UC San Diego

JACOBS SCHOOL OF ENGINEERING
Computer Science and Engineering

Wireless Sensor Network Localization: Individual Group Updates—May 14, 2022

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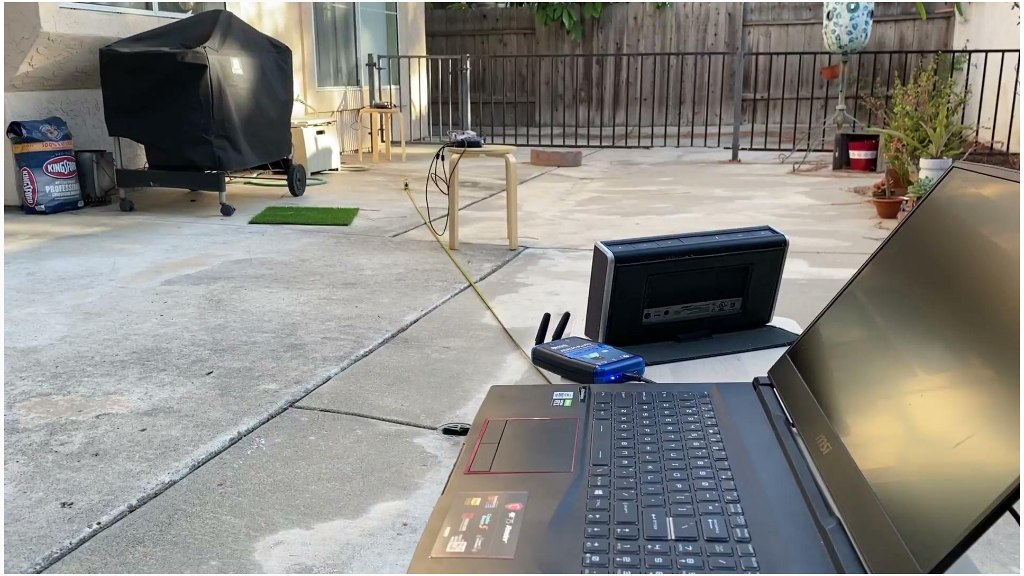
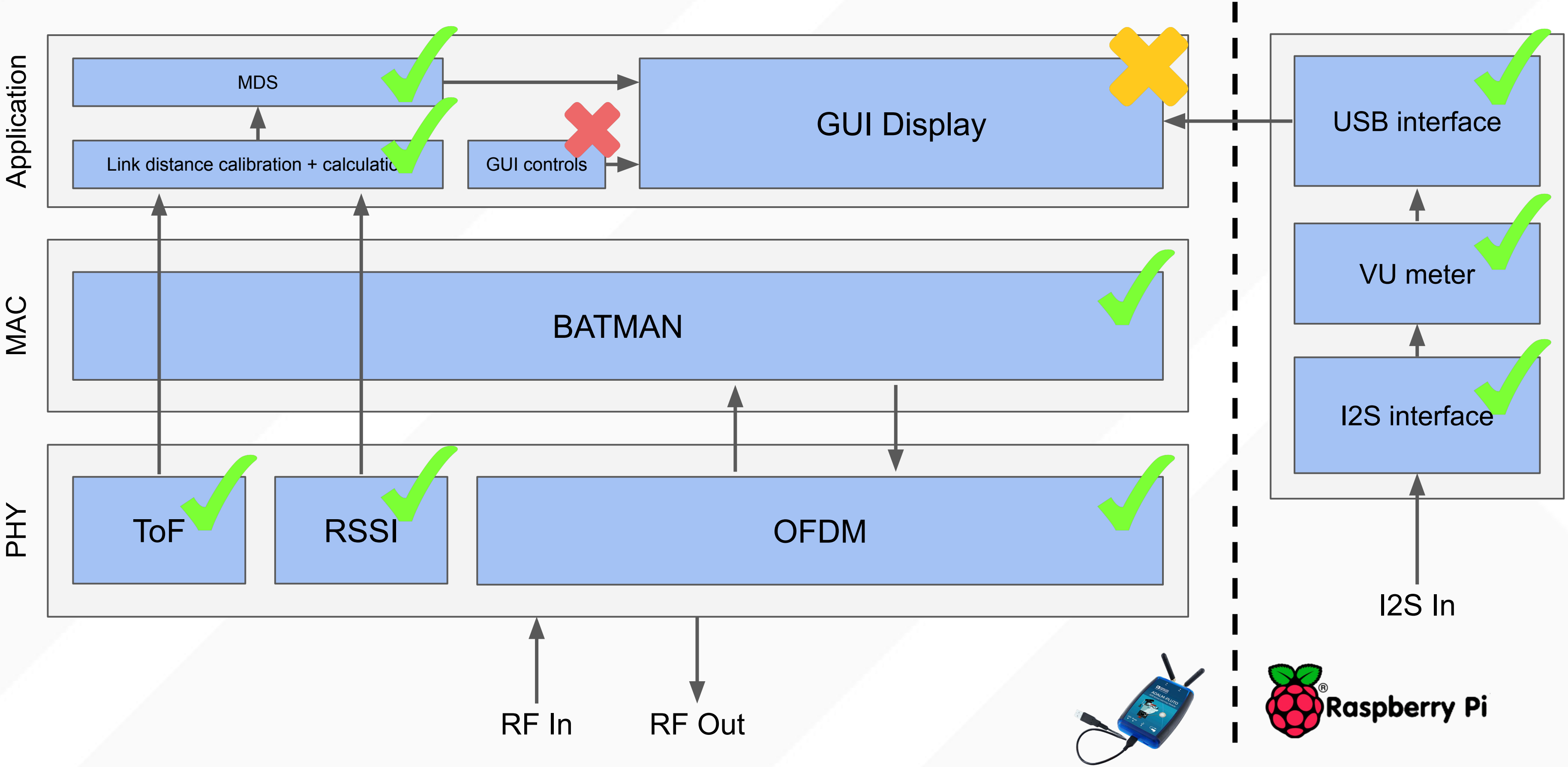
WES Spring 2022

