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Object Detection

Object localization

What are localization and detection?

网易云课堂

Image classification

"Car"

Classification with localization

"Car"

1 object

Detection

multiple objects

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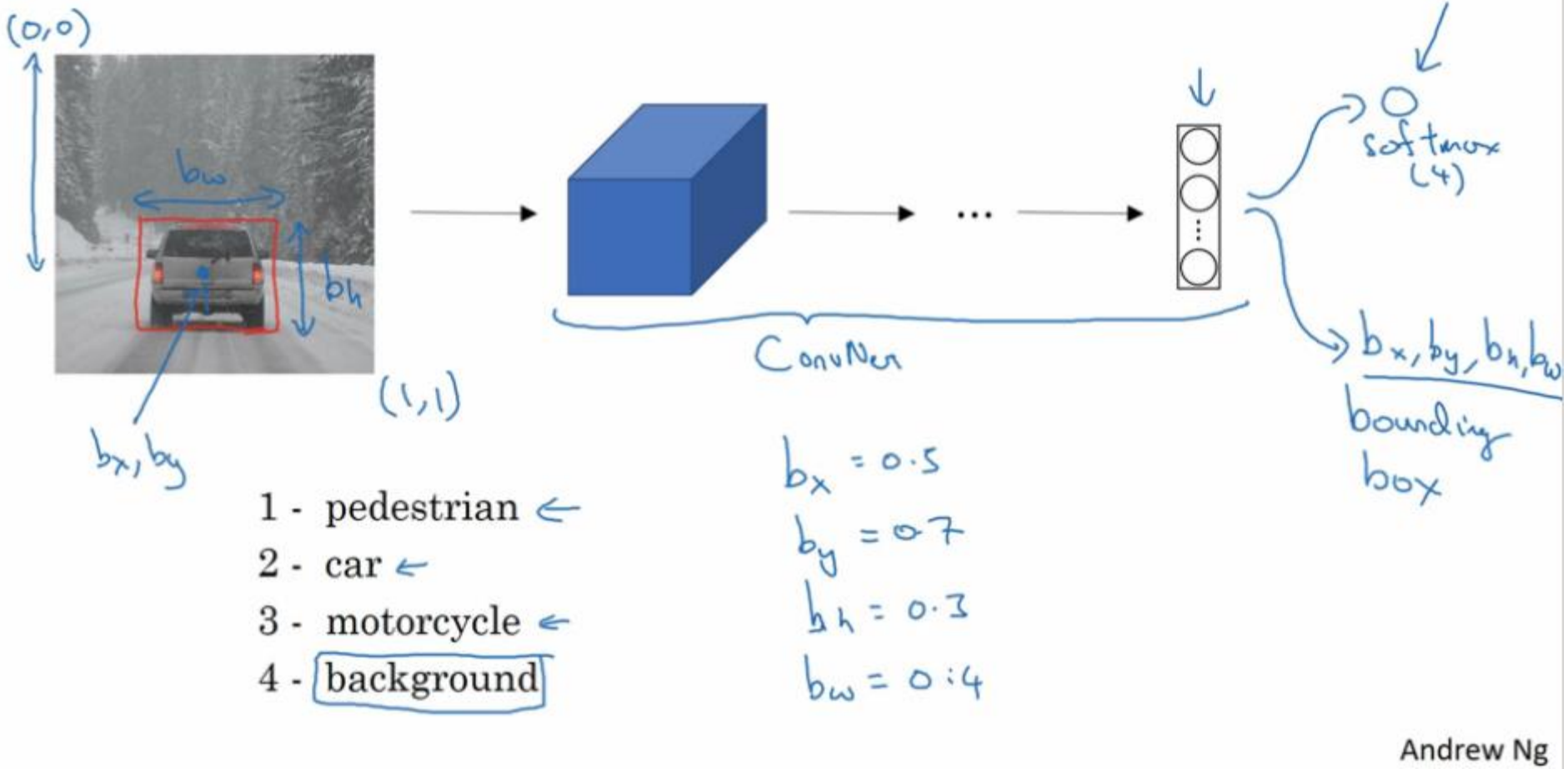
Classification with localization



1 - pedestrian
2 - car
3 - motorcycle
4 - background

$b_x = 0.5$
$b_y = 0.7$
$b_h = 0.3$
$b_w = 0.4$

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Defining the target label y

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1 - pedestrian
2 - car
3 - motorcycle
4 - background

Need to output b_x, b_y, b_h, b_w, class label (1-4)

$$\mathcal{L}(\hat{y}, y) = \begin{cases} (\hat{y}_1 - y_1)^2 + (\hat{y}_2 - y_2)^2 + \cdots + (\hat{y}_8 - y_8)^2 & \text{if } y_1 = 1 \\ (\hat{y}_1 - y_1)^2 & \text{if } y_1 = 0 \end{cases}$$

$$y = \begin{bmatrix} p_c \\ b_x \\ b_y \\ b_h \\ b_w \\ c_1 \\ c_2 \\ c_3 \end{bmatrix}$$

p_c: is there an object?

