Mini-Project 1

ECE 471
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Task 1

Q1: Overview of the .csv files

- ctl.csv
- cvip.csv
- traj.csv

```
      ts  agent_id  throttle     steer  brake
0  74325         0       0.9 -0.002665    0.0
1  74326         0       0.9 -0.011529    0.0
2  74327         0       0.9 -0.009963    0.0
3  74328         0       0.9 -0.011508    0.0
4  74329         0       0.9  0.000712    0.0
      ts  agent_id        cvip      cvip_x     cvip_y      cvip_z
0  74325         0  500.491189  198.767441 -95.832657 -499.819366
1  74326         0    5.595580  195.567444 -90.832657    0.100000
2  74327         0    5.592365  195.567444 -90.832657    0.095407
3  74328         0    5.589578  195.567444 -90.832657    0.084691
4  74329         0    5.587154  195.567444 -90.832657    0.069311
      ts  agent_id           x         y         z    v
0  74325         0  192.362411 -86.26268  0.539326  0.0
1  74326         0  192.362411 -86.26268  0.491906  0.0
2  74327         0  192.362411 -86.26268  0.438374  0.0
3  74328         0  192.362411 -86.26268  0.378732  0.0
4  74329         0  192.362411 -86.26268  0.312981  0.0
      ts  agent_id  throttle     steer  brake
0  47920         0       0.9  0.003714    0.0
1  47921         0       0.9  0.002394    0.0
2  47922         0       0.9  0.003967    0.0
3  47923         0       0.9  0.001942    0.0
4  47924         0       0.9  0.003237    0.0
      ts  agent_id        cvip      cvip_x     cvip_y      cvip_z
...
1  61517         0  192.362411 -86.26268  0.491906  0.0
2  61518         0  192.362411 -86.26268  0.438374  0.0
3  61519         0  192.362411 -86.26268  0.378732  0.0
4  61520         0  192.362411 -86.26268  0.312981  0.0
```

Output is truncated. View as a scrollable element or open in a text editor. Adjust cell output settings...

Task 1

Q2:

a. The duration of the scene is: ______ frames (The ‘ts’ column is in the unit of frames).

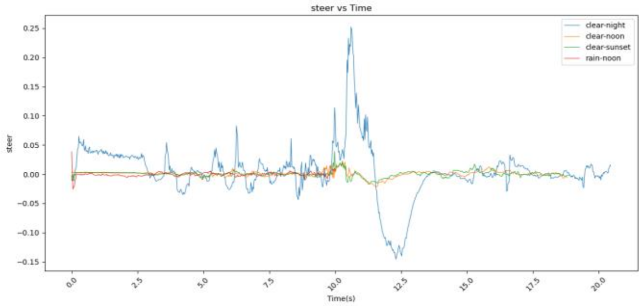
b. Mean and std of the features:

	clear-night	clear-noon	clear-sunset	haze-noon	haze-sunset	rain-noon
Duration	818	752	756	754	762	400
throttle	[0.62, 0.342]	[0.609, 0.282]	[0.611, 0.281]	[0.602, 0.299]	[0.607, 0.299]	[0.648, 0.272]
steer	[0.004, 0.046]	[0.0, 0.005]	[0.0, 0.005]	[0.001, 0.005]	[0.001, 0.005]	[-0.0, 0.004]
brake	[0.105, 0.307]	[0.058, 0.235]	[0.057, 0.232]	[0.057, 0.232]	[0.056, 0.231]	[0.042, 0.202]
cvip	[29.198, 29.973]	[19.514, 24.282]	[20.058, 24.641]	[19.996, 24.134]	[20.967, 24.883]	[7.052, 24.735]
x	[191.311, 1.168]	[192.92, 0.403]	[192.946, 0.401]	[192.94, 0.41]	[192.944, 0.41]	[192.631, 0.252]
y	[-31.8, 39.65]	[-31.315, 40.557]	[-31.223, 40.404]	[-31.74, 40.735]	[-31.502, 40.483]	[-63.985, 21.067]
v	[6.381, 2.927]	[6.927, 3.286]	[6.883, 3.315]	[6.907, 3.058]	[6.828, 3.071]	[6.34, 3.87]

