Good afternoon!

https://www.youtube.com/watch?v=tlThdr3O5Qo

Road Line Detection with Autonomous Cars

Volodymyr Shvets

Agenda

- What is autonomous driving?
- Road lane detection with computer vision
- Neural networks approach
- Conclusion

Autonomous driving

Self-driving car – a vehicle that is capable of sensing its environment and moving safely with little or no human input.

Synonyms:

- Autonomous vechicle.
- Driverless car.
- Robo-car/robotic car.

AUTOMATION LEVELS OF AUTONOMOUS CARS

LEVEL 0

There are no autonomous features.

LEVEL 1

These cars can handle one task at a time, like automatic braking.

LEVEL 2

These cars would have at least two automated functions.

LEVEL 3

These cars handle “dynamic driving tasks” but might still need intervention.

LEVEL 4

These cars are officially driverless in certain environments.

LEVEL 5

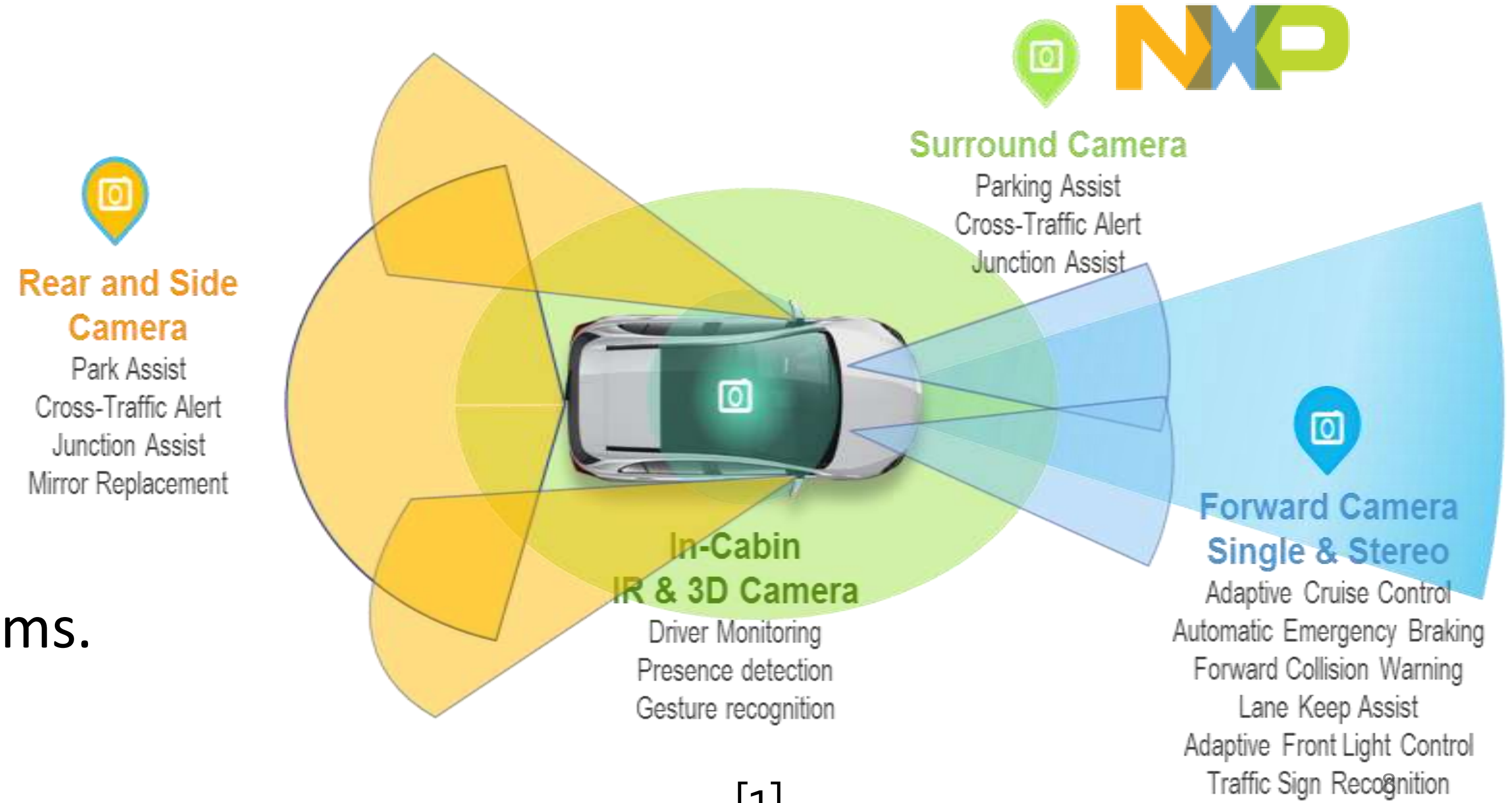
These cars can operate entirely on their own without any driver presence.

https://www.geospatialworld.net/blogs/five-levels-of-autonomous-cars/

What do autonomous cars use?

Self-driving cars combine a variety of sensors to perceive their surroundings, such as:

- RADAR
- SONAR
- LiDAR
- GPS
- Odometry and inertial measurement units.
- Advanced control systems.



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Step 0. Image detection

- Onboard camera, usually fixed at the front of a car and protected behind the windshield
- Takes N frames per second.
- Resolution: 480x640 pixels.
- Due to that **R**egion **O**f **I**nterest must be selected.

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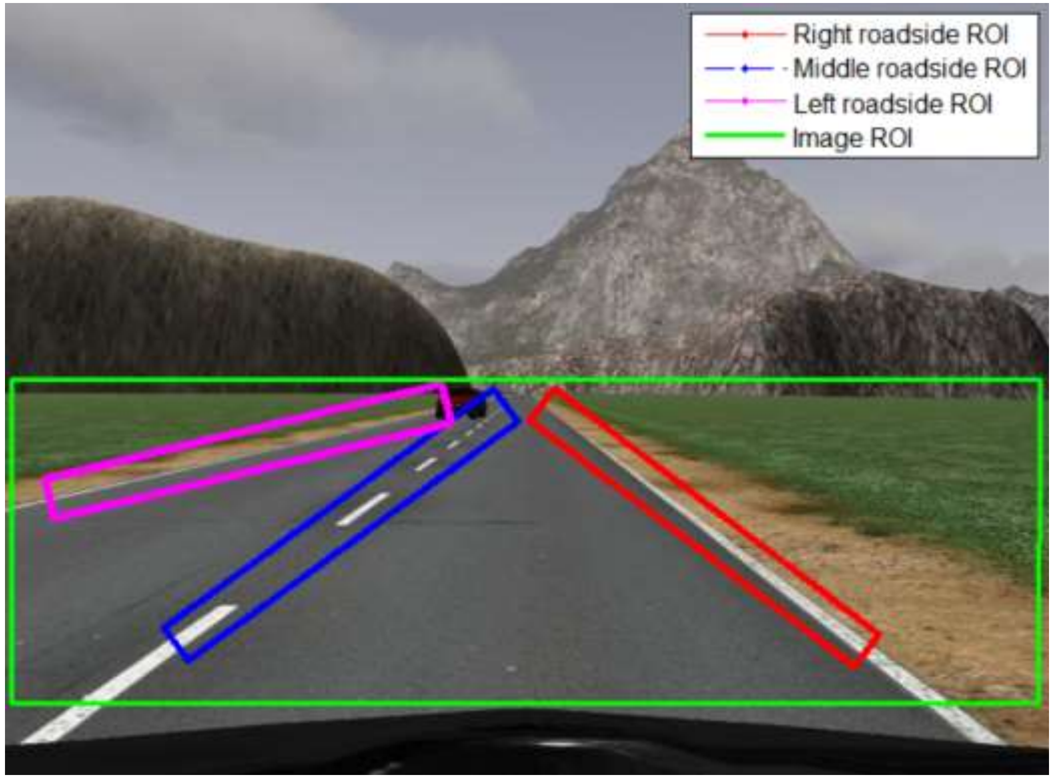
Step 1.Region of interest (ROI)

[3]

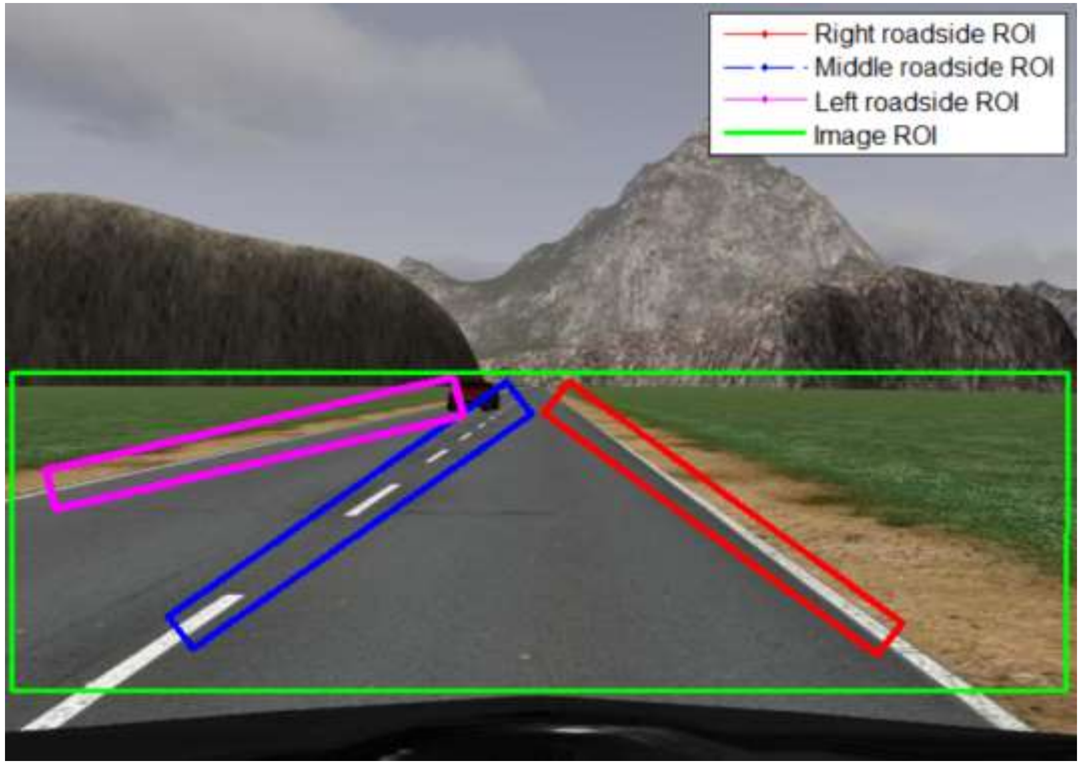


[4]

- ROI must contain road major information:
- Determining lines‘ position.
- Car position.