Previous sprint progress: Demo

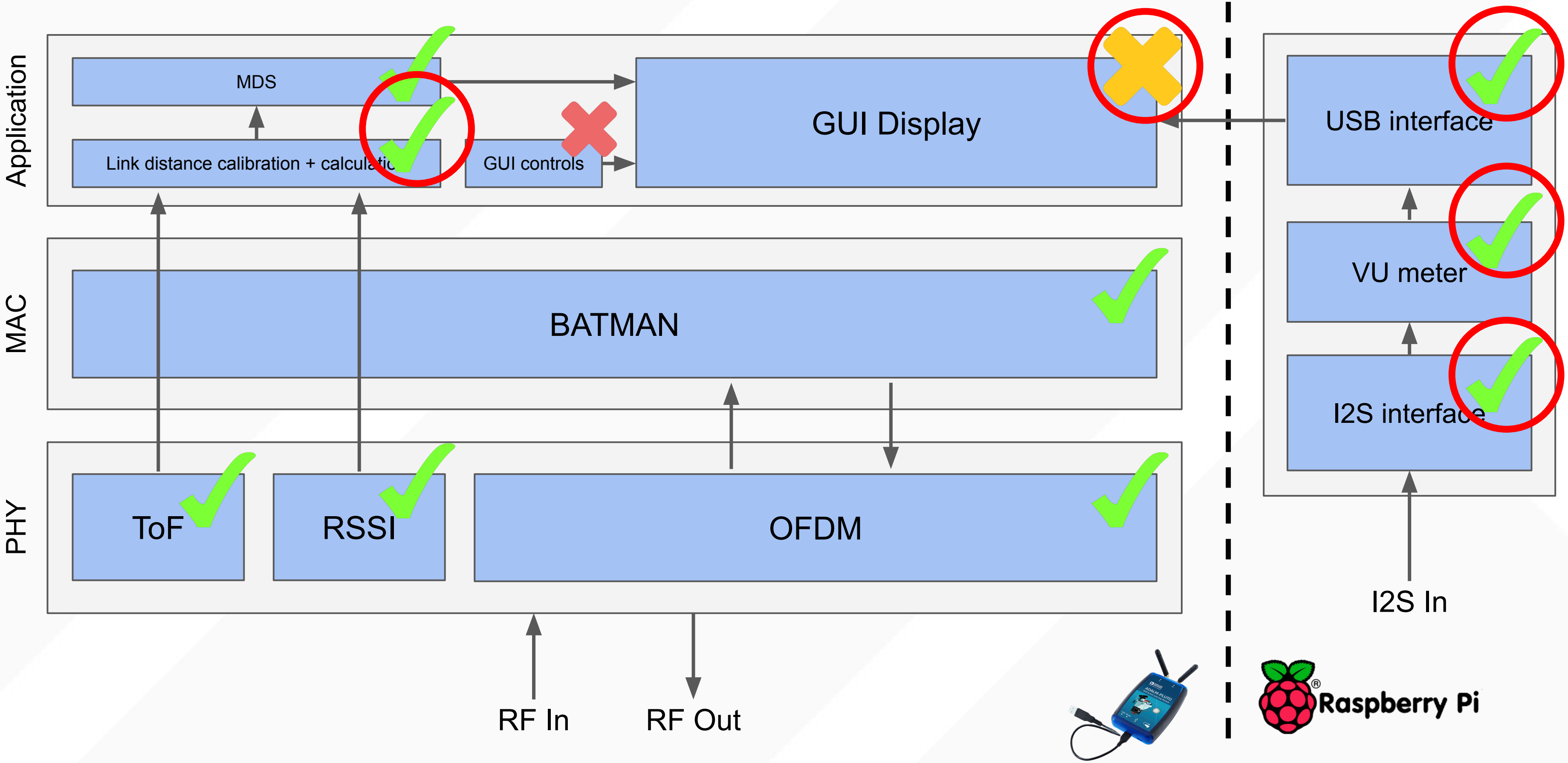
- 3 node network
  - String-of-pearls topology
- Demonstrates:
  - Full system operation
  - Farther node reports lower audio level (as expected)
  - Slight improvements to topology reconstruction



