Secure Autonomous Systems

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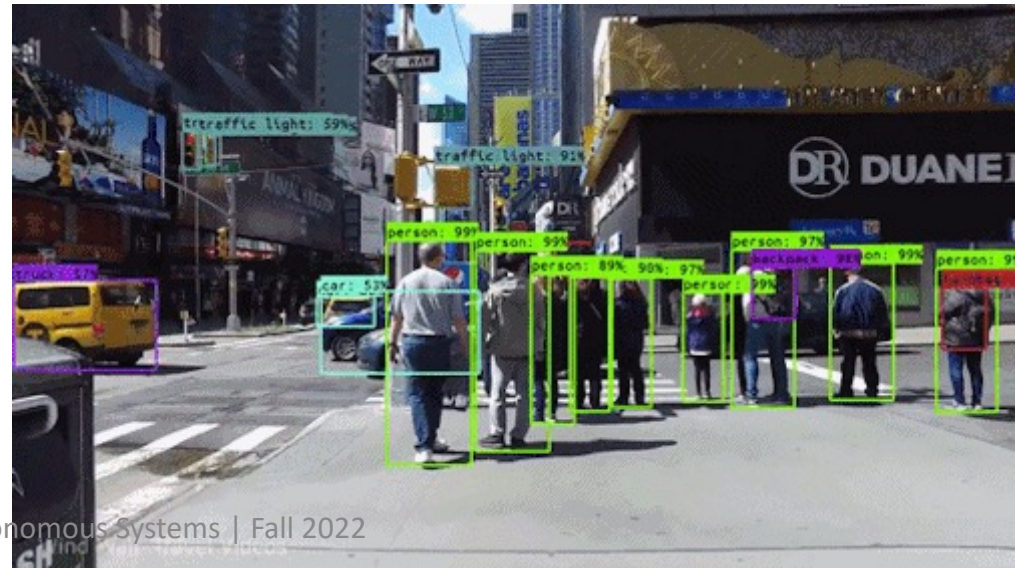
https://bit.ly/secureauto-fall22

Common Sensor Types

- **LiDAR/Millimeter Rada**
- **GPS**
- **Cameras**: lane, road, traffic light, stop line, surroundings
- **Stereo Vision**
- **Sonic**

Cameras

- Accurate way to create visual representations
- Front, left, right, rear cameras
  - to create **a 360-degree view**
- Main focus ➔ **object detection**

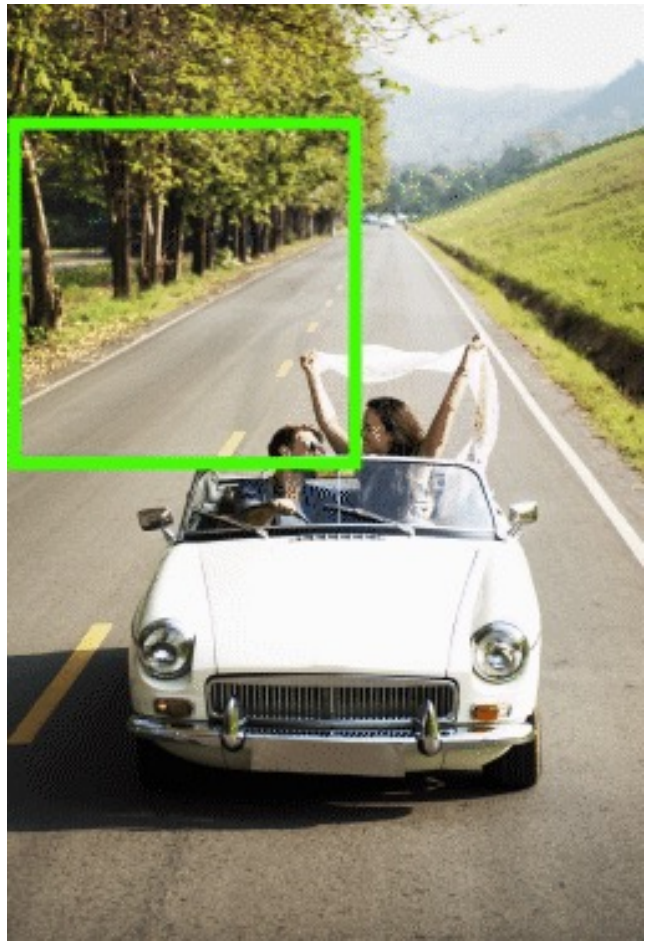


Cameras | Computer Vision

- Computer Vision algorithms for object detection
    1. Image classification ➔ determine objects in an image are
    2. Image localizations ➔ providing specific locations of image [bounding box]

