DRIVING BEHAVIOR ANALYSIS BY USING SMARTPHONE’S SENSORS AND ITS APPLICATIONS

HA-NAM NGUYEN
CONTENTS

• OUR OBJECTIVES
• CURRENT STATUS OF TRAFFICS IN VIETNAM
• OUR PROPOSAL
  • DATA PREPROCESSING
  • APPLICATION I - VEHICLES CLASSIFICATION
  • APPLICATION II – ACTIVITIES CLASSIFICATION
  • APPLICATION III - ABNORMAL DRIVING BEHAVIOR DETECTION
• CONCLUSION
OUR OBJECTIVES

1. DEVELOP A DRIVING ASSISTANT APPLICATION FOR THE POPULAR PRIVATE VEHICLES IN VIETNAM LIKE MOTORBIKES OR BICYCLES BASED ON SMARTPHONE SENSORS.

2. CONGESTION REDUCTION
CURRENT STATUS OF TRAFFIC IN VIETNAM
CURRENT STATUS OF TRAFFIC IN VIETNAM

<table>
<thead>
<tr>
<th></th>
<th>Bus</th>
<th>Car</th>
<th>Motobike/bike</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hanoi</td>
<td>9%</td>
<td>5%</td>
<td>84%</td>
</tr>
<tr>
<td>Hochimín</td>
<td>11%</td>
<td>6%</td>
<td>85%</td>
</tr>
</tbody>
</table>

Accident ratio of vehicles:
- Other: 6%
- Car: 25%
- Bike/Motobike: 69%

ACCIDENT TYPES:
- Excessive speed: 38%
- Not on the right lane: 7%
- Overtaking improperly: 4%
- Violating of regulation when redirection: 7%
- Don't give way: 9%
- Using alcohol: 9%
- Other mistaken: 26%
LIMITED OF CONVENTION APPROACHES
EXISTING TRANSPORT SUPPORTING DEVICES

Source: https://www.embitel.com
EXISTING TRANSPORT SUPPORTING DEVICES

- MUST BE CHEAP
- EASY TO USE AND TO REPLACE
A REASONABLE SOLUTION?

- SMARTPHONES:
  - LOWER PRICE
  - LIGHTWEIGHT AND EASY TO USE
  - SET OF SENSORS: ACCELEROMETER, GYROSCOPE, GPS, MAGNETOMETER, CAMERA...

- COMPUTATION: POWERFUL

- COMMUNICATION: GPS, WIFI
Population: 93M
Internet Users: 50M+
Mobile Subscription: 130M
Smartphone Penetration: 55% (~48M devices)

Mobile OS Market Share in Vietnam

- Android: 67%
- iOS: 29%
- Other: 4%

Source: MIC, VNPT, internetworldstats
GENERAL FRAMEWORK

Data preprocessing
(smoothing/ normalization/ transformation/ feature extraction)

Data analysis
Frequency Analysis
Statistical Machine Learning

Driving Behaviors
OUR FRAMEWORK

Data preprocessing
- Collecting data from smartphone/ transform and extract relevant information

Ob1: Data preprocessing

Data analysis
- Detect the modality of vehicles (i.e: working, bike, motorbike, car…)

Ob 2: Vehicle classification

Ob 3: Activities detection
- Sub Obj detect the status of drivers on the road (i.e: Stop, Driving, turn left, turn right)

Ob 4: Behavior analysis
- Detect the driving behavior (i.e: normal and abnormal behavior)

Driving Behaviors
SENSORS SELECTION?

