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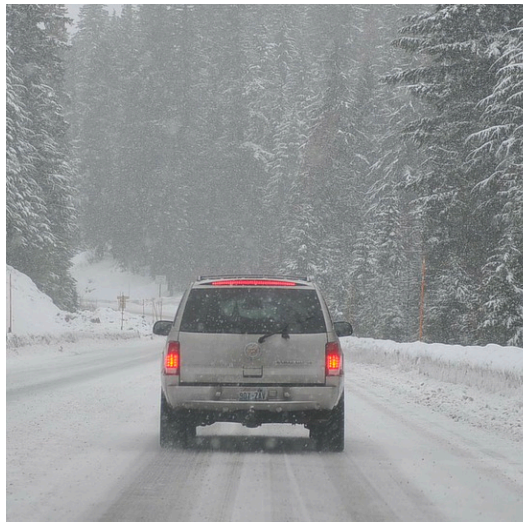
Object Detection

Object localization

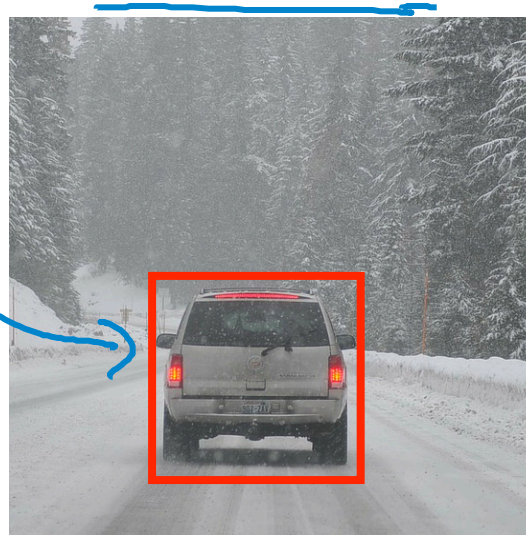
What are localization and detection?

Image classification



"Car"

Classification with localization



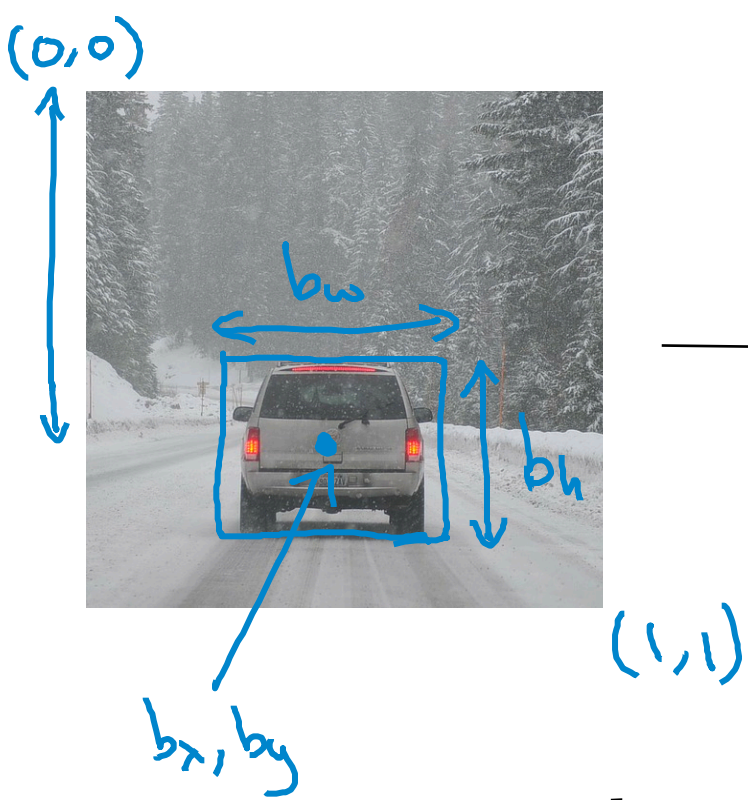
"Car"

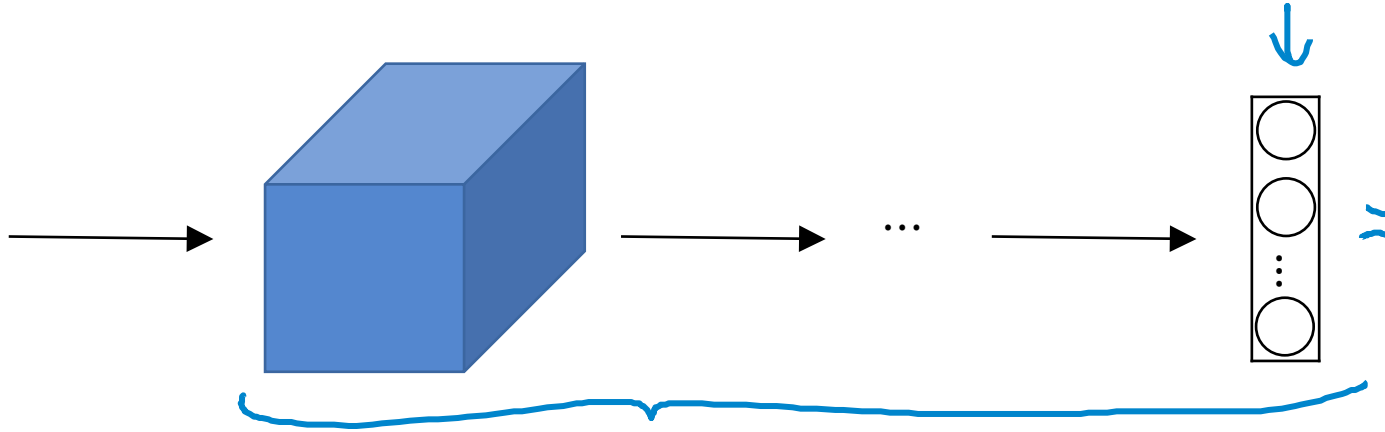
1 object

Detection

multiple objects

Classification with localization





1 - pedestrian

2 - car

3 - motorcycle

4 - background

$b_x = 0.5$

$b_y = 0.7$

$b_h = 0.3$

$b_w = 0.4$

Defining the target label y

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

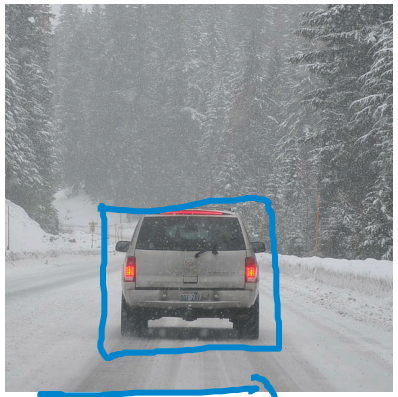
Need to output b_x, b_y, b_h, b_w, class label (1-4)

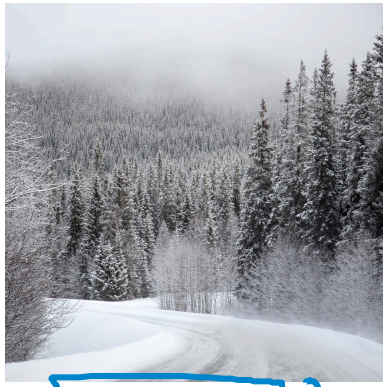
$$y = \begin{bmatrix} p_c \\ b_x \\ b_y \\ b_h \\ b_w \\ c_1 \\ c_2 \\ c_3 \end{bmatrix}$$

p_c is there an object?

