Unsupervised Detection of Harsh Cornering Behavior using Smartphone Telematics & Maps

Aristotelis Tsoutsanis[1,2], Apostolos Ziakopoulos[1], Zoe Vasileiou[2], George Yannis[1]

[1]National Technical University of Athens, Department of Transportation Planning and Engineering, Athens, Greece

[2]OSeven Telematics, Athens, Greece

Take-home message: Harsh cornering can be detected at scale using only smartphones and maps, without labels.

Motivation

- **Harsh cornering** is strongly linked to vehicle instability and crash risk.
- Existing telematics approaches:
  - Require fixed smartphone orientation or OBD.
  - Rely on labeled data.
- These assumptions fail in real-world, large-scale deployments.

Goal: Detect safety-relevant harsh cornering events robustly, unsupervised, and at scale.

Data & Core Idea

Data sources:
- Smartphone sensors (accelerometer, gyroscope, orientation)
- GPS (location, speed, heading) at 1Hz
- OpenStreetMap (road intersections)

Dataset:
- 4,017 naturalistic trips
- 1,76 million data points
- Urban and suburban driving (Attica region, Greece)

Key Idea:
A harsh cornering event must be:
1. **Dynamically extreme** (high yaw / inertial response), and
2. **Spatially plausible** (aligned with real road geometry)

The final dataset consists of all the cornering maneuvers in Athens, Greece. As shown in Figure 1, most turns involve angles ranging from 70° to 180°, while vehicle speeds during maneuvers are typically concentrated below 40km/h, consistent with expected driving behavior in urban environments. The final dataset is approximately 1,900 high-confidence cornering events in Attica region, Greece.

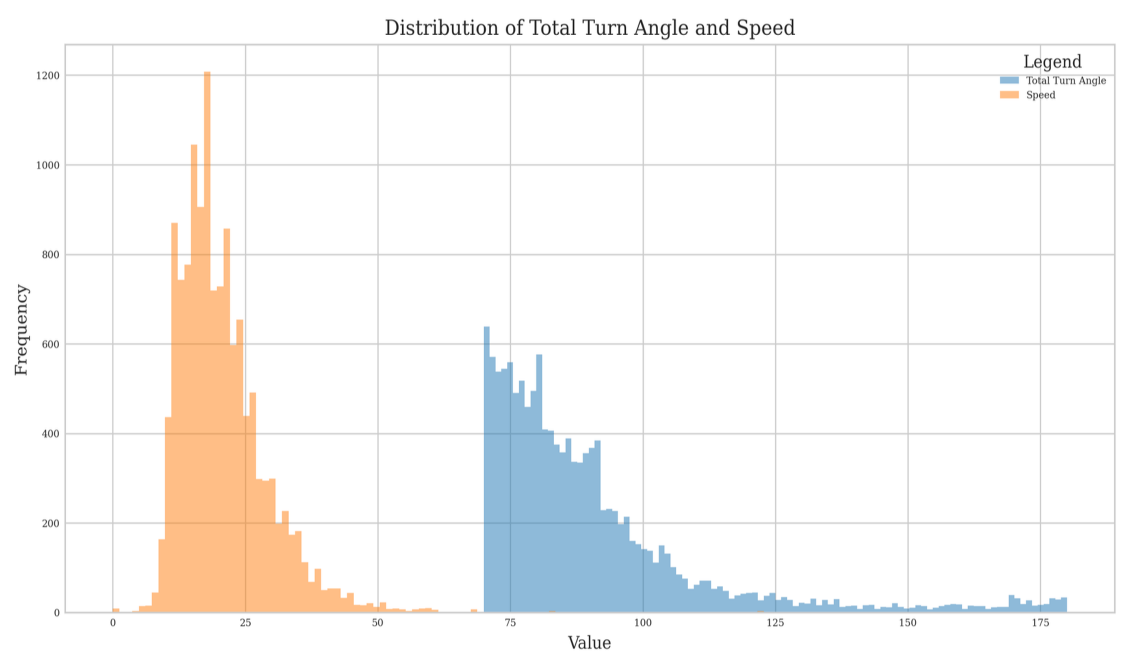

Figure 1: The histogram shows the distribution of total turn angles (blue) and vehicle speeds (orange) across all turning events.

