VAYAVISION

# Detecting the Unexpected: The Path to Road Obstacles Prevention in Autonomous Driving


Shmoolik Mangan, PhD
Algorithms Development Manager, VAYAVISION


AutonomousTech TLV Israel 2018

# VAYAVISION's approach

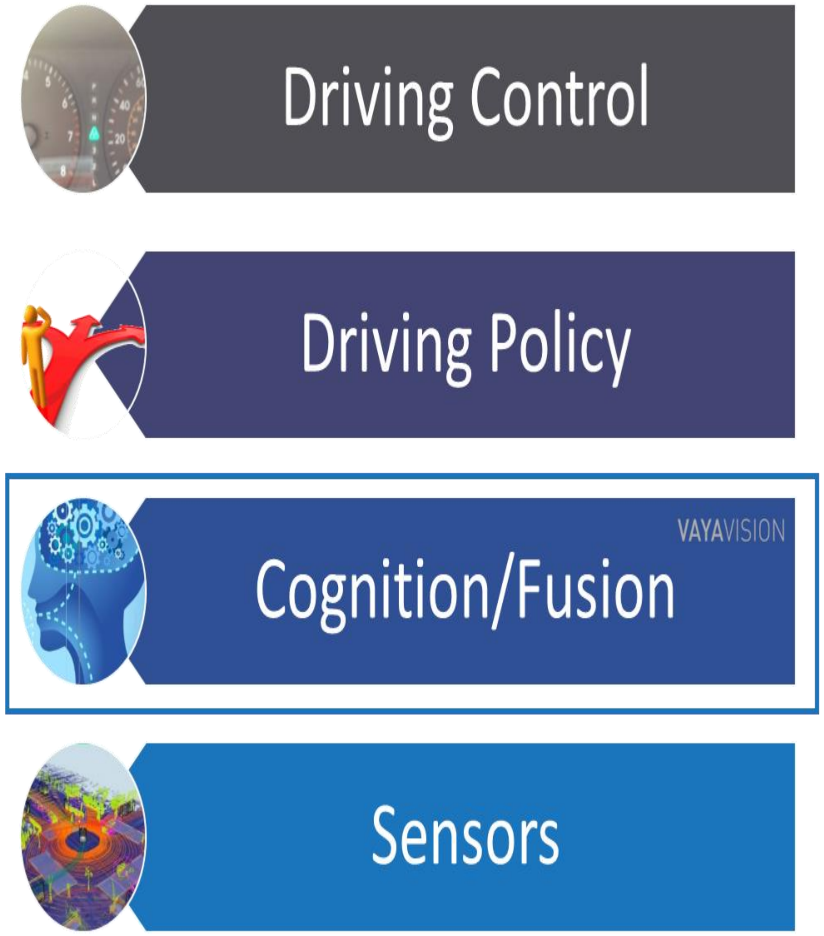
## Raw-Data, Sensor-Level Fusion

**followed by unique**

## Obstacle Detection Algorithms

**To provide**

## Top quality Perception/Cognition



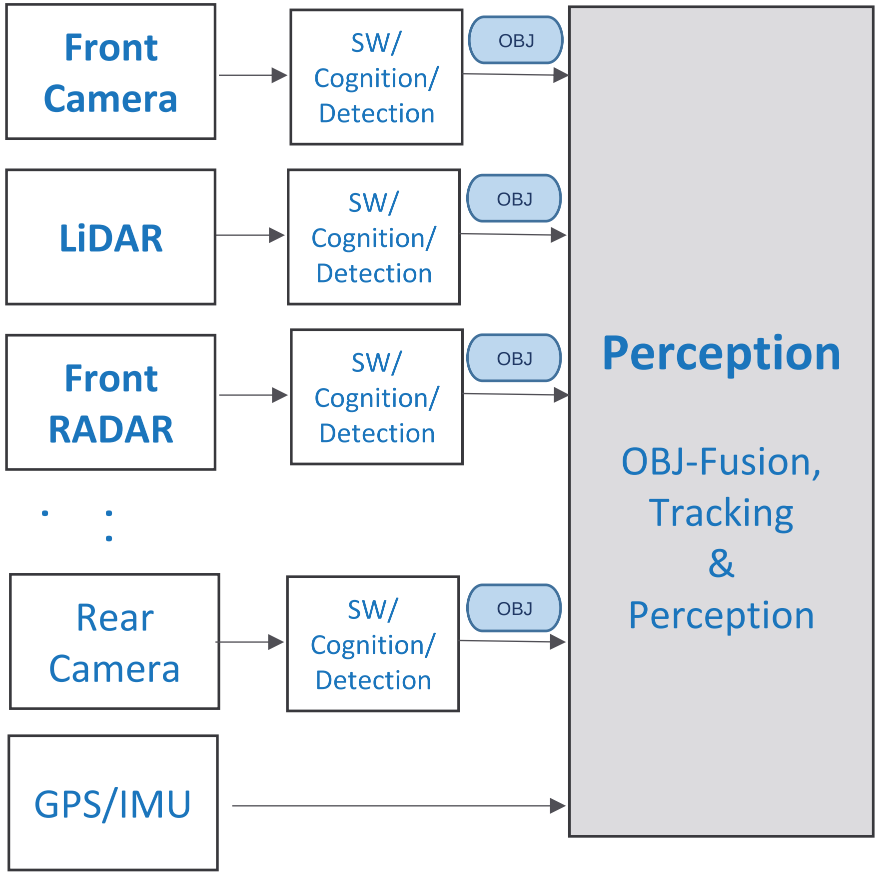



VAYAVISION

# Traditional Object-Level Fusion

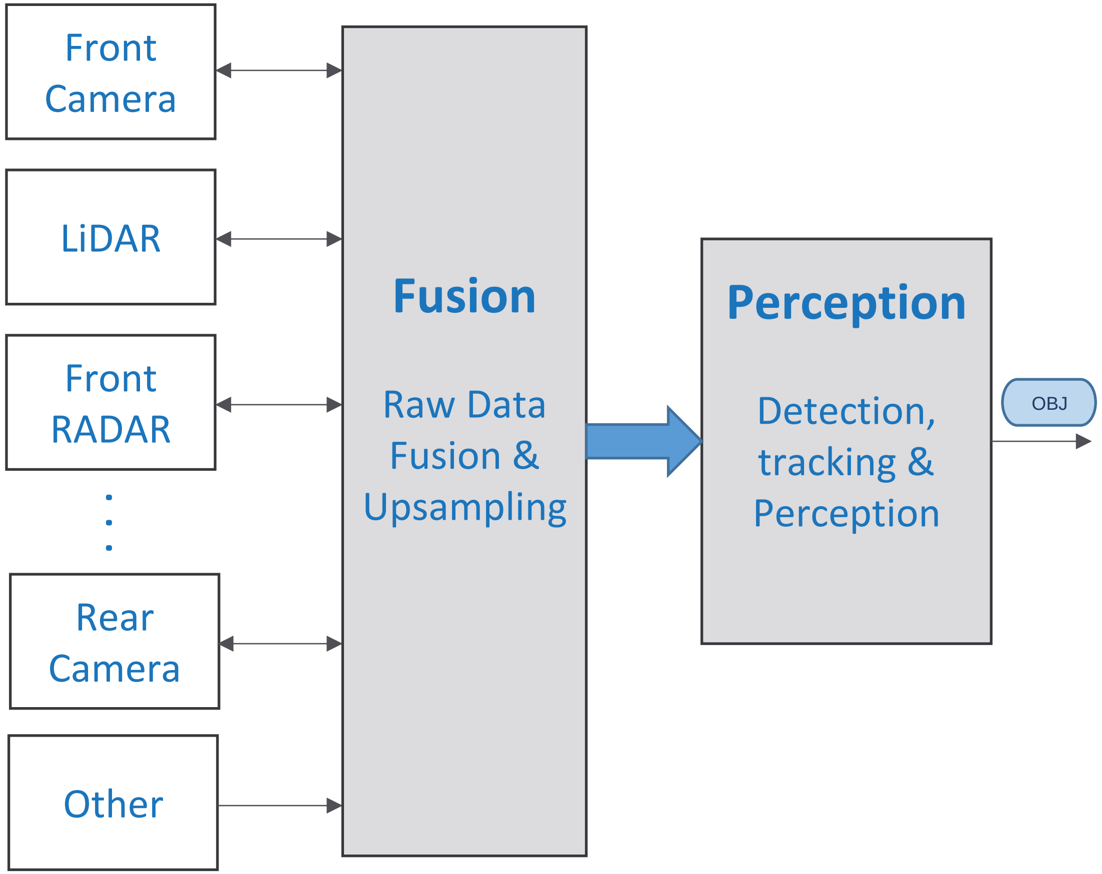
- Each sensor has a separate perception engine
- Fusion at the object level

| Type | Resolution | Strength | Weakness |
|---|---|---|---|
| Camera | Very high | High density<br>Color | No distance |
| LiDAR | Medium | Distance | Sparse |
| RADAR | Low | Speed<br>Distance | Very sparse<br>Moving only |



# VayaVision's Sensor-Level Raw-Data Fusion

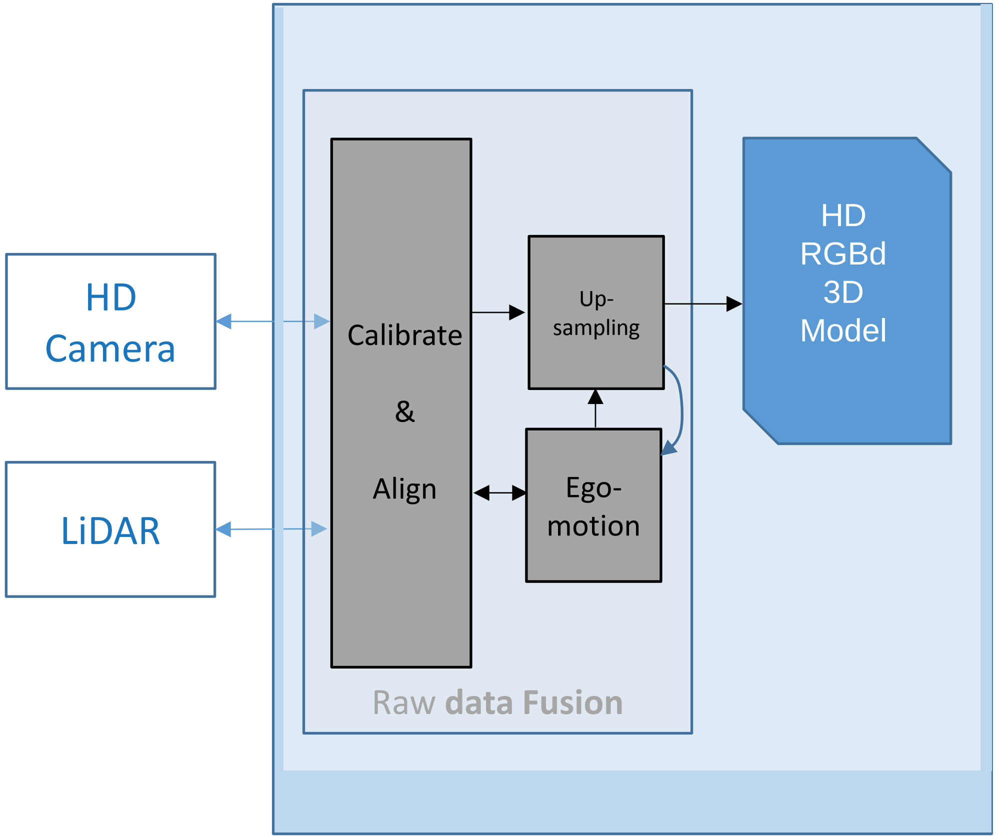
- Fusion of raw data, (not objects)
  - Joint probabilities preserved at pixel level
- Processing is done after fusion
  - Detection based on joint **look and location**
- Sensors complement each other, creating better results:
  - Better detection rates
  - Lower false detection rate
  - Lower latency






VAYAVISION

# Sensor-Level Raw-Data Fusion Principle: Lidar+Camera




- Input:
  - HD Camera image
  - Low density/resolution LIDAR point cloud

- Algorithm principles:
  1. Apply calibrations (Intrinsic & Extrinsic)
  2. Match RGB color and 3D pointcloud to create **RGBd** point-cloud
  3. RGBd points are accumulated over time
  4. 3D Point-cloud is Up-Sampled to the resolution of the HD image

- Output:
  - **HD-RGBd 3D model**:
    - Every camera pixel have 3D position
    - Each 3D point in the cloud has color
    - The “world model” is given at camera density




