

# Driver Mirror-Checking Action Detection Using Multi-Modal Signals

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# Motivation



- 100-car Naturalistic Study: Over 78% of crashes involved driver inattention
- It is estimated that drivers engage in potentially distracting secondary tasks about 30% of their time [Ranney, 2008]
- In-vehicle technologies, cell phones and navigation systems are estimated to increase exponentially [Broy, 2006]

# Why Mirror Checking Detection

- Mirror checking
  - Maintain situation awareness
  - Essential for lane switching
  - An eyes-off-the-road task
- Reduced mirror checking actions when
  - Fatigue
  - Cognitive workload



# Highlights of This Study

- Using real-world driving data from 20 different drivers
- Analysis of the mirror checking actions in both normal and secondary task conditions
- Detection of mirror checking action using multi-modal signals
  - Camera facing the drivers
  - CAN-Bus

# UTDrive

- **Camera facing drivers**
  - PBC-700, 320 x 240 at 30fps
- 4 - channel Microphone array
  - 25kHz
- **CAN Bus**
  - Steering wheel
  - Speed
  - Brake pedal
  - Gas pedal
- Road facing camera
  - 320 x 240 at 15fps



# Real Road Recording

- 20 drivers: 10 male, 10 female
- Valid US Driving License
- At least 18 years of age
- Good day light, dry weather
- Two laps of driving per subject
  - First run – with 7 tasks
  - Second run – neutral driving (without tasks)



## Secondary tasks

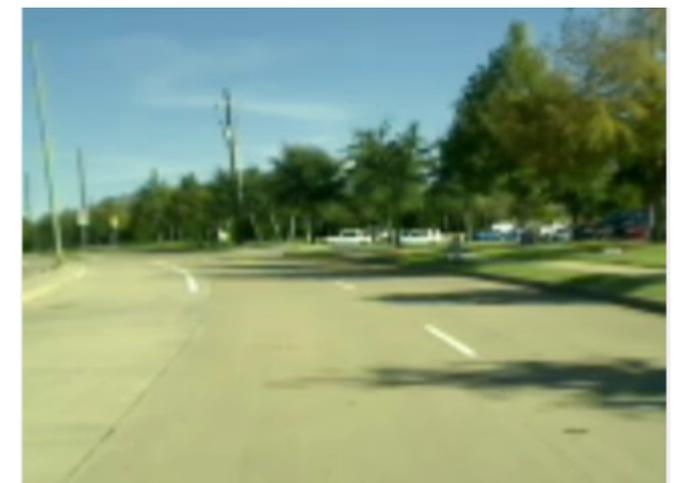
- Radio
- GPS - Operating
- GPS - Following
- Phone - Operating
- Phone - Talking
- Pictures
- Conversation

# Mirror Checking Annotation

- Two external observers annotated different recordings
- Both driver and road videos are used
- Annotate the starting and ending frame of each mirror checking action
- Four types of mirror checking actions:
  - left mirror (411 samples)
  - rear-view mirror (795 samples)
  - right mirror (78 samples)
  - combined right & rear mirror (39 samples)



