Guess Which Car Type I am Driving?

Information Leak via Driving Apps

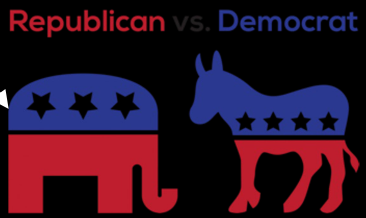
Dongyao Chen, Mert D. Pesé, and Kang G. Shin

Vehicle Type can link to Sensitive Info

Vehicle type information
(i.e., truck vs compact)

Targeted
advertising

Demographic
information



Political
tendency

Sensitive information

Vehicle Type can link to Sensitive Info

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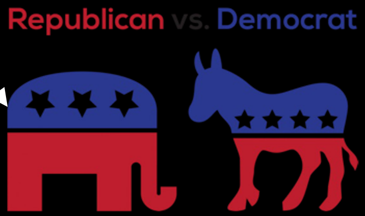
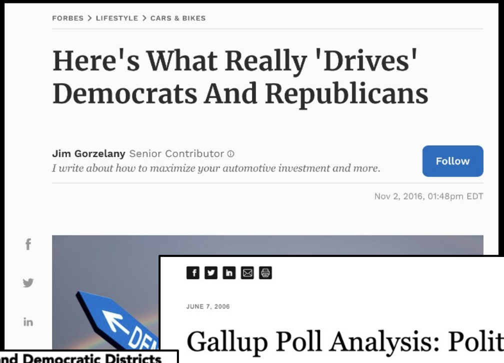


Political tendency

Sensitive information



FORBES > LIFESTYLE > CARS & BIKES

Here's What Really 'Drives' Democrats And Republicans

Jim Gorzelany Senior Contributor
I write about how to maximize your automotive investment and more.

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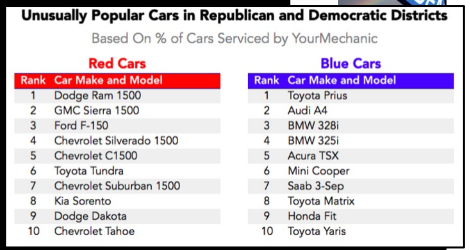


Unusually Popular Cars in Republican and Democratic Districts

Based On % of Cars Serviced by YourMechanic

Red Cars		Blue Cars	
Rank	Car Make and Model	Rank	Car Make and Model
1	Dodge Ram 1500	1	Toyota Prius
2	GMC Sierra 1500	2	Audi A4
3	Ford F-150	3	BMW 328i
4	Chevrolet Silverado 1500	4	BMW 325i
5	Chevrolet C1500	5	Acura TSX
6	Toyota Tundra	6	Mini Cooper
7	Chevrolet Suburban 1500	7	Saab 3-Sep
8	Kia Sorento	8	Toyota Matrix
9	Dodge Dakota	9	Honda Fit
10	Chevrolet Tahoe	10	Toyota Yaris

JUNE 7, 2006

Gallup Poll Analysis: Political Correlates of Car Choice

Americans' choice of car related to partisanship and ideology

BY FRANK NEWPORT

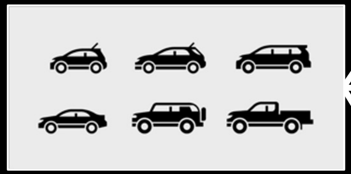
GALLUP NEWS SERVICE

PRINCETON, NJ -- Social scientists -- and automobile marketers -- have long noted that the choice of a car to drive is based on more than just price and functionality. Car brands and styles are associated with specific identities, positioning, and mental images, and one's choice of a car can be a significant statement about his or her desired presentation of self. A recent Gallup Panel Poll found that 93% of Americans say they personally drive a car or other vehicle. These drivers were asked to name the brand of car they personally drive most often.

Can our Smartphone Stealthily Leak this Info?

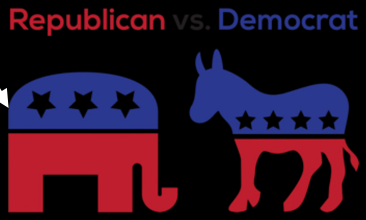
Driving analysis app, motion tracking app

?



Targeted advertising

Demographic information

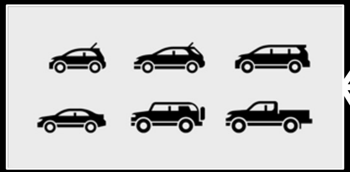


Political tendency

Sensitive information

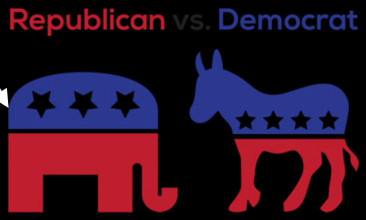
Can our Smartphone Stealthily Leak this Info?

