Computer vision based estimation algorithms for a motorbike adaptive headlamp in nighttime scenarios

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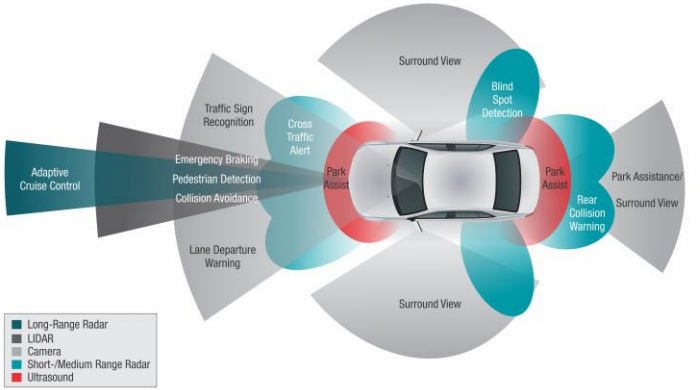
Introduction – Motivations

Motorbike adaptive headlamp: ADAS system



Motivations:

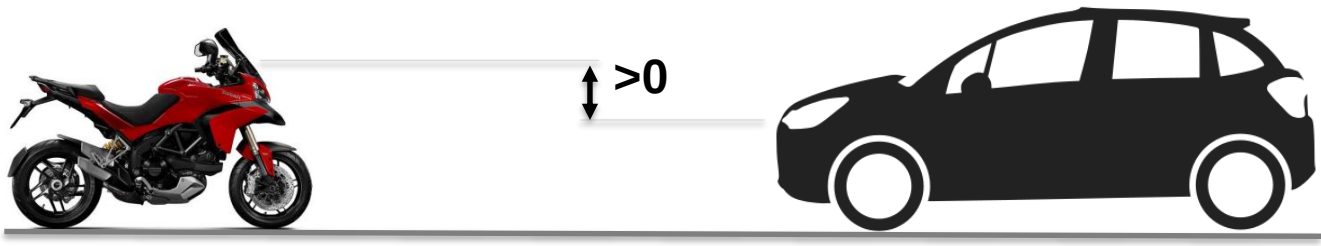
- Avoiding glare to other drivers**: prompt switching from high beams to low beams;**
- Improving visibility conditions**: optimizing the headlamp dimming especially in sharp curves;**

Introduction

Experimental setup:

Hypothesis:

- **Straight road**
- **Flat road**
- **Structured road**
- **Height of the camera > Height of vehicle lights.**



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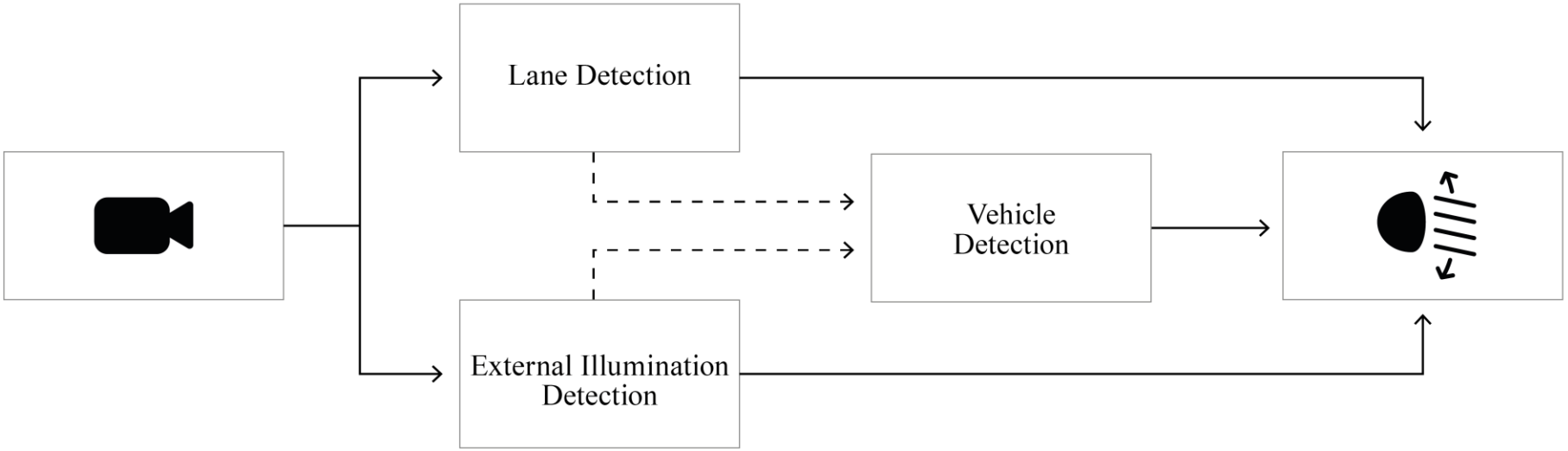
Introduction – General scheme

- **Objective: detect the presence of incoming and preceding vehicles and consecutively adapt headlamps**



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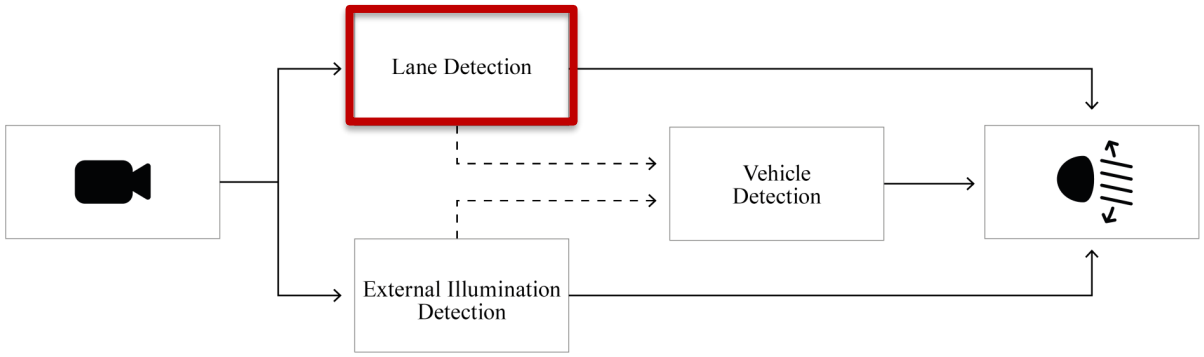
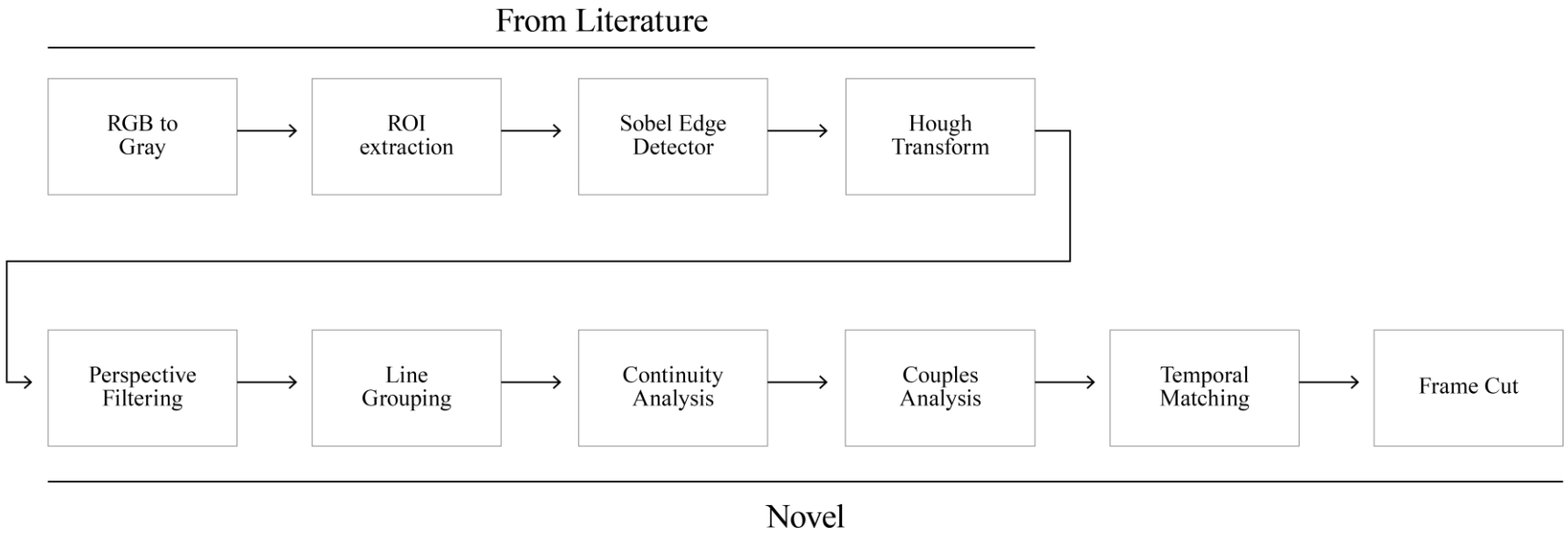
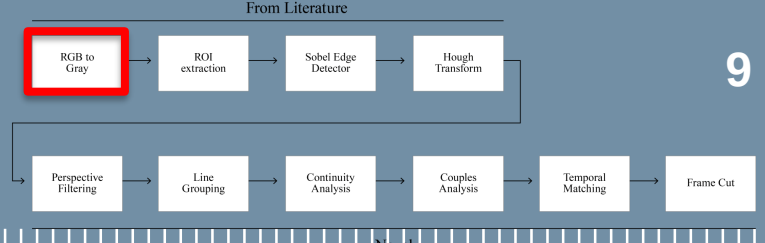
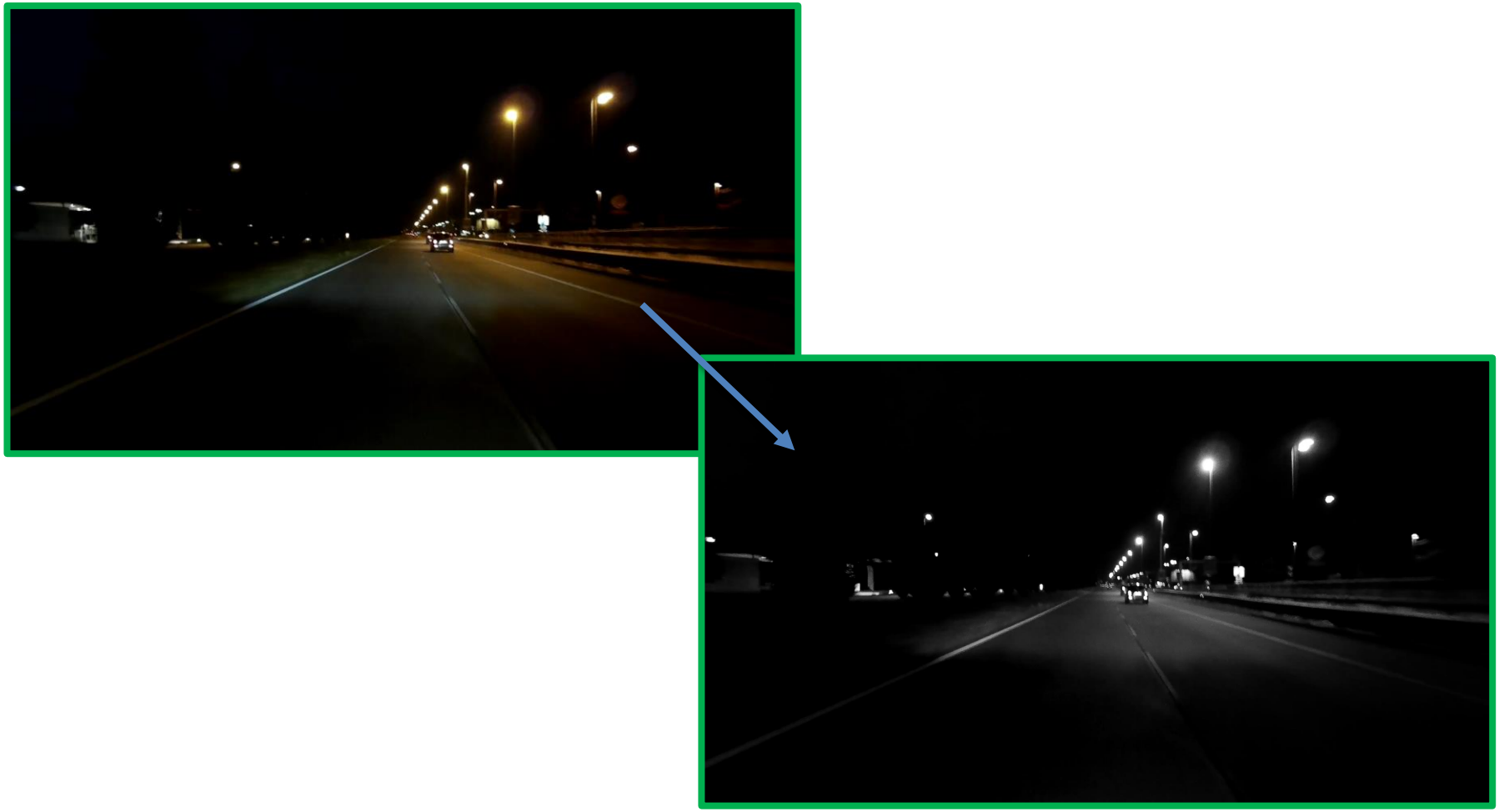


