PHOEBE Project

Athens Use Case – Video Recognition

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This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101076963

UK participants in Horizon Europe Project PHOEBE are supported by UKRI grant numbers 10038897 (The International Road Assessment Programme – iRAP) and 10056912 (The Floow)

Locations Spots

	Road Axes	Observed Metric
Spot 1	Leof. Vasileos Konstantinou	Speeding, Illegal Crossing
Spot 2	Leof. Vasilissis Amalias	Speeding, Illegal Crossing, (Jaywalking)
Spot 3	Leof. Vasilissis Amalias (Syntagma)	Speeding, Illegal Crossing, (Jaywalking)
Spot 4	Leof. Vasilissis Sofias	Speeding, Illegal Crossing, Jaywalking
Spot 5	Leof. Vasilissis Sofias-Panepistimiou	Illegal Crossing, Jaywalking
Spot 6	Panepistimiou-Korai	Illegal Crossing, Jaywalking
Spot 7	Panepistimiou-Santaroza	Illegal Crossing, (Jaywalking, Speeding)
Spot 8	Panepistimiou-Plateia Omonoias	Illegal Crossing, Jaywalking

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Video recordings details

The video recordings were conducted:

- in **8 locations**
- for **1-hour peak time**
- for **1-hour off-peak time**
- for **2 working days of a week (Tuesday and Thursday)**
- for **2 weeks of a month**

In total **64 hours of video** were collected, 8 hours for each location.

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Video data

Spot 3: Leof. Vasilissis Amalias -> Speeding, Illegal Crossing, (Jaywalking)

Spot 5: Leof. Vasilissis Sofias-Panepistimiou -> Illegal Crossing, Jaywalking

Spot 1: Leof. Vasileos Konstantinou -> Speeding, Illegal Crossing

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Tracking Logic (1)

The system uses a **multi-step tracking logic** that includes:

1. Object detection and YOLOv8 detector

- a neural network-based object detection framework, detecting objects **including pedestrians and vehicles**,
- in each frame of the video, **outputting bounding boxes** and confidence scores for each detected object.

2. Kalman filter-based prediction

- A recursive predictive algorithm that **estimates the position and velocity of objects** based on noisy observations.
- Kalman filter tracks continuous movement, objects can become occluded or temporarily disappear from the scene (e.g., a pedestrian walks behind a vehicle).

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Tracking Logic (2)

3. Hungarian Algorithm

Detected objects are **matched with tracked ones**, which is crucial for maintaining consistent identities.

4. Apply Savitzky-Golay Filter for Unmatched Objects

Is applied to **smooth the trajectory of tracked pedestrians** and vehicles that have temporarily gone unmatched

5. Re-identification

When they reappear, the Re-ID network helps **associate them with the correct history** by comparing their visual appearance (ResNet-50 features) and the Re-ID feature vectors.

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Homography and Ground Plane Projection

- Project points from the **2D image space** (the video frames) **into a real-world 2D plane** (the ground plane).

- This projection is necessary for **accurately determining whether pedestrians or vehicles** are inside certain regions, like crosswalks, which are defined in real-world coordinates.