Characterizing **Vibration Patterns** for differentiating cars



Targeted advertising

Demographic information



Political tendency

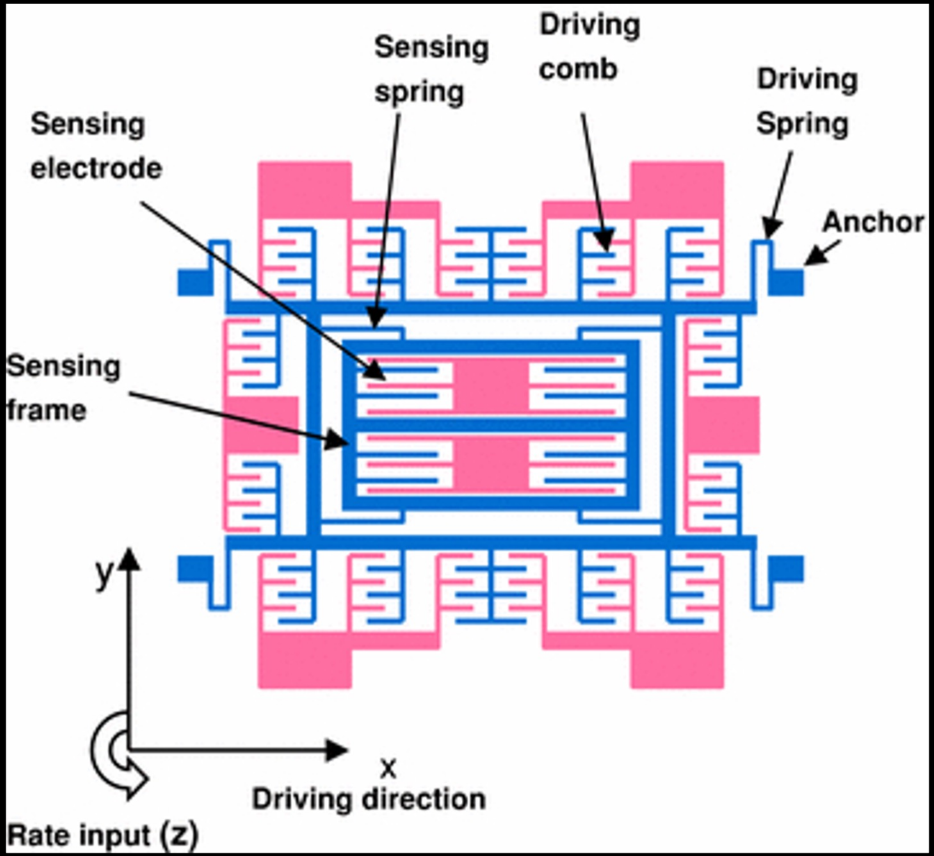
Motion Sensors can be a Loophole!

Sensitive information

They are pivotal but require zero-permission!

