

Digital Intelligent Services based on Vehicle Data

SCOTT Vehicle Data Hackathon



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Outline

- Introduction
- Proposed services
 - fuel consumption optimization
 - driving style
 - road statistics
 - security (authentication)
 - optimum placement of gas/charging stations
 - car safety
 - alerts/information
- Conclusion



Data is Gold!

- Vehicle CAN bus data provides a rich dataset
- Driving can be safer and more economic
- Information derived from cars can flow faster to stakeholders with an information system
- More meaningful decisions can be made



Stakeholders

- Drivers
- Road maintainers
- Car companies
- Insurance companies
 - insurance based on the driving region/behavior



Proposed Services

1. Fuel consumption optimization
2. Driving style
3. Road statistics
4. Security (authentication)
5. Optimum placement of gas/charging stations
6. Car safety
7. Alerts/information



1.1. Deceleration Alert

- No acceleration is usually needed while approaching red lights, roundabouts, roads with a lower speed limit, etc.
- The above limiting elements can be obtained from GPS map data, online information (if the car is enabled with 4G for example)
- Car can show an alert to the driver not (no need) to accelerate in these situations
- This can optimize fuel consumption



1.1. Deceleration Alert: Description

- Can be implemented in the car computer system
- Actor: driver
- Description:
 - get location and direction info from GPS
 - if approaching one of the aforementioned elements, and acceleration is not negative, then show/hint decrease speed signal



1.1. Deceleration Alert: Demonstration

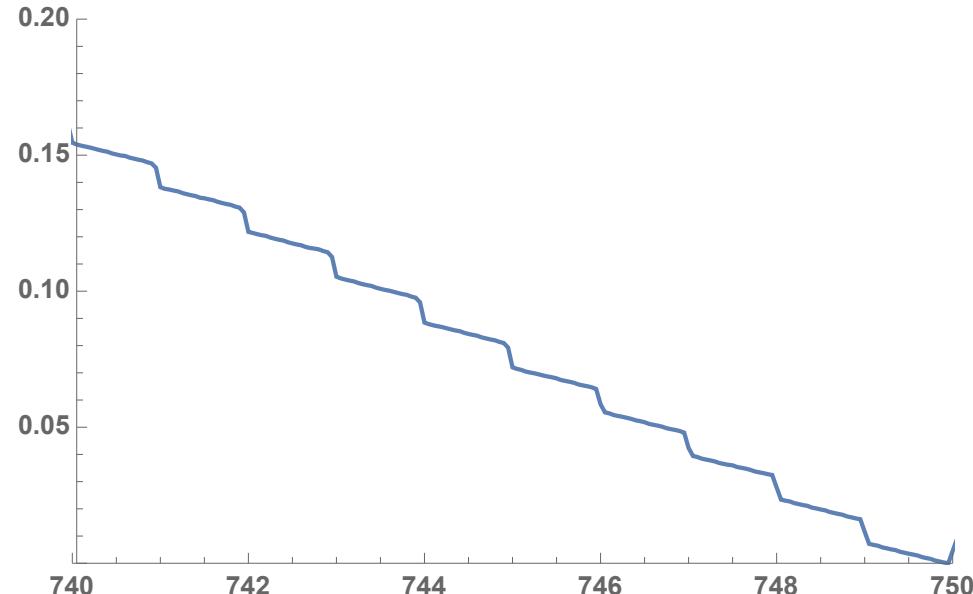
- Code in Mathematica [*]:

```
CleanSlate[];
ClearAll["Global`*"];
ac = Import["Downloads/20181116_Driver1_Trip3.hdf", {"Datasets", "/GPS/Acceleration"}];
la = Import["Downloads/20181116_Driver1_Trip3.hdf", {"Datasets", "/Math/Latitude_IMU"}];
lo = Import["Downloads/20181116_Driver1_Trip3.hdf", {"Datasets", "/Math/Longitude_IMU"}];
n1 = 740; n2 = 750; t = 750;
c1 = la[[t*20]][[1]]; c2 = lo[[t*20]][[1]];
d[p1_, p2_, i_] := Sqrt[(p1 - la[[i]][[1]])^2 + (p2 - lo[[i]][[1]])^2];
s[a_] := If[a > 0, 1, 0];
l = Table[{la[[i]][[2]], d[c1, c2, i]}, {i, 1, Length[la]}];
ListPlot[l, Joined → True, PlotRange → {{n1, n2}, {0, 0.2}}]
ListPlot[Reverse[ac, 2], Joined → True, PlotRange → {{n1, n2}, Automatic}]
l = Table[s[ac[[i]][[1]]], {i, 1, Length[ac]}];
ListPlot[l, Joined → True, PlotRange → {{n1, n2}, Automatic}]
```