Methodology

- **Turn Detection**
  - GPS-based yaw rate and cumulative heading change
  - Turns ≥ 60° over a 4-second horizon
  - Filters out minor lane changes and noise
- **Map-Based Validation**
  - Candidate turns validated near OSM-mapped intersections (15m radius)
  - Reduces false positives caused by GPS jitter
- **Orientation-Invariant Feature Extraction**
  - Use sensor magnitudes:
    - Acceleration magnitude
    - Gyroscope magnitude
  - Combine with yaw rate (GPS), speed
- **Unsupervised Harsh Detection**
  - DBSCAN (ε selected via k-distance heuristic)
  - Isolation Forest
  - Ensemble of both methods for robustness

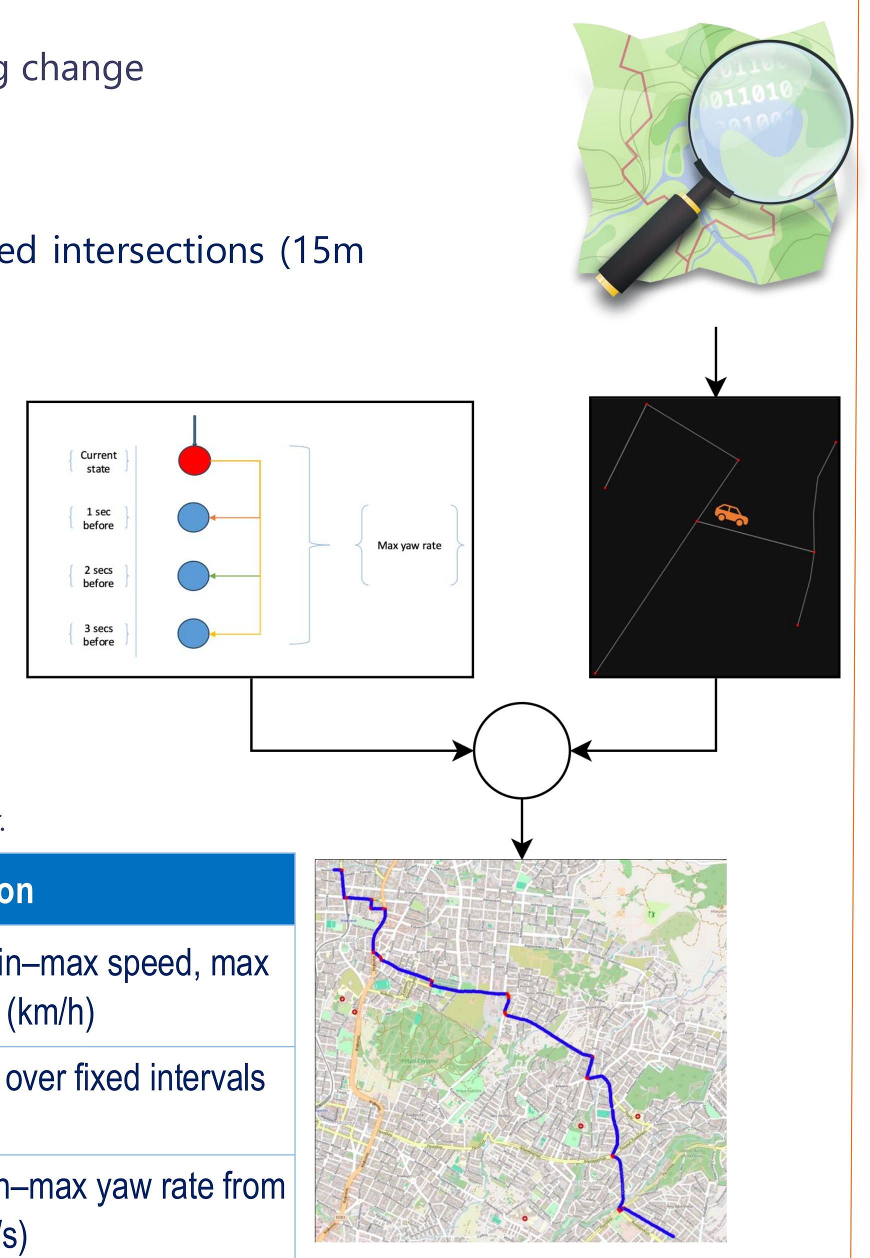

Figure 2: Turn detection pipeline

Table 1: Extracted features for each turn event.

Feature group	Description
Speed	Entry speed, exit speed, min–max speed, max speed change (km/h)
Turn geometry	Maximum heading change over fixed intervals (°)
Yaw rate	Max yaw rate from GPS; min–max yaw rate from device (°/s)
Acceleration magnitude	Min–max acceleration magnitude (m/s²)
Gyroscope magnitude	Min–max angular velocity magnitude (rad/s)

- After validation, as shown in Figure 2, the resulting dataset comprises approximately 1,900 high-confidence cornering events in Attica region of Greece, which form the basis for downstream clustering and anomaly detection.

- After feature extraction, as shown in Table 1, we standardize the feature matrix using z-score normalization and we apply **DBSCAN** to identify harsh cornering events. It **explicitly labels as noise** those points that do not belong to any dense region. In our setting, this noise corresponds to **abnormal** or **harsh turning events**. In addition, we use the **Isolation Forest**, as a complementary detector, for detecting anomalous cornering behaviors.

