Dynamic Range Prediction for an Electric Vehicle

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The Problem

- EVs have limited autonomy (e.g., 160 km)
- EV charging process is slow
- Missing EV charging infrastructures

Range Anxiety Problem

Fear that an electric vehicle (EV) will run out of charge before it reaches its destination
Range autonomy is based on:

- Vehicle model
- Battery Type
- Battery lifespan
- Battery SOC and SOH levels
- Power train

- Driver behavior (past driver profile)
- Acceleration
- Speed
- Weight
- Charge behavior
- Driving direction

- Traffic flow
- Charge infrastructure
- Temperature
- Wind
- Altitude
- Street consistency
- Personalized Range Prediction
- Range Presentation on a Map
- Information in Real Time on a Mobile Device
- Creation of a Driver Profile
Proposal

- **EVA Vehicle Interface System (VIS)**
- **Charging Functions**
- **Extended Range Navigation**
- **External Interface**
- **Range Prediction Process**
- **Driver Profile**
- **EV Data**
- **Home**
- **Public**
- **POI**
- **Energy Market**
- **Public Transportation**
- **GIS**
- **ENV**

**Inputs:**
- Topology
- Grade
- Road Type
- Traffic
- Wind
- Temperature
- Charge cycle
- Driving Style
- Consumption profile
- Trips profile
- EV energy parameters
- EV type
- Battery type
- Battery age

**Outputs:**
- Home
- Public
- POI
- Energy Market
- Public Transportation
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General Overview

Driver Profile
- Range Prediction
- Collaborative Broker

Main Functions
- IVCharging
- EV
- Electricity Market
- Transportation & Infrastructure

- Smart Charging
- Reserve Charging slots
- Remote Interaction
- Energy transactions Logs

- Range Representation
- Route Guidance
- Charge need to reach destination

- Aggregation of EV for market participation
- DER
- Profit share
- Exchange Account

- SoC
- Speed
- Temp...

- Prices
- Energy production information

- Transportation information (price and schedules)
- Parking places
- Traffic Information
- PoI
Driver Profile

Electric Vehicle 2

Electric Vehicle 1

Driver 1

Driver 2

Driver N

V2* App

V2* App

V2* App

Driver Profile (DP)

V2* Server

D11 – DP for driver 1 on EV1
D12 – DP for driver 1 on EV2
D21 – DP for driver 2 on EV1
DN1 - DP for driver N on EV1
Analyses of transactions data can be useful information for future charging or discharging processes, taking into account a smart charging strategy to combine distribution network limitation and low prices. All of this information is stored on the information repository on the central server. If internet communication is available, the driver can check remotely the home charging process, and interact with it, if he wants to.
Data mining approach combines past data of driver profile, with current information of EV (speed, SOC level), weather information and traffic.
Average Energy Consumption key influencing factors
## Data from ICE engine

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Values</th>
<th>Probability</th>
</tr>
</thead>
</table>
| Clutch Usage Per 100 Km | < 276.5929 | ![](blue_bar)
| Time Percentage With Engine Rotation In Yellow Band | < 1.764227 | ![](blue_bar)
| Clutch Usage Per 100 Km | 276.5929 - 604.5859 | ![](blue_bar)
| Inertial Time Traveled Percentage | 5.69054 - 9.32074 | ![](blue_bar)
| Time Percentage With Engine Rotation In Idle | 24.22572 - 31.11111 | ![](blue_bar)
| Time Percentage With Engine Rotation In Idle | < 24.22572 | ![](blue_bar)
| Day Part Segment | Daytime | ![](blue_bar)
| Day Part Segment | Morning rush hour | ![](blue_bar)
| Day Part Segment | < 5.69054 | ![](blue_bar)
| Day Part Segment | 1.764227 - 8.485124 | ![](blue_bar)
| Day Part Segment | 31.11111 - 38.81707 | ![](blue_bar)
| Day Part Segment | 9.32074 - 14.88033 | ![](blue_bar)
| Day Part Segment | Post afternoon rush hour | ![](blue_bar)
| Day Part Segment | Afternoon rush hour | ![](blue_bar)
| Day Part Segment | Nighttime | ![](blue_bar)
| Time Percentage With Engine Rotation In Yellow Band | >= 28.98299 | ![](blue_bar)
| Time Percentage With Engine Rotation In Idle | 36.81707 - 43.21214 | ![](blue_bar)
| Day Part Segment | Pre morning rush hour | ![](blue_bar)
| Time Percentage With Engine Rotation In Yellow Band | 8.485124 - 19.31218 | ![](blue_bar)
| Time Percentage With Engine Rotation In Idle | 19.31218 - 28.98299 | ![](blue_bar)
| Inertial Time Traveled Percentage | >= 23.44407 | ![](blue_bar)
| Inertial Time Traveled Percentage | 14.88033 - 23.44407 | ![](blue_bar)
| Clutch Usage Per 100 Km | 604.5859 - 976.6519 | ![](blue_bar)
| Time Percentage With Engine Rotation In Idle | >= 43.21214 | ![](blue_bar)
## Data from ICE engine

