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README - EKF

Guidance, Navigation and Controls Subsystem

Extended Kalman Filter class

Code author: Anway Deshpande
Created on: 21/08/2022
Last modified: 21/08/2022
Reviewed by: Name of the person who has reviewed the code
Description: The class EKF is the estimator for the state and its functions 'predict' and 'update' modify the state vector and covariance matrix.
References: EKF intuitive idea
Input parameters:
The input arguments to the class are:

1. **ini_x** : (float) - It is the projection of initial position vector joining reference point and rotor. *meters*
2. **ini_u** : (float) - It is the initial rate of change of ini_x vector. *meter/sec*
3. **ini_z** : (float) - It is the altitude of the rotor. *meters*
4. **ini_w** : (float) - It is the velocity in the z direction. *meter/sec*

Predict function of EKF class

Code author: Anway Deshpande
Created on: 21/8/2022
Last modified: 21/8/2022
Reviewed by: Name of the person who has reviewed the code
Description: The predict function gives a priori estimate for the state, using state estimate at previous time step. the state equation has the form $X_{k+1|k} = AX_{k|k} + BU_{k|k} + C$ and F matrix comes out to be A itself, and then the covariance matrix is estimated.
Formula & References:

$$\hat{\mathbf{x}}_{k|k-1} = \mathbf{f}(\hat{\mathbf{x}}_{k-1|k-1}, \mathbf{u}_k) \tag{1}$$

$$\mathbf{P}_{k|k-1} = \mathbf{F}_k \mathbf{P}_{k-1|k-1} \mathbf{F}_k^T + \mathbf{Q}_k \tag{2}$$

References: EKF predict function
Input parameters:
The input arguments to the function are:

1. **v_U** : (vector) - This is the input control that we give to the system. In this case it's constant so same value is passed every time.

2. **m_Q** : (matrix) - It is the process noise covariance matrix.

Output:
The function has void return type and it modifies the value of the state vector and covariance matrix of the class.

Update function of EKF class

Code author: Anway Deshpande
Created on: 21/8/2022
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Reviewed by: Name of the person who has reviewed the code
Description: The update function defines a quantity v_e called the innovation defined as difference between measurements and the output of the predict function. This innovation should converge down to 0 as time progresses. A function h(.) converts the state into proper orders do that z-h(X) is possible. Observation matrix(H) is calculates and then innovation covariance(S) is calculated.Using these, Kalman gain(K) is calculated and then finally the state is updated .
Formula & References:

$$\mathbf{e} = \mathbf{z}_k - h(\hat{\mathbf{x}}_{k|k-1}) \tag{3}$$

$$\mathbf{S}_k = \mathbf{H}_k \mathbf{P}_{k|k-1} \mathbf{H}_k^T + \mathbf{R}_k \tag{4}$$

$$\mathbf{K}_k = \mathbf{P}_{k|k-1} \mathbf{H}_k^T \mathbf{S}_k^{-1} \tag{5}$$

$$\mathbf{x}_{k|k} = \mathbf{x}_{k|k-1} + \mathbf{K}_k \mathbf{e} \tag{6}$$

$$\mathbf{P}_{k|k} = (I - \mathbf{K}_k \mathbf{H}_k) \mathbf{P}_{k|k-1} \tag{7}$$

Input parameters:
The input arguments to the function are:

1. **m_R** : (matrix) - It is the observation noise covariance matrix.

2. **v_Z** : (vector) - It is the measurement vector given to the function.

Output:
This also has return type void and it modifies the state vector and covariance matrix of the class.