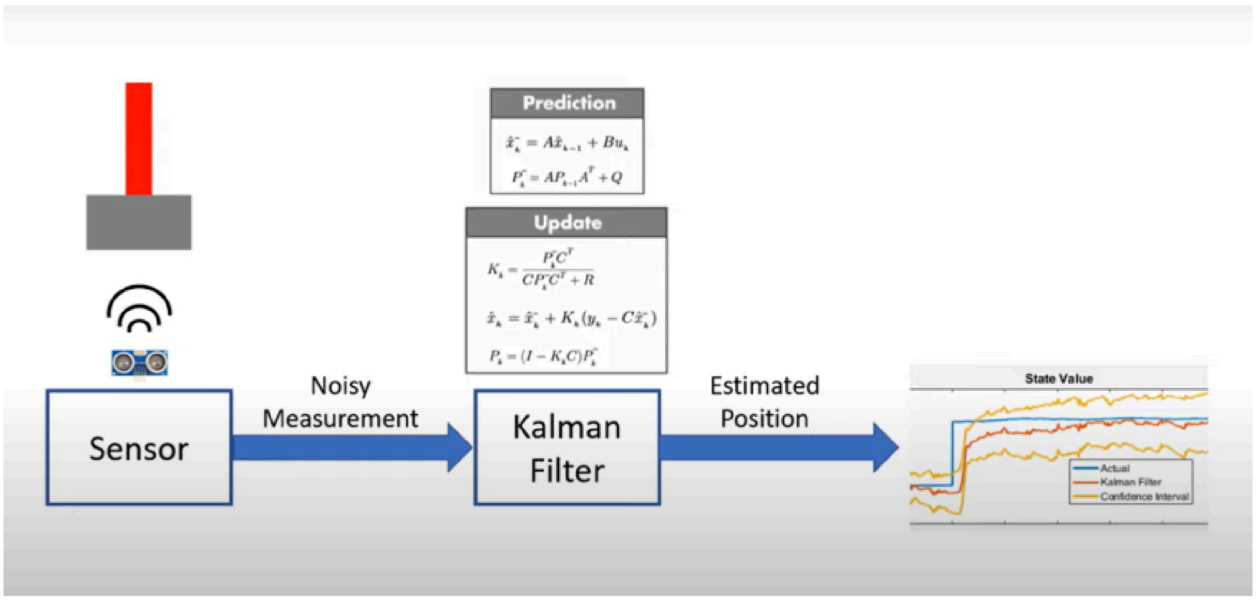
Documentation for **MAARG**

- Optimal estimation algorithm
- Can be used to estimate a system state when that cannot be measured directly
- The end estimate ideally should not have errors due to noises, which arise as a result of getting information from various sources to reach the estimate
- IMU readings are prone to drift due to small errors' accumulation over time that affects the final odometer reading in vehicles
- Mathematical model that one sets up to solve a problem, does not work exactly in the real world as the interested values are subjected to uncertainties
- The state estimator that we would build in any such problem, will minimize the difference between the estimated and actual state readings
- Hence, the system for estimation is made complete with the choice of an appropriate update sent in response from a controller, that acts as a state observer [one who handles the error]
- KF is used for choosing the appropriate controller gain term in minimum steps possible.
- Works based on the principle of probability distribution
- Best estimate is obtained by taking the product of probability functions and getting a Gaussian function with a smaller variance => Mean of this function would give us the required best estimate
- KF is a stochastic system => Uses the priori estimate (mathematically predicted ideal estimate) and measurement feedback obtained from the system to update appropriately => The hence updated value is called posteriori estimate
- Kalman gain(K) calculated such that it minimizes the posteriori error covariance. If measurement noise is small => K=1, Measurement is trusted more and if error in priori estimate is small => K = 0
- Algorithm repeats itself to perfectly mimic the original system. Use of more than one reading to obtain the values (measurement) would change the dimensions of the matrices used in the equation, though the basic equation in the algorithm remains same
- KF is best used in linear systems as the distribution of the linear transformation of the linear estimation maintains the gaussian property

