Linear Algebra

Least Square-based Sensor Data Processing

Automotive Intelligence Lab.

Contents

■ **Lane model fitting for camera lane detector**

■ **Ground model fitting for LiDAR measurements**

Lane model fitting for camera lane detector

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Various Camera based Perception Systems

■ StradVision

Cameras in Autonomous Vehicle

Surrounding view camera

Digital Side mirror camera

Rear view camera

Rear-side view camera

Sur[…] Camera

Side Sensing Camera

Rear V[…] Cam[…]

E-Mirror

Driver Monitoring

Surround View Camera

Front View Camera

● Applications for 'ISOCELL A[…]
● Applications for automotive

Front view camera

Driver monitoring camera

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Least Square Example: Visual SLAM

■ **Visual simultaneous localization and mapping (SLAM)**

▶ SLAM means estimating pose of the sensor while creating a map of the environment

▶ Visual SLAM uses only vision(camera) sensor for SLAM

ORB SLAM Demo Video

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Least Square Example: Structure from Motion (SfM)

■ **SfM with monocular camera**

▶ From 2D-image to 3D-model with monocular camera

▶ A photogrammetric range imaging technique for estimating three-dimensional structures from two-dimensional image sequences that may be coupled with local motion signals.
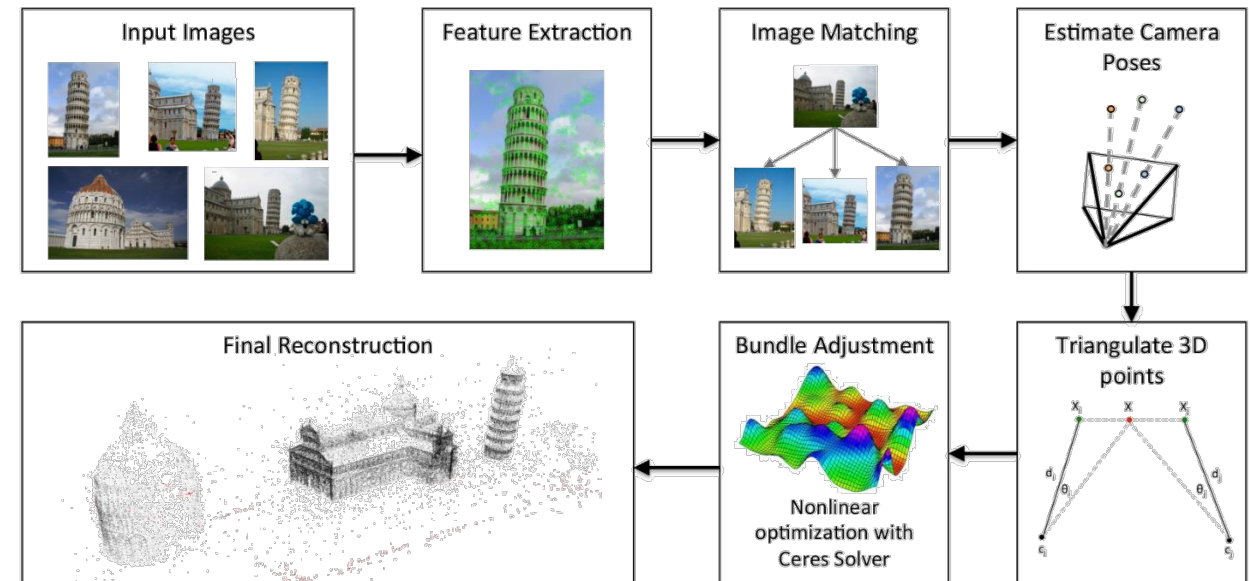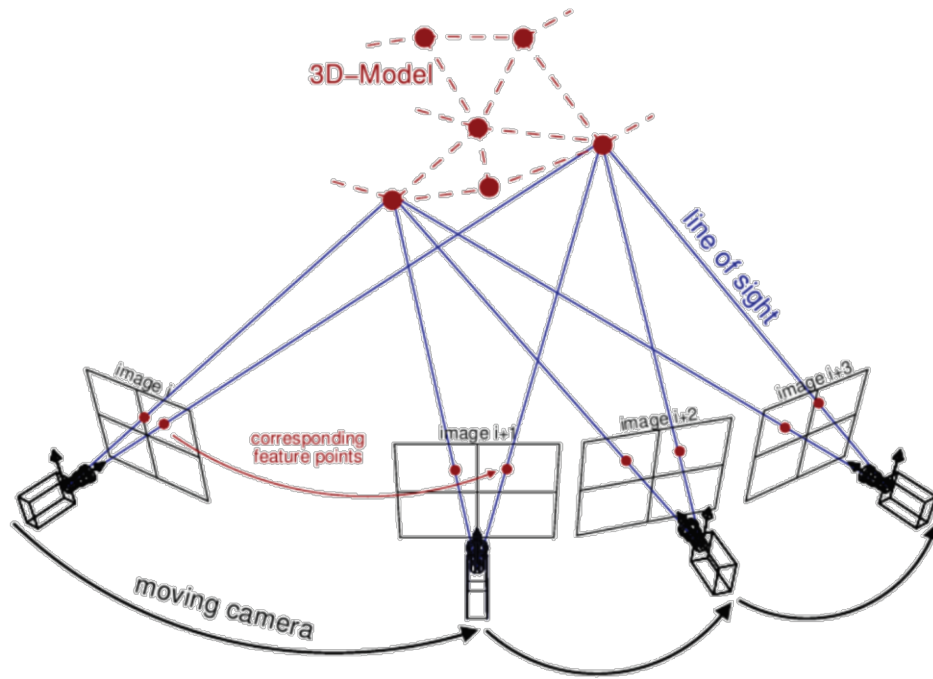
Structure from Motion (SfM) Demo

■ **SfM (Structure from Motion) demo video**

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Image Representation (1/2)

