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Robust Nighttime Vehicle Detection Based on Foveal Classifiers

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Introduction

- **Growing interest in vehicle surveillance:**

Safety, security and flow

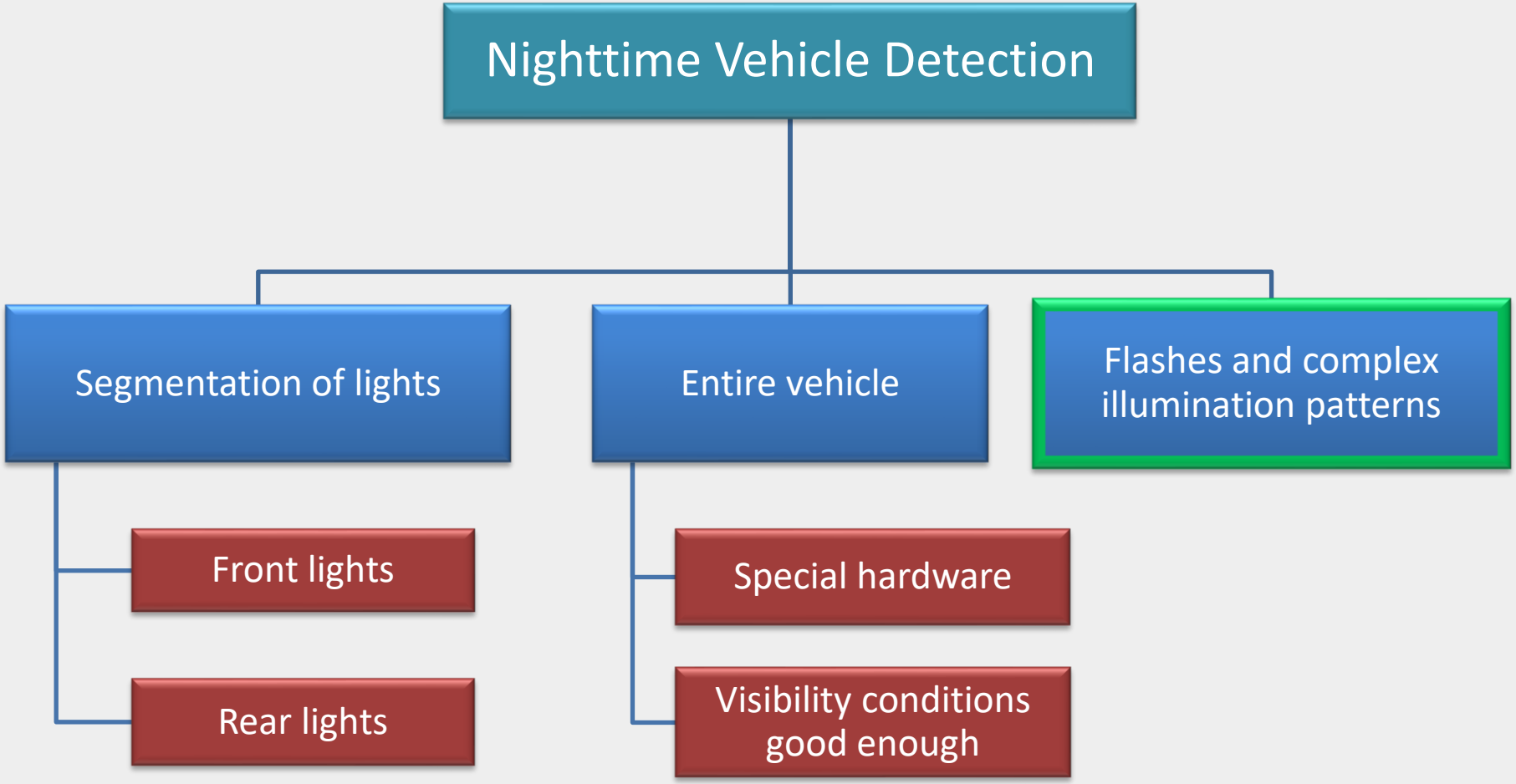
Relevant applications

The peak of video technologies

Adverse environments

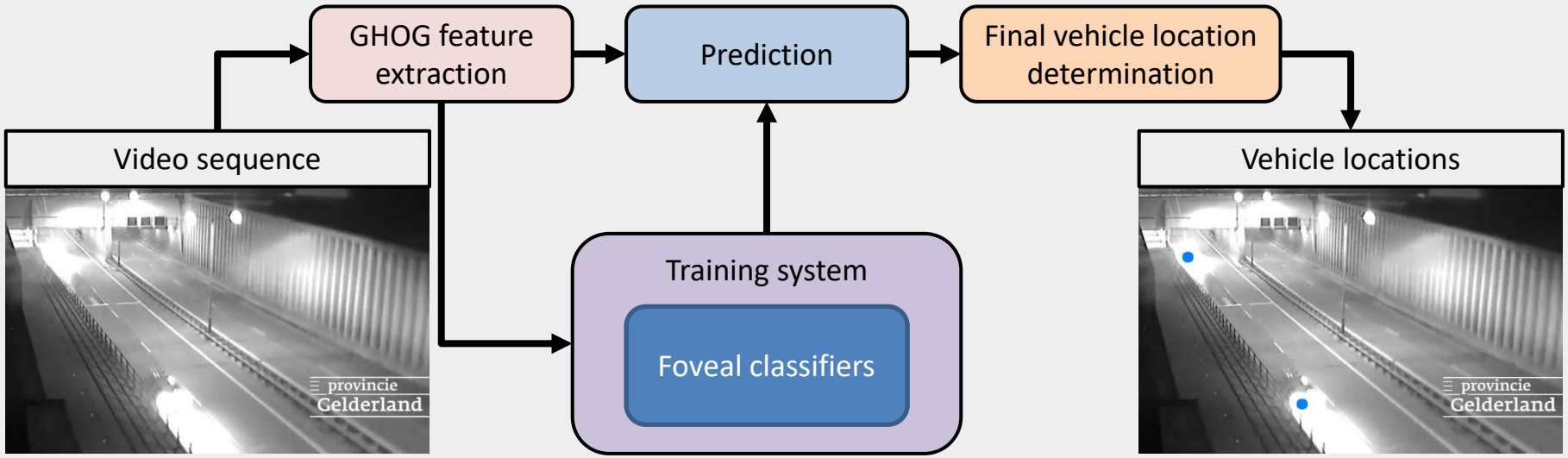
State of the art

- **Proposed taxonomy based on the approach:**



Nighttime Vehicle Detection System

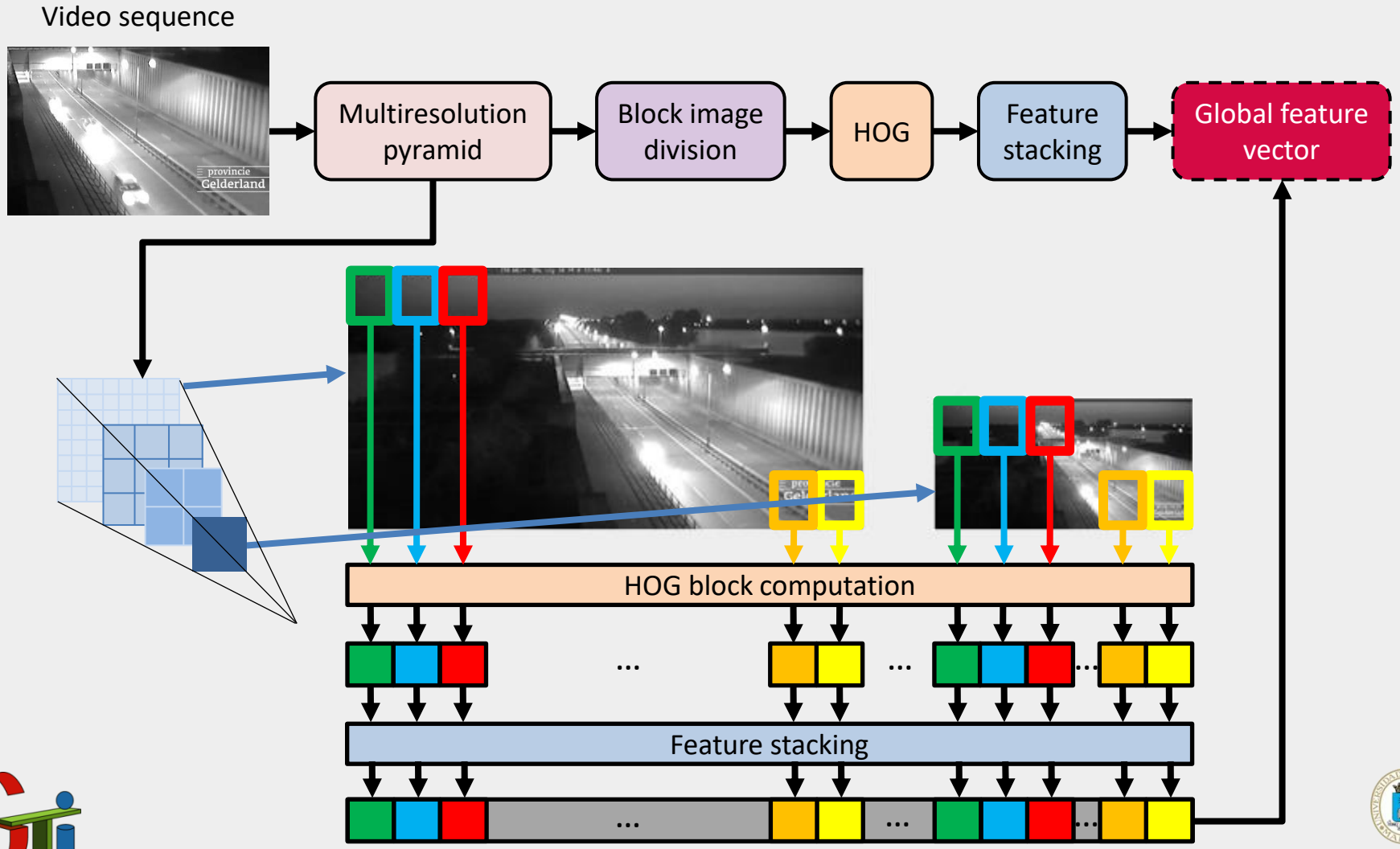
- **System overview:**



- **General features:**
  - Robustness to different illumination patterns and flashes.
  - Feature extraction: a single vector per image.
  - Prediction: spatial grid of foveal classifiers which share the same image descriptor.