Driver Video



Road Video

# Mirror Checking Annotation

- Samples of mirror checking frames in the dataset



Left mirror



Rear mirror



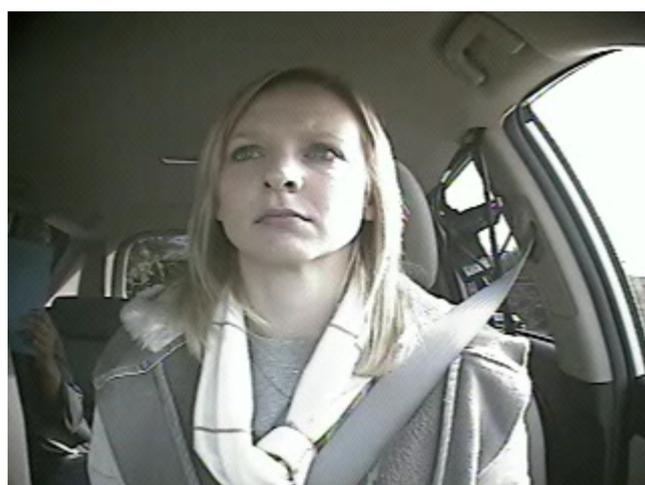
Right mirror

The mirror checking action in conversation is noisy



# Mirror Checking Behavior Analysis

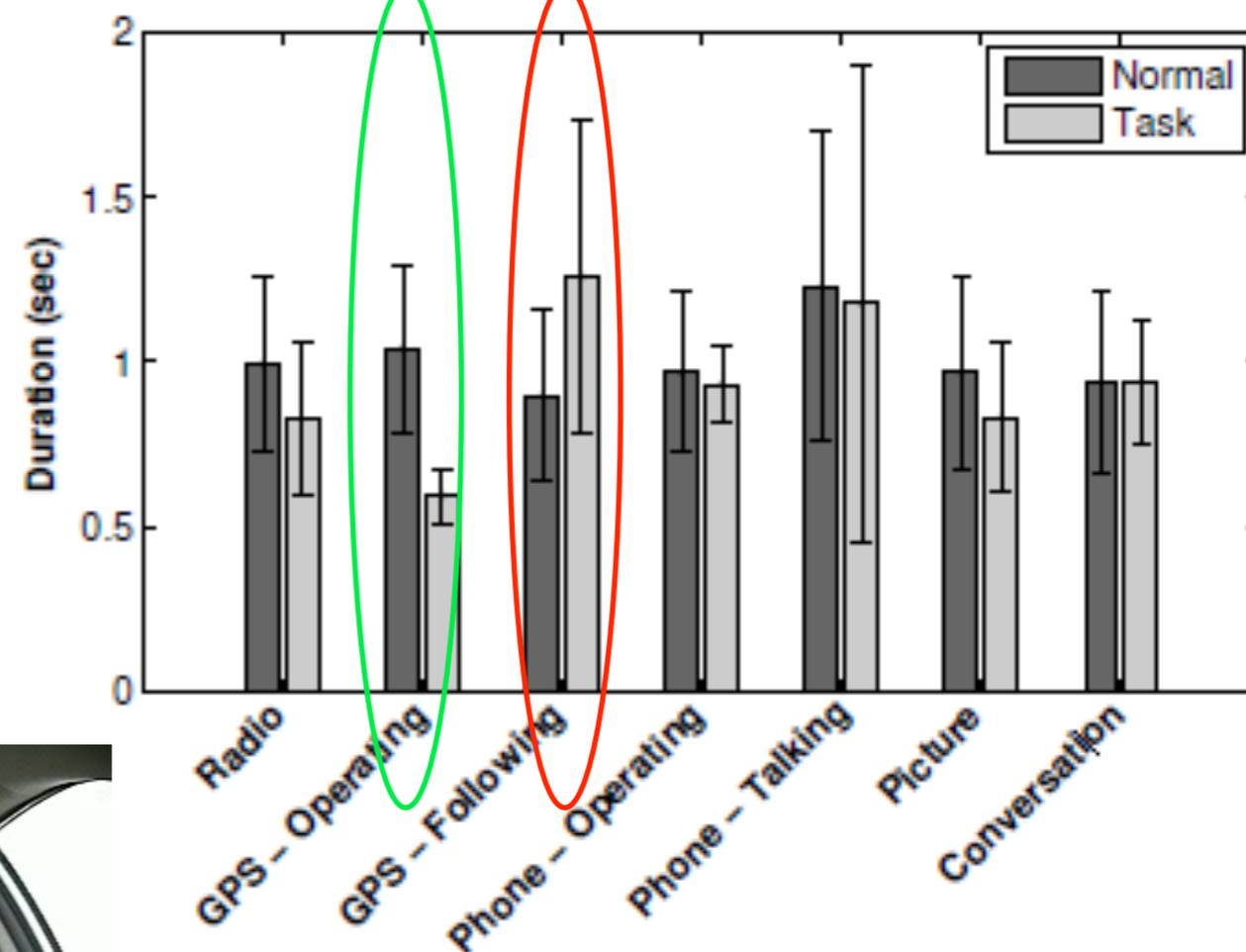
- Duration
  - Slightly shorter for task conditions
  - Exception for GPS Following
  - GPS Operating has larger difference



