Lecture on Kalman Filter

ESP 3201

Dr Ng Gee Wah

NUS
National University
of Singapore

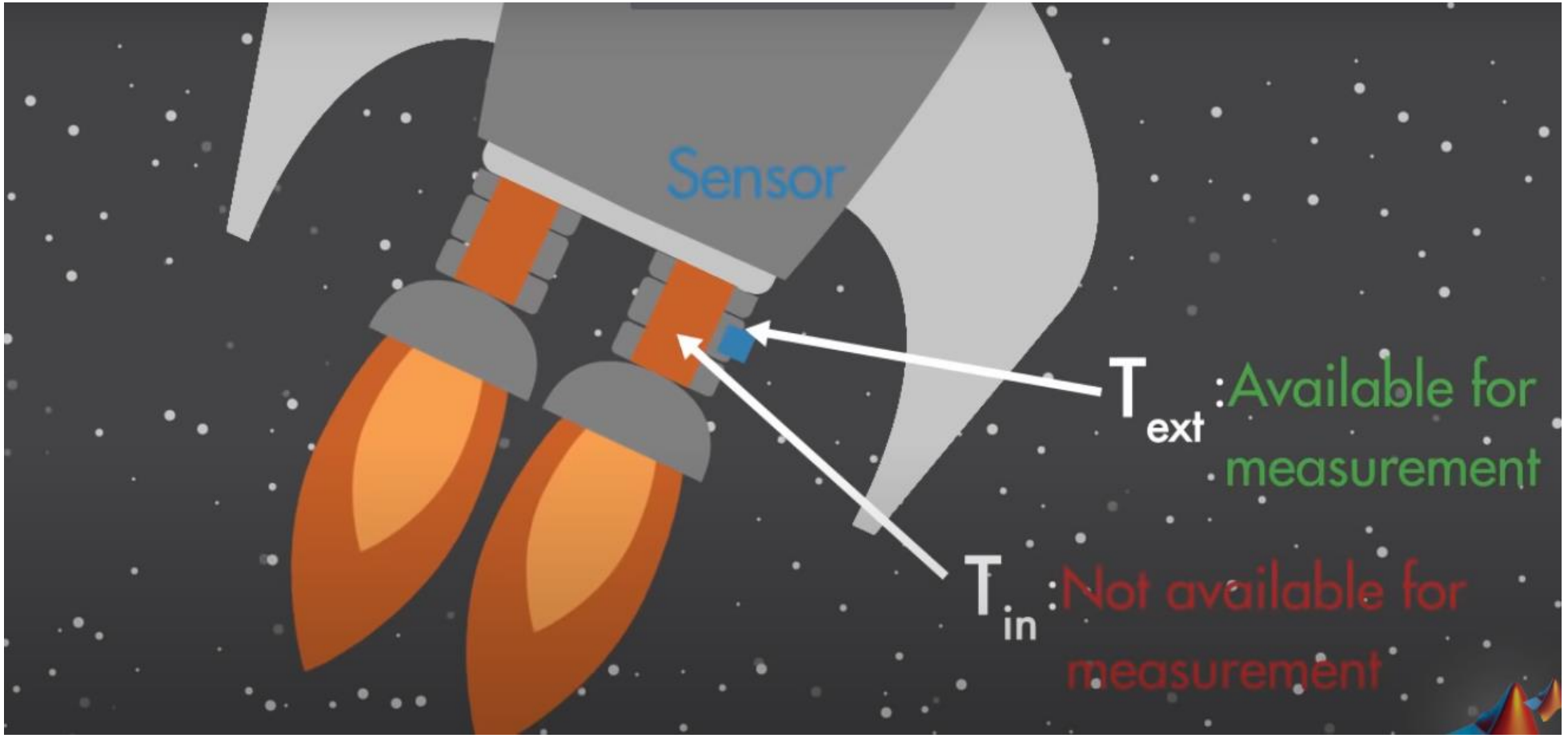
What and Why use Kalman Filter?

NUS National University of Singapore

- A Kalman filter is an optimal estimation algorithm. Meaning it is an algorithm that can:
  a. Estimate the state of a system where the state cannot be measured directly. For example: Estimation of the engine heat by indirect measurement of the temperature outside the engine.
  b. Estimate the state of a system where it is subject to noises. In this case measurements are available from various sensors but subjected to noise. By combining multiple sensors together to overcome the noise effect and provide an accurate estimation of the state. For example in a car where there are many sensors such as IMU (inertial measurement unit) which measures acceleration and angular velocity of the car. And odometer provide the relative position of the car, GPS receiver to locate the position of the car. The GPS receiver is not updated frequently and may be lost such as when the car enter a tunnel. Likewise the IMU and odometer accuracy are also affected by environmental and instrumental noises.

