Carnegie Mellon ROBOTICS CLUB

# Filtering

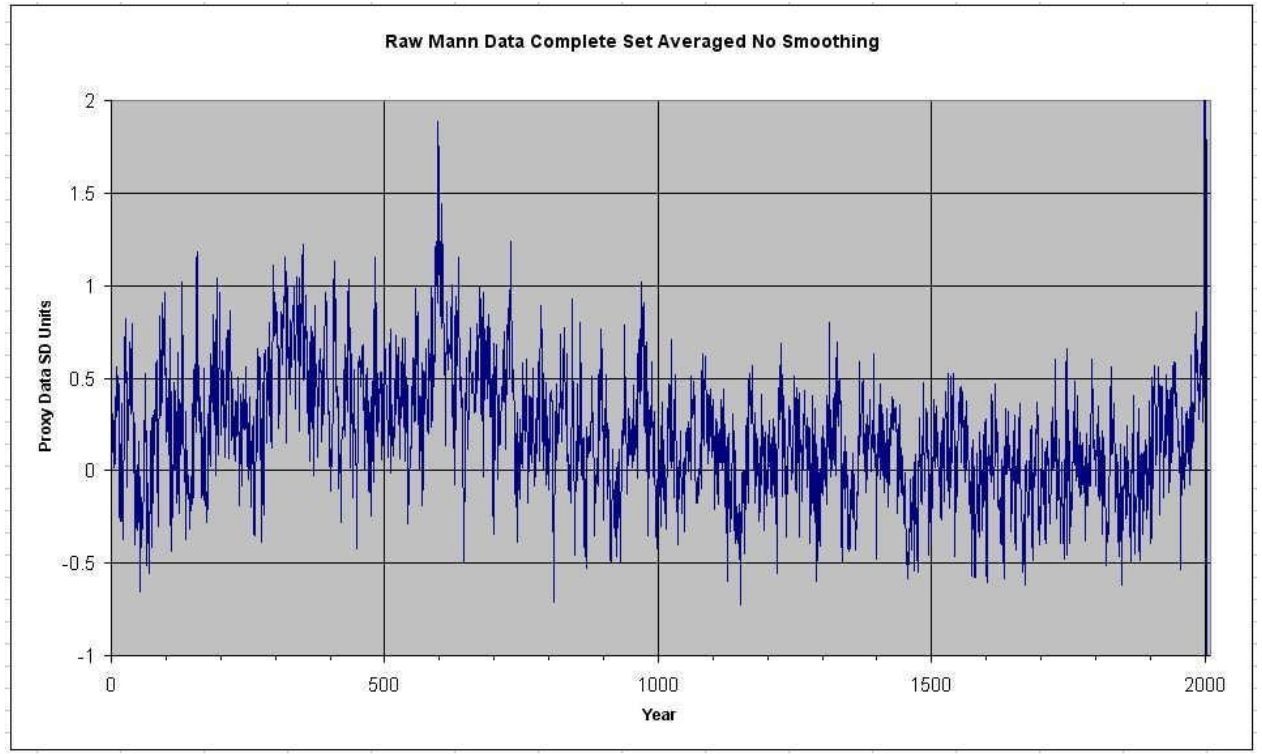
Spring 2026

# Overview

- What is data filtering and it’s important
- Filter examples
  - Rolling Average
  - Gaussian
  - Kalman
  - High/Low/Band-Pass

