Data Assimilation and YOU: Applications of the Kalman Filter

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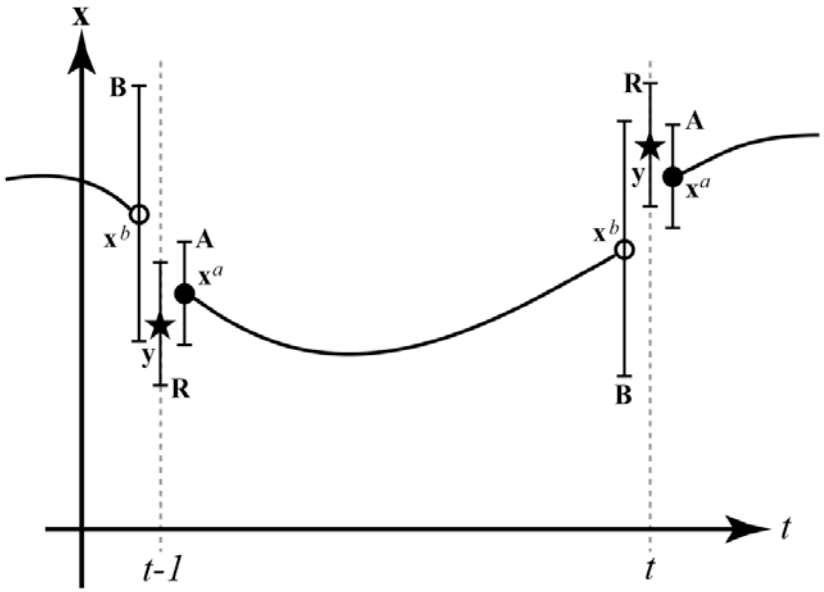
Kalman Filter Overview

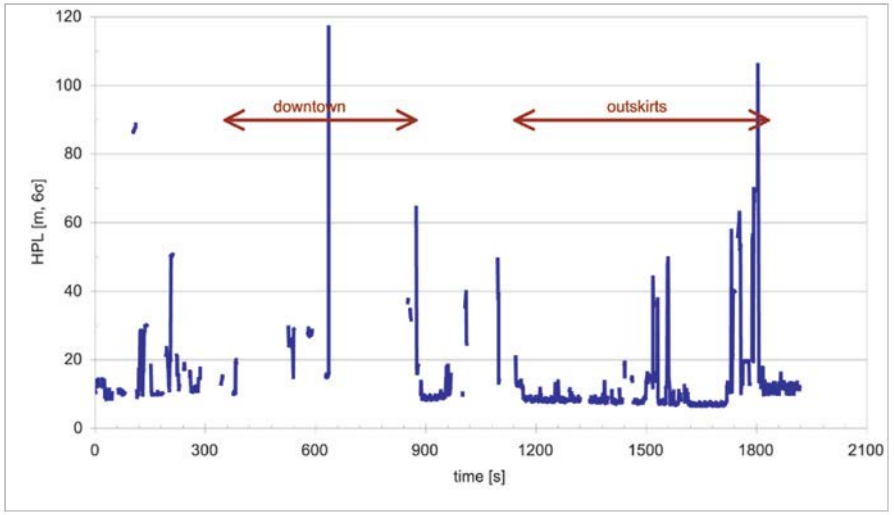
- Real time state estimate combining model + (multiple) observations
  - Iterative process applied at each time step

- Widely used in scientific applications:
  - Hydrology
  - Weather Forecasting
  - Chemical Weather (Coming soon!?)



Navigation/GPS

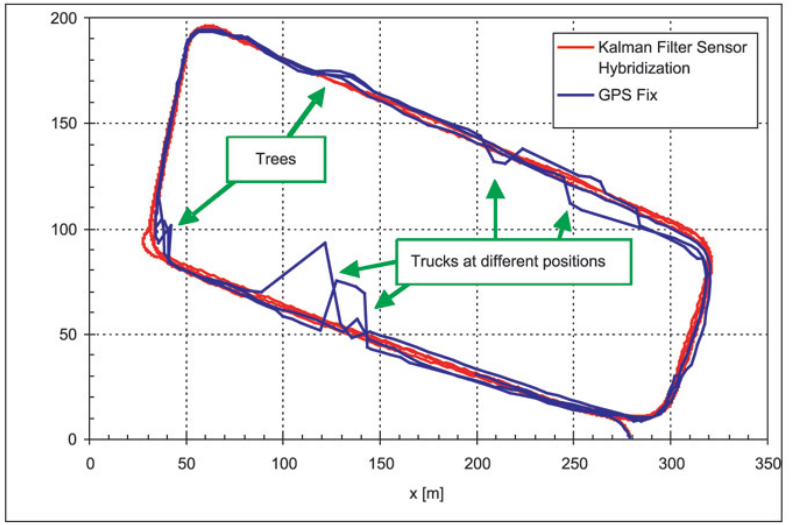
- Want a real time position for your car
- GPS signal will be accurate but is often very noisy
  - Will tend to jump around if used as the only information