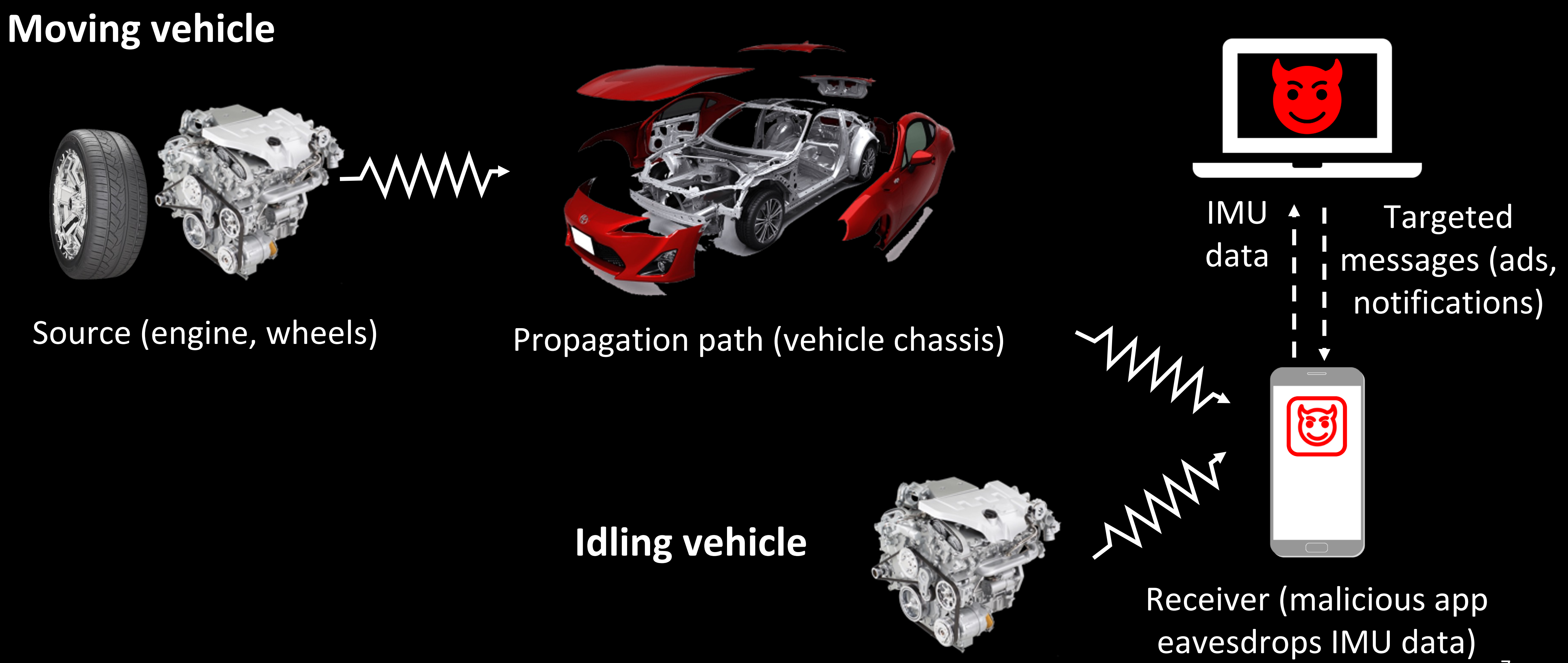
Sensing Vibrations with Motion Sensors (IMU)

- The embedded oscillator of accelerometer and gyroscopes can be used for sampling high-speed vibrations



[Michalevsky *et. al* 2014]

Threat Model



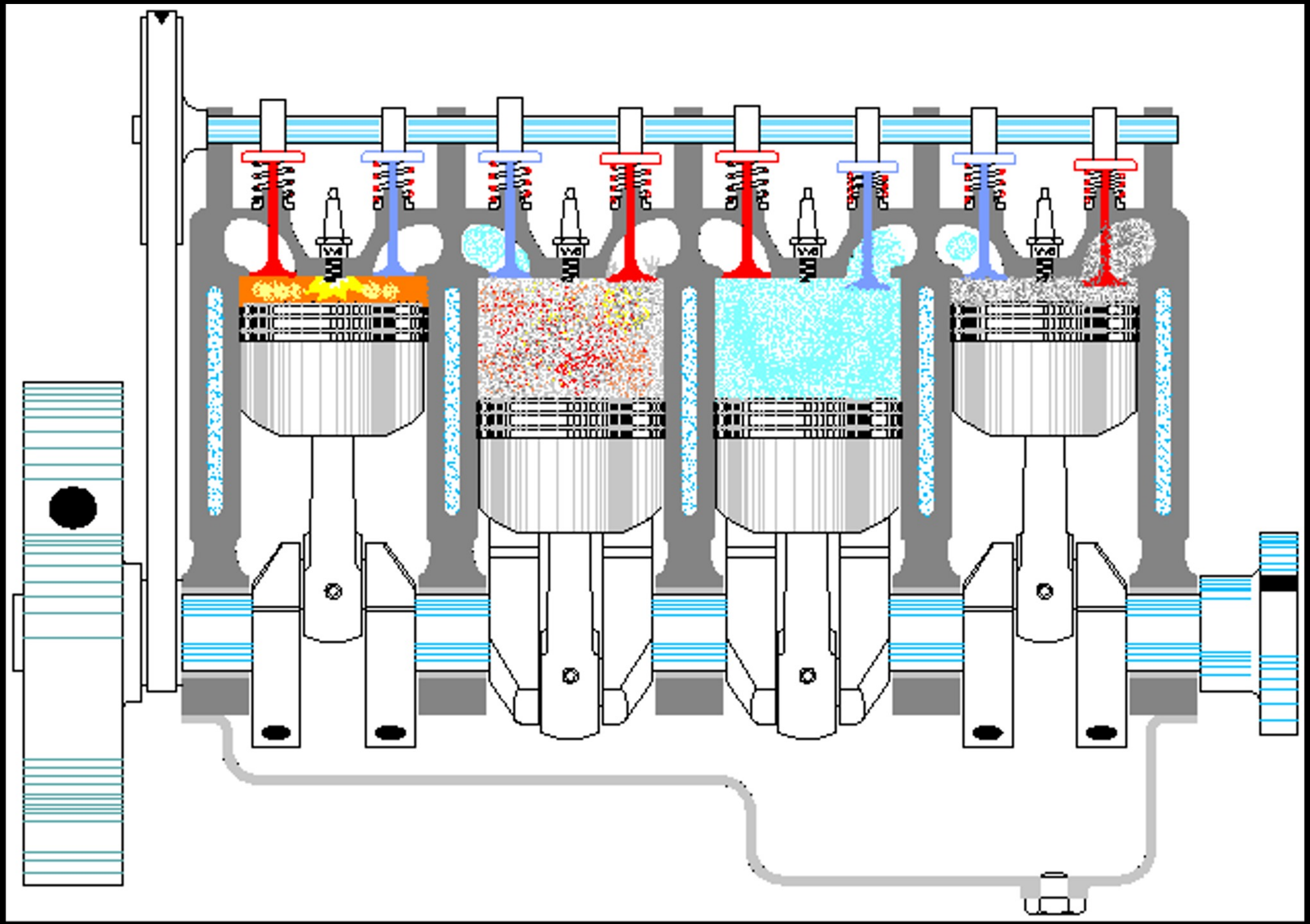
Inferring Type of an Idling and Moving Vehicle