Overall system progress

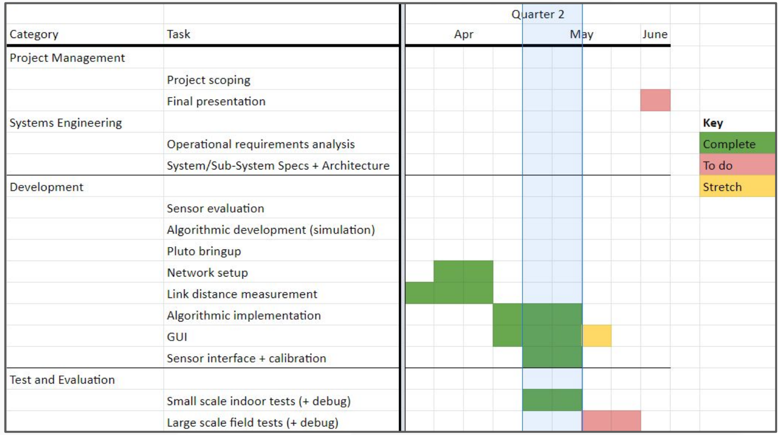


Previous sprint progress



Previous sprint progress: Overview

- **Goals:**
  - Mic sensor integration:
    - Reports % full scale over USB to Pluto, Pluto propagates info to network
  - Smarter link distance calculation
    - Bayesian fusion + Kalman filter
  - More field testing
    - More topologies, environments
  - More GUI work
    - Functional, but very laggy
    - Considering switching to PyQtGraph?