Advantage:
Applying ROI allows algorithm better target lines and minimize image-processing time

Step 2.Convert to grayscale



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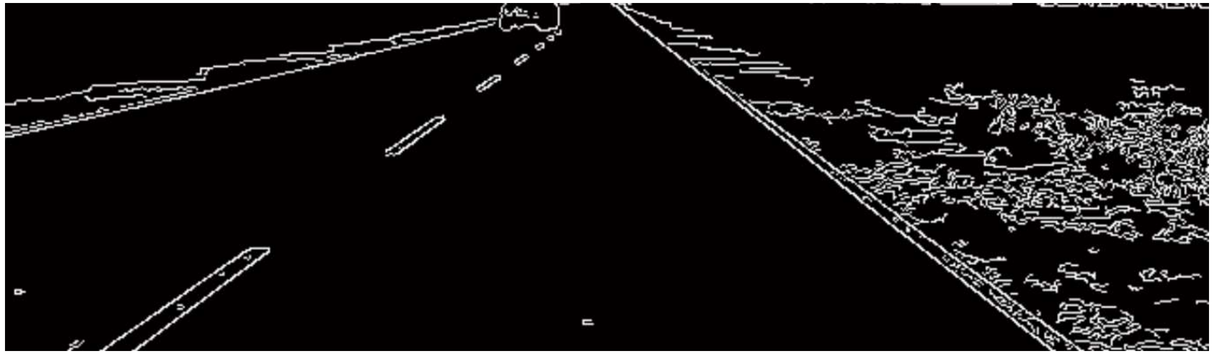
- The main objective is to generate an image with one layer rather than three(RGB)
- Image will contain only lane information.

Advantage:

The concept saves computational power for further data processing.



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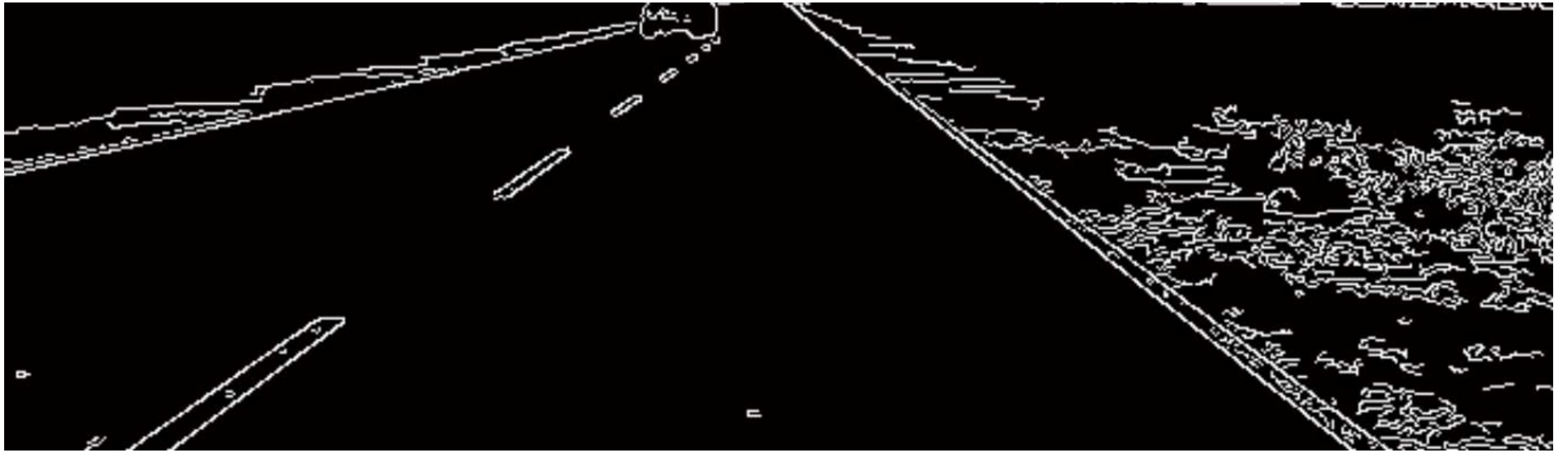
Step 3.Edge detection

To determine edges, there are several edge detectors:

- Sobel
- Laplacian
- Gaussian
- Canny.

Advantages of Canny:

1. Provides best edges frames:
2. Use all filters mentioned above.



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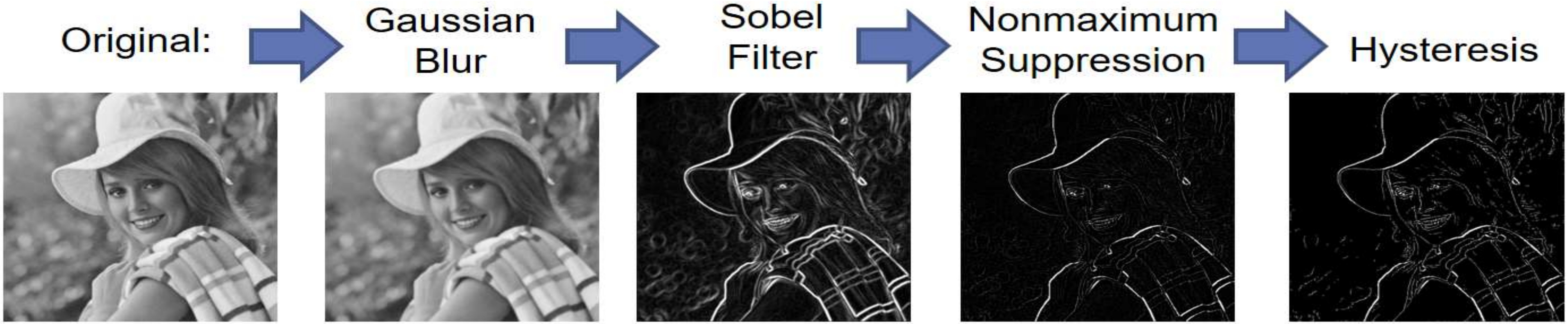
Canny edge detector

The Canny filter is a multi-stage edge detector.



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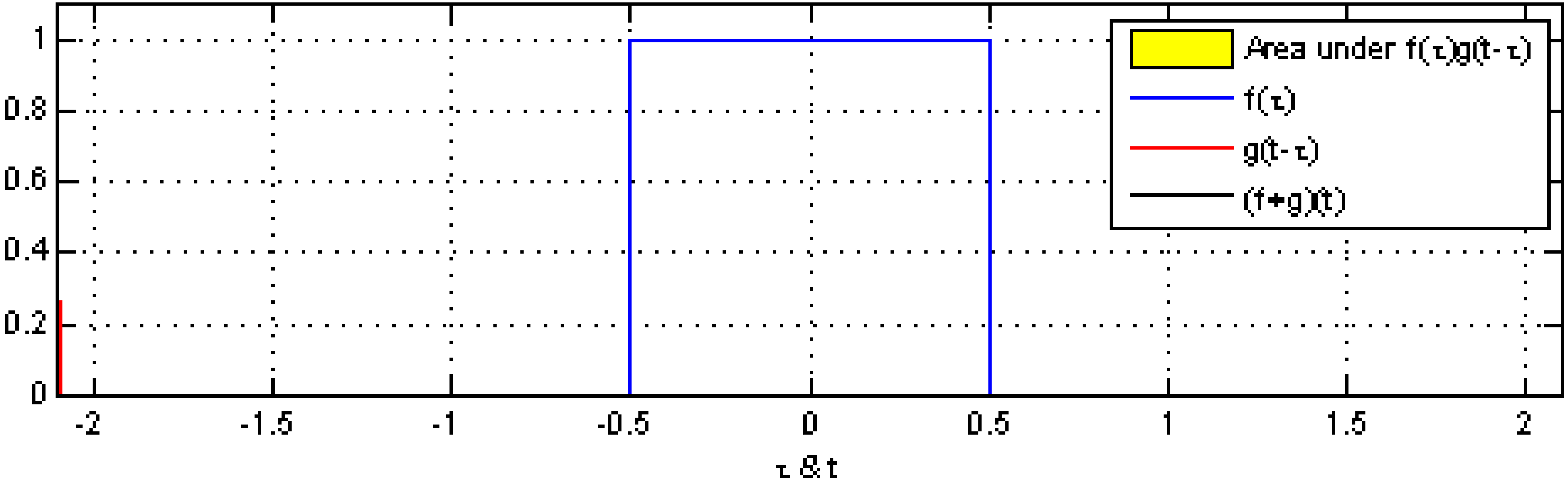
Recap.Convolution step by step



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Recap.Convolution step by step