$x =$

$$(x, y) \begin{bmatrix} 1 \\ b_x \\ b_y \\ b_h \\ b_w \\ 0 \\ 1 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} 0 \\ ? \\ ? \\ ? \\ ? \\ ? \\ ? \\ ? \end{bmatrix}$$

p_c

← "don't care"

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Object Detection

Landmark detection

Landmark detection

b_x, b_y, b_h, b_w

$l_{1x}, l_{1y},$
$\vdots$
l_{32x}, l_{32y}

$l_{1x}, l_{1y},$
$l_{2x}, l_{2y},$
$l_{3x}, l_{3y},$
l_{4x}, l_{4y}
$\vdots$
l_{64}, l_{64y}

X, y

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Object Detection

Object detection

Car detection example

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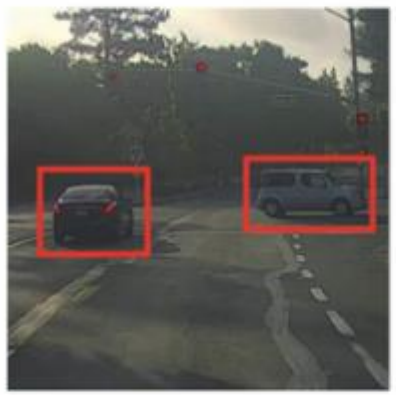
Training set:



x	y
	1
	1
	1
	0
	0

→ ConvNet → y

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Sliding windows detection

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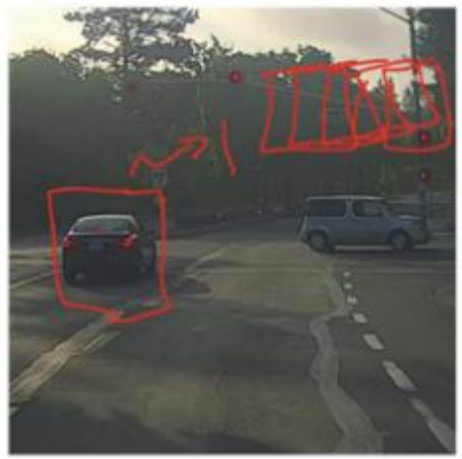