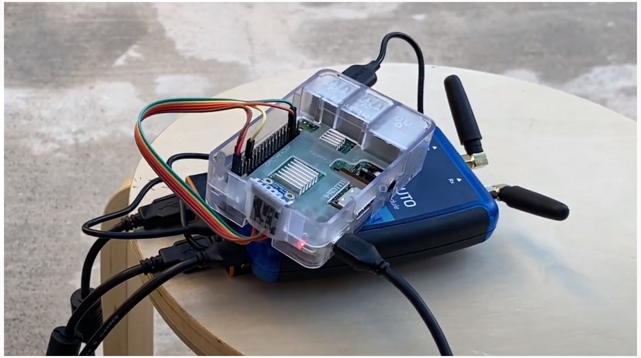


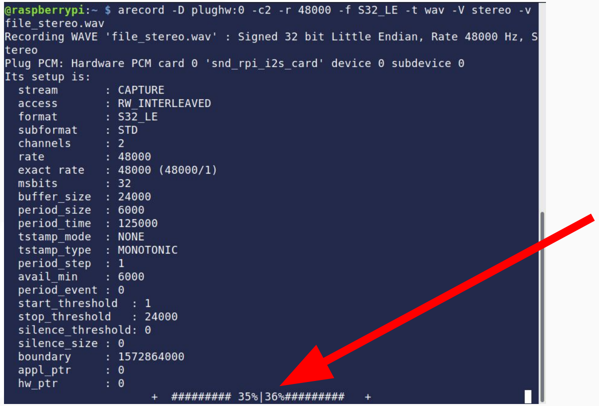
		Quarter 2								
Category	Task	Apr				May				June
Project Management										
	Project scoping									
	Final presentation									🟥
Systems Engineering										
	Operational requirements analysis									
	System/Sub-System Specs + Architecture									
Development										
	Sensor evaluation									
	Algorithmic development (simulation)									
	Pluto bringup									
	Network setup		🟩	🟩						
	Link distance measurement	🟩	🟩	🟩						
	Algorithmic implementation				🟩	🟩	🟩			
	GUI				🟩	🟩	🟩	🟨		
	Sensor interface + calibration					🟩	🟩			
Test and Evaluation										
	Small scale indoor tests (+ debug)					🟩	🟩			
	Large scale field tests (+ debug)							🟥	🟥	

Key	
🟩	Complete
🟥	To do
🟨	Stretch

Previous sprint progress: Mic integration

- 2 interfaces to set up:
  - Mic to Pi:
    - I2S, easy Adafruit setup
  - Pi to Pluto:
    - Ethernet over USB, so just scp’ing a file
- Bash script continually updates sensor data file using volume meter output of arecord
  - Reported as average percentage of full scale mic input
- Pluto polls file, reports value alongside link distances





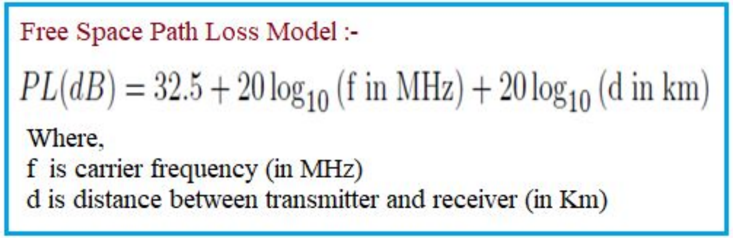
```
@raspberrypi:~ $ arecord -D plughw:0 -c2 -r 48000 -f S32_LE -t wav -V stereo -v
file_stereo.wav
Recording WAVE 'file_stereo.wav' : Signed 32 bit Little Endian, Rate 48000 Hz, S
tereo
Plug PCM: Hardware PCM card 0 'snd_rpi_i2s_card' device 0 subdevice 0
Its setup is:
  stream       : CAPTURE
  access       : RW_INTERLEAVED
  format       : S32_LE
  subformat    : STD
  channels     : 2
  rate         : 48000
  exact rate   : 48000 (48000/1)
  msbits       : 32
  buffer_size  : 24000
  period_size  : 6000
  period_time  : 125000
  tstamp_mode  : NONE
  tstamp_type  : MONOTONIC
  period_step  : 1
  avail_min    : 6000
  period_event : 0
  start_threshold  : 1
  stop_threshold   : 24000
  silence_threshold: 0
  silence_size : 0
  boundary     : 1572864000
  appl_ptr     : 0
  hw_ptr       : 0
                      +  ######### 35%|36%#########   +
```

Previous sprint progress: Smarter link distance calculation

- End goal: Combine sensors w/ different sources of error to get cleaner combined output
- Previously just did pure average of RSSI- and ToF-based measurements, over all time
- Problems:
  a. Throws away precision/uncertainty, e.g. if one measurement is more stable
  b. Doesn’t handle disagreement between two methods well
  c. Doesn’t handle node movement, i.e. changing measurements over time
- Solution: use two sensor fusion techniques
  1. Bayesian fusion w/ spurious rejection (solves **a**, **b**)
  2. Kalman filtering (solves **c**)

