Weighted Feature Extraction for Driving Maneuver Recognition: A Study using Naturalistic UTDrive Data

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Outline

- Research Objective
  - NHTSA & TRB Statistics
  - Research Questions
  - Methods to Understand Driver's Intention
- UTDrive Project
  - Data Collection System
  - Route & Driving Tasks
  - Naturalistic Driving Corpus Statistics
- Maneuver Recognition
  - Analysis of Maneuvers
  - Example
  - Signals & Features & Frames
  - Results & Discussions
- Summary

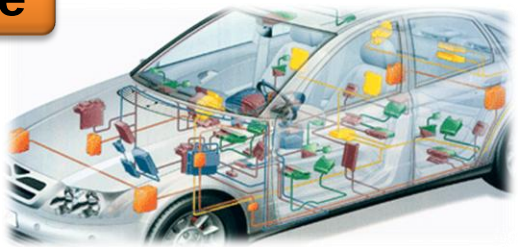
First Time Drivers!

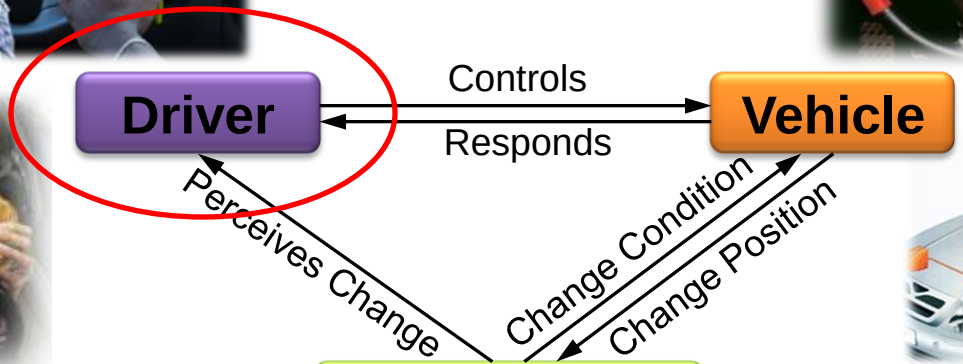
Objectives: Understanding Drivers (Distracted, Intent, etc.)

- **NHTSA 2010 –**
  - **5,474 deaths & 448,000 injuries due to distraction in 2009.**
- **USA daily estimates –**
  - **15 killed & 1,227 injured due to distracted driver.**
- **TRB 2013 –**
  - **Driver Behavior contributes to >90% crashes & is the primary factor for >60% crashes.**
- **FHWA 2009 –**
  - **58% of roadway fatalities are lane departures, while 25-50% of severe departure crashes occurred on curves.**
- **Highway Safety Manual –**
  - **Crash modification factors for left-turn lanes ranges from 0.45 to 0.90.**