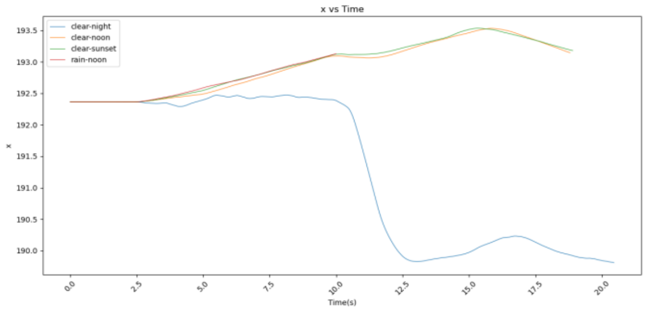
Task 1

Q3: Campaign result visualization

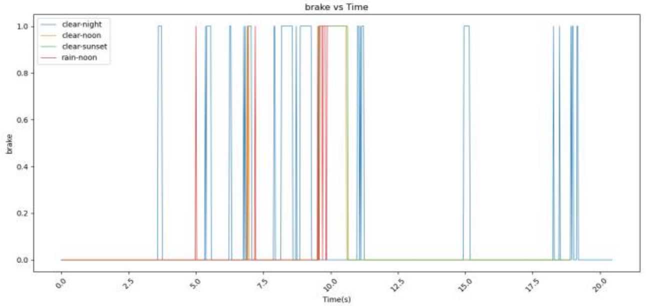
- steer



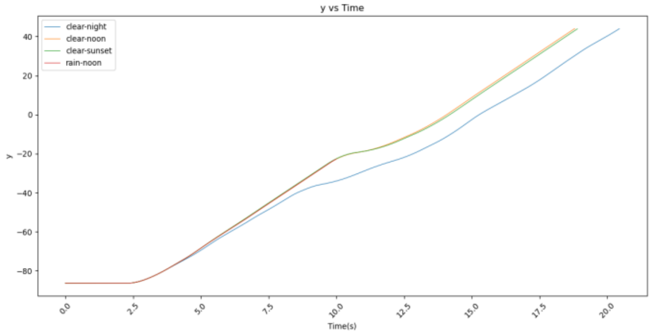
- x



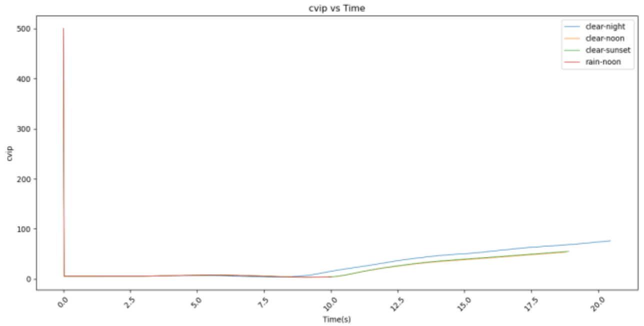
- brake



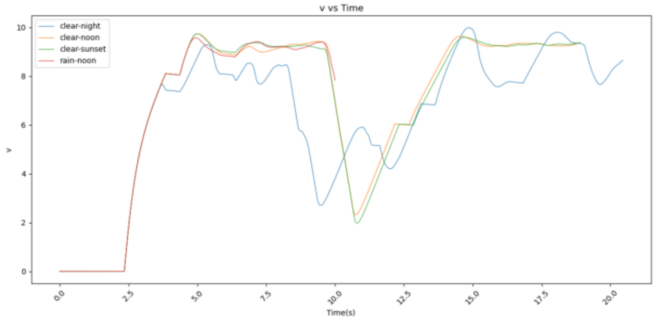
- y



- cvip



- v



Task 1

Q4: Based on your intuition and life experience, which of the features do you think will change during an accident? How will the feature(s) change? By looking at the plots you generated in Task 1.3, combined with your reasoning (without looking at ‘route_highway.txt’), which weather condition(s) has an accident?

The most telltale sign of an accident is the simulation stopping early compared to the others. If a stimulation that stops early also applies brakes and/or steering a lot, together with a very low cvip, it is very likely that the simulation ended in an accident

From looking at the plots we guess that there was an accident in rain-noon simulation, because this simulation stops before the others.

Task 2

Q1: The probability of accident is __1/6______.

Task 2

Q2: By looking at the completion records and the plots you generated in Task 1, under which weather condition(s) did the accident happen? Does that match your guess in Task 1? When did the accident happen during those simulation runs? Why do you think the accident happened at that instance? Discuss each accident case separately.

A: Under rainy conditions at noon, the simulation fails, which aligns with our prediction in Task 1. By examining the plots, we see that all the red curves end at time = 10s, indicating that the accident occurred at this moment. The accident seems to happen because the vehicle did not slow down fast enough before collision. It is possible that the vehicle detected the obstruction too late due to the weather, or that the weather caused slower braking.

Task 2

Q3: From the plots you generated in Task 1.3, do you observe any other abnormal behavior? If so, what do you think is (are) the cause(s) of this behavior?

A: The two abnormal runs are clear-night and rain-noon.