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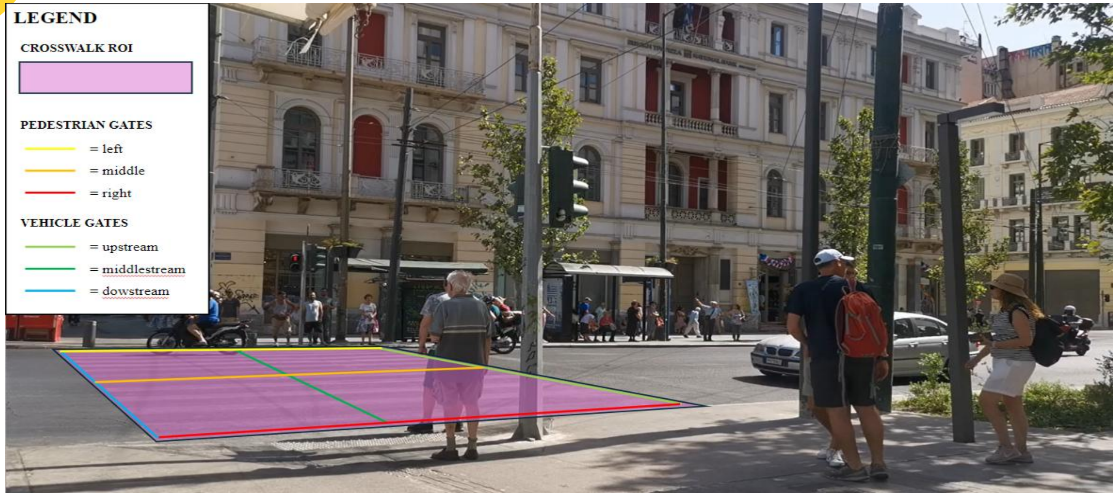
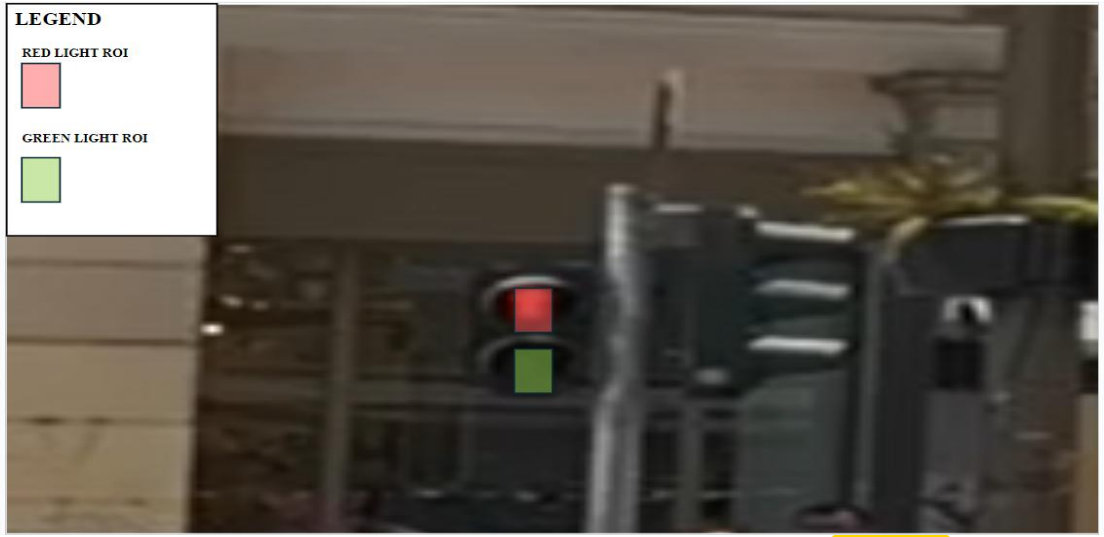
ROI and Traffic Light Detection



Projected Object Behavior Analysis

- The algorithm checks their positions relative to Regions of Interest (ROI), which define critical areas such as crosswalks or traffic light positions.
- If a **pedestrian** is found inside the crosswalk during a pedestrian red traffic light, their behavior is **flagged as illegal**.
- Similarly, vehicles entering the crossing area during a pedestrian green traffic light are flagged as illegal.



Traffic Light Detection

- The traffic light detection component isolates the regions corresponding to the traffic lights using Regions of Interest (ROIs) and **applies color segmentation** to determine whether the light is red or green.

