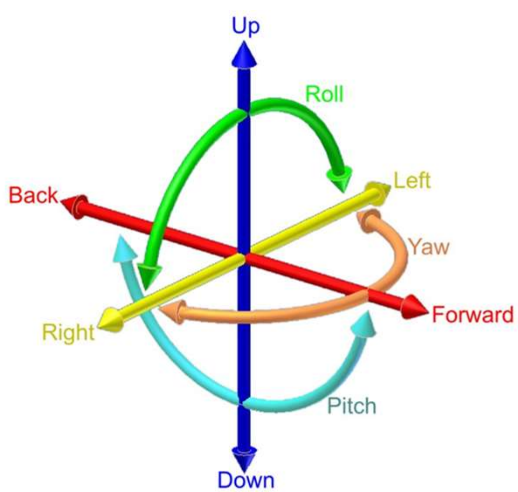
Localization and Mapping

Localization

What does it provide ?

- Current location
- Current position



How is it done ?

- Filtering sensor data
  - LiDAR
  - Stereocam
  - Odometer
  - GPS
  - IMU
  - Why so many? – tunnel example
- Localization algorithms

Mapping

What does it provide ?

- Map of the surrounding
  - Metric – absolute coordinates
  - Topological – distance relations

Why is it needed ?

- For the robot to localize itself in the surrounding
- More importantly, for path planning

SLAM

What is it and more importantly why is it ?

Map is required for localization

Position estimate is needed for mapping

Most used tool – Kalman Filter

Noisy dynamic system + Noisy measurements – use kalman

Applications in system having

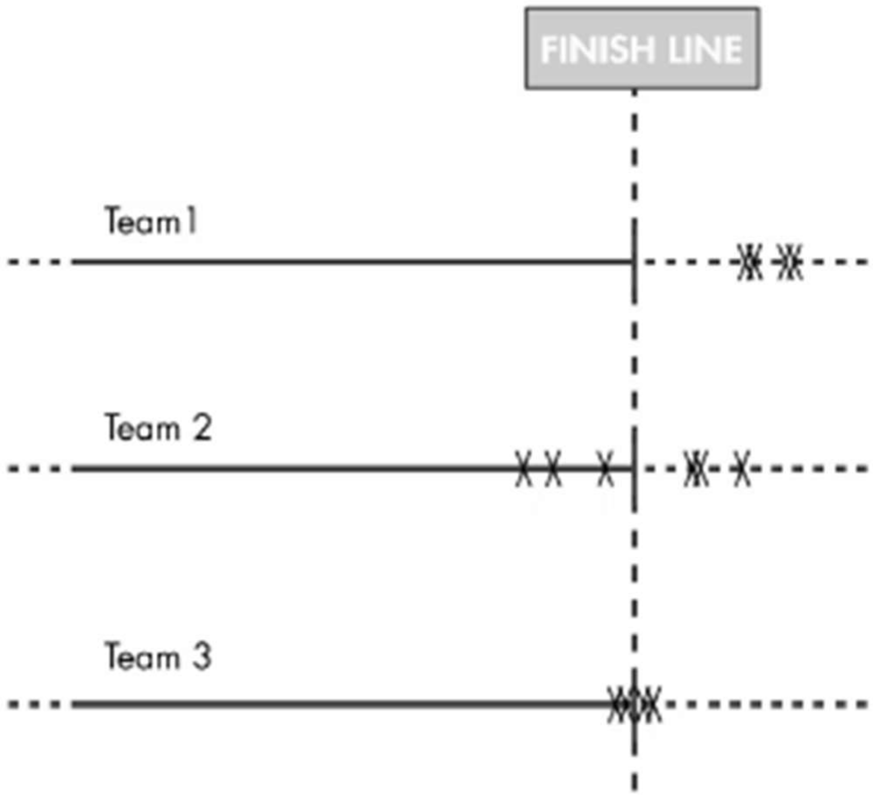
Uncertain information	Can make an educated guess	Continuously changing

What is a Kalman filter

- Optimal estimation algorithm
- Estimating system state when direct observation is not possible
  - The temperature example – state observer
- New concept – nah
  - Earliest usage dates back to trajectory planning in Apollo
- State observer for stochastic systems (one or more modules having randomness associated with it)

State estimator

- How high the internal temperature of the engine
  - To regulate the fuel flow to your rocket
- Problem – no internal access, possible mathematical model using Text
- Still problems, why ?
  - Perfect model without any uncertainties
  - Real system and model have same initial conditions
    - Then your measurement and estimated output values would match
- Try to minimize the difference between the estimated and measured external temperature
- Optimal way of choosing the gain K is performed using Kalman filters



*To simplify graphic, each set of the black X's represents all 100 trials.