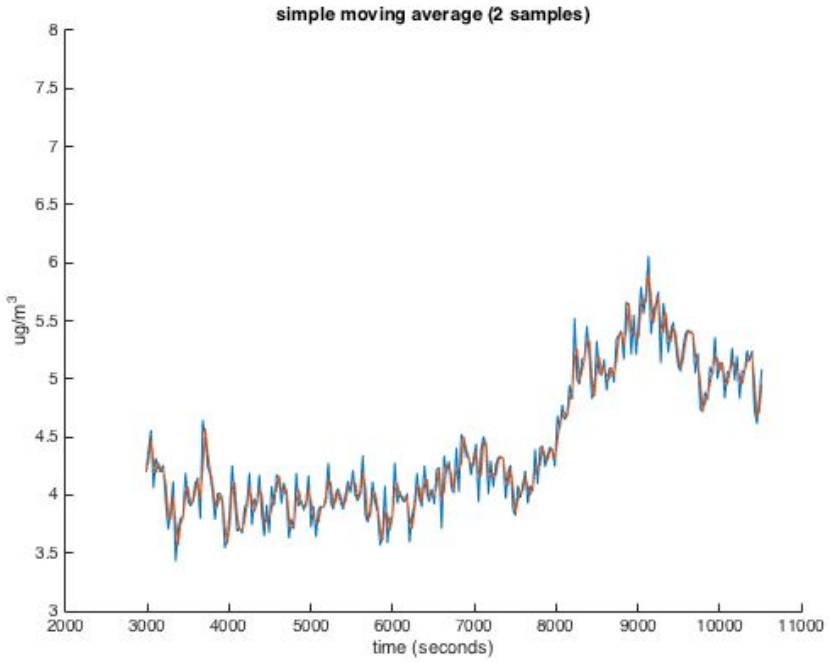
# What and Why?

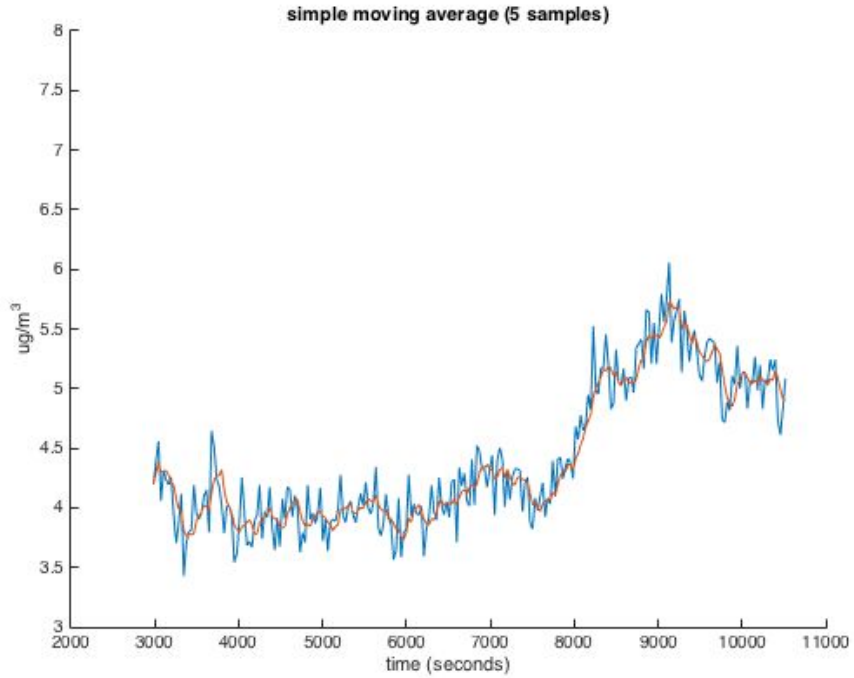
- Raw data is not very clean
- But clean data is easier to work with