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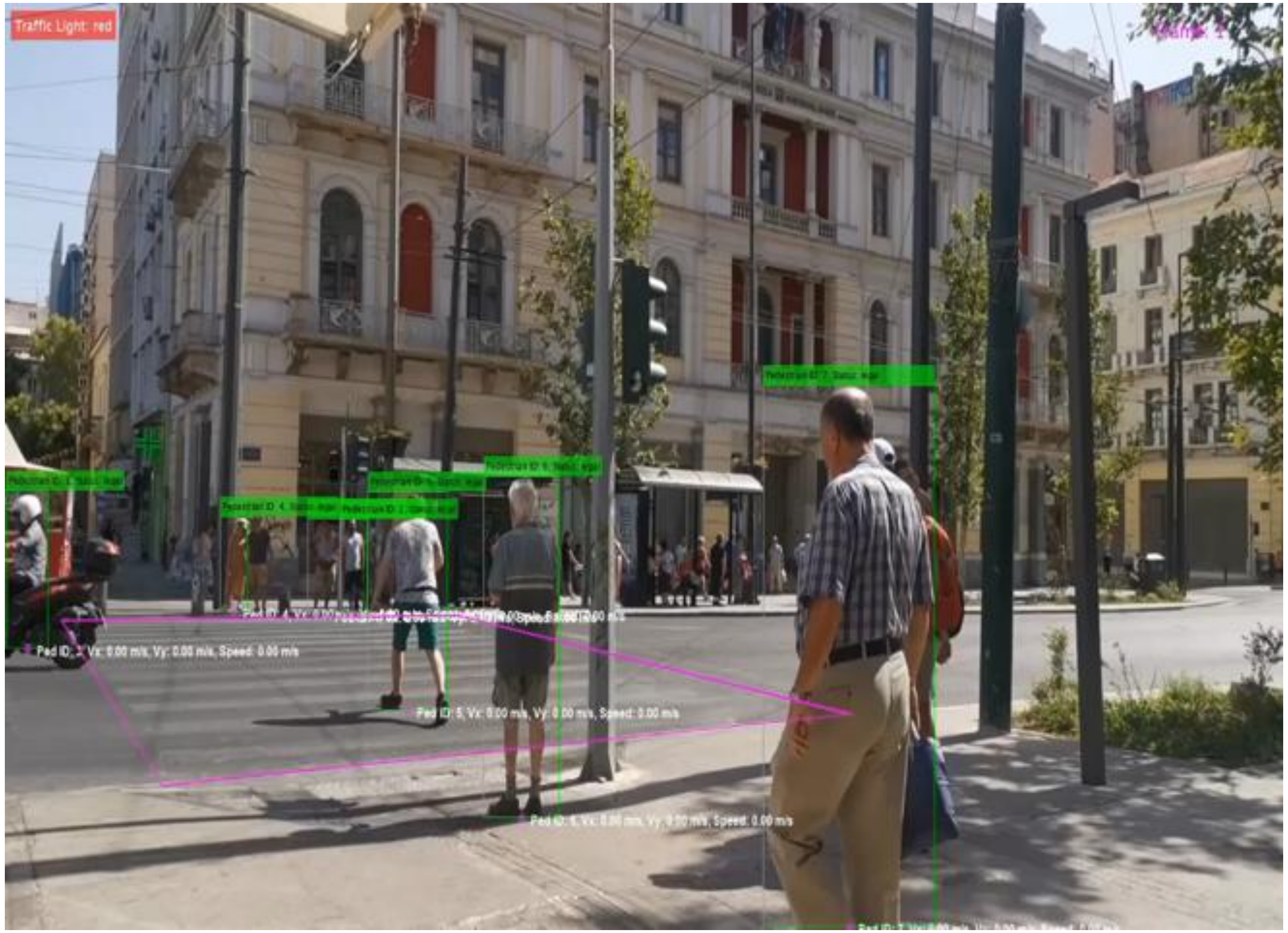
Results (1) –
Legal and Illegal Behavior Detection



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Results (2) – Static Map

A satellite map image is used as the underlying reference frame to provide a real-world spatial context.