Source: NHTSA, SHRP2

Research Questions for Driving

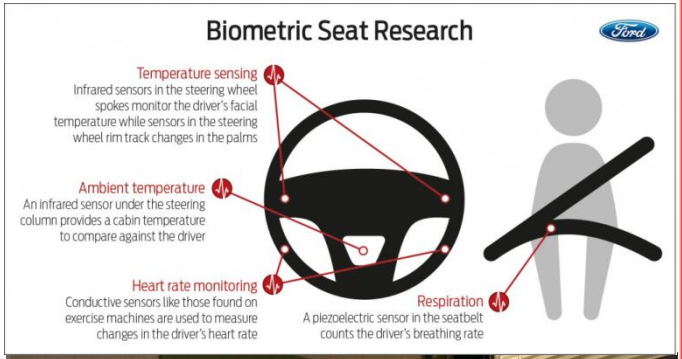


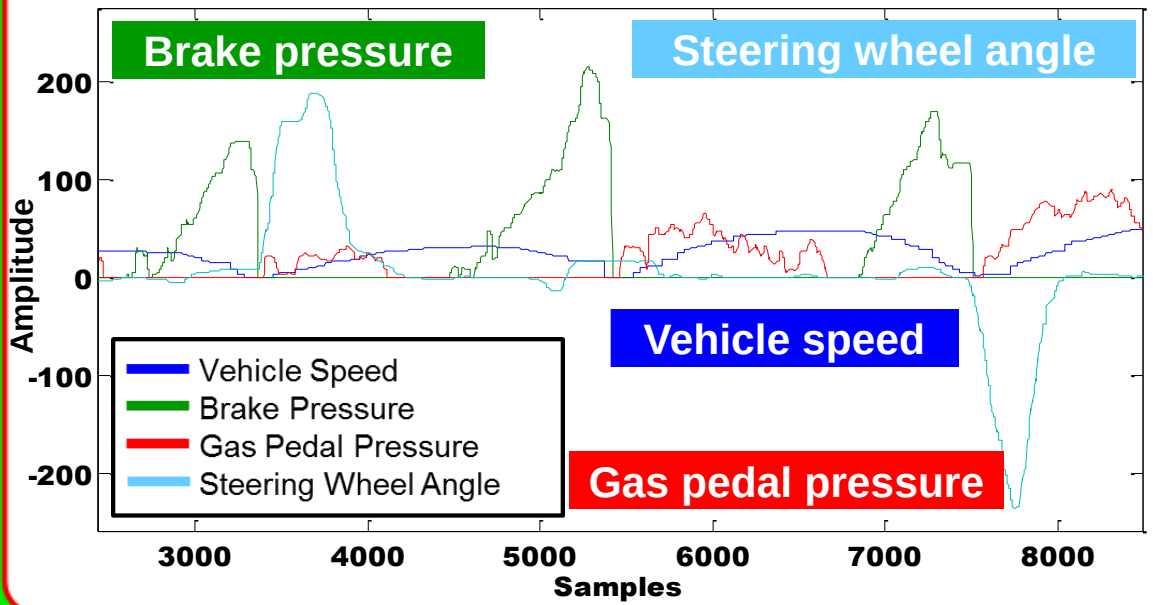


- How does a driver control his vehicle?
- How does vehicle dynamics reflect driver's intention?
- How does a driver performs in specific environments?

Understanding Driver Intention

- **Simulator Studies vs. Naturalistic Data**
- **Direct Approach**
  - Heart rate variability (HRV), skin conductance (GSC), EEG, ECG and EMG. -> Intrusive
- **Indirect Approach**
  - From vehicle &/or environment sensors & systems.
  - Driver's primary contact with the vehicle.