VAYAVISION

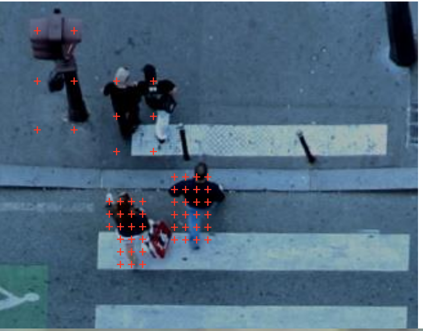
# VAYAVISION's Development Vehicle
## Rev.1: HD Camera, Velodyne 64, i7 PC, One GPU

120° HD Camera

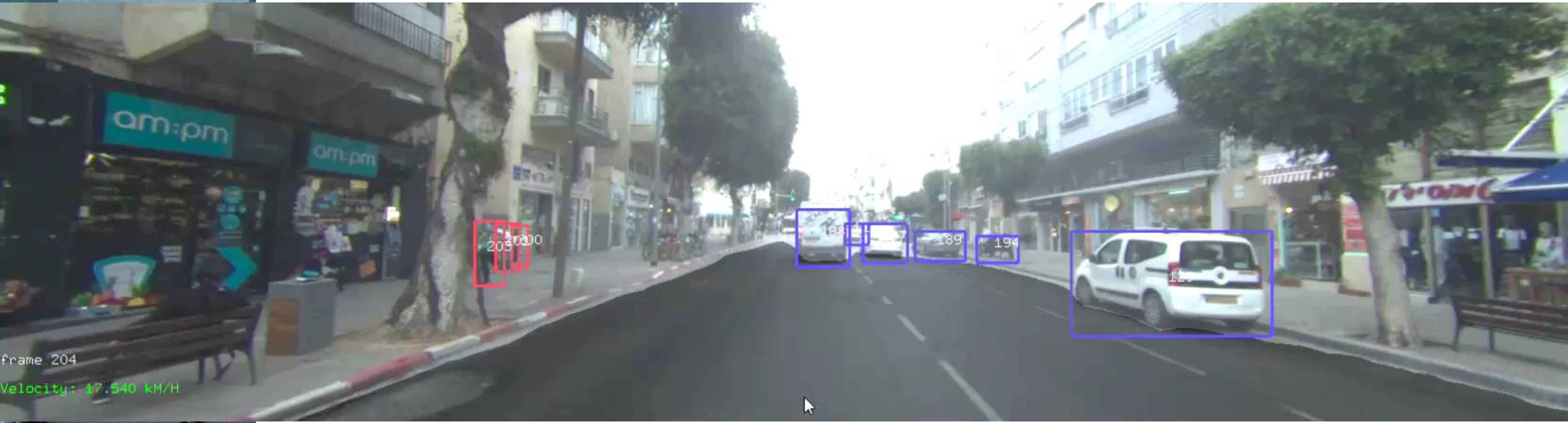
Velodyne 64


i7 PC, One Nvidia GPU

Complete perception runs in Real-Time: Fusion, Detection, Classification, Tracking



# VayaVision`s Complete Perception: Road Free-Space and Object Detection




Complete perception runs in Real-Time: Fusion, Detection, Classification, Tracking
Using single GPU

Setup: HD Camera, Velodyne 64, One Nvidia GPU, i7 PC

# Obstacle Prevention Problem: How to Detect the Unexpected

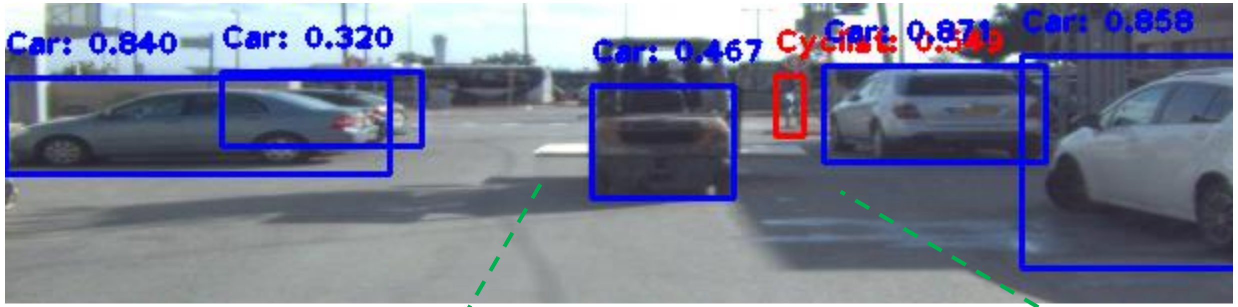
Why is it important?

- Unidentified obstacles create unexpected conditions
- Unexpected situations cause accidents

What is an obstacle?

- Oxford dictionary:
  A **thing** that **blocks one's way** or **prevents progress**

# Identifying Cars and Pedestrians: Easy with DNN




- Free Nvidia library can do it
- YOLO, fast and free DNN can do it,
- Android mobile app can do it

https://play.google.com/store/apps/details?id=org.tensorflow.detect


- Every tech student can download a GIT and do it

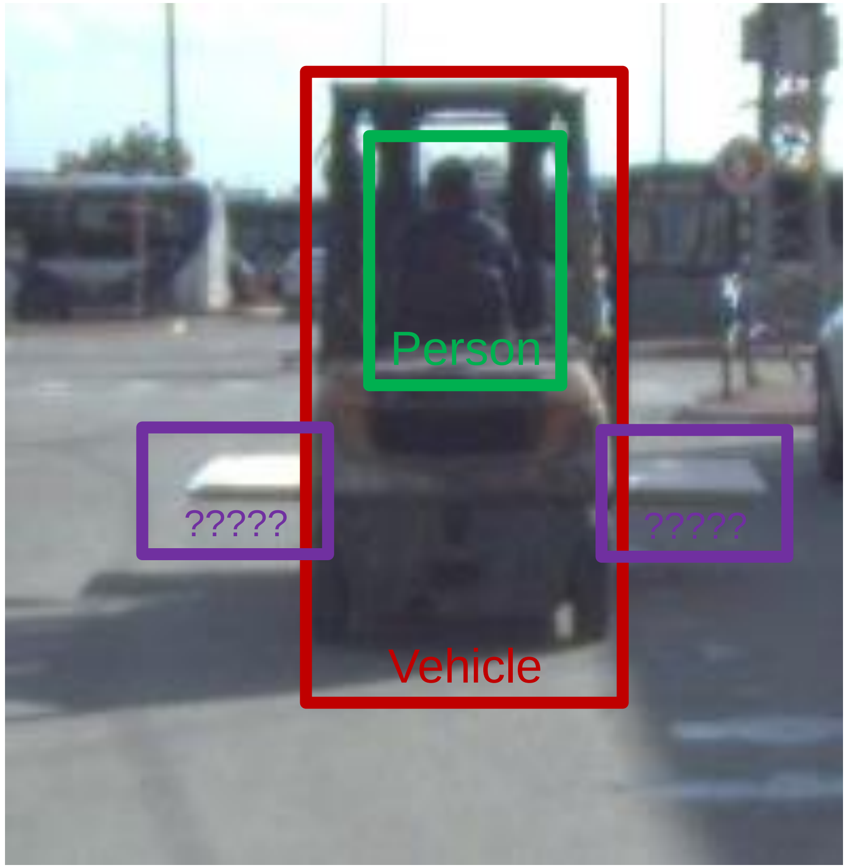
Can one train a DNN to detect every***thing***?