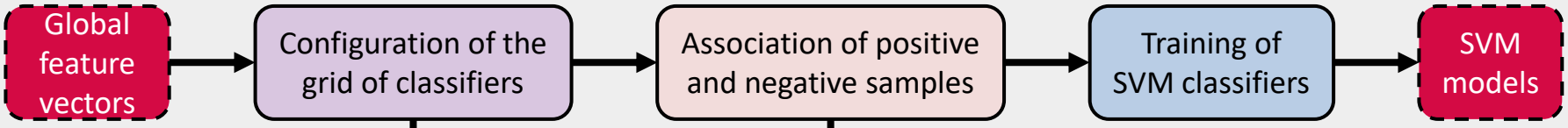
Nighttime Vehicle Detection System

- **GHOG feature extraction:**

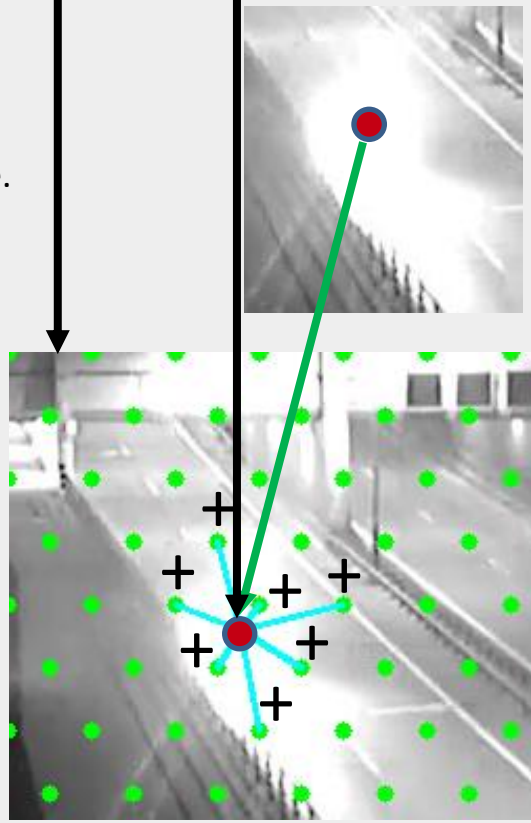


Nighttime Vehicle Detection System

- **Training:**

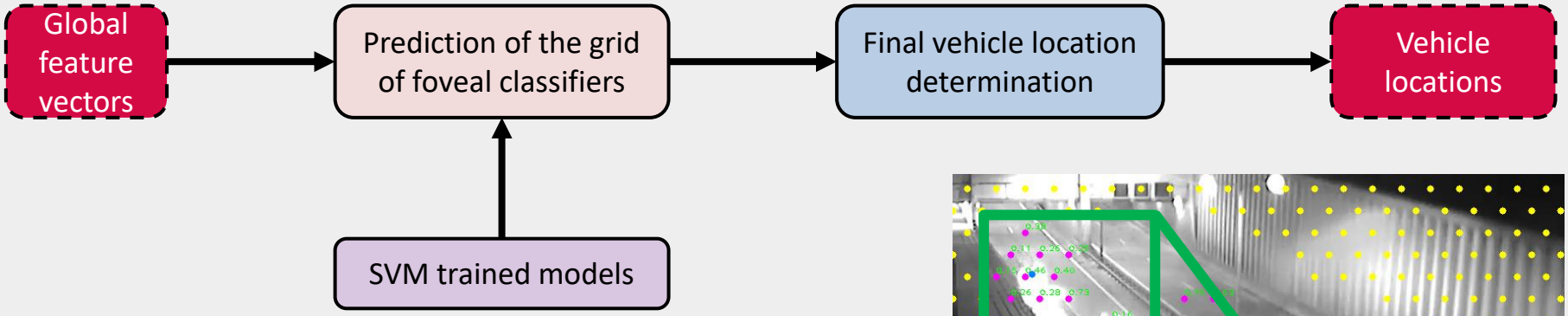


  - Grid of foveal classifiers:
    - Each one focused on a learned foveal region.
      - Represented by a reference point in the image.
    - Regular hexagonal geometric pattern used.
    - SVM for the implementation of the classifiers.
  - Dynamic association of samples based on distances:
    - Between the point-based ground-truth of a vehicle and the reference point of a classifier.
    - For a classifier, the common feature vector of an image:
      - Positive sample if distance ≤ threshold.
      - Negative sample if not.