Cameras | Image Classification

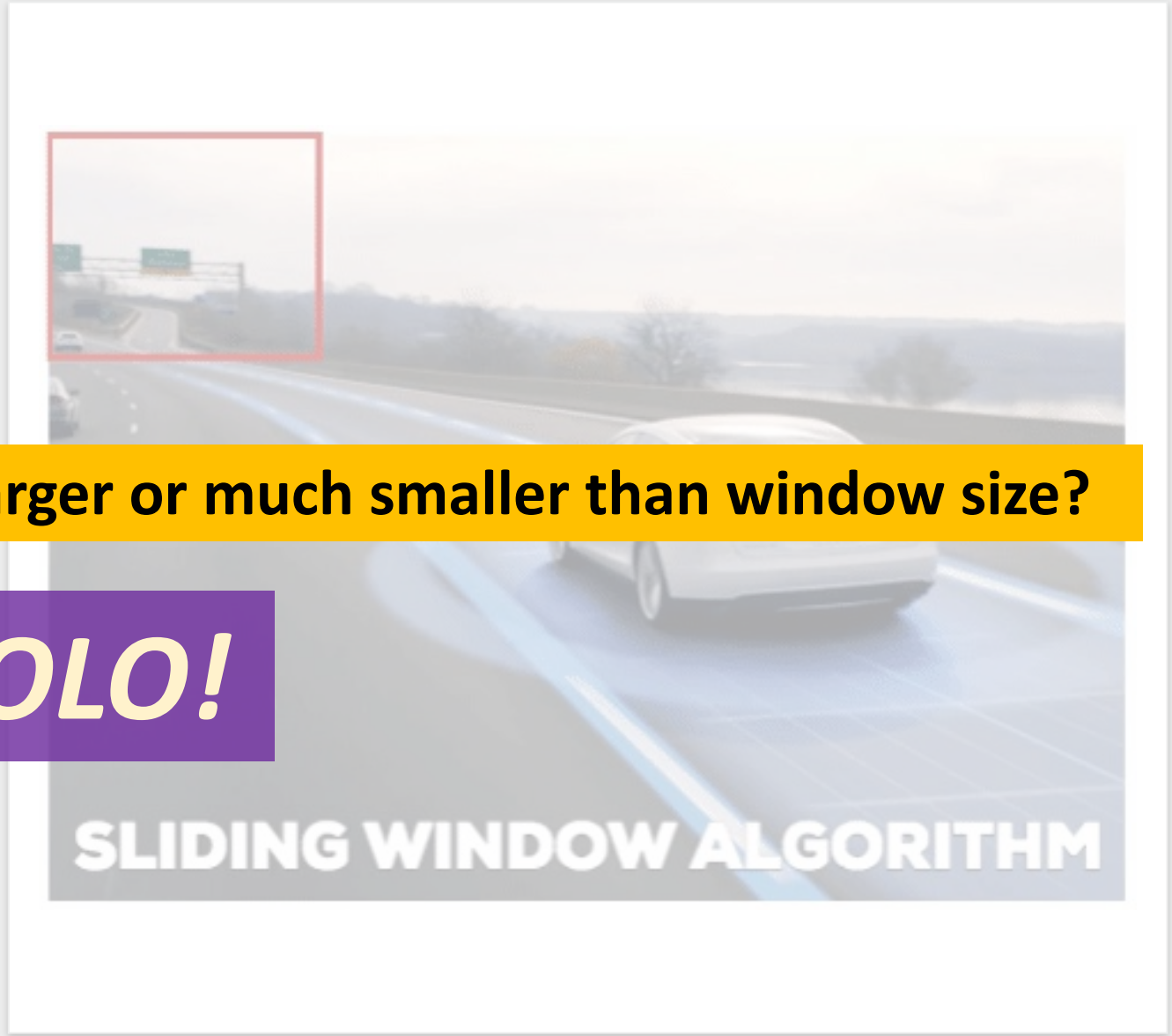
- Convolutional Neural Networks (CNNs)
  - **trained** to recognize objects like cars, pedestrians, etc.
  - performs **convolution operations at runtime**
    - to classify images from camera
- CNNs limited to single objects taking up entire image
- **Sliding Windows**!



