**NATIONAL UNIVERSITY OF SINGAPORE**

**Department of Electrical and Computer Engineering**

**EE 5103 Kalman Filter**

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1. **Part 1**

Given that the true state position of first order

Where the gaussian noise factor w(k) and v(k) have

And the initial value = 5, . A Kalman model is designed based on this model.

The graphs and calculation can be shown below when k = 0,1…. 10000.

Graph 1: (solid line), (dotted line)

Graph 2:

Graph 3:

Bias = -0.0033, Var = 0.0983

From graph 1 we can see that and do not has much difference in value, which can also be shown in bias result, which is – 0.0033. The estimation value is similar to true value with low error and variance, meaning that the Kalman filter estimation is accurate and has good performance in single value estimation. For graph 2, is 1 when N =0, then it drops down quickly to and rapidly approaches to 0.0951. For graph 3, = 1 when N = 0 and approaches to 0.0951 quickly too. For variance = =0.0983, and when n >1 = in theory. However, in estimation part the result we got is quite similar but not in the same value, it may be due to that the noise added is random.



1. **Part 2**

Given that the true state position of second order.

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B = []

C = [1 0]

Where the gaussian noise factor w(k) and v(k) have

And T = 1, the initial value = 0, = 30. The initial setting is:

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A Kalman model is designed based on this model. The graphs and calculation can be shown below when k = 0,1…. 10000.

Graph 4: ,

Graph 5: ,

Graph 6:

Graph 7:

Graph 8:

Graph 9:

Bias\_1 = -0.0210

Bias\_2 =-0.0074

Var\_1 = 0.3637

Var\_2 = 0.1292

From graph 4 and graph 5 we can see that and do not has much difference in value, because andand both have low bias, which is -0.02 and -0.0074 respectively. The estimation value is similar to true value, meaning that the Kalman filter estimation is accurate and has good performance in second order value estimation. For graph 6, graph 7. 1 when n = 0, then they drop to 0.36 and 0.04 respectively at steady state. For graph 8 and graph 9, and at steady state. In theory, when at steady state, E{(- )^2} = bias\_1, = E{(- )(-)} = , = E{(- )^2} = bias\_2, which can be confirmed by the estimation result.







1. **Part 3**

This question can also be seen as a second order system since the position has dimension y and z in the figure, where represents y axis and represents z axis. The state model can be written as:

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Where A = , c1 = c2 = [0 1], are gaussian noises variable and , therefore R = Ry = Rz =1. The initial point we set is the rightest point of the circle, which is (10,0) meaning that = 10 and .

The initial setting is ,. For both axis y and z, the Kalman filter is applied. The graphs and calculation can be shown below when k = 0,1…. 24.

Bias\_y =-0.4849

Bias\_z =-0.2431

Var\_y =1.3291

Var\_z =0.8633

The estimation bias and variance calculated are relatively low, which means the estimated point is not so far from the original positions as can be seen from the first graph. Kalman filter has a relatively good performance in position estimation of y and z axis. However, it still has bias and at first the deviation is relatively large, it may be due to the noise selected is large. For further improvement, the velocity steady state model may be added to have provide more information and have better modelling rather than single position estimation model.