■ Image Acquisition Process
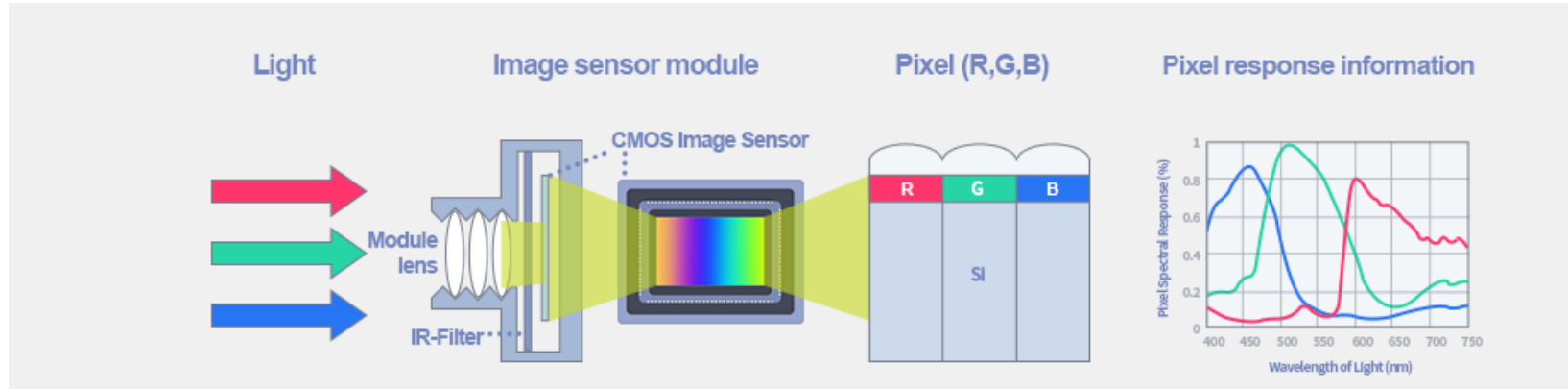
■ Image Representation

▶ Pixel
- The smallest unit that composes an image
- An image is an array of pixels

▶ Image coordinates
- Normally, the top left is (0,0)
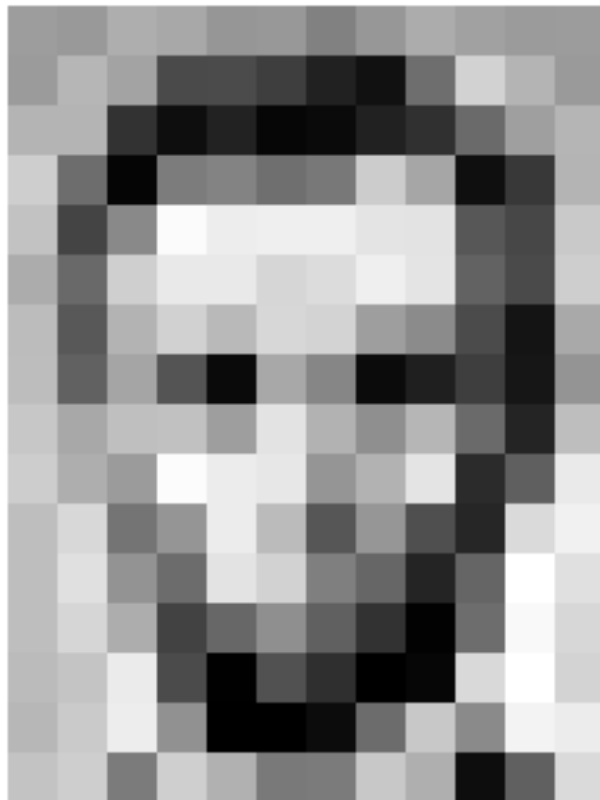- $f(x,y)$: pixel values at coordinates (x,y)
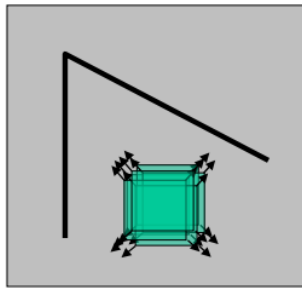
Image Representation (2/2)

Image Feature Extraction

■ **What is feature?**
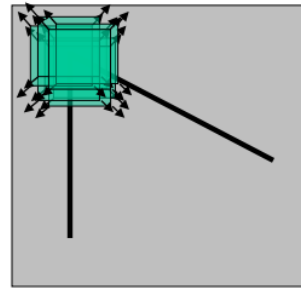
▶ Local, meaningful, detectable part of the image

▶ Edges

  ● A part where pixel values change rapidly in one direction

  ● Can determine the outline of an object

▶ Corners

  ● A part where pixel values change rapidly in all direction

Original Image Edge Detected

Example of edge detection

"flat" region:
no change in
all directions
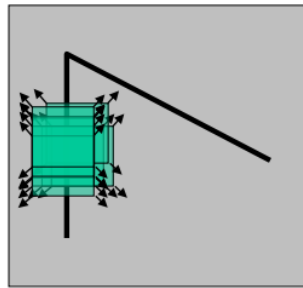
"edge":
no change along
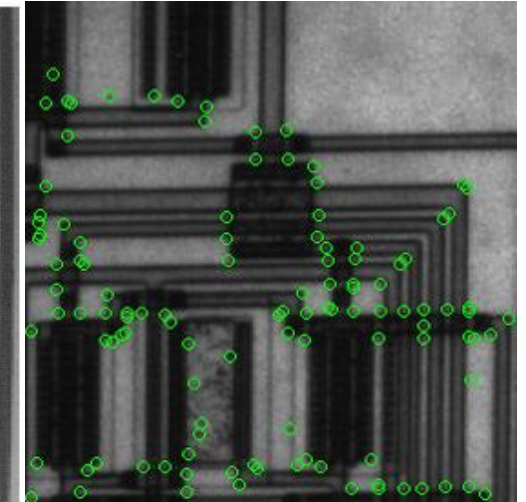the edge direction