Two step process

Prediction step

- Priori state estimate and error covariance

Updating step

- Posteriori state estimate and error covariance

Function of Kalman gain

- Kalman gain is calculated such that it minimizes the posteriori error covariance

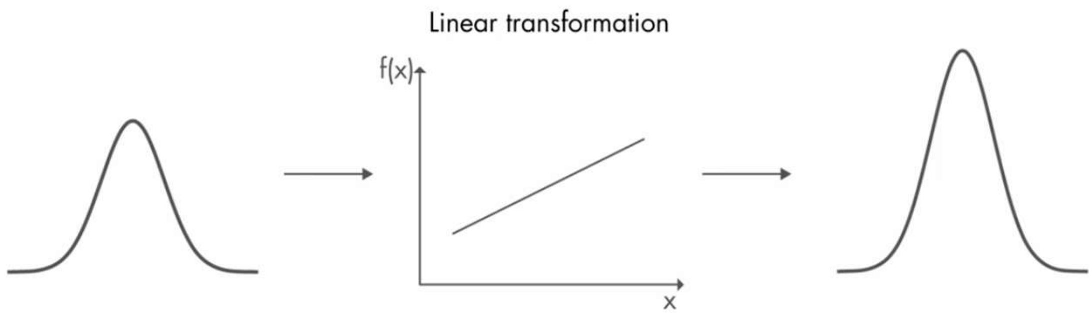
Recursive process

Non-Linear State Estimators

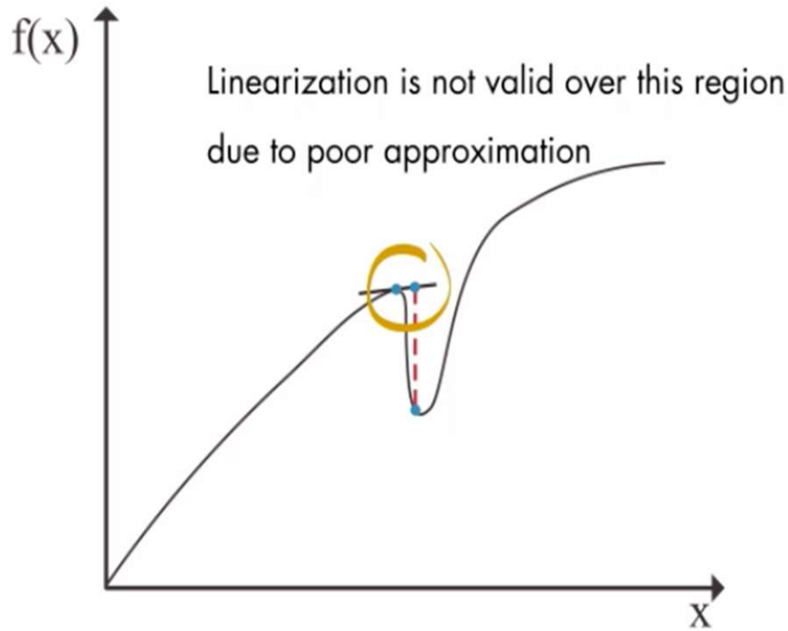
- Extended Kalman Filters
- Unscented Kalman Filters
- Particle Filters

Kalman filter is only defined for linear systems

- Extended Kalman filters –
  - Linearize the distribution around the mean of the current estimate
  - Use this linearization in the predict and update states of the Kalman filter algorithm
  - Linearization not possible in some regions



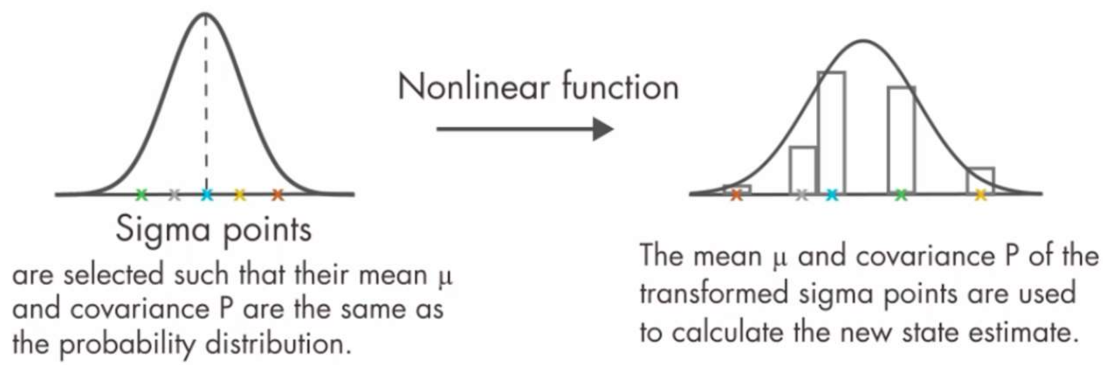
Drawbacks of EKF



- EKF works on systems having differentiable model
- Not optimal for highly non-linear system

What if no Gaussian approximation ?!!
A whole different story !!!!!

Unscented Kalman Filters



- Approximating nonlinear function ☹
  - Approximate probability distribution ☺
- Select minimal set of sample points (sigma points) having same mean and covariance as distribution – get empirical gaussian distribution – calculate new state estimate