# Detecting Unexpected Obstacle:

The inherent flaw of guided machine learning systems (aka DNN):

- How can one **expect the unexpected ?**

- If it never appeared in your training data, what are the chances of identifying an obstacle?




*"Nobody expects the Spanish inquisition..." Monty Python*





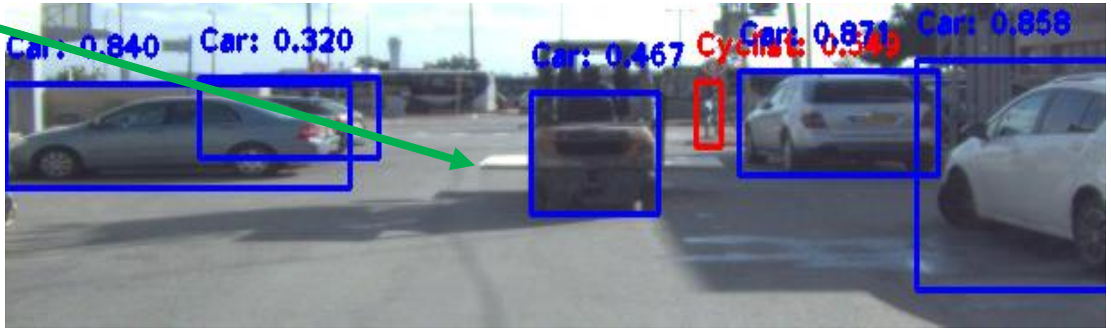
VAYAVISION

# Trained DNN Cannot Deal with the Unfamiliar, Unexpected

Thin **construction-board** on a **Forklift**:

- Bounding-Box based DNN vehicle detection: failed on this unfamiliar object

- Semantic segmentation free-space DNN: failed on this unfamiliar object



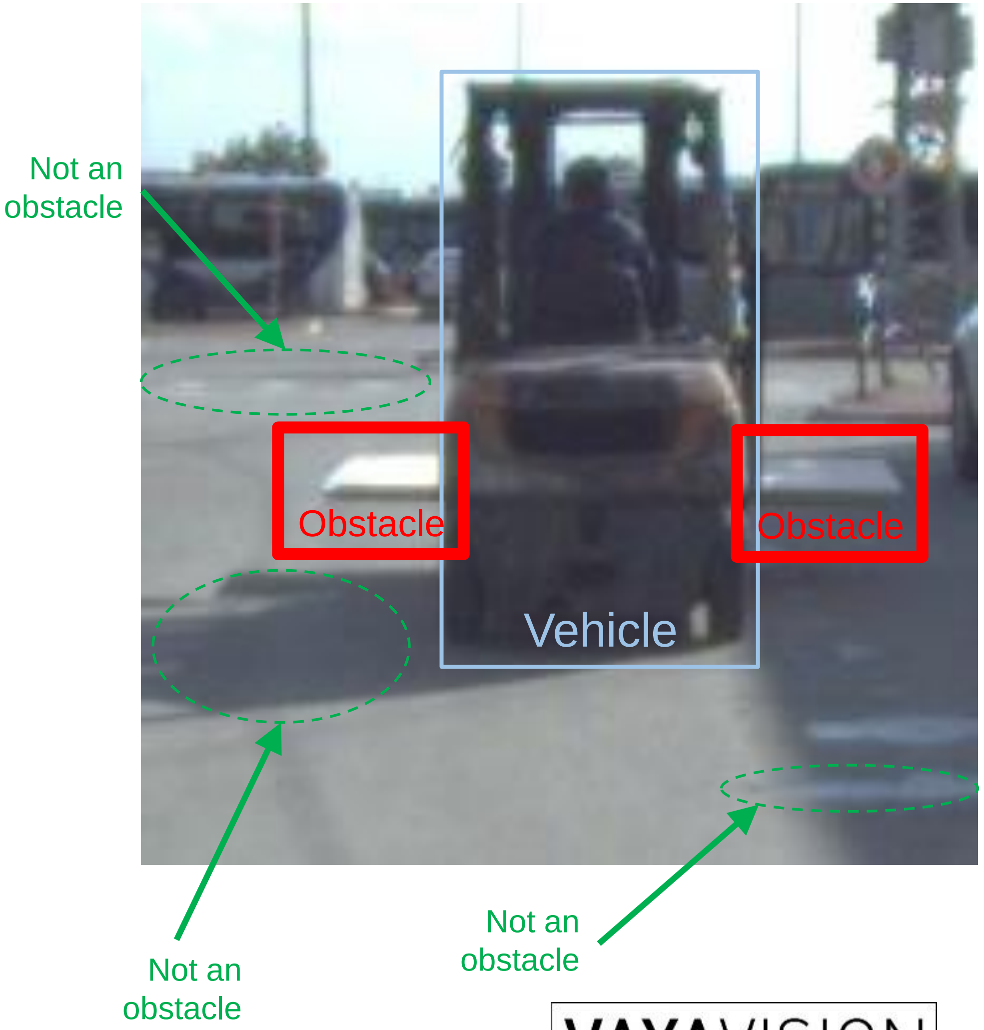

➢ It's impractical to train a DNN to detect everything!