"corner":
significant change
in all directions

Example of Corner detection

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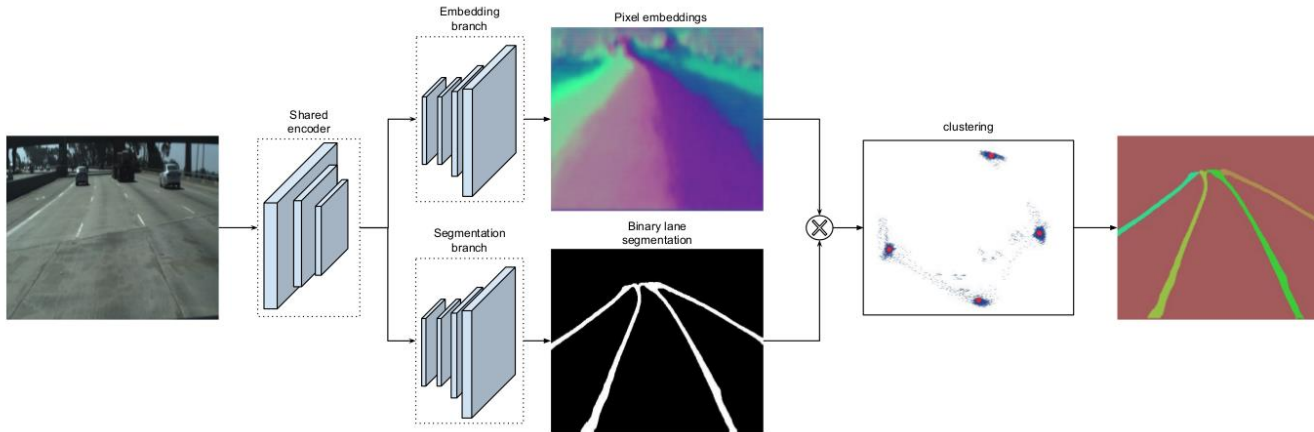
Machine Learning based Lane Detection

■ LaneNet: Real-time lane detection networks for autonomous driving

▶ Model takes driving scene image

▶ Shared layer extracts feature from image

▶ Two branch architecture

- Embedding branch extracts instance information to give unique identification between lanes
- Segmentation branch identifies lane segment

LaneNet Architecture
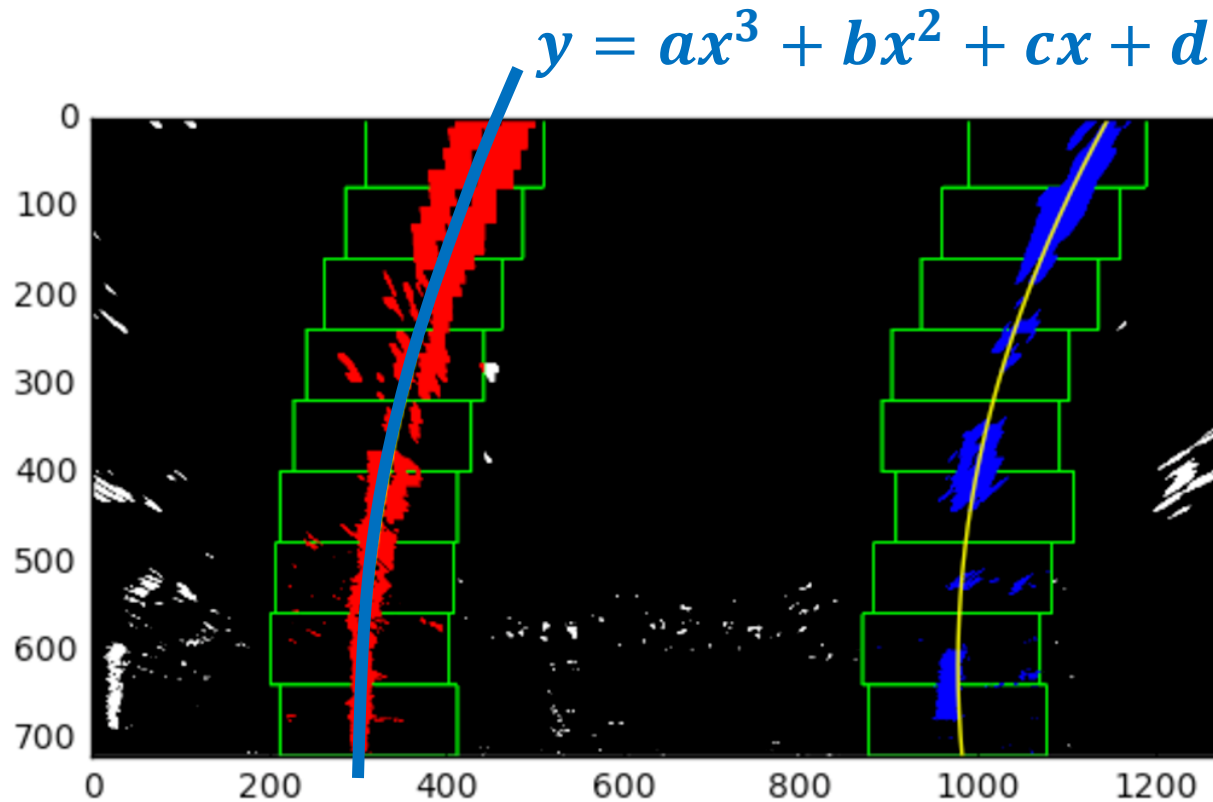

Lane detection demo

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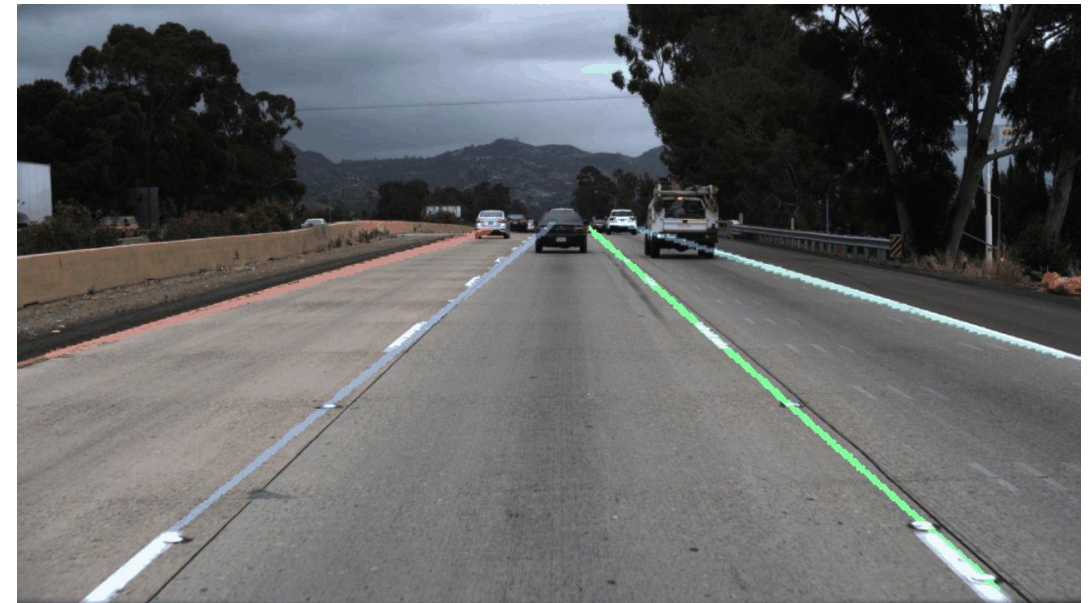
Lane Model Fitting with Least Sqaure