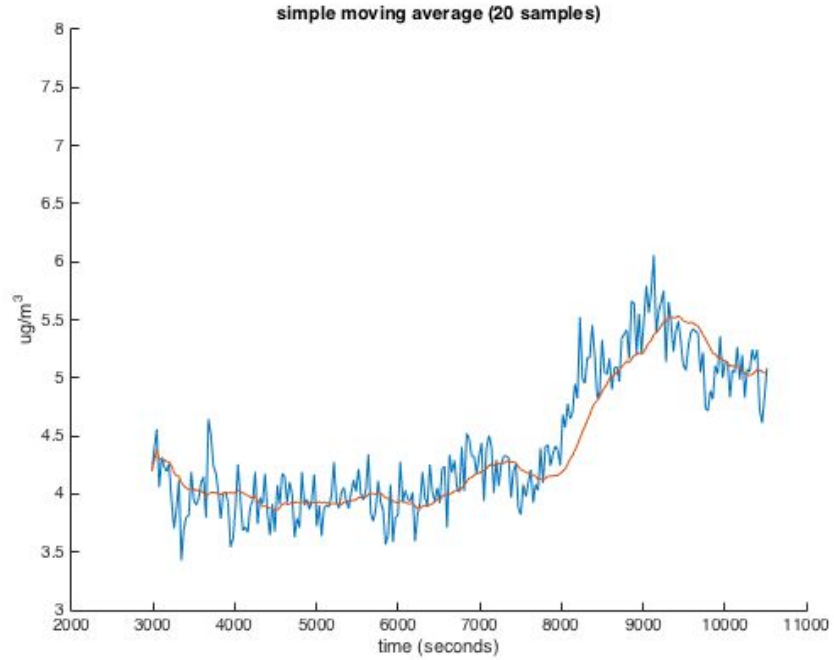


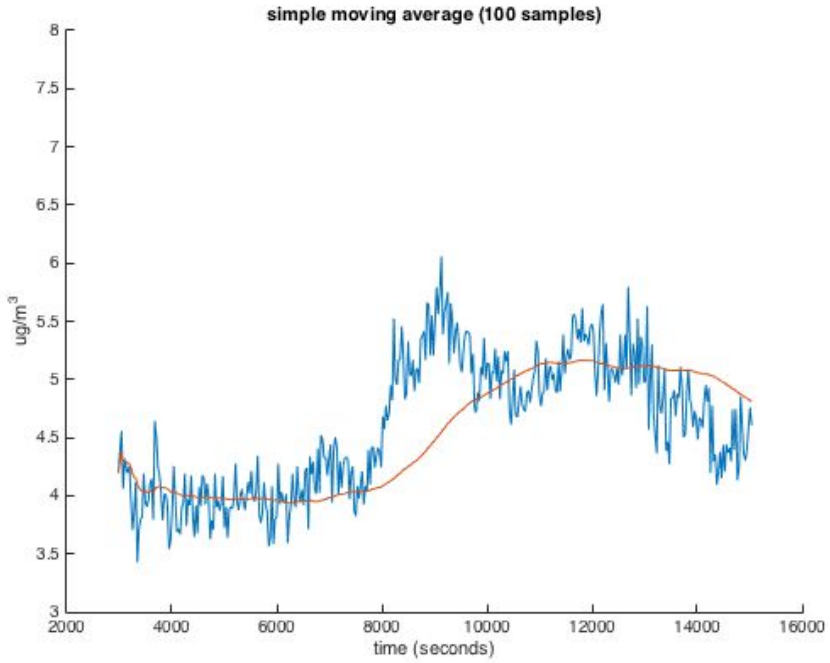
# Moving Average

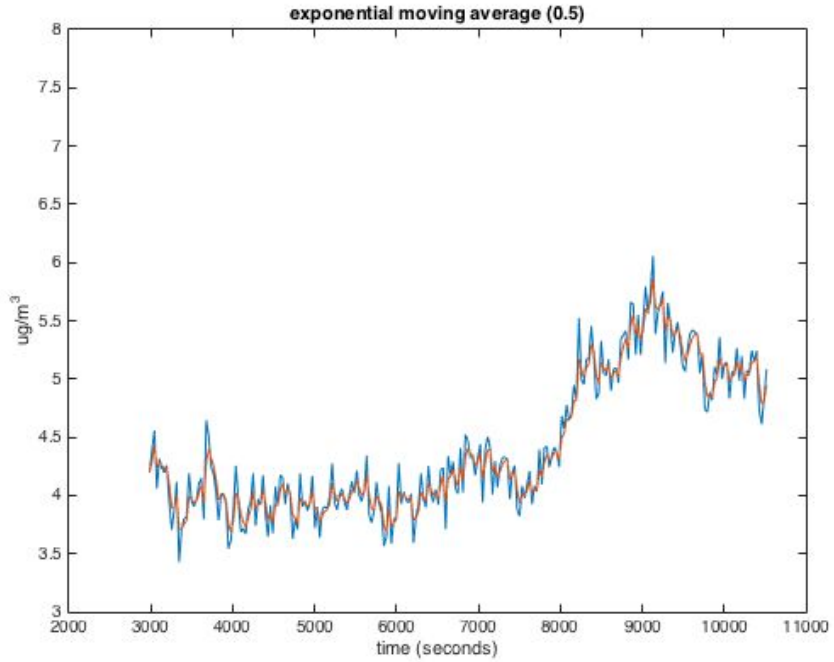
- Very easy filter
- Simple moving average
  - Ex: Average of new reading and last 5 readings
  - Sensor reading's impact on average stays constant and then goes to 0