1.1. Deceleration Alert: Demonstration

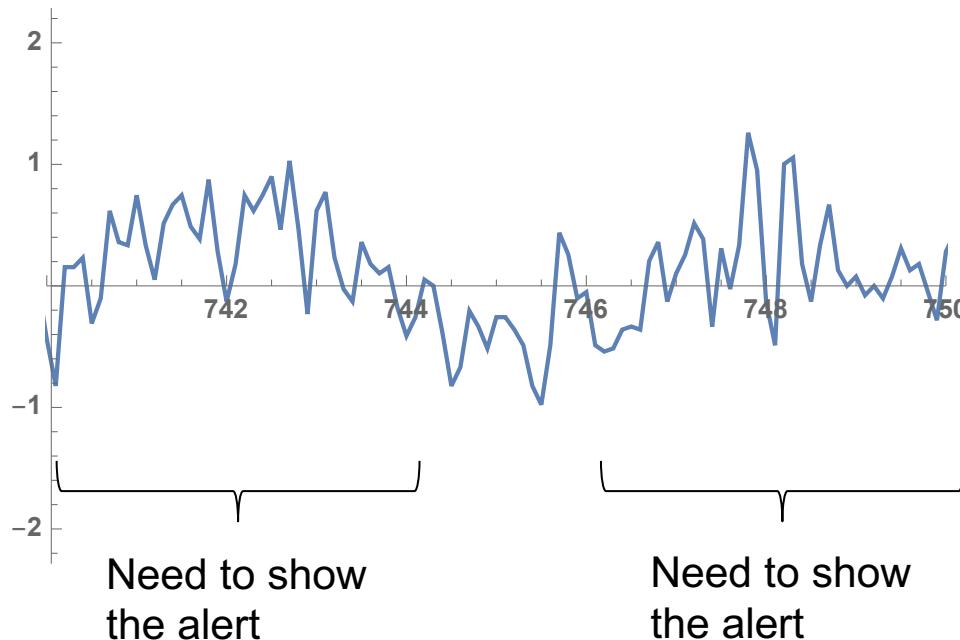
- Assume that driver 1 reaches a limiting element in trip 3 at second 750
- The code first plots the Euclidean distance to the limit:





1.1. Deceleration Alert: Demonstration

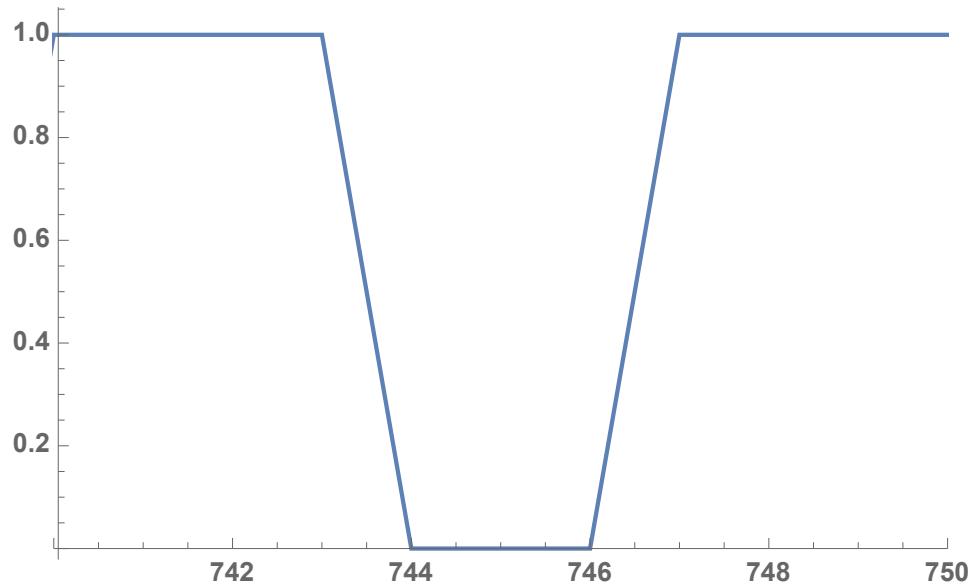
- It then obtains acceleration values and plots them:





1.1. Deceleration Alert: Demonstration

- If acceleration is positive, then a signal is produced
- The signal plot: (can be shown as a light in the car dashboard)





1.2. Economical Driving Mode

- When driving downhill, usually there is no need to use more fuel consumption modes
- The gravity can help accelerate!
- The car can automatically switch to a more economical mode
- The modes can be defined with more granularity
 - depending on the slope, the most appropriate one is used



1.2. Economical Driving Mode: Description

- Can be implemented in the car computer system
- Actor: driver
- Description:
 - if the route is known (e.g. the driver is following a route on GPS map) and the car is driving downhill, or
 - if the route is unknown and the altitude is decreasing in the past, for example, 10 seconds, then
 - switch to the more economical mode
 - the mode can be dependent on the slope in case there are more fine-grained modes defined in the car



1.2. Economical Driving Mode: Demonstration

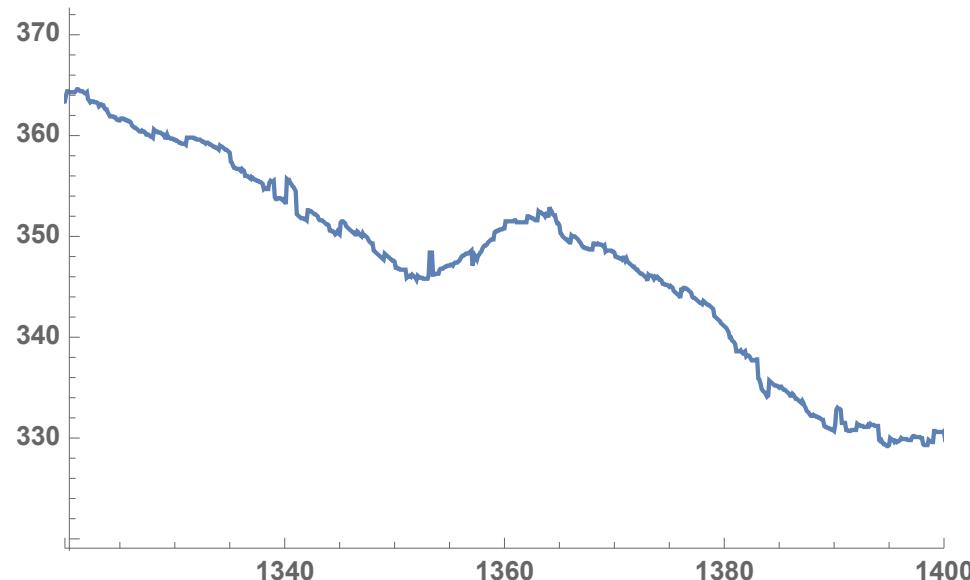
- Code in Mathematica [*]:

```
CleanSlate[];
ClearAll["Global`*"];
n1 = 1320; n2 = 1400; w = 10;
z = Import["Downloads/20181116_Driver1_Trip3.hdf", {"Datasets", "/GPS/Z"}];
y = Reverse[z, 2];
v = MovingAverage[y[[All, 2]], w*20];
l = Table[{y[[i + w*20 - 1]][[1]], v[[i]]}, {i, 1, Length[v]}];
ListPlot[y, Joined → True, PlotRange → {{n1, n2}, Automatic}]
ListPlot[l, Joined → True, PlotRange → {{n1, n2}, Automatic}]
s = Table[If[l[[i]][[2]] - l[[i - 1]][[2]] < 0, {l[[i]][[1]], 1}, {l[[i]][[1]], 0}], {i, 2, Length[l]}];
ListPlot[s, Joined → True, PlotRange → {{n1, n2}, Automatic}]
```