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

$x =$





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

(x, y)

$$y = \begin{bmatrix} p_c \\ ? \\ ? \\ ? \\ ? \\ ? \\ ? \\ ? \end{bmatrix}$$

p_c

"don't care"

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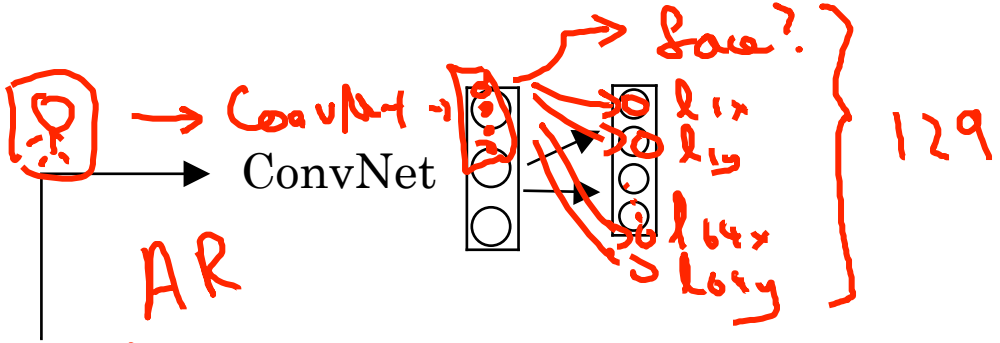
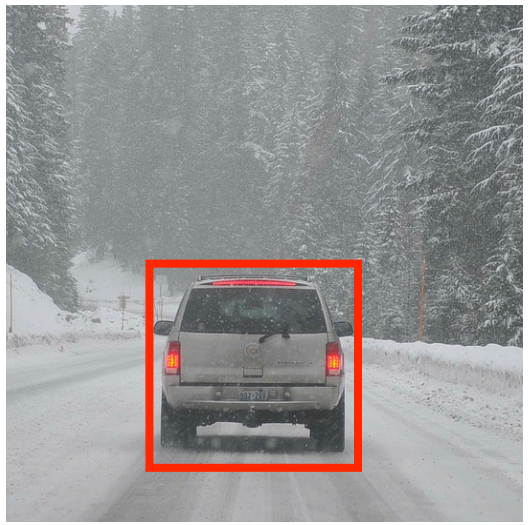
Object Detection

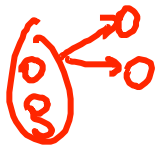
Landmark detection

Landmark detection





$b_{1x}, b_{1y}, b_{1h}, b_{1w}$



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

x, y

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

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Object Detection

Object detection

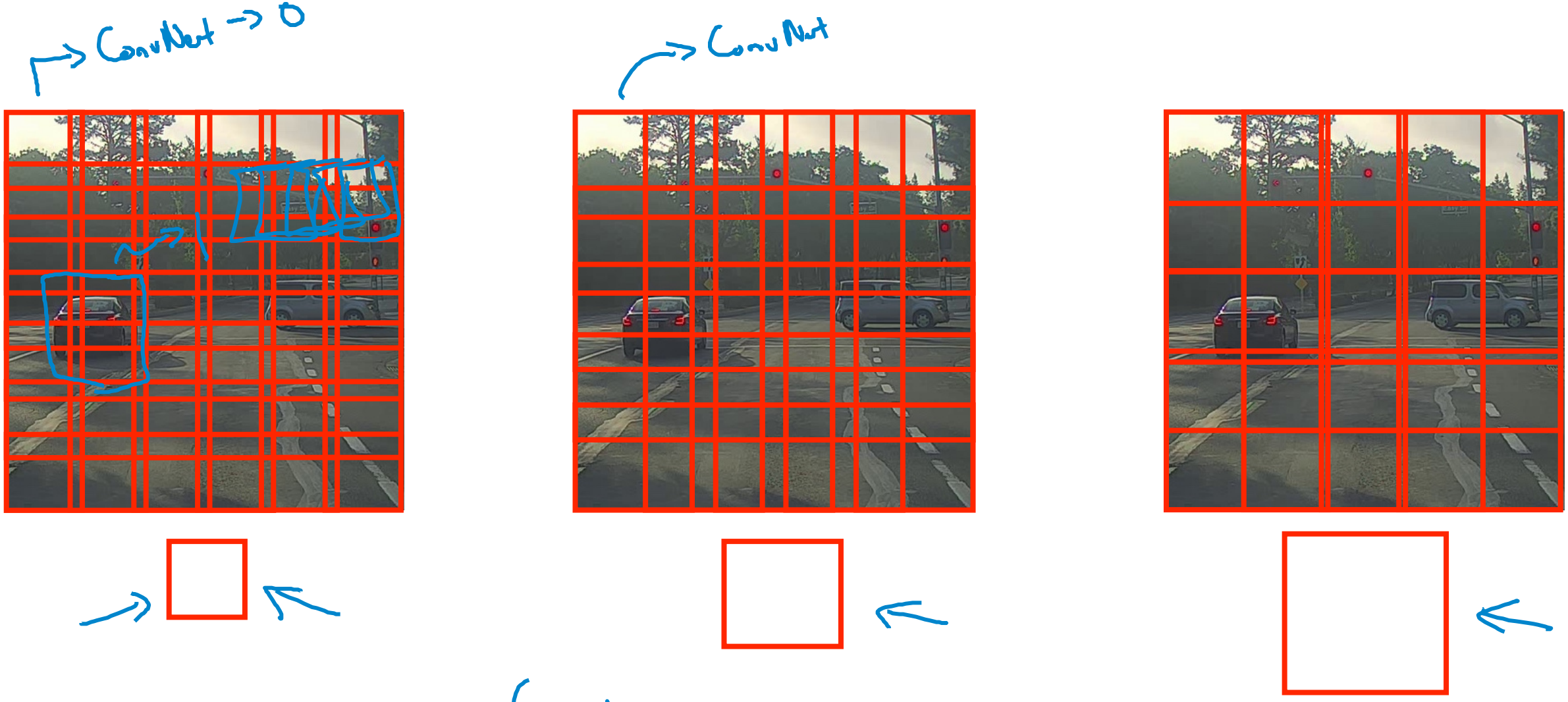
Car detection example

Training set:

x	y
	1
	1
	1
	0
	0

→ ConvNet → y

Sliding windows detection



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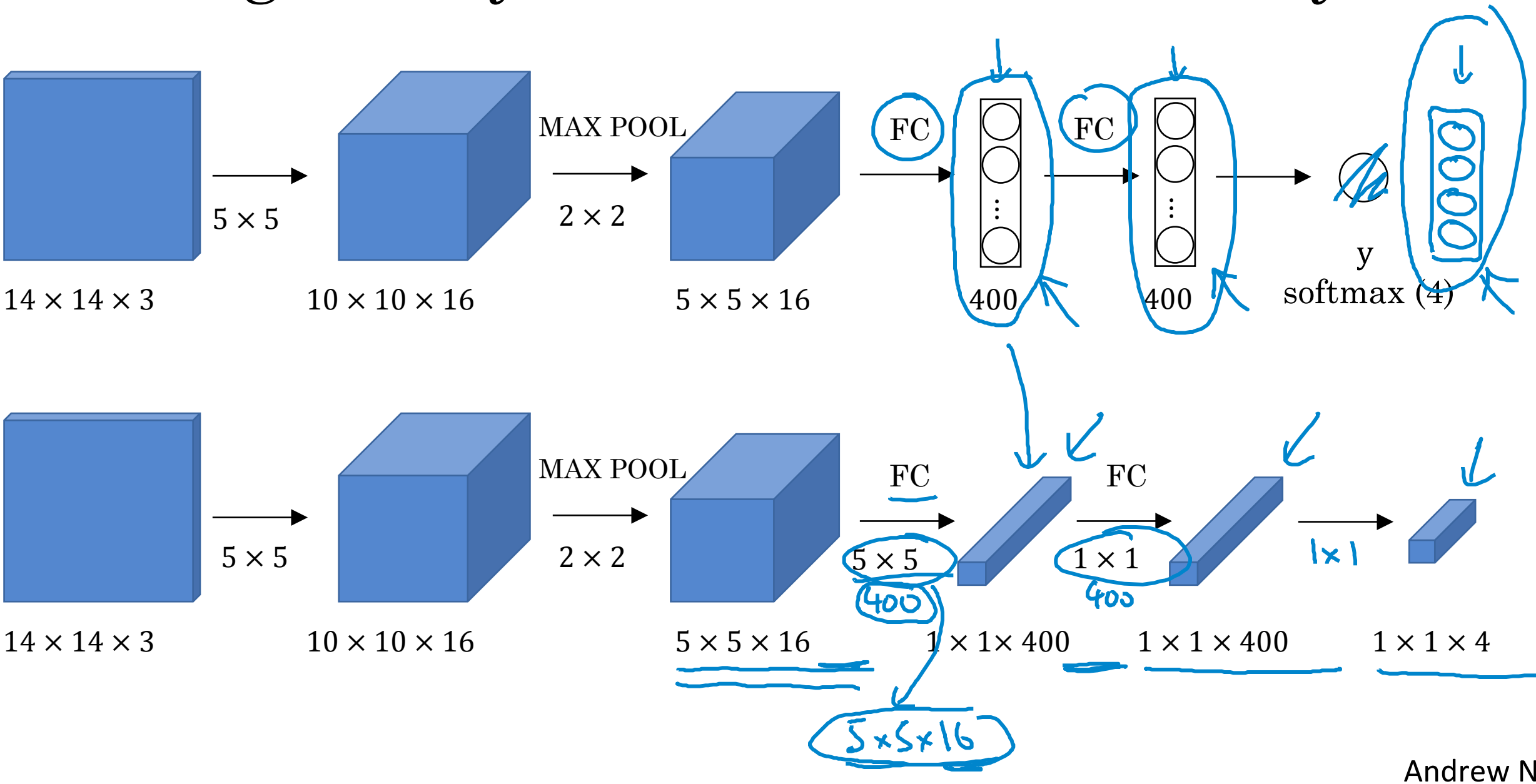
Object Detection

Convolutional implementation of sliding windows

Turning FC layer into convolutional layers



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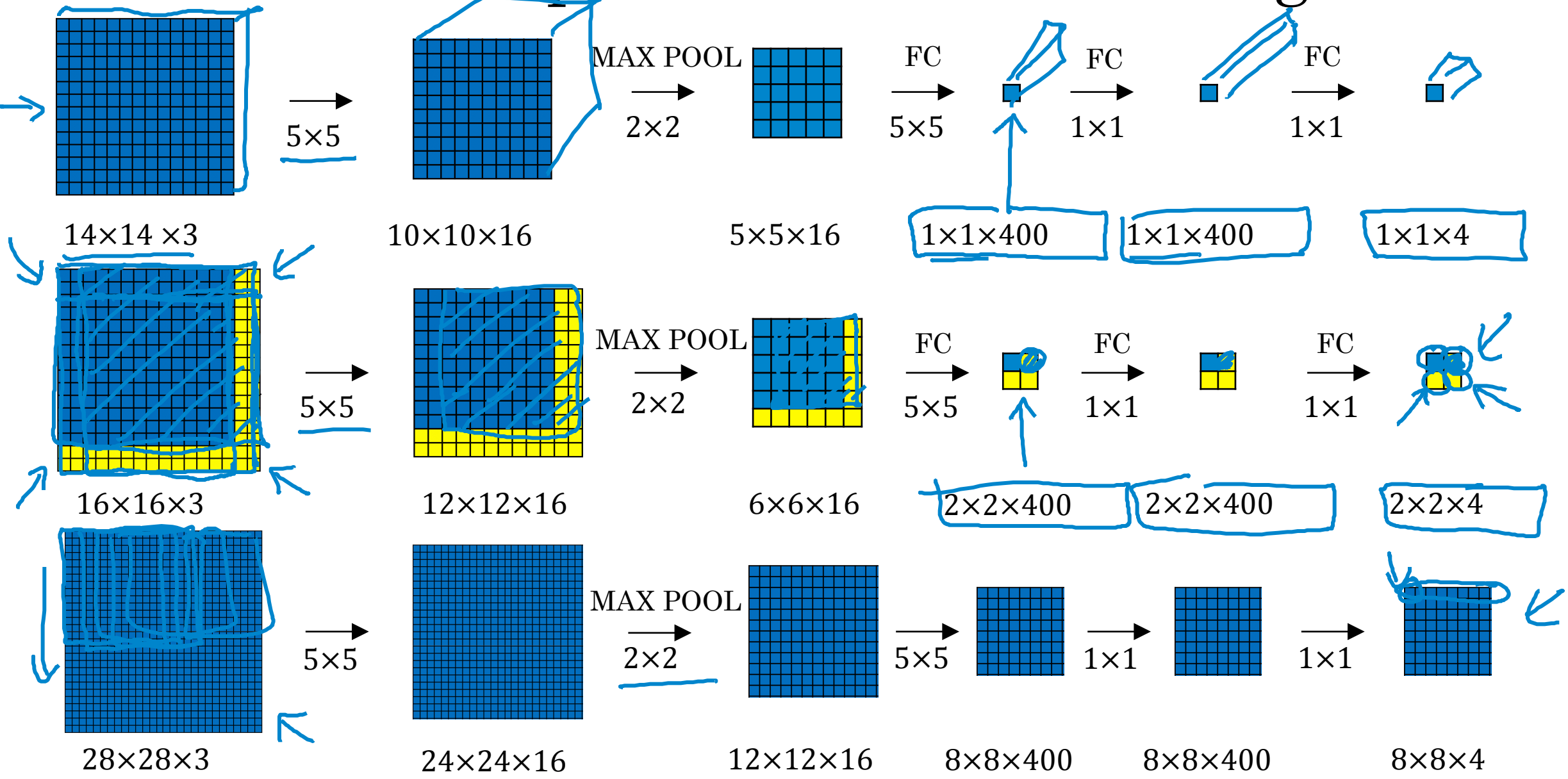
Convolution implementation of sliding windows