- Exponential moving average
  - Ex: Avg = 0.2 * new_reading + 0.8 * Avg
  - Sensor reading's impact on average slowly decreases over time
- Average can lag behind actual readings

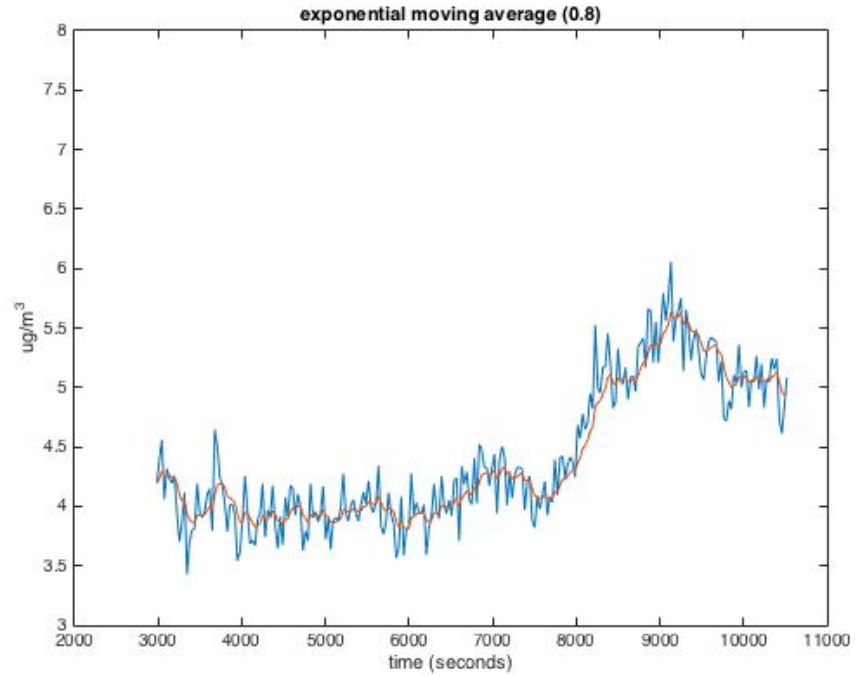

simple moving average (2 samples)
ug/m3
time (seconds)

