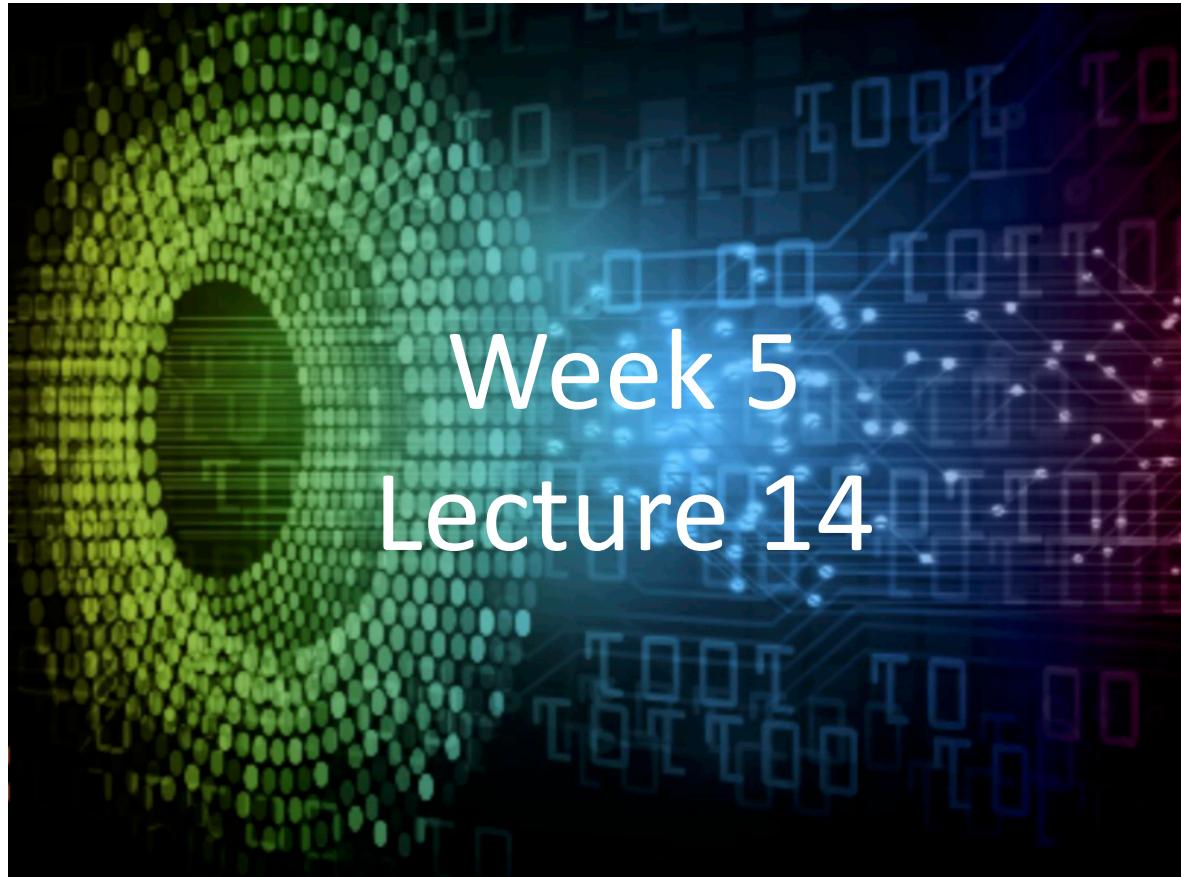


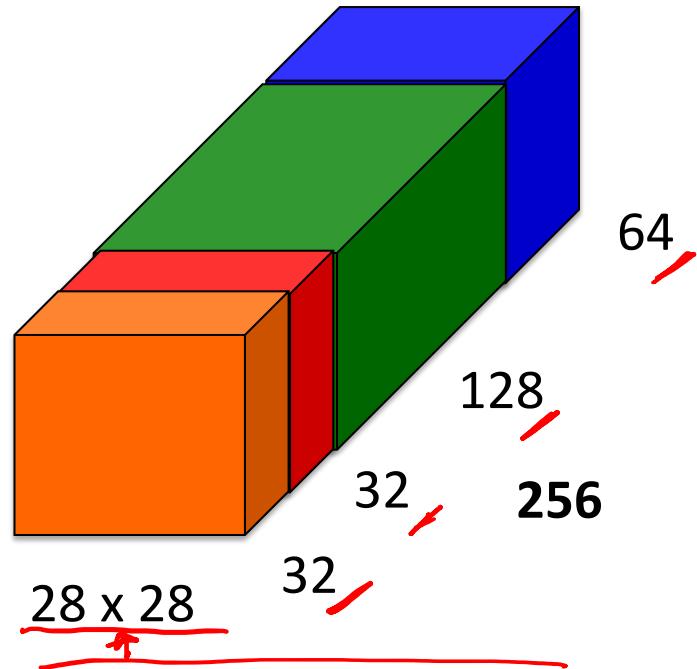
# Introduction to Deep Learning Applications and Theory