0	0	0	0	0	0	0
0	60	113	56	139	85	0
0	73	121	54	84	128	0
0	131	99	70	129	127	0
0	80	57	115	69	134	0
0	104	126	123	95	130	0
0	0	0	0	0	0	0

Kernel

0	-1	0
-1	5	-1
0	-1	0

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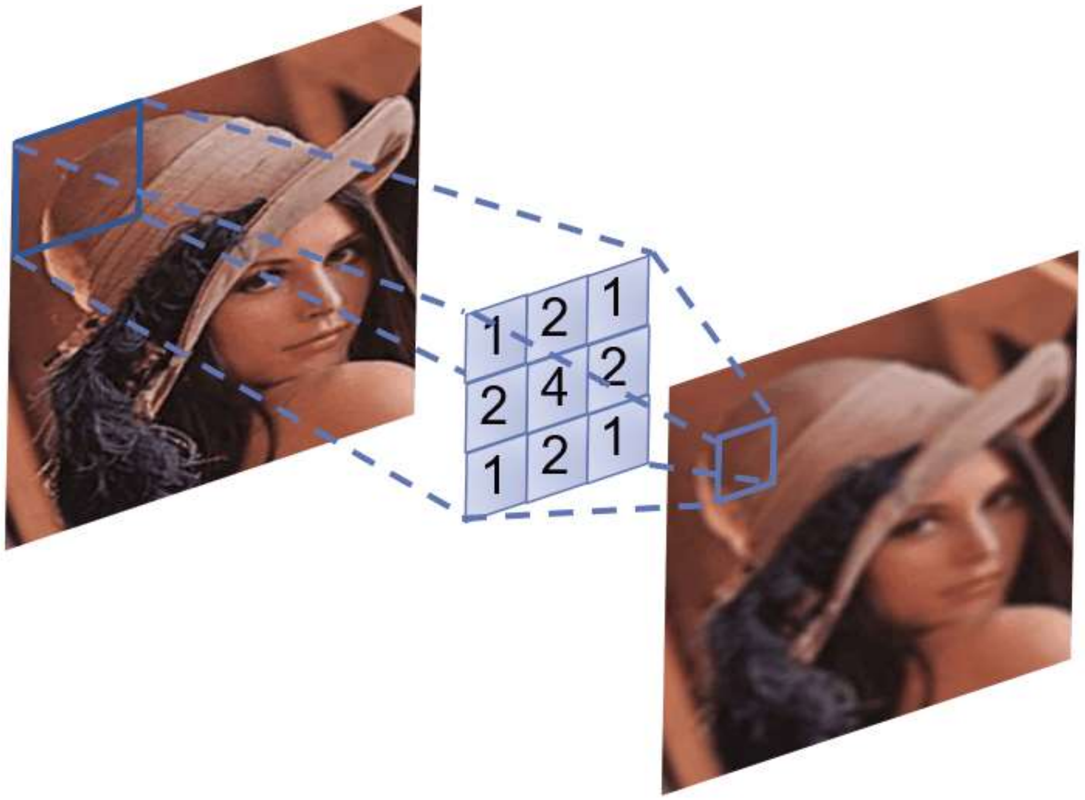


[5]

Canny edge detector example

[5]

Step 4. Detect road boundaries

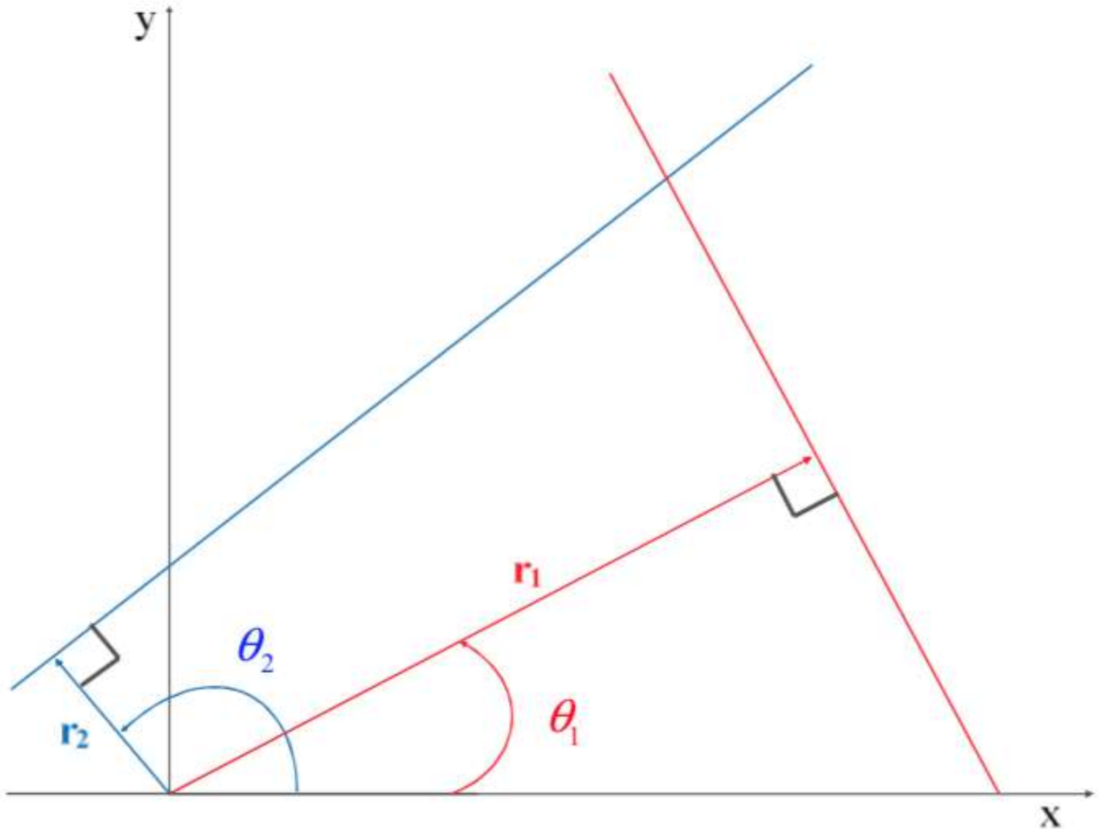
- Need to convert from 3D -> 2D world
- One of the most effective methods is **H**ough **T**ransform (**HT**)

Advantages:

Transforms a set of frame pixels from Cartesian - > Hough space

Disadvantages:

Computationally expensive



<u>Used when vehicle loose lane tracking.</u>

$$r_i = x\cos\theta_i + y\sin\theta_i$$

[4]

Step 5. Live update.Polynomial approximation

1. Define ROI

2. Convert image to greyscale

3. Define polynomial model template:

$$y = p_n x^n + p_{n-1} x^{n-1} + \ldots + p_0$$

4. Find mathematical model, polynomial that fits the road boundary edges:

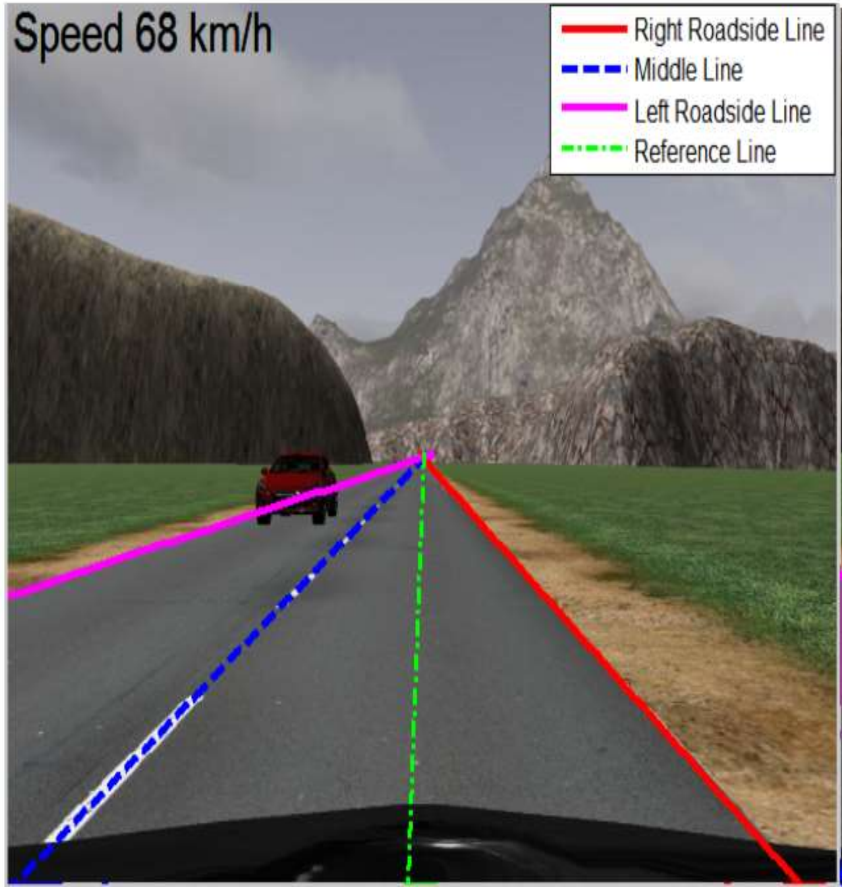
5. Compare retrieved model with template.