■ **Find a polynomial equation from the detected pixel.**

$$y = ax^3 + bx^2 + cx + d$$

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Meaning of Curve Equation

$$y = ax^3 + bx^2 + cx + d$$

■ **Lane Position**

▶ $y|_{x=0} = a * 0^3 + b * 0^2 + c * 0 + d = d$

■ **Heading Angle**

▶ $Heading\ angle = \mathrm{atan} \left. \frac{dy}{dx} \right|_{x=0} \approx \left. \frac{dy}{dx} \right|_{x=0}$

▶ $\left. \frac{dy}{dx} \right|_{x=0} = 3ax^2 + 2bx + c|_{x=0} = c$

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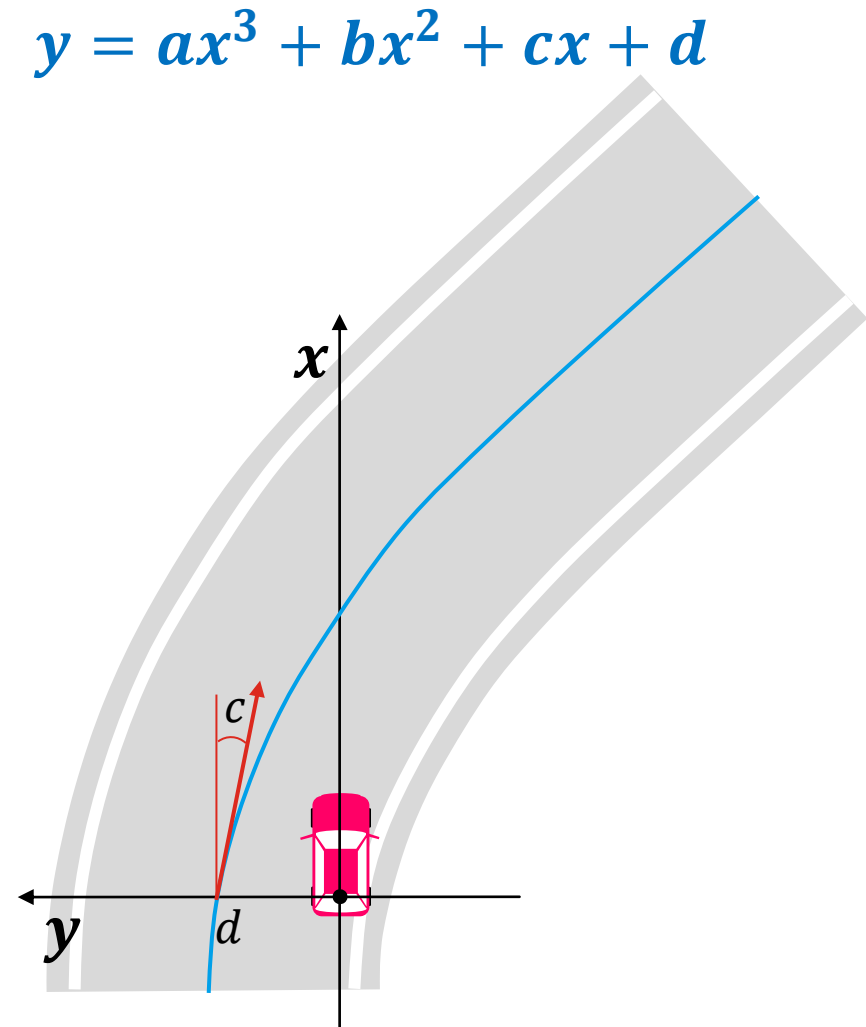
Meaning of Curve Equation

$$y = ax^3 + bx^2 + cx + d$$

■ **Curvature**

▶ $R = \dfrac{1}{\kappa} = \dfrac{\left(1+y'^2\right)^{\frac{3}{2}}}{y''}, \quad y'' = \dfrac{d^2y}{dx^2} = 6ax + 2b$