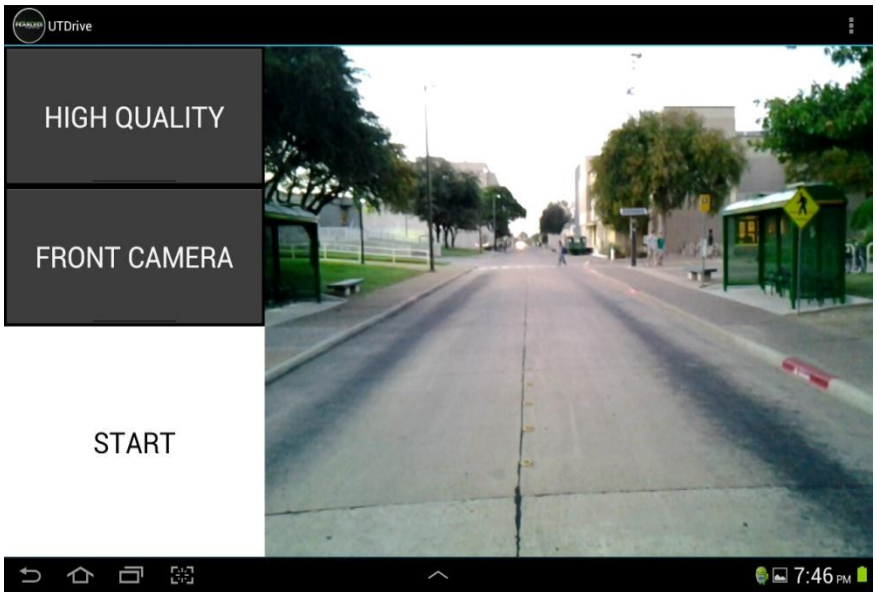


Source: EPFL, Ford, AT&T

Data Collection System

Instrumented Vehicle

Sensor loaded portable platform



Geo & Inertial Sensors

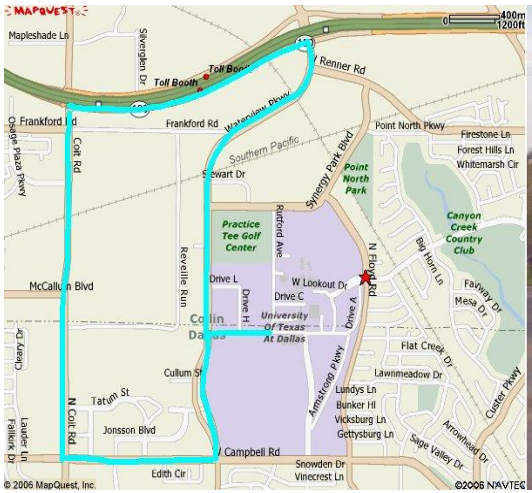
Classical approach

Low cost, portable approach

[1] K. Takeda, J.H.L. Hansen, P. Boyraz, L. Malta, C. Miyajima, H. Abut, "An International Large-Scale Vehicle Corpora for Research on Driver Behavior on the Road," *IEEE Trans. on Intelligent Transportation Systems*, 12(4):1609-1623, Dec.2011.

[2] A. Sathyanarayana, O. Sadjadi, J.H.L. Hansen, "Automatic Driving Maneuver Recognition and Analysis using Cost Effective Portable Devices," *SAE Inter. Journal on Passenger Cars - Electronic & Electrical Systems*, 6(2): 467-477, 2013

Route & Driving Tasks

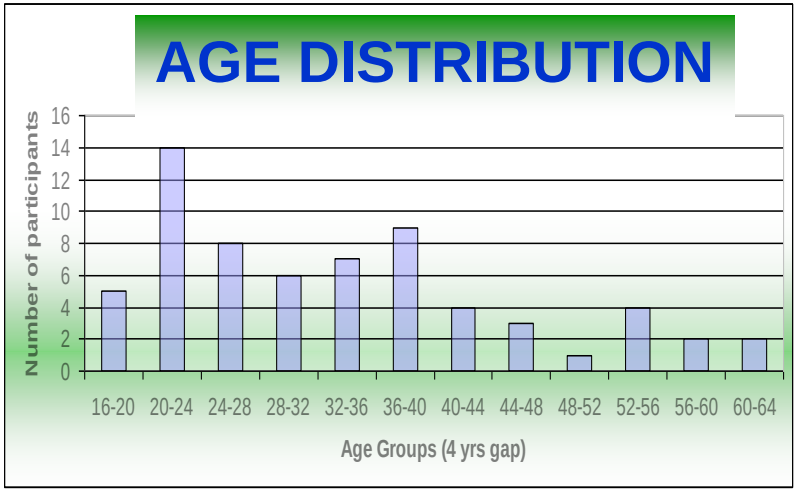


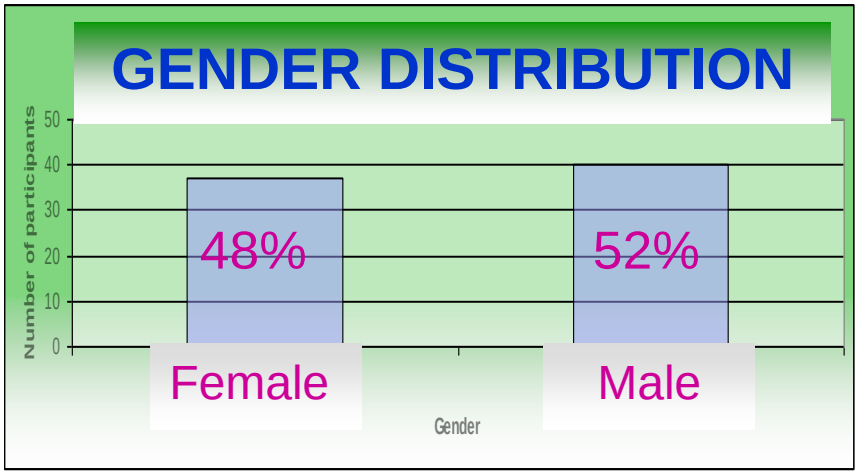
- **Two routes**
  - Route1: residential area
  - Route2: business district
- 10-15 minutes/route
- Three-lane streets
- Speed limit 20-50 mph
- Route1: 6 lights & 11 stops
- Route2: 14 lights & 2 stops

