideal state.

The observed state is generated using CS4300_Sensor which takes in the covariance matrix C, the previous state x and the Q noise matrix.

All of these states are added to an appropriate trace including the Kalman Filtered estimate. These vectors are then plotted on the chart and ellipses staggered throughout the entire graph display the range of error.

This method is completed for both the linear motion and projectile motion. The main difference is that in the projectile motion there is a conditional statement that ends the steps once the projectile reaches the ground (y <= 0). In addition, the obj_frequency staggers the data recorded.

3. Verification - Johnny Le

Verification will be done by stepping through the first few steps of the linear motion and the projectile motion and verifying the correctness of the states as generated by the sensor, kalman filter and process.

Linear motion:

Iteration	Xa (Actual)	X (Kalman Filter Estimate)	Z (Sensor)
1	[0.2446,0.2448,4.0212,3.9618]	[0.4014,0.4040,4.0000,4.0001]	[0.7517, 1.3976]
2	[0.4549,0.4180,4.0493,3.9255]	[0.6410,0.6363,4.0210,3.9616]	[-0.3009,-0.1544]

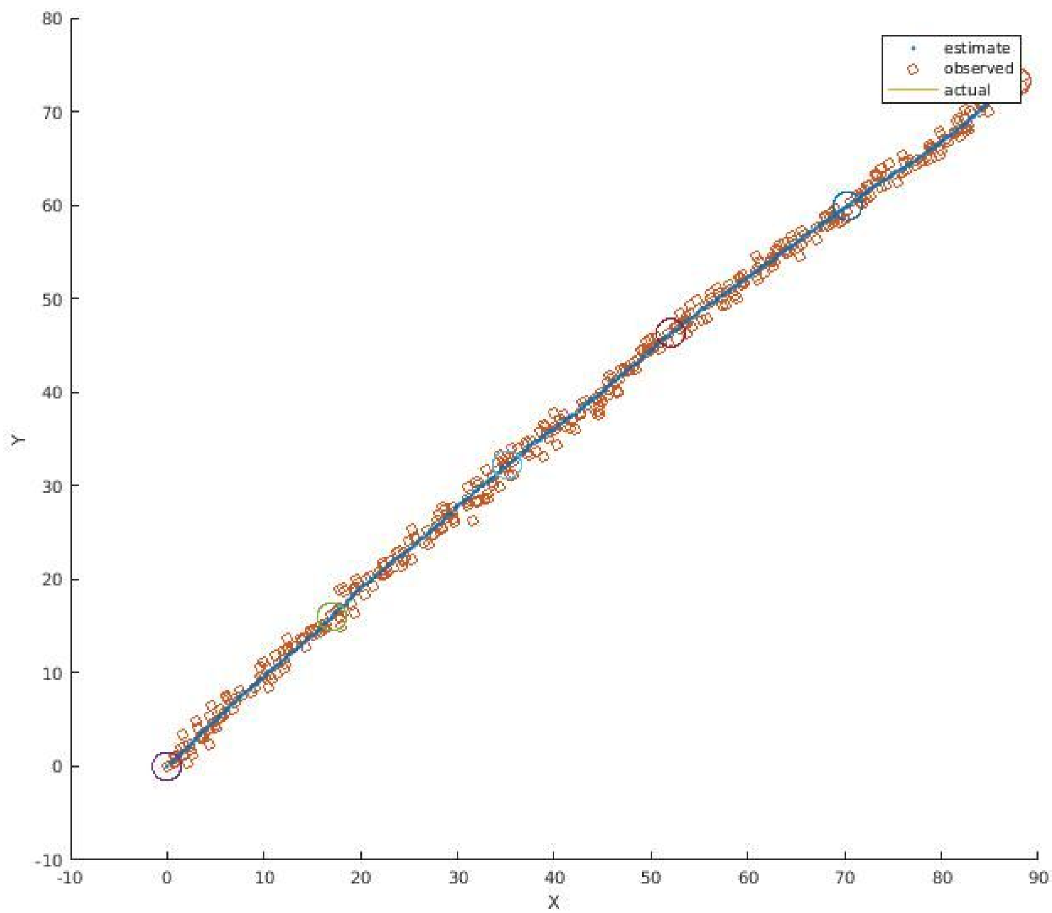
3	[0.7007,0.5602,4.0461,3.9179]	[0.8604,0.8103,4.0494,3.9255]	[0.9264,0.7814]
4	[0.9376,0.7911,4.0188,3.9204]	[1.0951,0.9425,4.0451,3.1970]	[0.0791,0.0038]
...	...	...	...
400	[79.5208,67.2523,3.6055,3.2350]	[79.6737,67.4285,3.5159,3.1898]	[78.6360,67.1252]
401	[79.7628,67.3993,3.5849,3.2543]	[79.911,67.5774,3.6220,3.2359]	[80.2642,67.5972]