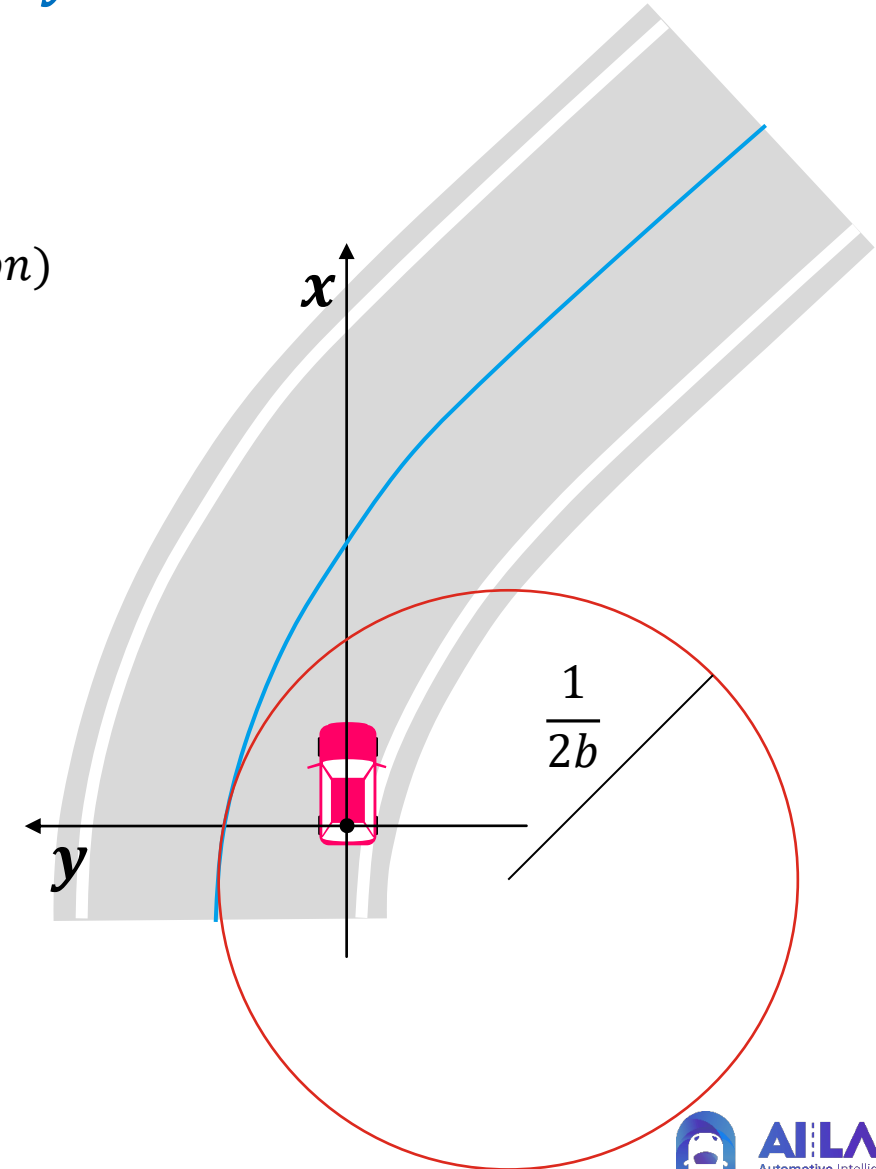▶ $\kappa = \dfrac{y''}{\left(1+y'^2\right)^{\frac{3}{2}}}\Bigg|_{x=0} = \dfrac{2b}{(1+c^2)^{\frac{3}{2}}} \approx 2b \quad (c \ll 1, small\ angle\ estimation)$

■ **Curvature Derivative**

▶ $\dfrac{d\kappa}{dx} = \dfrac{d}{dx}\dfrac{y''}{\left(1+y'^2\right)^{\frac{3}{2}}} = \dfrac{y'''\left(1+y'^2\right)^{\frac{3}{2}} - 3y''^2\left(1+y'^2\right)^{\frac{1}{2}}}{\left(1+y'^2\right)^{3}}$

▶ $\kappa' \approx y'''|_{x=0} = 6a, \quad (when\ y' \ll 1\ \ and\ \ y'' \ll 1)$

https://www.intmath.com/applications-differentiation/8-radius-curvature.php

x

y

$\dfrac{1}{2b}$

Ground model fitting for LiDAR measurements

LiDAR (Light Detection And Ranging)

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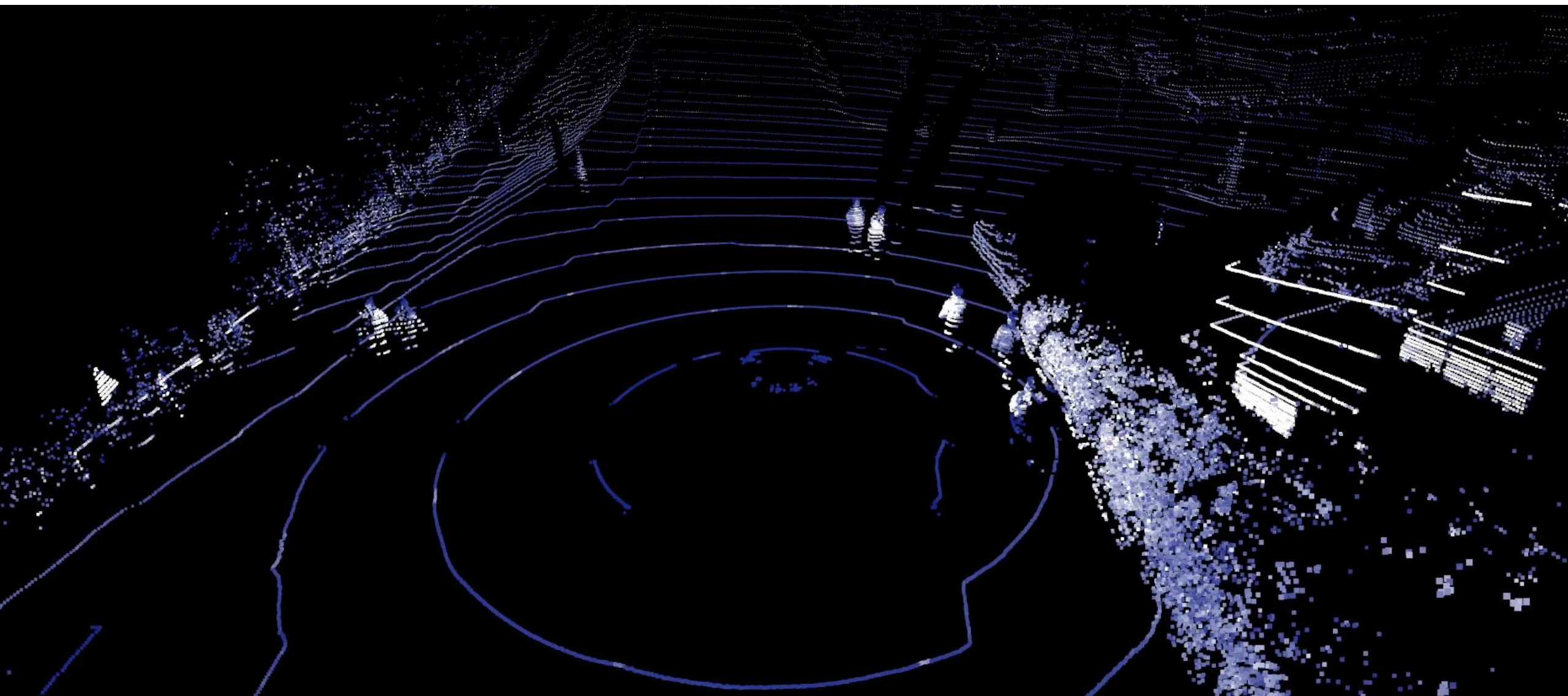
LiDARs on Autonomous Cars