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

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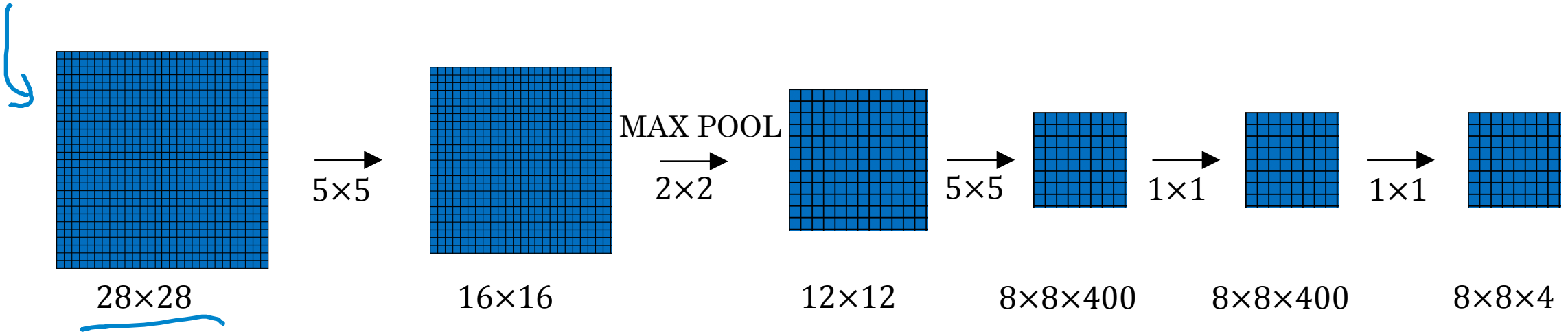
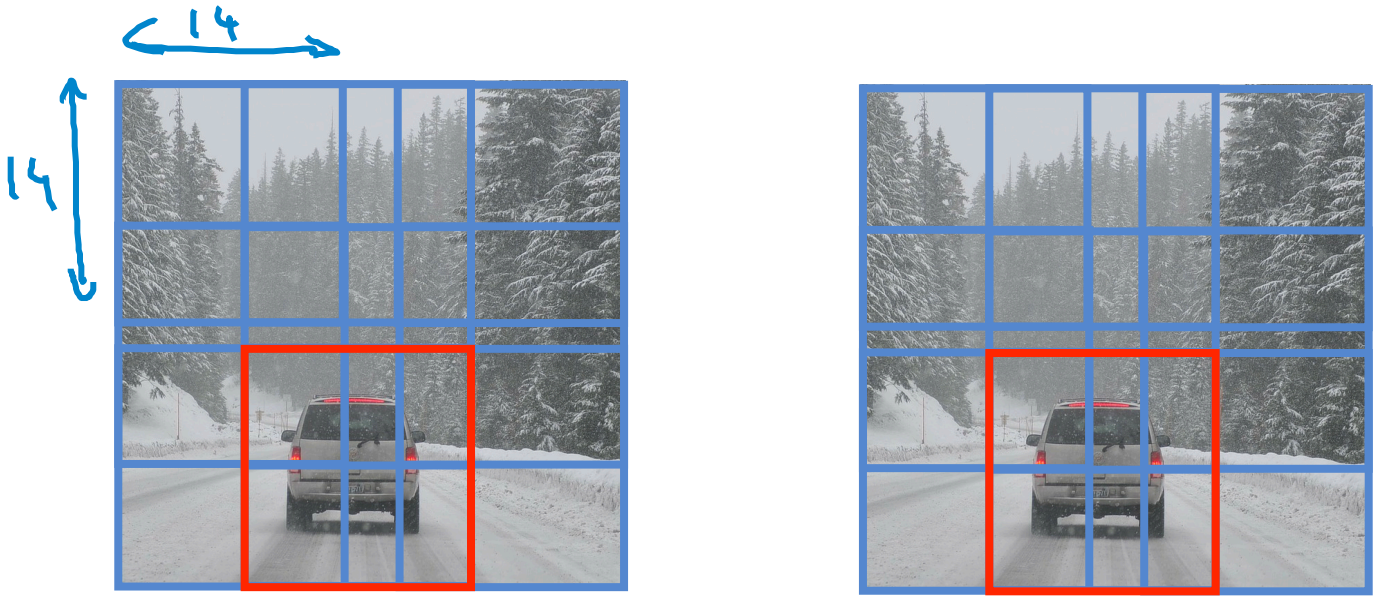
Convolution implementation of sliding windows





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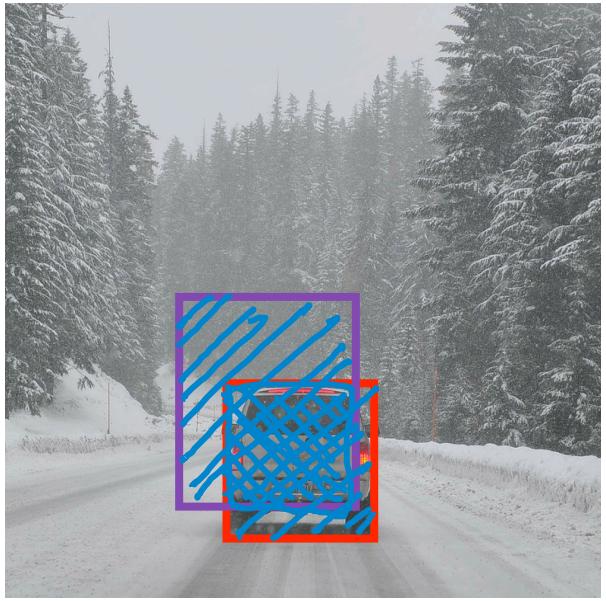
Object Detection