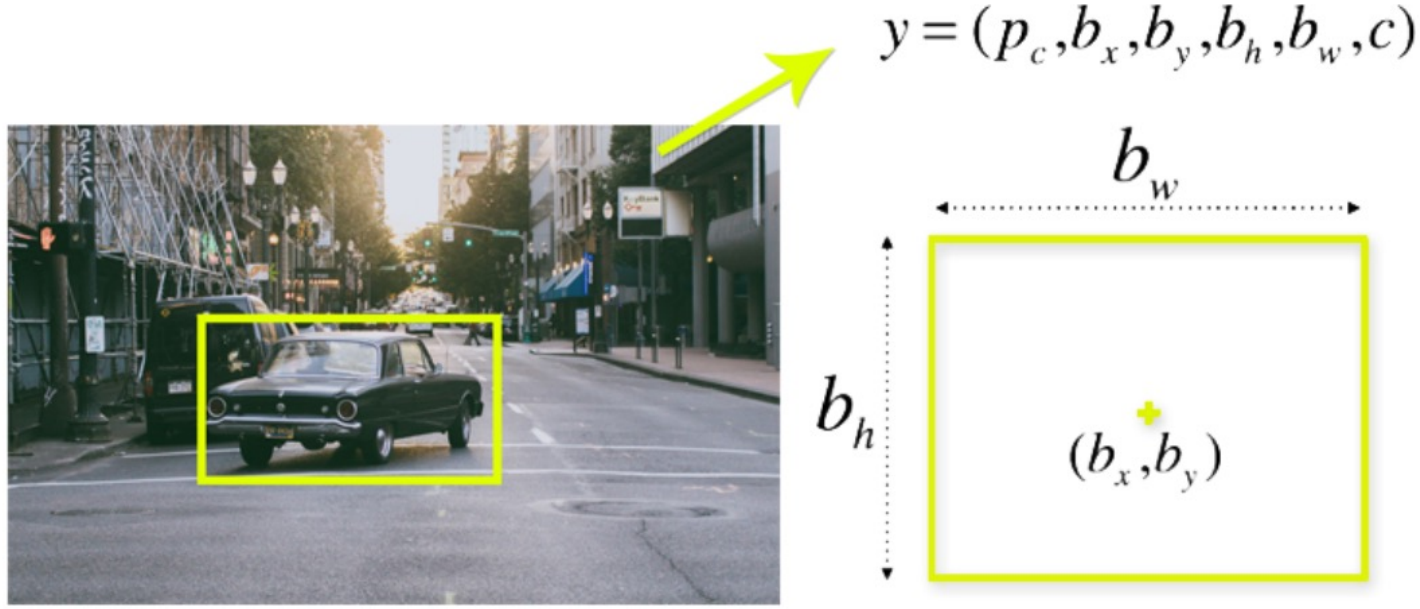
Cameras | Sliding Window Algorithm

What about objects much larger or much smaller than window size?

YOLO!



