ECE3

PROJECT LECTURE

RECORD!

FROM COURSE EVALUATIONS

"I think an area of improvement would be a smoother transition from doing the lab to doing the project, at certain point I felt pretty lost with a sudden lack of instruction or clear goal to work toward to."

"I feel a little bit confused since there is no clear instruction to refer to."

Many of you are transfer students. You will experience a major change in expectations.

I am trying to prepare you for the world of undergrad research, of work, of internships, and entry-level engineering positions. You will not be given a series of steps to accomplish a task. You will be expected to figure out how to accomplish the task with minimal intervention from your supervisor or co-workers.

ARDUINO INSTALL

Downloads

Arduino IDE 1.8.15

The open-source Arduino Software (IDE) makes it easy to write code and upload it to the board. This software can be used with any Arduino board.

Refer to the **Getting Started** page for Installation instructions.

SOURCE CODE

Active development of the Arduino software is **hosted by GitHub**. See the instructions for **building the code**. Latest release source code archives are available **here**. The archives are PGP-signed so they can be verified using **this** gpg key.

DOWNLOAD OPTIONS

Windows Win 7 and newer
Windows ZIP file
Windows app Win 8.1 or 10 Get
Linux 32 bits
Linux 64 bits
Linux ARM 32 bits
Linux ARM 64 bits
Mac OS X 10.10 or newer

Release Notes Checksums (sha512)

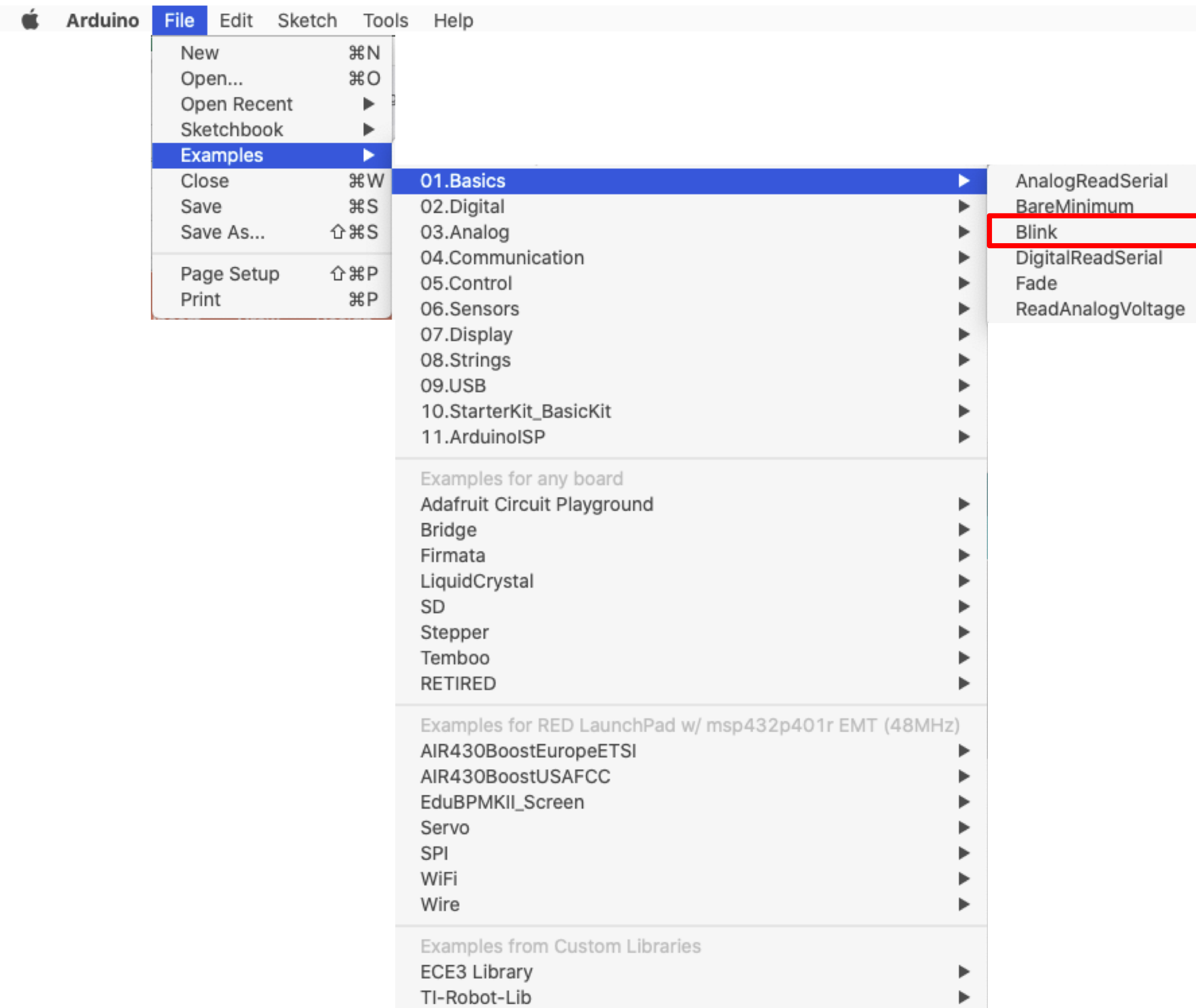
https://www.arduino.cc/en/software

Mark Easley
Published January 28, 2021

Robotics System Workshop: Arduino Programming on TI-RSLK MAX

https://www.hackster.io/measley2/robotics-system-workshop-arduino-programming-on-ti-rslk-max-d33faa

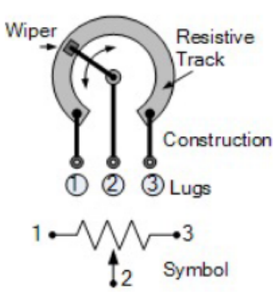
CHANGING BLINKY FLASH RATE

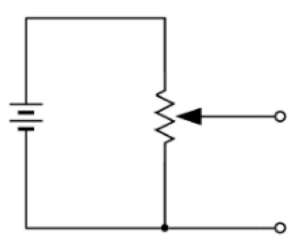


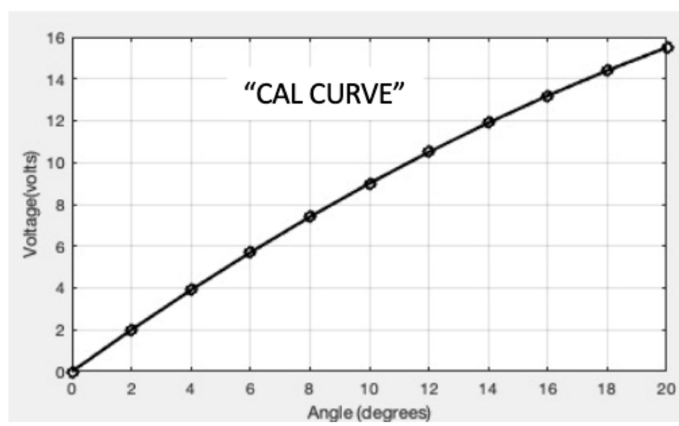
PATH SENSOR CALIBRATION

CALIBRATION

- Relates two physical quantities
- Often voltage vs physical quantity
- Example: Wing Aileron