1.2. Economical Driving Mode: Demonstration

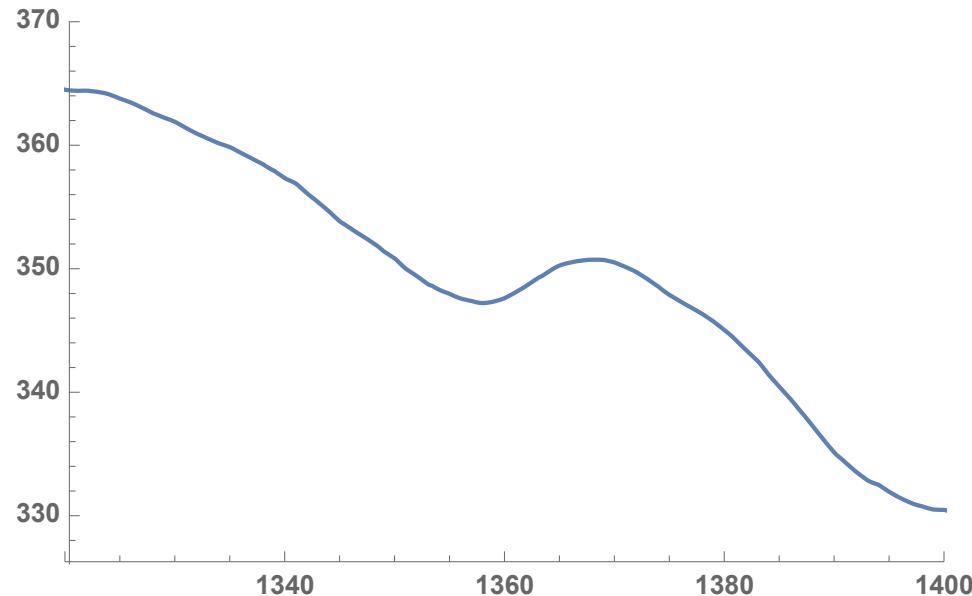
- The code obtains and plots altitude from GPS:





1.2. Economical Driving Mode: Demonstration

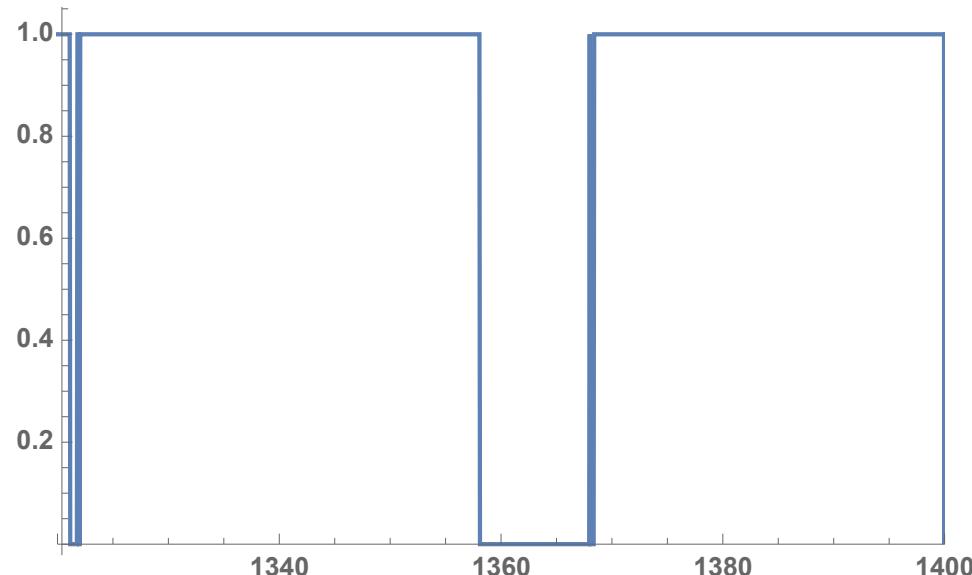
- Since variation is not small in the values, the moving average of altitude is calculated:





1.2. Economical Driving Mode: Demonstration

- The switching to a more economical mode signal:
 - “1” means showing the signal to the driver or automatically switching to a more economical mode





Proposed Services

1. Fuel consumption optimization
2. Driving style
3. Road statistics
4. Security (authentication)
5. Optimum placement of gas/charging stations
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2.1. Acceleration Distribution