Lane Detection – General scheme



Lane Detection –RGB to Grayscale





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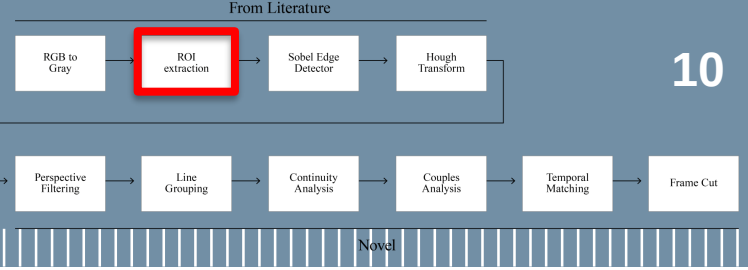
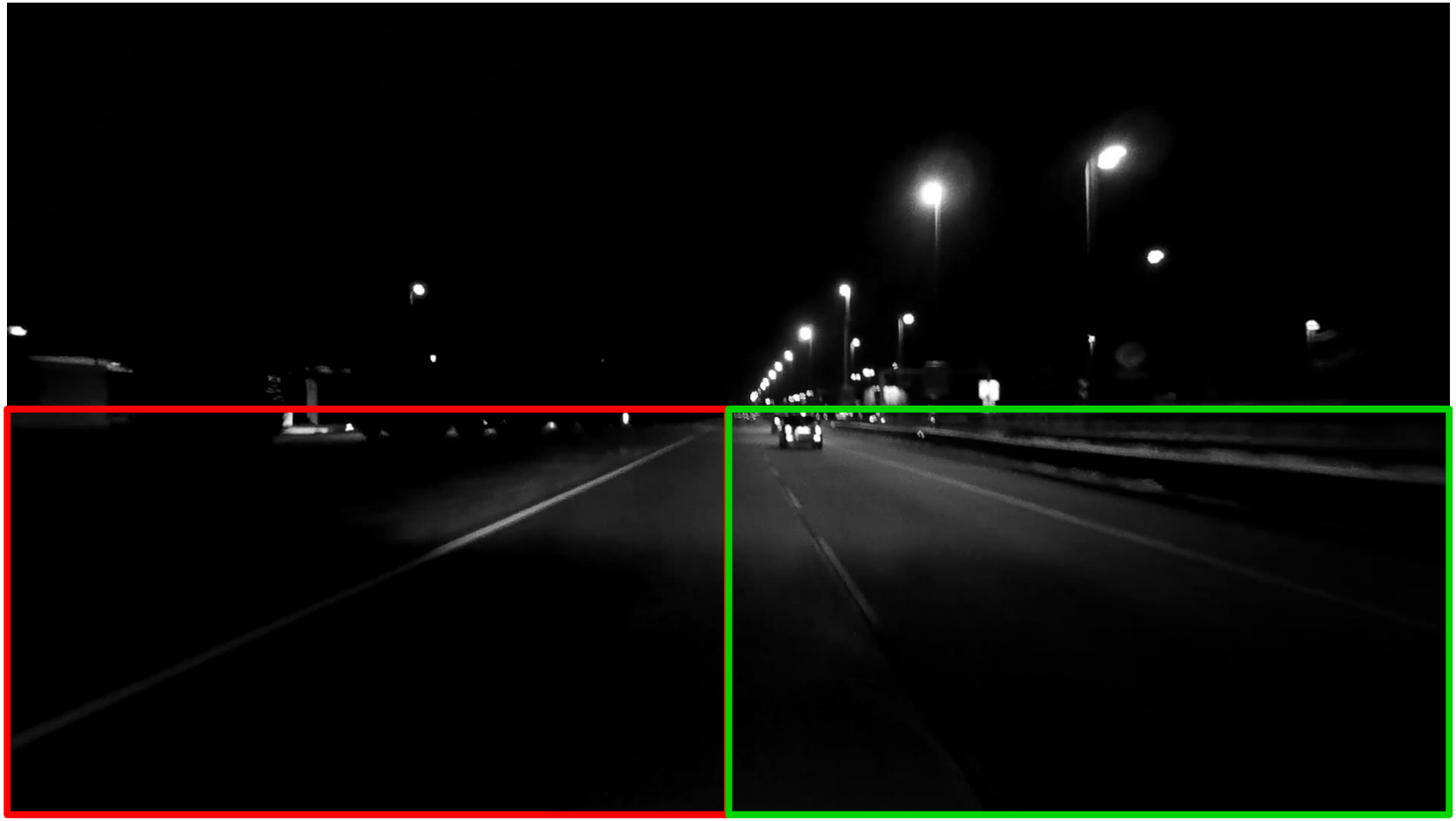
Lane Detection – ROI Extraction





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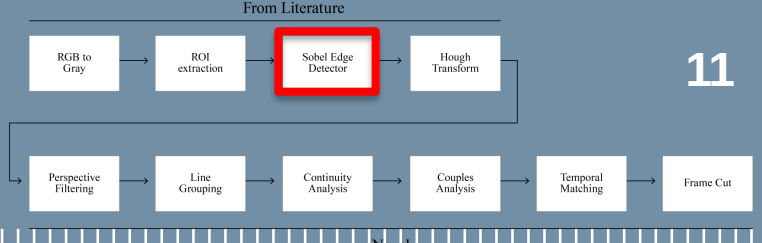
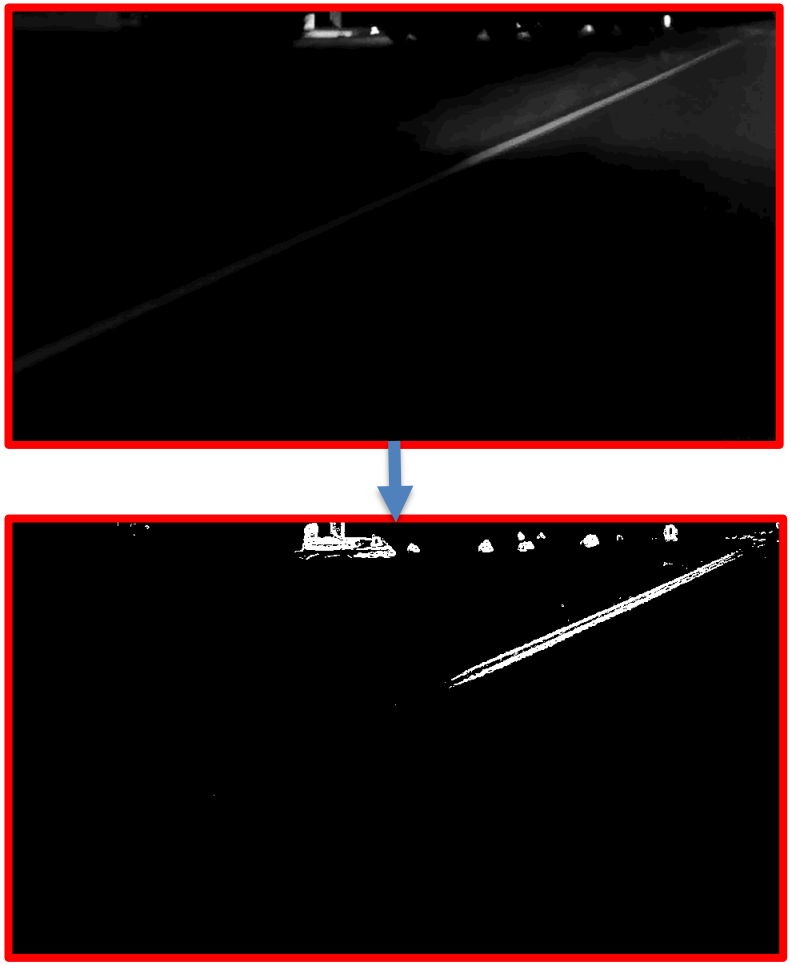
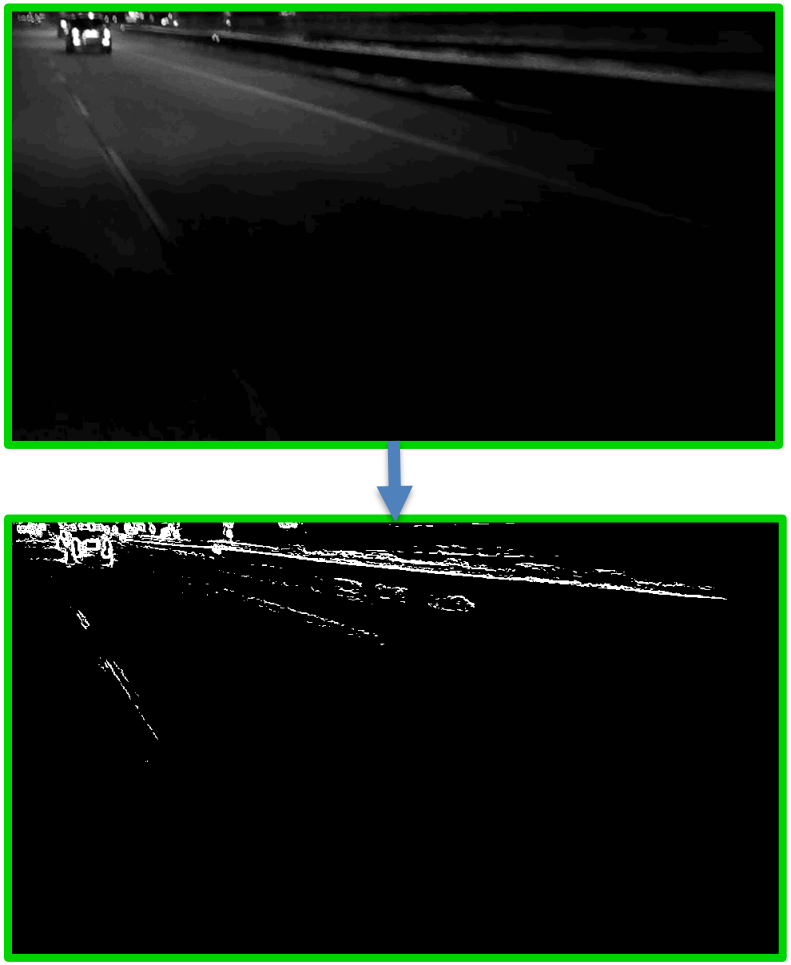
Lane Detection – Sobel Edge Detector







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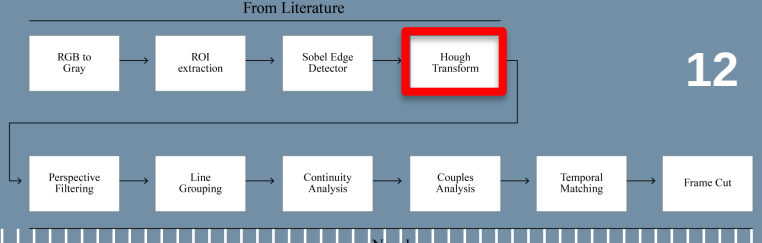
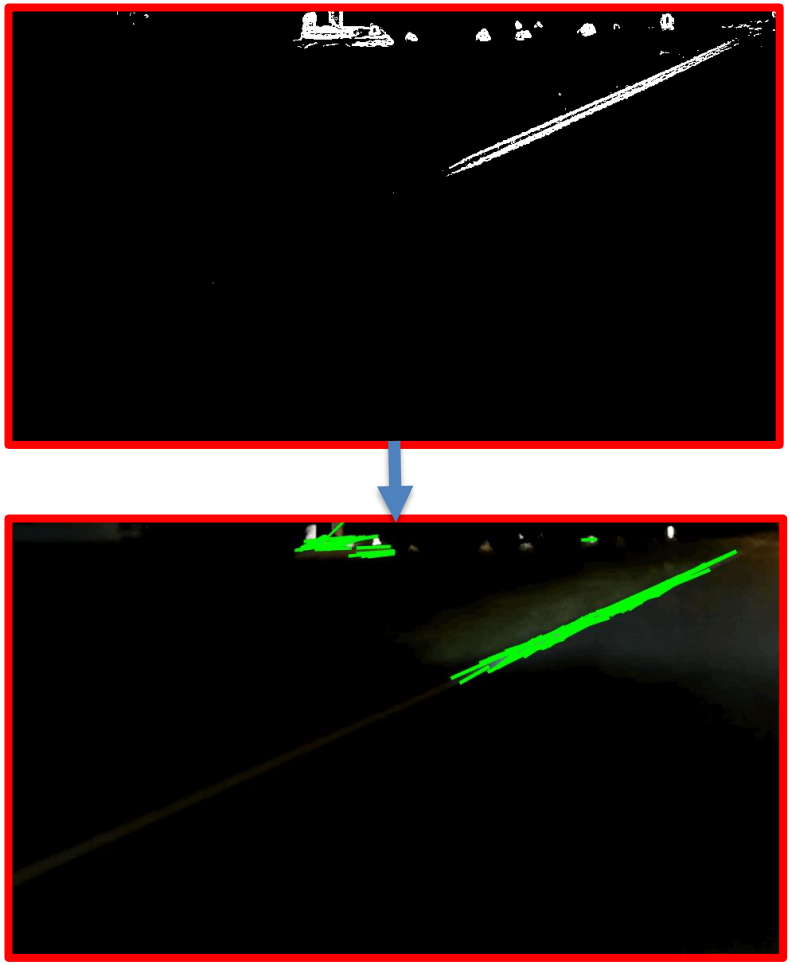
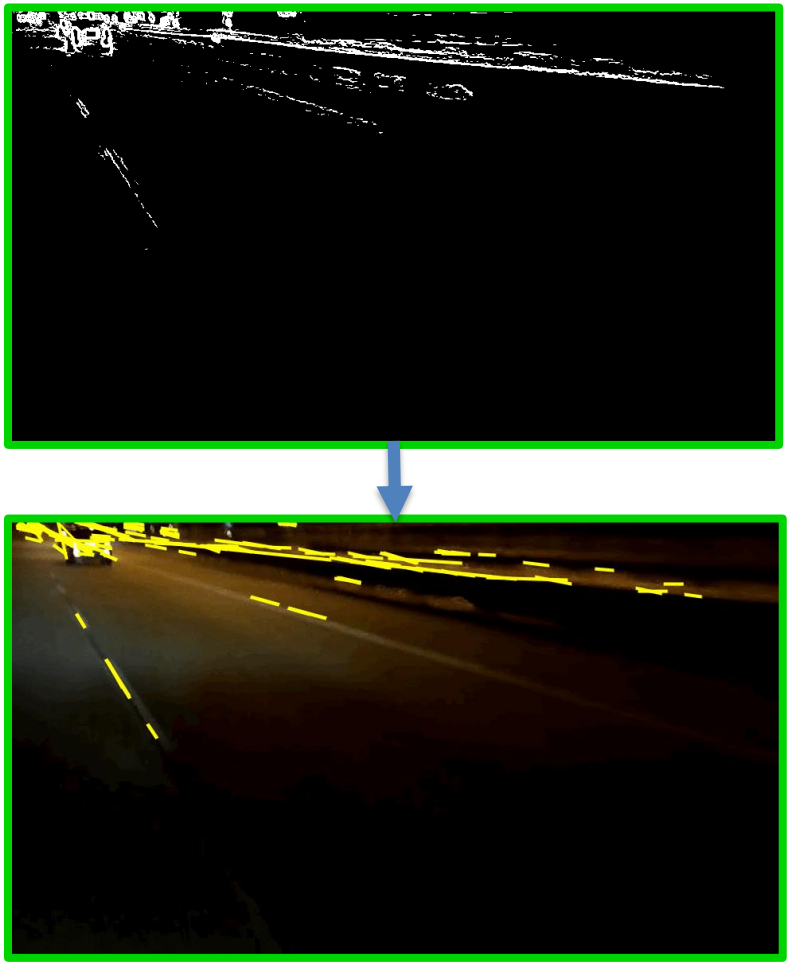
Lane Detection –Hough Transform