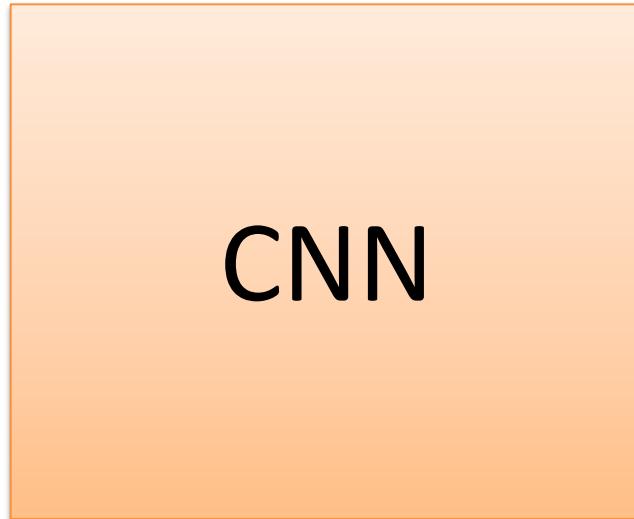
ECE 596 / AMATH 563

# Previous Lecture: Advanced CNNs

- More Layers and Stability
  - Skip connections *ResNet*
  - Residual Blocks
- Multi-Component CNNs
  - Bottleneck Layers *1x1 Conv*
  - InceptionNet
- Beyond Global Classification



# Object Localization



$y = \underline{pc}$ : object?