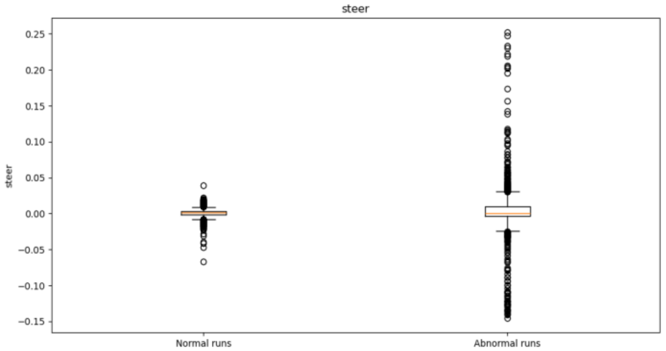
The rain-noon run results an accident.
- We observe frequent braking before the accident occurred. It is possible that the autonomous vehicle (AV) detected a nearby non-playable character (NPC) and attempted to avoid a collision.
- We also observe that the velocities drop at approximately the same time in the clear-subset, clear-noon, and rain-noon cases. However, in the rainy-noon case, the velocity decreases more slowly.

For the other abnormal run (clear-night). There is much more steering than in the other runs. It looks like, form the x-values plot, that the vehicle switched lanes, possibly to avoid conflict.

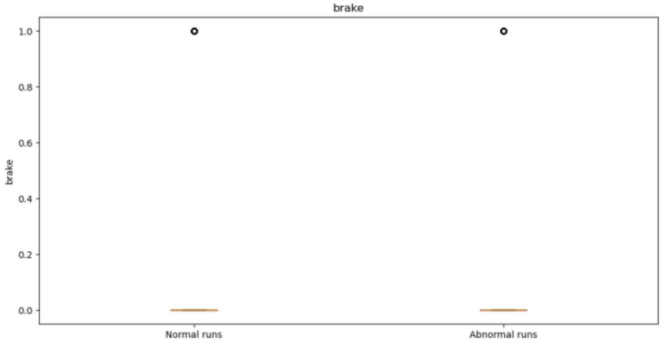
Task 2

Q4.a: Distribution of the features: abnormal (including accidents) vs normal

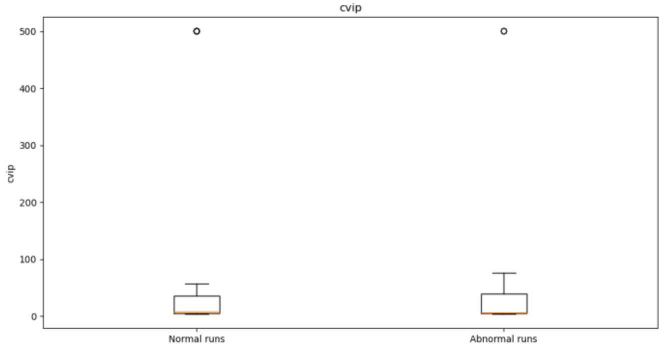
- steer



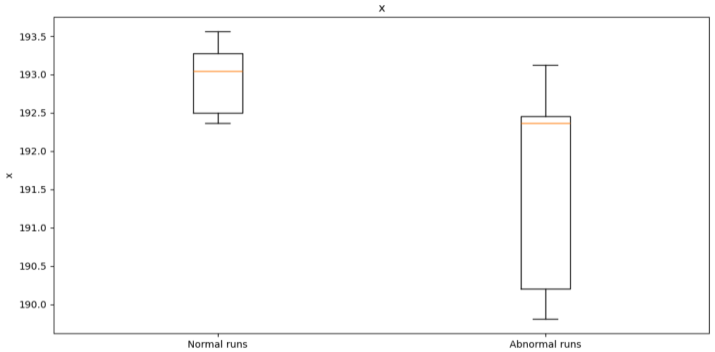
- brake



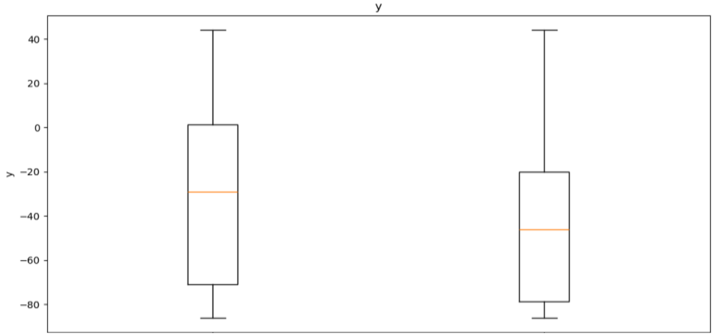
- cvip



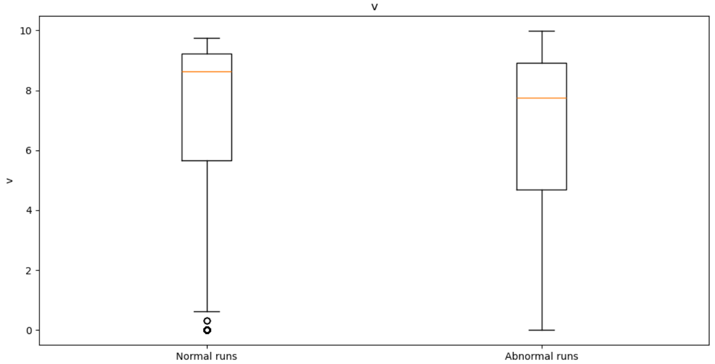
- x



- y



- v



Task 2

Q4.b: Use 2-sample t-test to test on the **'steer'** values of **abnormal runs vs normal runs.**

i. State the null and alternative hypotheses

H0: The means of the steering values from the abnormal runs and the normal runs are the same