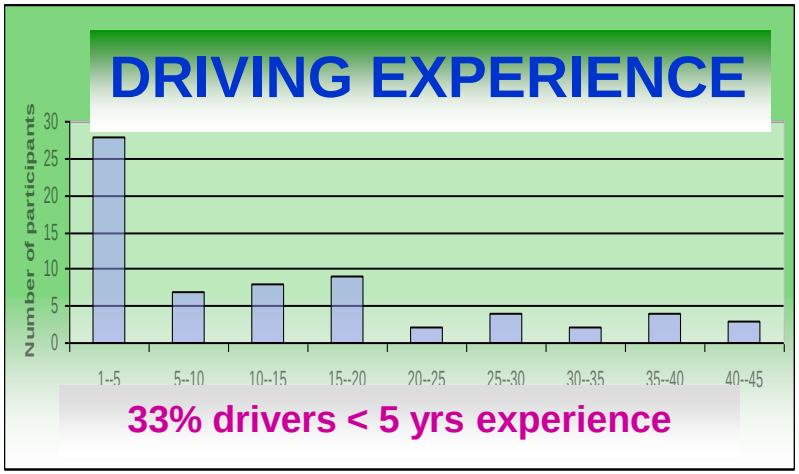
SECONDARY TASKS

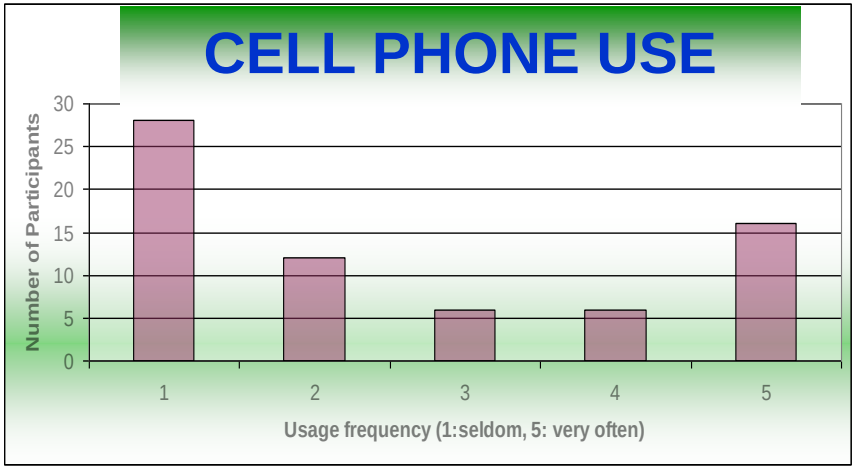
- Lane Changing
- Cell-phone interaction with TellMe Dialog System
- Cell-phone interaction with AA Airline Dialog System
- Common Tasks
- Conversation
- Sign Reading
- Spontaneous Speech

Corpus Statistics



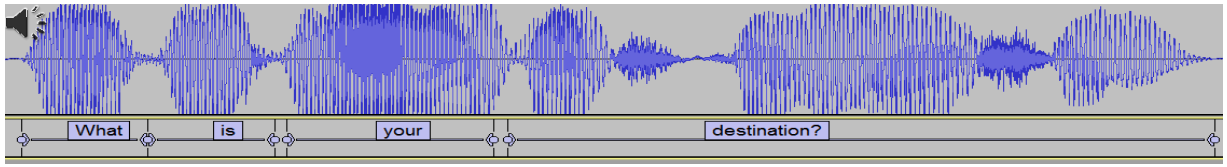




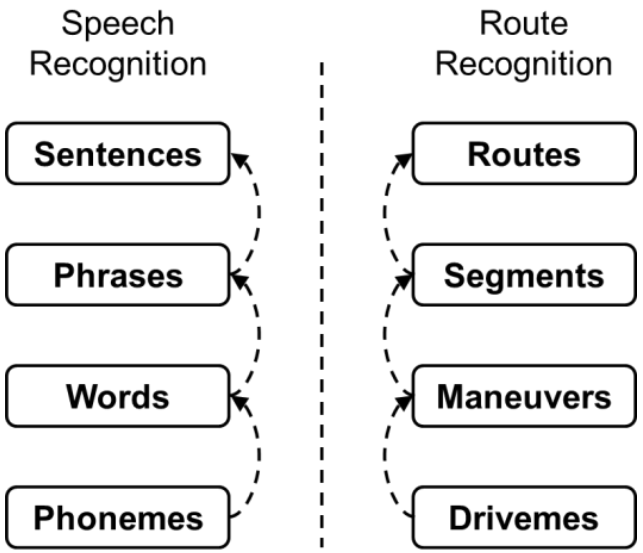


37 Female, 40 Male ; each 6GB data stream; over 120 driving hours in total

Driving & Speaking



- How spoken sentence reveals the current state of the person.
- Maneuvers - building blocks of route.
- Analyzing variations in maneuvers could provide insight on driver's cognitive state.