- Add model to smooth out noisy signal
  - Calculate car's change in position from one time step to the next using dynamics

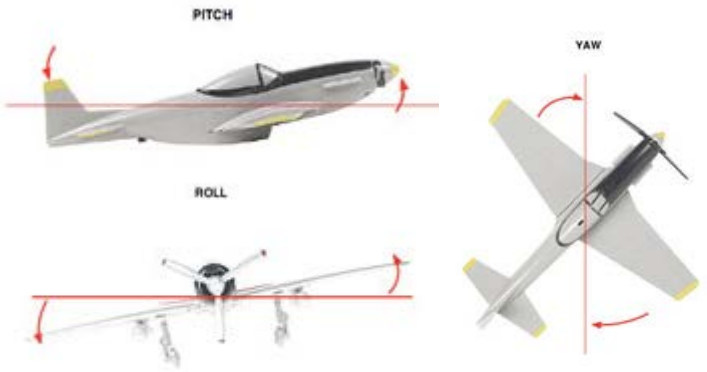
$$\text{new position} = \left(\text{old position} + v\Delta t + \frac{1}{2} a \Delta t^2 \right)(1 - G) + \text{GPS} \cdot G$$

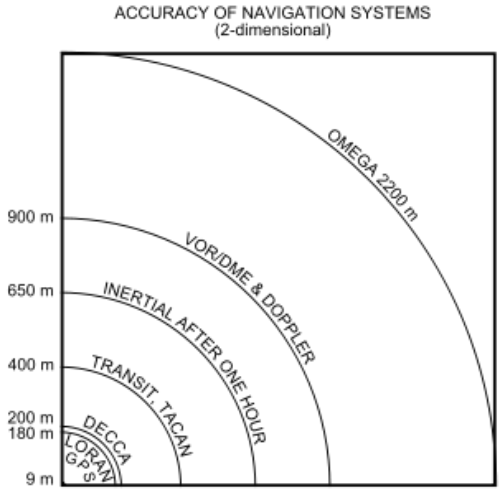
$$G = \frac{\text{model error}}{\text{model error} + \text{GPS noise}}$$



Aircraft Autopilot

- Originally designed for rockets





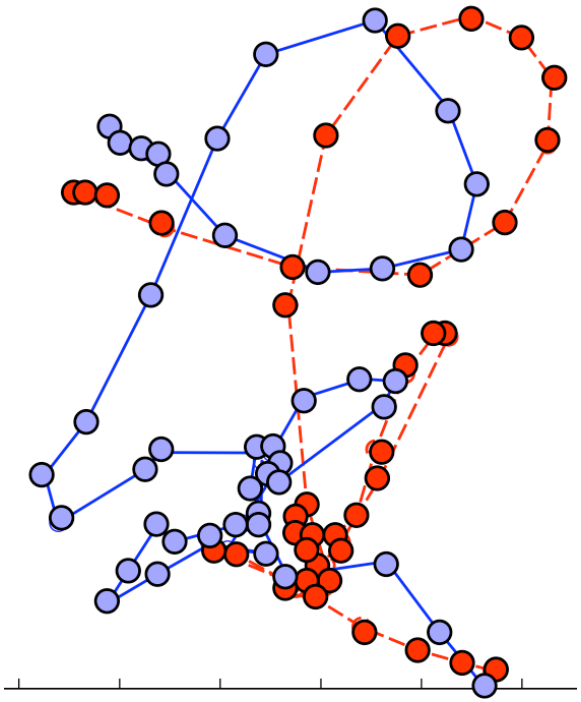
R. Munroe (XKCD 2011)

- Computer control can optimize speed/efficiency
- Can allow operation in poor conditions

- Correct <u>error estimates very important</u>!

Mind-Brain Interface

- Goal: Decode measurements of neural signals and to control computer/prosthetics
- Case study – replicate full 2D mouse/cursor motion (Wu et al. 2003)
  - State vector is cursor position/velocity/accel (as in previous example)
  - Assume neural firings are linearly related to state -- $\underset{\text{new position}}{\hat{\mathbf{x}}_t} = \underset{\text{model position}}{\mathbf{x}_{at}} + \mathbf{G}_t(\underset{\text{neural firings}}{\mathbf{x}'_t} - \underset{\text{modeled firings}}{\mathbf{K}_t\mathbf{x}_{at}})$



Red = true cursor
Blue = reconstruction

State of the science:
providing functionality to persons with paralysis