- **Validation via Classifier-Based Separability:** evaluated how well the extracted features could separate harsh and normal turns using a supervised learning proxy using the ensembled labels.
  - Logistic regression
  - Random Forest
  - Applied 5-fold cross-validation using ROC-AUC as the evaluation metric
  - Feature importance from the Random Forest

Results

Table 2 summarizes the overlap and divergence between DBSCAN and Isolation Forest in detecting harsh cornering events. Only 50 harsh corner events were detected by both, representing nearly 3% of the entire dataset. DBSCAN contributed to 22 unique detections, typically involving sharp turns with high yaw rates, while Isolation Forest identified 26 distinct events characterized by subtle but higher speeds as shown in Figure 3. The complementary nature of these results supports the use of an ensemble approach that combines both methods to improve detection robustness. Figure 4 shows two examples of harsh corner events that were detecting by our ensemble pipeline.

Table 2: Summary of harsh cornering detections by DBSCAN and Isolation Forest.

Method	Harsh Corners Detected	Unique Events
DBSCAN	72	22
Isolation Forest	76	26
Intersection (Both)	50	-

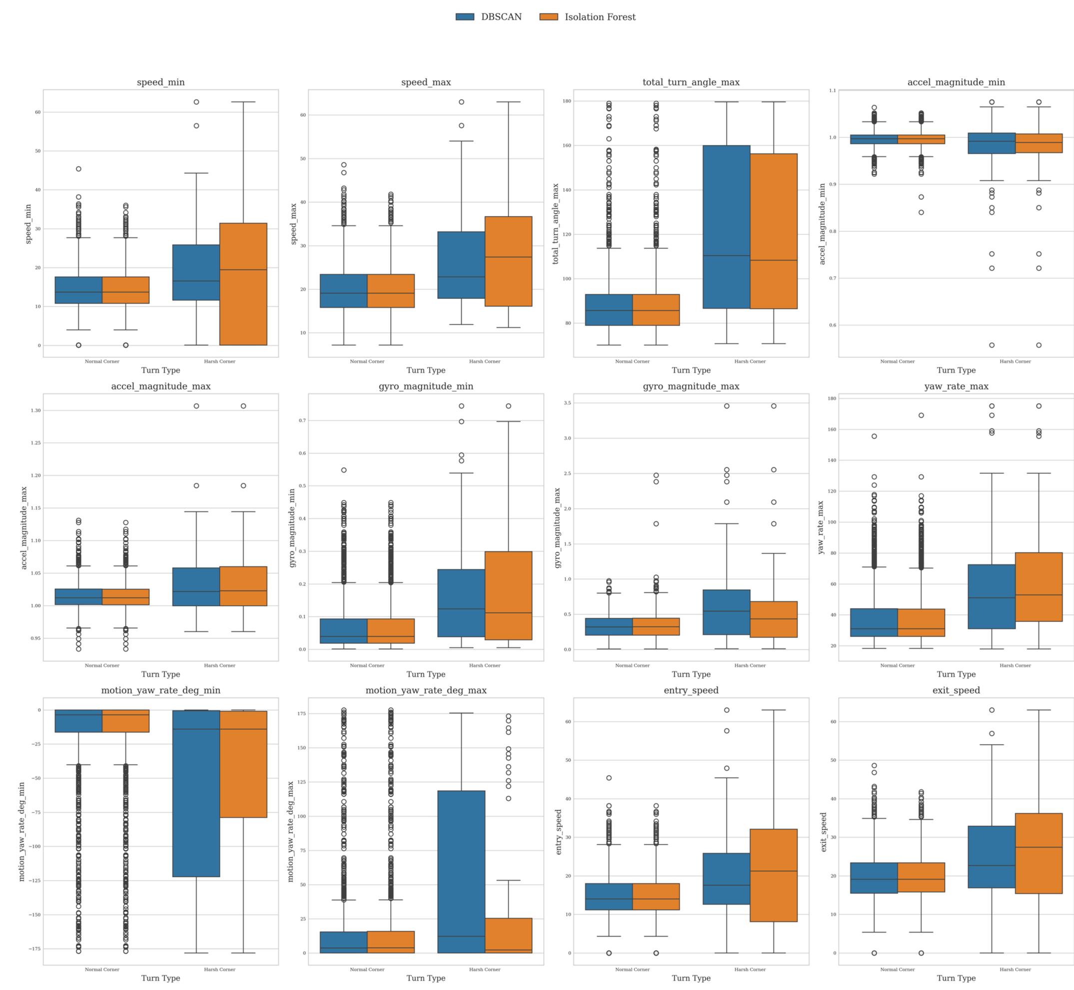

Figure 3: Comparison of feature distributions per method of harsh cornering and normal turns.