Normal

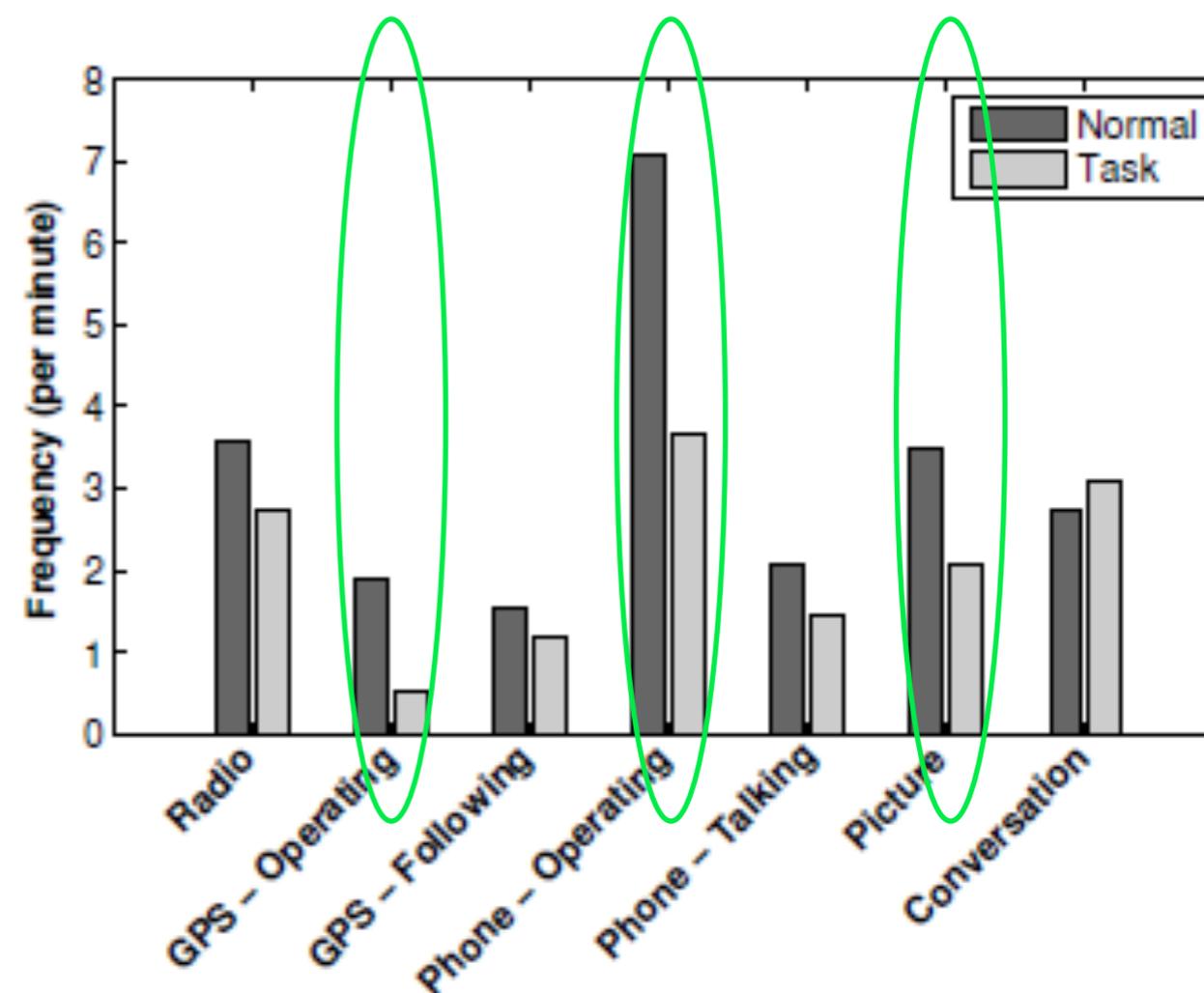


GPS Operating



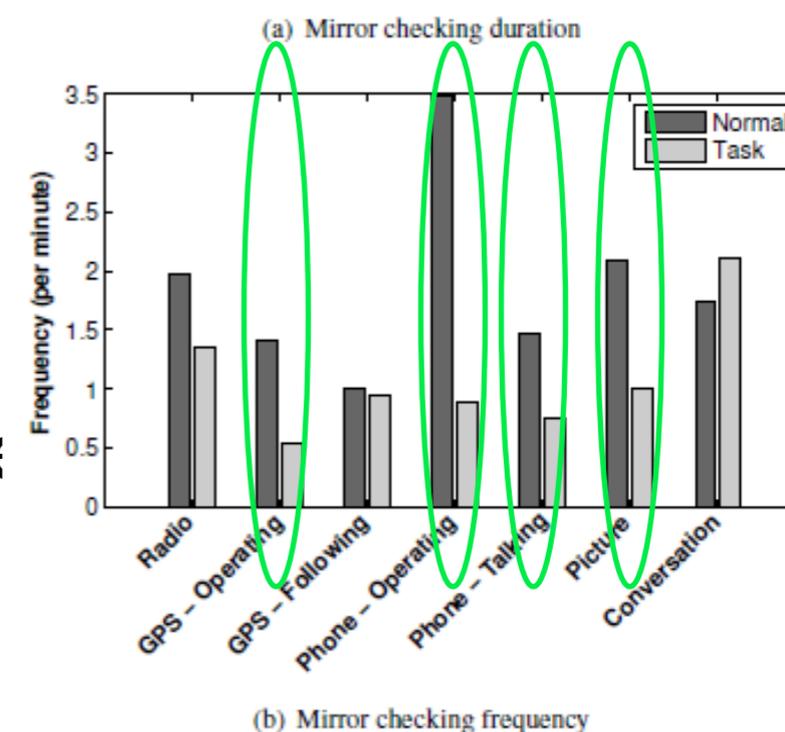