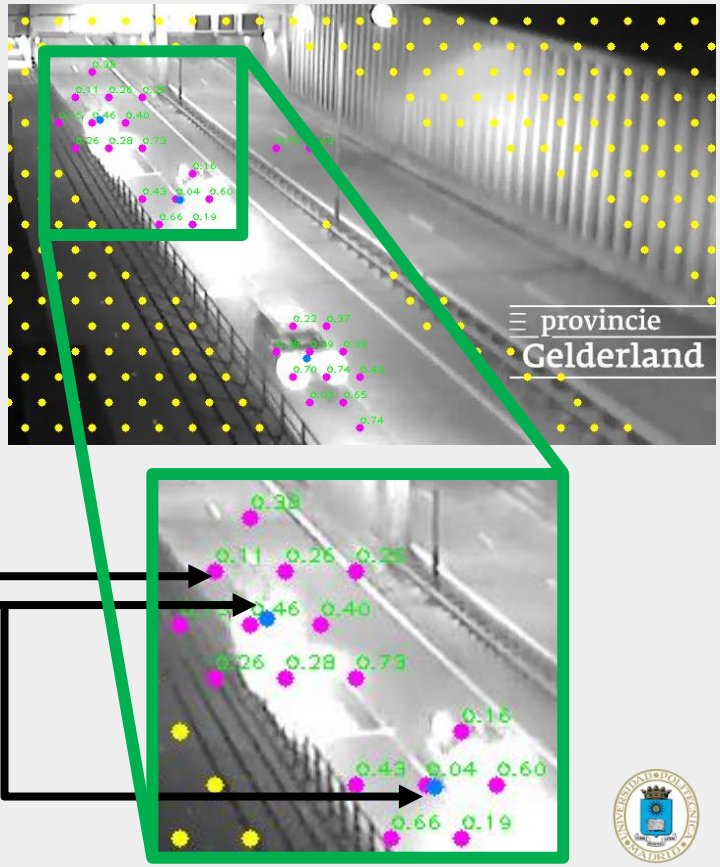


Nighttime Vehicle Detection System

- **Prediction and final vehicle location determination:**



  - Prediction of each foveal classifier using the common feature vector:
    - Determination of the presence of a vehicle in the fovea of a classifier.
  - Fusion of predictions and non-maxima suppression algorithm to filter and refine point-based detections.



Databases

- **Nighttime Vehicle Database (NVD):**
  - Sequences from a surveillance camera on a highway in Gelderland (Netherlands).
  - Manual annotations of vehicle centroids.
  - 15 sequences and 14970 frames.
  - Video characteristics:
    - Image resolution: 1280 x 720.
    - Framerate: 25 fps.
    - High compression.

Results

- **Vehicle detection results:**
  - Adaptation of Faster R-CNN to point-based detections.
  - Advantages of the proposed system in practical deployment.
  - Flexibility in real-time requirements.

Proposed system								
Sequence	Grid resolution	# trained classifiers	P	R	F	μ_D	σ_D	$\bar{t}$ CPU (ms)
Seq3	37 x 50	327	0.988	0.902	0.943	7.134	4.894	52
Seq4			0.930	0.892	0.911	10.170	8.380	52
Seq6			0.979	0.923	0.950	8.890	6.920	52
Average			0.966	0.906	0.935	8.731	6.731	52
Adapted Faster R-CNN								
Sequence	RPN anchor scales	RPN NMS threshold	P	R	F	μ_D	σ_D	$\bar{t}$ GPU (ms)
Seq3	(16, 32, 64, 128, 256)	0.7	0.970	0.926	0.948	5.024	5.199	136
Seq4			0.946	0.935	0.941	5.210	6.203	132
Seq6			0.956	0.950	0.953	4.170	4.482	134
Average			0.958	0.937	0.947	4.801	5.294	134

	Feature extraction		Prediction		
Grid resolution	Vector length	$\bar{t}_{extraction}$ (ms)	# trained classifiers	$\bar{t}_{prediction}$ (ms)	$\bar{t}$ (ms)
13 x 17	169200	23	65	6	31
17 x 25			110	10	34
31 x 41			243	21	45
37 x 50			327	29	52
45 x 58			409	36	59
49 x 65			489	43	66

Conclusions

- **Novel algorithm for vehicle detection in nighttime scenarios:**
  - Based on a novel grid of foveal classifiers which share a single feature vector per image.
  - Advantages:
    - Ability to analyse complex illumination patterns and flashes.
    - Adaptability to different scenarios, objects, illumination and cameras.
    - Point-based vehicle ground-truth annotations.
- **Nighttime Vehicle Database (NVD) publicly available:**
  - Created to validate the proposed system.
- **Real-time operation:**
  - Viable with a single-threaded implementation.
- **Based on a one-year research scholarship funded by the "Dirección General de Tráfico" (DGT).**

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