Step 6. Live update. Noise handling

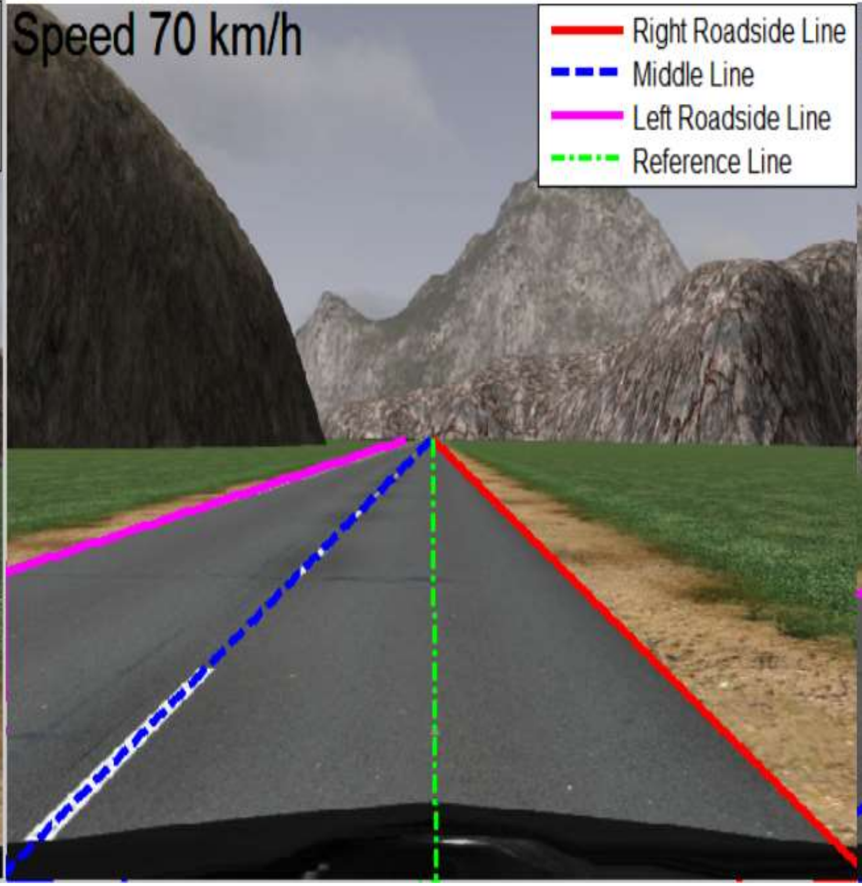
- Road can cause some vibrations, bad surface.
- Low visibility: weather conditions
- Need to estimate future lines and ROI position based on current information.
- **Apply Kalman filter!**

Computer vision. Example

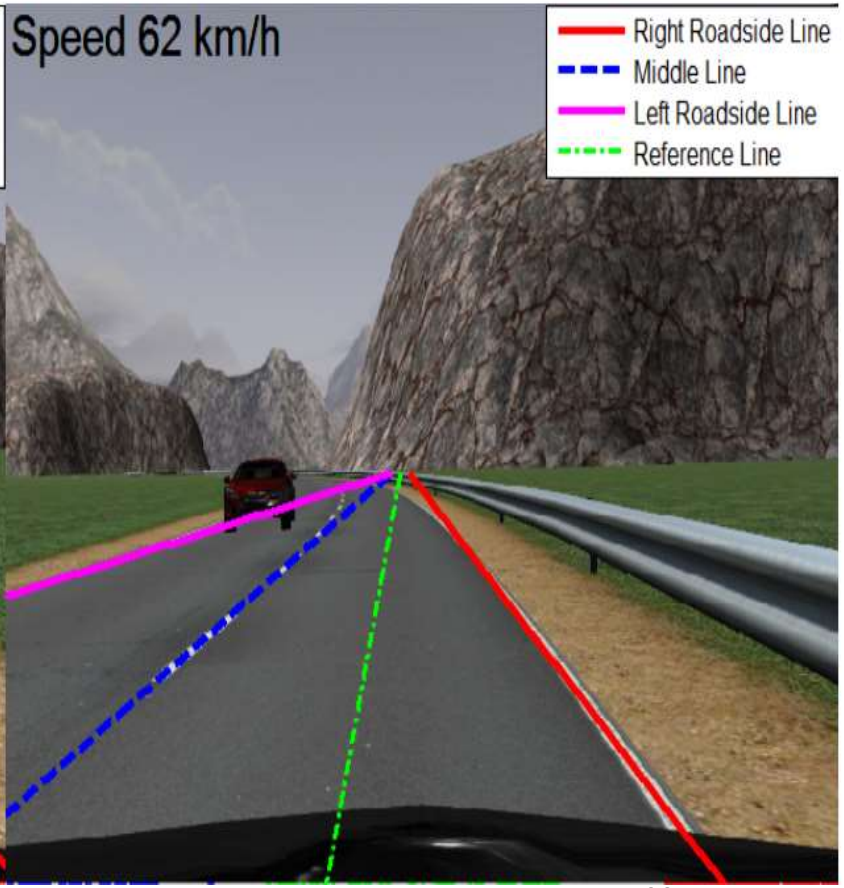
Speed 68 km/h



Speed 70 km/h



Speed 62 km/h



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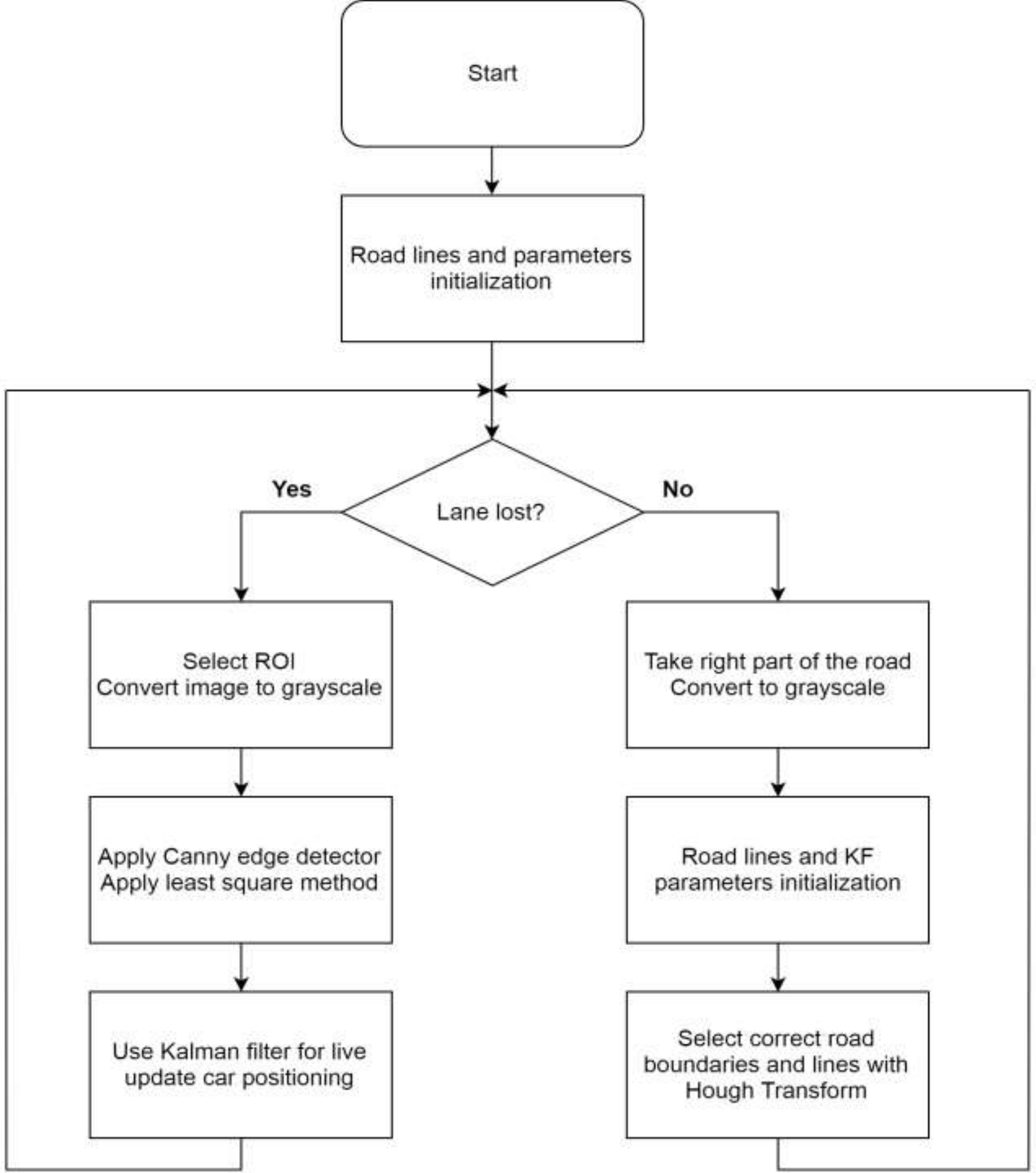
Computer vision. Summary