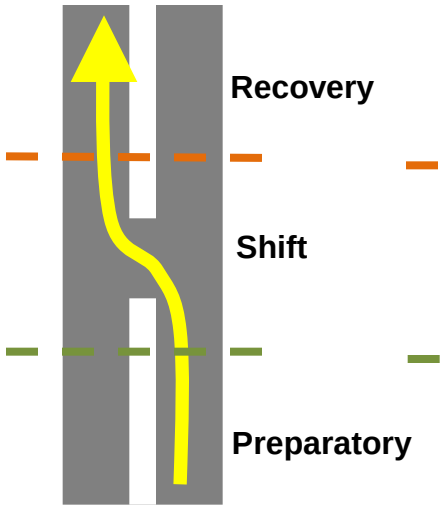


START, STR, RTR, LRC, RRC, RTR, STR, LTR, STR, STP, RTR, FINISH

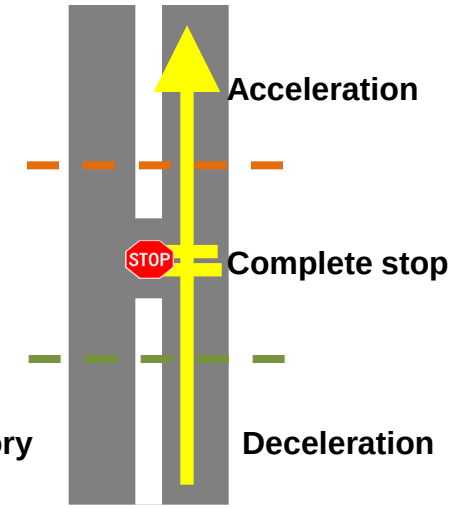
- **Maneuvers analysis, why?**
  - Driver dependent maneuver recognition – driver behavior model.
  - Identify variations in normal maneuver execution – comparison for distraction.
  - Assess safety level – easy to locate at specific situation.

Analysis of Maneuvers

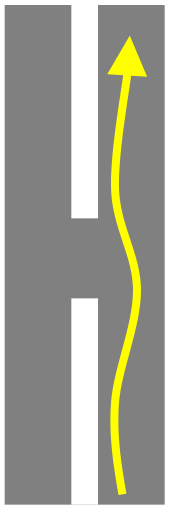
Lane Change
RLC, LLC (3-5 sec)



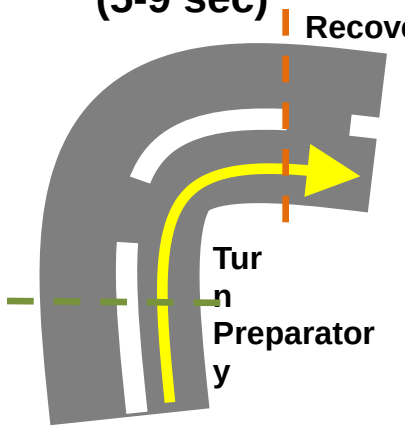
Stops
STP (5-15 sec)



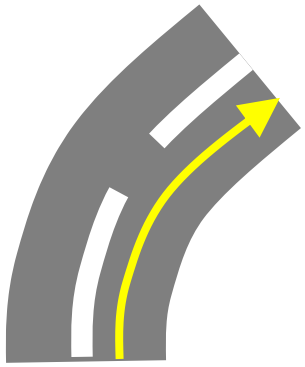
Straight
STR (15-30 sec)



Turns
RTR, LTR
(5-9 sec)