How do you estimate the state of a system if you cannot measure it directly?

Example 1

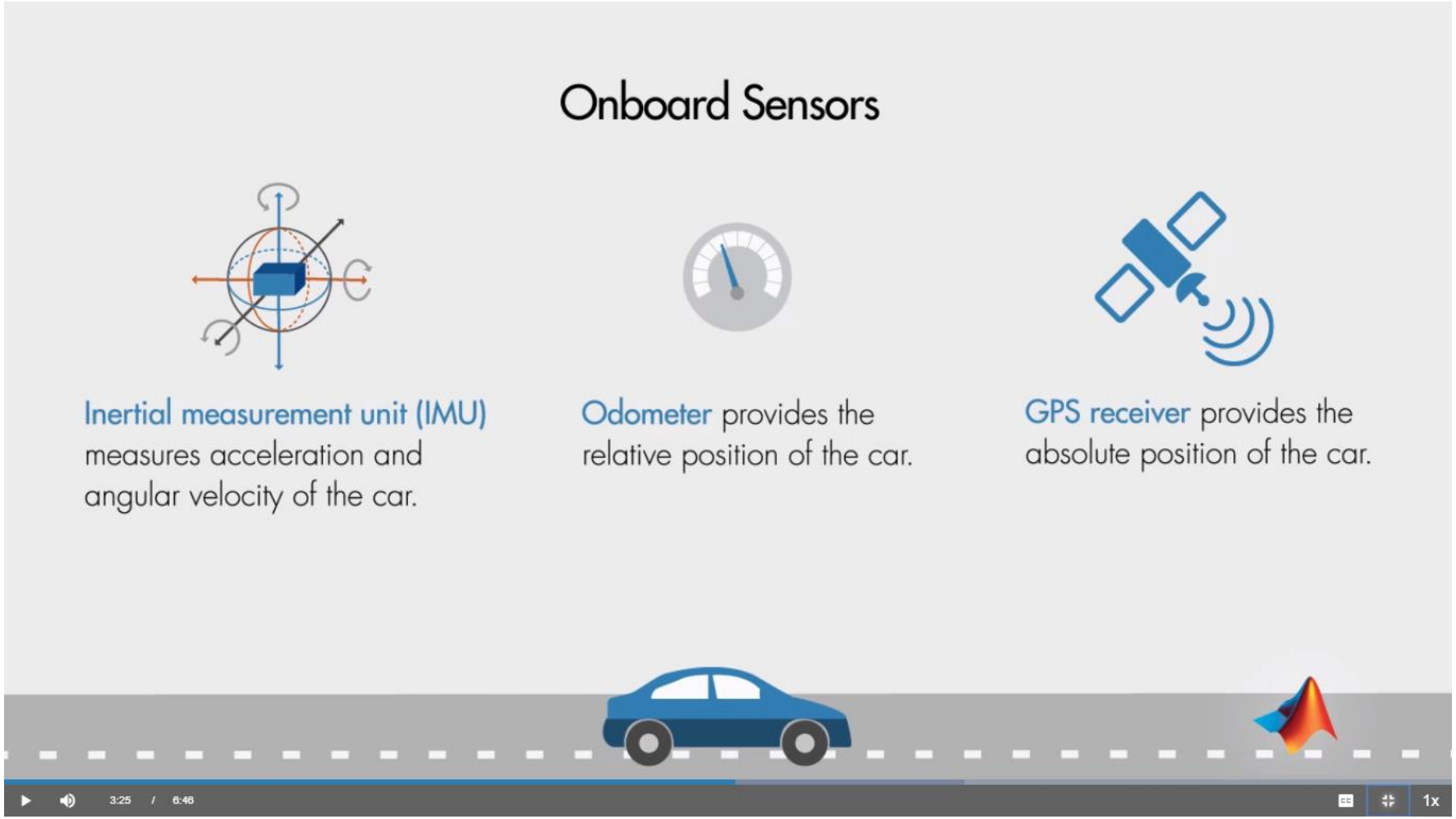


Estimate the state of a system where the state cannot be measured directly.