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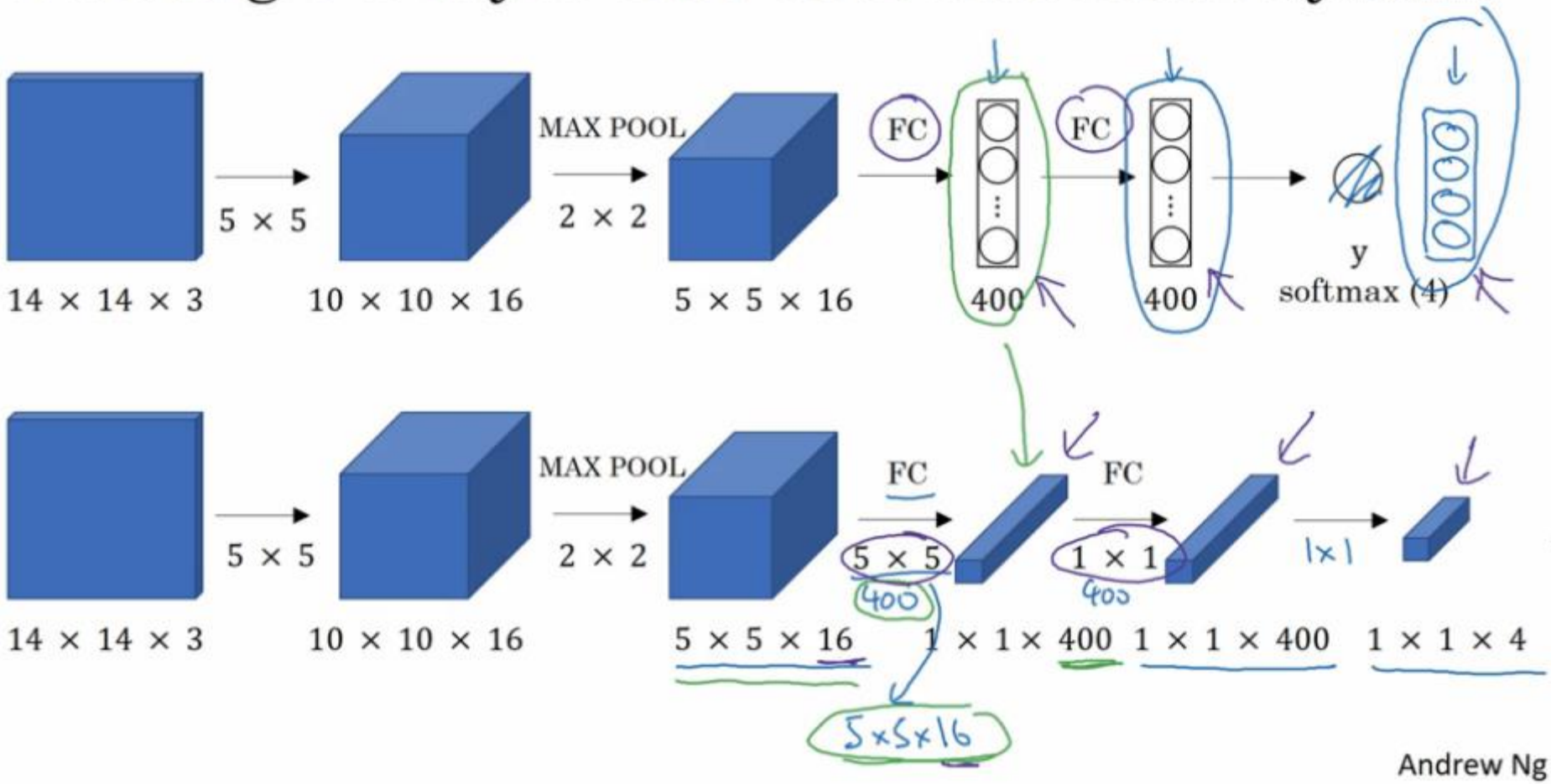
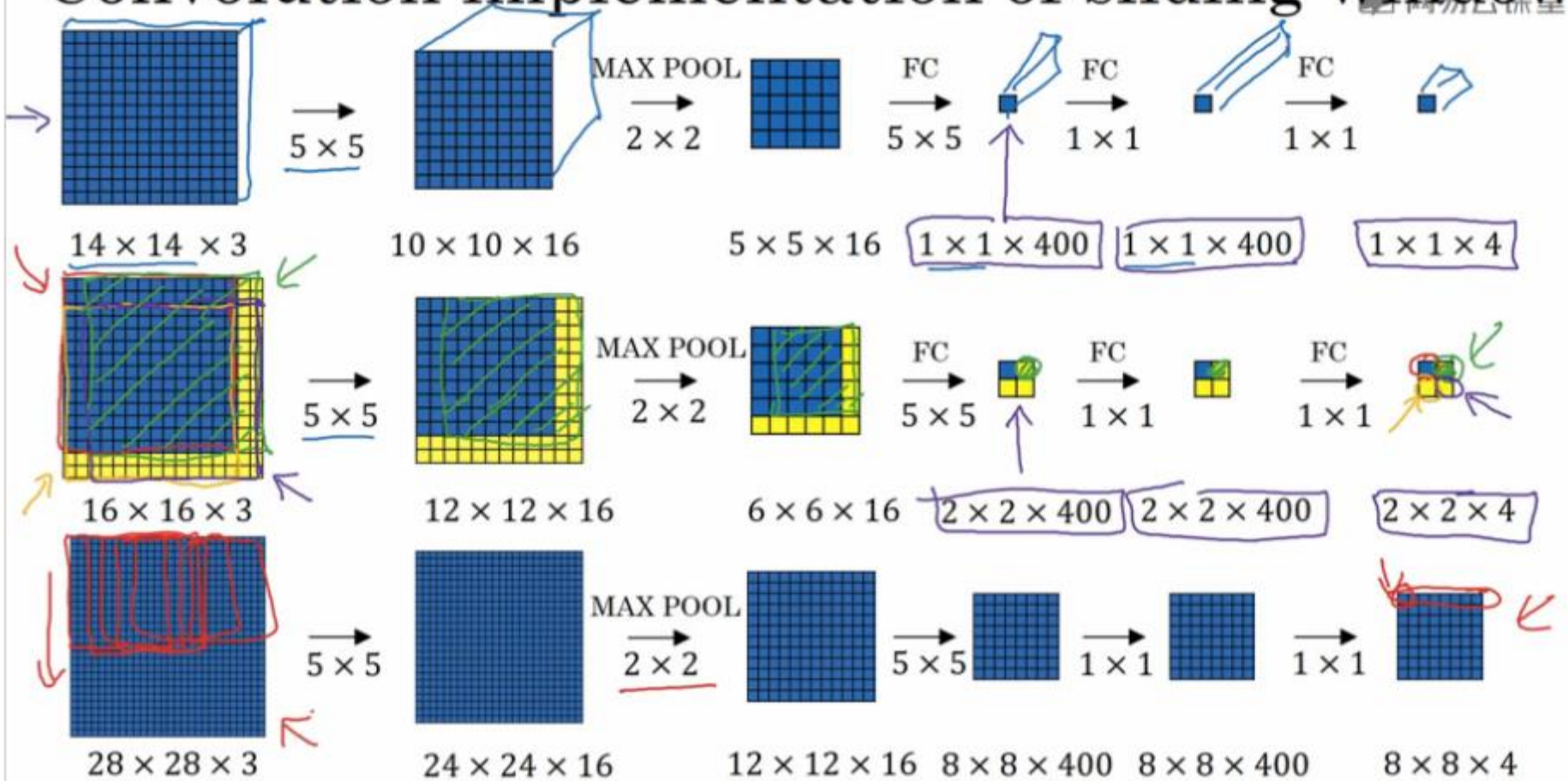
Convolutional implementation of sliding windows

