EE793 Target Tracking: Lecture 0
Course Information

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Course Info

This is an advanced graduate course given for the first time in METU-EEED.

Target tracking

- Target tracking is basically to use the state estimation tools in realistic environments.
- State estimation algorithms are developed theoretically under strict assumptions, in a real environment those assumptions are commonly violated.
- Some real environment aspects to consider are
  - Missing detections
  - Association uncertainty
  - Model mismatch (maneuvers)
- A combination of control theory and signal processing

Course Info

- Has widespread military and civilian applications:
  - Defense surveillance (radar)
  - Air traffic surveillance (radar)
  - Video surveillance
  - Robotics (video, laser)
- This problem has been studied for quite a long time.
- Estimation algorithms known as Kalman filters are used as the main solutions.
- Still a very active and expanding research area.

Abstract textbook problem

Problem Definition

Consider the system

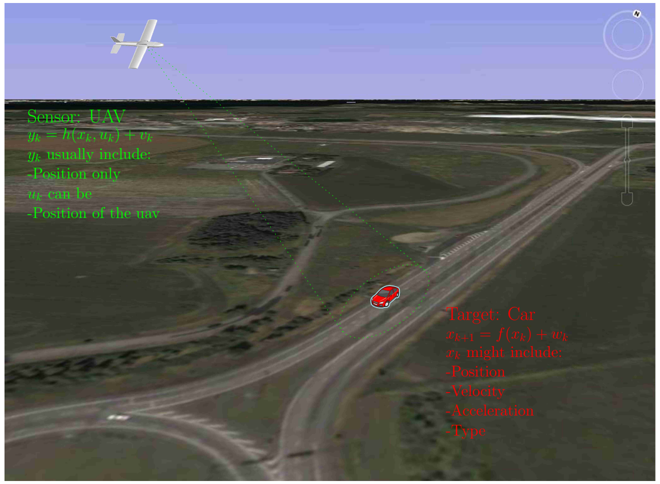
$$\begin{aligned} x_{k+1} &= f(x_k) + w_k \\ y_k &= h(x_k) + v_k \end{aligned}$$

where $x_0 \sim p(x_0)$.
Aim: Find

$$\begin{aligned} \hat{x}_{k|k} &= \mathrm{E}\{x_k|y_{0:k}\} \\ P_{k|k} &= \mathrm{Cov}\{x_k|y_{0:k}\} \end{aligned}$$

Visualization: Target tracking

Incorporates all significant aspects of estimation problems that appear in other applications.



Back to abstract textbook problem

Problems with the Problem Definition

Consider the system

$$\begin{aligned} x_{k+1} &= f(x_k) + w_k \quad (maneuver) \\ y_k &= h(x_k) + v_k \quad (multiobjects) \end{aligned}$$

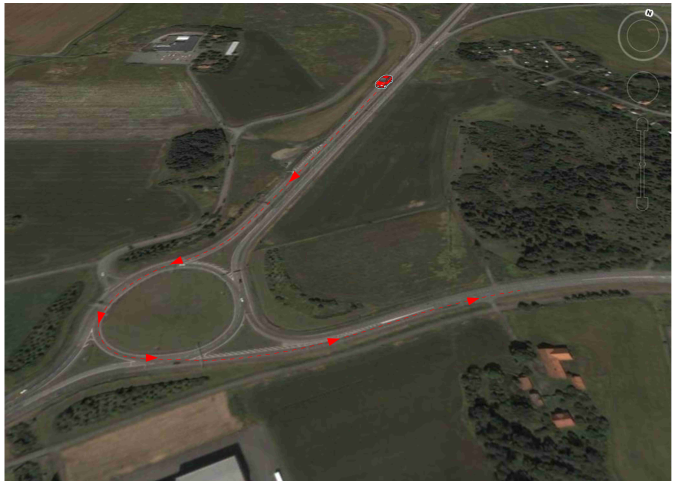
where $x_0 \sim p(x_0).(initialization)$

Aim: Find

$$\begin{aligned} \hat{x}_{k|k} &= \mathrm{E}\{x_k | y_{0:k}\} \\ P_{k|k} &= \mathrm{Cov}\{x_k | y_{0:k}\} \quad (multisensor) \end{aligned}$$