- ALWAYS AVAILABLE
- BATTERY CONSUMPTION

Sensors in smartphones (source: http://myphonefactor.in/)
DATA PREPROCESSING

1. Vehicle detection
2. Activity Detection

Frequency-based Data Extraction
Time-based Data Extraction
Hjorth parameters-based Data Extraction

Feature extraction

Time series data (x, y, z)
DATA PREPROCESSING

Fixed position

Smartphone Coordinate

Vehicle Coordinate

Changeable position

transfer axes coordinates

Accelerometers data

window technique

Raw data

Fixed size window

Variable size window
DATA PREPROCESSING

APPLICATION 1 - VEHICLES CLASSIFICATION

Data Preprocessing

Training data

Ground truth

Data Preprocessing

Set of Features

Number of Features

<table>
<thead>
<tr>
<th>Domains</th>
<th>Set of Features</th>
<th>Number of Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (T)</td>
<td>T1</td>
<td>20</td>
</tr>
<tr>
<td>Frequency (F)</td>
<td>F1</td>
<td>04</td>
</tr>
<tr>
<td>Hjorth (H)</td>
<td>H1</td>
<td>03</td>
</tr>
<tr>
<td>T+F+H</td>
<td>TFH1</td>
<td>27</td>
</tr>
</tbody>
</table>
APPLICATION 2 - ACTIVITIES CLASSIFICATION

- walking
- moving
- moving
- idle
- walking

Start driving → Driving → About to stop

Time

STOP MOVING TURN LEFT TURN RIGHT
DATA PREPROCESSING

APPLICATION 2 - ACTIVITIES CLASSIFICATION

Data Preprocessing

Training data

Ground truth

Frequency-based

Time-based

Hjorth parameters

Set of Features

Number of Features

<table>
<thead>
<tr>
<th>Domains</th>
<th>Set of Features</th>
<th>Number of Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>T2</td>
<td>34</td>
</tr>
<tr>
<td>Frequency</td>
<td>F2</td>
<td>07</td>
</tr>
<tr>
<td>Hjorth</td>
<td>H2</td>
<td>18</td>
</tr>
<tr>
<td>T+F+H</td>
<td>TFH2</td>
<td>59</td>
</tr>
</tbody>
</table>
APPLICATION 2 – ACTIVITIES CLASSIFICATION

**Primitive Activities Classification (Offline)**

- Collected data (Accelerometer, Gyroscope, Magnetic sensor)
- Data preprocessing
  - Frequency-based
  - Time-based
  - Hjorth parameters
- Model Training

**Primitive Activities Prediction (Monitoring)**

- Data preprocessing
- Identifying
  - Frequency-based
  - Time-based
  - Hjorth parameters
- Monitoring
  - Go straight
  - Stop
  - Turn left
  - Turn right

**Domains**

<table>
<thead>
<tr>
<th>Domains</th>
<th>Set of Features</th>
<th>Number of Features</th>
<th>Applied Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>T2</td>
<td>34</td>
<td>Activity Detection</td>
</tr>
<tr>
<td>Frequency</td>
<td>F2</td>
<td>07</td>
<td></td>
</tr>
<tr>
<td>Hjorth</td>
<td>H2</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>T+F+H</td>
<td>TFH2</td>
<td>59</td>
<td></td>
</tr>
</tbody>
</table>

(a) Weaving, (b) Swerving, (c) Sideslipping, (d) Fast U-turn, (e) Turning with a wide radius, (f) Sudden braking.

APPLICATION 3 - DRIVING BEHAVIOR DETECTION

NORMAL

STOP
MOVING
TURN LEFT
TURN RIGHT

ABNORMAL
APPLICATION 3 - DRIVING BEHAVIOR DETECTION

Collected data (Accelerometer, Gyoscope, Magnetic sensor)

Model Training
Primitive Activities Classification (Offline)

Frequency-based
Time-based
Hjorth parameters

Frequency-based
Time-based
Hjorth parameters

Identifying

Monitoring data

Monitoring data

W_x

W_y

\[
\begin{align*}
X_1 & \quad X_2 & \quad \ldots & \quad X_{n-2} & \quad X_{n-1} & \quad X_n \\
Y_1 & \quad Y_2 & \quad \ldots & \quad Y_{n-2} & \quad Y_{n-1} & \quad Y_n
\end{align*}
\]

\[
\sum X \leq \sum Y \leq \epsilon
\]

\[
\begin{align*}
& \text{True} \quad \text{NORMAL} \\
& \text{False} \quad \text{ABNORMAL}
\end{align*}
\]
TRAFFIC MONITORING SYSTEM