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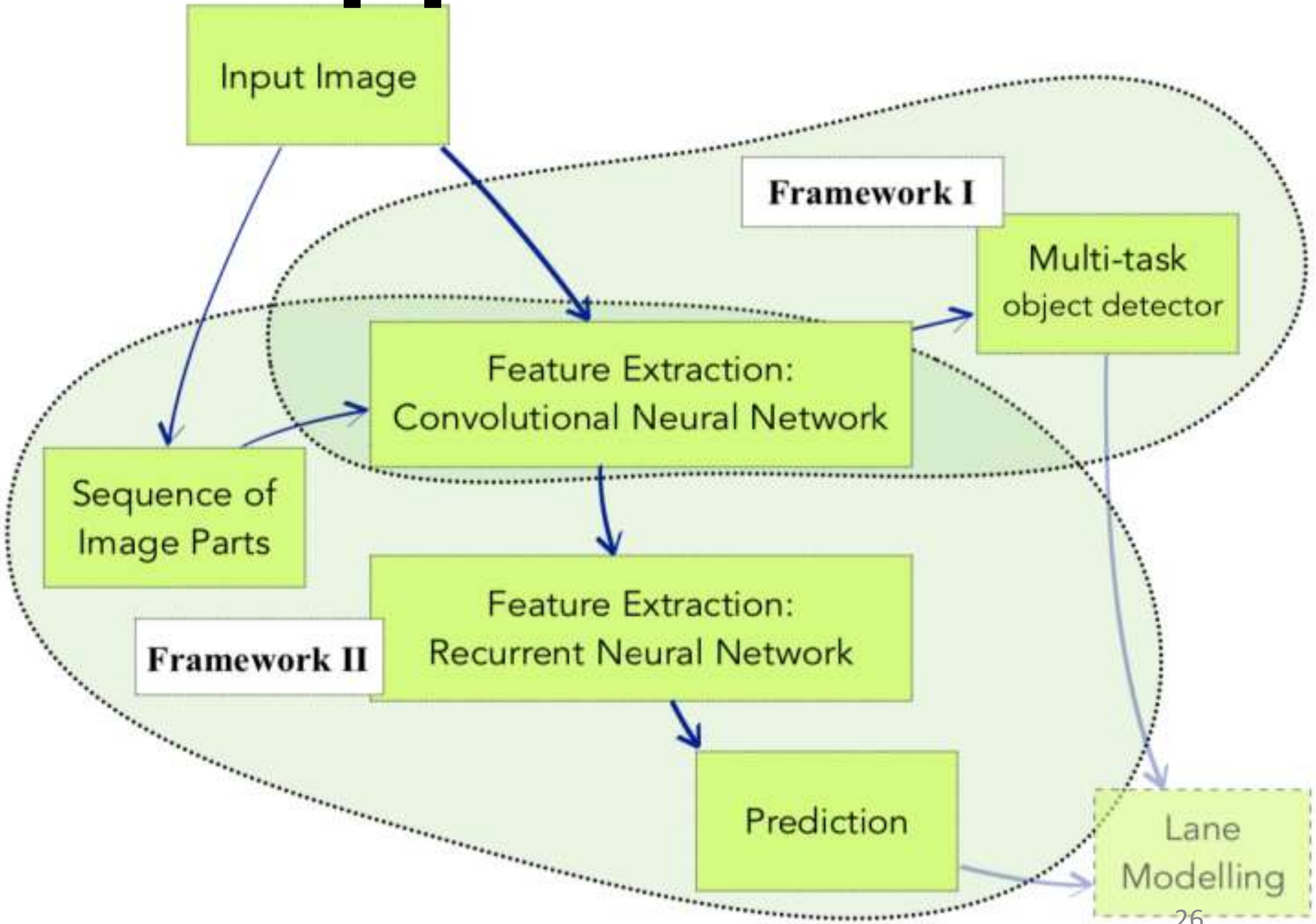
Neural Network approach

Framework I

- Detects lane boundaries and outline.
- **CNN**

Framework II

- Pedicts lane outline
- **RNN**



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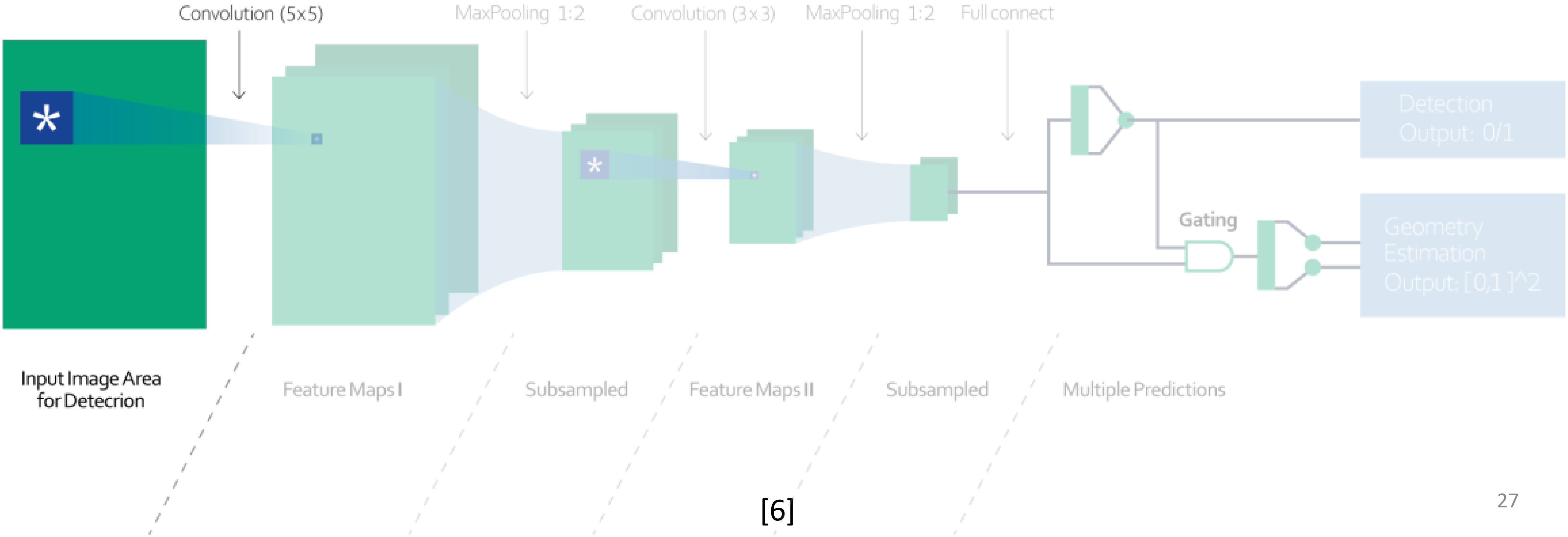
Multi-task Object Detector

1. Input is ROI from an image.



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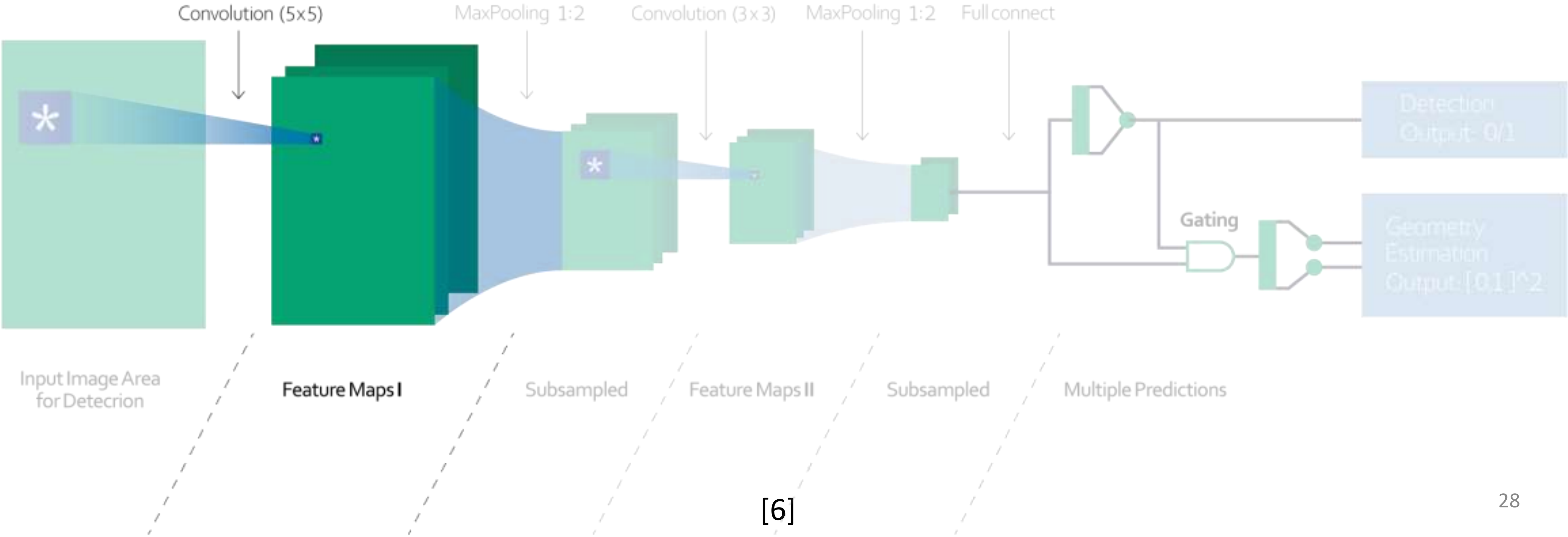
Multi-task Object Detector