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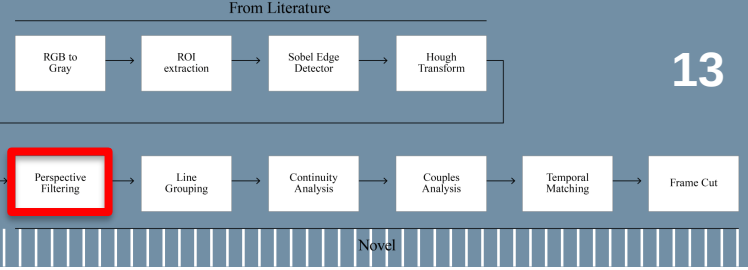
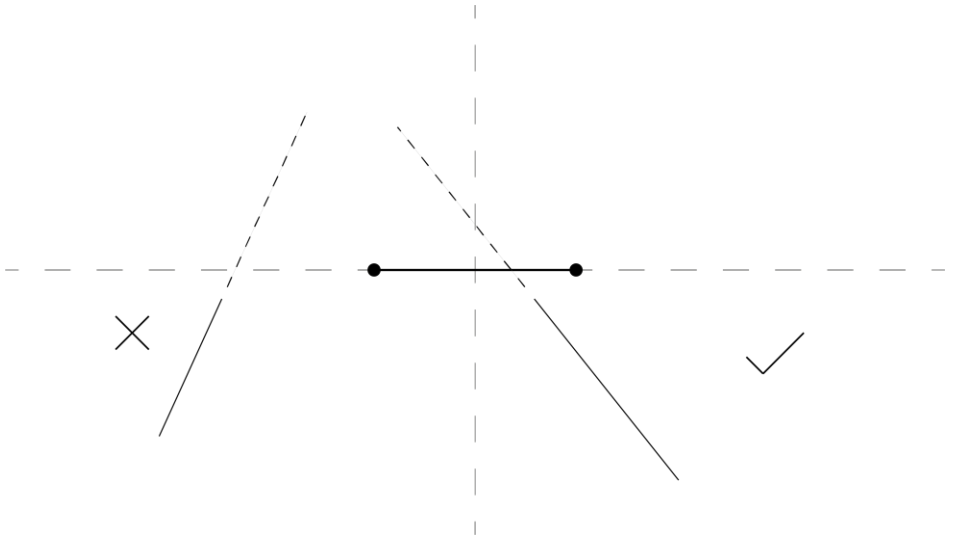
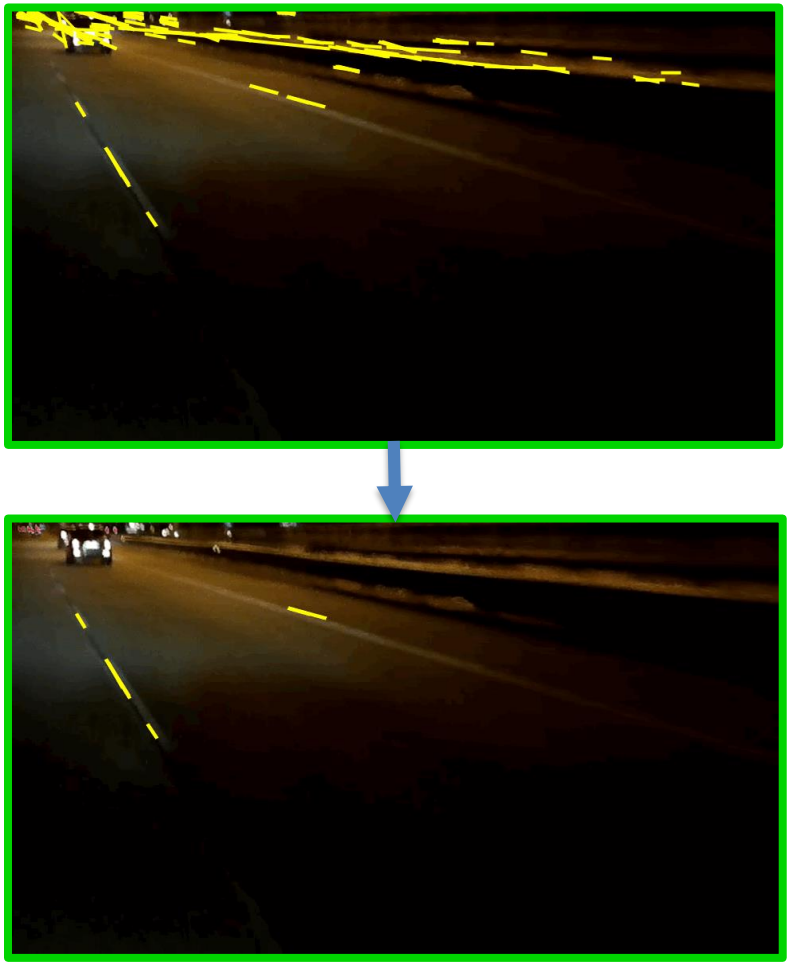
Lane Detection –Perspective Filtering



Noise reduction using perspective filtering





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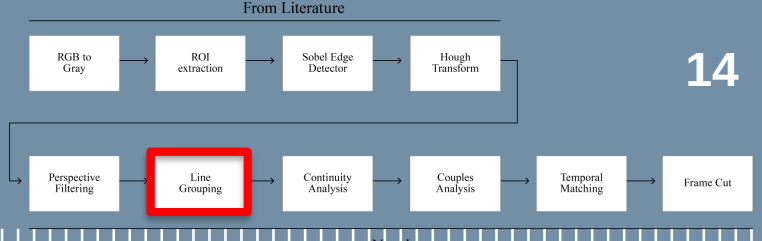
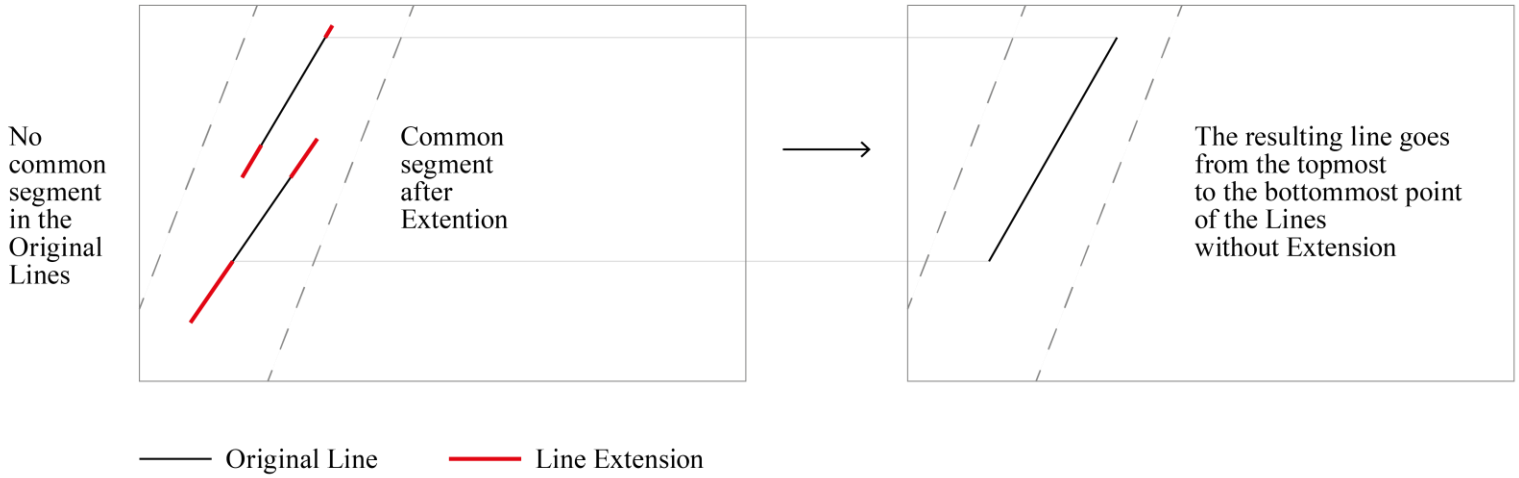
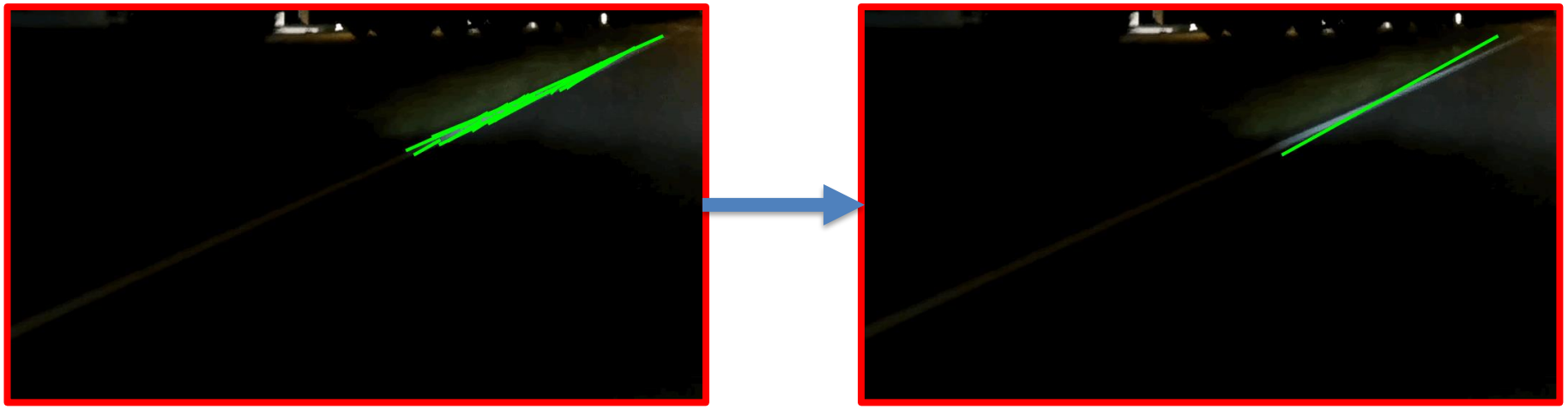
Lane Detection – Novel – Line Grouping







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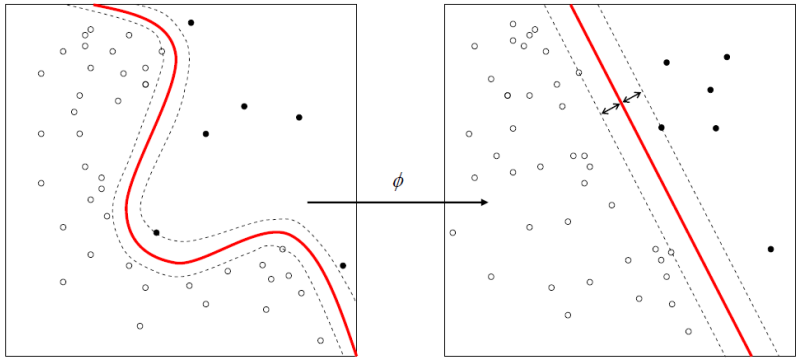
Lane Detection – Classification using SVM



Motivations:

Robustness

Generalization

Measure of confidence

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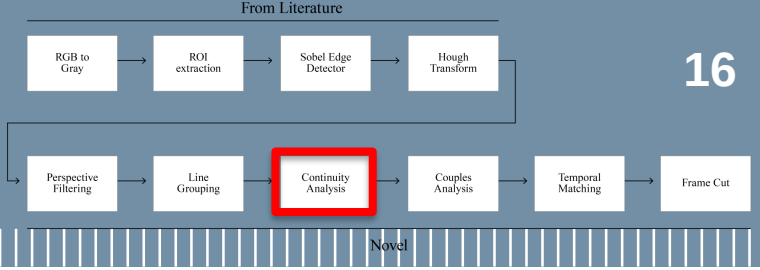
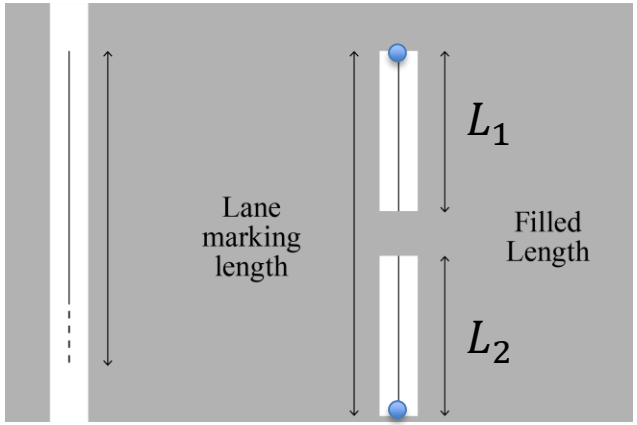
Lane Detection – Continuity Analysis – Features