PATH SENSOR CALIBRATION

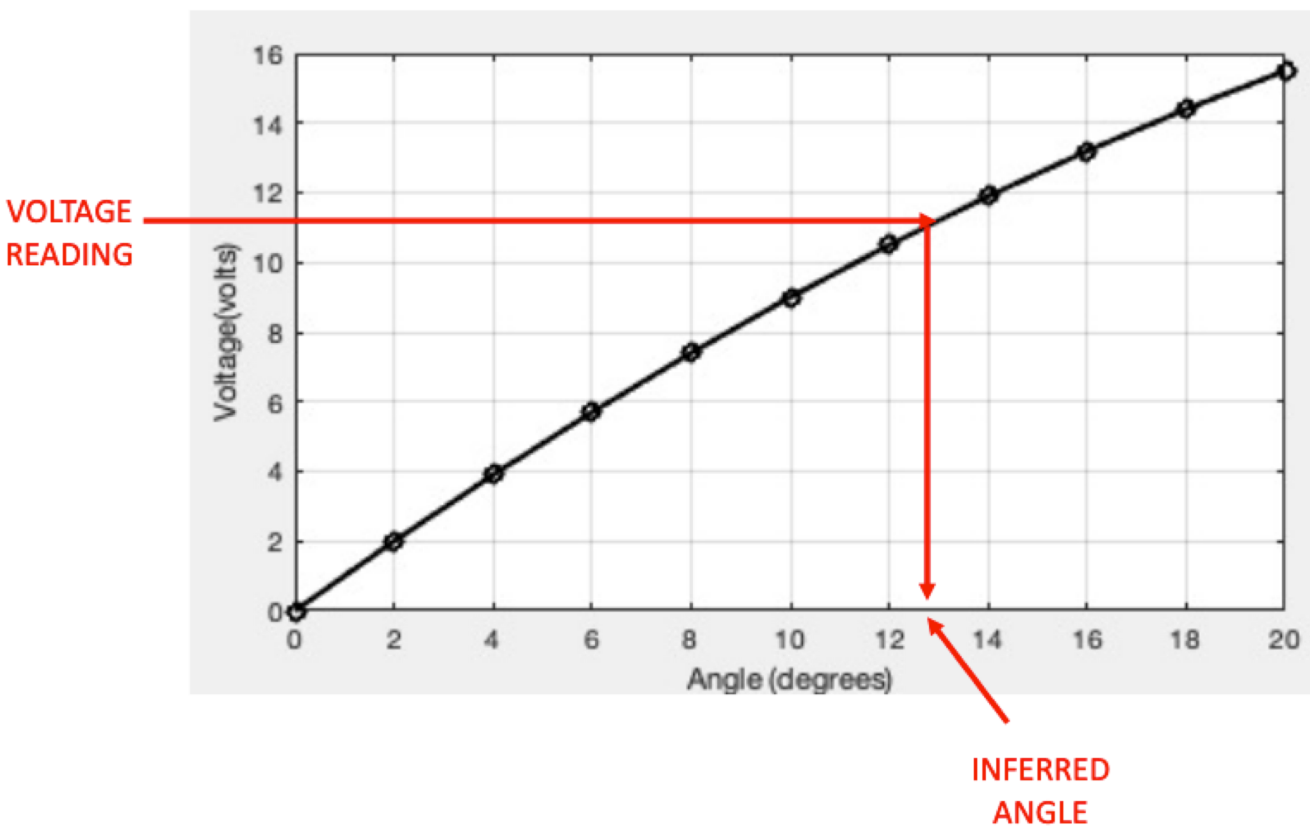
GENERATE A CALIBRATION CURVE

- Set aileron to known angle
- Measure voltage from potentiomenter

KNOWN ANGLE	OUTPUT VOLTAGE
0°	0.0
2°	2.0
4°	3.9
6°	5.7
8°	7.4
10°	9.0
12°	10.5
14°	11.9
16°	13.2
18°	14.4
20°	15.5

PATH SENSOR CALIBRATION

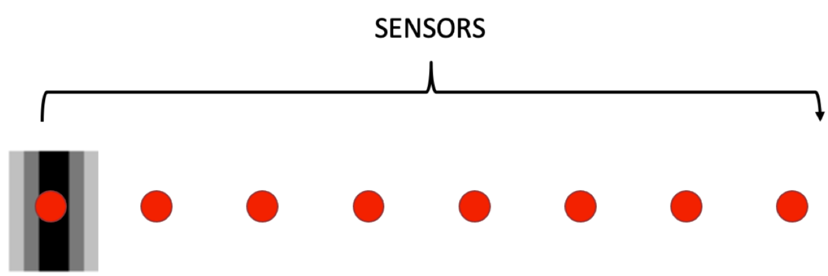
TAKE A MEASUREMENT



PATH SENSOR CALIBRATION

WHAT YOU WILL DO

Imagine that you are looking down on the car



PATH SENSOR CALIBRATION

WHAT YOU WILL DO

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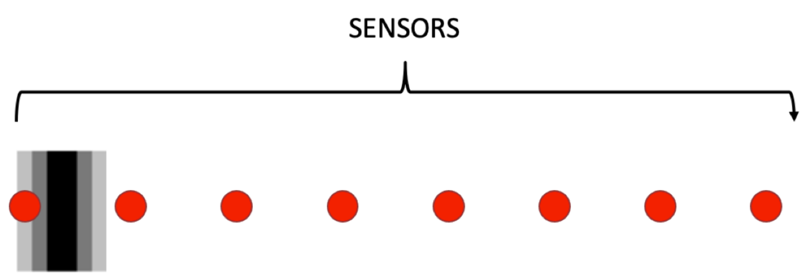

PATH SENSOR CALIBRATION

WHAT YOU WILL DO

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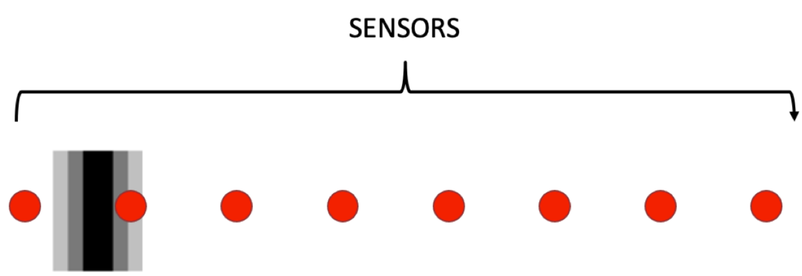