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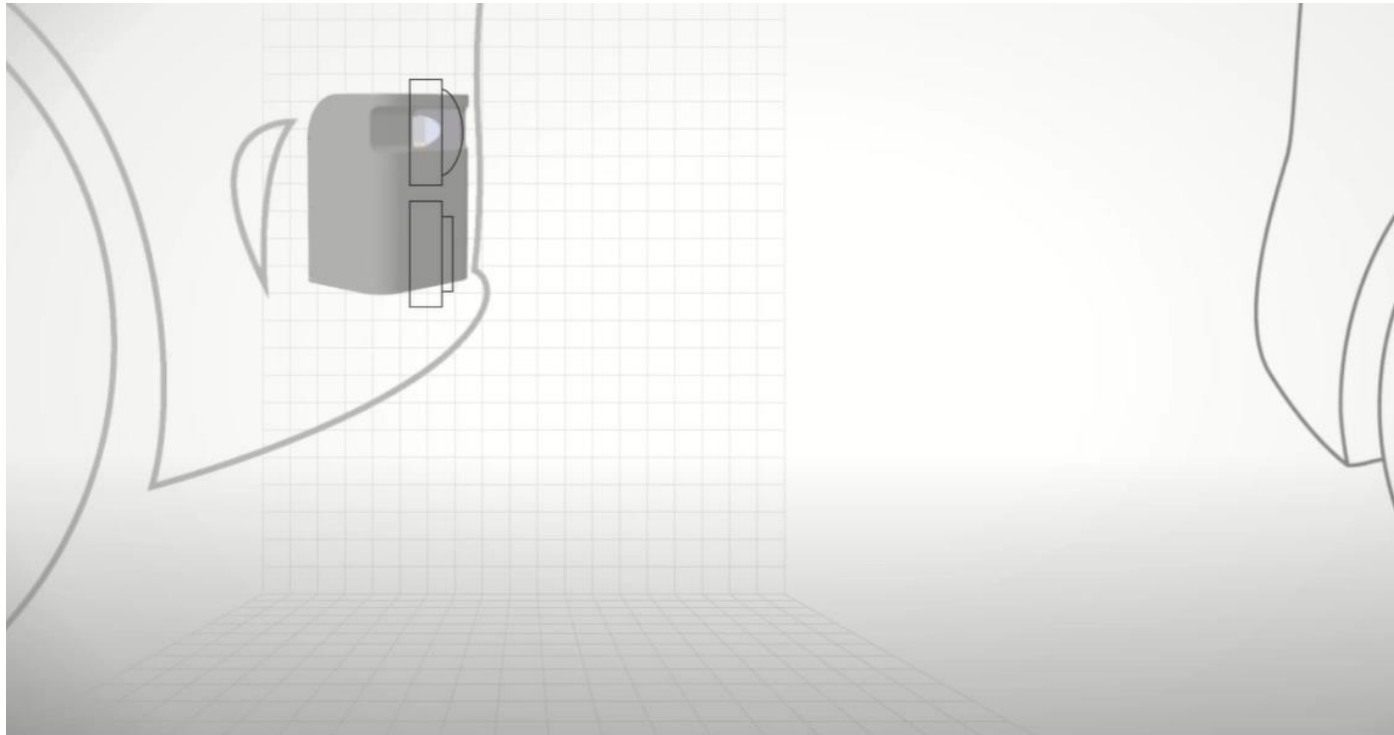
ToF (Time of Flight)

■ Time of Flight (ToF)
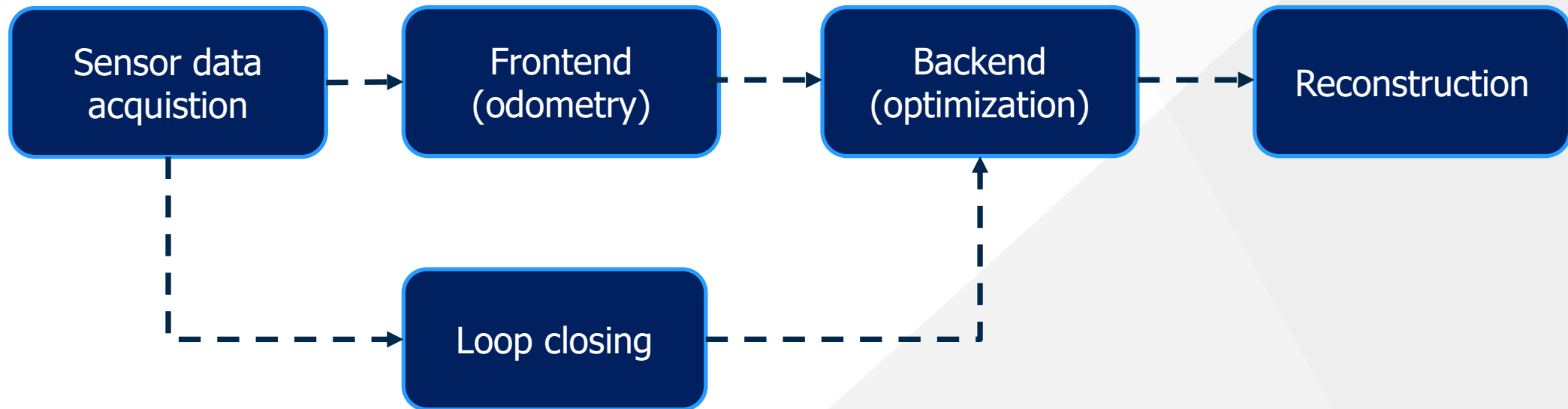
▶ Emitting a laser pulse on a surface