- Acceleration (including both positive and negative values) is a combined metric of pressing the gas and brake pedals
- Can reflect the driving style
- Can be used as a means of identifying the driver
- Identify the risk level of the driver for insurance companies



2.1. Acceleration Distribution: Description

- Can be implemented in the car computer system
- Actor: driver identification module, insurance companies, etc.
- Description:
 - obtain acceleration values
 - calculate statistical values of the data, e.g. mean, variance
 - the distribution can also be obtained



2.1. Acceleration Distribution: Demonstration

- Code:

```
CleanSlate[];  
ClearAll["Global`*"];  
z = Import["Downloads/20181113_Driver1_Trip2.hdf", {"Datasets", "/GPS/Acceleration"}];  
z = Reverse[z, 2];  
Print[Min[z[[All, 2]]], "\t", Mean[z[[All, 2]]], "\t", Max[z[[All, 2]]], "\t", Variance[z[[All, 2]]]]  
z = Import["Downloads/20181116_Driver1_Trip3.hdf", {"Datasets", "/GPS/Acceleration"}];  
z = Reverse[z, 2];  
Print[Min[z[[All, 2]]], "\t", Mean[z[[All, 2]]], "\t", Max[z[[All, 2]]], "\t", Variance[z[[All, 2]]]]  
z = Import["Downloads/20181114_Driver2_Trip1.hdf", {"Datasets", "/GPS/Acceleration"}];  
z = Reverse[z, 2];  
Print[Min[z[[All, 2]]], "\t", Mean[z[[All, 2]]], "\t", Max[z[[All, 2]]], "\t", Variance[z[[All, 2]]]]  
z = Import["Downloads/20181114_Driver2_Trip2.hdf", {"Datasets", "/GPS/Acceleration"}];  
z = Reverse[z, 2];  
Print[Min[z[[All, 2]]], "\t", Mean[z[[All, 2]]], "\t", Max[z[[All, 2]]], "\t", Variance[z[[All, 2]]]]  
z = Import["Downloads/20181114_Driver2_Trip3.hdf", {"Datasets", "/GPS/Acceleration"}];  
z = Reverse[z, 2];  
Print[Min[z[[All, 2]]], "\t", Mean[z[[All, 2]]], "\t", Max[z[[All, 2]]], "\t", Variance[z[[All, 2]]]]
```



2.1. Acceleration Distribution: Demonstration

- Results:

		Min	Mean	Max	Variance	
Driver 1	Trip 2	-57.61	0.0003	28.78	0.75	More stable in acceleration
	Trip 3	-8.46	0.0014	7.94	0.62	
Driver 2	Trip 1	-24.31	0.0020	35.21	1.34	More variations in acceleration
	Trip 2	-34.36	0.0036	30.82	2.23	
	Trip 3	-27.28	0.0005	37.96	0.46	



2.1. Acceleration Distribution: Demonstration

- Finding a distribution function fitting the data:
 - with the FindDistribution command

		Function
Driver 1	Trip 2	StudentTDistribution[0.0177689, 0.242434, 1.45387]
	Trip 3	LaplaceDistribution[0.00125023, 0.519172]
Driver 2	Trip 1	MixtureDistribution[{0.171996, 0.828004}, {LogisticDistribution[-0.0101865, 0.492662], CauchyDistribution[-0.025938, 0.21569]}]
	Trip 2	MixtureDistribution[{0.15552, 0.84448}, {LaplaceDistribution[0.742762, 1.52849], CauchyDistribution[-0.016463, 0.152987]}]
	Trip 3	MixtureDistribution[{0.263411, 0.736589}, {LogisticDistribution[0.0400912, 0.182406], CauchyDistribution[-0.100337, 0.37527]}]



2.2. Hard Brakes

- When (negative) acceleration is smaller than a threshold
 - several threshold values can be defined: e.g. hard brakes, very hard brakes
- Might lead to a full stop!
- Can reveal
 - the driving style
 - problems with the road design, road constructions, wrong placement of road signs, etc. (when combined with GPS locations)
- Can be used as a way of identifying the driver