PATH SENSOR CALIBRATION

WHAT YOU WILL DO

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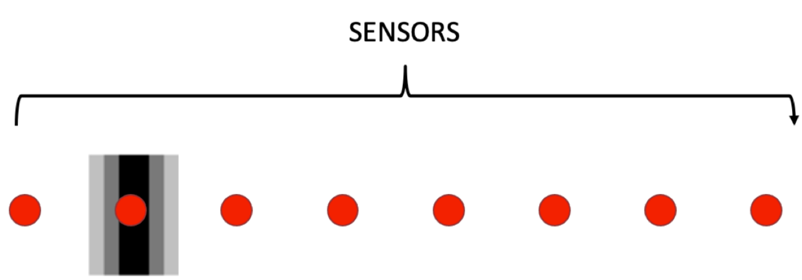

PATH SENSOR CALIBRATION

WHAT YOU WILL DO

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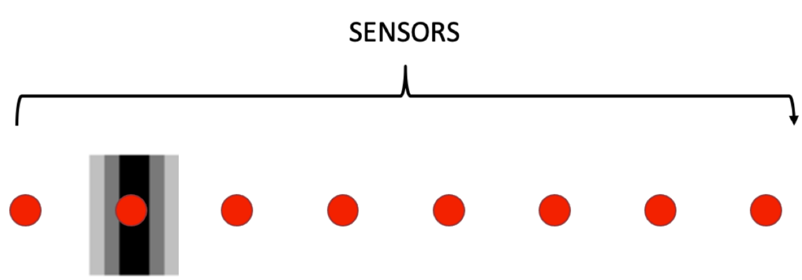
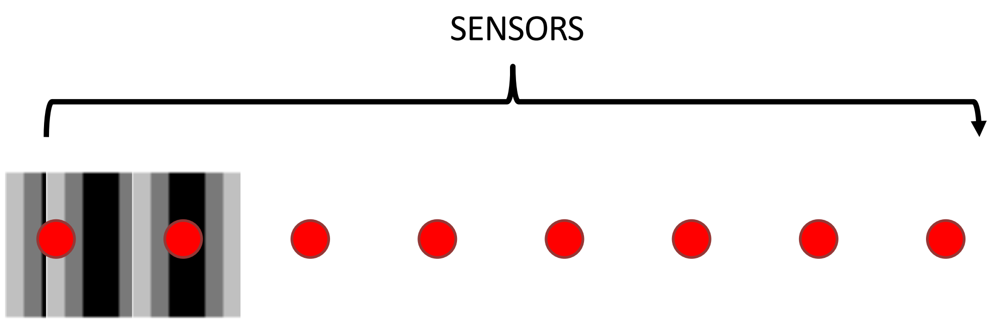


WATCH THE VIDEO!

https://www.youtube.com/watch?v=swOMZOSCpzM

WHAT YOU WILL DO

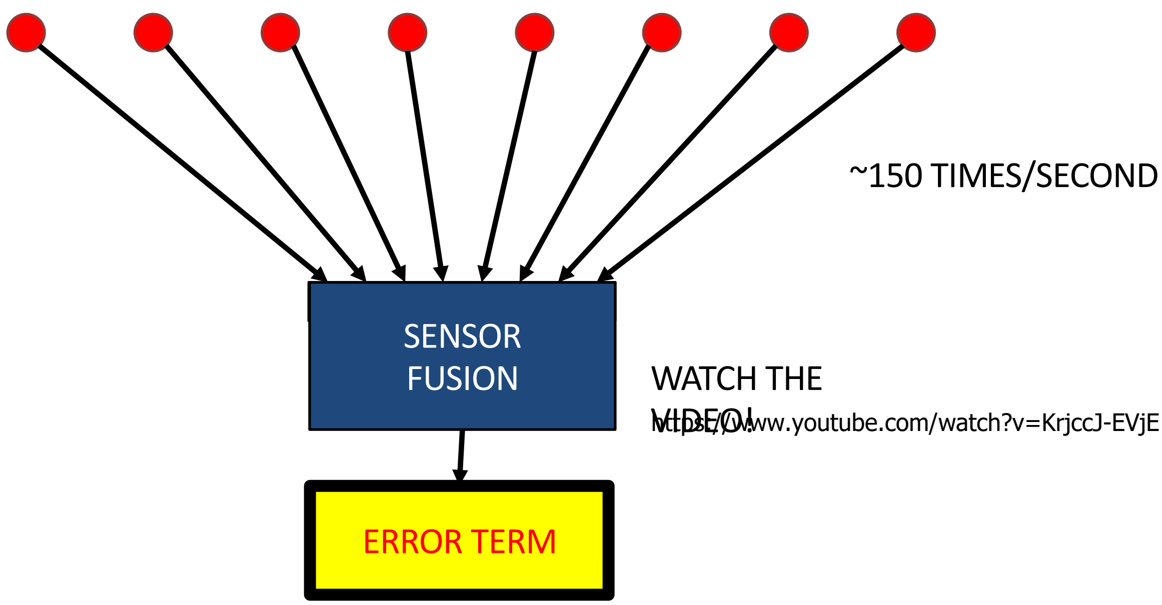
Imagine that you are looking down on the car



WATCH THE VIDEO!