### Attribute profiles

<table>
<thead>
<tr>
<th>Attribute</th>
<th>States</th>
<th>Population (All)</th>
<th>Predicted</th>
<th>Average Fuel Consum.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clutch Usage Per 300 Km</td>
<td>c 276.5523 276.5529 624.5859</td>
<td>67.02544 - 79.53213</td>
<td>55.7322 - 67.02544</td>
<td>44.74324 - 55.7322</td>
</tr>
<tr>
<td>Day Park Segment</td>
<td>Morning rush hour Afternoon rush hour Post afternoon rush hour Other</td>
<td>5.635054 - 9.320704</td>
<td>&lt; 5.635054</td>
<td>&lt; 4.46967</td>
</tr>
<tr>
<td>Time Percentage With Engine Rotation In Idle</td>
<td>24.21572 24.21572 - 51.11111</td>
<td>51.11111 - 36.81707</td>
<td>&gt; 36.81707</td>
<td>Other</td>
</tr>
<tr>
<td>Time Percentage With Engine Rotation In Yellow Band</td>
<td>1.794227 1.794227 - 8.485124</td>
<td>8.485124 - 19.31218</td>
<td>&gt; 19.31218</td>
<td>Other</td>
</tr>
</tbody>
</table>

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Range Representation Process

1. ID range autonomy
2. Range is more than 1/3 of the maximum range?
   - Direct distance is based on GPS coordinates (vector distance)
   - EV GPS coordinates
3. ID City in a direct distance of range autonomy - 15%?
4. Calculate real distance using Google Maps API
5. ID Villa in remain range using a direct distance
   - Calculate city near by villa distance using Google Maps API
   - List of Villa with GPS coordinates
6. Map range representation

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[Organizational logos and names]
EVA Portal in MVC (Model View Controller) approach. EVA Server and Application architecture.
Range Representation in a trip:

1) Starting point of the EV with full charge
2) After 25 km of trip
3) After 100 km of trip
4) After 150 km of trip
The red shadow is a range that is possible to achieve, but for which the driver needs to perform driving optimization (with air conditioner off and avoiding big accelerations). This could be a helpful information, because the driver can customize his behavior in function of the range he needs to achieve in his trip. This process can be continuously updated, and thus, when the SOC level is low, this uncertainty is also low.
Range Representation on a Charging Process

Range Representation with SOC level in 5%

Range Representation with SOC level in 80%
Results - Range prediction interaction process:

(a) EV position; (b) Available functions; (c) Range representation.
Screens of the EVA mobile application of the route paths near the limit of the EV range autonomy.

Screens of the EVA mobile application related with details about Charging Stations (CS) and Points of Interest (POI).
Results

Screens of the EVA mobile application:
(a) Guidance to Charging Stations (CS) and Points of Interest (POI);
(b) Alert of insufficient charge to reach a desired destination.

Screens of the EVA mobile application getting past information from historical events data.
The current work has as main goal to minimize the driver range anxiety problem by:

1. an accurate EV range prediction based on past driver behavior, batteries SOC level and external parameters, like road characteristics, traffic conditions and weather;

2. range representation on a map taking into account current driver position with an uncertainty associated with driver behavior.

Other important work output is the historical driver profile data that can be used to establish driver communities profiles (drivers with similar behavior), and from this information start driver education towards energy savings.
Thank you for your attention.