D³: Abnormal Driving Behavior Detection and Identification Using Smartphone Sensors

Zhongyang Chen†, Jiadi Yu†, Yanmin Zhu†, Yingying Chen‡, and Minglu Li†
†Department of Computer Science and Engineering, Shanghai Jiao Tong University
‡Department of Electrical and Computer Engineering, Stevens Institute of Technology
Traffic Accidents
Human Factors

Fatigued

Distracted

Drunk
Abnormal Driving Detection

- Alcohol sensor
- Infrared sensor
- Camera

Cost
Smartphones-based vehicular applications

Navigation
Driving Safety
Accident Detection

Driving behavior analysis is also a popular direction

Coarse-grained Abnormal Driving Behaviors Monitoring
Abnormal Driving Behaviors

- weaving
- swerving
- sideslipping
- fast u-turn
- turning with a wide radius
- sudden braking

Fine-grained Abnormal Driving Behaviors Monitoring
D³ System Architecture

Modeling Driving Behaviors (offline)
- Collected Data
- Feature Extracting
  - Max (accx)
  - Min (accy)
  - Std (ori)
- Training
- Model

Monitoring Driving Behaviors (online)
- Data Sensing
  - Acceleration
  - Orientation
- Coordinate Reorientation
- Cutting Driving Behaviors' Patterns
- Identifying
  - weaving
  - fast u-turn
  - swerving
  - sudden braking
  - sideslipping
  - turning with a wide radius
- Alerting

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System Architecture

Modeling Driving Behaviors (offline)

Collected Data

Feature Extracting
- Max (acc_x)
- Min (acc_y)
- Std (ori_x)

Monitoring Driving Behaviors (online)

Data Sensing
- Orientation
- Acceleration

Coordinate Reorientation

Cutting Driving Behaviors’ Patterns
- weaving
- fast u-turn
- swerving
- sudden braking
- sideslipping
- turning with a wide radius

Alerting
Data Collection

• Training Set
  – 6 months: Jan. 11 to July 12, 2014
  – 20 smartphones of 5 types:
    • Huawei Honor3C  ZTE U809  HTC sprint
    SAMSUNG Nexus3  SAMSUNG Nexus4
  – 20 drivers/vehicles:
    • commute to work, shopping, touring
    • 60 – 80 km/day
  – Car DVR: record driving behaviors
  – Totally 4029 abnormal driving behaviors
Pattern Analysis

(a) Weaving

(b) Swerving

(c) Sideslipping

(d) Fast U-turn

(e) Turning with a wide radius

(f) Sudden braking
Weaving

range[accX] – Big
μ[accX] ≈ 0
σ[accX] – Big
T – Long
Swerving

range[accX] – Big
range[oriX] – Big
σ[accX] – Big
σ[oriX] – Big
μ[accX] ≠ 0
T – Short
Sideslipping

\[
\min[\text{accY}] < 0 \\
\mu[\text{accY}] < 0 \\
\text{range}[\text{accY}] \rightarrow \text{Big} \\
\mu[\text{accX}] \neq 0 \\
T \rightarrow \text{Short}
\]
$\sigma[\text{accX}]$ – Big at beginning/end
$\mu[\text{accX}] \neq 0$
$\text{range}[\text{accX}]$ – Big
oriX across 0 point T – Long

**Fast U-turn**
Turning with a wide radius

\[ \sigma[\text{accX}] \approx 0 \]

\[ \mu[\text{accX}] \neq 0 \]

\[ \sigma[\text{oriX}] \approx 0 \]

\[ \mu[\text{oriX}] \neq 0 \]

T – Long
Sudden braking

σ[accX] – Small
σ[accY] – Big
range[accY] – Big
oriX across 0 point
T – Short
Feature Extraction

Normal vs. Abnormal
Weaving vs. Swerving
Weaving vs. Sideslipping
Weaving vs. Fast T-turn
Weaving vs. Turning with a wide radius
Weaving vs. Sudden braking
Feature Extraction

Normal vs. Abnormal
(range[acc,x], range[acc,y])

Weaving vs. Swerving
(σ[acc,x], σ[ori,y])

Weaving vs. Sideslipping
(μ[acc,x], range[acc,y])

Weaving vs. Fast T-turn
(μ[acc,x], max[ori,y])

Weaving vs. Turning with a wide radius
(μ[acc,x], σ[ori,y])