Vibration pattern varies depends on whether the vehicle is moving

Idling vehicle

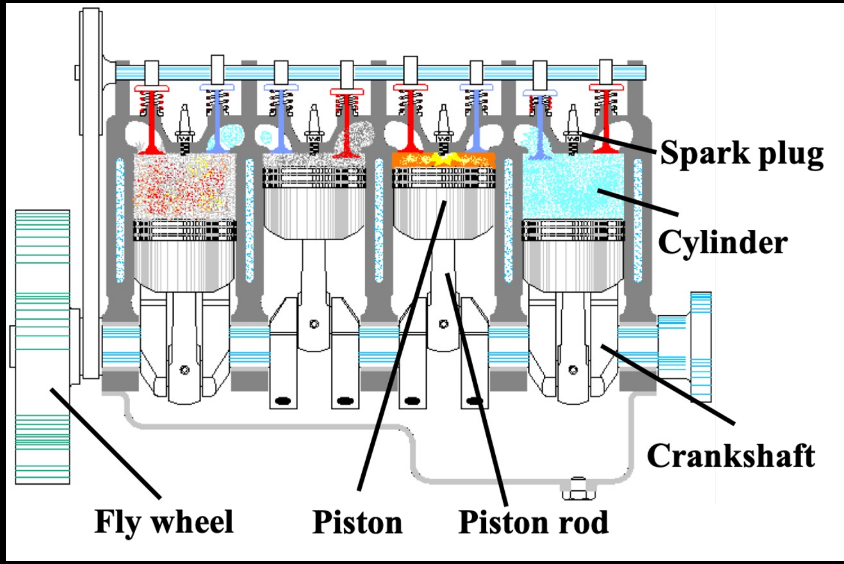
Moving vehicle

Inferring Type of an Idling Vehicle



- Engine is the dominant source of vibration when car is idling
- Engine is representative of car types
  - Hybrid: 3~4-cylinder
  - Pickup truck: 6~8-cylinder