- *"NOBODY expects the Spanish Inquisition! **Our chief weapon is surprise…**"*

# The Real Driving Challenge is: *Detecting the Unexpected*

- Detection begins with **sensing**
- *To **avoid it** - you have to **sense it***

- **Image sensors alone** – insufficient for detecting
  - Based on image look, without depth – impractical to say it’s an obstacle
  - Too many “patches” in the image
    - Too many FA
    - Cant avoid mis-detection
    - Cant deal with every arbitrary shape and look

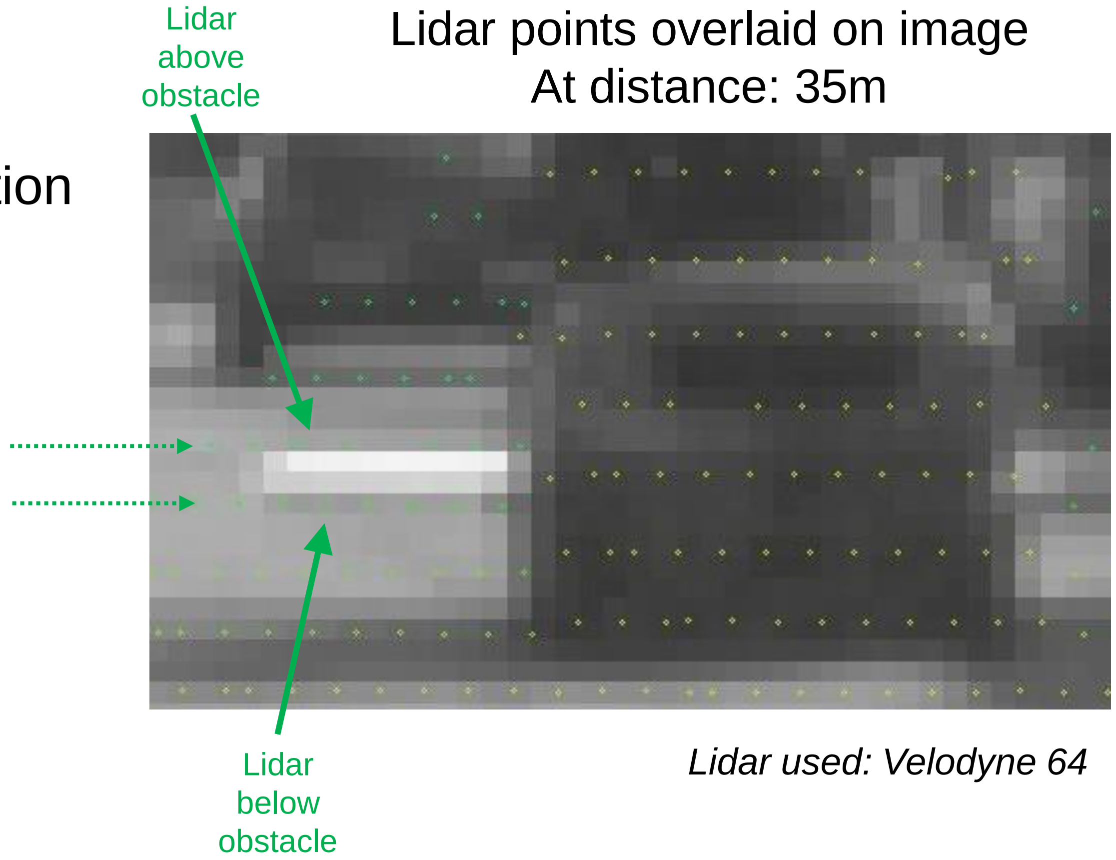


# The Real Driving Challenge is: *Detecting the Unexpected*

- Detection begins with **sensing**
- *To **avoid it** - you have to **sense it***

- Lidar sensor alone – insufficient resolution
  - Sparse - too few data points
    - Small obstacles “fall between the lines”
    - One frame you see it, the other you don’t

Lidar points overlaid on image
At distance: 35m




*Lidar used: Velodyne 64*



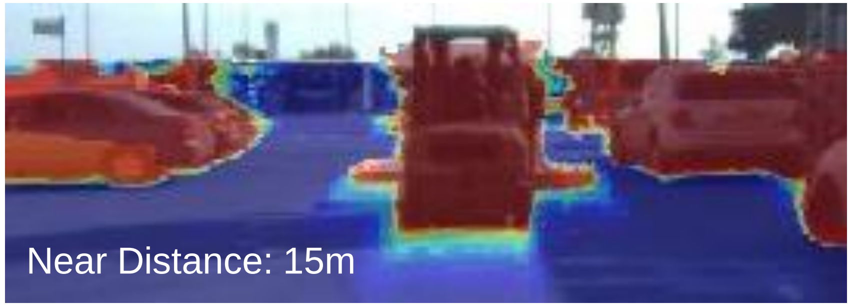


VAYAVISION

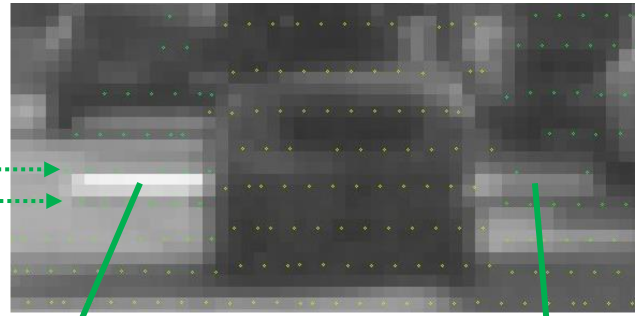
# *Detecting the Unexpected -*
# Enabled by Raw-Data Sensor fusion

- *Detection begins with **sensing***
- *To **avoid it** - you have to **sense it***

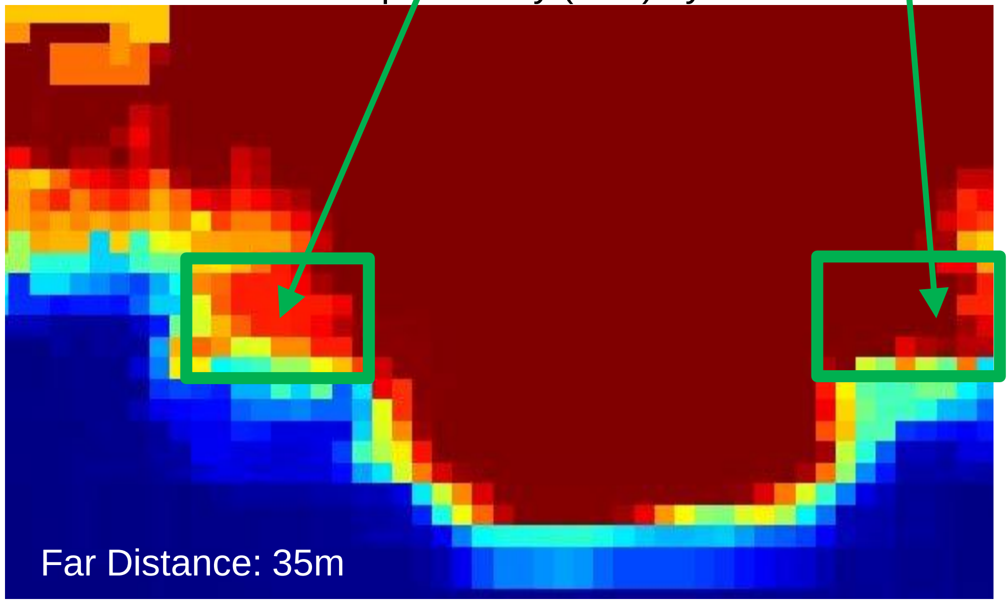
- RGBd from raw data fusion does the job:
  - Over-time accumulating RGBd points for detection
  - Obstacle height above road is determined at image resolution
  - Free road is accurately determined