H1: The means of the steering values are different.

ii. Perform the test and calculate test statistics

T-statistic: -1.9433898083217644

P-value: 0.05219581870253174

iii. Assume a significance level of 0.05, what is your conclusion?

Fail to reject the null hypothesis. There is no significant difference between the two groups.

Q4.c: Does the testing result contradict your observation on the "steer" feature in part 4.a? Why?

There is no significant difference between the means of the steering values of the normal and abnormal runs. This is to be expected. One should test for the differences in variance instead. So it does not contradict our observation in 4.a.

Task 2

Q5: Some of the features are better indicators of abnormal AV behavior, can you identify them?

a. By looking at the distribution plots of the features in Task 2.4, explain your choice of indicators.

- The greatest indicators are throttle median and variance in steering values. The variance in steering is by far the biggest indicator.

b. For the fields you identified as good accident indicators above, are they related (Calculate the Pearson correlation coefficient between each pair of the indicators to justify your answer)? If so, how does that affect the predicting power of using one indicator versus using all of them?

```
The correlation coefficients between the throttle and steering values for each scenario are
clear-night    -0.057537
clear-noon     -0.314144
clear-sunset   -0.225582
haze-noon       0.277303
haze-sunset     0.383341
rain-noon      -0.236158
dtype: float64
The total correlation over all values of steer and throttle is
-0.025992147583378918
```

- We see that there can be a correlation between the steer and the throttle values per specific scenario, but overall the two variables seem to be quite independent.

Task 2

Q6: Suppose we want to use hypothesis testing to test whether the field you choose from Task2.5 is indeed a good indicator of abnormal AV behavior, using the Kolmogorov–Smirnov two-sample test.

a. Construct the null and the alternative hypothesis and state them below

H0: The steering values for normal and abnormal AV behavior are drawn from the same distribution.

H1: The steering values for normal and abnormal AV behavior are drawn from different distributions.

b. Perform the KS two-sample test and calculate its statistics.

```
KS statistic: 0.2304199060138164
p-value: 5.498993919966062e-41
```

c. Assume a significance level of 0.05, what is your conclusion?

```
Reject the null hypothesis: The two samples are drawn from different distributions.
```

d. Repeat the same test on a feature that you did not select as an indicator of abnormal behavior in Task 2.5, what is your conclusion?

```
KS statistic: 0.1439623622149555
p-value: 3.479044086166835e-16
Reject the null hypothesis: The two samples are drawn from different distributions.
```

e. What are the major differences between th

- The KS-test is a nonparametric test that compares entire distributions, whereas the ttest is a parametric test that compares means.
- The KS-test does not assume any specific type of data distribution, whereas the t-test assumes that the data are normally distributed.
- The KS-test is sensitive to the shape of the distribution, while the t-test is sensitive to differences in sample means.

Task 2

Q7: Keeping in mind that this experiment is executed over a period of time, what assumption did you make when using the KS two-sample test on the distributions in Task2.6? Are you able to come up with one situation where this assumption fails?

- We assumed that all the values at each time are independent. This is more so the case for brake, since it's discrete, but less so for steering. If wheels are turned at an angle α at time t0, then at times close to t0, the angle will be close to α , because steering is a continuous process. In fact, all the variables, except the brake, are continuous in time, so the values at times close to t0 will be close to the values at time t0. So the assumptions for the KS test are not satisfied.

Task 2

Q8: The dynamic-time-wrapper (DTW) is a method to compare two time-series data (such as the control and the trajectory data collected in our simulation). Use the DTW package in python (dtaidistance · PyPI), and apply the DTW distance on the two time-series dataset (using steering data of clear-noon as a reference): (1) steering data of clear-night and (2) steering data of clear-sunset. What can you say about the DTW distance for (1) and (2) with respect to the reference?

- DTW distance between clear-noon and clear-night: 1.0919970442580629
- DTW distance between clear-noon and clear-sunset: 0.058689994198986864
- The Dynamic Time Warping (DTW) distances reveals that the steering behavior during clear sunset is closely aligned with that of the reference clear noon, as indicated by a smaller DTW distance. In contrast, the larger DTW distance for clear night conditions signifies a notable divergence in steering behavior from the reference