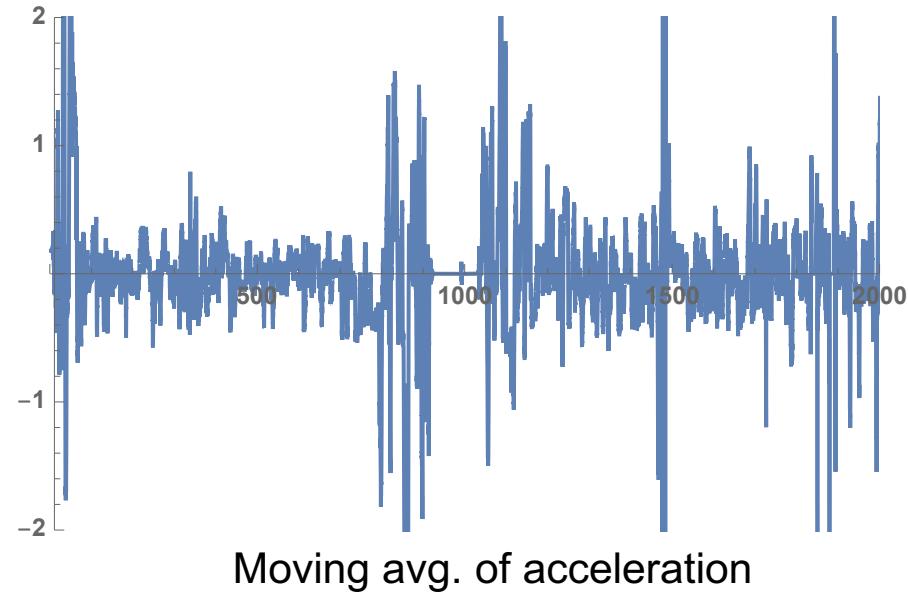
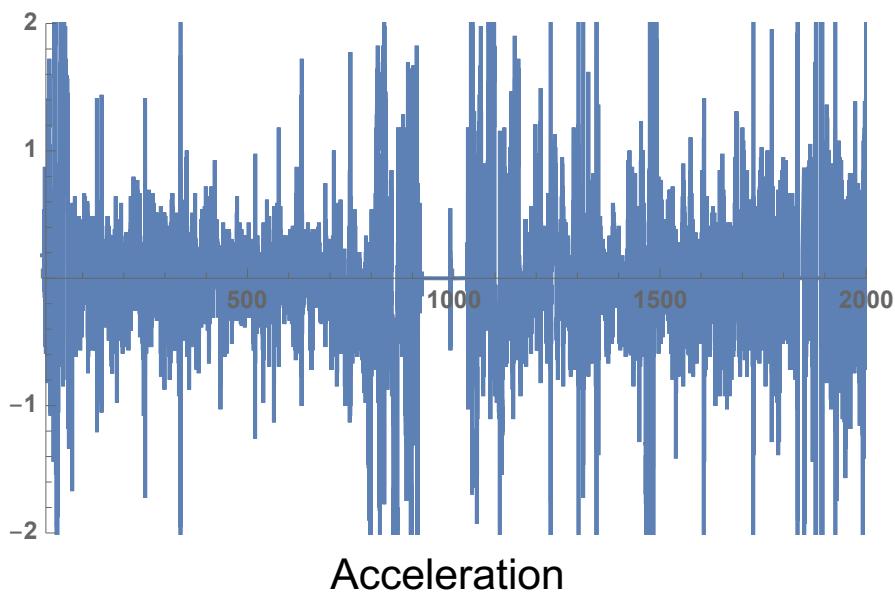
2.2. Hard Brakes: Description

- Can be implemented in the car computer system
- Actor: driver identification module, insurance companies, road maintenance authorities, etc.
- Description:
 - obtain acceleration and speed values
 - calculate the moving average on acceleration (window size: 1 sec)
 - if (the moving avg. of) acceleration is smaller than the threshold:
 - count as a hard brake
 - if the speed becomes zero, also count as hard brake causing full stop
 - obtain the GPS location for further investigations



2.2. Hard Brakes: Demonstration

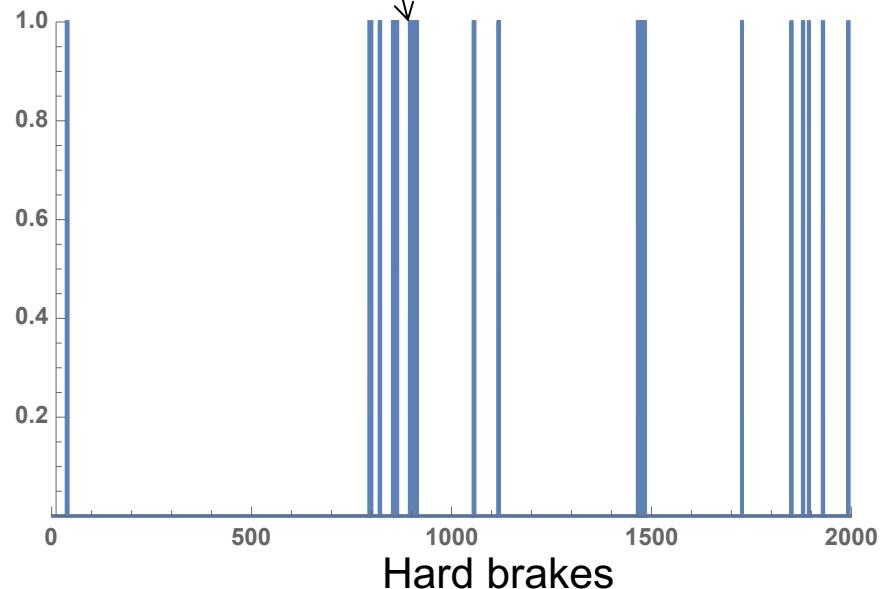
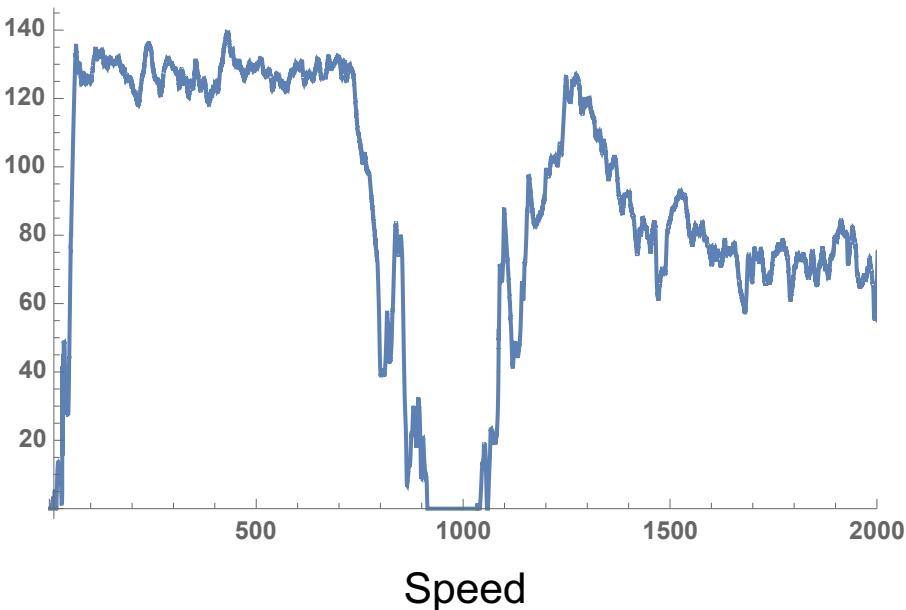
- Code is a bit large!
- Results for driver 1 trip 2:





2.2. Hard Brakes: Demonstration

- Results:
 - “1” means there was a hard brake

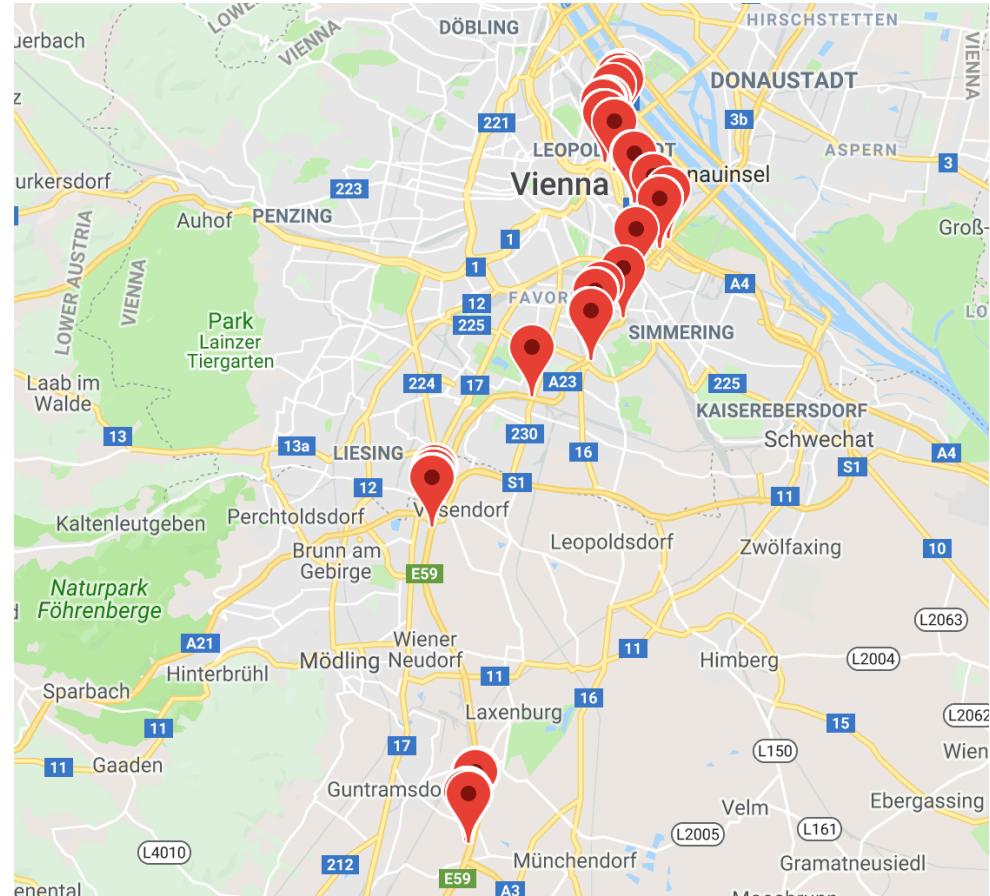




2.2. Hard Brakes: Demonstration

Combining with GPS locations and integrating with Google maps showing where those happened:

zoomable for further details





2.3. Sharp Turns

- Combining the steer angle and the vehicle speed can make another metric!
- Can reveal
 - the driving style
 - problems in the road design, road constructions, wrong placement of road signs, etc. when combined with GPS locations
- Can be used as a way of identifying the driver
- “Sharp” can be defined as a function of the steer angle and speed.
 - For example: if $\text{angle} > 540 e^{(-0.025 \text{ speed})}$, then it's sharp!