Feature Filled Ratio:



Solidness measurement of lane marking

$$R_{filled} = \frac{L_1 + L_2}{L_{total}}$$

Feature Expanded length:

Length of the longest segment of a lane marking

$$L_i^{ext} = L_i \cdot C_i$$

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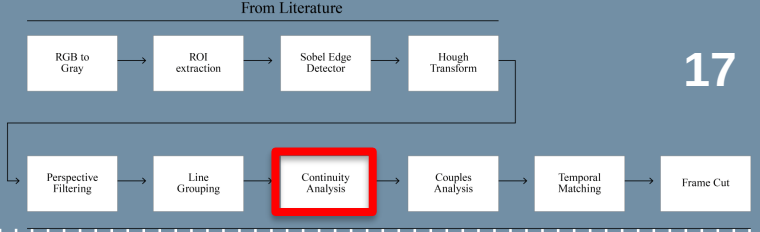
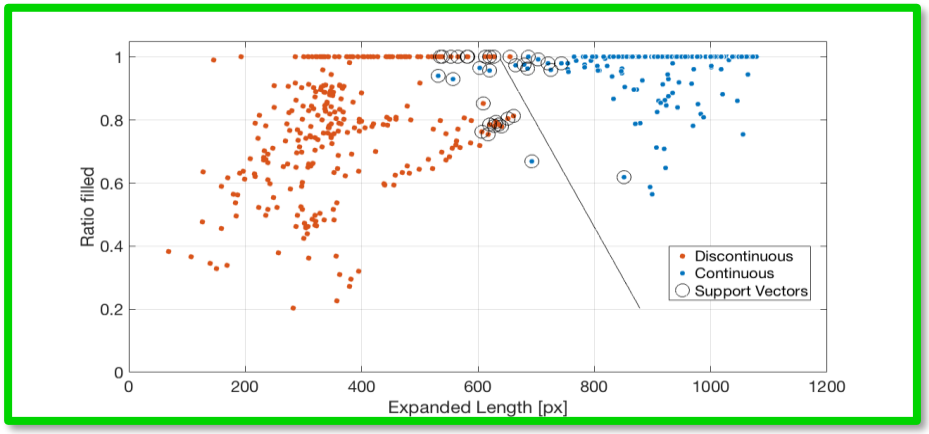
Lane Detection – Continuity Analysis – Results





Training set:

Linearly separable

Continuous Lines

Discontinuous Lines

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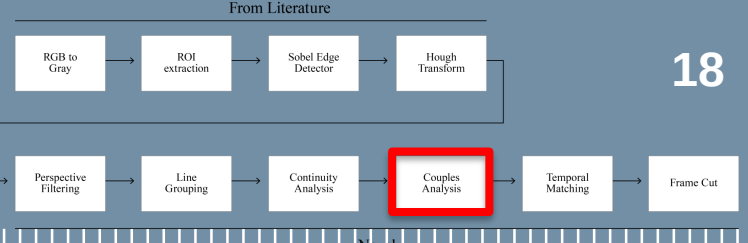
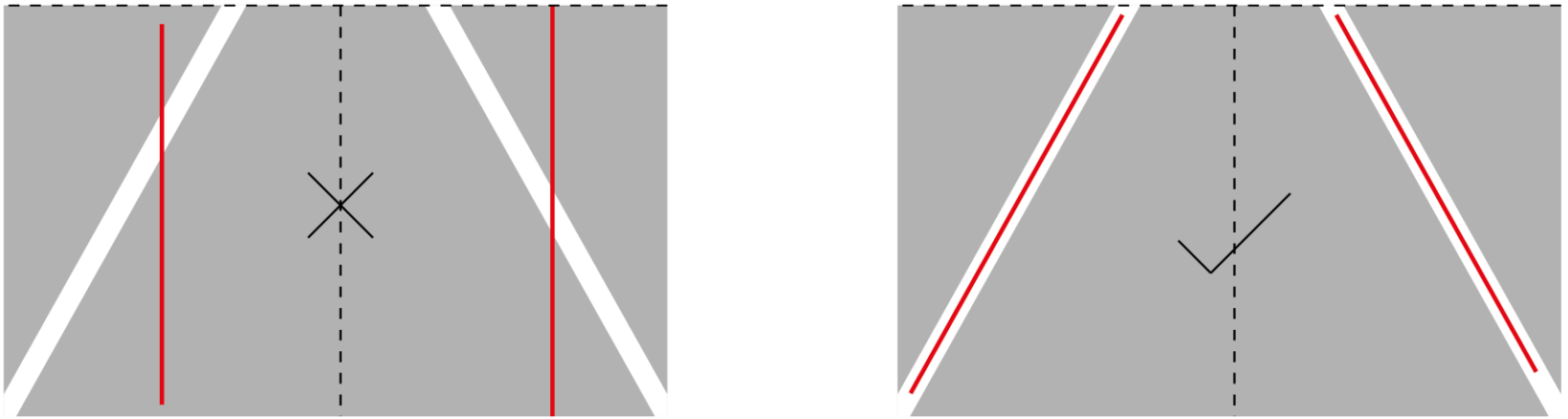
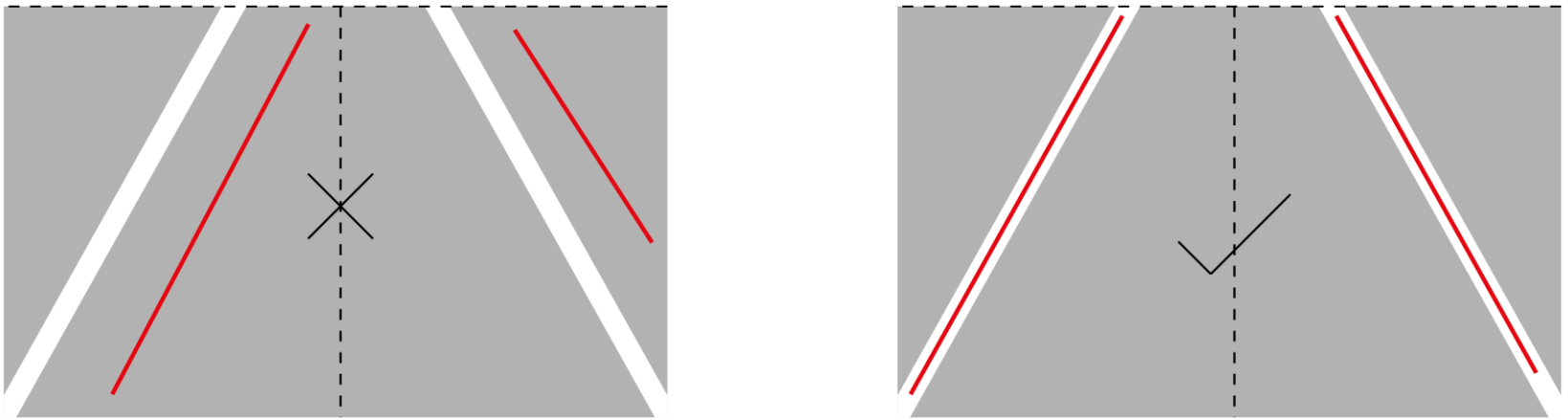
Lane Detection – Lane Analysis – Features



Sum of $\theta = \theta_R + \theta_L$



Sum of $\rho = \rho_R + \rho_L$



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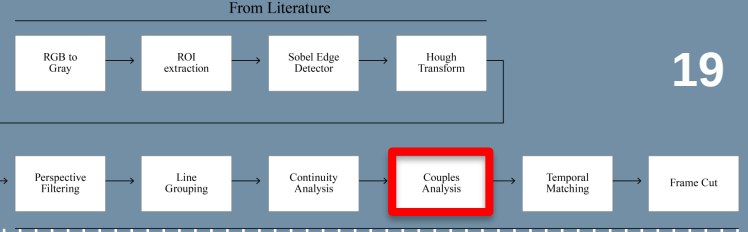
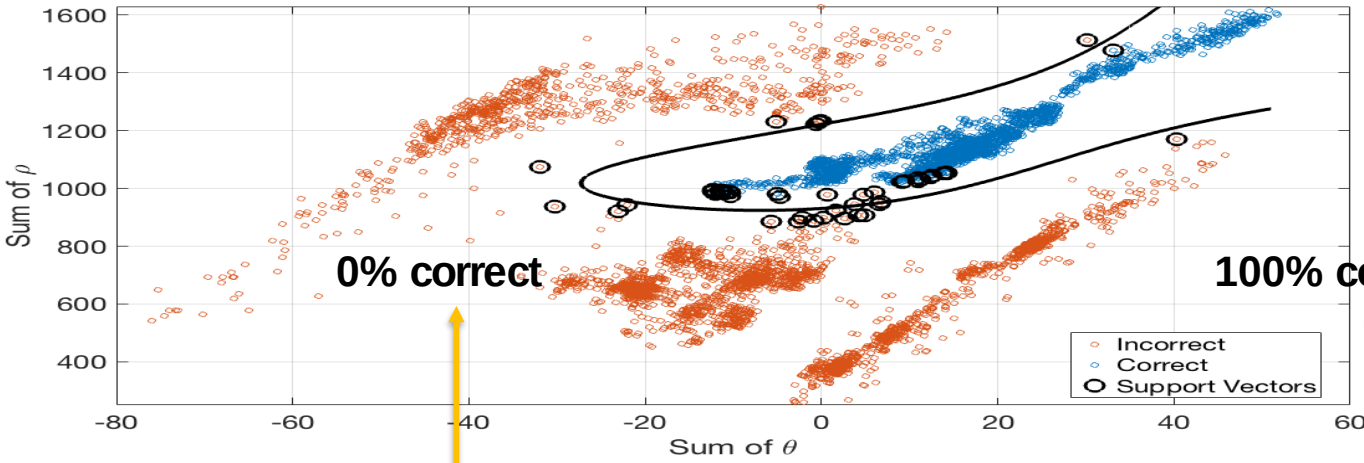
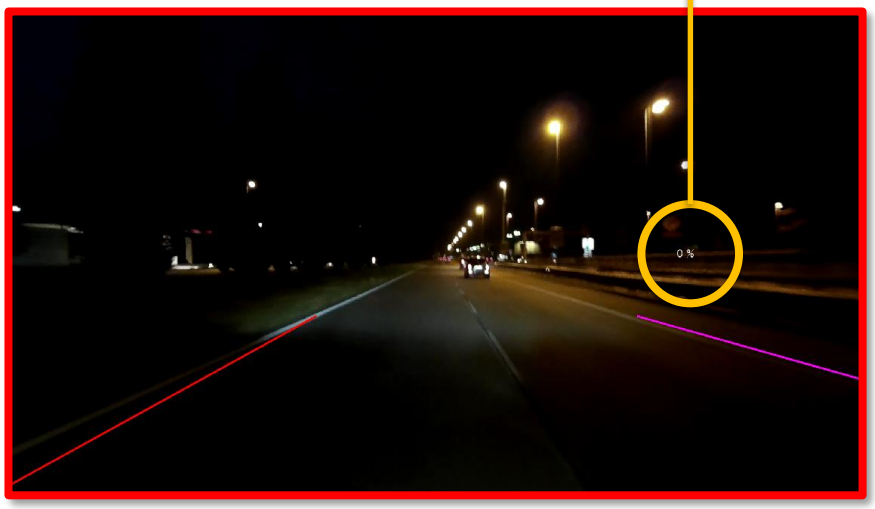
Lane Detection – Lane Analysis – Results