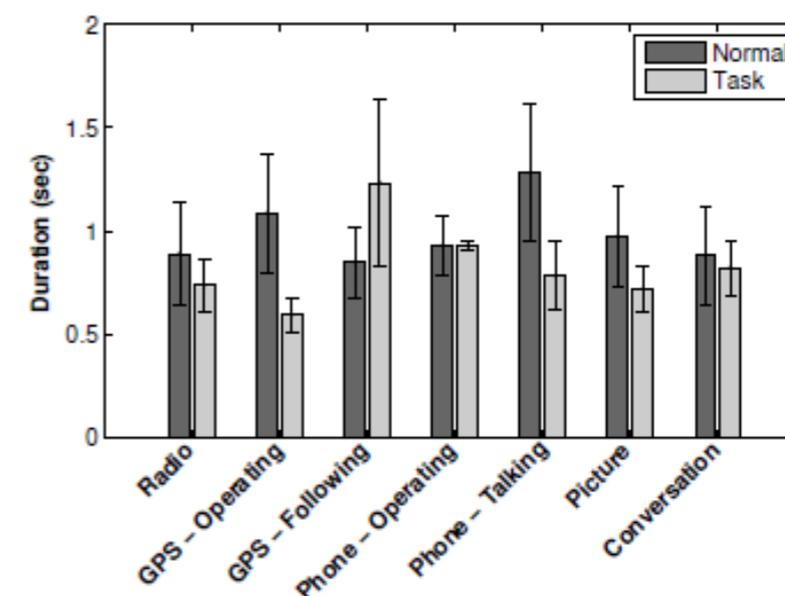
# Mirror Checking Behavior Analysis