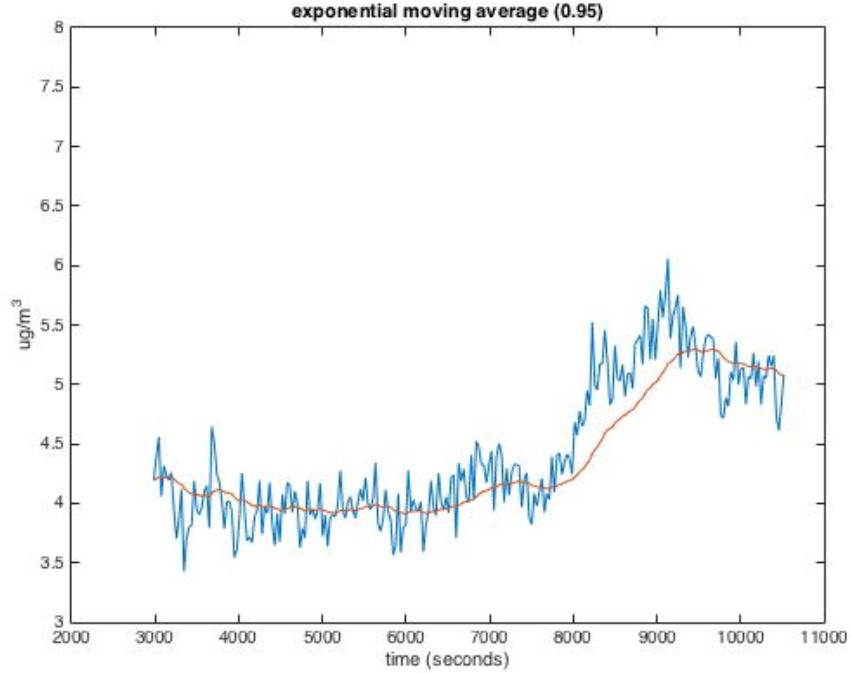

simple moving average (5 samples)
ug/m3
time (seconds)

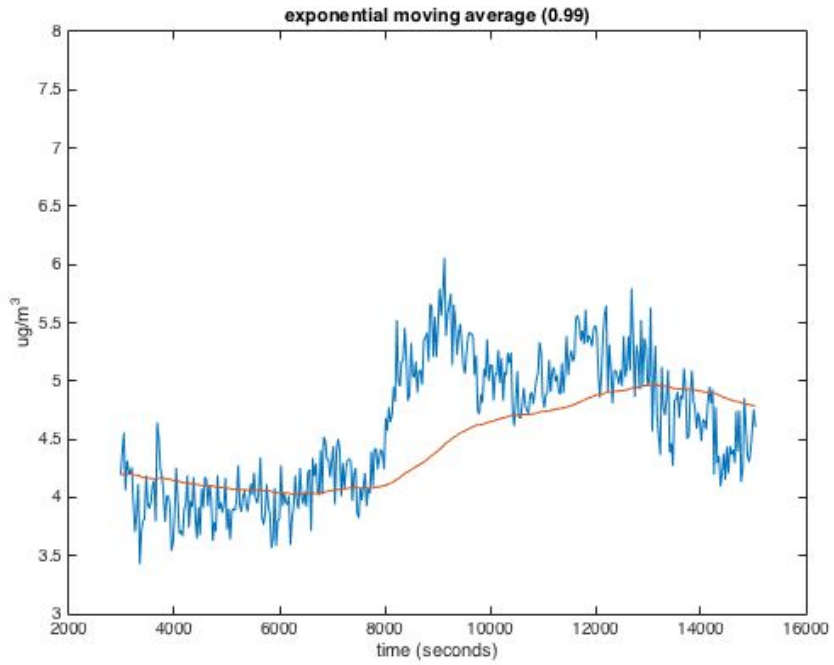

simple moving average (20 samples)
ug/m3
time (seconds)


simple moving average (100 samples)
ug/m3
time (seconds)


exponential moving average (0.5)
ug/m3
time (seconds)