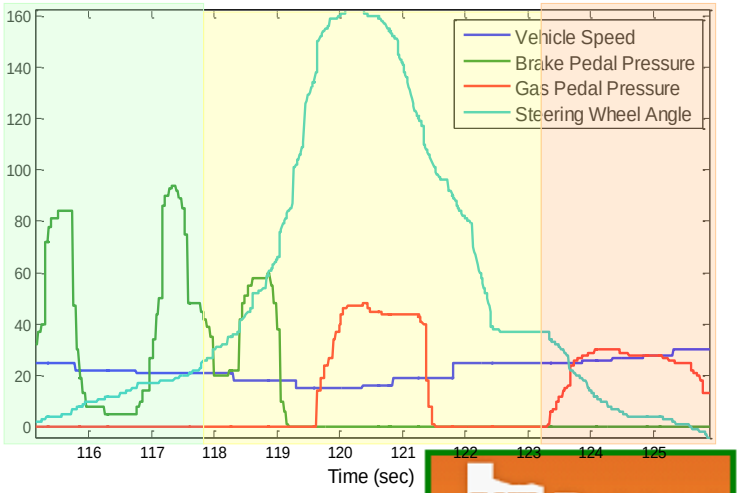
Road Curves
RRC, LRC
(10-15 sec)



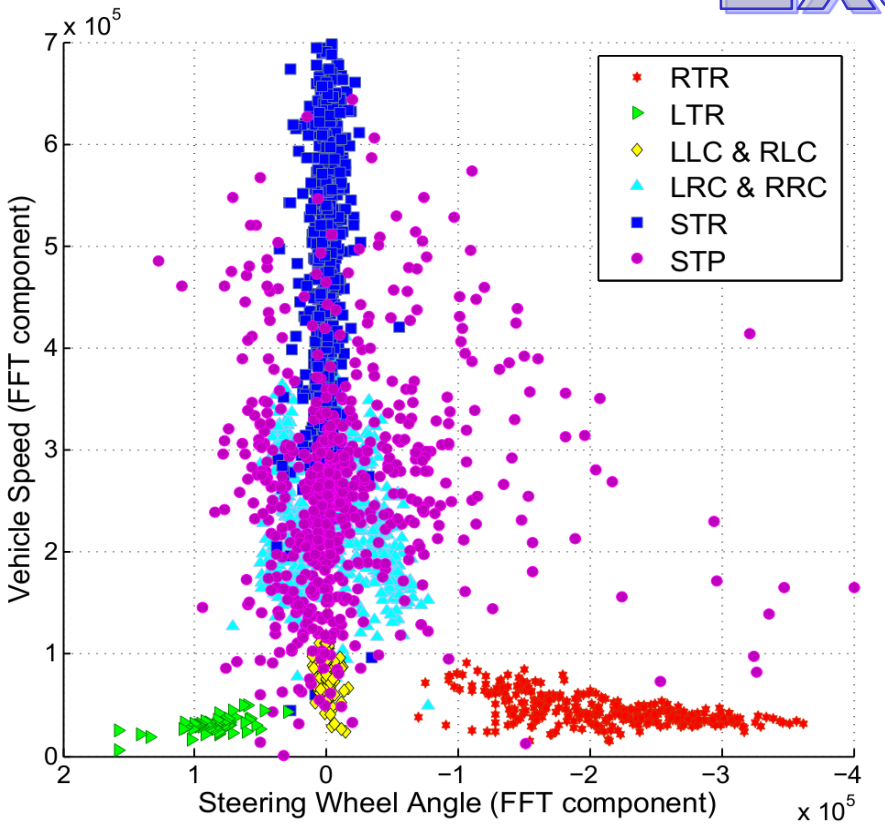
Maneuvers ←→ Vehicle dynamics

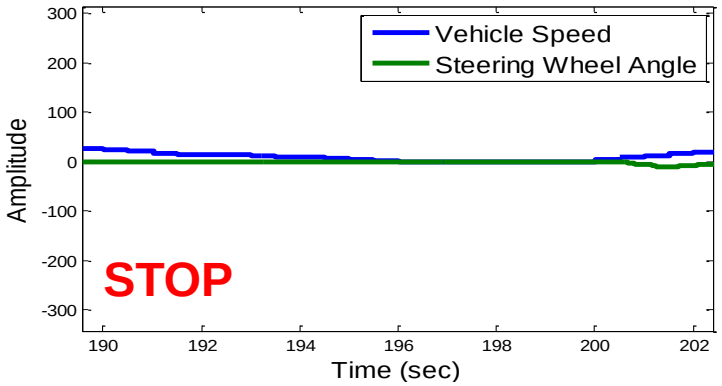
- Moving vehicle changes in time & space through lateral & longitudinal changes.
- Hence vehicle speed & angle of vehicle orientation are sufficient signals.