Lidar points on image



Obstacle probability (Red) by RGBd








VAYAVISION

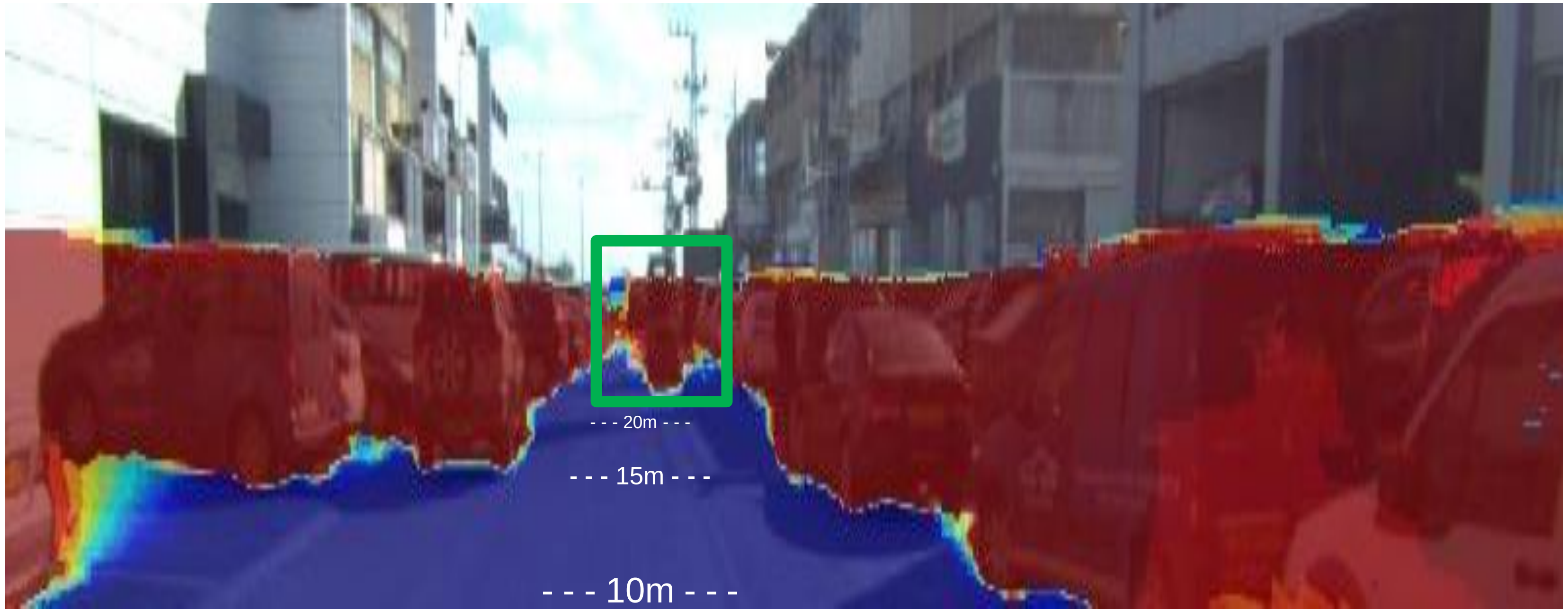
*Lidar used: Velodyne 64*

# Free-Space in Front-View and Birds-Eye View (at 35m)

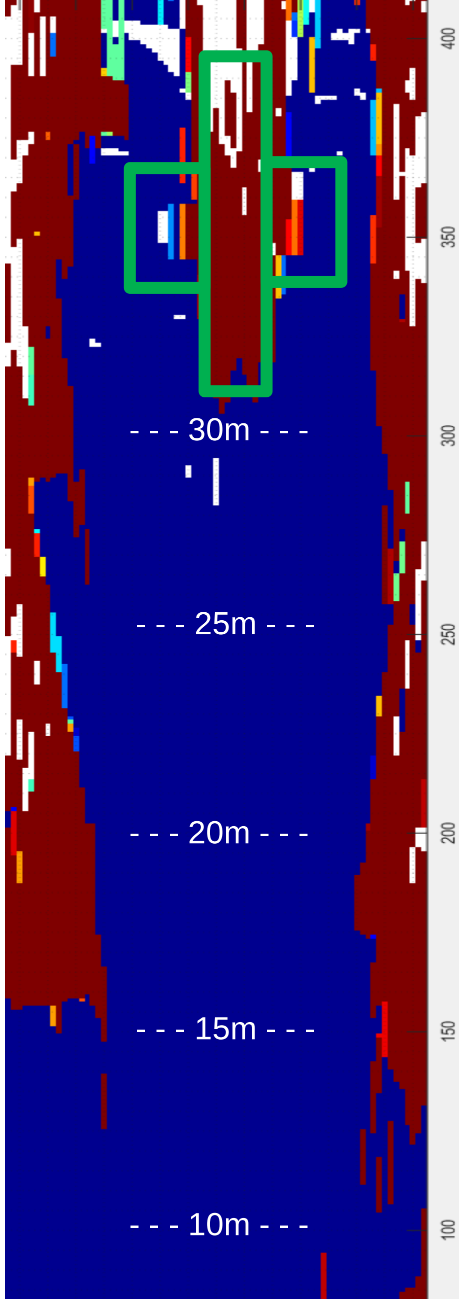
Top view Transform

Bird's eye view

Front-view




Free-space Probability (Blue)