Turning FC layer into convolutional layers



Convolution implementation of sliding windows



[Sermanet et al., 2014, OverFeat: Integrated recognition, localization and detection using convolutional networks]

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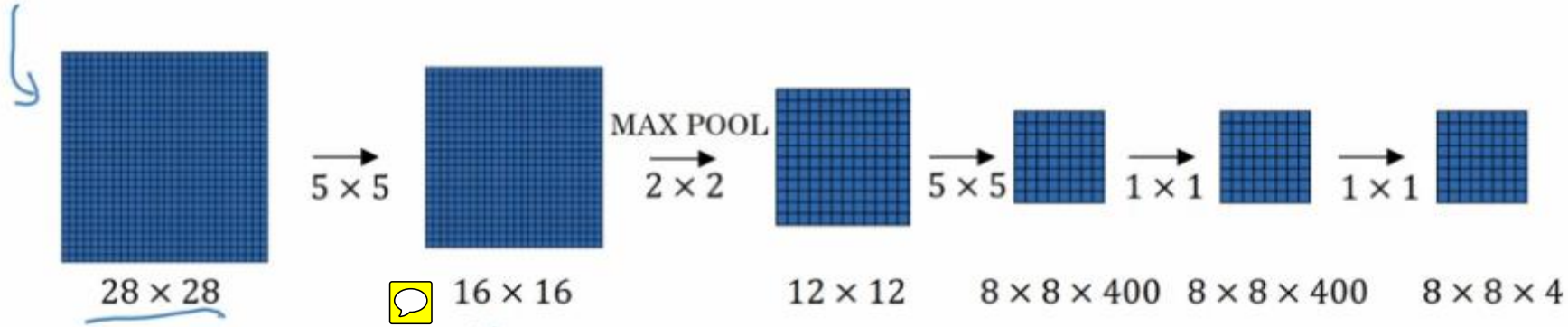
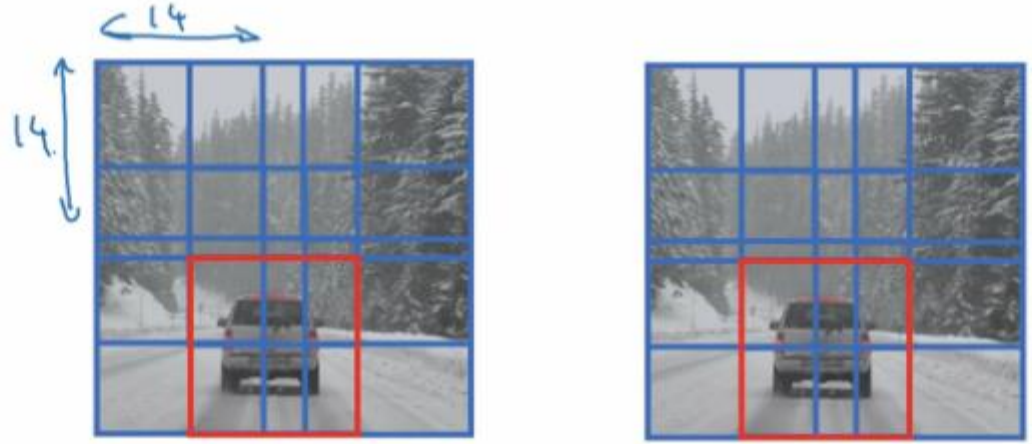
Convolution implementation of sliding windows