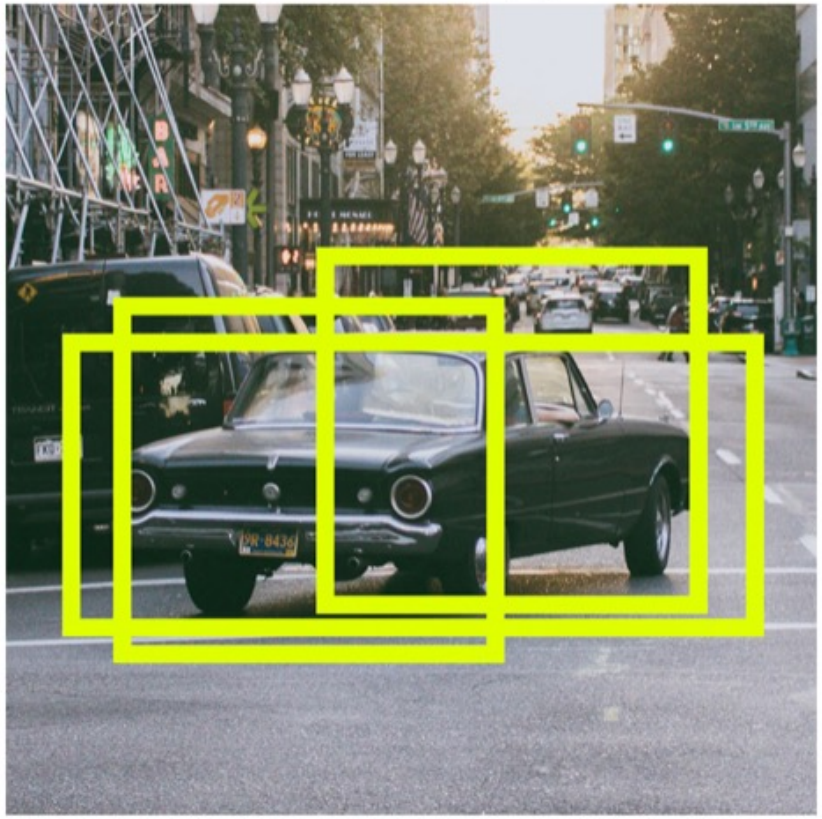
Cameras | YOLO

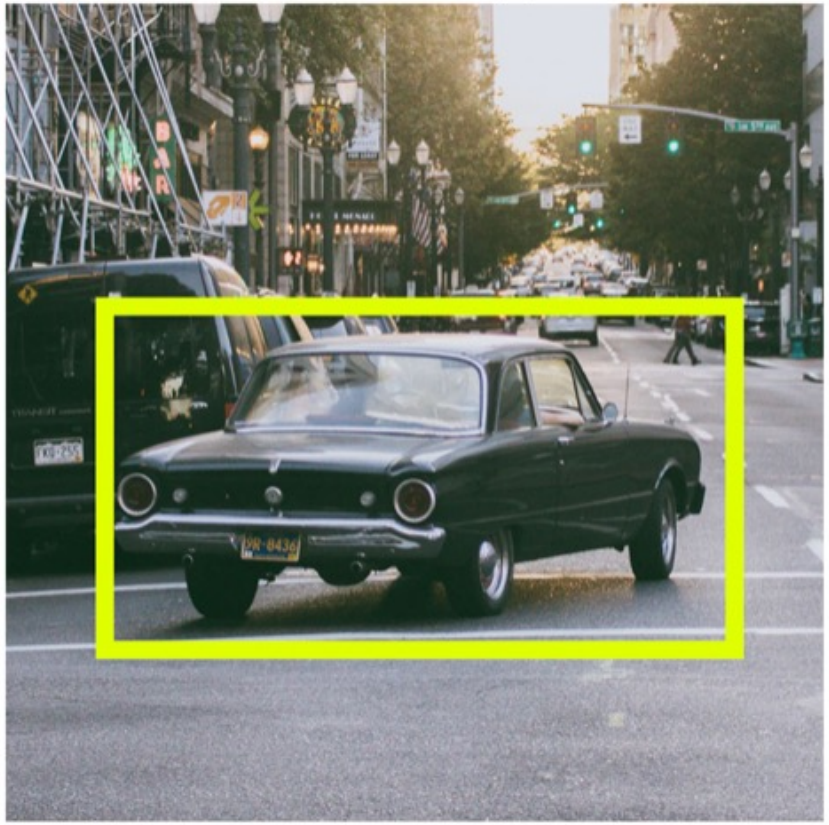


- "**you only look once**"
- Image split up into grid ➔ run once through CNN

Cameras | YOLO [contd.]

preprocessed image
(608, 608, 3)