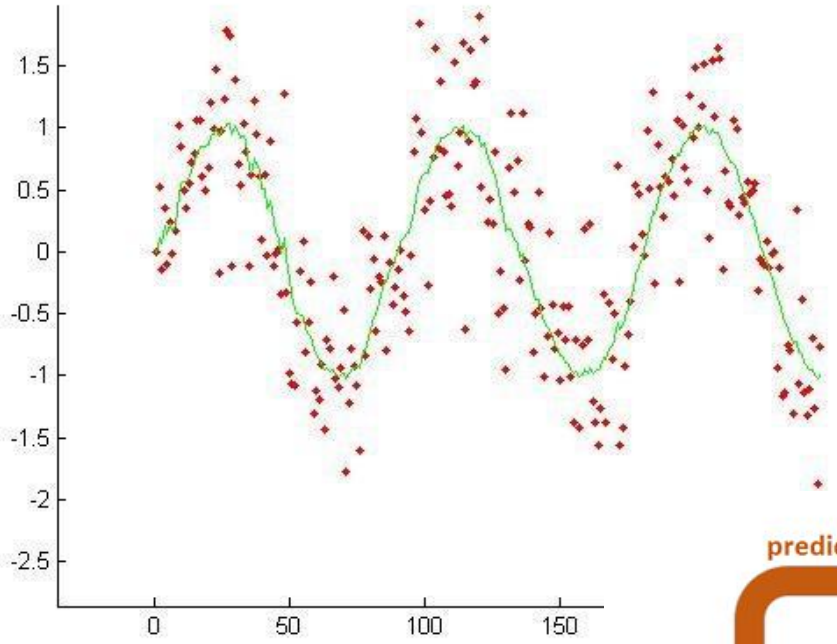

exponential moving average (0.8)
ug/m3
time (seconds)

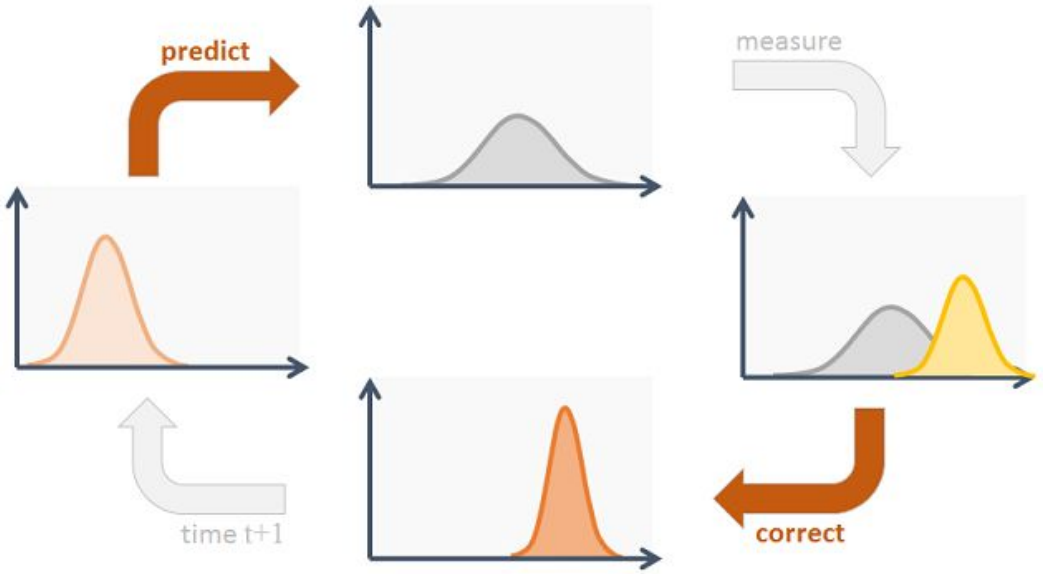

exponential moving average (0.95)
ug/m3
time (seconds)


exponential moving average (0.99)
ug/m3
time (seconds)