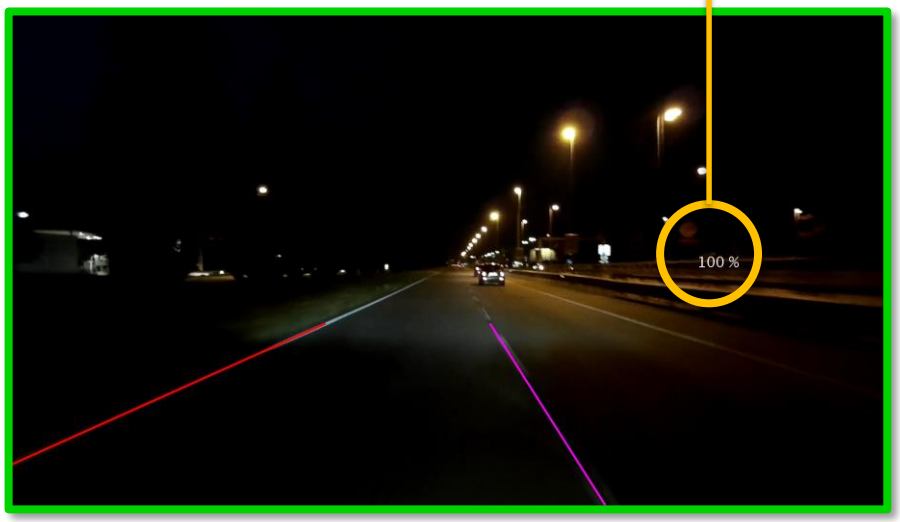




0% correct

100% correct





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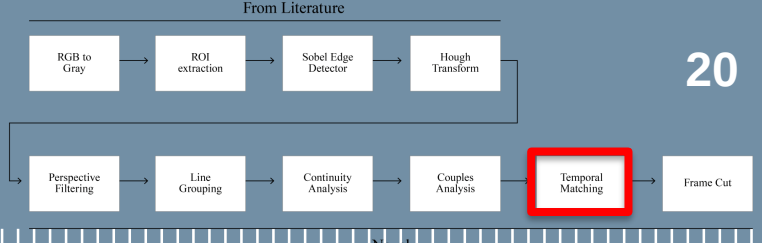
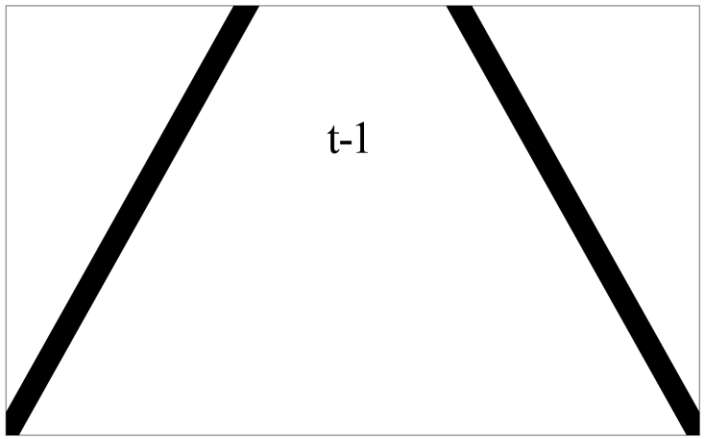
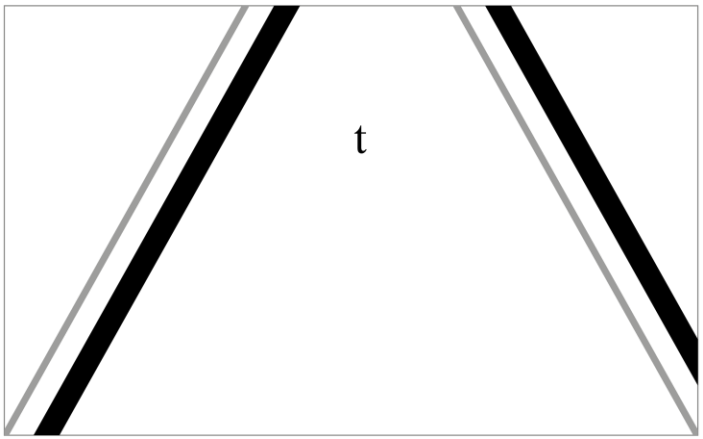
Lane Detection – Temporal Matching

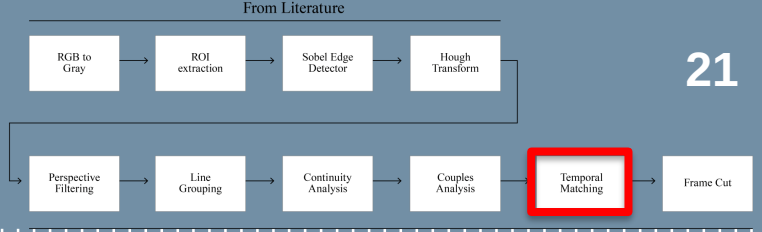




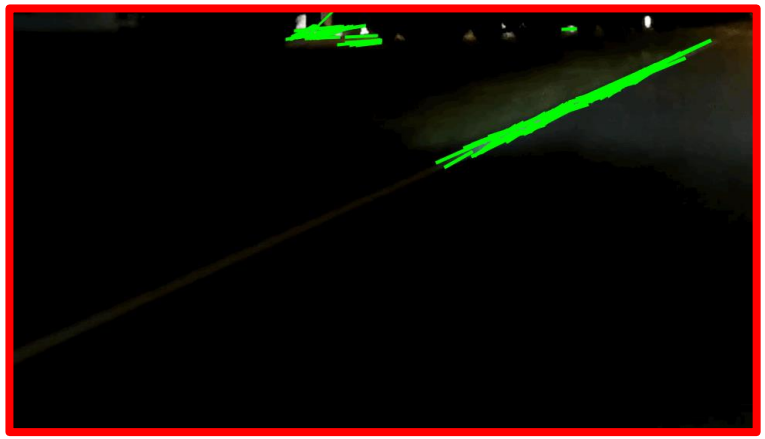


1. **Appear: New couple found.**
2. **Update: A couple in memory is matched with a couple in the current Frame.**
3. **Disappear: A couple is not matched for 5 frames then it is deleated.**

Lane Detection – Temporal Matching– Application



Reduction of the Detection Range around the Detected lane



Tracking

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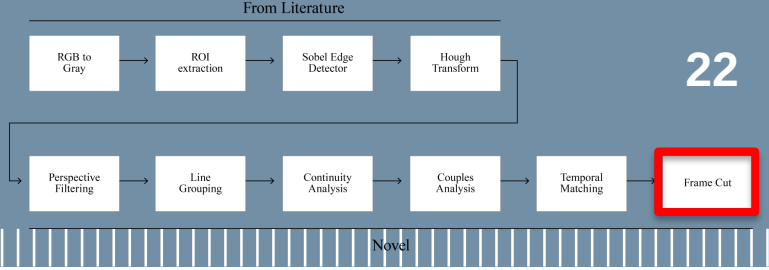
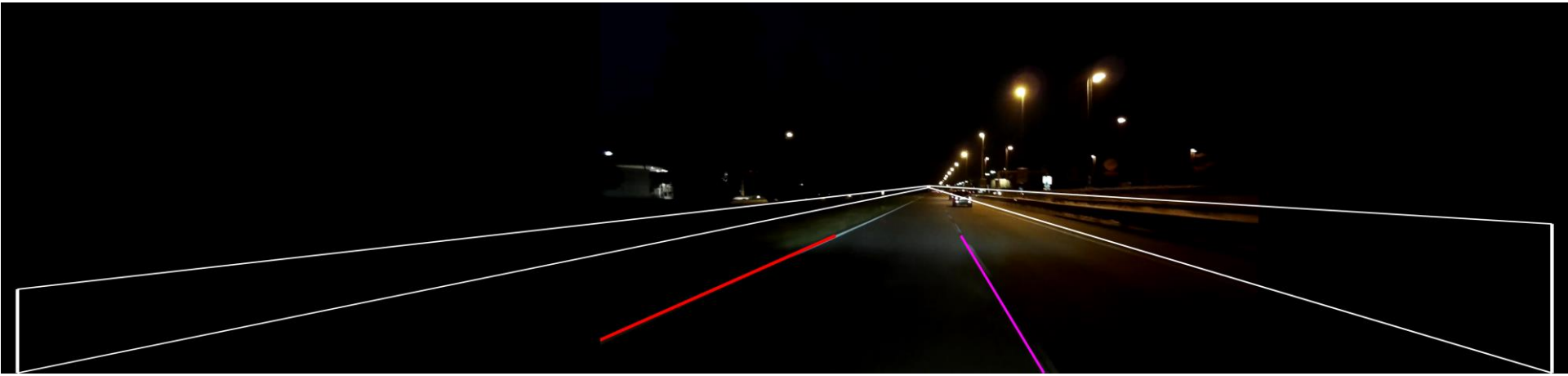
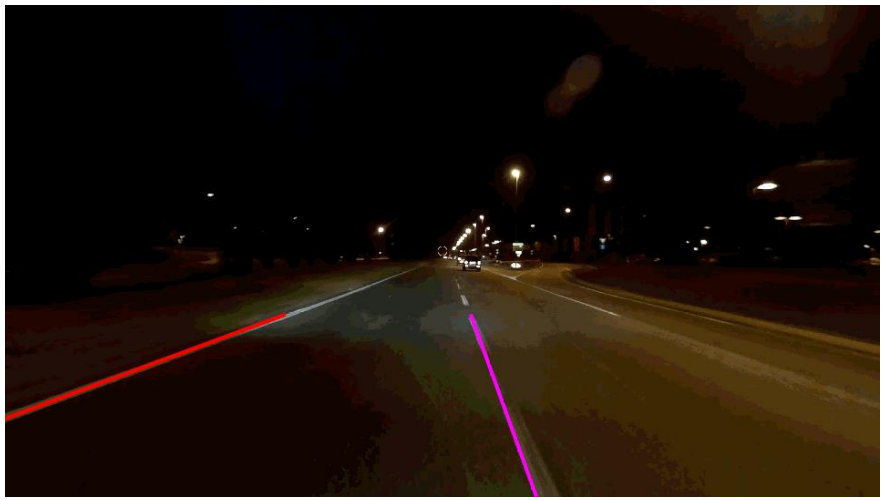
Lane Detection – Frame Cut







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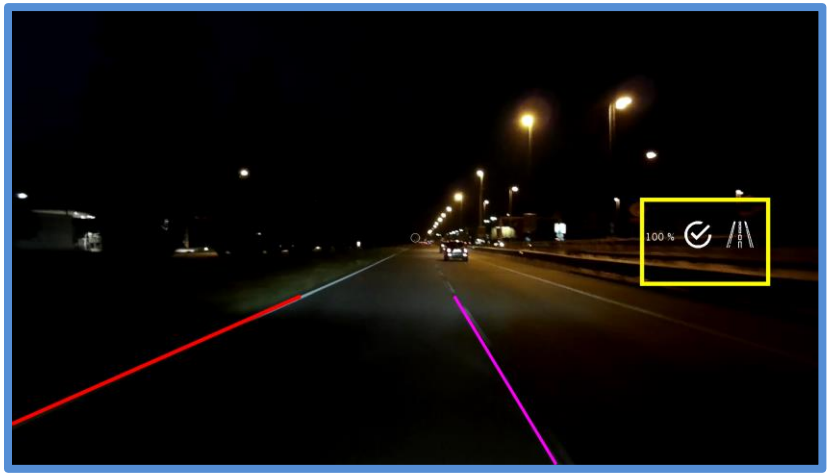
Lane Detection – Output

Frame with the Lane information



Frame for Vehicle Detection

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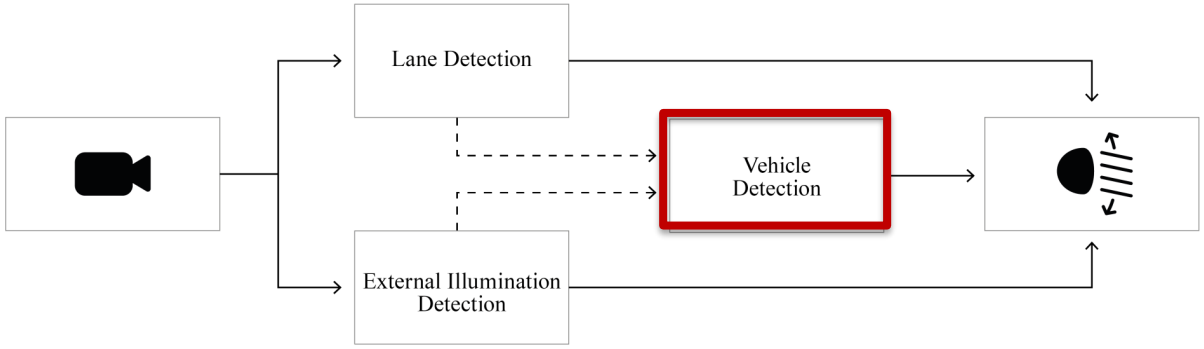
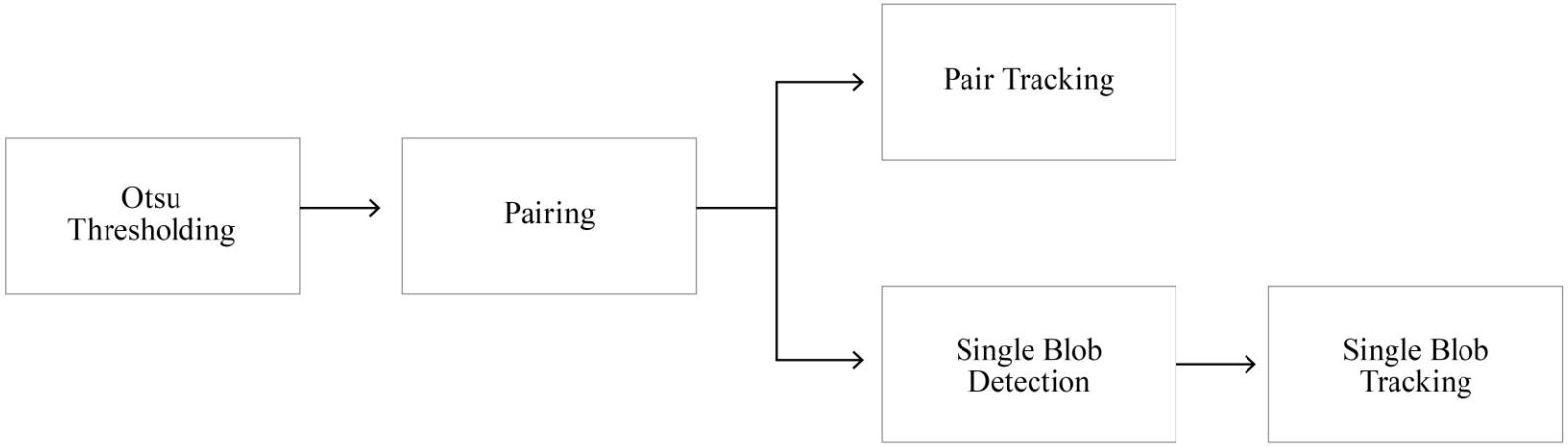


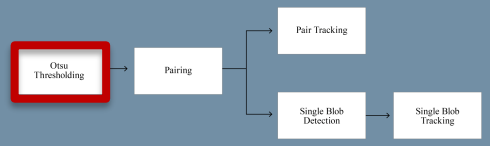
Vehicles Detection – Overview

Objective: find vehicles to understand its location and consecutively adapt the headlamp.