2. Apply convolution image filters and get feature map.



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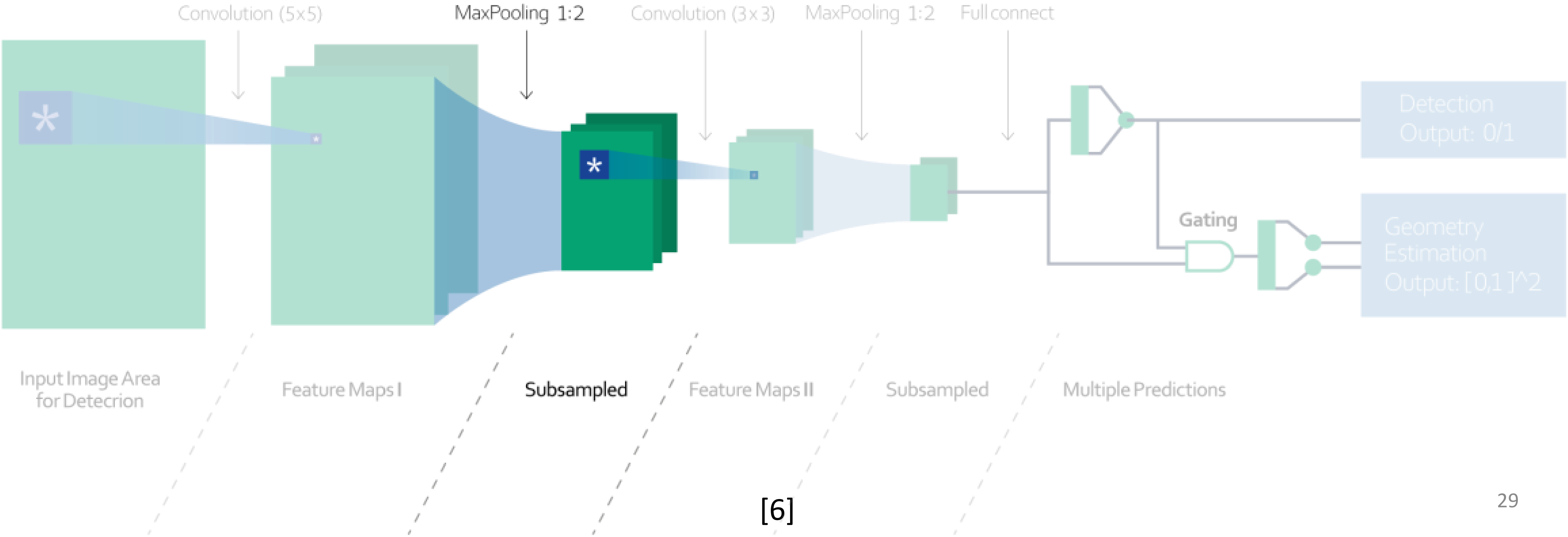
Multi-task Object Detector

3. Apply down-sample (shrink the size of the feature maps by pooling the maximum filter responses from local)



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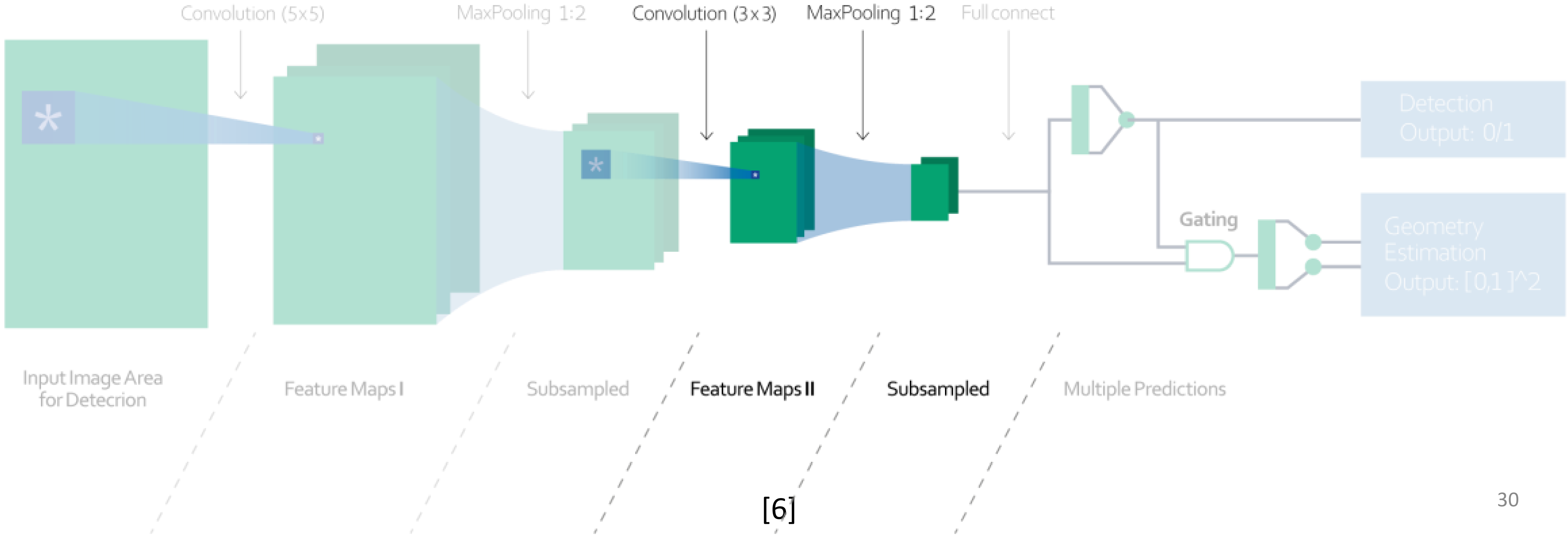
Multi-task Object Detector

4. Repeat Step 2 and Step 3 twice for better robust detection. As well effective geometric prediction.



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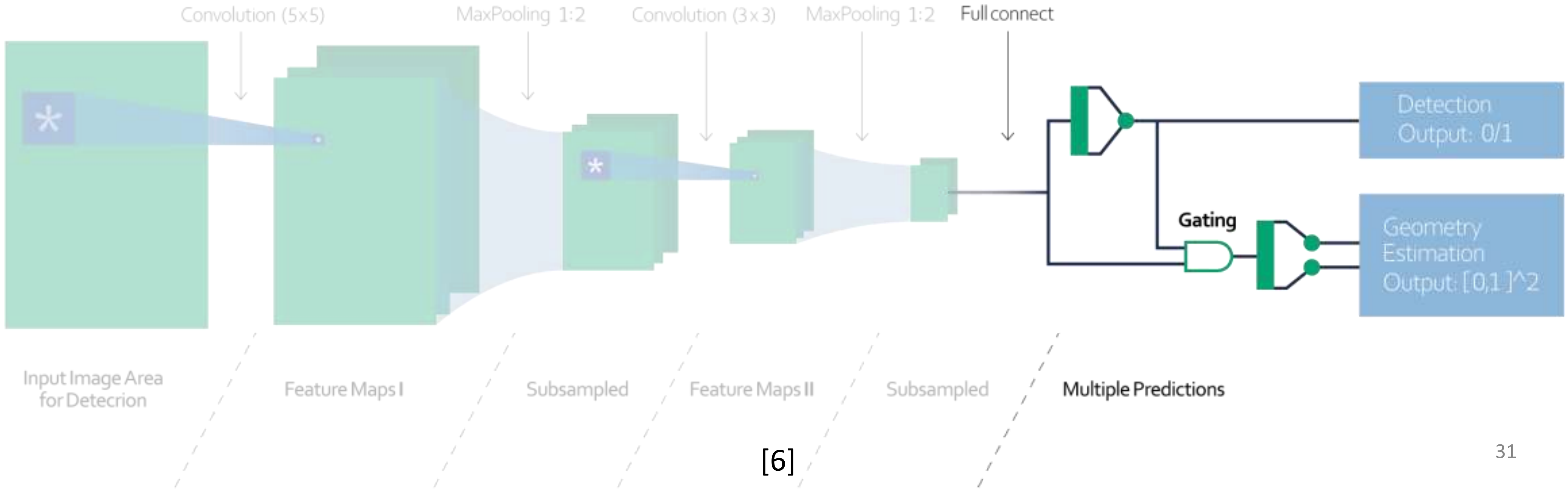
Multi-task Object Detector

5. Check the information if target(lane) is present
    - ➢ No: Detection output -> found object must be classified
    - ➢ Yes: Geometry estimation output - > detected object is line segment



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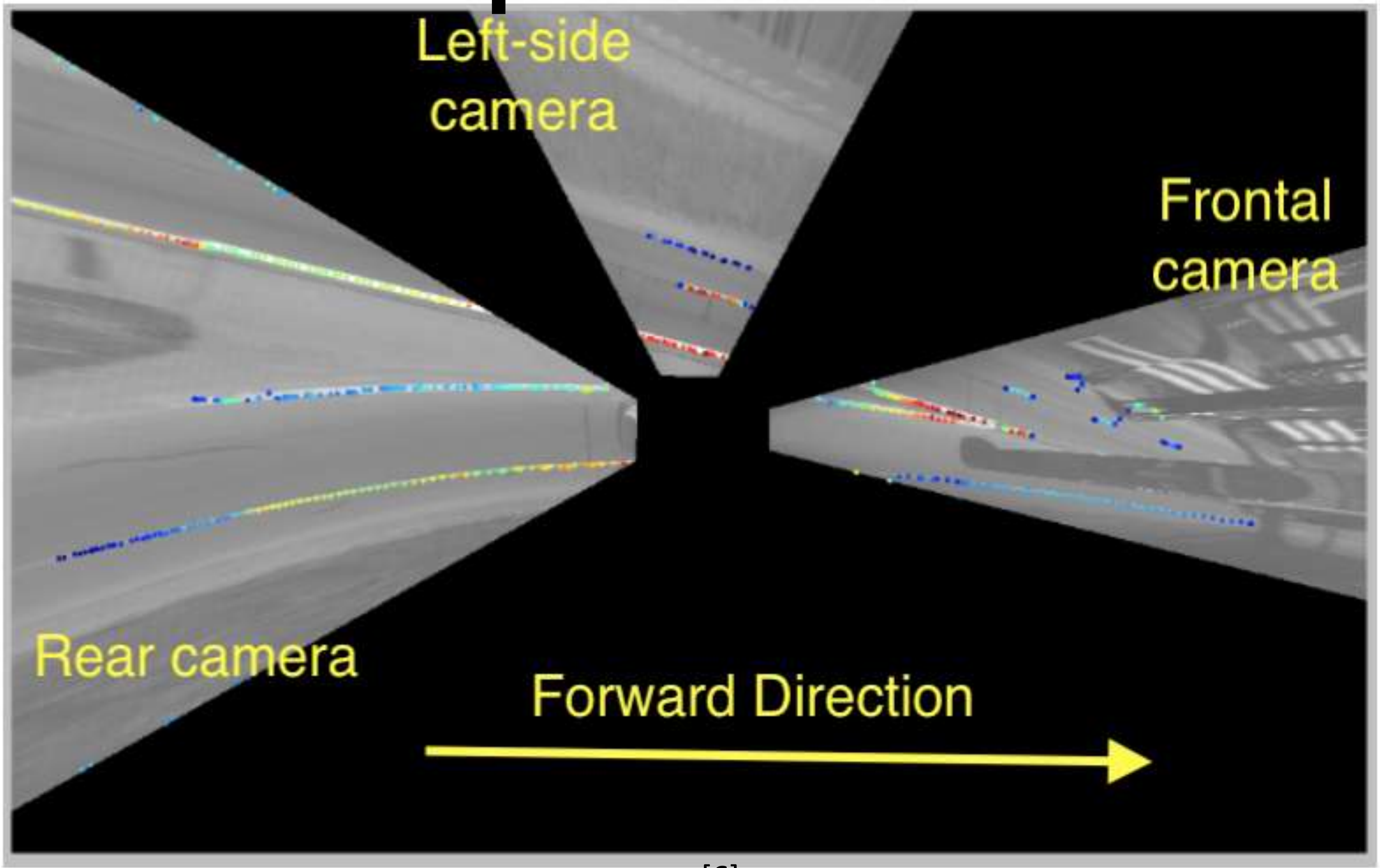
CNN Example



