Why it is important to understand KF internals

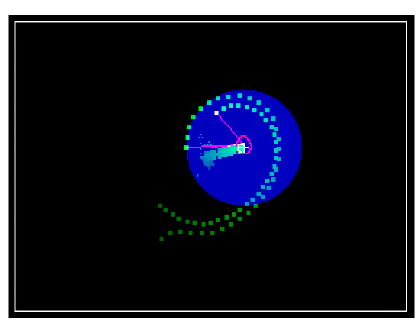
- There are many nuances to applying KF to specific problems.
- You can “learn” KF in a week, but you can also spend an entire career exploring the breadth and depth of the subject.
- In this specialization, you will learn the most commonly used forms of KF and how to apply them robustly to real problems.
- You will learn how to develop the underlying math, which often proves to be necessary to be able to re-derive the methods to adapt them to new situations.
  - It is not generally sufficient simply to implement a toolbox function.
  - Many applications violate the assumptions made during the standard Kalman-filter derivation and require revising the derivation to compensate.
- The following slides share some examples that my students and I have worked on.
  - Most have required some level of mathematical and procedural modifications to the standard KF methods to apply KF to the specific problem.

Track marker dots on actors

- OBJECTIVE: Track marker dots on actors.
  - State: (x, y) position and velocity of dots in frame.
  - Observation: (x, y) positions of dots in frame (unlabeled).
  - Issues: Data association, tracking markers when dots are obscured.

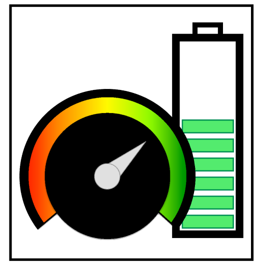
Track an uncooperating target

- OBJECTIVE: Search-and-rescue (equivalently, localizing “bad guys”).
  - State: (x, y) position and velocity of target.
  - Observation: Radar azimuth/elevation (and possibly also range).
  - Issues: Nonlinear relationship between measurements and position; measurements arriving to KF out-of-sequence from multiple measurement platforms; sensor fusion of these measurements.



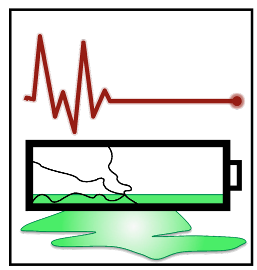
State estimation for nonlinear system

- OBJECTIVE: State-of-charge (SOC) estimation for lithium-ion battery cells.
  - State: SOC, polarization voltages, hysteresis voltages.
  - Observations: Battery-cell current, temperature, and voltage under load.
  - Issues: Lack of available simple battery model, nonlinear dynamics and measurement, dc bias in current sensor, cell-to-cell variation, efficient state estimation for large battery packs.
- See also the course: "Battery State-of-Charge (SOC) Estimation" in the "Algorithms for Battery Management Systems" Specialization on Coursera.



Parameter estimation

- OBJECTIVE: State-of-health (SOH) estimation for lithium-ion battery cells.
  - State: Resistance and capacity of battery cells.
  - Observations: Battery-cell current, temperature, and voltage under load.
  - Issues: Parameter estimation, not state estimation; vastly different timescales of parameter and state dynamics; jointly estimating state and parameters.
- See also the course: "Battery State-of-Health (SOH) Estimation" in the "Algorithms for Battery Management Systems" Specialization on Coursera.



Navigation of quadrotor drone

- OBJECTIVE: Localize myself (navigation).
  - State: 3-d position, orientation.
  - Observations: Accelerations, rotations, GPS fixes.
  - Issues: Correct for drift of inertial-navigation system using GPS measurements.

Summary

- There are often challenges when implementing KFs.
- Some level of re-derivation or modification is frequently required when applying KFs to a new application.
- But, when properly employed, there are innumerable applications.
- These include all kinds of state estimation, target tracking, parameter estimation, and navigation.
- In this specialization, you will learn how to derive and implement xKFs that are able to perform all the above kinds of tasks robustly.

Credits

Credits for photos in this lesson

- Photos of man with marker dots on slide 2 from: James Dennis Musick, “Target Tracking a Non-Linear Target Path Using Kalman Predictive Algorithm,” MSEE Thesis, University of Colorado Colorado Springs, 2005.
- “Quadrotor drone” on slide 6: Pixabay license (`https://pixabay.com/en/service/license/`), from `https://pixabay.com/photos/drone-industrial-design-design-1204473/`