- Frequency
  - Reduction when driver is engaged in most of the secondary tasks
- Significantly different under matched pair T-test ( $p$ -value= 0.05)
  - GPS Operating
  - Phone Operating
  - Picture



# Checking Behavior for Rear Mirrors

- Matched pair T-test significant for frequency (p-value = 0.05):
  - GPS Operating
  - Phone Operating
  - Phone Talking
  - Pictures
- Rear mirror checking actions are more affected by secondary tasks



# Mirror Checking Detection

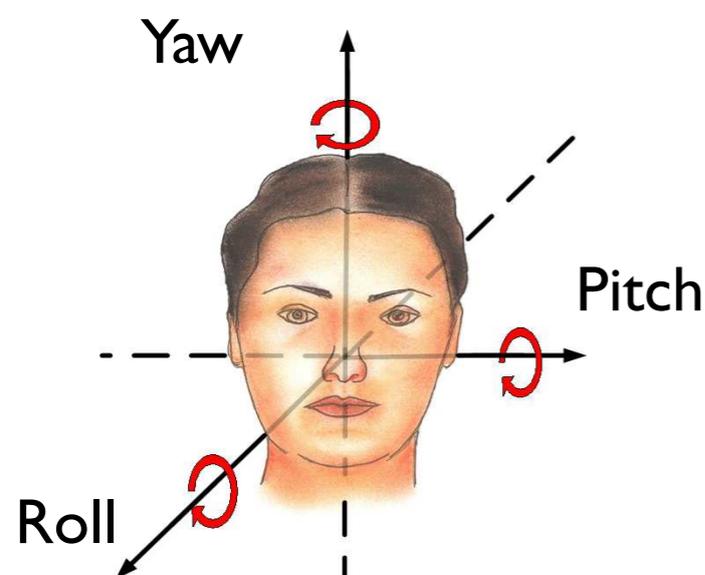
- Detection of mirror checking action using binary classifiers
- Positive class (1054 samples) – video segments containing mirror checking actions under normal and task conditions
- Negative class (24373 samples) – rest of the data is segmented into video segments of similar duration

# Multimodal Features

- CAN Bus
  - Speed
  - Brake
  - Steering Wheel
- Frontal Camera
  - Head pose
  - Eye glance behavior
  - High level eye movement



# Multimodal Features



AU 45

- Head pose (yaw, pitch and roll)
- Action Unit 45 (Blink)
- High level eye features
  - eye-off-the-road (EOR)
  - longest eye-off-the-road (LEOR)
  - eye-off-the-road frequency
  - eye blink frequency

Extracted with the Computer Expression Recognition Toolbox (CERT) (M.S. Bartlett, G.C. Littlewort, M.G. Frank, C. Lainscsek, I. Fasel, and J.R. Movellan, "Automatic recognition of facial actions in spontaneous expressions," Journal of Multimedia, vol. 1, pp. 22–35, September 2006)