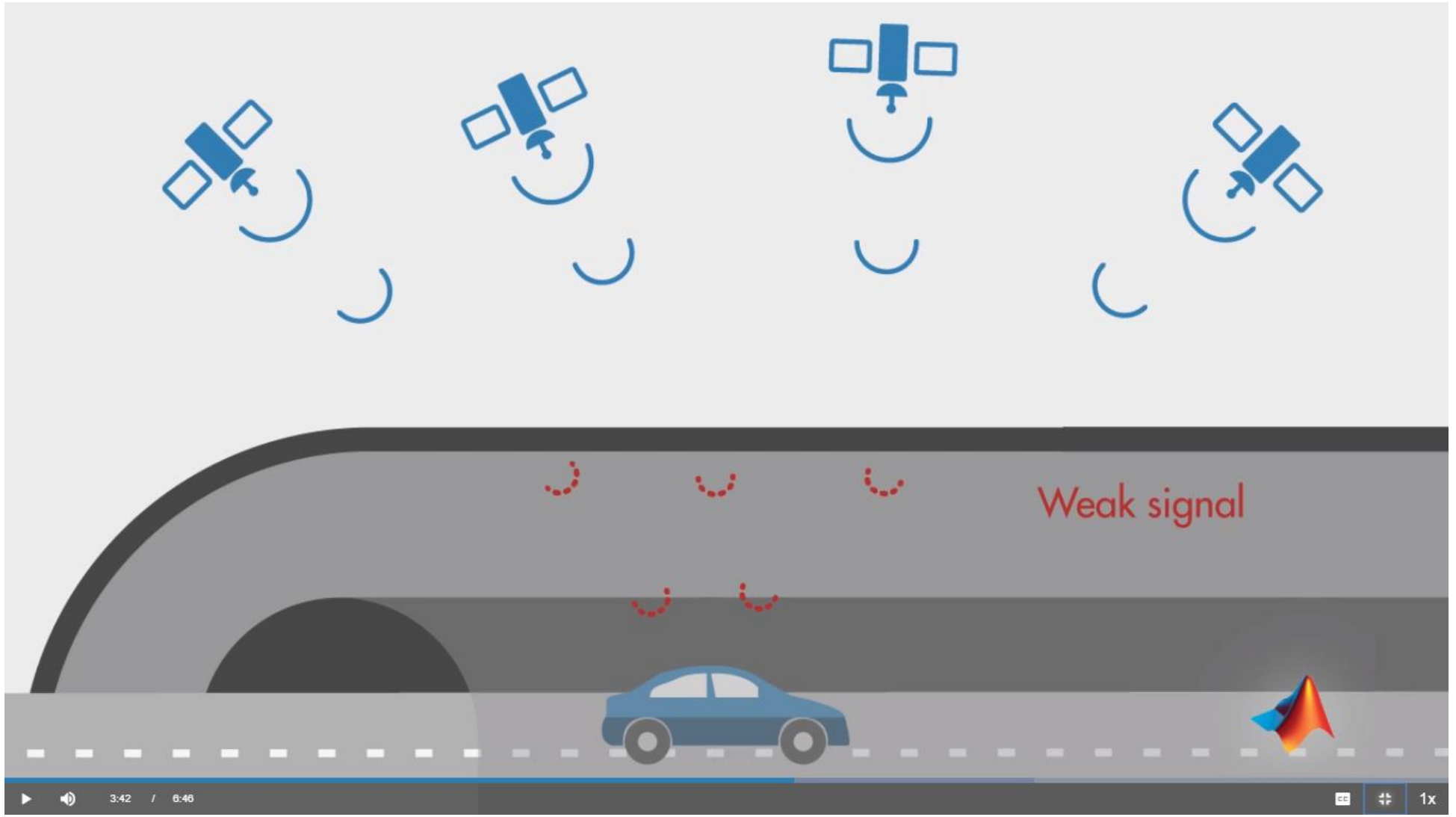
How do you estimate the state of a system if the system is noisy?

How do you combine multiple sensors noisy reading together to provide a good accuracy?