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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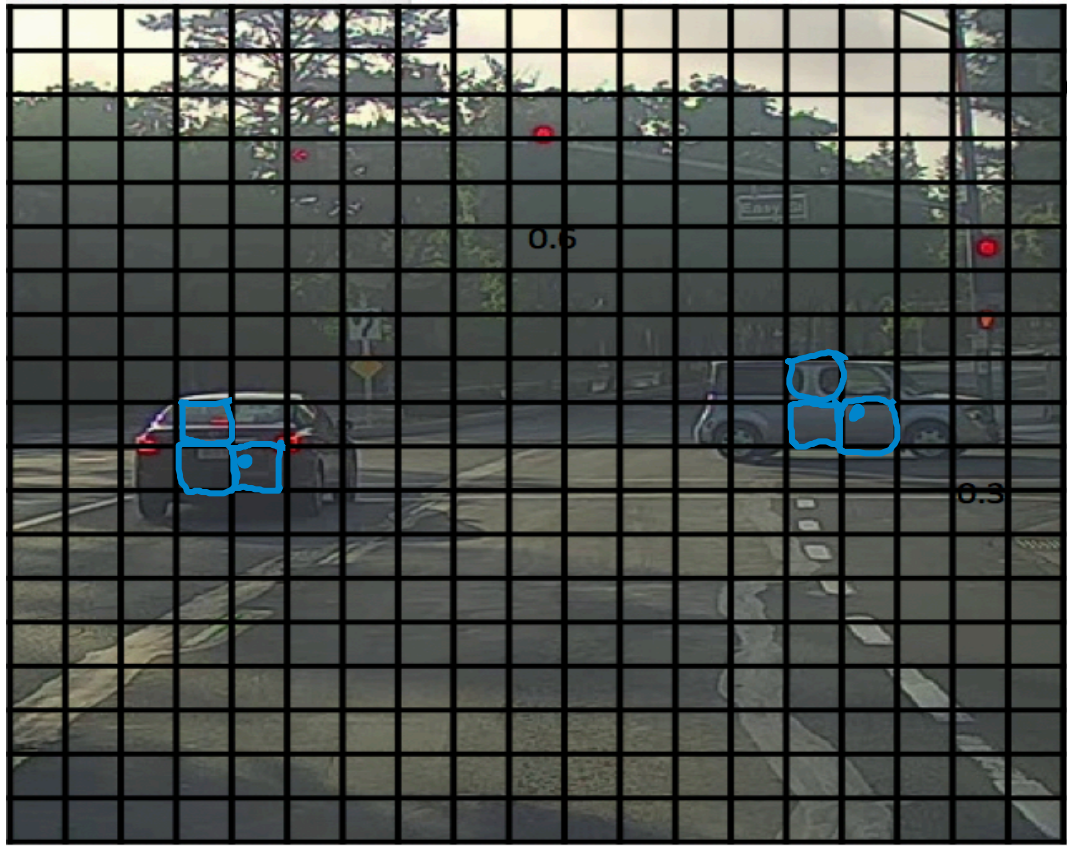
Object Detection