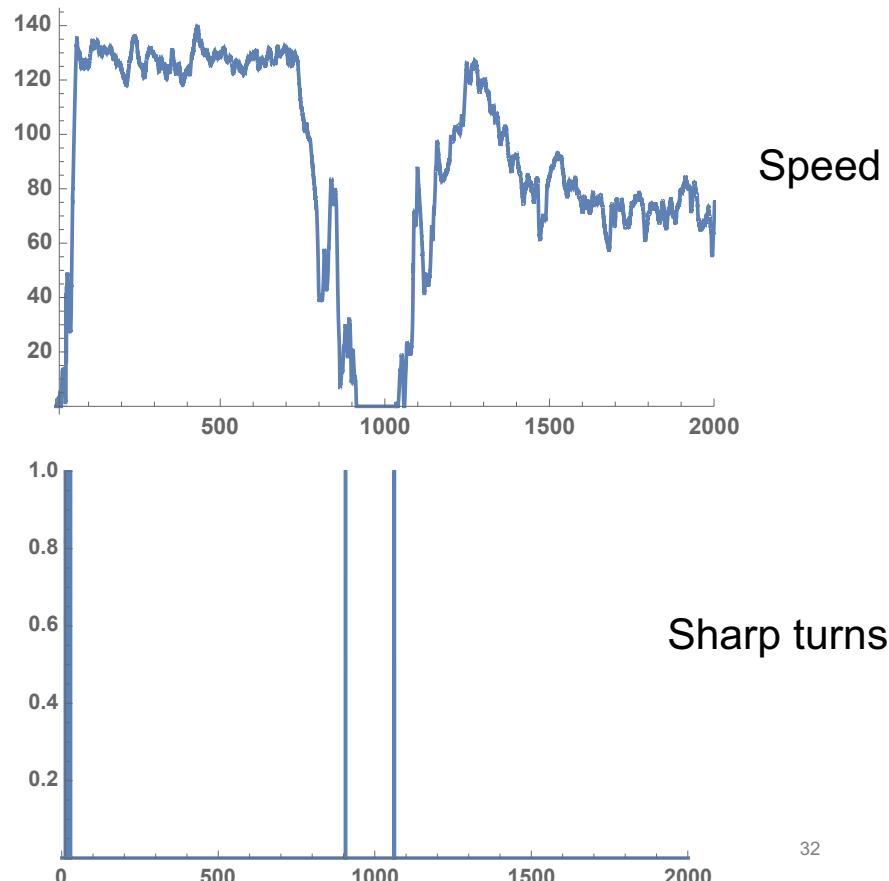
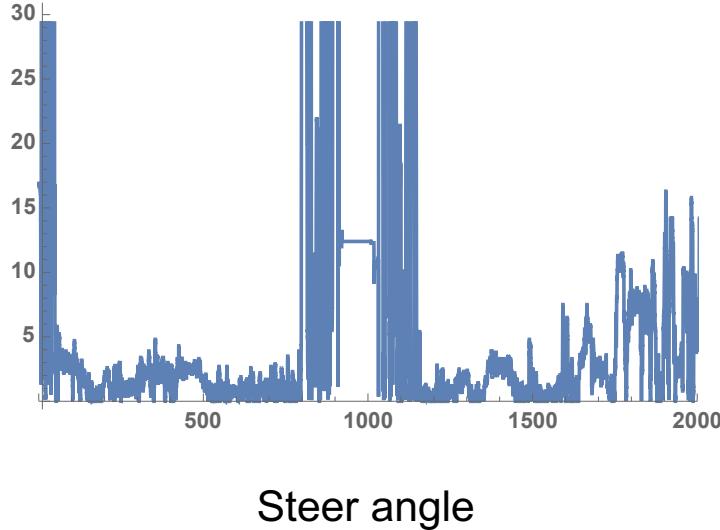
2.3. Sharp Turns: Description

- Can be implemented in the car computer system
- Actor: driver identification module, insurance companies, road maintenance authorities, etc.
- Description:
 - obtain steer angle and speed values
 - if the function defined before returns 1 for any pair of speed and steer angle values, then mark the GPS location



2.3. Sharp Turns: Demonstration

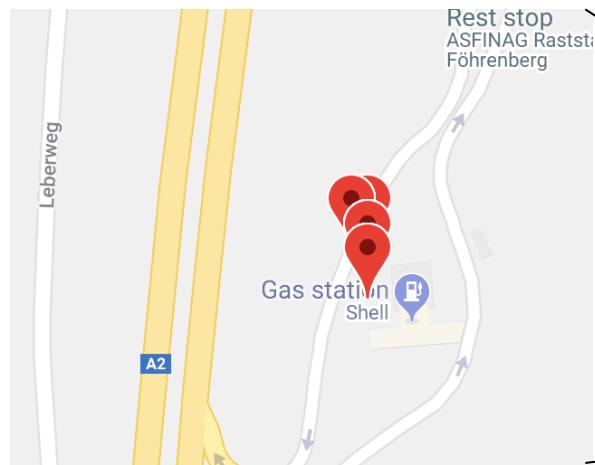
- Code is a bit large!
- Results for driver 1 trip 2:



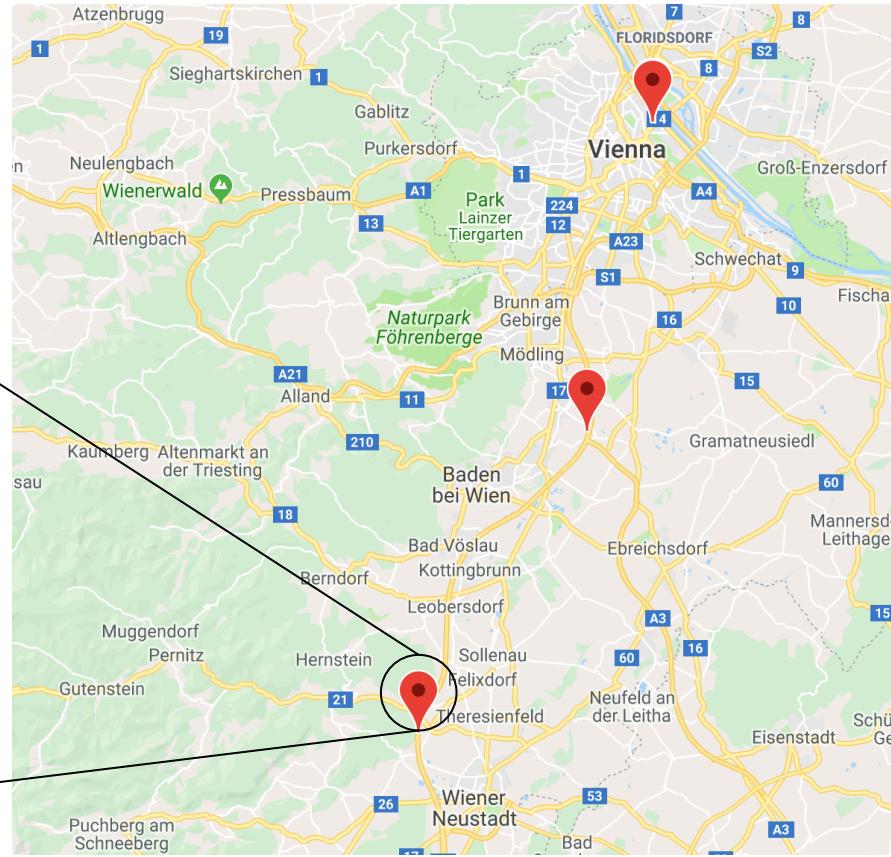


2.3. Sharp Turns: Demonstration

Combined with
Google maps showing
where those happened



22.05.2020



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Proposed Services

1. Fuel consumption optimization
2. Driving style
3. Road statistics
4. Security (authentication)
5. Optimum placement of gas/charging stations
6. Car safety
7. Alerts/information



Road Statistics: Proposed Services

- The number of hard brakes at certain points
 - shown before
- The number of sharp turns at certain points
 - shown before
- The number of part failures at certain points
 - problems such as crash, flat tire, etc.
 - can reflect a problem with the road



Road Statistics: Proposed Services

- Matching the speed limit and cars' speed in roads
 - might need to reconsider the limit, or force new prohibitory means such as speed cameras
- Implementation could be done via a cloud-based system
 - cars upload their statistics
 - data is processed and the required information is derived
- The last two services were not done in this demo since they need more information/part failure signals



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Security: Proposed Services

- Learning the driver behavior based on the derived statistics to have an additional means of authentication
 - overcome the challenge of passive keyless entry
- Machine learning can be based on different data
 - acceleration
 - sharp turning
- Different learning techniques can be used



4.1. Driver Authentication

- We use acceleration as a means of identifying the driver
- Acceleration includes values of pressing the gas and brake pedals
- Can be used as a service in the car to learn the driver's behavior. In case of detecting a violation from the common behavior, the car can, for example, inform the owner



4.1. Driver Authentication: Description

- Can be implemented in the car computer system
- Actor: driver identification module
- Description:
 - obtain acceleration values per driver per trip
 - calculate their statistical values such as min, max, mean, 25% and 75% quantiles.
 - choose an appropriate learning technique
 - use part of data per driver as the training set
 - use the remaining part of data as the test set



4.1. Driver Authentication: Demonstration

- Code: training using the drivers' trip 2 and trip 3
- Depending on the data, it automatically chooses a learning method, e.g. regression, SVM, Neural Networks

```
trainingset = {{Min[y2], Quantile[y2, 0.25], Median[y2], Quantile[y2, 0.75], Max[y2]} → "Driver1",
{Min[y3], Quantile[y3, 0.25], Median[y3], Quantile[y3, 0.75], Max[y3]} → "Driver1",
{Min[z2], Quantile[z2, 0.25], Median[z2], Quantile[z2, 0.75], Max[z2]} → "Driver2",
{Min[z3], Quantile[z3, 0.25], Median[z3], Quantile[z3, 0.75], Max[z3]} → "Driver2"};
```

```
c = Classify[trainingset]
```

- Testing:

```
c[{Min[z1], Quantile[z1, 0.25], Median[z1], Quantile[z1, 0.75], Max[z1]}, "Probabilities"]|
```



4.1. Driver Authentication: Demonstration

- Results: the test returns the probability that a test set belongs to either driver 1 or driver 2
- If we train our model and then, we feed driver 2 trip 1 to our model as the test set, it returns:

```
= ClassifierFunction[ -> Input type: NumericalVector (length: 5)  
Classes: Driver1, Driver2  
Method: NaiveBayes  
Number of training examples: 4 ]  
  
= <| Driver1 → 0.00226244, Driver2 → 0.997738 |>
```

showing the chosen learning method, and that the trip belongs to driver 2 with probability 0.997738!

This needs more and more training and test sets. We are now working on this as a paper.



Proposed Services

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Optimum Placement of Gas/Charging Stations

- Using information such as Fuel Consumption in vehicle CAN, authorities can determine how much fuel/electricity has been used on average to reach point B from point A
- This can help decide where and on which side of the road to place facilities such as fuel/charging stations
- This can mitigate the charging problem of short-range electric cars

Since this data was zero in the provided data sets, the demo was not done



Proposed Services

1. Fuel consumption optimization
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Car Safety: Proposed Services

- Ordering car parts in case of imminent failure
 - can be detected from the data
 - needs communication with the service center (e.g. with 4G)
- Ordering a service/maintenance
 - in case the car reaches some limits, e.g. mileage, duration
- Alerting/ordering tire change (getting a flat tire)
 - in case tire sensors (if present) detect a constant pressure loss, they can notify the driver or a service center

Since this data was zero/not available in the provided data sets, the demo was not done



Proposed Services

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Alerts/Information: Proposed Services

- The driver can be notified with a richer set of alerts/information derived from the data
- Can be shown as messages on the car dashboard
- Examples of services:
 - alerts showing the driving is not safe
 - when there are sharp turns
 - can be combined with weather information: if it is raining, sharp turning is more dangerous, and has a new definition
 - when there is no need to accelerate
 - alerts obtaining from other drivers' behavior, e.g. alerting when approaching a point at which drivers usually have hard brakes!



Conclusion

- We demonstrated some digital services
 - optimizing fuel consumption, obtaining the driving style, finding road problems, learning the driver behavior for security purposes
- We also proposed services such as placement of stations, car safety, and car alerts
 - can be implemented if more data is provided
- A complete information system utilizing the CAN bus data can be beneficial to almost everyone!



Thanks!