Weaving vs. Sudden braking
(range[acc,x], min[acc,y])
### Machine Learning

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>range(acc_x)</td>
<td>subtraction of maximum minus minimum value of (acc_x)</td>
</tr>
<tr>
<td>range(acc_y)</td>
<td>subtraction of maximum minus minimum value of (acc_y)</td>
</tr>
<tr>
<td>(\sigma_{acc,x})</td>
<td>standard deviation of (acc_x)</td>
</tr>
<tr>
<td>(\sigma_{acc,y})</td>
<td>standard deviation of (acc_y)</td>
</tr>
<tr>
<td>(\sigma_{ori,x})</td>
<td>standard deviation of (ori_x)</td>
</tr>
<tr>
<td>(\sigma_{ori,y})</td>
<td>standard deviation of (ori_y)</td>
</tr>
<tr>
<td>(\mu_{acc,x})</td>
<td>mean value of (acc_x)</td>
</tr>
<tr>
<td>(\mu_{acc,y})</td>
<td>mean value of (acc_y)</td>
</tr>
<tr>
<td>(\mu_{ori,x})</td>
<td>mean value of (ori_x)</td>
</tr>
<tr>
<td>(\mu_{ori,y})</td>
<td>mean value of (ori_y)</td>
</tr>
<tr>
<td>(\mu_{acc,x,1})</td>
<td>mean value of 1(^{st}) half of (acc_x)</td>
</tr>
<tr>
<td>(\mu_{acc,x,2})</td>
<td>mean value of 2(^{nd}) half of (acc_x)</td>
</tr>
<tr>
<td>(\max_{ori,x})</td>
<td>maximum value of (ori_x)</td>
</tr>
<tr>
<td>(\max_{ori,y})</td>
<td>maximum value of (ori_y)</td>
</tr>
<tr>
<td>(\min_{acc,y})</td>
<td>minimum value of (acc_y)</td>
</tr>
<tr>
<td>(t)</td>
<td>time duration between the beginning and the ending of a driving behavior</td>
</tr>
</tbody>
</table>
System Architecture

Modeling Driving Behaviors (offline)

Collected Data

Feature Extracting

Max (acc_x)

Min (acc_y)

Std (ori_x)

Training

Model

Monitoring Driving Behaviors (online)

Data Sensing

Acceleration

Orientation

Coordinate Reorientation

Cutting Driving Behaviors' Patterns

Identifying

weaving

fast u-turn

swerving

sudden braking

sideslapping

turning with a wide radius

Alerting

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Evaluation

• **Metrics:**
  
  **Accuracy:** The probability that the identification of a behavior is the same as the ground truth.

  **Precision:** The probability that the identifications for behavior A is exactly A in ground truth.

  **Recall:** The probability that all behavior A in ground truth are identified as A.

  **FPR:** The probability that a behavior of type Not A is identified as A.
Test Set

- 4 months: July 21 to Nov. 30, 2014
- 20 smartphones of 5 types:
  • Huawei Honor3C
  • ZTE U809
  • SAMSUNG Nexus3
  • HTC sprint
  • SAMSUNG Nexus4
- 20 drivers/vehicles:
  • commute to work, shopping, touring
  • 60 – 80 km/day
- Car DVR: record driving behaviors
- Totally 3141 abnormal driving behaviors
Prototype

D3: abnormal driving behavior detection and identification system

<table>
<thead>
<tr>
<th>Behavior</th>
<th>Count</th>
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<tbody>
<tr>
<td>Weaving</td>
<td>11</td>
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<tr>
<td>Swerving</td>
<td>3</td>
</tr>
<tr>
<td>Sideslipping</td>
<td>4</td>
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<tr>
<td>Fast U-turn</td>
<td>20</td>
</tr>
<tr>
<td>Turning with a wide radius</td>
<td>17</td>
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<tr>
<td>Sudden braking</td>
<td>36</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>91</strong></td>
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</table>

Abnormal Driving Behavior Analysis

Start  Stop

2014-05-11

D3: abnormal driving behavior detection and identification system
# Accuracy Evaluation

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<tr>
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<th>Accuracy(%)</th>
<th>Precision(%)</th>
<th>Recall(%)</th>
<th>FPR(%)</th>
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<tbody>
<tr>
<td>Normal</td>
<td>99.84</td>
<td>98.80</td>
<td>100.00</td>
<td>0.19</td>
</tr>
<tr>
<td>Abnormal</td>
<td>94.81</td>
<td>100.00</td>
<td>99.80</td>
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<tr>
<td>Weaving</td>
<td>98.43</td>
<td>92.55</td>
<td>87.87</td>
<td>0.63</td>
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<tr>
<td>Swerving</td>
<td>97.94</td>
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<td>94.15</td>
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<tr>
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<tr>
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<td>89.30</td>
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<td>0.86</td>
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Conclusion

• We identify sixteen representative features to capture the patterns of abnormal driving behaviors.

• We use a machine learning method, SVM, to train the features of driving behaviors and obtain a classifier model.

• We propose a fine-grained abnormal driving behaviors monitoring system, $D^3$, to perform real-time high-accurate abnormal driving behaviors detection and identification.
Thanks!