Non-max suppression

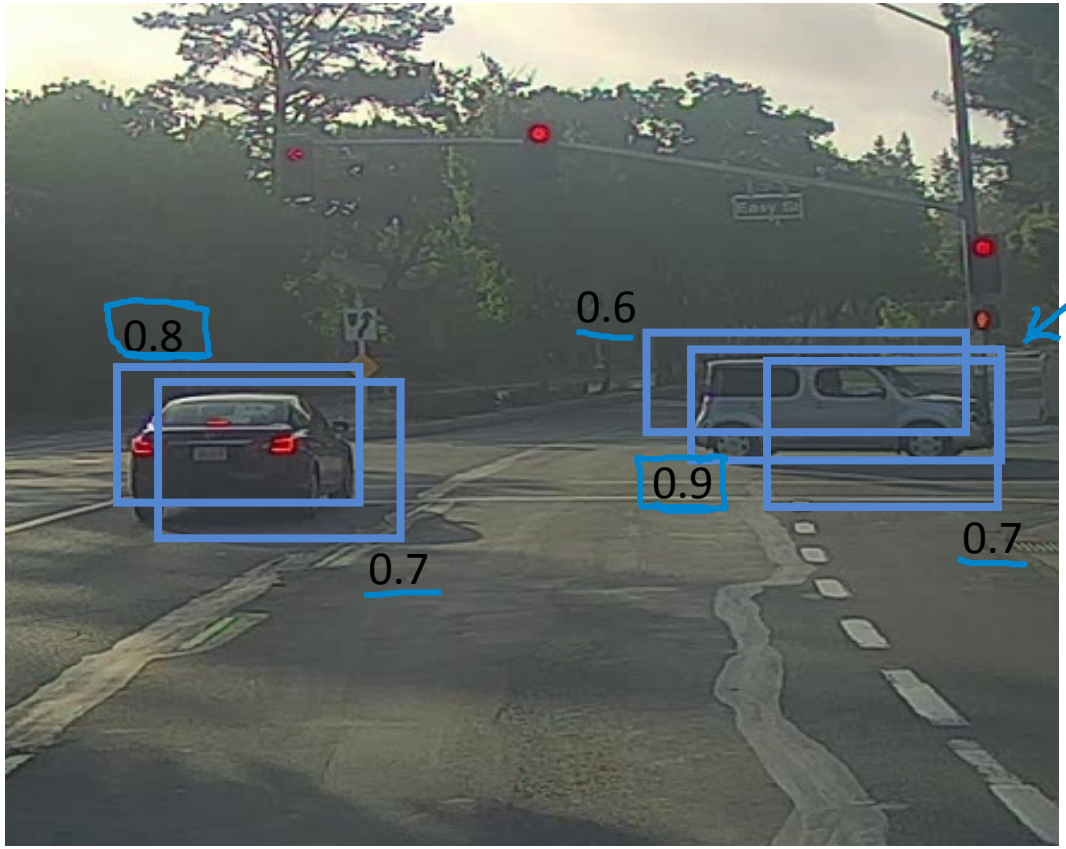
Non-max suppression example

Non-max suppression example



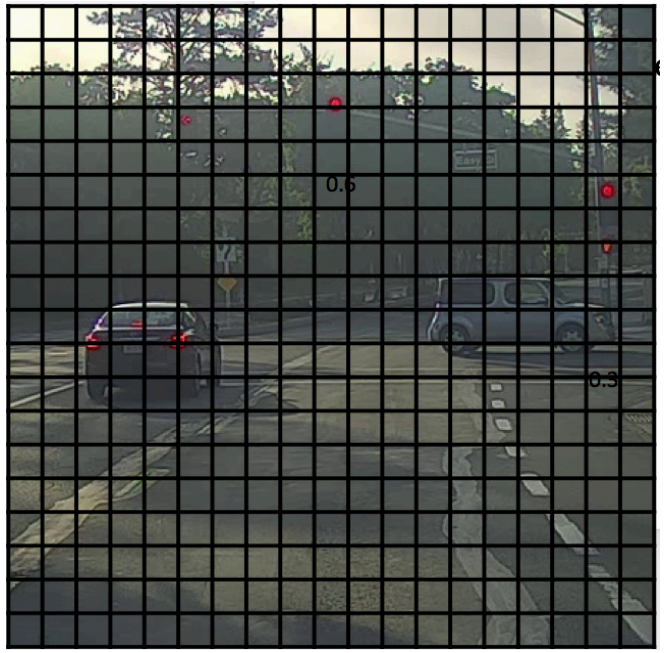
19×19

Non-max suppression example



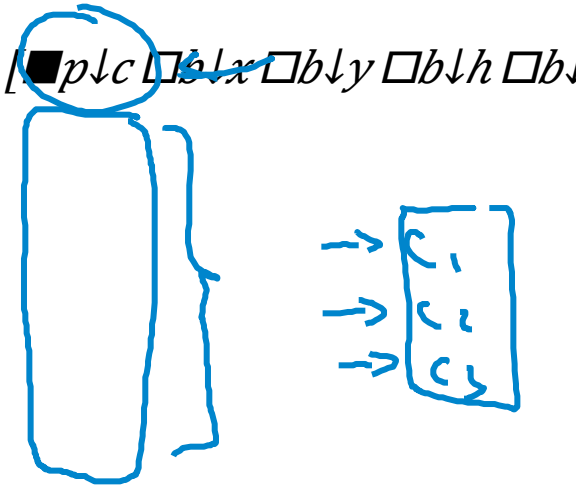
p_c

Non-max suppression algorithm



19×19

Each output prediction is:



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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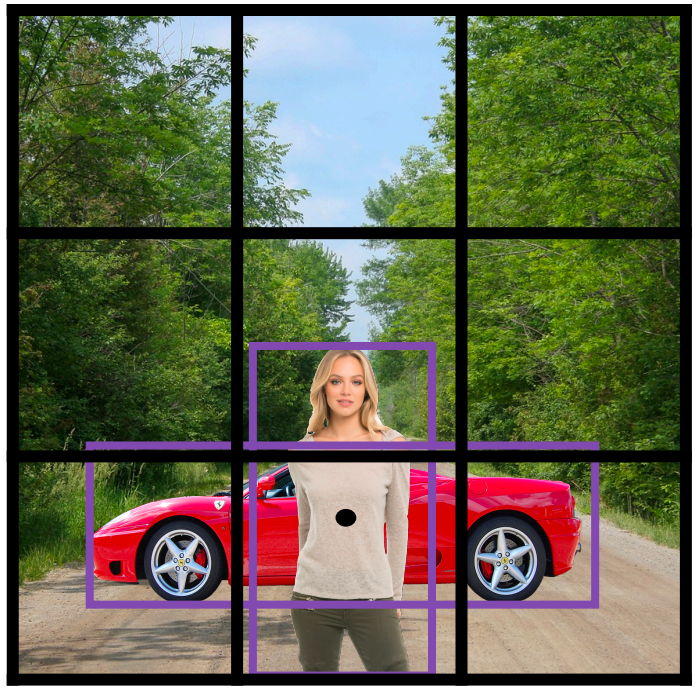
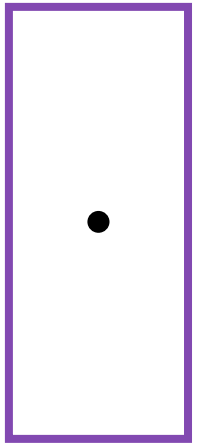
Object Detection

Anchor boxes

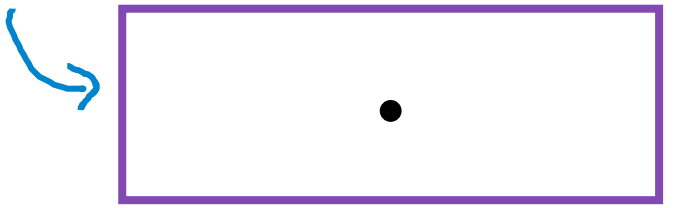
Overlapping objects:



Anchor box 1:

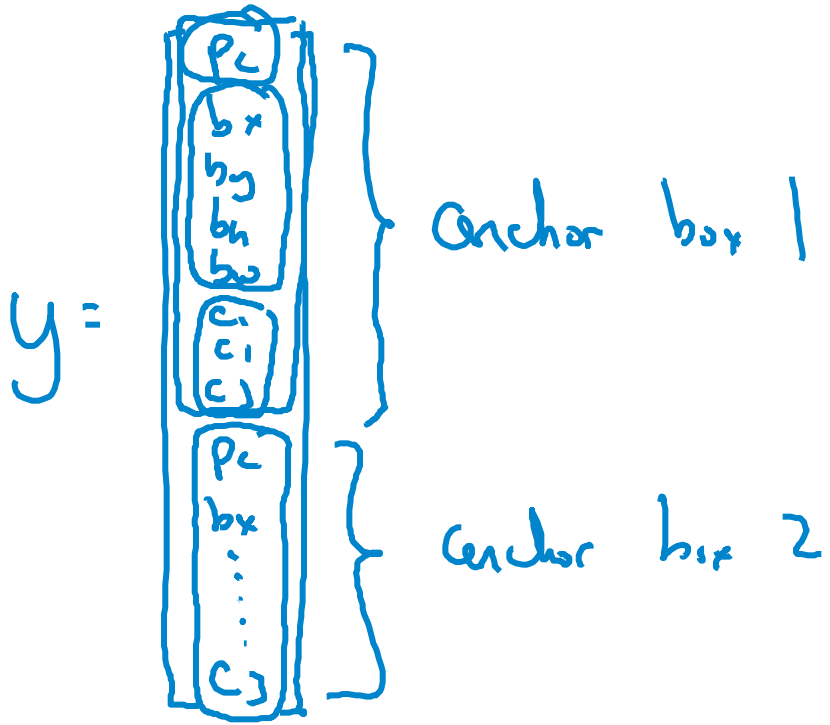


Anchor box 2:



$[\blacksquare p_c \square b_x \square b_y \square b_h \square b_w \square c_1 \square c_2 \square c_3]$

$y =$



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

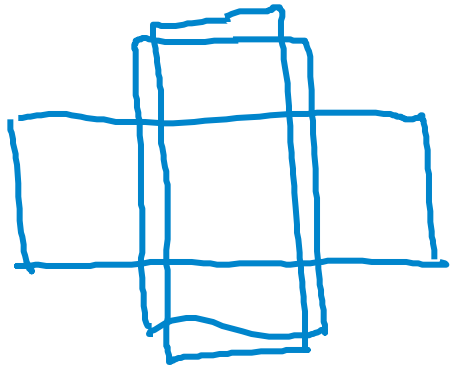
Anchor box algorithm

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)