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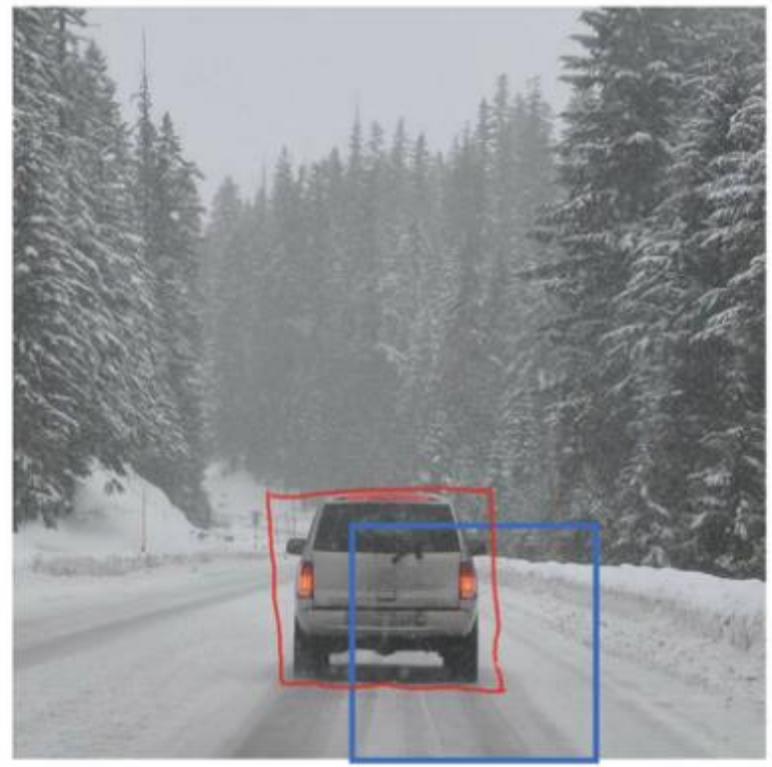
Object Detection

Bounding box predictions

Output accurate bounding boxes



YOLO algorithm

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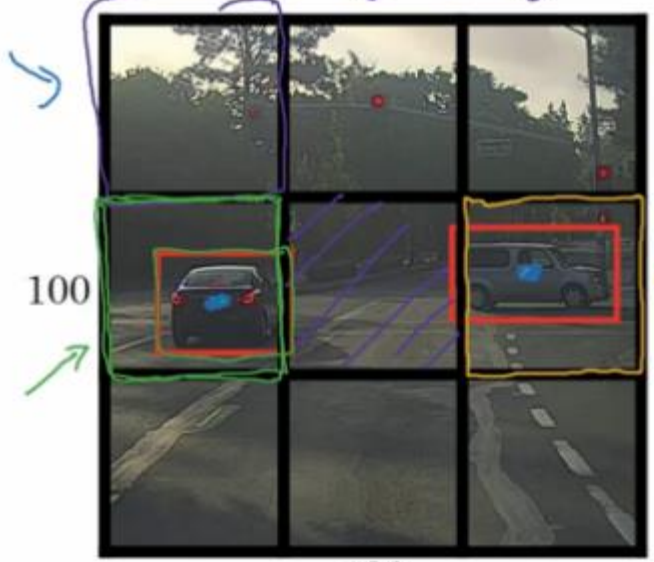
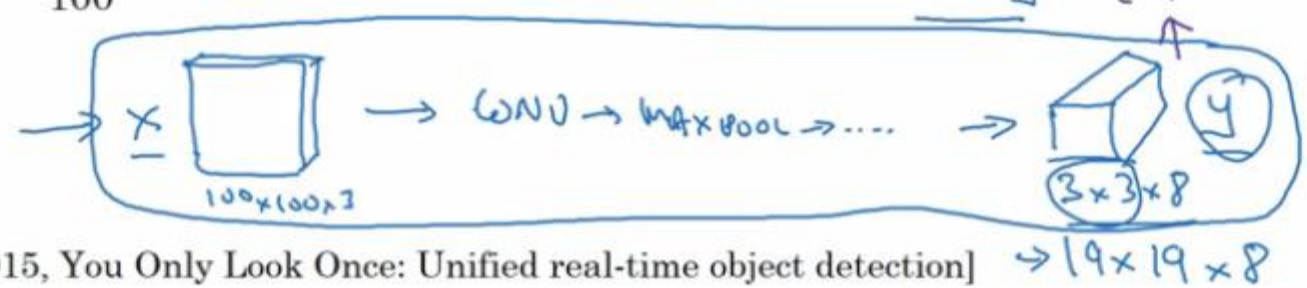


Labels for training

For each grid cell:

$y = \begin{bmatrix} p_c \\ b_x \\ b_y \\ b_h \\ b_w \\ c_1 \\ c_2 \\ c_3 \end{bmatrix}$

Target output: $3 \times 3 \times 8$



[Redmon et al., 2015, You Only Look Once: Unified real-time object detection]