▶ Catching the echo pulse to the LiDAR pulse source with sensors

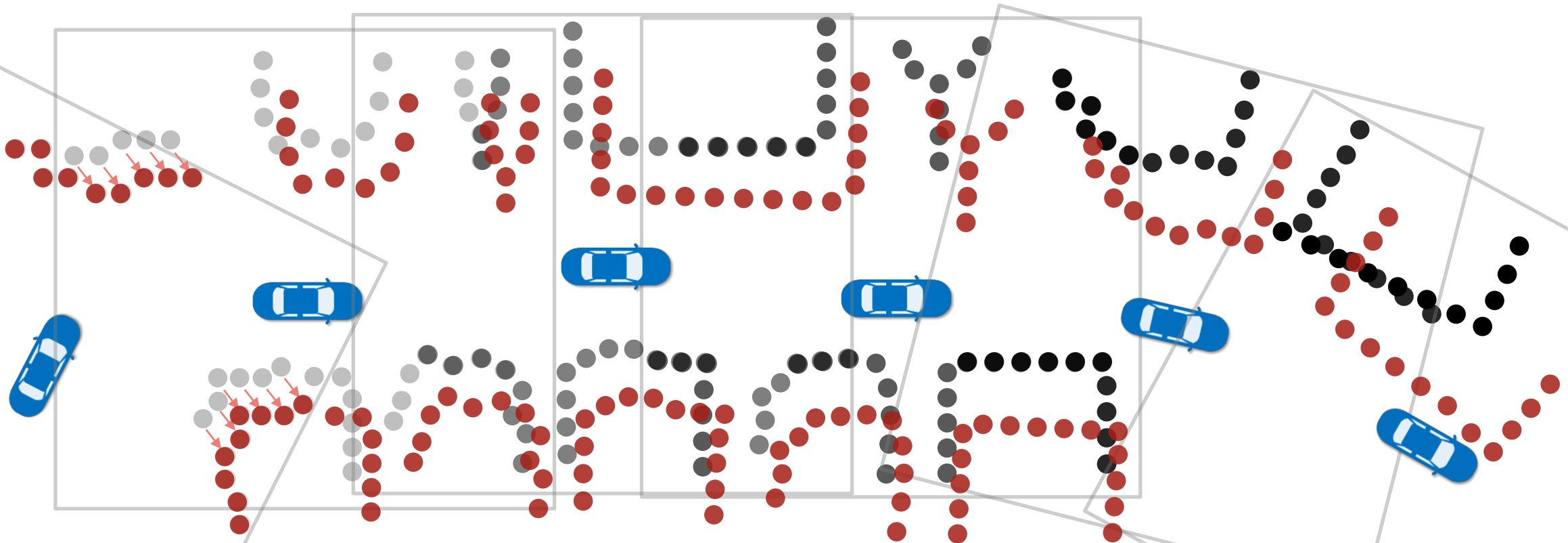▶ Measuring the time laser travelled using TDC (time to digital converter) threshold