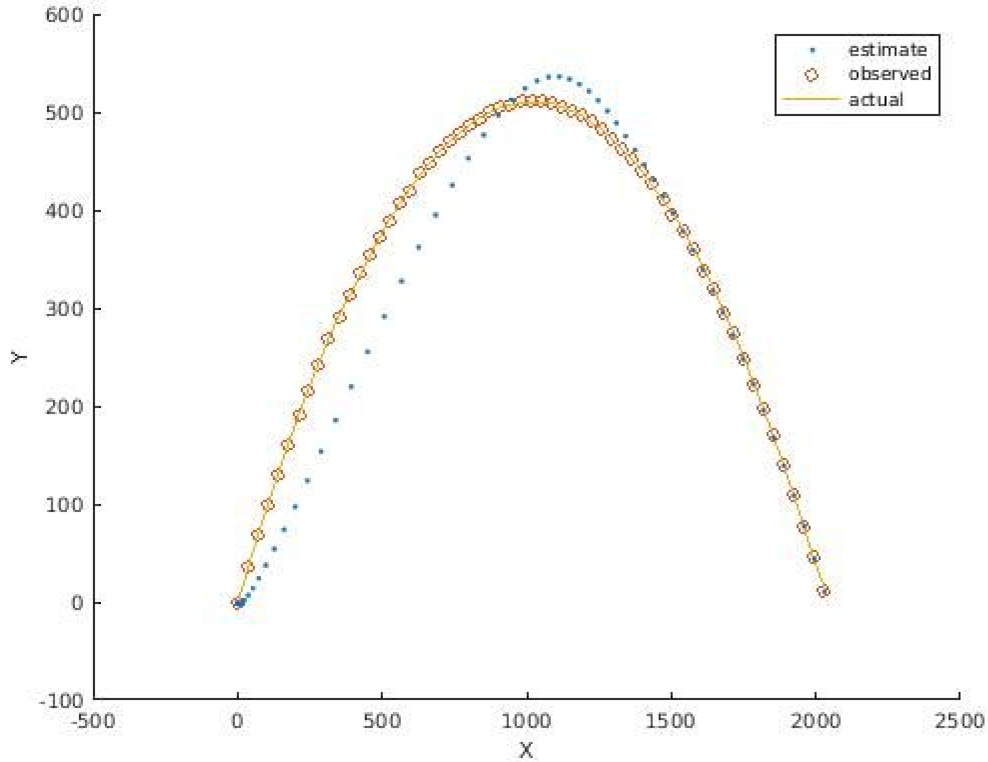
Projectile Motion

Iteration	Xa (Actual)	X (Kalman Filter Estimate)	Z (Sensor)
1	[0,0,100,100]	[-1.46,-0.691,0,0]	[-1.4675,-0.6913]
2	[35.0352,34.7770,99.9914,96.591]	[-1.0016,0.0075,-3.4228]	[34.0987,34.8027]
3	[70.0215,67.697,99.0625,96.5914]	[0.0198,-1.6448,0.0661,-6.7956]	[69.5354,67.6766]
4	[104.9928,99.5702,100.356,89.10]	[13.6463,-0.6986,1.4493,-15.734]	[105.6793,100.1014]
...	...	...	...
58	[1.994e03,44.7787,100.31,-95.52]	[1.9945e03,44.4335,99.93,95.592]	[1.9965e03,43.4172]
59	[2.03e03,10.76,100.0,-98.93]	[2.0296e3,10.284,99.9416,-99.07]	[2.0287e03,9.4691]