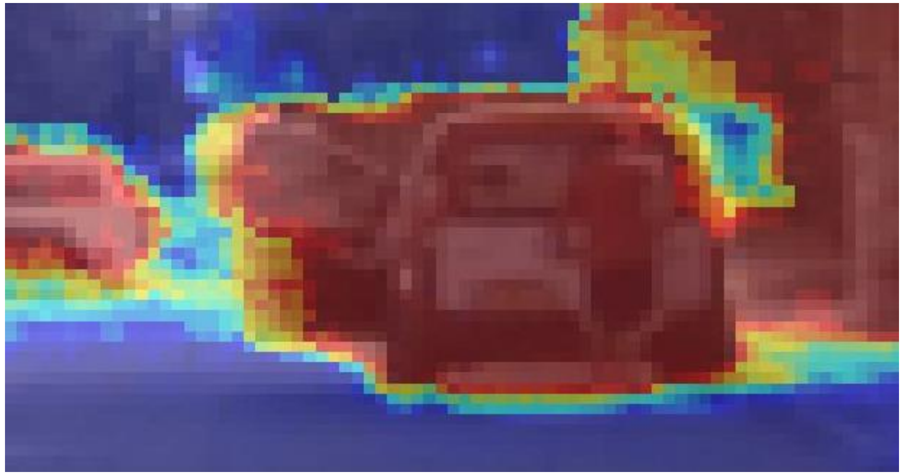







VAYAVISION

# Case 2: Detecting Door Opening
## 40m away

# Case 3: Trash Bin on the Road
## 65m away

# Case 4: Peacocks on the Road at Twilight

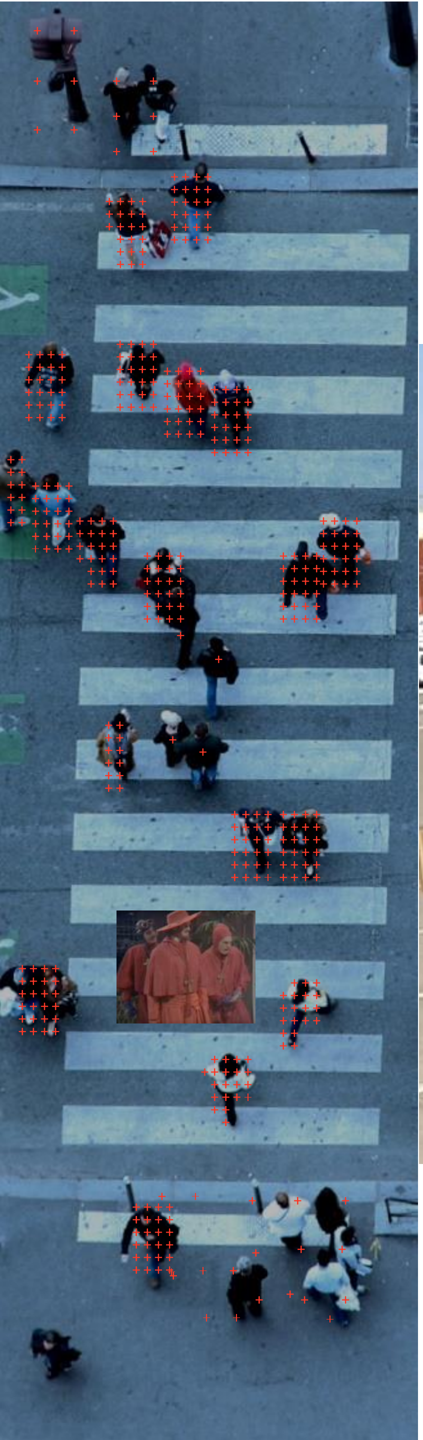
# Case 5: Small Obstacle on a Dirty Road





VAYAVISION

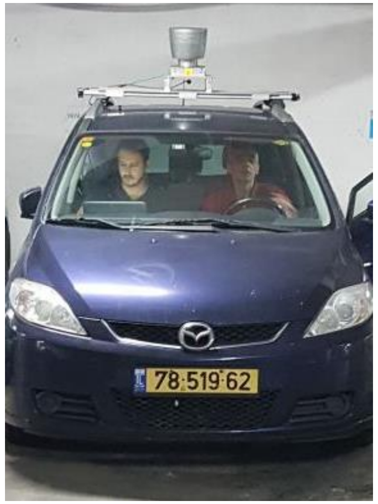
# Small Obstacle Detections Study
# Variable Shape, Size and Color




Setup: HD Camera, Velodyne 64, One Nvidia GPU, i7 PC

# Small Obstacles Detection Distances
## While driving at 40KM/h

| Object | Height [cm] | Detection distance [m] |
|---|---|---|
| Laptop box | 10 | 33.7 |
| Keyboard box | 16 | 49.4 |
| Display box | 17 | 38 |
| Basketball | 21 | 49 |
| Small basket | 22 | 46.4 |
| Large basket | 32 | 48 |



# Same Ride, same Parameters – Practically Zero FAs on the Road





VAYAVISION

# Complete Perception scheme: with Unidentified Obstacle Detection


Complete perception runs in Real-Time: Fusion, Detection, Classification, Tracking

Setup: HD Camera, Velodyne 64, One Nvidia GPU, i7 PC

# Complete Perception scheme: with Unidentified Obstacle Detection


Complete perception runs in Real-Time: Fusion, Detection, Classification, Tracking

Setup: HD Camera, Velodyne 64, One Nvidia GPU, i7 PC



VAYAVISION

# Summary

- **Low-level Raw-Data sensor fusion** through up-sampling is superior
  - ✓ Uses local correlations to enhance resolution of Lidar to **produce High-density RGBd image**

- **Pixel-level detection** based on ***up-sampled HD-3D physical model*** is superior for ***unfamiliar*** objects
  - ✓ Depth sensing resolution and accuracy are enhanced through up-sampling
  - ✓ Provides utmost fidelity in obstacle detection, regardless of size shape look or **familiarity**