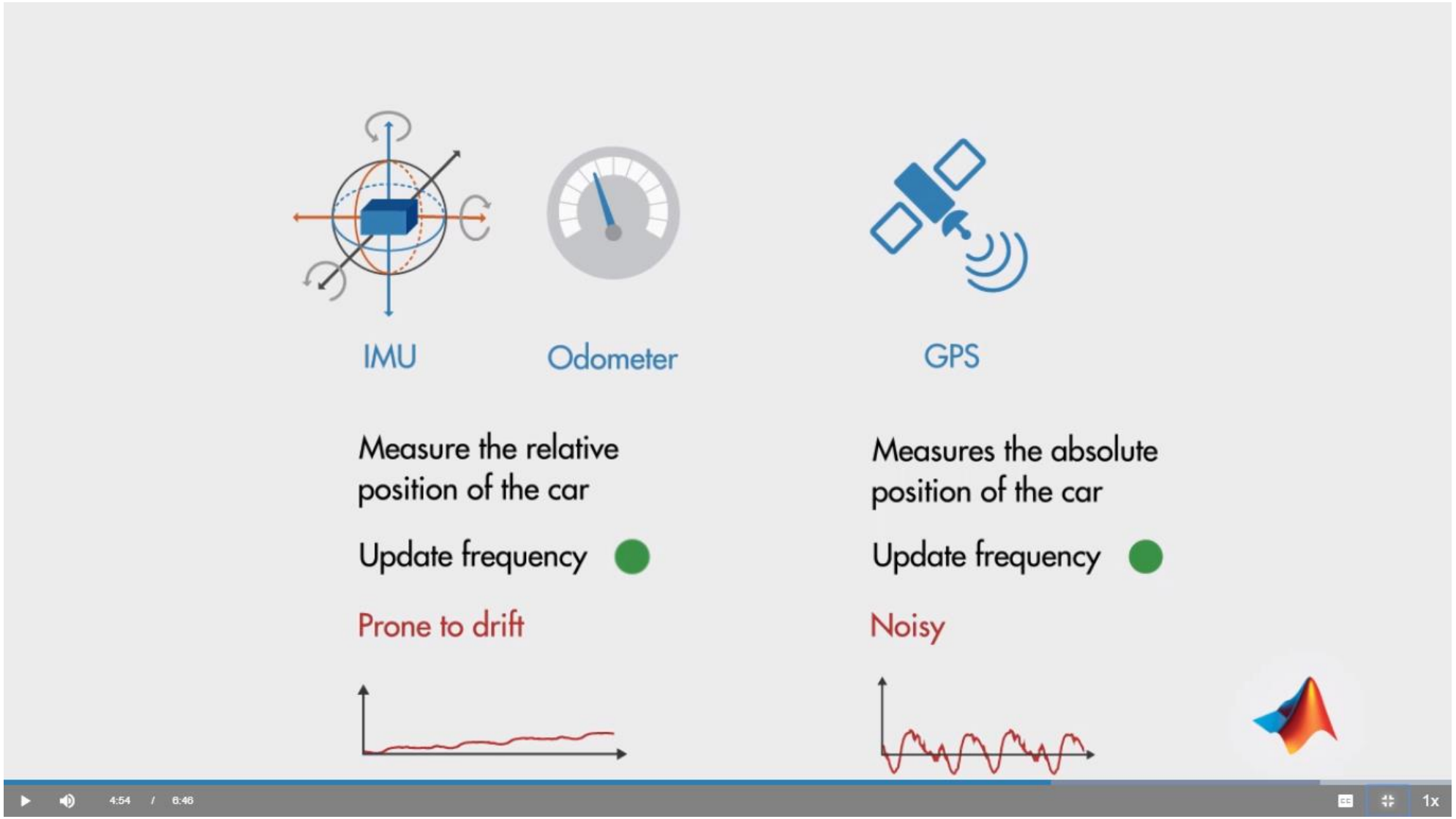
Example 2



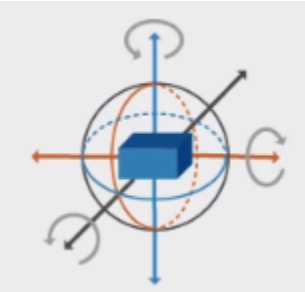
Measurement from sensors in the present of noise. For example onboard the car there are three sensors



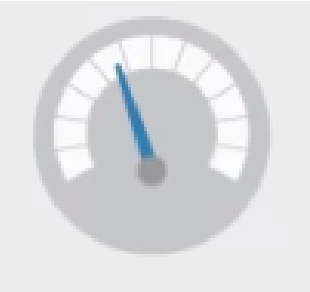
Noise affect the sensors measurement



Kalman filter can be used to fused these three measurement to find the optimal position of the car.



Inertial measurement unit (IMU) measures acceleration and angular velocity of the car.



Odometer provides the relative position of the car.

GPS receiver provides the absolute position of the car.

Who invented Kalman Filter?

National University of Singapore

- Named after Rudolf E. Kálmán (1930-2016)
- Rudolf E. Kálmán presented in 1960, the seminal paper entitled: “A New Approach to Linear Filtering and Prediction Problems”.
- His proposed technique is in the context of extracting the actual value of measurement (or better said the most likely value), given a long list of noisy measurements.
- Read the paper in the lecture note folder.

What is a Kalman Filter?

The Kalman Filter is an Optimal Estimation algorithm and has been used for many tracking and data prediction tasks.

The Kalman filter is optimal in the sense that it minimizes the variance in the estimated states. And it can be shown to represent a linear filter. (Look up this website for more information - http://www.swarthmore.edu/NatSci/echeeve1/Ref/Kalman/OptSysKalman.html).

http://web.mit.edu/kirtley/kirtley/binlustuff/literature/control/Kalman%20filter.pdf

Common Applications

- Guidance and navigation systems such as missiles, vehicles, spacecraft.
- Tracking objects
- Computer vision systems
  - Stabilizing depth measurements
  - Feature tracking
  - Cluster tracking

- Signal processing

One of the very first applications of the Kalman Filter was the Apollo Project

$(x\_k)^{\rightarrow}=(p^{\rightarrow},v^{\rightarrow})$

Position and Velocity

Thank you for your attention