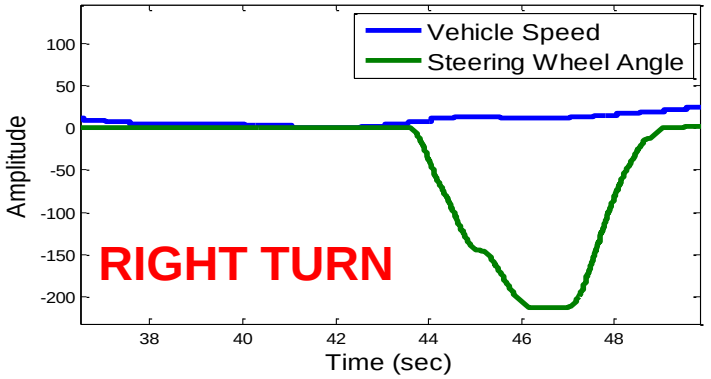
Preparatory **Turn** **Recovery**



Maneuver Recognition Example







- Consider vehicle speed and steering wheel angle as the signals.
- Extract FFT components as features of each signal.
- Use k-NN or SVM classifiers for maneuvers tagging.

Signals & Features

CAN-Bus (5 signals)

- Vehicle Speed
- Brake Pedal Pressure
- Gas Pedal Pressure
- Steering Wheel Angle
- Engine RPM

Portable Device (23 signals)

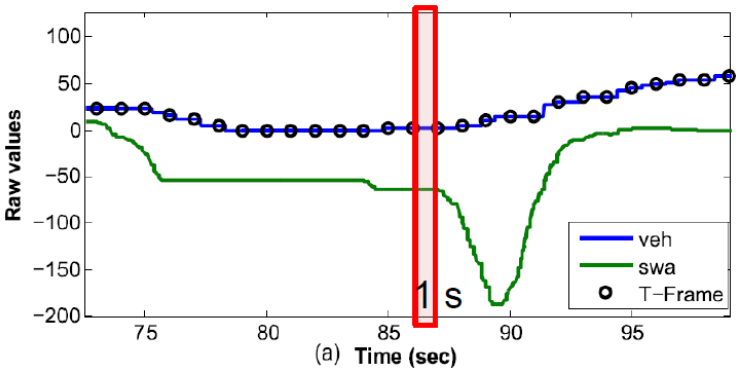
- 3-axis accelerometer
- 3-axis gyroscope
- 3-axis magnetometer
- 3-axis gravity
- 3-axis linear accelerometer
- 3-axis orientation
- 3-axis rotation vector
- GPS (vehicle speed & bearing)

Features (25) = 15 static + 10 dynamic

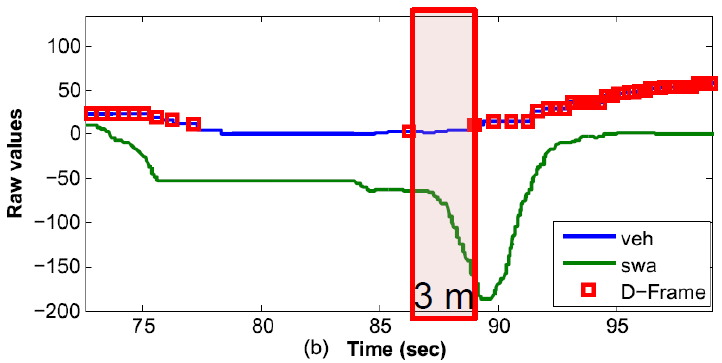
Feature	Description
amp	Difference between the maximum and mean value of the signal
namp	Difference between the mean value and minimum of the signal
med	Median of the signal
mean	Mean of the signal
min	Minimum value of the signal
max	Maximum value of the signal
p2p	Difference between the maximum and minimum value of the signal
std	Standard deviation of the signal
var	Variance of the signal
rms	Root mean square value of the signal
s2e	Amplitude of the difference between the first and the last samples of the signal
lpE	Variance of error in a 10^{th} order linear prediction (LP) analysis
ent	Entropy of the signal
dcVal	DC value of the signal
energy	Energy of the signal