https://www.youtube.com/watch?v=swOMZOSCpzM

SENSOR FUSION



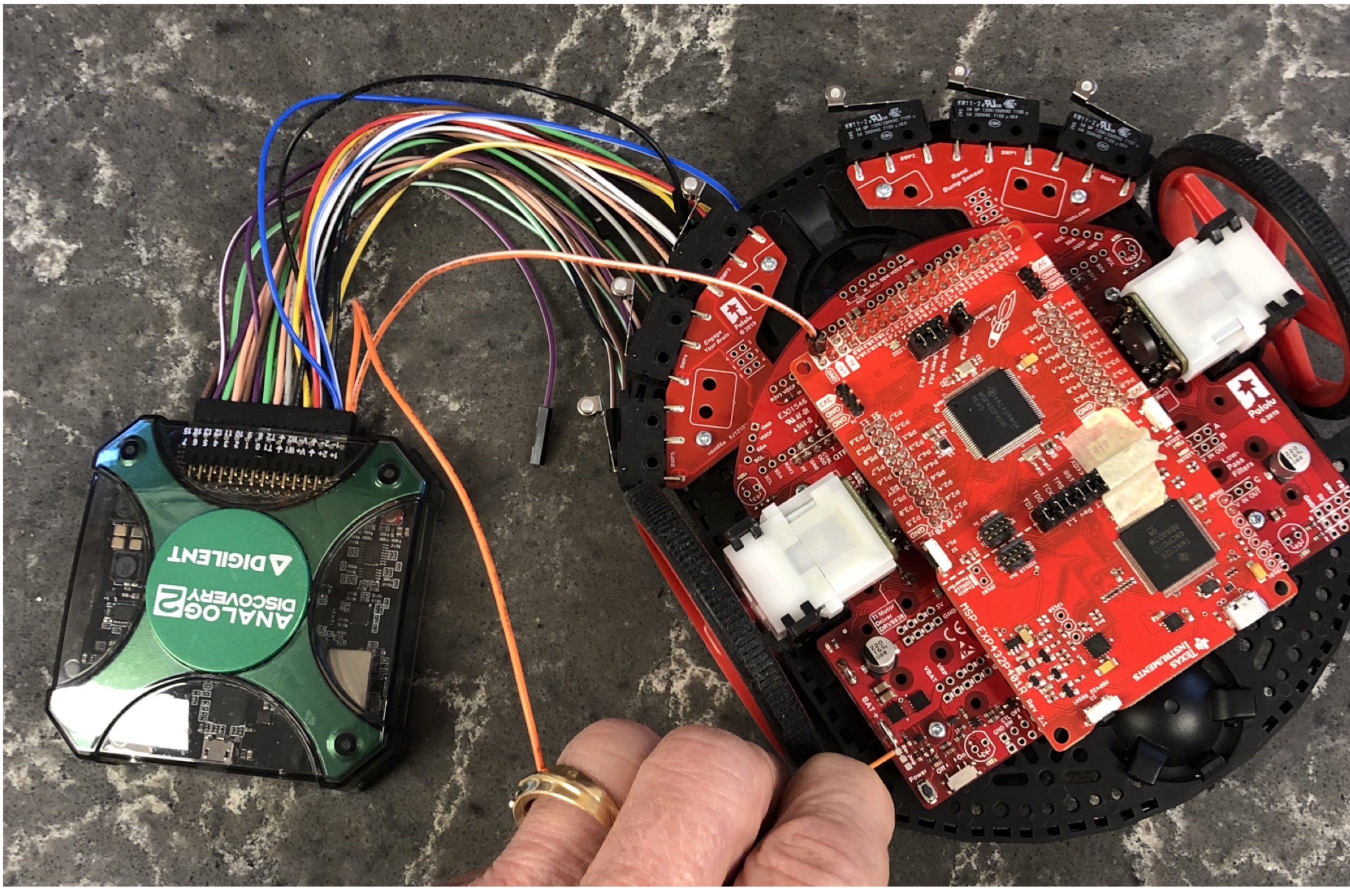
WATCH THE VIDEO!
https://www.youtube.com/watch?v=KrjccJ-EVjE

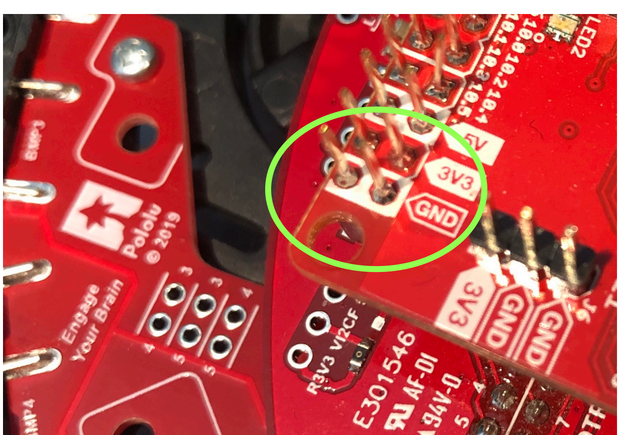
TAKING TEST DATA

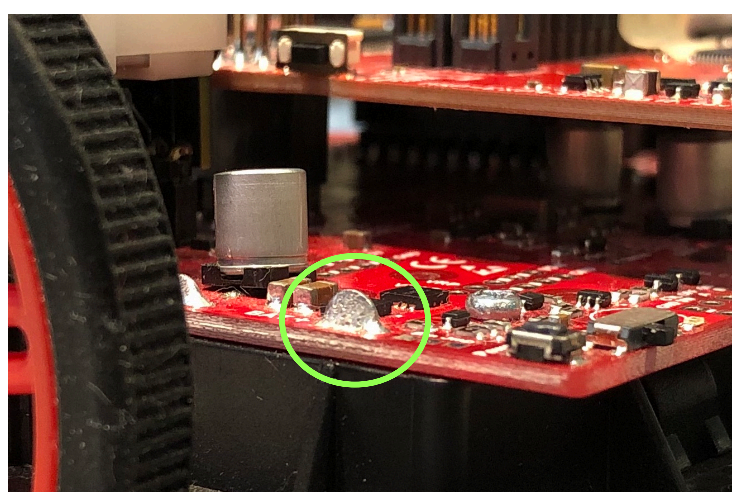
25 Apr 2021

	Speed	Kp	Kd	Start Pos	Batt Volt	Wts	Result
1	30	.35	3.5	0	7.6	84 21	Success, but takes long time to ctr on straightaway
2	30	.35	3.5	0	8.5V	84 21	Failed on last turn (10)
3	30	.35	3.5	0	8.5	84 21	Failed on Turn 2
4	30	.35	3.5	0	8.5	84 21	Failed on Turn 9
5	30	.35	3.5	0	8.5	85 31	Failed on Turn 9
6	30	.35	3.5	0	8.5	85 31	Failed on Turn 9
7 = 6						10 6 3 1	Failed on Turn 9
8 = 7							Success but long ctring time
9 = 7							Success " " "
10 = 7		.70					Success, better ctring time
11 = 10							= 10
12							= 10 48.1s
13	40	.70	3.5	0	8.5	10 6 3 1	Success
14 = 13							Failed on T9
15 = 13							Success 36.7s
16	40	1.0	3.5	0	8.0	10 6 8 1	Success 34.8s