Previous sprint progress: Sources of error

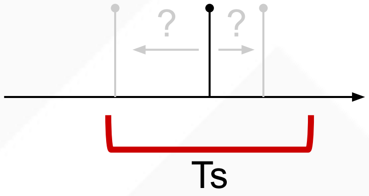
- RSSI
  - Ideal: free space path loss equation
  - Errors from:
    - Non-ideal channel, different environments
    - Poor (unstable) TX power control
- ToF
  - Ideal: correlation peak of PN seq captured perfectly
  - Errors from:
    - Clock synch dependent
    - Peak strength affected by SNR/multipath
    - True peak can be anywhere within sample window
- So comparatively:
  - RSSI has higher environmental dependence—more likely to be spurious
  - ToF generally larger σ

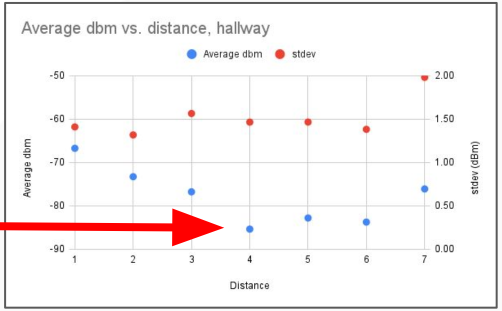


Free Space Path Loss Model :-

$$PL(dB) = 32.5 + 20\log_{10}(\text{f in MHz}) + 20\log_{10}(\text{d in km})$$

Where,
f is carrier frequency (in MHz)
d is distance between transmitter and receiver (in Km)

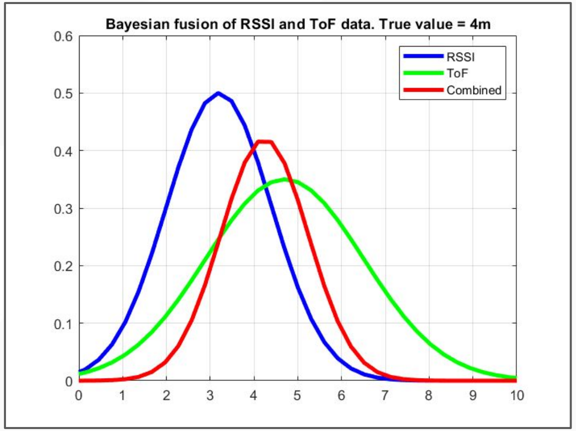


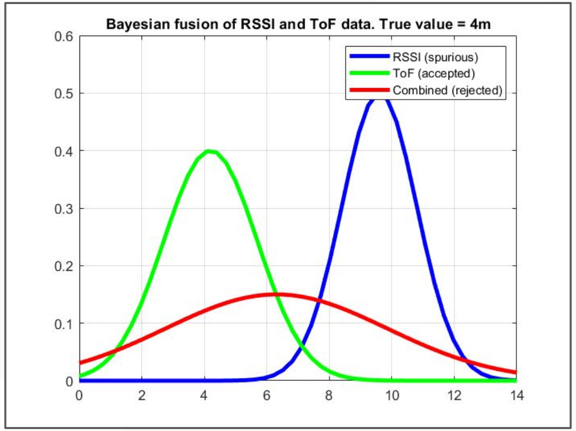


Previous sprint progress: Bayesian fusion w/ spurious rejection

From “A Generalized Approach for Inconsistency Detection in Data Fusion from Multiple Sensors” by Kumar et al.