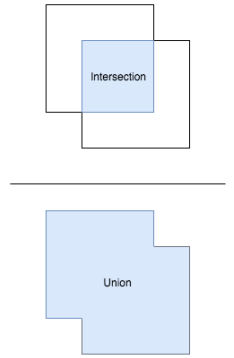


Cameras | YOLO | Image Localization

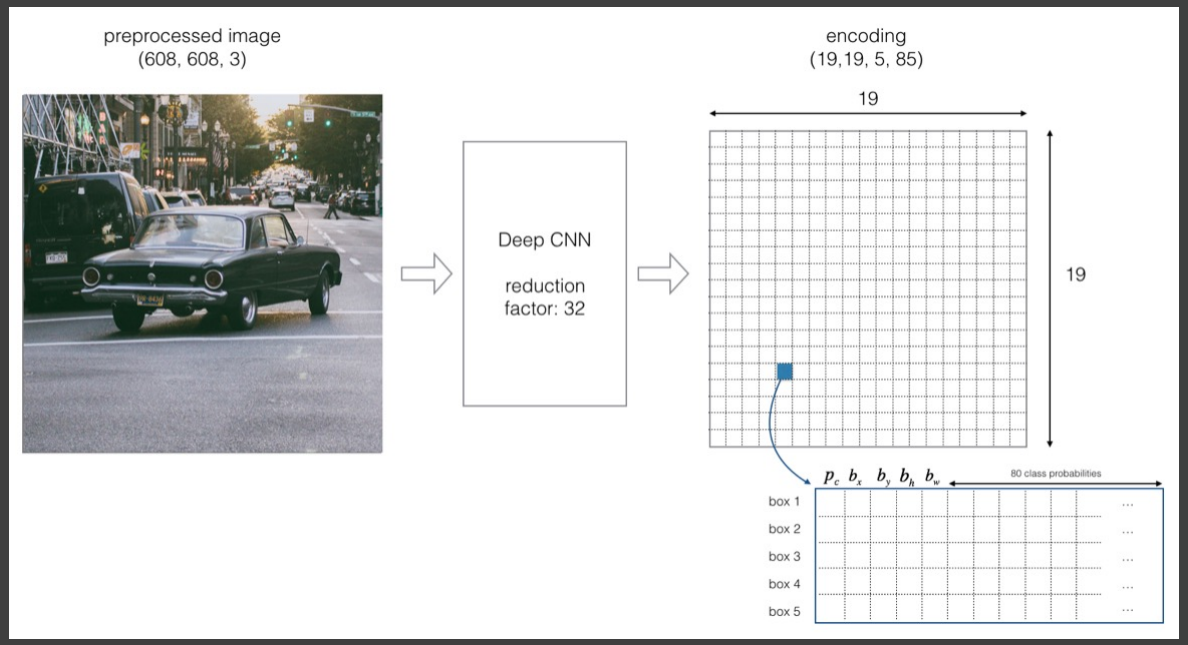
Cameras | YOLO | IoUs

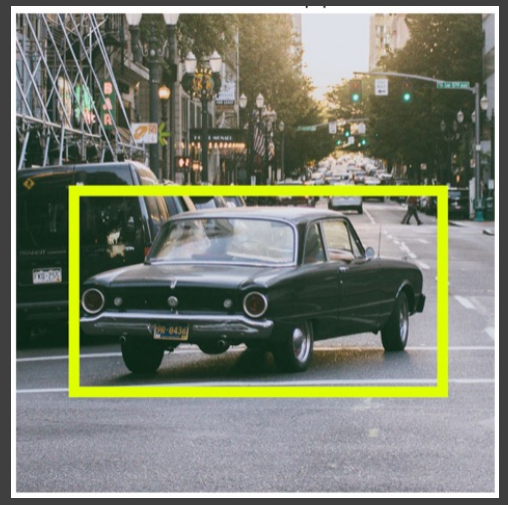
- During training ➔ compare CNN bounding box to **actual** ones
- Cost function, "**intersection over union**" (**IoU**)

$$\boldsymbol{IoU} = \frac{area\ of\ \boldsymbol{intersection}\ of\ bounding\ boxes}{area\ of\ \boldsymbol{union}\ of\ bounding\ boxes}$$



