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
How does a driver control his vehicle?
How does vehicle dynamics reflect driver’s intention?
How does a driver performs in specific environments?
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
Instrumented Vehicle

Classical approach

Low cost, portable approach

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

Two routes

Route 1: residential area
Route 2: business district

- 10-15 minutes/route
- Three-lane streets
- Speed limit 20-50 mph
- Route 1: 6 lights & 11 stops
- Route 2: 14 lights & 2 stops
Corpus Statistics

AGE DISTRIBUTION

GENDER DISTRIBUTION

48% Female
52% Male

DRIVING EXPERIENCE

33% drivers < 5 yrs experience

CELL PHONE USE

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.

**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.
Maneuvers ↔ Vehicle dynamics

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

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

No Weights

Weights on Signals

Weights on Features

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
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.
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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