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RNN Network

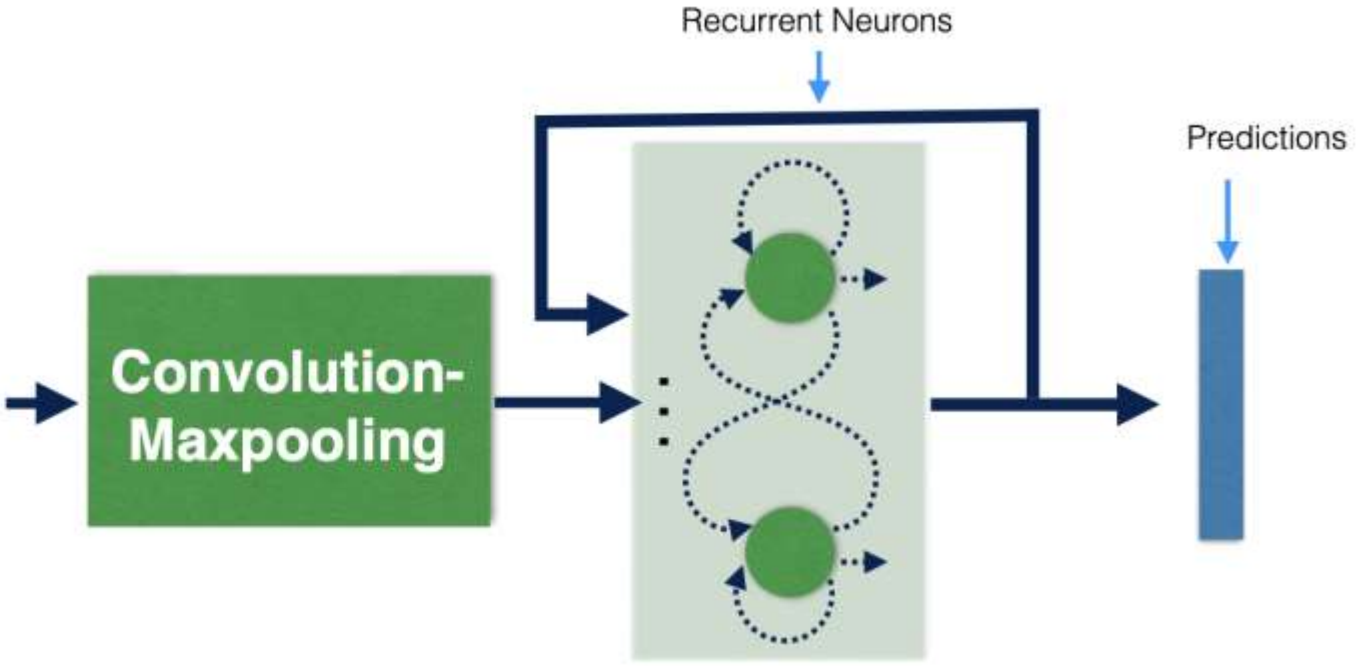
Predicts line allignment

Algorithm flow:

1. Generating feature maps from input image by applying convolution.

2. Process feature map to hidden layers for better precision.

3. Output predictions.



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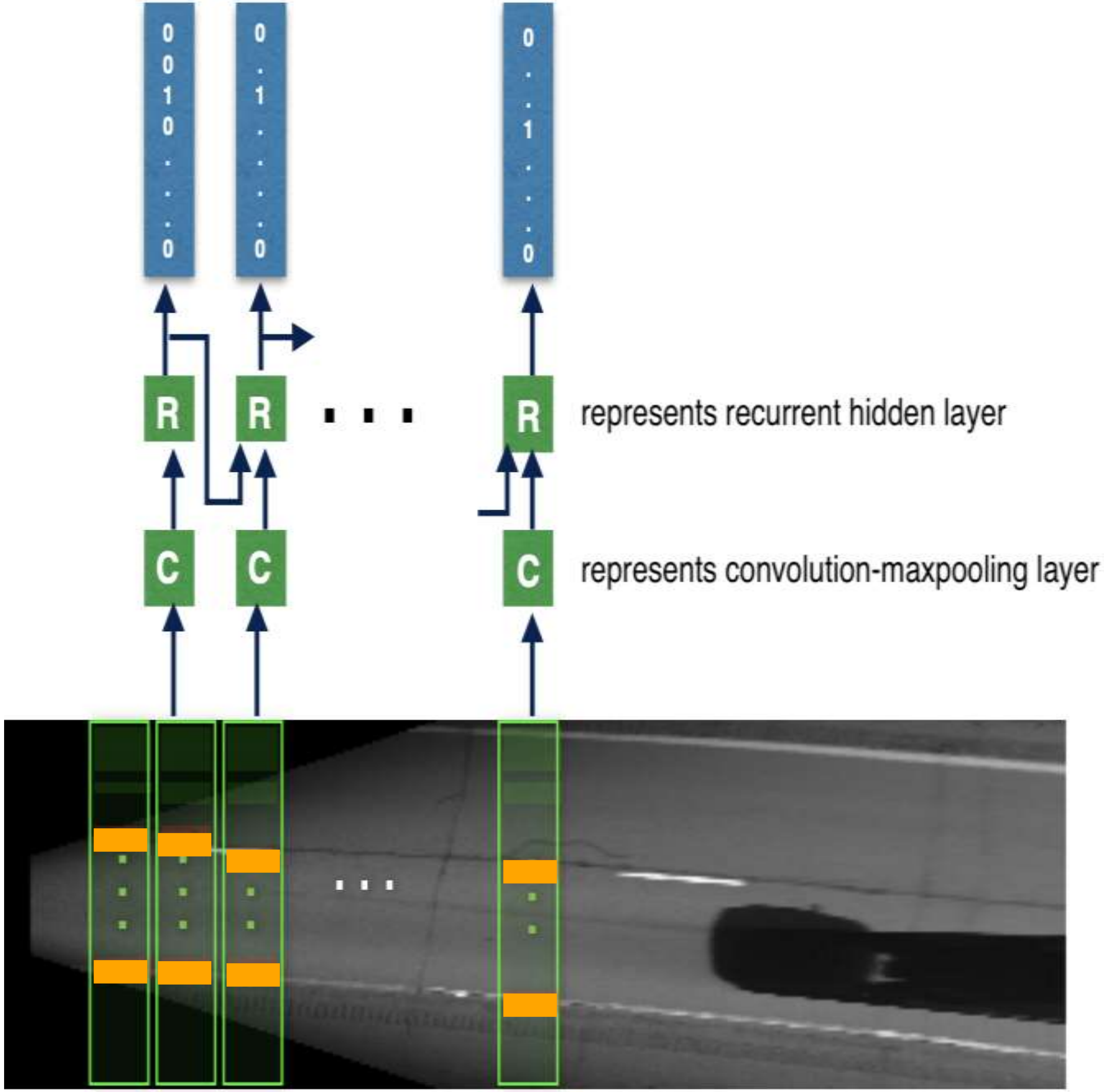
RNN Example

- Green rectangle box – ROI
- The orange patches contain
  lane boundaries.*
- Green dots width of the lane(estimated)