Inferring Type of an Idling Vehicle



1. Combustion frequency: $f_C = \frac{RPM}{60}\frac{C}{2}$

2. N-th order overtones: $f_{C,N} = N f_C$

3. Aliased frequency that can be detected by motion sensors

$$f_{C,N}^{a} = \left| f_{C,N} - K f_s \right|$$

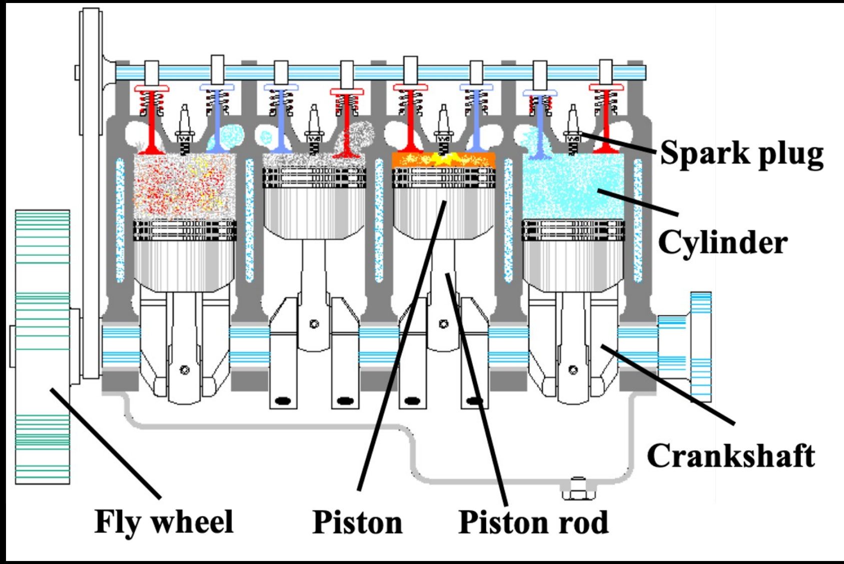
4. The detectable engine overtone at specific engine RPM is:

$$f_{C,N}^{a}(RPM) = \left| N \frac{RPM}{60}\frac{C}{2} - K f_s \right|$$

$$0 \leq f_{C,N}^{a} \leq {f_s}/{2} \quad K \in \mathbb{Z}$$

The first **2** order overtones are the strongest

Inferring Type of an Idling Vehicle

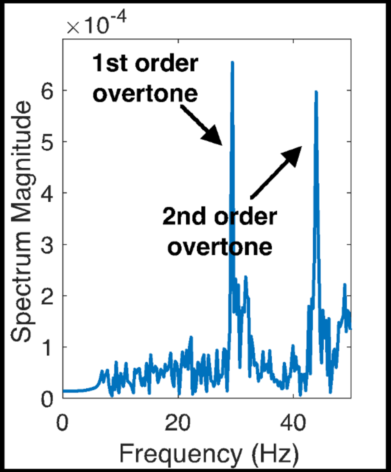


Overtone order / # cylinder	N=1	N=2	N=3
4	[20 33.3]	[33.3, 50]	[0, 40]
6	[30, 50]	[0, 40]	[0, 50]
8	[33.3, 50]	[0, 33.3]	[0, 50]

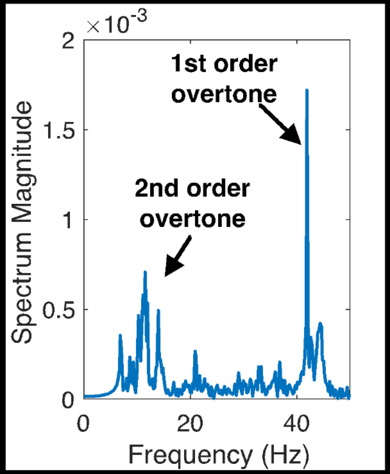
The detectable engine overtone at specific engine RPM:

$$f^{a}_{C,N}(RPM) = \left| N \frac{RPM}{60} \frac{C}{2} - K f_s \right|$$

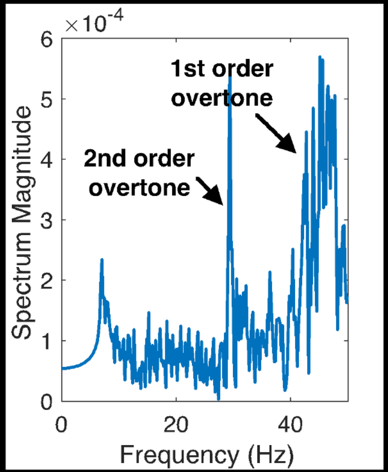
$$0 \le f^{a}_{C,N} \le {}^{f_s}/_{2} \qquad K \in \mathbb{Z}$$