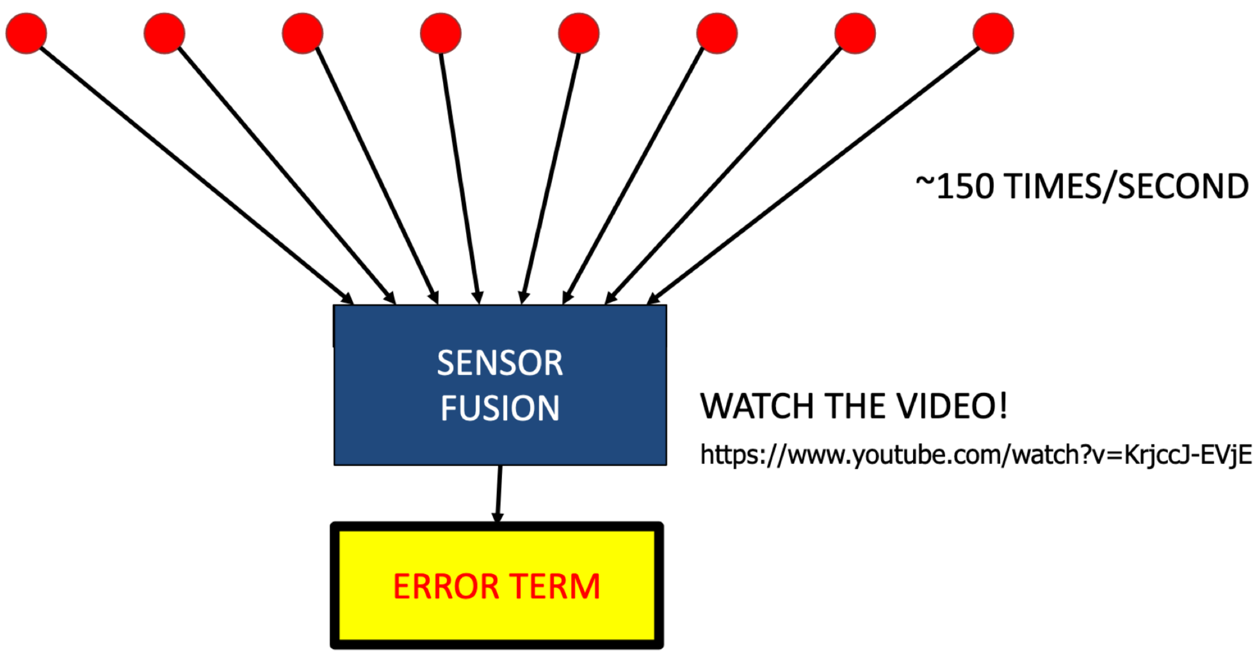
MEASURING BATTERY VOLTAGE







SENSOR FUSION

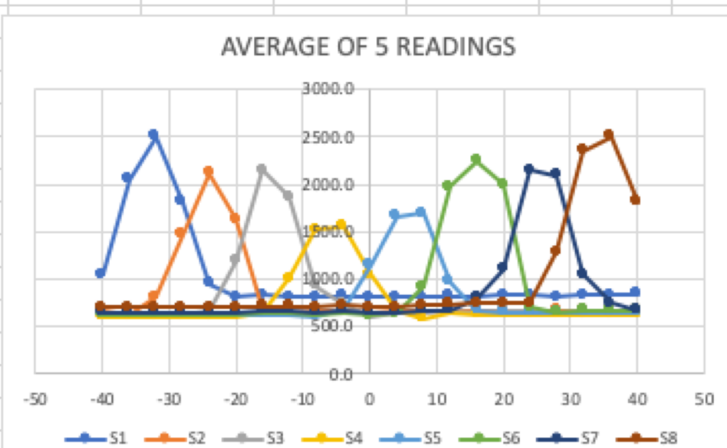


CALIBRATION & SENSOR FUSION PROCESS

Take 5 calibration readings at each error position
Compute average of 5 readings at each position
Move the average readings to a new sheet

IN SPREADSHEET
- For each of the 8 sensors
  - Find the minimum average among all positions

ORIGINAL DATA (AVERAGE OF 5 READINGS)								
ERROR	S1	S2	S3	S4	S5	S6	S7	S8
-40	1048.2	676.0	652.6	607.0	629.6	629.6	652.6	699.4
-36	2053.6	629.8	639.2	607.0	629.8	629.8	653.2	699.8
-32	2500.0	815.0	652.8	607.0	629.8	629.8	652.8	699.0
-28	1807.2	1462.8	630.0	607.2	630.0	630.0	653.2	699.4
-24	954.0	2116.6	676.0	607.0	630.0	630.0	653.0	699.0
-20	814.0	1626.2	1184.2	607.0	630.0	630.0	653.0	699.0
-16	827.6	697.6	2149.2	651.6	629.2	651.6	670.0	716.8
-12	813.6	652.6	1866.0	1004.0	629.8	652.6	666.4	712.4
-8	814.2	676.0	930.0	1526.4	607.8	630.0	653.0	699.0
-4	823.0	674.8	734.8	1559.2	684.0	652.2	674.8	721.0
0	814.8	653.0	607.8	1046.4	1139.8	621.4	653.0	699.4
4	814.6	671.0	652.4	670.8	1658.0	638.8	652.4	698.8
8	814.2	675.8	653.0	585.0	1699.0	916.0	675.8	721.8
12	827.0	675.2	675.2	652.2	975.6	1977.2	675.2	739.6
16	814.2	675.4	652.8	630.0	675.4	2241.0	795.4	744.6
20	832.2	675.4	675.4	629.8	652.6	2000.4	1101.0	744.6
24	837.2	675.2	675.2	629.8	652.2	698.2	2141.2	744.2
28	814.2	676.0	652.4	630.0	652.4	652.4	2093.4	1283.0
32	832.6	675.6	670.8	630.0	652.4	675.6	1045.8	2346.8
36	837.6	675.6	675.6	629.8	652.6	675.6	744.8	2496.4
40	838.2	675.2	675.2	630.0	652.8	675.2	675.2	1812.2
Minimum	813.6	629.8	607.8	585	607.8	621.4	652.4	698.8



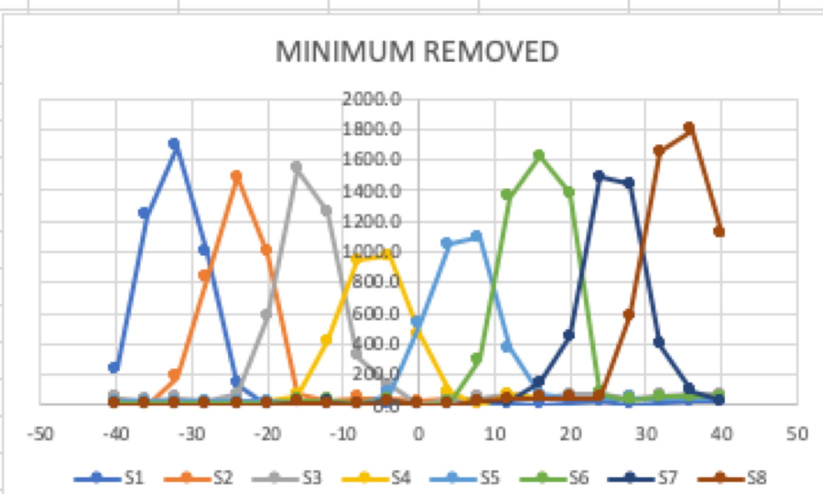
Try Alexiy's cal code!