Maneuvers $x_{k+1} = f(x_k) + w_k$

Systems have a variety of modes



Maneuvers $x_{k+1} = f(x_k) + w_k$: Abstraction

Multiple model system description

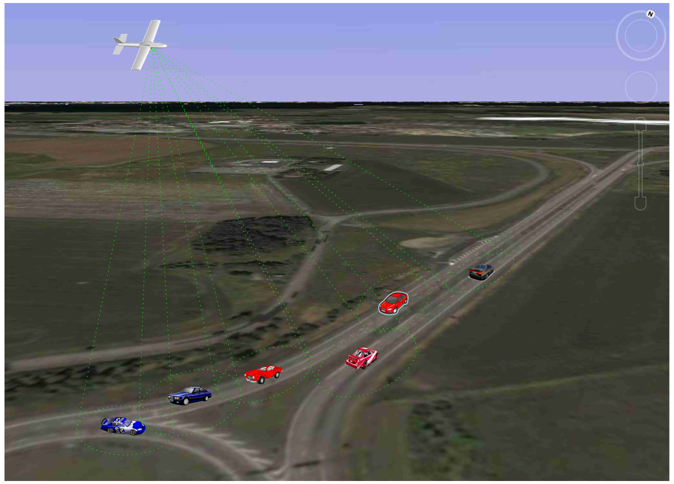
$$x_{k+1} = f_{r_k}(x_k) + w_k$$

where $r_k \in \{1, 2 \ldots, R\}$ is the mode variable which determines the target model by selecting among $\{f_1(\cdot), f_2(\cdot) \ldots, f_R(\cdot)\}$.

- Early approaches make decision+tracking (< 1990).
- State of the art: Use all models at the same time (> 1990)

Multiple objects $y_k = h(x_k) + v_k$

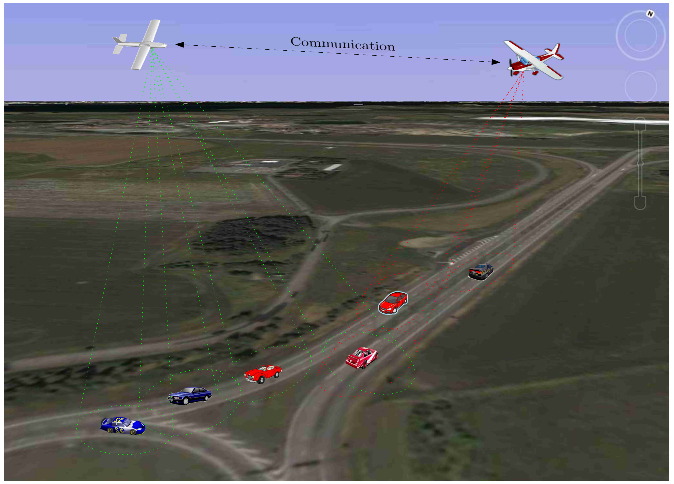
Data origin uncertainty



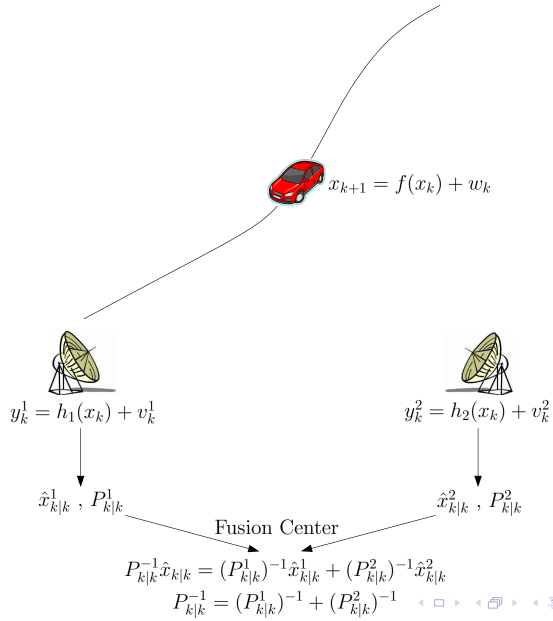
Multiple objects $y_k = h(x_k) + v_k$ cont'd

- Define $x_k \triangleq \left[x_k^1, x_k^2, \ldots, x_k^N\right]^T$
- Define $y_k \triangleq \left[y_k^{\sigma(1)}, y_k^{\sigma(2)}, \ldots, y_k^{\sigma(N)}\right]^T$
- Data Association + Single object estimation
- Computation: $N! \times$ Single object estimation!
- There are also false alarms and missed detections
- State of the art (2000→):
  - Try to bypass data association
  - Use new modeling methodologies: Random sets, PMHT