- Implementation
- Simulation
- Visualization
- Driving behavior model
- Travel model
- Scenarios analysis
- Analysis and planning
CONCLUSION

• TO PROPOSE TWO SET OF RELEVANT FEATURES FOR VEHICLE CLASSIFICATION AND ACTIVITIES CLASSIFICATION

• TO BUILD A FRAMEWORK FOR CLASSIFYING VEHICLE MODALITY AND ITS ACTIVITIES

• TO PROPOSE AND BUILD A NOVEL SOLUTION TO DETECT ABNORMAL BEHAVIOR BASED ON ACTIVITIES IDENTIFICATION
THANK YOU!?
## DATA PREPROCESSING

<table>
<thead>
<tr>
<th>Type</th>
<th>Features</th>
<th>Definition</th>
<th>Applied components</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Statistic</strong></td>
<td><strong>μ</strong></td>
<td>Mean</td>
<td>(a_x, a_y, a_z, \text{a}_{\text{rms}}, \phi, \theta)</td>
</tr>
<tr>
<td></td>
<td><strong>σ²</strong></td>
<td>Variance</td>
<td>(a_x, a_y, a_z, \phi, \theta)</td>
</tr>
<tr>
<td></td>
<td><strong>σ</strong></td>
<td>Standard deviation</td>
<td>(a_x, a_y, a_z)</td>
</tr>
<tr>
<td></td>
<td>Diff = max(x)-min(x)</td>
<td>Difference</td>
<td>(a_x, a_y, a_z)</td>
</tr>
<tr>
<td></td>
<td><strong>R</strong></td>
<td>Cross correlation</td>
<td>((a_x, a_y), (a_x, a_z), (a_z, a_y))</td>
</tr>
<tr>
<td></td>
<td><strong>ZC</strong></td>
<td>Zero crossings</td>
<td>(a_x, a_y, a_z)</td>
</tr>
<tr>
<td><strong>Time domain</strong></td>
<td><strong>PAR</strong></td>
<td>Peak to average ratio</td>
<td>(a_x, a_y, a_z)</td>
</tr>
<tr>
<td></td>
<td><strong>SMA</strong></td>
<td>Signal magnitude area</td>
<td>(a_x, a_y, a_z, \text{a}_{\text{rms}})</td>
</tr>
<tr>
<td></td>
<td><strong>SVM</strong></td>
<td>Signal vector</td>
<td>(\text{a}_{\text{rms}})</td>
</tr>
<tr>
<td></td>
<td><strong>DSVM</strong></td>
<td>Differential signal magnitude</td>
<td>(\text{a}_{\text{rms}})</td>
</tr>
<tr>
<td></td>
<td><strong>I</strong></td>
<td>Integration</td>
<td>(\phi, \theta)</td>
</tr>
<tr>
<td><strong>Hjorth parameters</strong></td>
<td><strong>A</strong></td>
<td>Activity</td>
<td>(a_x, a_y, a_z, \text{a}_{\text{rms}}, \phi, \theta)</td>
</tr>
<tr>
<td></td>
<td><strong>M</strong></td>
<td>Mobility</td>
<td>(a_x, a_y, a_z, \text{a}_{\text{rms}}, \phi, \theta)</td>
</tr>
<tr>
<td></td>
<td><strong>C</strong></td>
<td>Complexity</td>
<td>(a_x, a_y, a_z, \text{a}_{\text{rms}}, \phi, \theta)</td>
</tr>
<tr>
<td><strong>Frequency domain</strong></td>
<td><strong>E_{FFT}</strong></td>
<td>Energy</td>
<td>(a_x, a_y, a_z, \text{a}_{\text{rms}})</td>
</tr>
<tr>
<td></td>
<td><strong>En</strong></td>
<td>Entropy</td>
<td>(a_x, a_y, a_z)</td>
</tr>
</tbody>
</table>