CALIBRATION & SENSOR FUSION PROCESS

<u>IN SPREADSHEET</u>

- For each position average
  - Subtract that minimum
  - Find the maximum average (after minimum has been subtracted)

	DATA WITH MINIMUM VALUE SUBTRACTED							
ERROR	S1	S2	S3	S4	S5	S6	S7	S8
-40	234.6	46.2	44.8	22.0	21.8	8.2	0.2	0.6
-36	1240.0	0.0	31.4	22.0	22.0	8.4	0.8	1.0
-32	1686.4	185.2	45.0	22.0	22.0	8.4	0.4	0.2
-28	993.6	833.0	22.2	22.2	22.2	8.6	0.8	0.6
-24	140.4	1486.8	68.2	22.0	22.2	8.6	0.6	0.2
-20	0.4	996.4	576.4	22.0	22.2	8.6	0.6	0.2
-16	14.0	67.8	1541.4	66.6	21.4	30.2	17.6	18.0
-12	0.0	22.8	1258.2	419.0	22.0	31.2	14.0	13.6
-8	0.6	46.2	322.2	941.4	0.0	8.6	0.6	0.2
-4	9.4	45.0	127.0	974.2	76.2	30.8	22.4	22.2
0	1.2	23.2	0.0	461.4	532.0	0.0	0.6	0.6
4	1.0	41.2	44.6	85.8	1050.2	17.4	0.0	0.0
8	0.6	46.0	45.2	0.0	1091.2	294.6	23.4	23.0
12	13.4	45.4	67.4	67.2	367.8	1355.8	22.8	40.8
16	0.6	45.6	45.0	45.0	67.6	1619.6	143.0	45.8
20	18.6	45.6	67.6	44.8	44.8	1379.0	448.6	45.8
24	23.6	45.4	67.4	44.8	44.4	76.8	1488.8	45.4
28	0.6	46.2	44.6	45.0	44.6	31.0	1441.0	584.2
32	19.0	45.8	63.0	45.0	44.6	54.2	393.4	1648.0
36	24.0	45.8	67.8	44.8	44.8	54.2	92.4	1797.6
40	24.6	45.4	67.4	45.0	45.0	53.8	22.8	1113.4
Maximun	1686.4	1486.8	1541.4	974.2	1091.2	1619.6	1488.8	1797.6



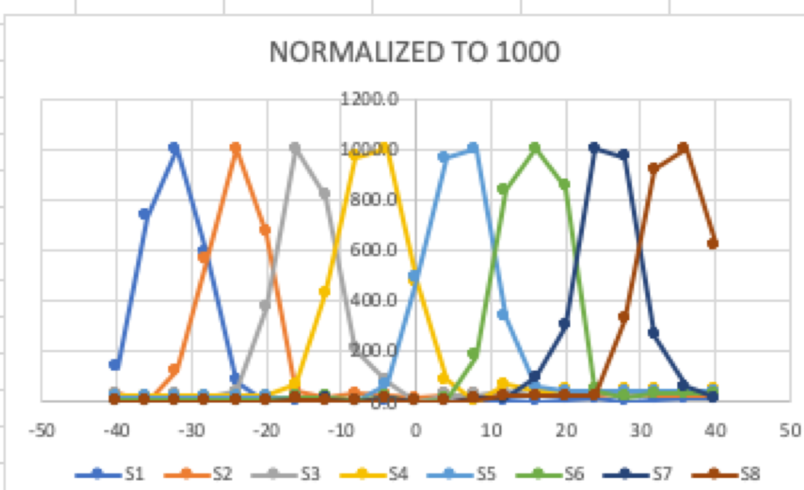
CALIBRATION & SENSOR FUSION PROCESS

IN SPREADSHEET

- For each position average
  - Ratio the position average to 1000 to obtain normalized values

DATA NORMALIZED TO 1000

ERROR	S1	S2	S3	S4	S5	S6	S7	S8
-40	139.1	31.1	29.1	22.6	20.0	5.1	0.1	0.3
-36	735.3	0.0	20.4	22.6	20.2	5.2	0.5	0.6
-32	1000.0	124.6	29.2	22.6	20.2	5.2	0.3	0.1
-28	589.2	560.3	14.4	22.8	20.3	5.3	0.5	0.3
-24	83.3	1000.0	44.2	22.6	20.3	5.3	0.4	0.1
-20	0.2	670.2	373.9	22.6	20.3	5.3	0.4	0.1
-16	8.3	45.6	1000.0	68.4	19.6	18.6	11.8	10.0
-12	0.0	15.3	816.3	430.1	20.2	19.3	9.4	7.6
-8	0.4	31.1	209.0	966.3	0.0	5.3	0.4	0.1
-4	5.6	30.3	82.4	1000.0	69.8	19.0	15.0	12.3
0	0.7	15.6	0.0	473.6	487.5	0.0	0.4	0.3
4	0.6	27.7	28.9	88.1	962.4	10.7	0.0	0.0
8	0.4	30.9	29.3	0.0	1000.0	181.9	15.7	12.8
12	7.9	30.5	43.7	69.0	337.1	837.1	15.3	22.7
16	0.4	30.7	29.2	46.2	62.0	1000.0	96.1	25.5
20	11.0	30.7	43.9	46.0	41.1	851.4	301.3	25.5
24	14.0	30.5	43.7	46.0	40.7	47.4	1000.0	25.3
28	0.4	31.1	28.9	46.2	40.9	19.1	967.9	325.0
32	11.3	30.8	40.9	46.2	40.9	33.5	264.2	916.8
36	14.2	30.8	44.0	46.0	41.1	33.5	62.1	1000.0
40	14.6	30.5	43.7	46.2	41.2	33.2	15.3	619.4