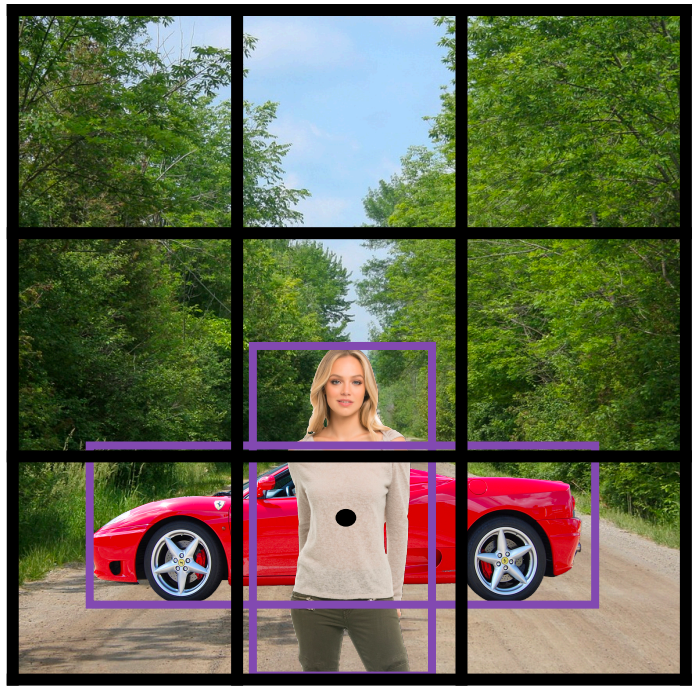
Output y:

$3 \times 3 \times 16$

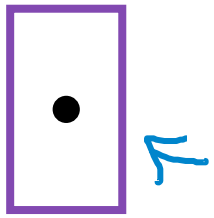
$3 \times 3 \times 2 \times 8$

Anchor box example

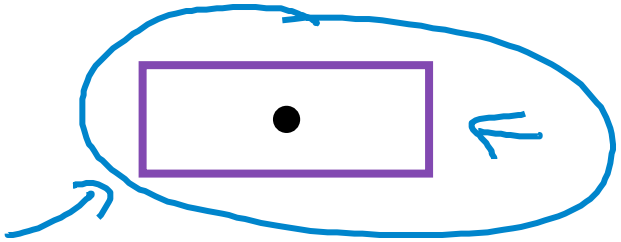
$y = [\blacksquare\ p_c\ b_x\ b_y\ b_h\ b_w\ c_1\ c_2\ c_3\ p_c\ b_x\ b_y\ b_h\ b_w\ c_1\ c_2\ c_3]$



Anchor box 1:



Anchor box 2:



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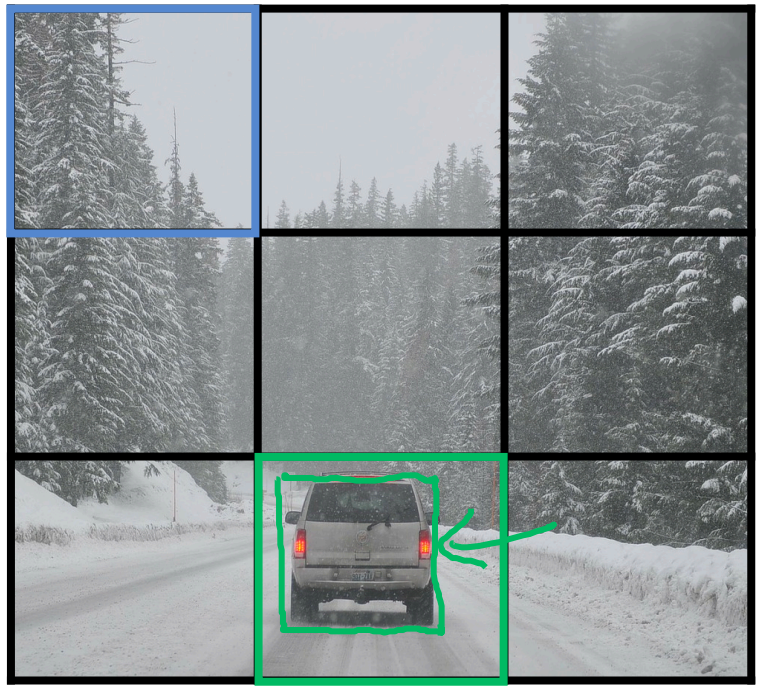
Object Detection

Putting it together: YOLO algorithm

Training

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 □
□?□?□ □?□?□
?□?□? ?□?□?
□?□0□ □?□1□
?□?□? b↓x □
□?□?□ b↓y □
?□?] b↓h □
b↓w □
0□1□0
]