▶

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Application: Point Cloud-based SLAM
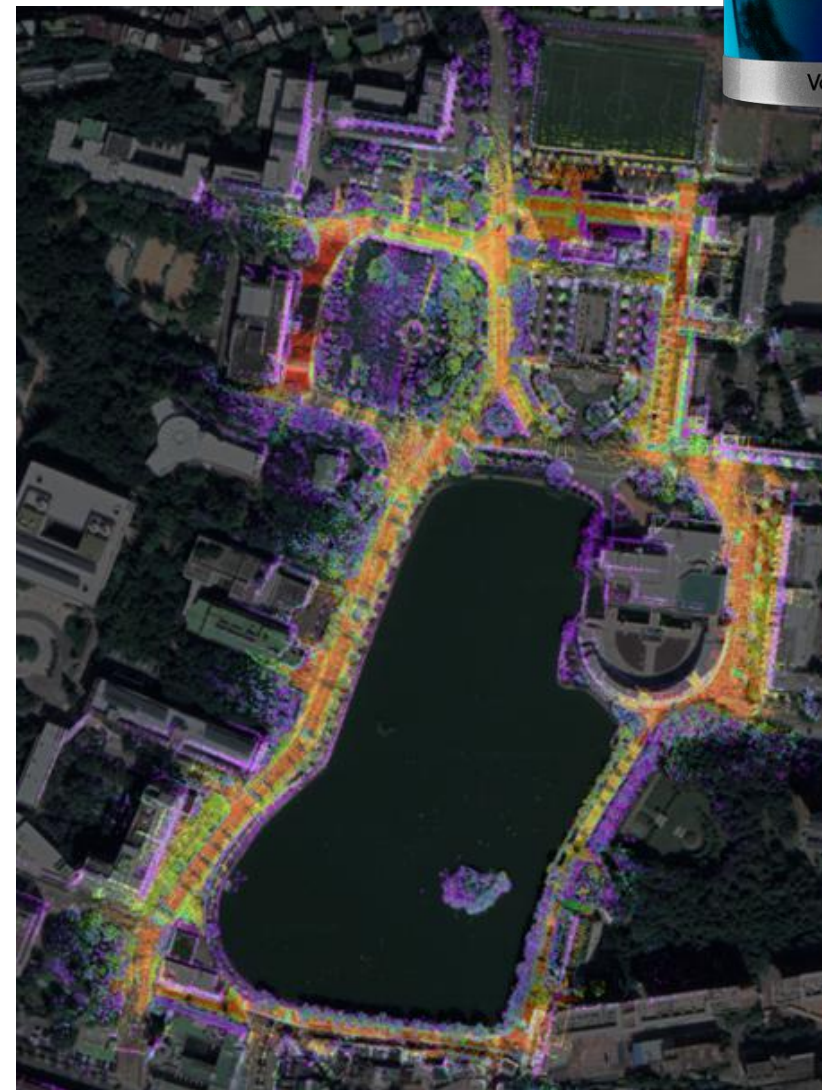
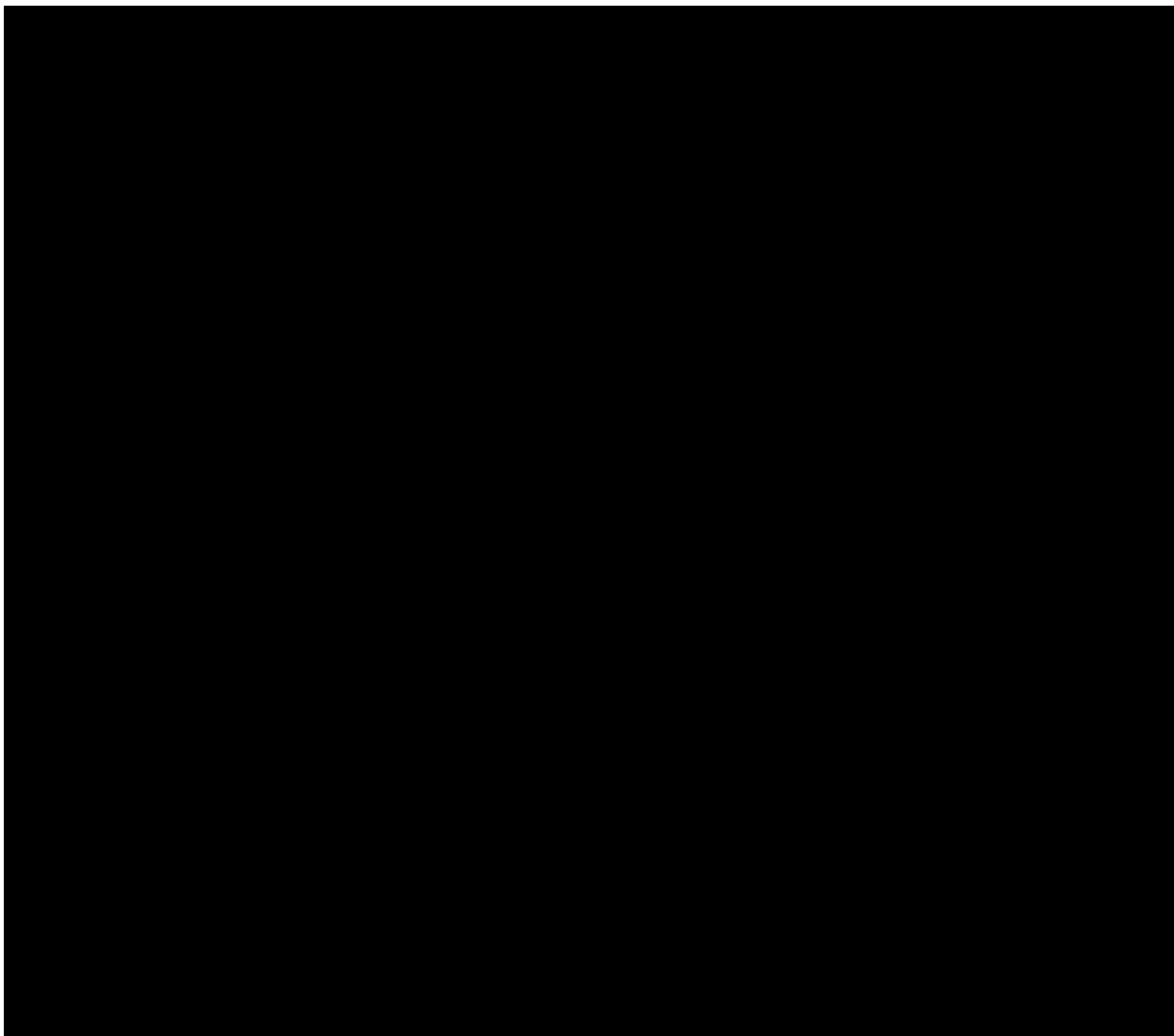## ■ Optimization-based SLAM framework

1. Sensor data acquisition
2. **Frontend**: Point cloud registration-based odometry
3. **Backend**: Filtering or Optimization
4. Loop Closing
5. Reconstruction

Application: Point Cloud SLAM for map generation

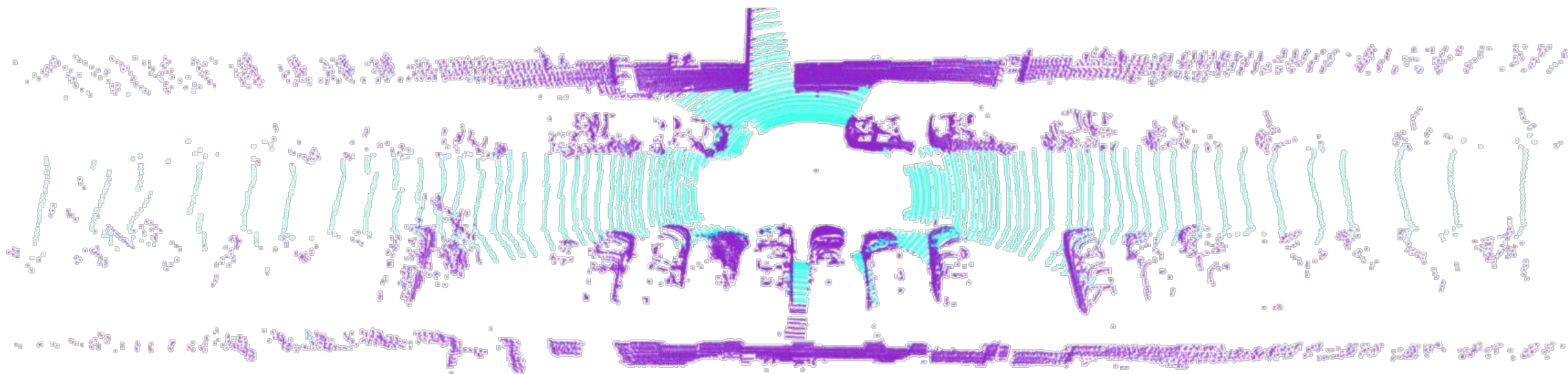| Sensor data | → | Frontend | → | Backend | → | Reconstruction |

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LiDAR-based SLAM for map generation (I)

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LiDAR-based SLAM for map generation (II)

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Ground Model Fitting

- **Identifying and removing ground points from the collected point cloud.**
- **It is needed to detect and analyze non-ground objects such as vehicles, pedestrians, and buildings within a 3D environment.**
  - ▶ Least square, RANSAC(Random Sample Consensus), Height-based thresholding etc..

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THANK YOU
FOR YOUR ATTENTION

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