- If IoU is closer to **1** ➔ better the bounding box





Cameras | YOLO | Non-Max Suppression

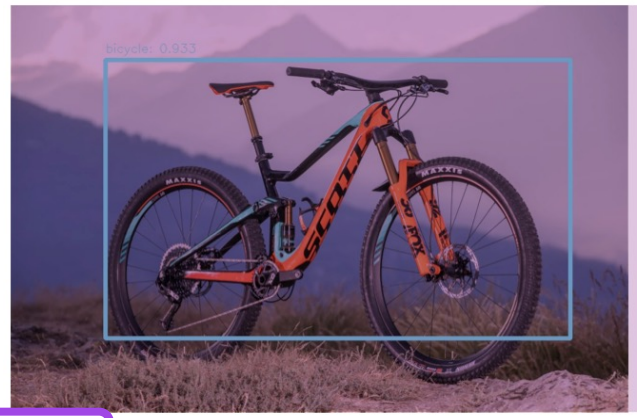
- Majority of the cells won't have bounding boxes
- Remove boxes with
  - low object probability
  - highest shared area
- **non-max suppression**
  - discard bounding boxes with probability less than threshold *i.e.* p < 0.5 or 0.6
  - take box with highest prediction value
  - discard/suppress boxes with IoU > threshold with that box *i.e.* 0.5 or 0.6
- suppress boxes that don't have maximum probability

Attacking Object Detectors?

- Falsify the training set
  - Larger impact
  - Harder to do – less public access
- Modify objects being detected
  - Add paint/tape/appendages to cars to that it presents differently
- Attack the inputs
  - Add stickers to objects
  - Add extraneous pixels/data to the camera inputs

Attacking Object Detectors | Example

- Maximize loss of CNN classifier
- Maximize loss of object detector



40x40 patch

Cameras

- Additional cameras
  - Lane following
  - Traffic signal monitoring

Stereo Vision

- Problem with regular cameras+YOLO is **2D vision**
- "Fuse" camera data with LiDAR ➔ expensive

- Align **two cameras** and use **geometry**
- **Pseudo-LiDAR**

Stereo Vision

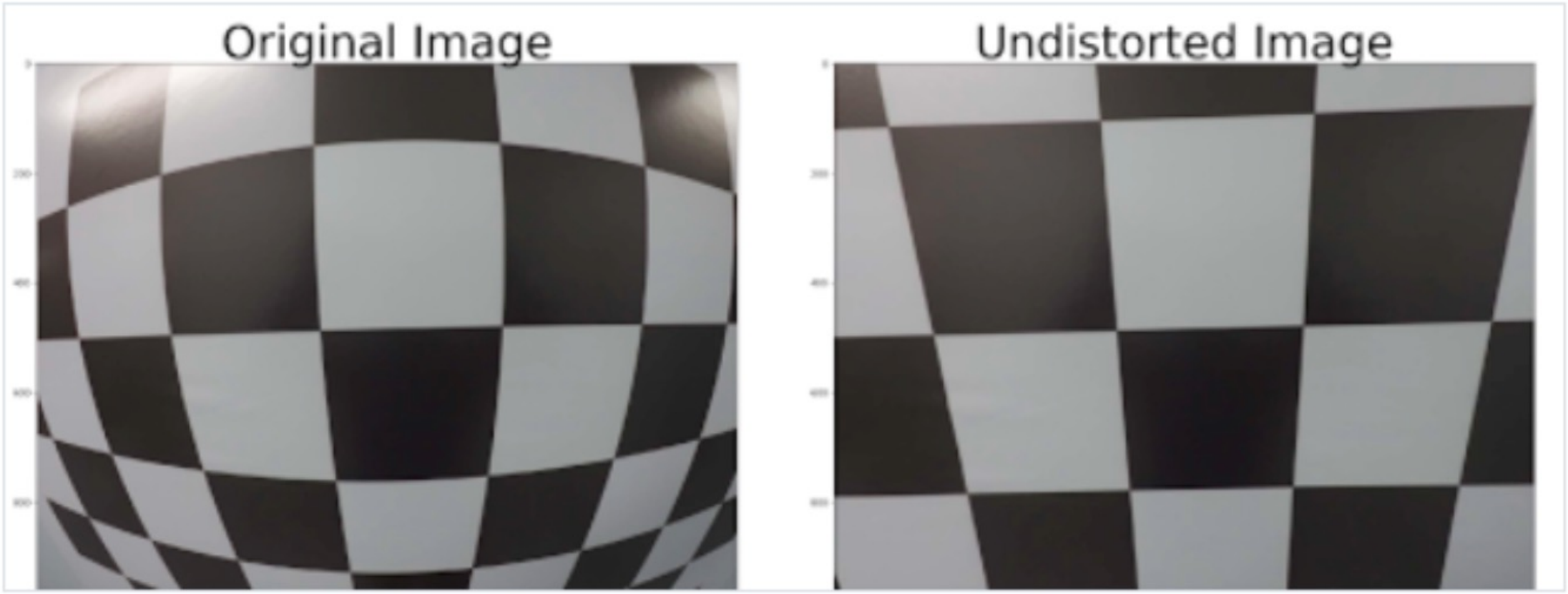
- Retrieve distance of an object using **two cameras** and **triangulation**