4-cylinder



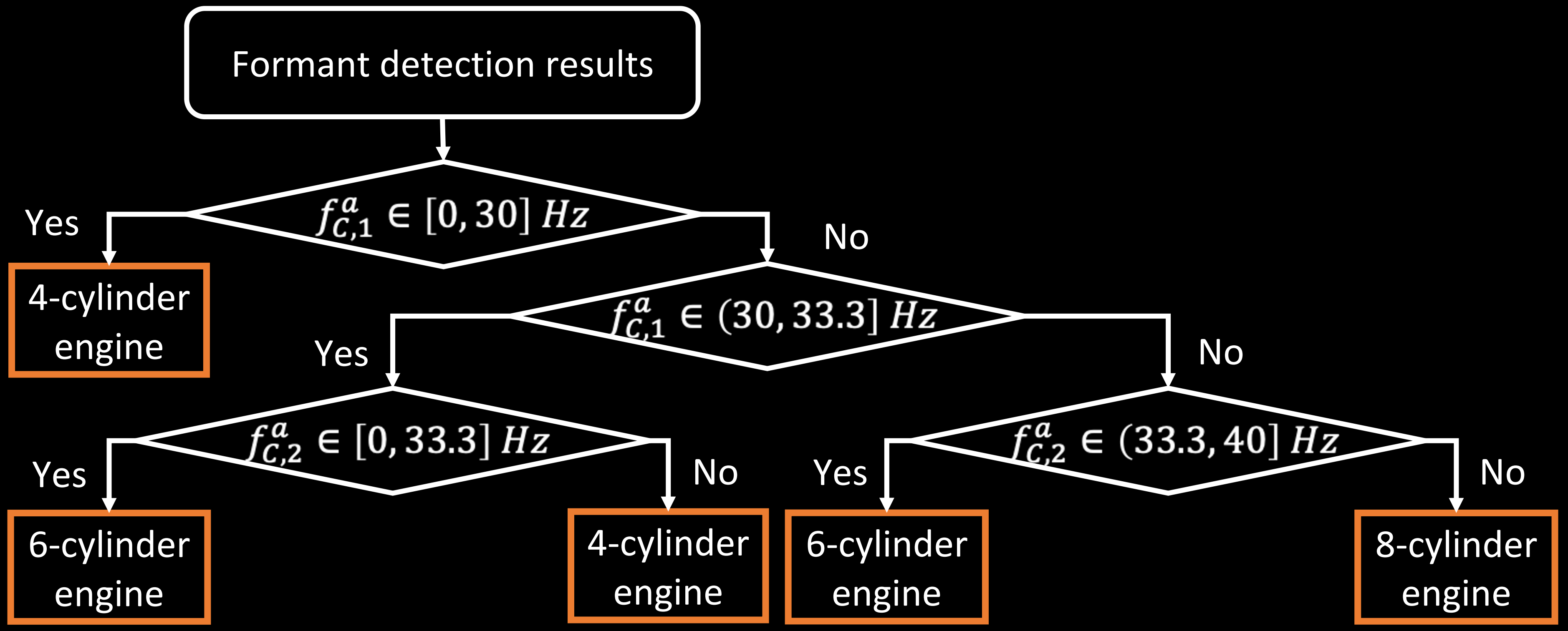
6-cylinder



8-cylinder

Inferring Type of an Idling Vehicle

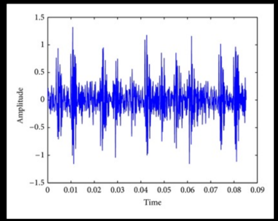
A decision tree can be constructed based on the distribution of $f_{C,N}^{a}$



Inferring Type of a Moving Vehicle

Vibration source
(Engine)

Filters (vehicle frame, chassis,
suspension etc.)