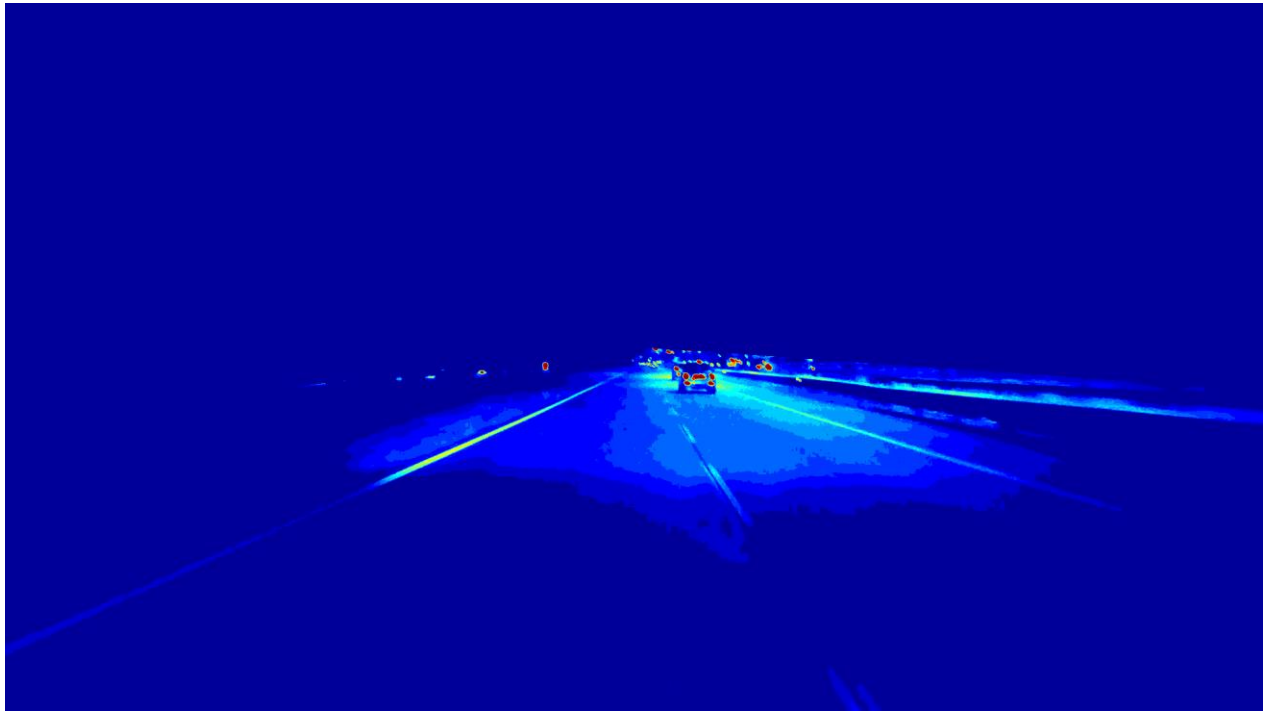
Idea: exploits vehicles lights to identify vehicles.



Vehicles Detection – Otsu Thresholding



Adaptive thresholding that divides pixels having a different intensity level.



Pixels intensities:

$I < th_1$

$\vdots$

$th_8 < I < th_9$

$\vdots$

$th_{19} < I$

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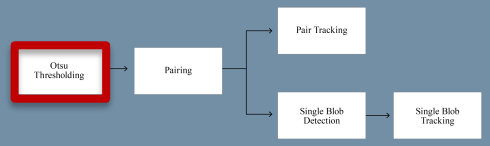
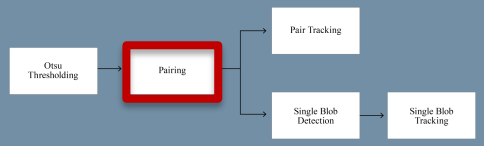
Vehicles Detection – Blob analysis



A bounding-box is created around each blob.

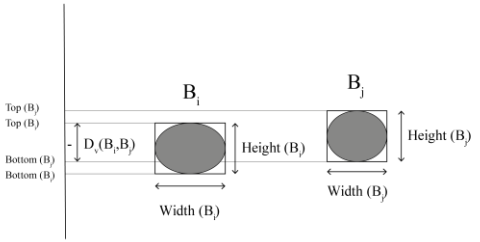
- **Binarized image based on the highest intensity threshold;**
- **Connected component analysis calculating the relevant features.**

Vehicles Detection – Pairing

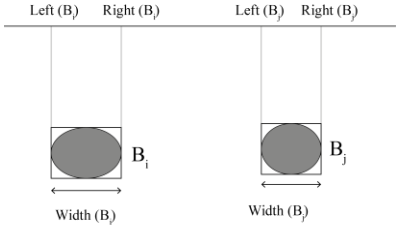


Each blob is compared with all the others and only those that satisfy the conditions are joined in the same bounding-box.

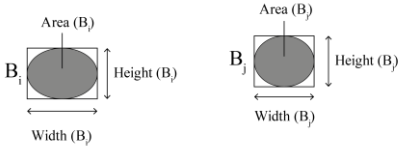
Vertical overlapping



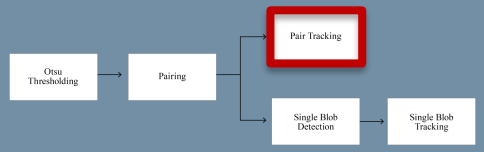
Horizontal proximity



Similar width, height and area

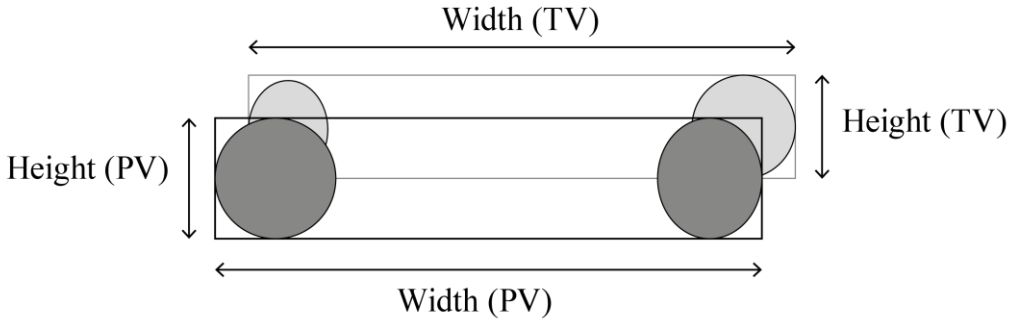


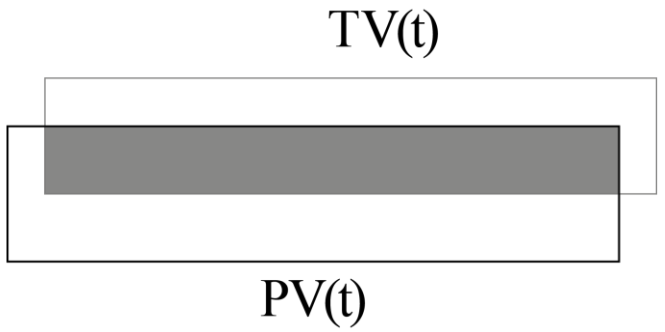
Vehicles Detection – Heuristic tracking



Two rules are used to match the same vehicle in two consecutive frames:

- **Comparable size of the bounding-box;**
- **Overlapping area of the bounding-box should be considerable;**

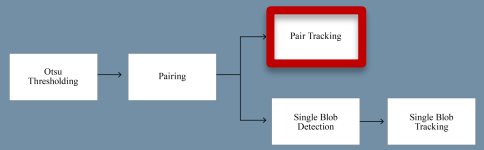




TV: tracked vehicle up to the current frame

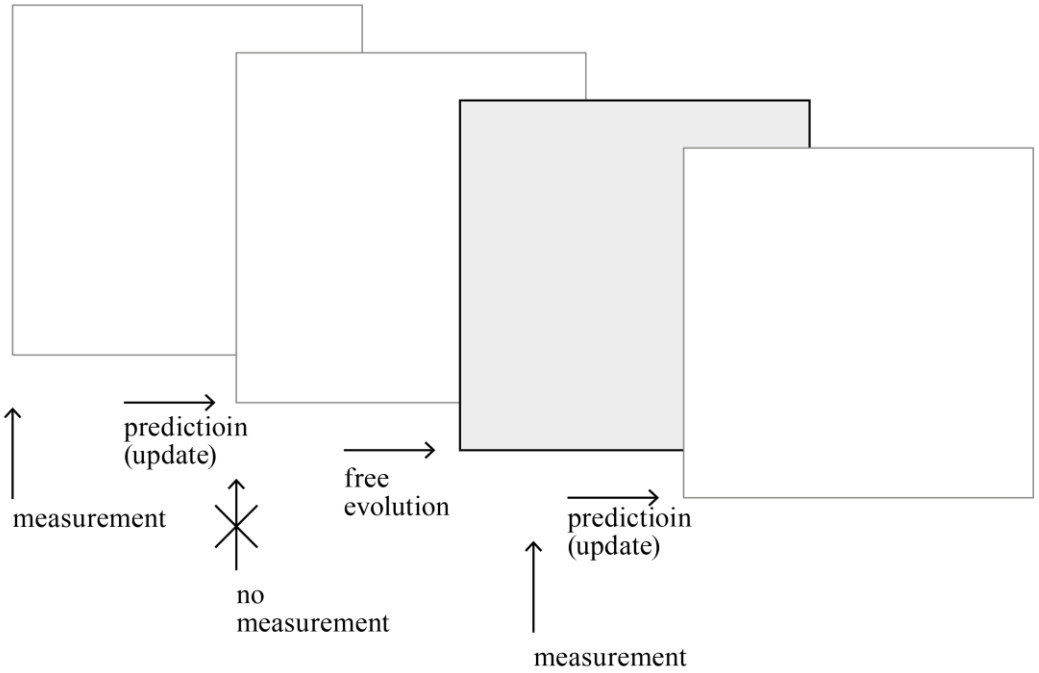
PV: new possible vehicle

Vehicles Detection – Pair tracking

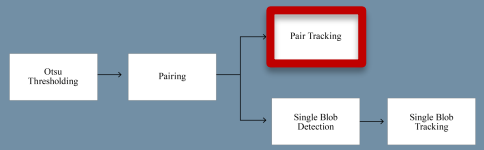


To make tracking more robust with respect to disturbances, heuristic tracking is combined with Kalman tracking.

- Heuristic tracking **matches**
- Kalman tracking **predicts**



Vehicles Detection – Kalman Model 1



Constant speed linear model

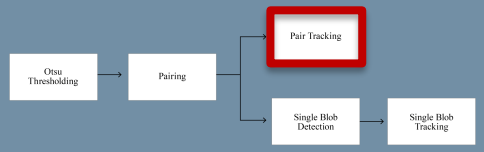
$$\begin{cases} x(t+1) = x(t) + t * v_x(t) \\ y(t+1) = y(t) + t * v_y(t) \\ v_x(t+1) = v_x(t) \\ v_y(t+1) = v_y(t) \end{cases}$$

$$A = \begin{bmatrix} 1 & 0 & t & 0 \\ 0 & 1 & 0 & t \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

It is used for object tracking in general, not only for vehicle tracking.

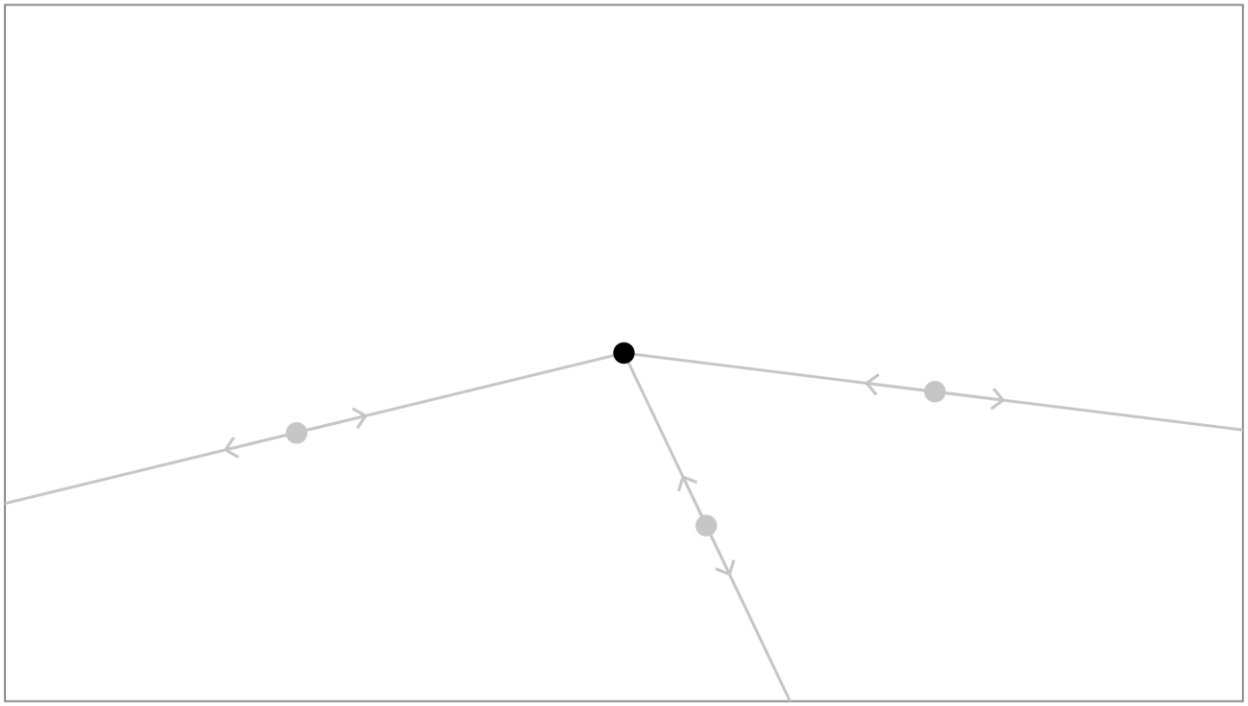
→ **It do not exploit the specific** perspective motion **of vehicles.**