Steps

- Stereo calibration
- Epipolar geometry
- Disparity mapping
- Depth mapping
- Obstacle detection estimation

Stereo Vision | Calibration

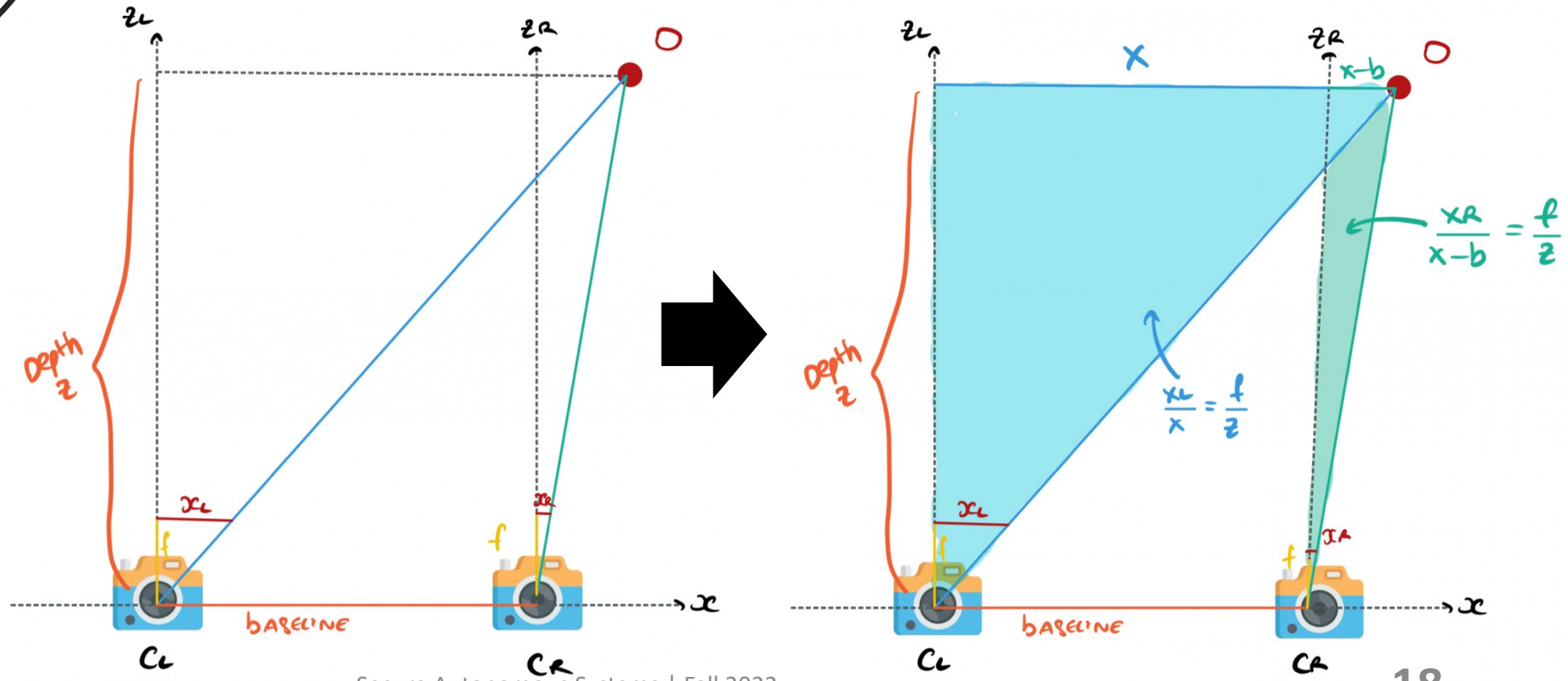
Create undistorted images from original camera ones