- EKF and UKF => Extended KF determines the state using linearization approximation and has its own drawbacks => Unscented KF that uses sigma points to calculate the empirical gaussian distribution for the given nonlinear system
- Particle filters => Approximates any arbitrary distribution to an empirical gaussian distribution that closely resembles it.
- N-matrix in Simulink represents the cross-covariance matrix which describes the correlation between the process noise and measurement noise => 0 in our case



Gaussian distribution :

- A symmetrical bell shaped curve centered at average value
- The standard deviation of the distribution helps us evaluate the range where 95% measurements will lie [around +/- 2*SD the mean]
- The width of the curve is decided by the SD and thus the height, which tends to inversely vary with width

Central limit theorem :

- Means of random points from a uniformly distributed sample may not be uniformly distributed
- They are normally distributed and same is the case with means of random points calculated

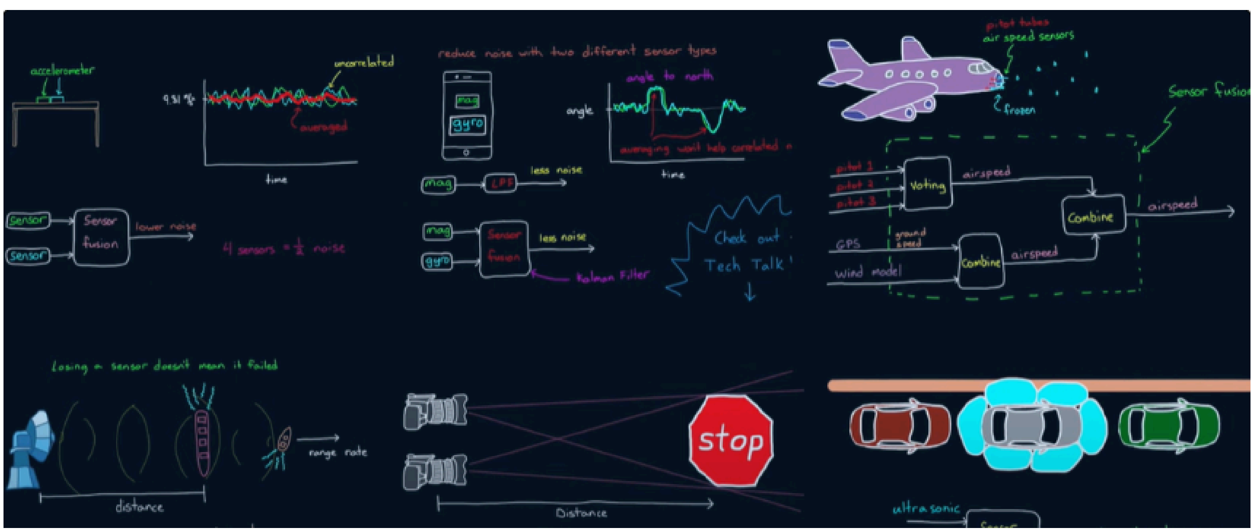
State space equations:

- Derivatives of the states are dependent on the current state as well as the inputs being provided

- State variables are the minimum set of variables required to define a system fully.Fully, here highlights that the information should be enough to predict the future behavior. The number of state variables again indicate the order of the differential equation that we'd have to solve to make the prediction
- The highest derivative => Number of state variables =n
- Inputs we have => Count of variables on the RHS of the equation =r
- Outputs => Count of variables whose solutions we'd obtain from the equation =m
- A = n x n ; B =n x m ; C = m x n ; D = m x m
- https://youtu.be/HGFZ_fl3C0c => Video to understand the evaluation of A,B,C from the formulated differential equation

Sensor fusion:

- The act of combining the data from various sources to understand the system, to a better degree
- The data source may be sensors or mathematical model encoding an algorithm
- Perceive step of an autonomous system is highly essential as it includes two main **awareness**':
- Self - Localization and Situational - Tracking
- Kalman filters => Effective combination of sensor measurements



Angle of attack sensor : Angle of attack sensors typically include an **external drag profile**

which is supported by a rotary shaft. The sensor is mounted on the side of the airplane fuselage and measures local airstream angle with respect to the fuselage horizontal reference plane.