Vehicles Detection – Kalman Model 2

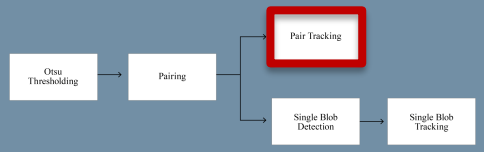


Based on the initial assumptions, each object in the image has a fixed trajectory, according to the optical flow**.**

$$\frac{y - y_0}{x - x_0} = \frac{v_y}{v_x}$$



Vehicles Detection – Kalman Model 2



$$\begin{cases} x(t+1) = x(t) + v_x(t) \cdot t \\ y(t+1) = y(t) + v_y(t) \cdot t \\ v_x(t+1) = v_x(t) \\ v_y(t+1) = v_x(t) \cdot \dfrac{y - y_0}{x - x_0} \end{cases}$$

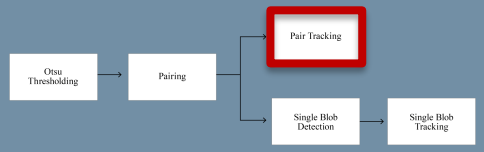
Division from zero on the vertical optical axis

The information concerning the specific motion is added to the constant speed model

The model is become non-linear:
Extended Kalman filter should be applied

$$A = \begin{bmatrix} 1 & 0 & t & 0 \\ 0 & 1 & 0 & t \\ 0 & 0 & 1 & 0 \\ -\dfrac{y}{x^2} v_x & \dfrac{v_x}{x} & \dfrac{y}{x} & 0 \end{bmatrix}$$

Vehicles Detection – Kalman Model 3

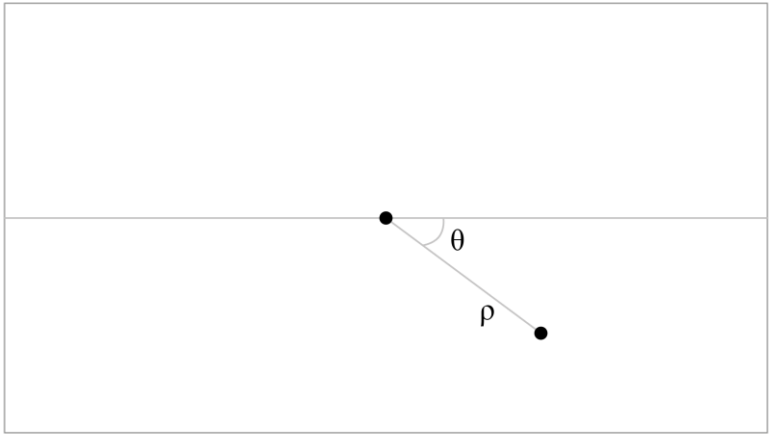


A simple and clever solution: polar coordinates.

$$\begin{cases} \rho(t+1) = \rho(t) + v_\rho(t) \cdot t \\ v_\rho(t+1) = v_\rho(t) \\ \vartheta(t+1) = \vartheta(t) \end{cases}$$

The distance from the center evolves with a constant speed motion

The angle remains constant (fixed direction)



$$A = \begin{bmatrix} 1 & t & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Linear model that also solves the division from zero problem.

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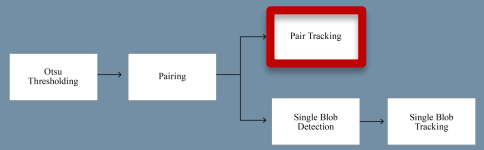
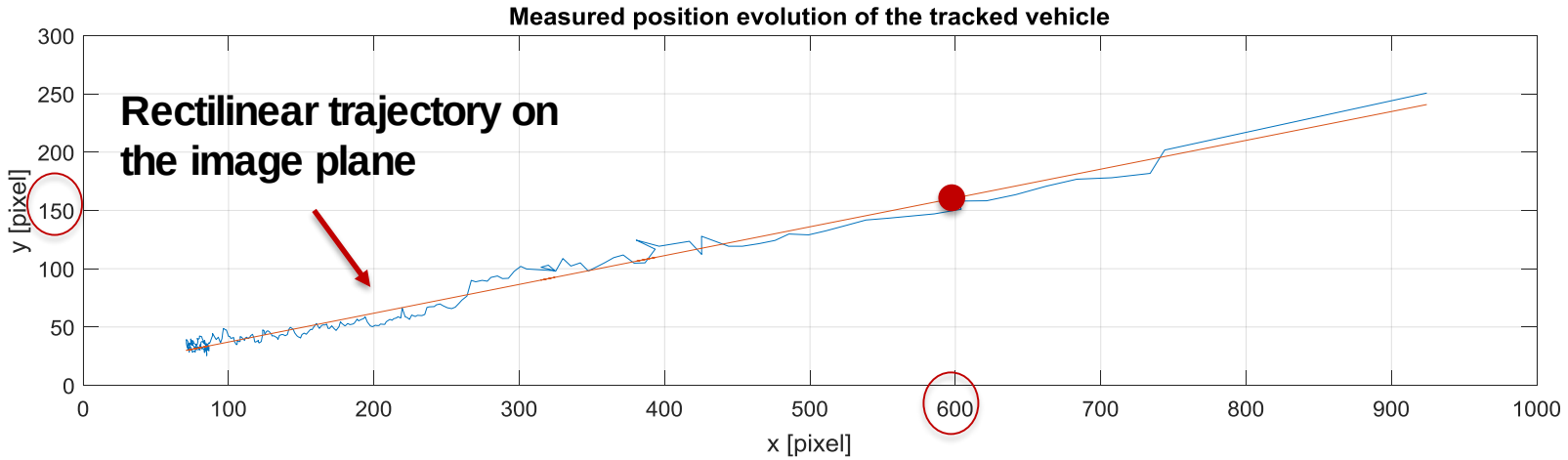
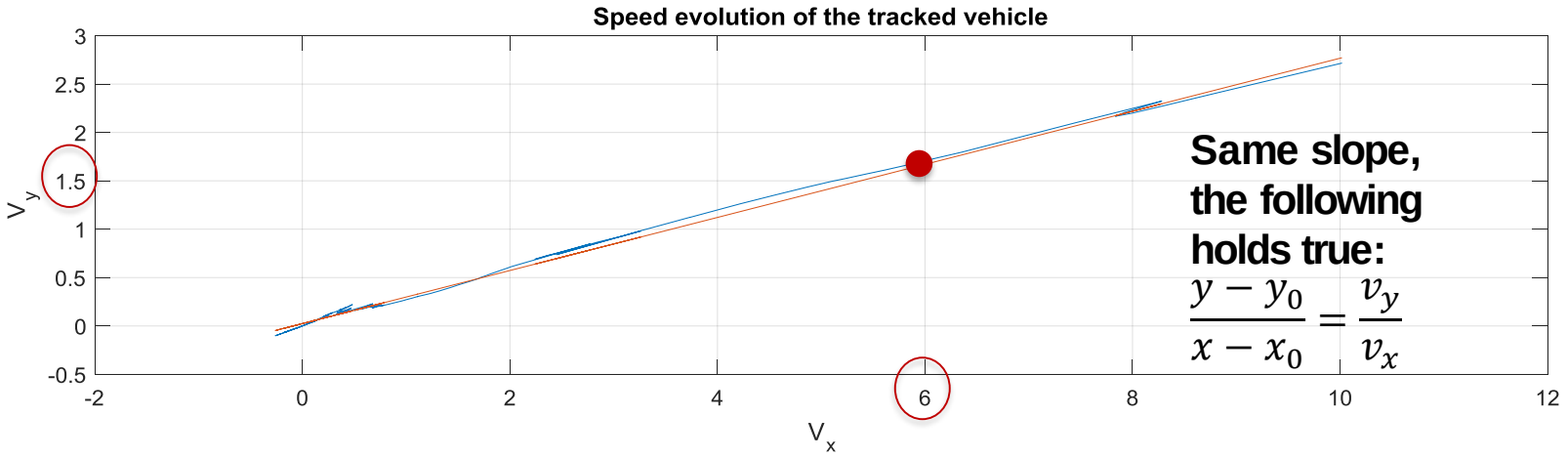
Fabio Oprandi

Vehicles Detection – Kalman Model Validation







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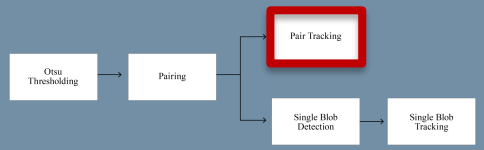
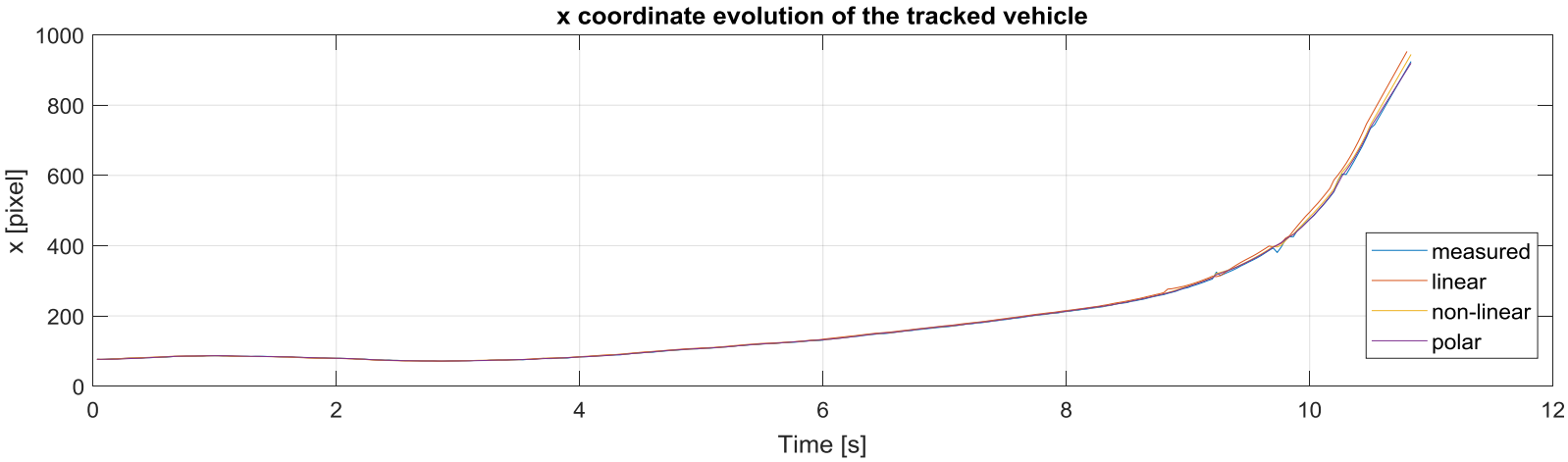
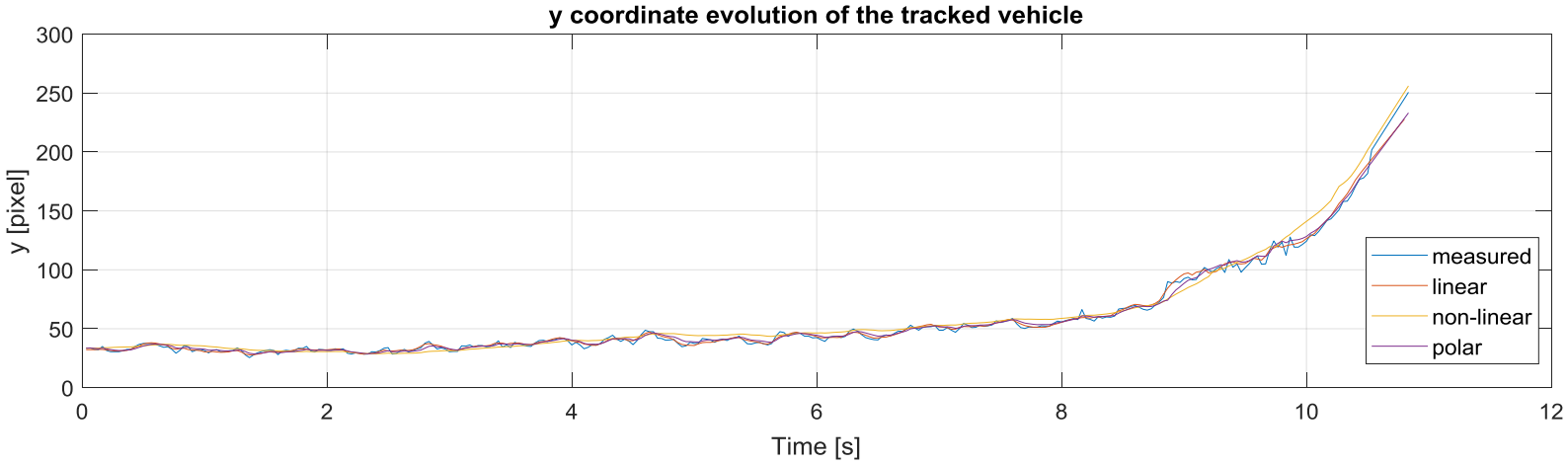
Vehicles Detection – Models comparison