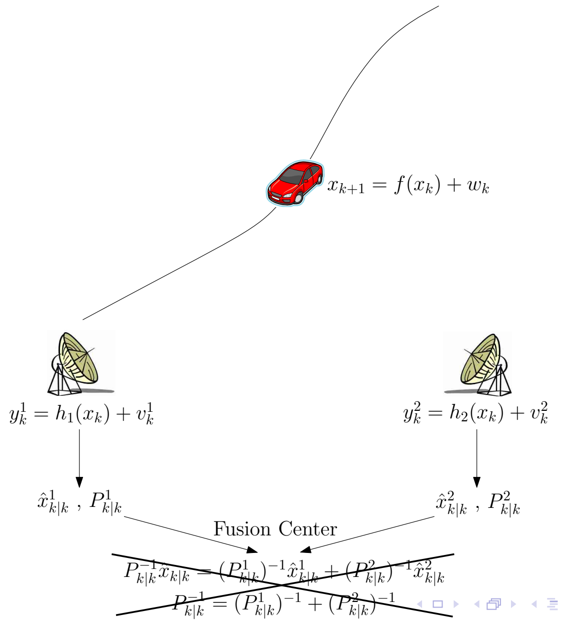
Multiple Sensors



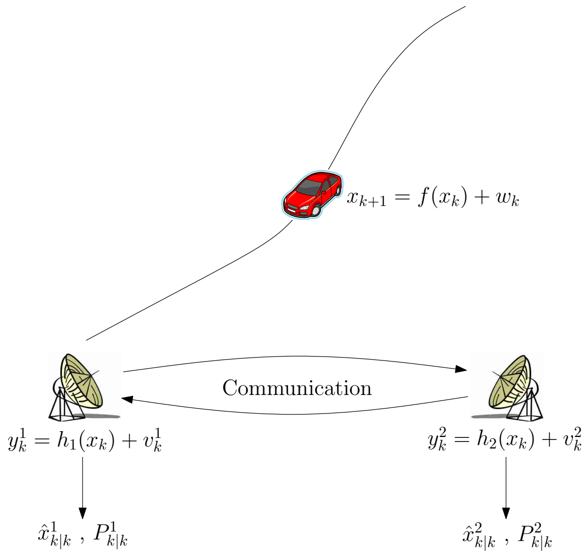
Multiple Sensors: Correlation and Consistency



Multiple Sensors: Correlation and Consistency



Multiple Sensors: Correlation and Consistency



Multiple Sensors

Multiple Sensors:

- Centralized solution is optimal.
- Decentralization is where we are converging to.
- Correlation has to be compensated.
  - Extra communication.
  - Postmodern approaches like "covariance intersection"
- Consistency should not be neglected and must be given importance as much as bias and efficiency.

Course Info

Tentative Lecture Plan

Nr.	Subject
1	Course Info & Introduction to State Estimation
2	TT concepts and main issues
3	Single TT issues: Track life and association
4	Maneuvering TT Part I. Classical Approaches
5	Maneuvering TT Part II. Multiple model filtering, IMM
6	Multiple TT Part I. Single hypothesis tracking: GNN
7	Multiple TT Part II. Single hypothesis tracking: JPDA
8	Multiple TT Part III. Multiple hypothesis tracking MHT
9	Multiple sensor issues and architectures
10	Track association and fusion
11	Out of sequence measurements
12	Extended target tracking
13	An overview of advanced target tracking methods

Course Info: Literature

The only book that covers (almost) all of it is

Book:
S. Blackman and R. Popoli, Design and Analysis of Modern Tracking Systems, Artech House, Norwood MA, 1999.

- A good reference in the long term if you are dealing with TT.
- Related section numbers to the lectures are given in the course web page (lectures). `http://www.eee.metu.edu.tr/~umut/ee793/`
- When a more detailed coverage or derivations are necessary, they will be provided in the class.

Course Info: Student responsibilities

- Get an overview on the subject before the class by reading the related sections in the book (see webpage of lectures).
- Do not indulge in the details in the book while reading, just try to get an overview.
- Complete the exercises (50%) and submit their codes and reports.
- Midterm (practical 25%) and Final (theoretical 25%)

Tentative Plan for Exercises:

Nr.	Subject
1	State Estimation
2	Track handling in clutter and missed detections (Midterm)
3	Maneuvering TT with IMM
4	Multiple TT Part I: GNN & JPDA
5	Multiple TT Part II: MHT
6	Multiple sensors and track fusion

Course Info: Who can take this course?

- Knowledge about Probability and Stochastic Processes is required
  - to fully understand the concepts/derivations covered in the class
  - to succeed in the final exam
- A lot of time is required to complete the computer exercises.
  - A reasonable estimate for this time is $\hat{T} \geq 15$ working days spread over the semester.
  - The ones that have very limited time and unable to spend this much time on the course are highly recommended NOT to take the course.
- A good knowledge of how to program in Matlab is definitely necessary.

Course Info: Content Disclaimer

Target tracking is a vast field and no single course can cover all of its aspects. Below are some limitations on the content of this course.

- We mainly consider radar sensors to be of interest. The issues related to sensors like video or laser are mostly not covered.
- We are mostly constrained to point targets.
- Even with the radar sensors, issues like
  - Bias
  - Registration
  - Attribute (Target-Type) Estimation

  are not covered.

QUESTIONS!