1. Satellite Image as a Base:

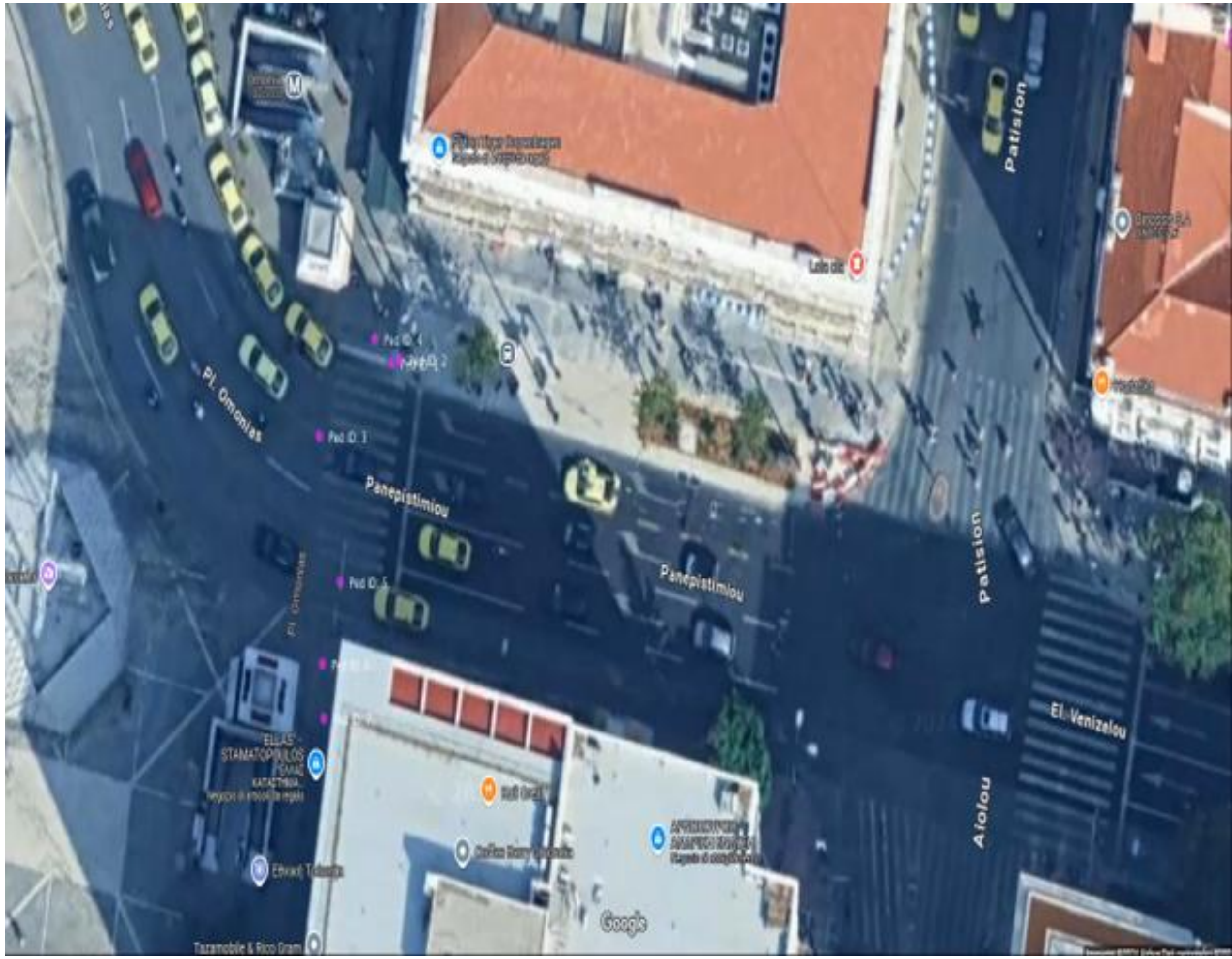
- The ground video utilizes a static Google Maps image of the observed area, offering an overhead view.
- This map serves as the real-world reference for visualizing object movements.

2. Position Projection via Homography:

- The real-time positions of pedestrians and vehicles, detected from the on-street video, are projected onto the Google Maps image using homography transformation.
- This allows objects detected in the video frames to be accurately placed on the ground plane of the map, reflecting their actual locations in the real-world coordinates.

3. Dynamic Object Overlay:

- As pedestrians and vehicles are tracked in the street video, their positions are updated and shown as moving points or icons on the static Google Maps image.
- This provides an overhead view of the area, illustrating the paths of the objects over time.