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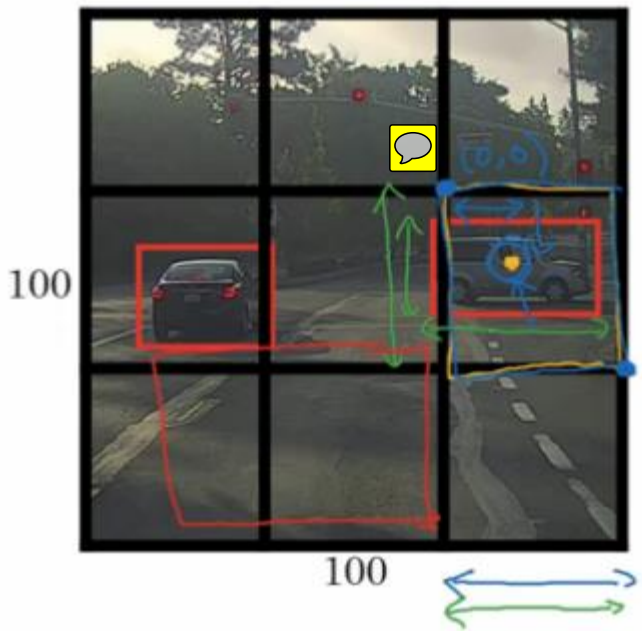
Specify the bounding boxes



$$y = \begin{bmatrix} 1 \\ b_x \\ b_y \\ b_h \\ b_w \\ 0 \\ 1 \\ 0 \end{bmatrix}$$

0.4, 0.3 } between 0 and 1

0.9, 0.5 } could be > 1

[Redmon et al., 2015, You Only Look Once: Unified real-time object detection]

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Object Detection

Intersection over union

Evaluating object localization

Intersection over Union (IoU)

$$= \frac{\text{size of } \square}{\text{size of } \square}$$

"Correct" if IoU $\geq$ 0.5 ←

0.6 ←

More generally, IoU is a measure of the overlap between two bounding boxes.

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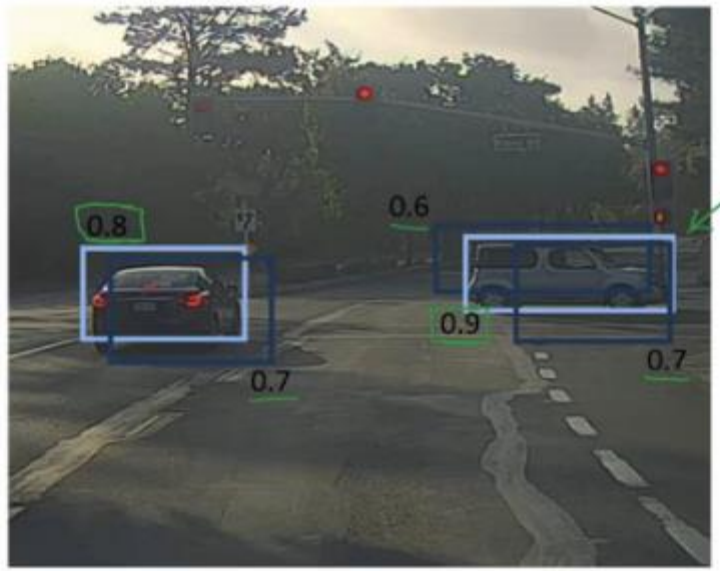
Object Detection

Non-max suppression

Non-max suppression example



p_c

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Non-max suppression algorithm

19× 19

Each output prediction is: p_c, b_x, b_y, b_h, b_w

Discard all boxes with $p_c \leq 0.6$

While there are any remaining boxes:

- Pick the box with the largest p_c
  Output that as a prediction.
- Discard any remaining box with IoU ≥ 0.5 with the box output in the previous step

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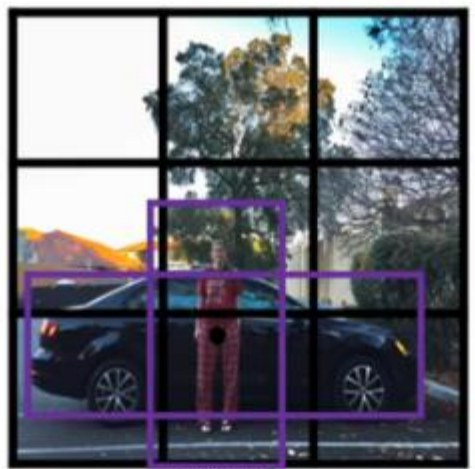
Object Detection

Anchor boxes

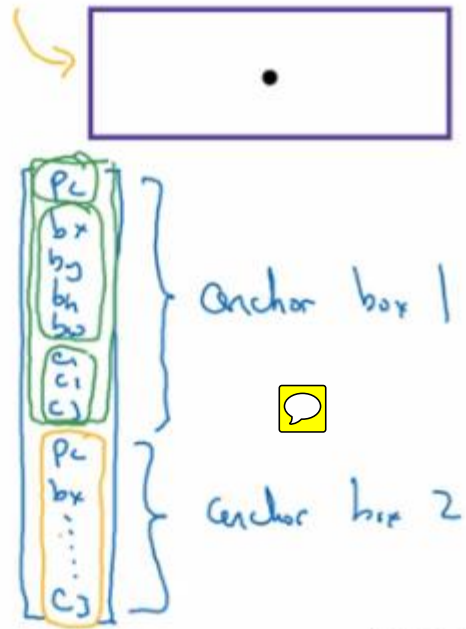
Overlapping objects:



$$y = \begin{bmatrix} p_c \\ b_x \\ b_y \\ b_h \\ b_w \\ c_1 \\ c_2 \\ c_3 \end{bmatrix}$$