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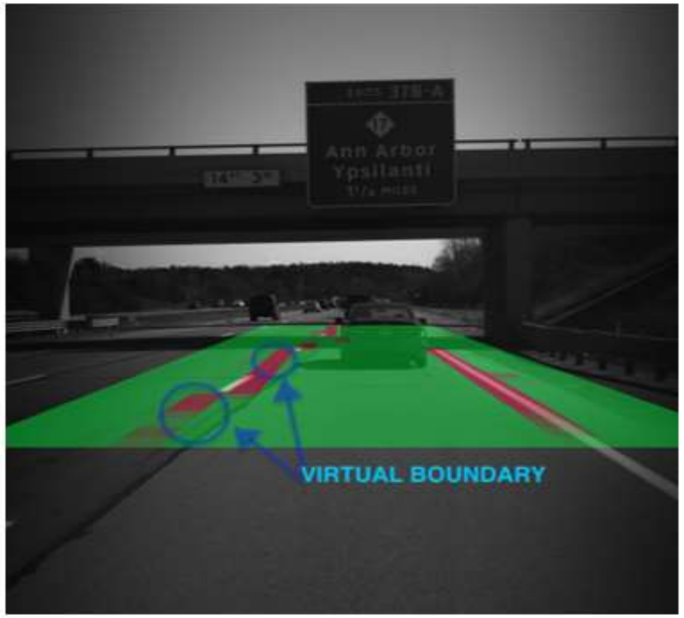
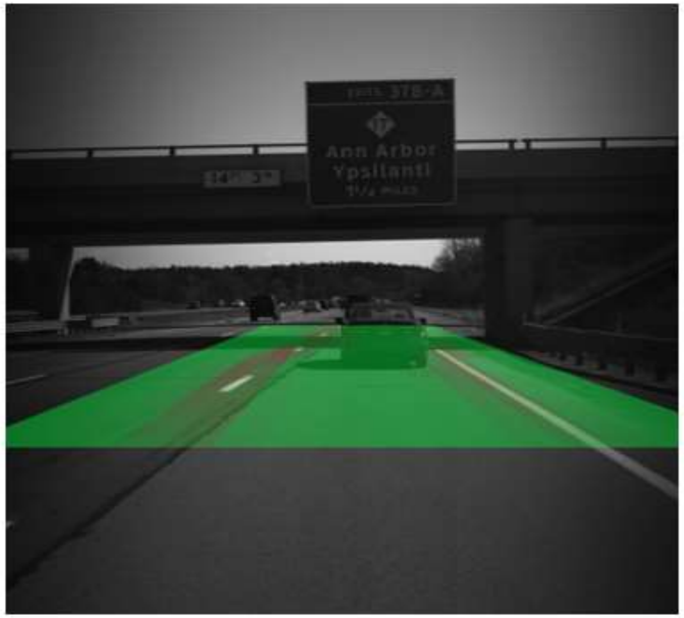
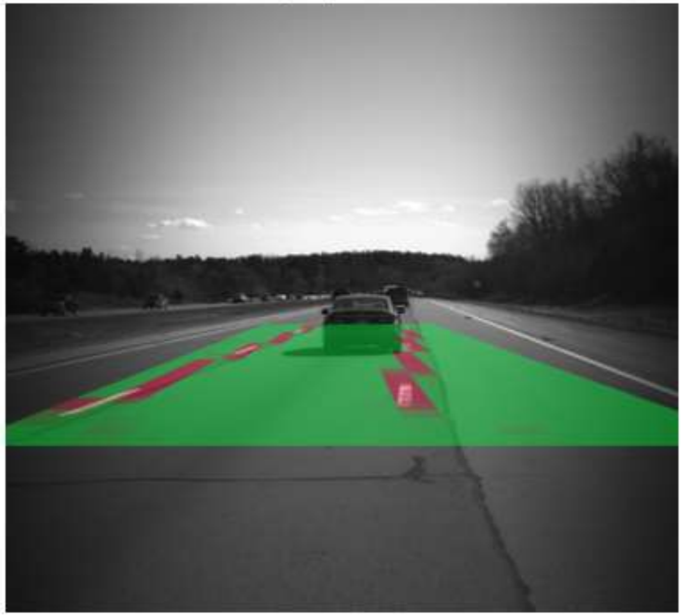
RNN **CNN**



(a$_1$)



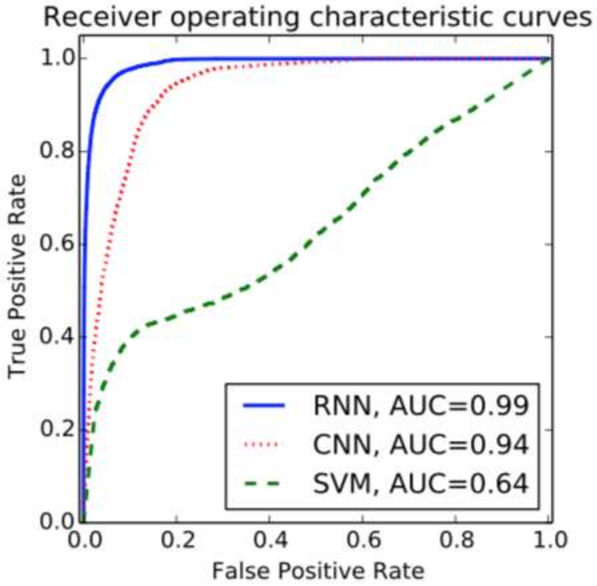
(b$_1$)



(a$_2$)

[6]

(b$_2$)



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Conclusion

Computer vision approach:

1. Select ROI.
2. Grayscale conversion.
3. Canny edge detector.
4. Position car with Hough
5. Transform
6. Live update with polynomial approximation.
7. Predict ROI with Kalman filter

Neural Network approach:

1. Select ROI.
2. Apply CNN to get lane detection(complex)
    1. Convolutional Neural Network to get feature map of the image(complex)
3. Apply RNN to predict lane positioning.
    1. Use hidden layers for better resolution

Conclusion

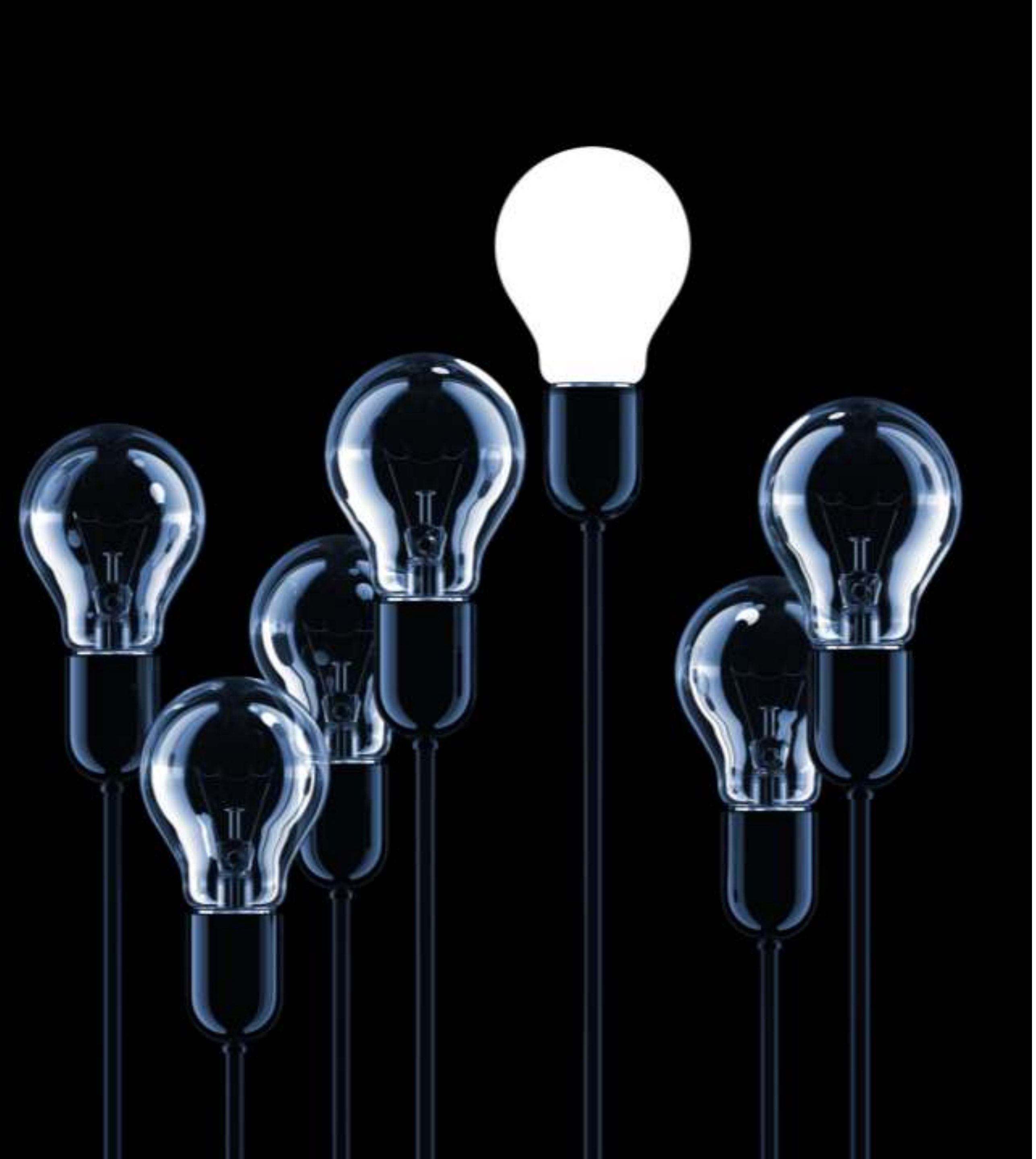
- Which approach to select?

  It depends
- CV less expensive.

  Applied for speed < 70 km/h.

  Robust against noise
- NN more expensive.

  Need more resources(computational + dataset)
  More time and resources on development



Thank you for your attention

Questions?

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Feedback

References

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[2] https://www.importantinnovations.com/2018/09/ai-cameras-on-autonomous-cars.html?spref=pi

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[4] Bounini, Farid & Gingras, Denis & Lapointe, Vincent & Pollart, Herve. (2015). Autonomous Vehicle and Real Time Road Lanes Detection and Tracking. 1-6. 10.1109/VPPC.2015.7352903.

[5] https://www.legupcomputing.com/blog/index.php/2017/08/25/canny-edge-detector-using-legup/

[6] J. Li, X. Mei, D. Prokhorov and D. Tao, "Deep Neural Network for Structural Prediction and Lane Detection in Traffic Scene," in *IEEE Transactions on Neural Networks and Learning Systems*, vol. 28, no. 3, pp. 690-703, March 2017.
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