3 × 3 × 16

y is 3×3×2×8

19×19×16
19×19×40

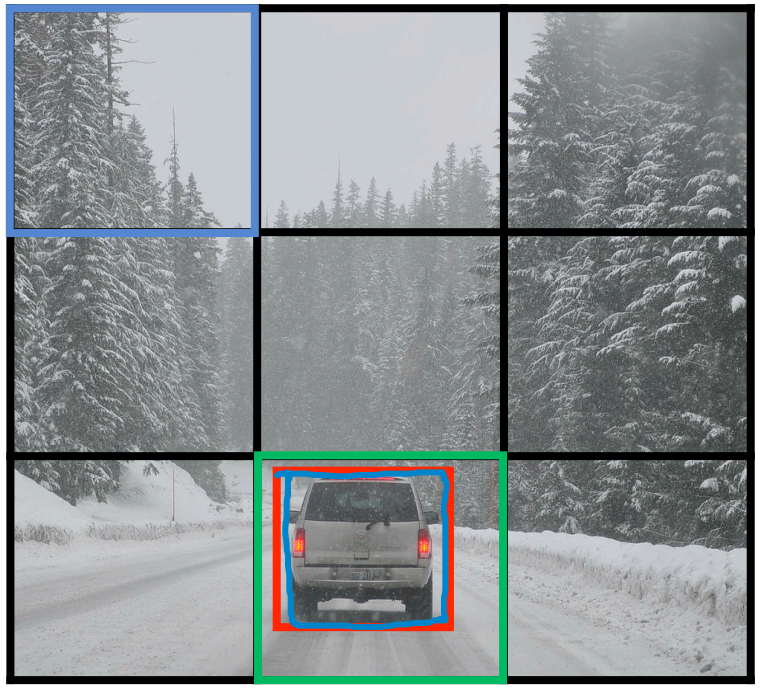
#anchors

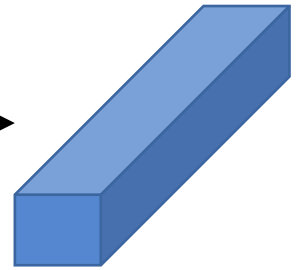
5 + #classes

100×100×3 → ConvNet → 3×3×16

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

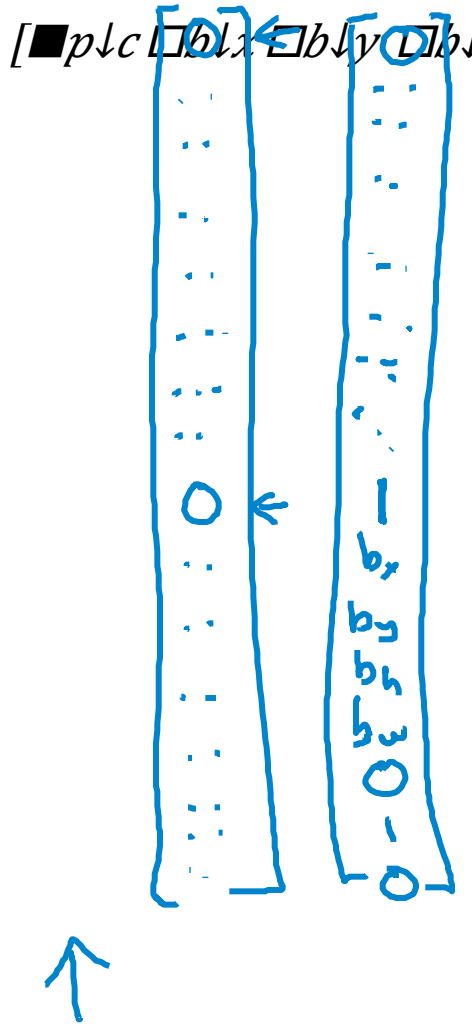
Making predictions



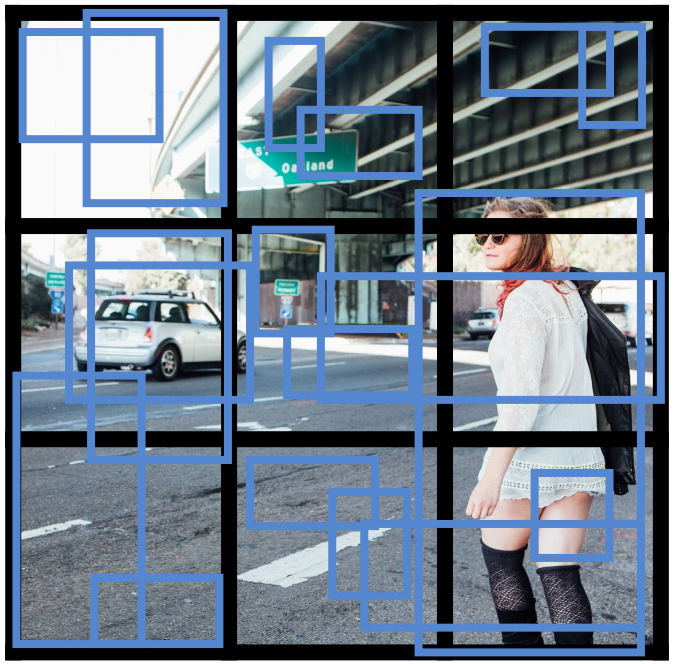


$3\times3\times2\times8$

$y =$



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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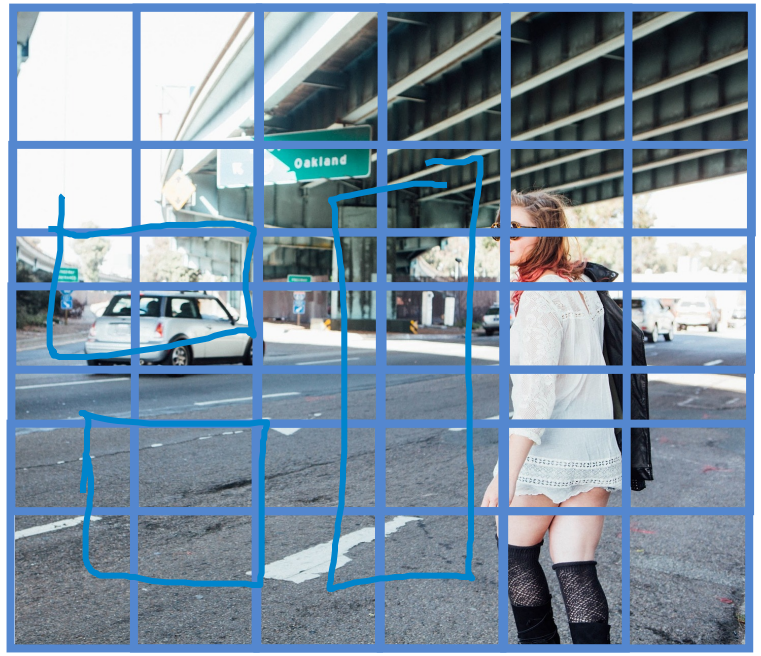
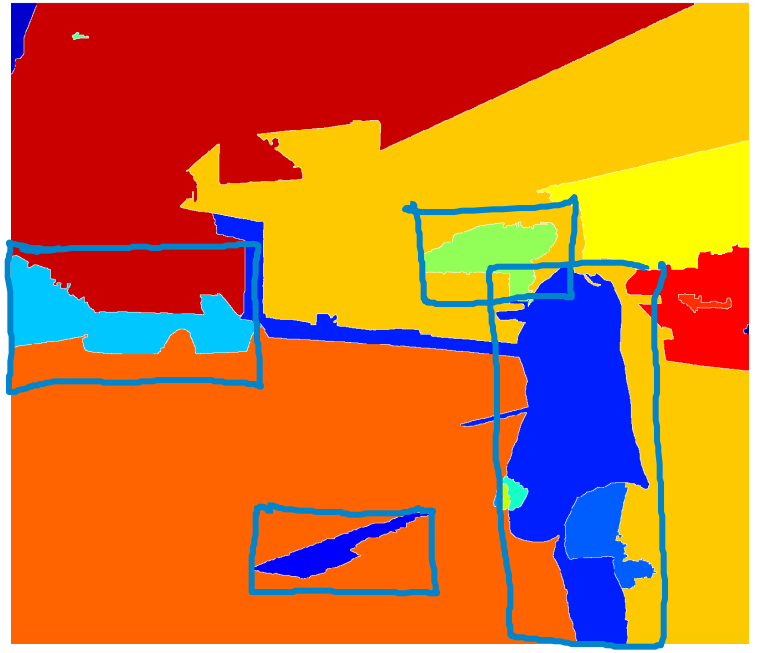
Object Detection

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]