Anchor box 1:

Anchor box 2:



$y =$

[Redmon et al., 2015, You Only Look Once: Unified real-time object detection]

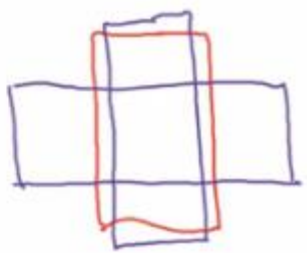
Anchor box algorithm

Previously:

- Each object in training image is assigned to grid cell that contains that object's midpoint.

Output y:

$3 \times 3 \times 8$



With two anchor boxes:

- Each object in training image is assigned to grid cell that contains object's midpoint and anchor box for the grid cell with highest IoU.

(grid cell, anchor box)

Output y:

$3 \times 3 \times 16$

$3 \times 3 \times 2 \times 8$

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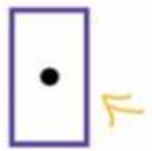
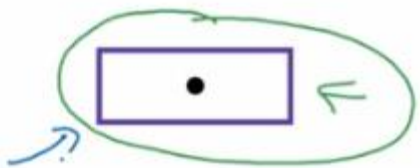
Anchor box example

Anchor box 1:



Anchor box 2:



$$y = \begin{bmatrix} p_c \\ b_x \\ b_y \\ b_h \\ b_w \\ c_1 \\ c_2 \\ c_3 \\ p_c \\ b_x \\ b_y \\ b_h \\ b_w \\ c_1 \\ c_2 \\ c_3 \end{bmatrix}$$

anchor box 1

anchor box 2

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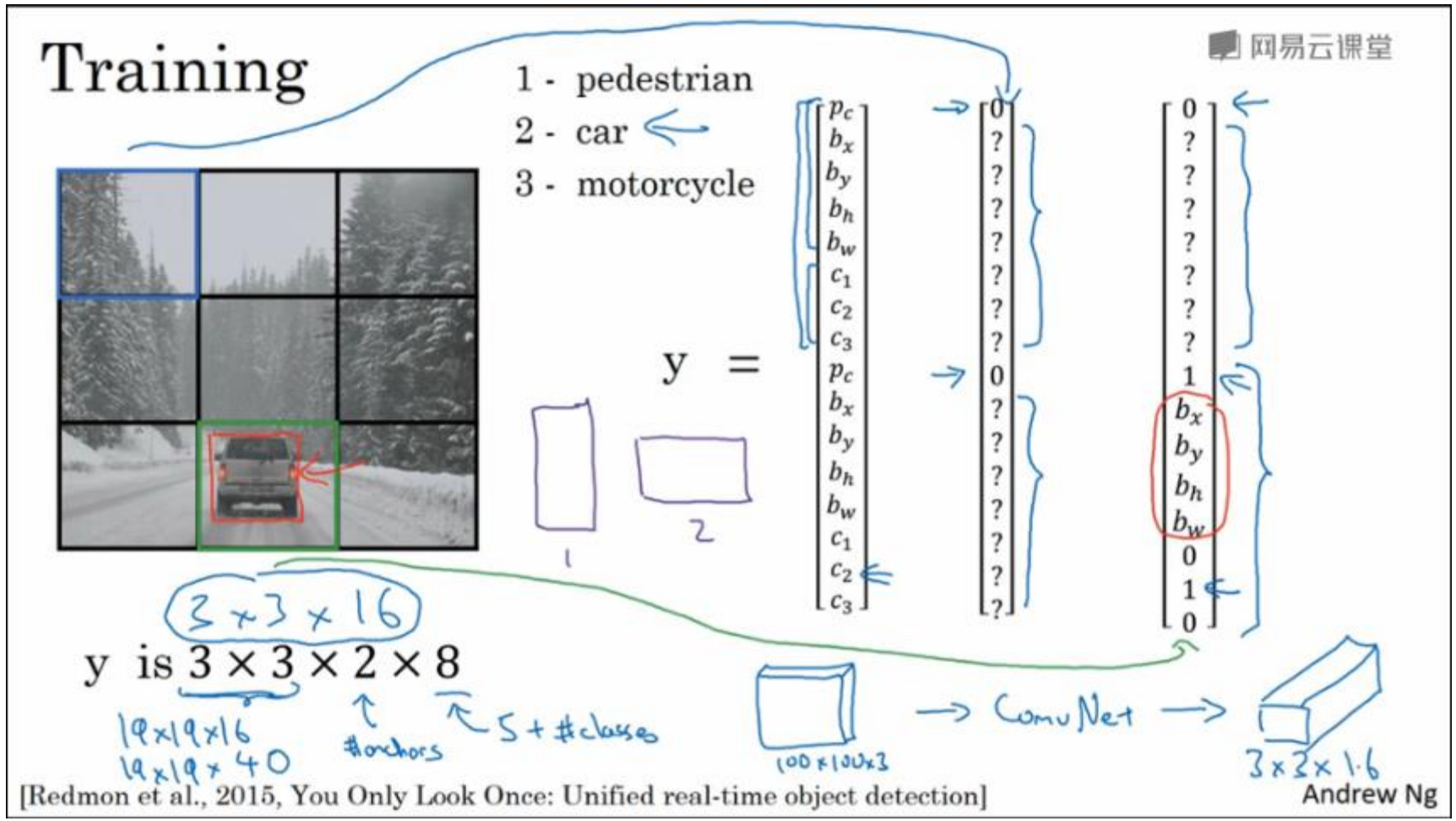
Object Detection