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Speed, TTC & PET Calculation

Speed

- Speed is calculated by measuring the displacement of the object over time. For each tracked pedestrian or vehicle, the **algorithm estimates their velocity based on their change in position** (world coordinates) across frames.
- To ensure realistic speeds, the algorithm imposes a maximum plausible speed: **10 m/s for pedestrians and 40 m/s for vehicles**.
- Speeds exceeding these thresholds are discarded to avoid inaccuracies caused by noise or sudden false detections.
- The algorithm uses Median Absolute Deviation (MAD) to remove outliers in the speed calculations.

Time to Collision (TTC) & Post Encroachment Time (PET)

- For each pair of tracked pedestrians and vehicles, the algorithm computes the relative position and velocity vectors. The relative velocity between a pedestrian and a vehicle is calculated as the difference between their velocity vectors.
- If the pedestrian and vehicle are moving toward each other, the **TTC/PET is positive, indicating a potential collision**. If they are **moving apart, the TTC/PET is infinite**.
- It calculates and stores the TTC/PET for every pedestrian vehicle pair and highlights the pair with the minimum TTC/PET for each frame. This value determines which pairs are at the highest risk of collision and can be used for safety warnings or interventions.

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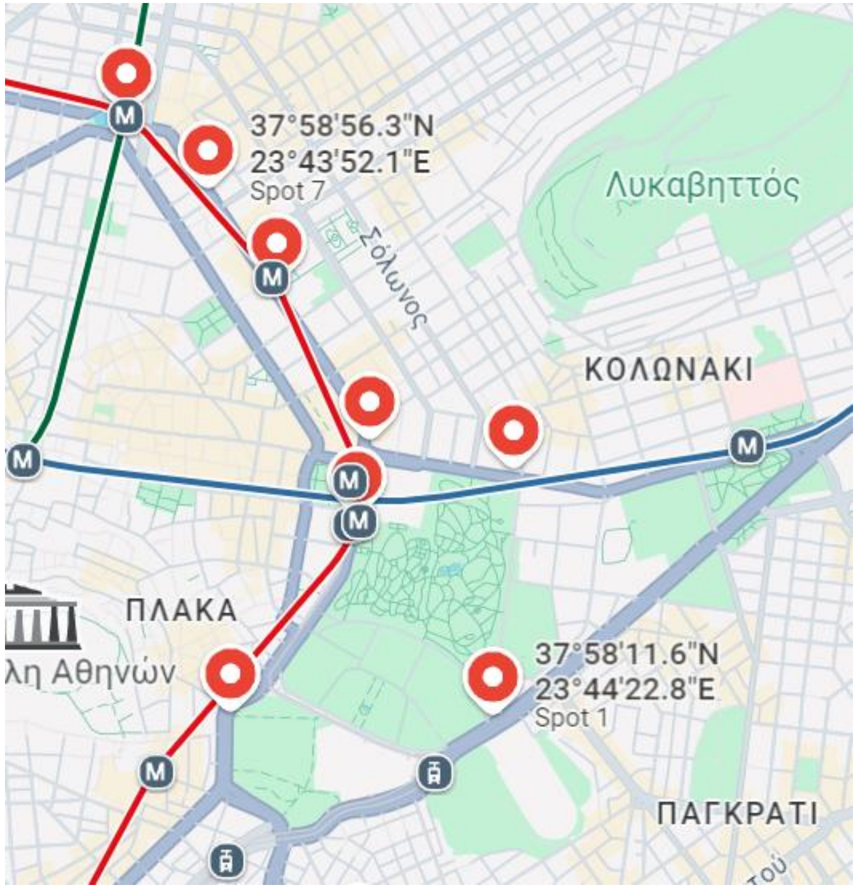
KPIs

- This algorithm tracks **pedestrians and vehicles**
- Determines their **legal/illegal behavior** with respect to traffic lights, and
- Calculates **the time to collision (TTC) and Post Encroachment Time (PET)** by an advanced multi-stage approach.
- The ground video, combined with the tracking algorithm, allows for the real-time detection, tracking, and analysis of traffic participants, ensuring safe and efficient monitoring of urban environments



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