Framing Strategies Comparison

Fixed-time window

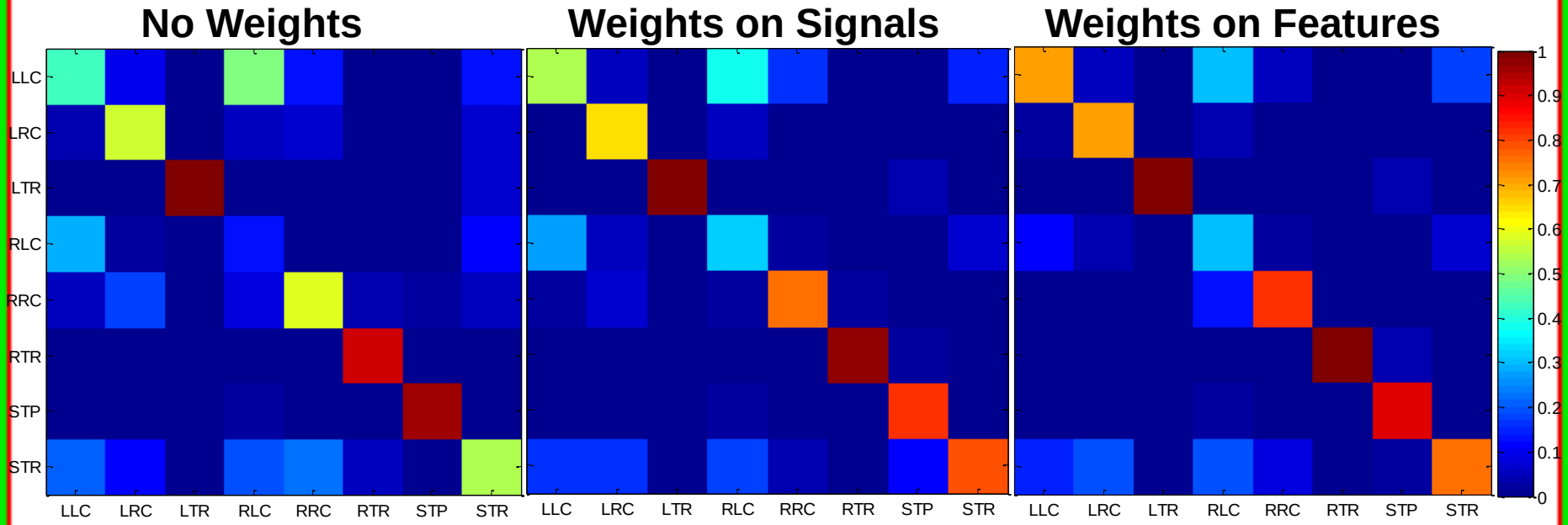


Fixed-distance window



- Employ fixed-time window or fixed-distance window to partition route into segments; don't carry sufficient maneuver information.
- Since we want to find out the most dominating signals and features for maneuvers, we use the full length maneuvers for test in this study (assuming we can somehow get the maneuvers boundary), ground truth is provided by manual transcriptions.

Confusion Matrix for Maneuver Recognition



AVG: **64.12%** **73.78% (9.66% up)** **77.90% (4.12% up)**

- 32 RTR, 35 LTR, 33 RLC, 34 LLC, 23 RRC, 22 LRC, 50 STR, 27 STP. (256)
- The x-row represents what the maneuvers should be.
- The y-column represents the recognized maneuvers.
- No Weights < Weights on Signals < Weights on Signals & Features

Discussion

- Accuracy can be improved by introducing weight factors on individual signals & features.
- Selecting different weight factors can result in variable accuracy of each maneuver; can be useful when focus is on specific maneuver.
- “Left Turns” are perfectly recognized, which may be helpful for studies on this situation.
- “Lane Changes” are not recognized well.
- Difficult to know maneuvers boundaries without manual transcription; will focus on time/distance windows for recognition.

Summary

- Study focus on understanding driver intention.
- Vehicle dynamic signals can be used to infer driver behavior.
- UTDrive naturalistic driving corpus.
- Maneuvers are basic units to build up a route.
- Use CAN-Bus signals and its features to recognize maneuvers.
- Weights on signals & features to improve recognition accuracy.

Thank you!

http://www.utdallas.edu/research/utdrive/UTDrive-Website.htm

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