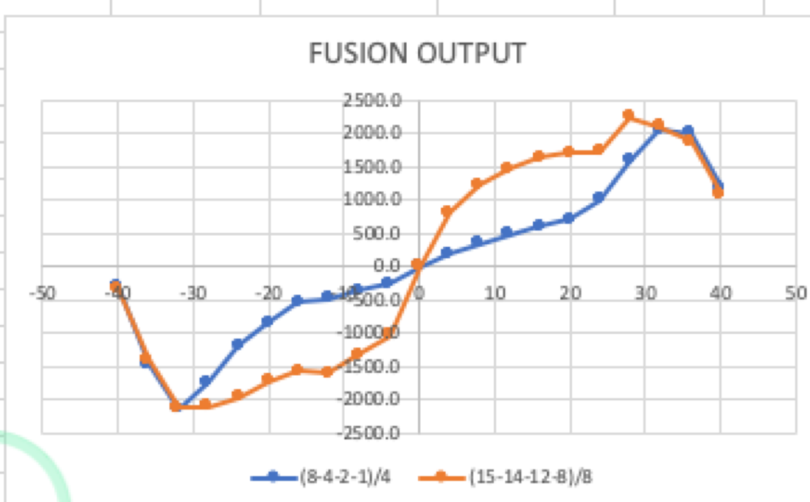


CALIBRATION & SENSOR FUSION PROCESS

IN SPREADSHEET

- For each of the 8 sensors
  - Assign a weighting factor
- For each position
  - Compute a weighted average of the 8 sensor normalized values

WEIGHTING SCHEME		
ERROR	(8-4-2-1)/4	(15-14-12-8)/8
-40	-321.1	-353.0
-36	-1477.1	-1401.9
-32	-2136.7	-2130.7
-28	-1742.6	-2099.7
-24	-1185.9	-1965.8
-20	-854.9	-1727.5
-16	-533.2	-1576.7
-12	-491.8	-1601.6
-8	-374.6	-1326.0
-4	-265.9	-1039.2
0	-12.5	-13.4
4	180.6	797.5
8	335.9	1225.5
12	478.0	1459.2
16	605.0	1633.5
20	702.1	1707.2
24	992.5	1717.9
28	1579.9	2228.1
32	2039.4	2089.9
36	1996.3	1882.3
40	1187.9	1086.6



CALIBRATION & SENSOR FUSION PROCESS

FROM SPREADSHEET TO ARDUINO CODE

Copy the:
- 8 minimums
- 8 maximums
- 8 weights

Into your code. You will have 3 arrays, each 8 values long

IN YOUR CODE
- Each time through your loop, your code will be presented with a new set of 8 readings (one from each sensor)
- For each sensor
  - Subtract the minimum for that sensor (don't let the result go negative!)
  - Ratio the result to 1000 using the maximum value
- Compute the weighted average of the 8 sensor readings. This is your current error value.
- Using the error value, decide how to steer the car by controlling the motor speeds

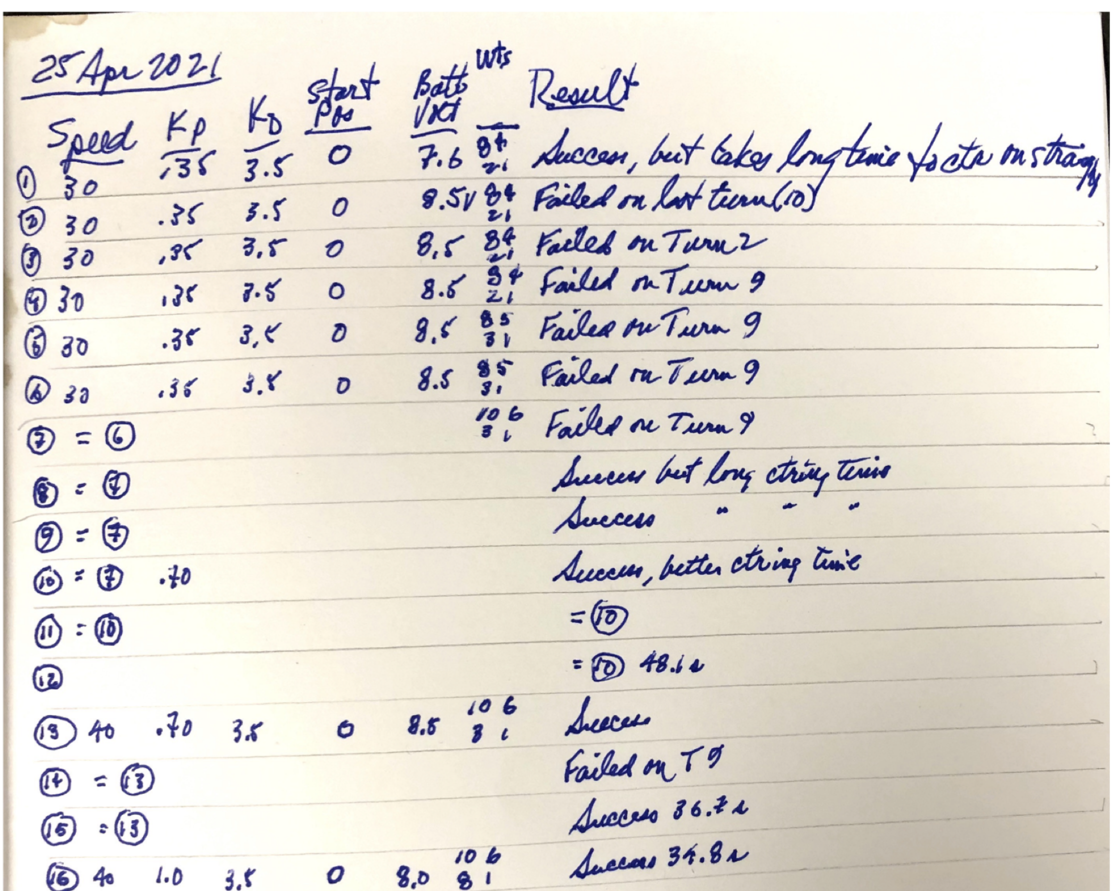
CALIBRATION & SENSOR FUSION PROCESS

IN YOUR CODE

- Each time through your loop, your code will be presented with a new set of 8 readings (one from each sensor)
- For each sensor:
  - Subtract the minimum for that sensor (don't let the result go negative!)
  - Ratio the result to 1000 using the maximum value for that sensor
- Compute the weighted average of the 8 sensor readings. This is your current **error value**.
- Using the error value, decide how to steer the car by controlling the motor speeds

RECORDING DEVELOPMENT DATA

- Keep a logbook
- Record every full-up test run (not calibration tests!).
- Quantitative results (distance traveled, weaving on a scale of 1 to 5, etc.
- Enables refer-back.
- Required for the Project Report.
- ORIGINAL hand-written REQUIRED (for authenticity).
- LEGIBLE handwriting (I actually read these things!)
- Handwritten into electronic tablet OK (for this class)



25 Apr 2021

	Speed	Kp	KD	Start Pos	Batt Volt	Wts	Result
1	30	.35	3.5	0	7.6	84 21	Success, but takes long time to ctr on straighty
2	30	.35	3.5	0	8.5V	84 21	Failed on last turn (10)
3	30	.35	3.5	0	8.5	84 21	Failed on Turn 2
4	30	.35	3.5	0	8.5	84 21	Failed on Turn 9
5	30	.35	3.5	0	8.5	85 31	Failed on Turn 9
6	30	.35	3.5	0	8.5	85 31	Failed on Turn 9
7 = 6						106 31	Failed on Turn 9
8 = 7							Success but long ctring time
9 = 7							Success " " "
10 = 7		.70					Success, better ctring time
11 = 10							= 10
12							= 10 48.1s
13	40	.70	3.5	0	8.5	106 81	Success
14 = 13							Failed on T9
15 = 13							Success 36.7s
16	40	1.0	3.5	0	8.0	106 81	Success 34.8s

Hi Professor Briggs,

Thank you blah blah blah

Also, I can now definitely say that a lot of the details you covered in class are helpful for my job at Lawrence Livermore. Working at the lab has been intimidating, but just knowing how to use an oscilloscope and DMM means I can run experiments on my own which is a major help. Also, I can confirm that we use logbooks with pens to record our experiments.