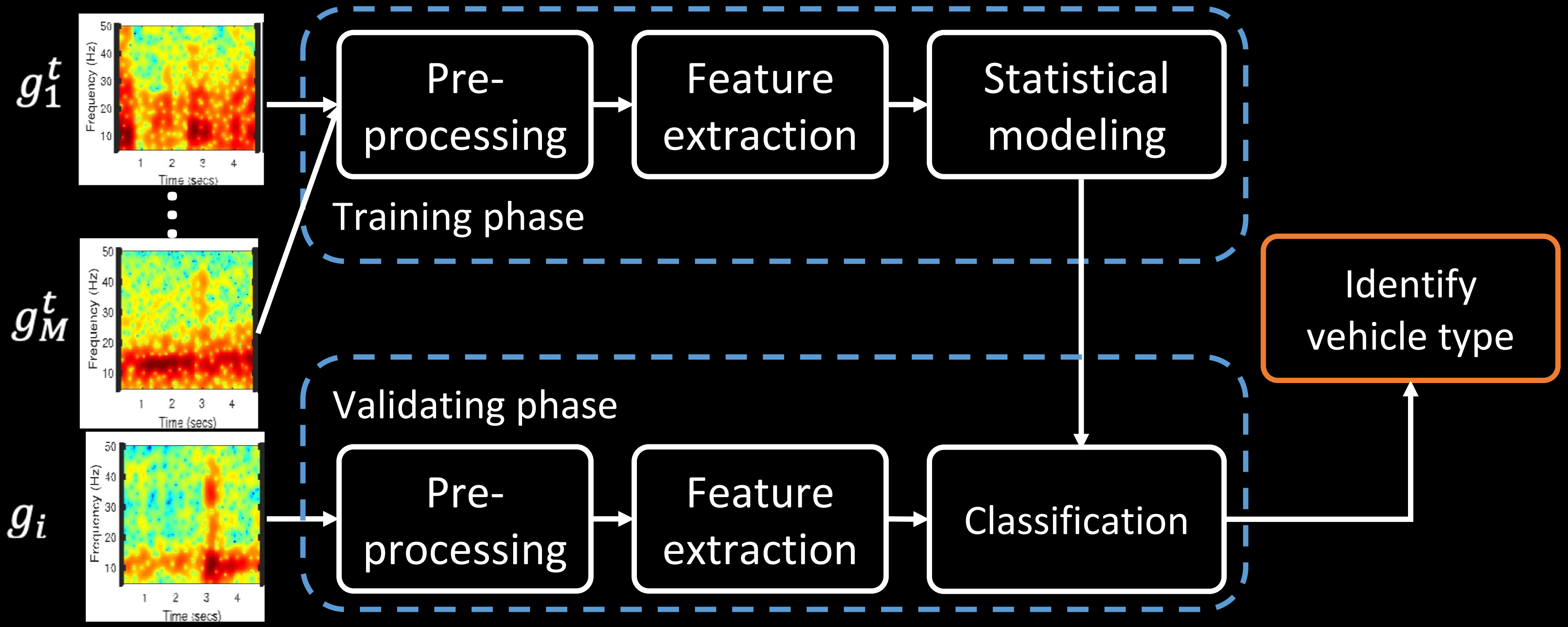


Vibration
signal

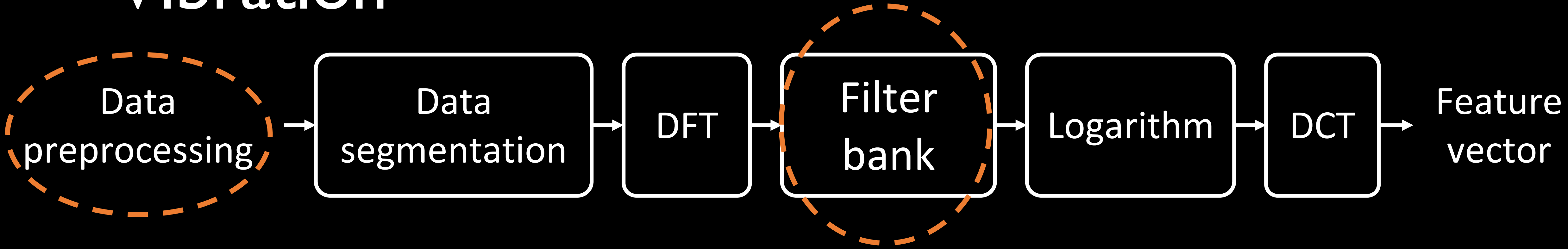
Inferring Type of a Moving Vehicle

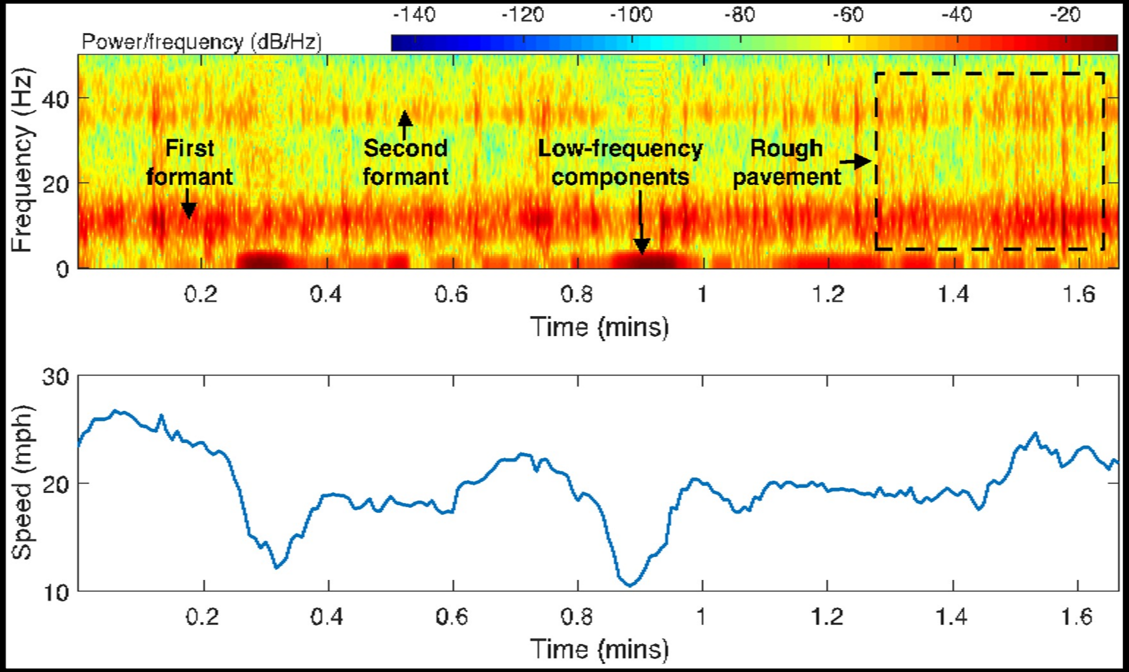
- Insights from the pipeline of speaker recognition

Raw vibration data → Source filter model → Characterizing the car type



Feature Extraction: Adapt to Vehicle Vibration





Spectral features when the vehicle is moving

1. Maneuver generates the low-frequency components (<5 Hz)
2. Key formants are distinguishable even on rough pavement

Evaluation Setting

Cases	Vehicle type	Experimental vehicle(s)
C-1	Compact	Toyota Corolla 2009; Hyundai Elantra 2008; Nissan Sentra 2018
C-2	Mid-size	Honda Accord 2006, 2013; Toyota Camry 2010, Toyota Camry 2010, 2011; Ford Fusion 2018; Mercedes Benz C180 2016