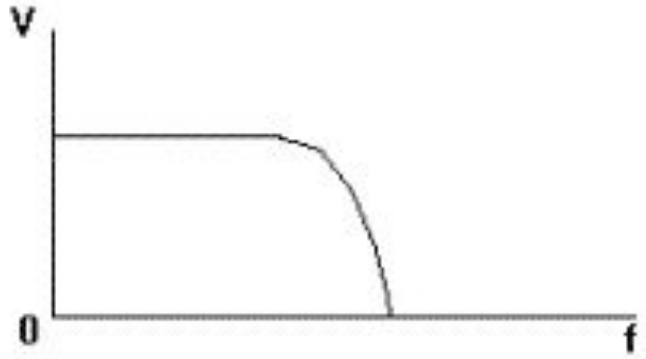
# Kalman

- Complicated filter
- Uses a model of the system to increase accuracy
- Works really well

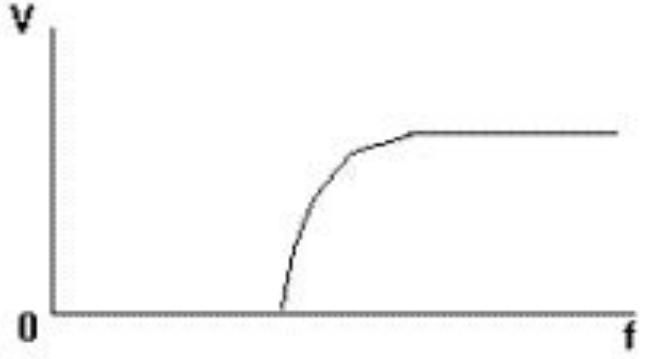


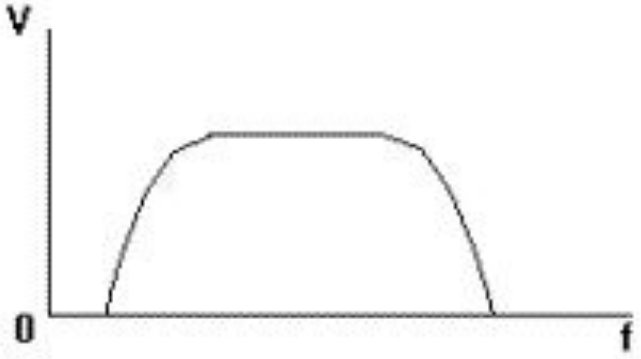
# Low/High/Band-pass



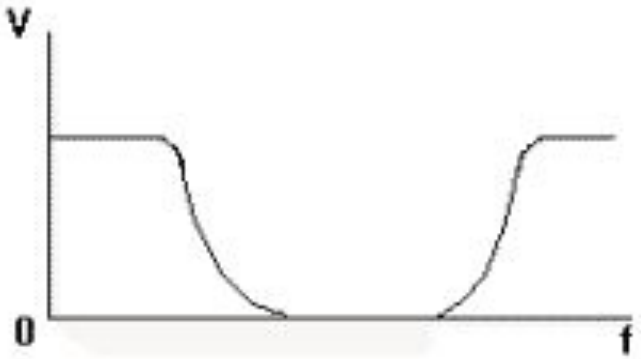

Low Pass




High Pass




Band Pass




Band Stop

Fig. 3

# Comparison of Filters

| Filter | Pros | Cons |
|---|---|---|
| Moving Average | • Easy code<br>• Little processing power needed<br>• Great for filtering sensors | • Identifying Sharp spikes<br>• Frequency analysis |
| Kalman | • Good filter<br>• Takes sensor/robot into account | • Complicated<br>• Lots of processing |
| Low/High/Band Pass | • Frequency Analysis | • Hard to implement in software |