# Eye-off-the-road detection

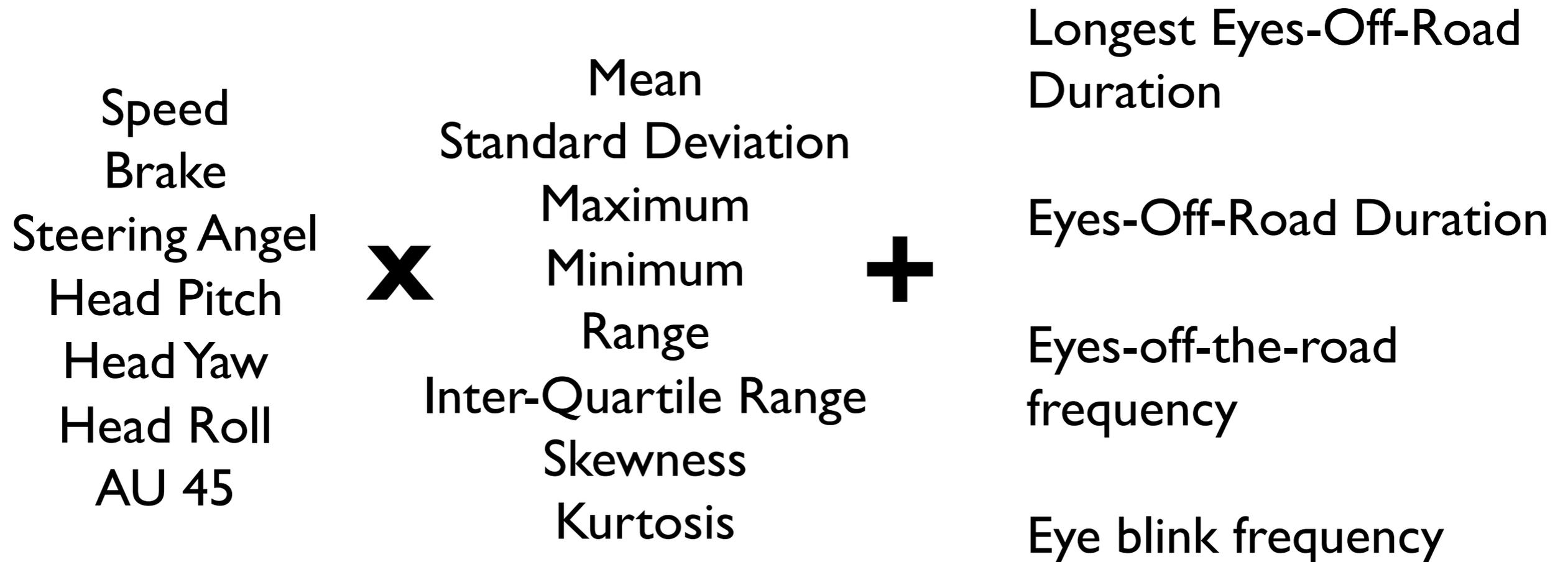
- A driver dependent box is set
- EOR is detected when head orientation is out of the box

Eye-on-road region



- eye-off-the-road (EOR)
- longest eye-off-the-road (LEOR)
- eye-off-the-road frequency

# Multimodal Features



7 signals x 8 statistics + 4 gaze features = 60 in total

# Detection Results

- Classifiers
  - Linear discriminant classifier (LDC)
  - K-Nearest Neighbor (k-NN) classifier
  - Quadratic discriminant classifiers (QDC).
- Leave-one-driver-out cross-validation

	<b>Precision</b>	<b>Recall</b>	<b>F-score</b>
LDC	57%	53%	0.54
KNN	68%	51%	0.57
QDC	62%	73%	0.65

# Detection Results

- Confusion matrix from QDC classifier
  - Performance is affected by the unbalance classes
  - Recall rate of 73 % is promising

	<b>Predicted Mirror Checking</b>	<b>Predicted Non Mirror Checking</b>
<b>Actual Mirror Checking</b>	612	442
<b>Actual Non Mirror Checking</b>	3282	21091

# Conclusions

- Analysis shows that mirror checking behavior is affected by the secondary tasks.
- The proposed multimodal features can capture the mirror checking actions
- F-score of 0.65 (recall 73%, precision 68%) is achieved

# Future work

- Include additional features and AUs
  - Facial expression
  - Road camera
- Only consider data when vehicle speed is greater than certain threshold
- Build driver dependent model

Thank you!  
Questions?

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