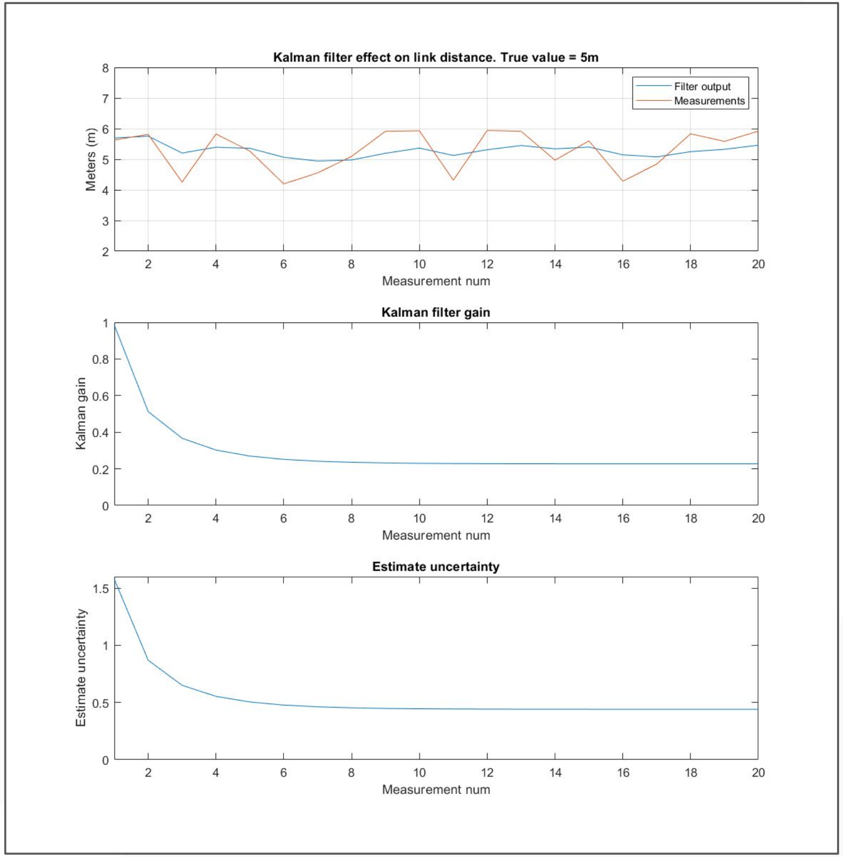
- High level concept:
  - Assume input variables are normal, calculate (μ, σ)
  - Combine via weighted average using ratio of σ_1 and σ_2, skew result’s variance by $(\mu_1 - \mu_2)$
  - If combined distribution has a smaller variance than the inputs, fusion is useful
    - If variance is larger, one sensor likely spurious, so return solely sensor w/ lower σ
- Applied to our data:
  - See improved accuracy in **left**, correct rejection on **right**





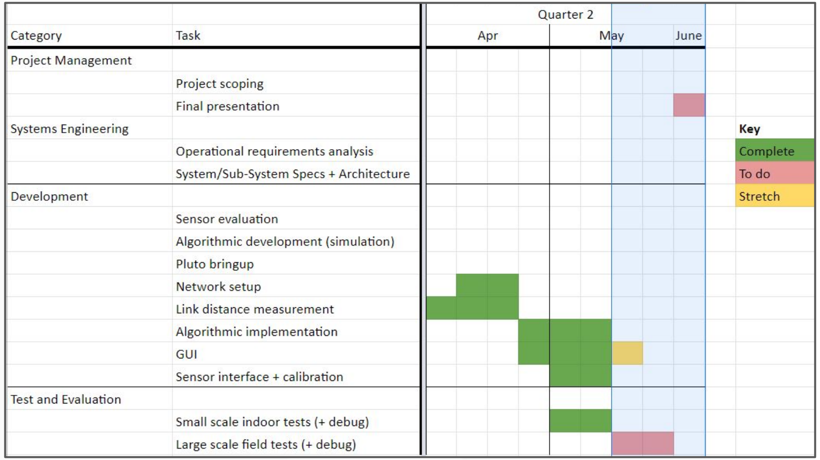
Previous sprint progress: Kalman filtering

- Method of estimating a system’s state given a series of measurements over time
  - Usually used in robotics/controls
  - “Filtering” comes from deciding how to incorporate incoming measurements into existing state variables - dependent on uncertainty
- Have measurements w/ uncertainty from fusion step
- Can see that this leads to a nice smoothing-over-time effect



Next sprint progress: Overview

- **Next (final!) sprint goals:**
  - Scale up to 5 nodes
  - Finish GUI
  - Prep demo
    - Still 5 node demo measuring sound level out of a speaker at various points within the room



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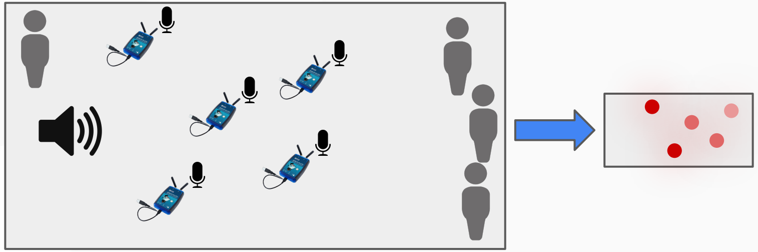

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Questions?