Sincerely,

Dhruv Srinivas

PREPARING FOR THE FINAL REPORT

LOG BOOK

The project goal is the successful following of a track from beginning to end. It consists of:

- Preparation:
  - Calibrating the sensors,
  - Fusing their outputs into an error term
- In the car, on the track, every 6 milliseconds:
  - Receiving a new set of 8 sensor outputs,
  - Fusing the outputs into an error term, and
  - Using the error term, writing code to steer the car to:
    - Follow the track
    - Avoid obstacles,
    - Detect the turnaround point, and
    - Stop automatically at the end.
- After every test run, documenting the setup and result in your log book

Your log book, if properly updated, will have much of the material that you will need for your Final Report.

YOU WILL BE PRESENTING THE DATA THAT YOU COLLECT

From the Final Report Guidelines

Analyze (You **must** analyze your on-track test data that you collected under Conduct Tests! **Captions only**; just tables and graphs)
Objective: arrange your data in ways that are easy to interpret.
•You must provide the raw data in your on-track test logs in table form! **ORIGINAL handwritten test logs will score higher** than computer-generated test logs. URL for Google Docs or equivalent is OK.
Show graphs and tables (graphs preferred) that present the data you collected under Conduct Test in ways that facilitate analysis. This means that you may need to quantify essentially qualitative data. Ex: provide a rating on the amount of weaving back and forth, perhaps a scale of 0 (no weaving) to 5 (maximum weaving).

QUANTIFY QUALITATIVE DATA

Qualitative Data

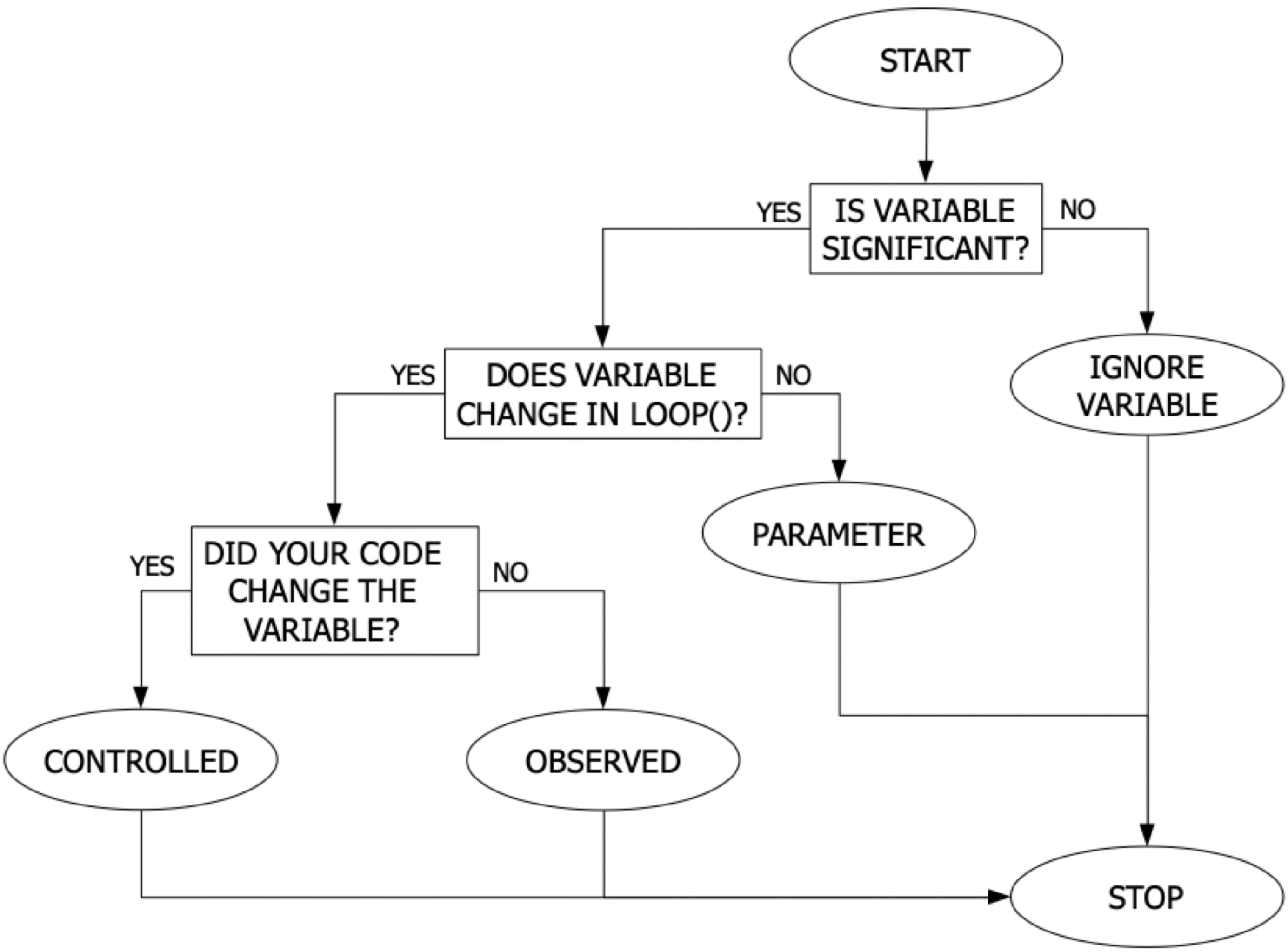
Information that is not naturally described with numbers.

Example

The amount of weaving back and forth. Assign it a number from 1 to 5, where 1 is essentially no weaving and 5 is catastrophic weaving that results in off-track excursions.

CONTROL YOUR VARIABLES

Parameters vs Observed Variables vs Controlled Variables



WRITE YOUR CODE