Stereo Vision | Calibration + Epipolar Geometry

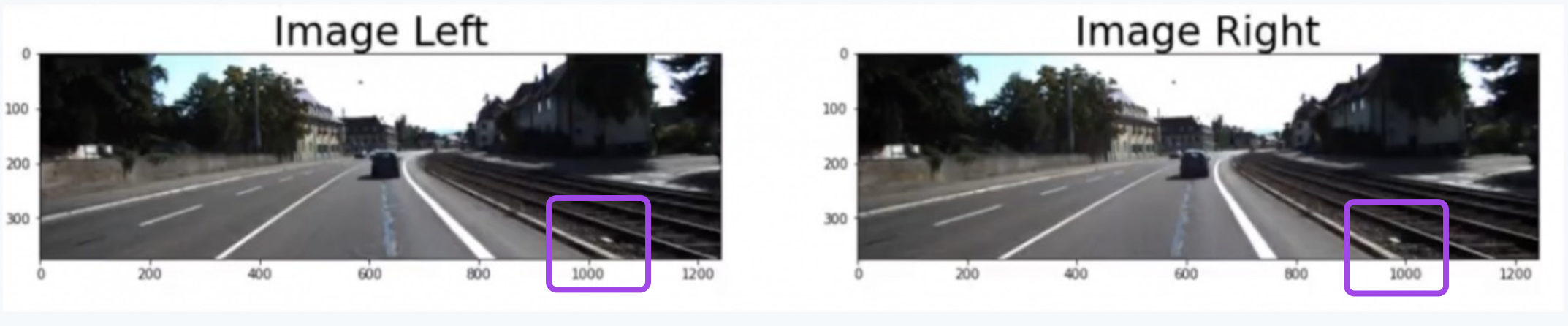
$$Z = \frac{f \cdot b}{x_L - x_R} = \frac{f \cdot b}{d}$$

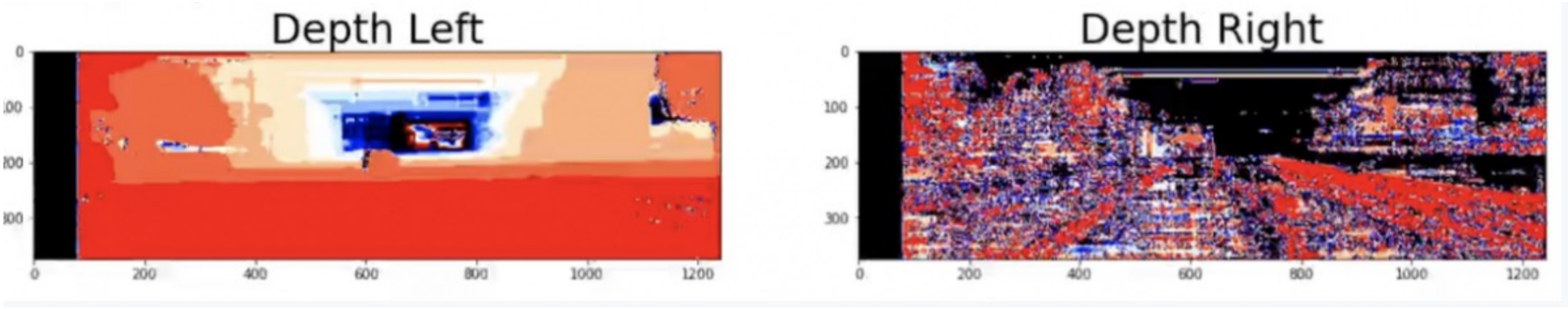
Geometry Calculations



Stereo Vision | Disparity Mapping

- Difference in image location of same 3D point from 2 camera angles





Stereo Vision | Depth Map

- **Distance of each pixel** in an image
  - Using other image+disparity map

Stereo Vision | Estimate Depth

- Using depth map, combine with YOLO
- E.g. run YOLO on left image and then use depth map
- In bounding box from YOLO, closest point can be taken

References

- mmWave

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- Computer Vision/YOLO

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- Attack on YOLO paper

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- Stereo Vision/Pseudo LiDAR

https://www.thinkautonomous.ai/blog/?p=pseudo-lidar-stereo-vision-for-self-driving-cars