# TL;DR

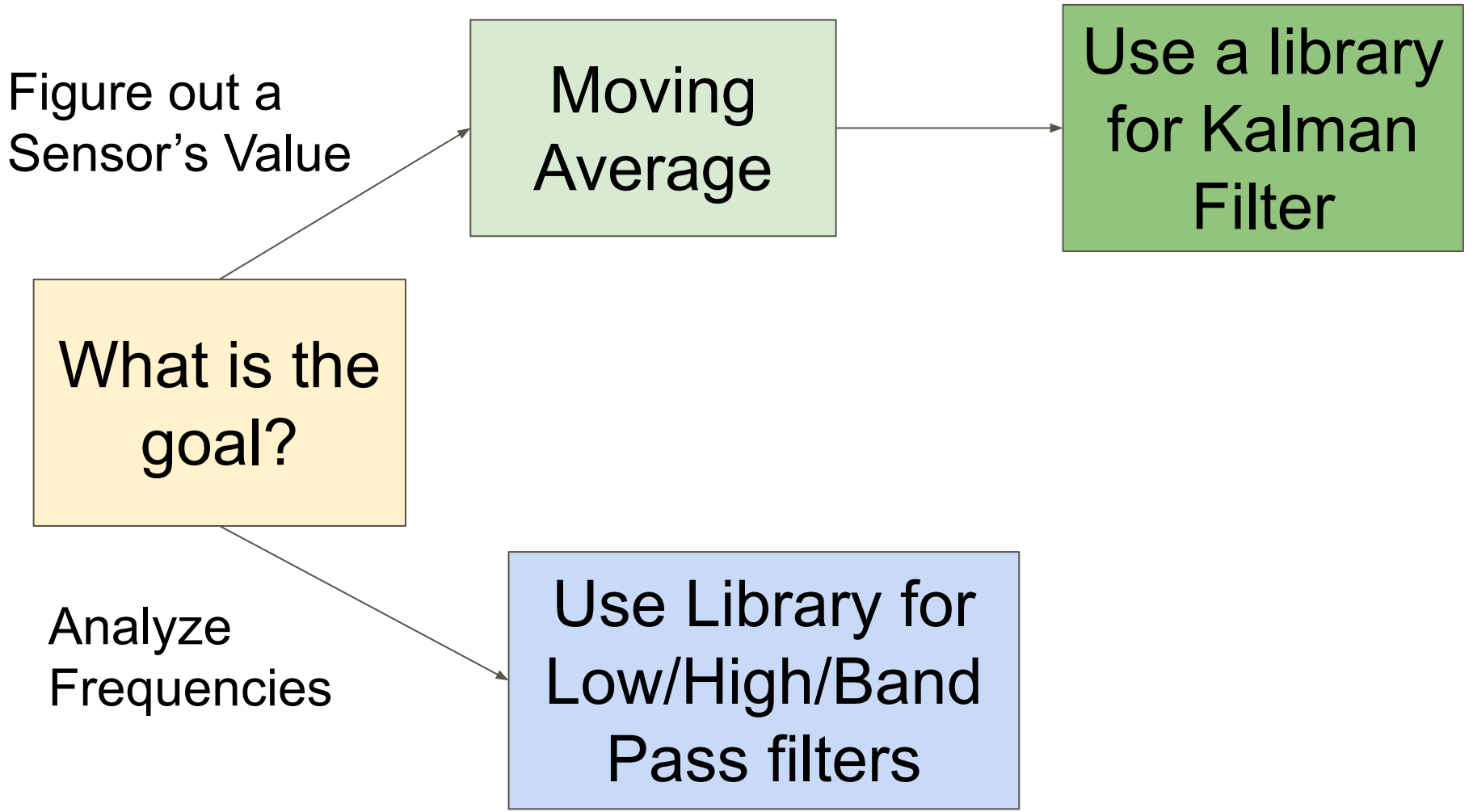


Figure out a Sensor's Value
Moving Average
Use a library for Kalman Filter
What is the goal?
Analyze Frequencies
Use Library for Low/High/Band Pass filters

# But What about Control Lab?

- Sometimes the error needs to be filtered for derivative control
  - Do you have weird oscillations when you add derivative?
- Easiest option: Moving average
  - May delay the error too much to be useful
  - Will probably want a small sample size for the average
- Harder option
  - Research what filters are used for derivative control in real world PID controllers

# Attendance Quiz

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