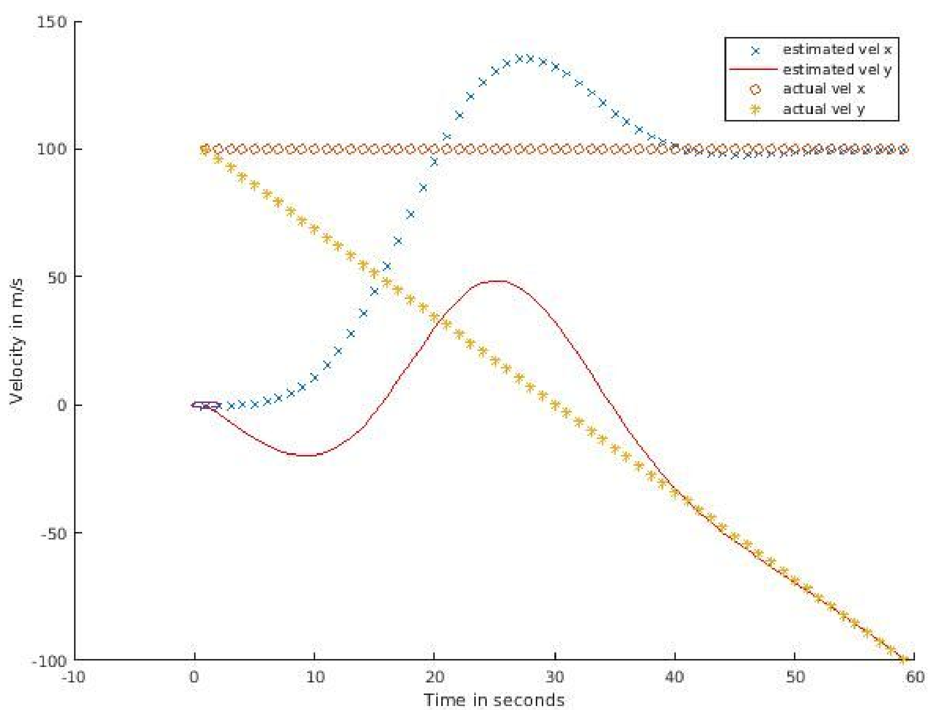
4. Data and Analysis - Trung Le

Here are the resulting plots:





estimate
observed
actual
Y
X
600
500
400
300
200
100
0
-100
-500
0
500
1000
1500
2000
2500



estimated vel x
estimated vel y
actual vel x
actual vel y
Velocity in m/s
Time in seconds
150
100
50
0
-50
-100
-10
0
10
20
30
40
50
60

5. Interpretation - Johnny Le

For the data shown, linear motion displayed a mostly straight line with variations scattered about it. The error ellipses were in line with those deviations and the overall data trended along the same route. In the parabolic projectile motion, there was a slight difference in the estimate and the observed where the observed was offset to the left of the estimate. The most probable reason for this is the noise continually contributed to the positioning; however, it became less and less pronounced after reaching its apex.

For the chart describing the velocity, the actual data displayed a linear change in the vertical velocity which is to be expected; however, the estimated was less consistent. This attribute most likely arose from the noise as referenced in the above paragraph began to lose its strength in deviation slowly becoming closer and closer to the ideal data.

Increasing the covariance would cause the plot to have a larger variance in data and the plot lines would take longer to coalesce. Similarly, the noise would primarily affect the size of the ellipses and length of time it took to coalesce as well. Changes in the initial velocities would change the graph in terms of size but overall the ratios were the same.

6. Critique - Trung Le

The assignment gave a lot of insight into how to map out ideal and more realistic patterns for physical objects. Noise was useful as it seemed to account for a decent number of external factors. In physics, friction and air resistance can be calculated to create this noise; however, these approximations of noise make it statistically close enough. With all that being said, for more specific analysis of projectile motion in both linear and parabolic states graphs, a more accurate formula may be necessary.

To supplement this experiment, it may be beneficial to take approximations for each of the external values so that multiple noises would be calculated instead of a single one.

7. Log

Interpreting Assignment:

- Trung Le: 4 hours
- Johnny Le: 4 hours

Projectile Implementation:

- Trung Le: 8 hours
- Johnny Le: 5 hours

Analysis and Lab Report Write Up:

- Trung Le: 3 hours
- Johnny Le: 3 Hours