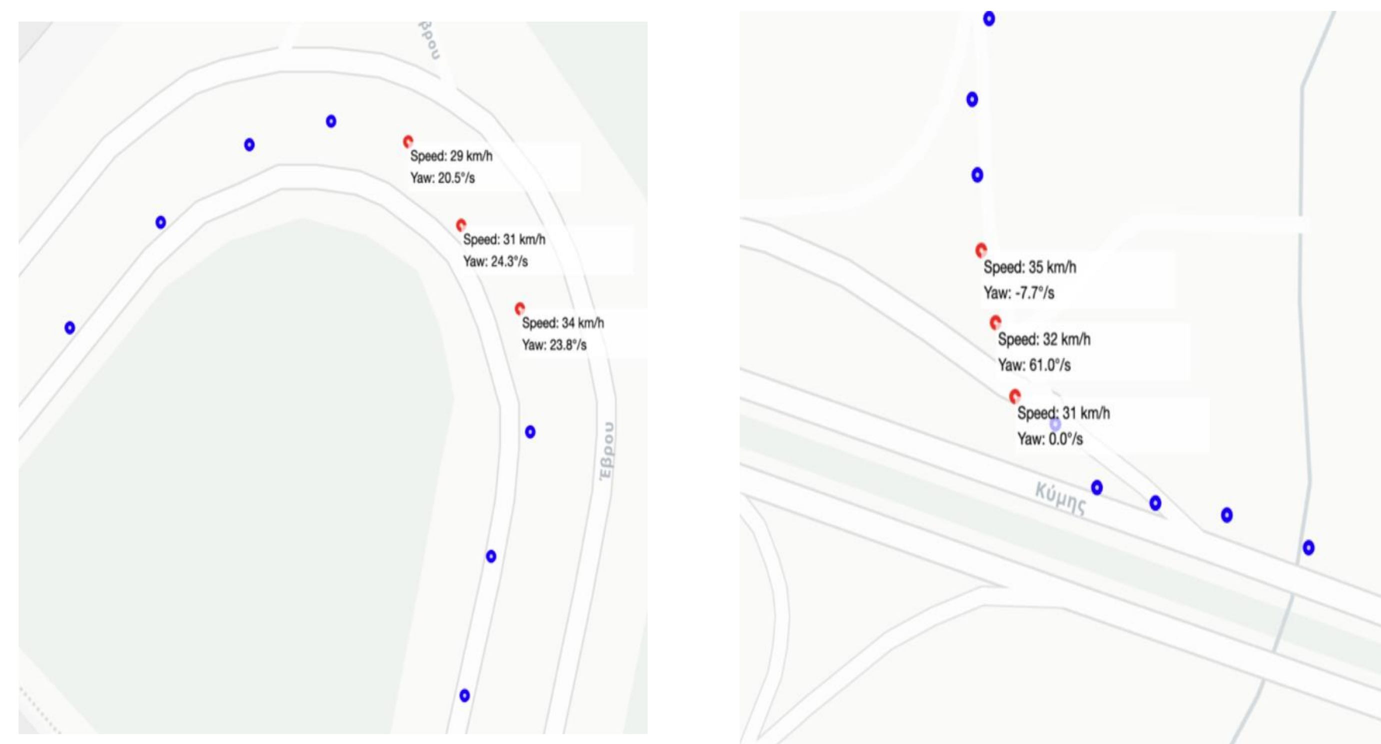

Figure 4: (a) Example of harsh right turn with a speed above 30km/h (b) Example of a harsh right turn at a speed of 32km/h, the vehicle undergoes a sharp change marked by a yaw rate of 61°/s.

Key Takeaways

- Fully unsupervised harsh cornering detection
- Robust to smartphone placement and orientation
- Requires only commodity smartphones and open maps
- Scalable to large fleets and real-world deployments

Limitations

- Sampling at 1 Hz restricts the granularity of yaw rate estimation
- Lack of labeled ground truth data precludes formal validation
- The use of OpenStreetMap for validating turns assumes high-quality and up-to-date map data, which may not hold true in all regions

Acknowledgments

IVORY

This research has been conducted within the IVORY project. The project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101119590.

Contact Information:
Aristotelis Tsoutsanis, MSCA Researcher
Department of Transportation Planning and Engineering, NTUA
OSeven Telematics
Email: atsoutsanis@oseven.io , a_tsoutsanis@mail.ntua.gr
Linktree: https://linktr.ee/atsoutsanis

105th Annual Meeting of the Transportation Research Board
January 11-15, 2026, TRBAM-26-01984

TRB ANNUAL MEETING