~~*NOBODY expects the Spanish Inquisition!*~~

*NOBODY expects the Small Obstacle!*

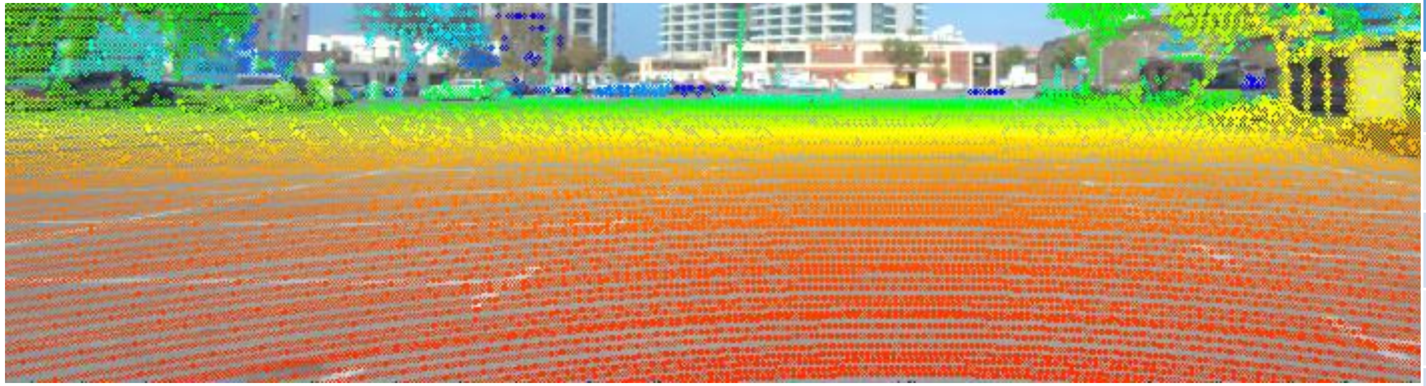
*Their chief weapon is surprise…*

~~**Monty Python**~~

**VAYAVISION**

# Thank you

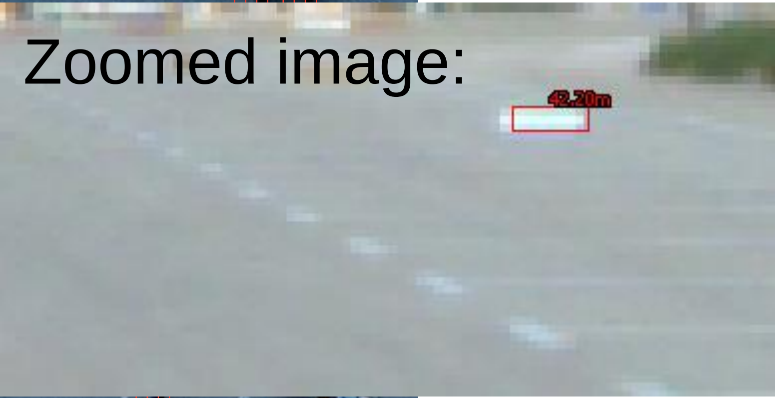
# Up-Sampled Model allows Bridging the Lidar Sparsity Gaps

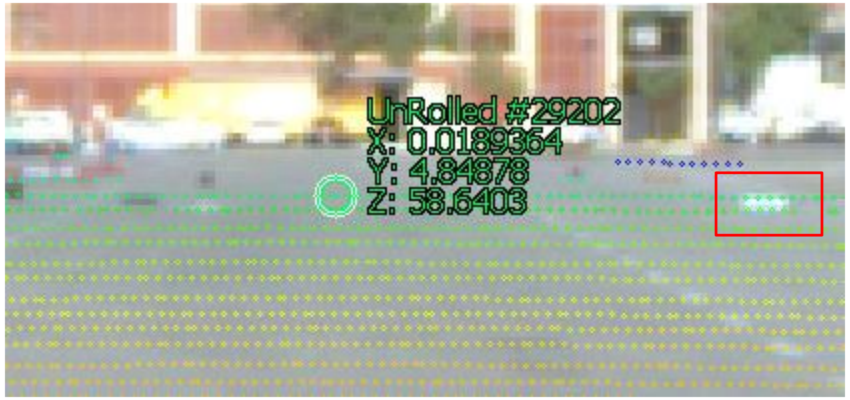



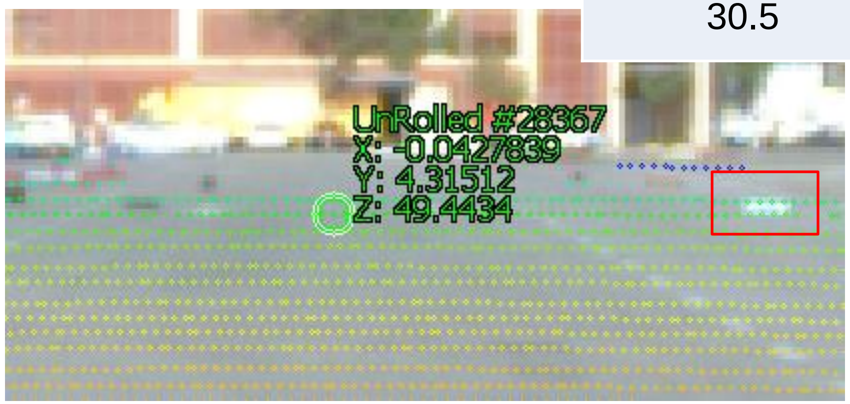
| LiDAR reflections from road [m] |
|---|
| 58.6 |
| 49.5 |
| 42.9 |
| 37.7 |
| 33.1 |
| 30.5 |

Zoomed LiDAR on image:

Zoomed image:



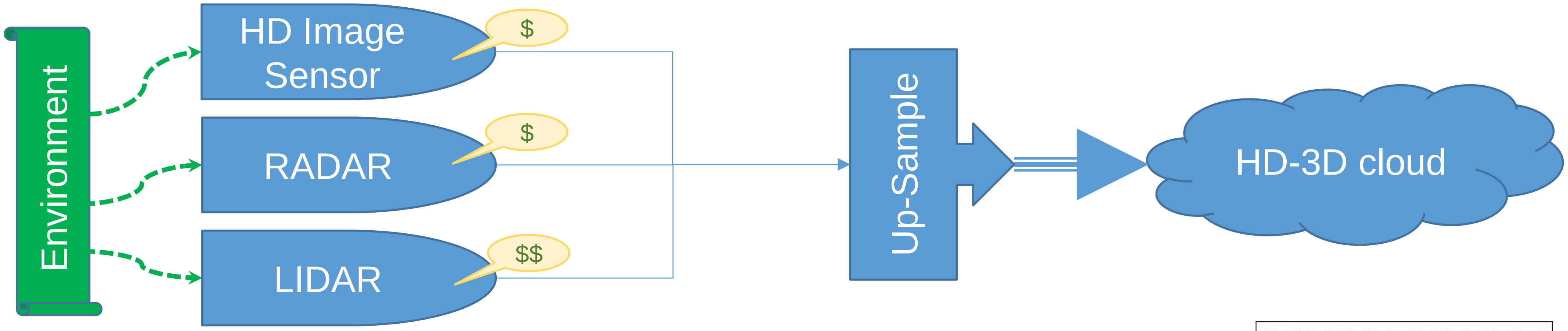




*Lidar used: Velodyne 64*

# So, if Dense-3D Cloud does the work, why do we need RGB Camera Image?

- Alternative solution:


- Cost effective alternative:








VAYAVISION