C-3	SUV	Honda CRV 2013, 2014; Jeep Campus 2014; Ford Explorer 2011, 2016
C-4	Pickup truck	GMC Sierra 2015, 2016; Ford F-150 2017

- For each vehicle type we extract the gyroscope sensor data from idling and moving stages

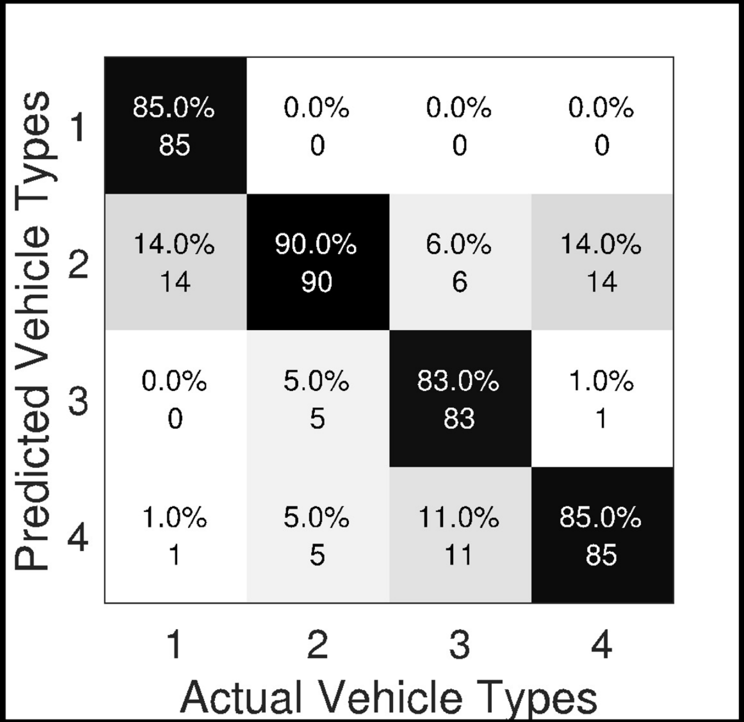
Evaluation

Identifying types of idling vehicles

# cylinder	Precision	Recall	F-1
4	0.82	0.82	0.82
6	0.67	0.50	0.57
8	0.67	1.00	0.80

Evaluation

Identifying types of moving vehicles



The overall accuracy is **85.75%**

Conclusion

- VeFi exploits the vibration pattern to differentiate vehicle types
- A high-frequency vibration pattern can characterize:
  - Engine type for idling cars
  - Car body type for moving cars

Thanks!

Q & A

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