Putting it together: YOLO algorithm


Training
网易云课堂
1 - pedestrian
2 - car
3 - motorcycle
y =
p_c b_x b_y b_h b_w c_1 c_2 c_3 p_c b_x b_y b_h b_w c_1 c_2 c_3
0 ? ? ? ? ? ? ? 0 ? ? ? ? ? ? ?
0 ? ? ? ? ? ? ? 1 b_x b_y b_h b_w 0 1 0
1
2
3 × 3 × 16
y is 3 × 3 × 2 × 8
19×19×16
19×19×40
#anchors
5 + #classes
100×100×3
ConvNet
3×3×16
[Redmon et al., 2015, You Only Look Once: Unified real-time object detection]
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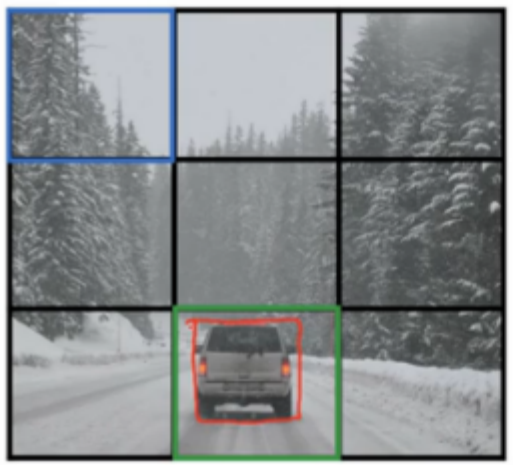
Making predictions



$3 \times 3 \times 2 \times 8$

$$y = \begin{bmatrix} p_c \\ b_x \\ b_y \\ b_h \\ b_w \\ c_1 \\ c_2 \\ c_3 \\ p_c \\ b_x \\ b_y \\ b_h \\ b_w \\ c_1 \\ c_2 \\ c_3 \end{bmatrix}$$

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Outputting the non-max supressed outputs

- For each grid call, get 2 predicted bounding boxes.
- Get rid of low probability predictions.
- For each class (pedestrian, car, motorcycle) use non-max suppression to generate final predictions.

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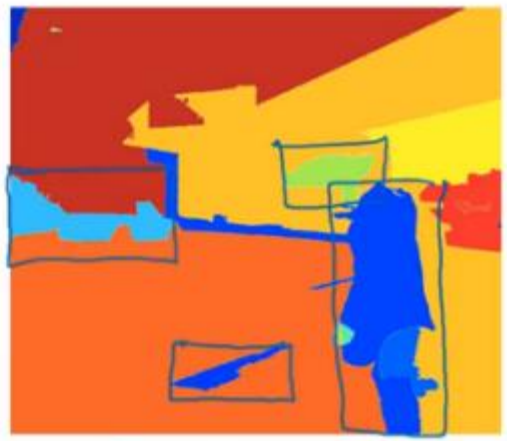
Object Detection

Region proposals (Optional)

Region proposal: R-CNN



Segmentation algorithm

~2,000

[Girshik et. al, 2013, Rich feature hierarchies for accurate object detection and semantic segmentation]

Faster algorithms

R-CNN: Propose regions. Classify proposed regions one at a time. Output label + bounding box.

Fast R-CNN: Propose regions. Use convolution implementation of sliding windows to classify all the proposed regions.

Faster R-CNN: Use convolutional network to propose regions.

[Girshik et. al, 2013. Rich feature hierarchies for accurate object detection and semantic segmentation]
[Girshik, 2015. Fast R-CNN]
[Ren et. al, 2016. Faster R-CNN: Towards real-time object detection with region proposal networks]