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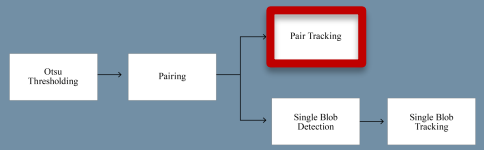
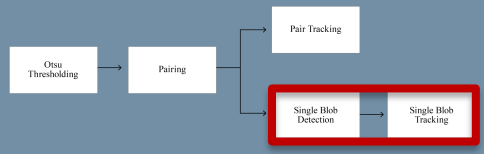
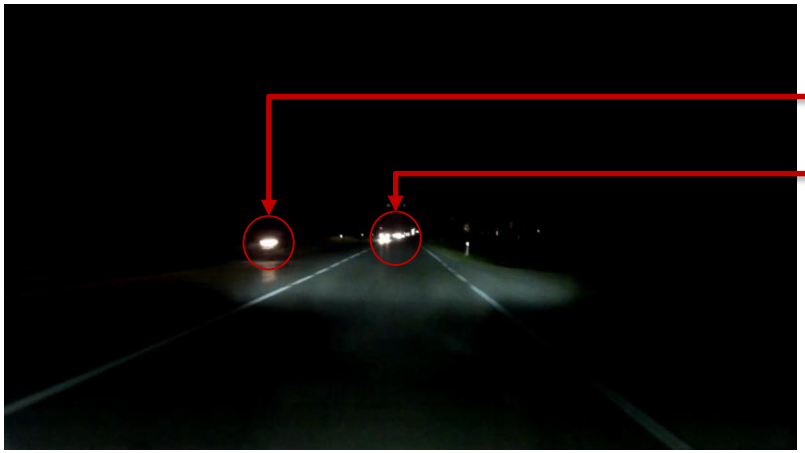
Vehicles Detection – Models comparison



Models	States number	Linear	Tailored
Model 1	4	✓	✗
Model 2	4	✗	✓
Model 3	3	✓	✓

Vehicles Detection – Single Blobs





Motorbike

Vehicles at a considerable distance

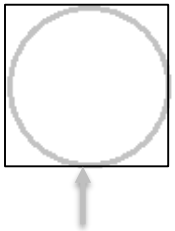
Vehicles with only one light
(e.g. motorbikes)

⇩

Single blob detection

Pairs are excluded;

Small blobs are not considered;



Remaining blobs are detected and tracked
(using the same approach as for pairs)

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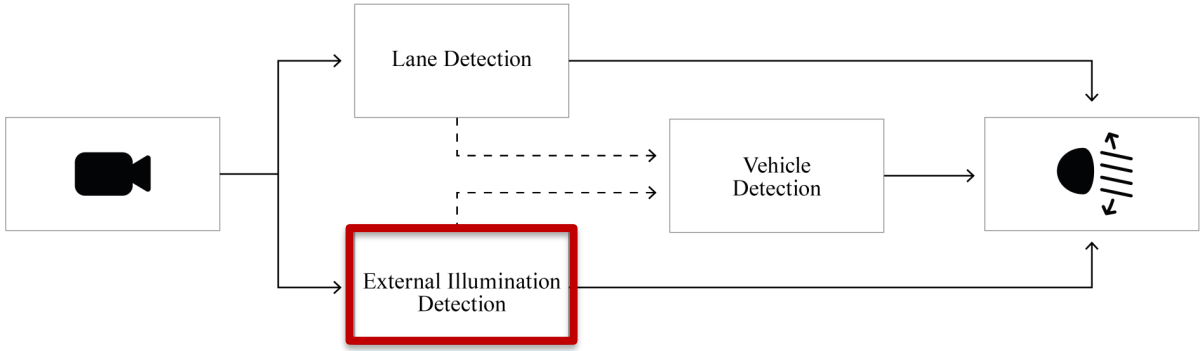
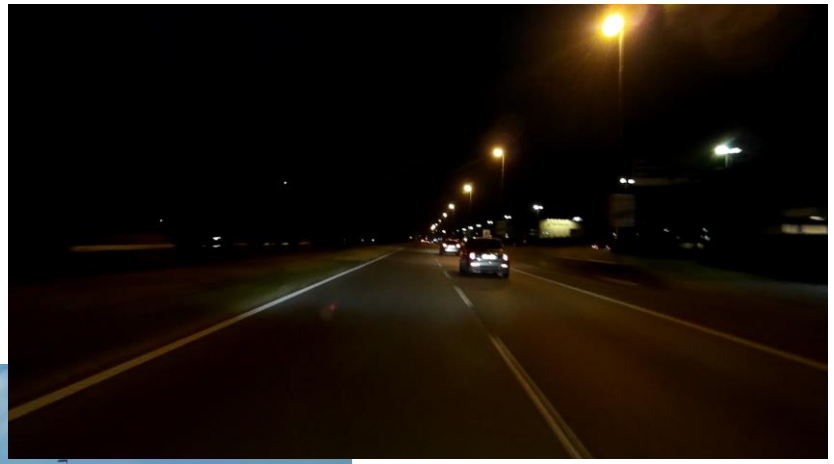
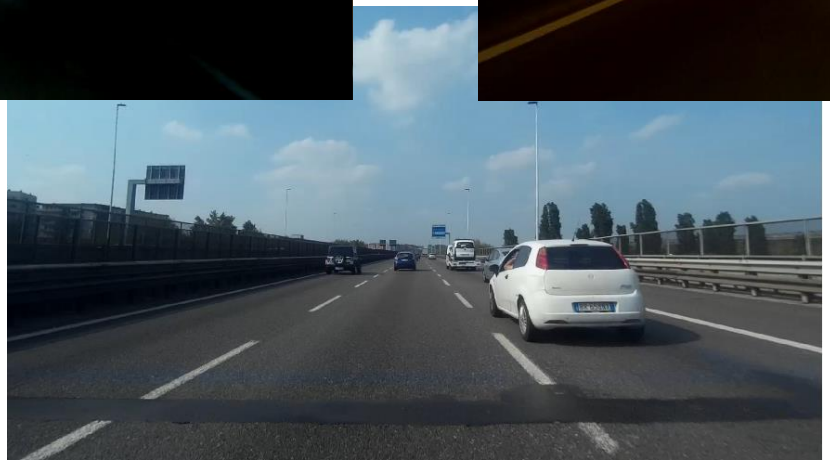


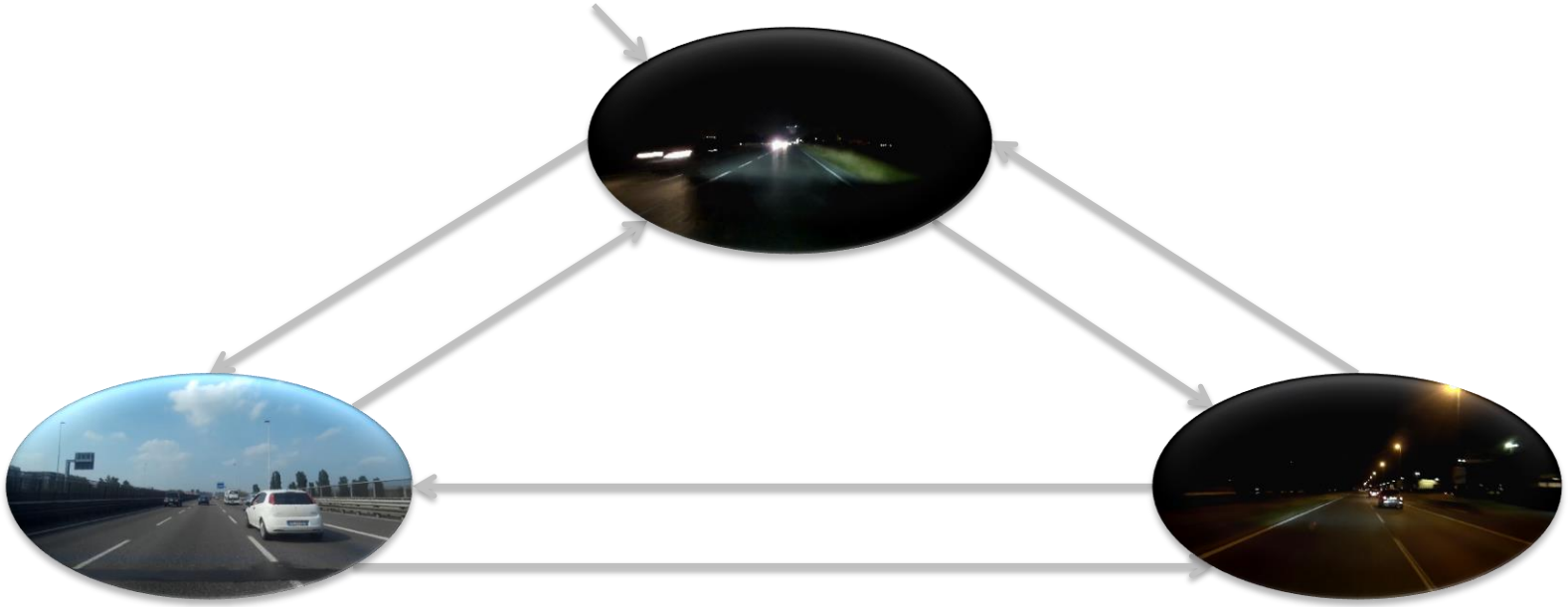
External Illumination Detection - Objective

Understand the external illuminating conditions, and so when it is actually necessary to activate the adaptive headlamp.





External Illumination Detection – Switching Rules



Switching rules exploit:

- **The average image intensity;**
- **The number of streetlamps detected.**

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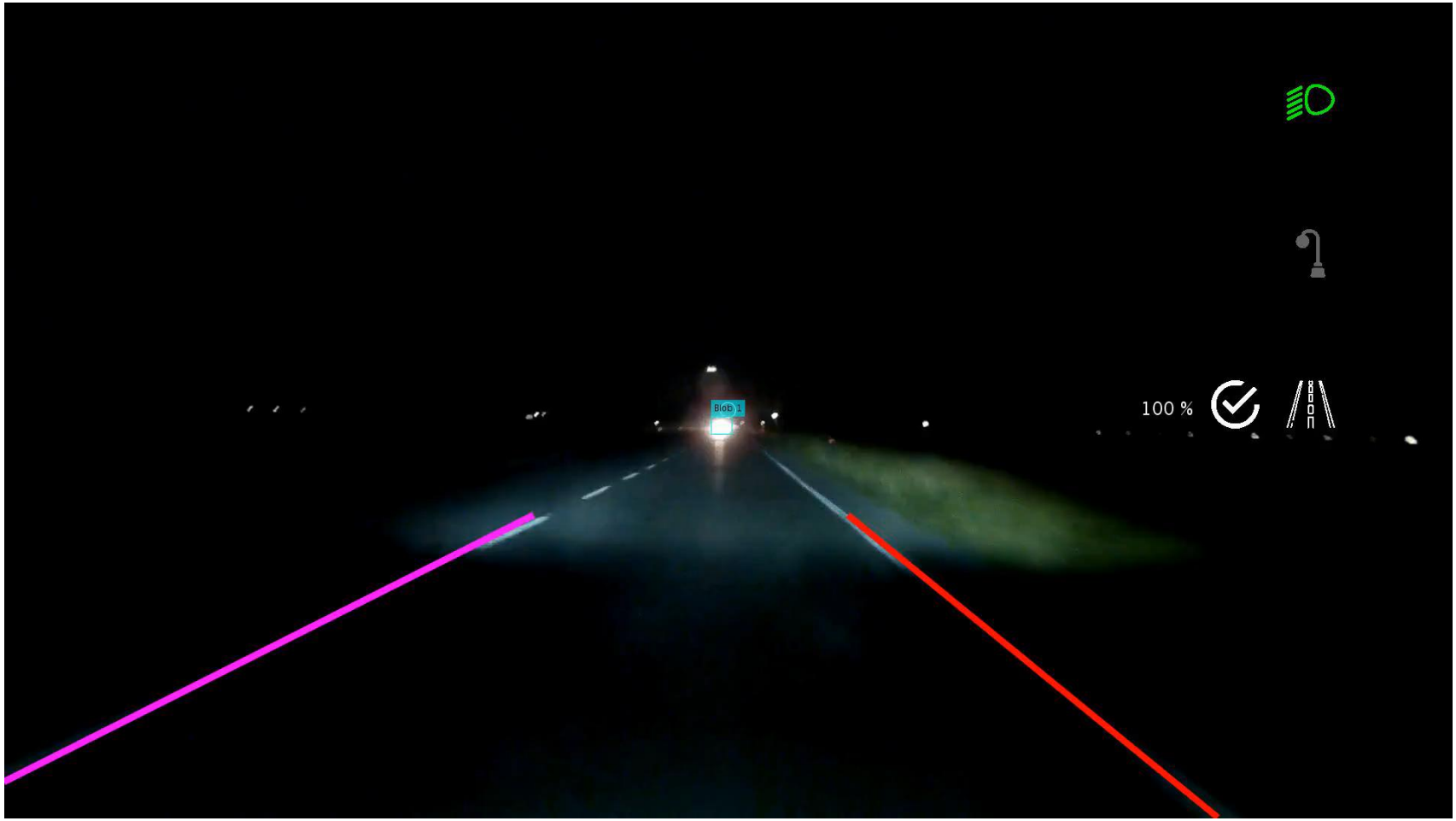
Experimental results – Dark video



Experimental results – Light video

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Experimental results – Day video

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Conclusions – Future works

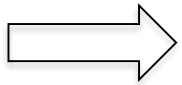
Conclusions

In this work it has been accomplished the sensing for a motorbike adaptive headlamp:

- **Lane detection;**
- **Vehicle detection;**
- **External illumination detection.**

} **Interaction between them**

Future works



Thank you for paying attention.