$bx$

$by$

$bw$

$bh$

$c1$

$c2$

$c3$

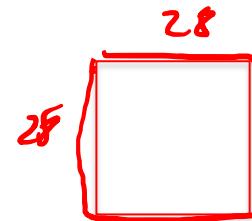
$c4$

$(bx, by)$



$bw$

# Object Detection



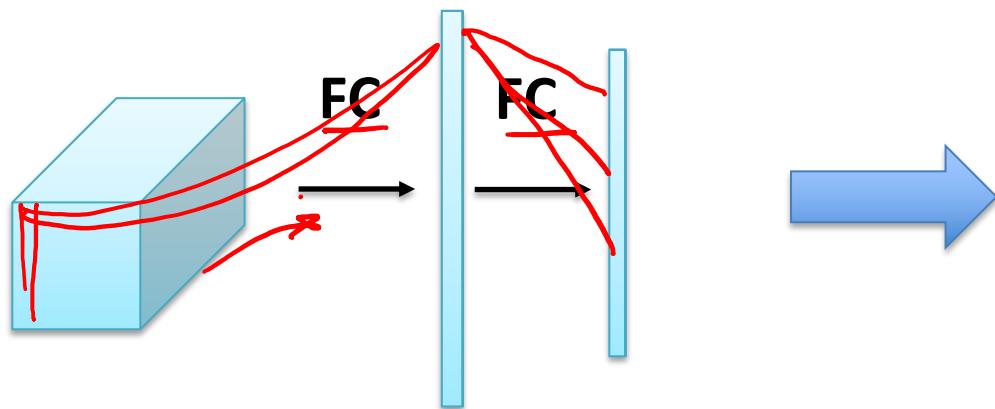
- Sliding window detectors

$$\underline{B \cdot N^2 O(N^2 n^3)}$$



# FC -> CONV

FCONV



5x5x16

400    200

$$\vec{z}^f = \underline{W}^f \cdot \underline{\alpha}^{f1} + \vec{b}^f$$

FCONV

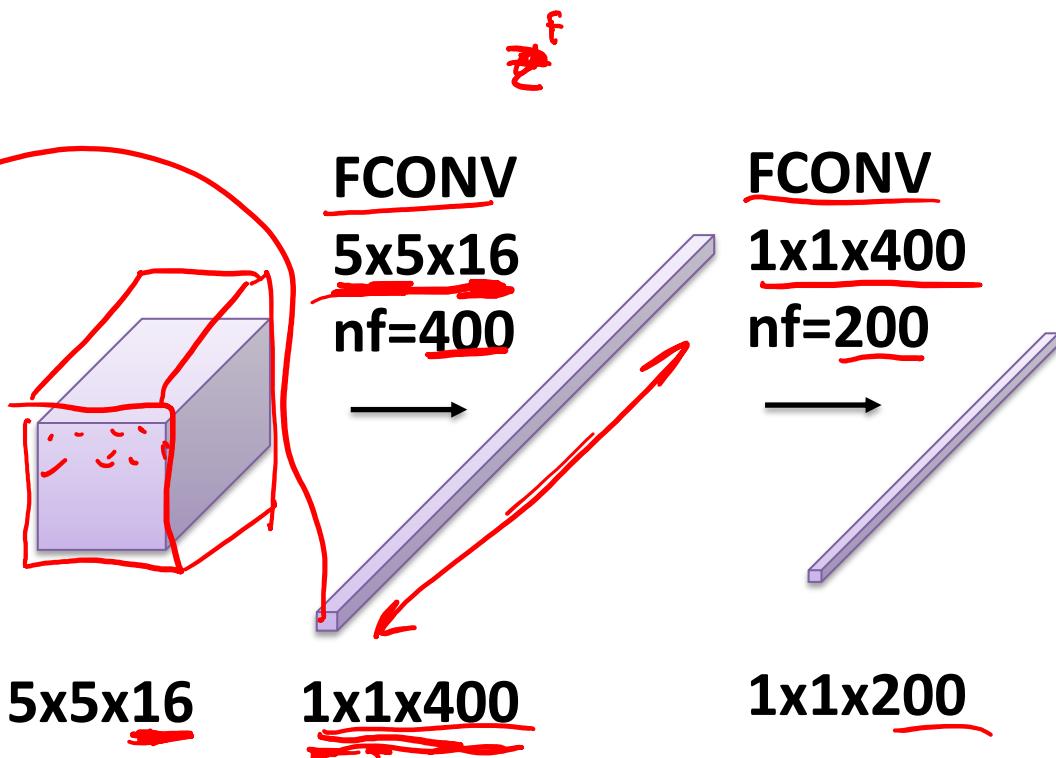
5x5x16

nf=400

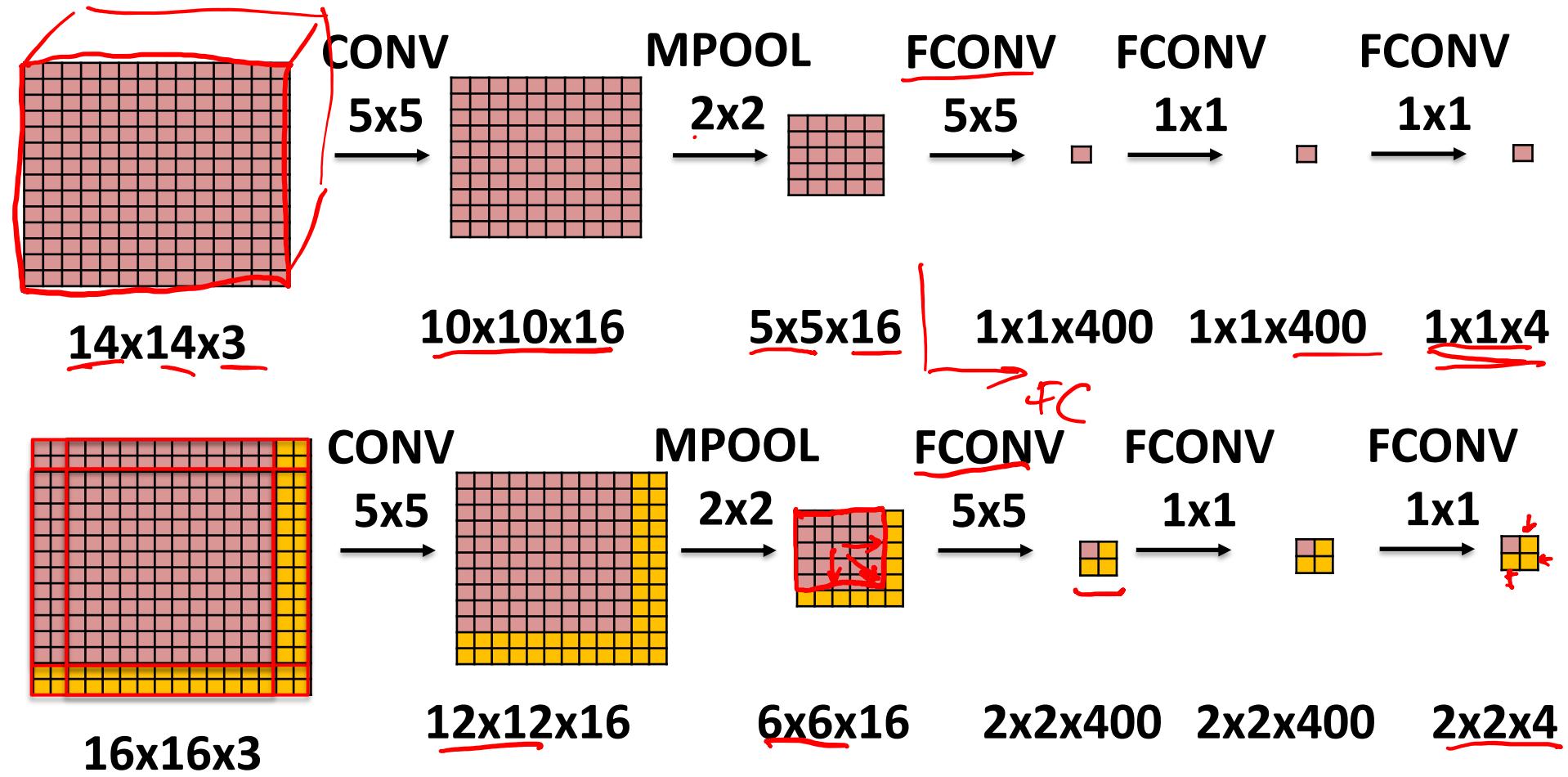
FCONV

1x1x400

nf=200

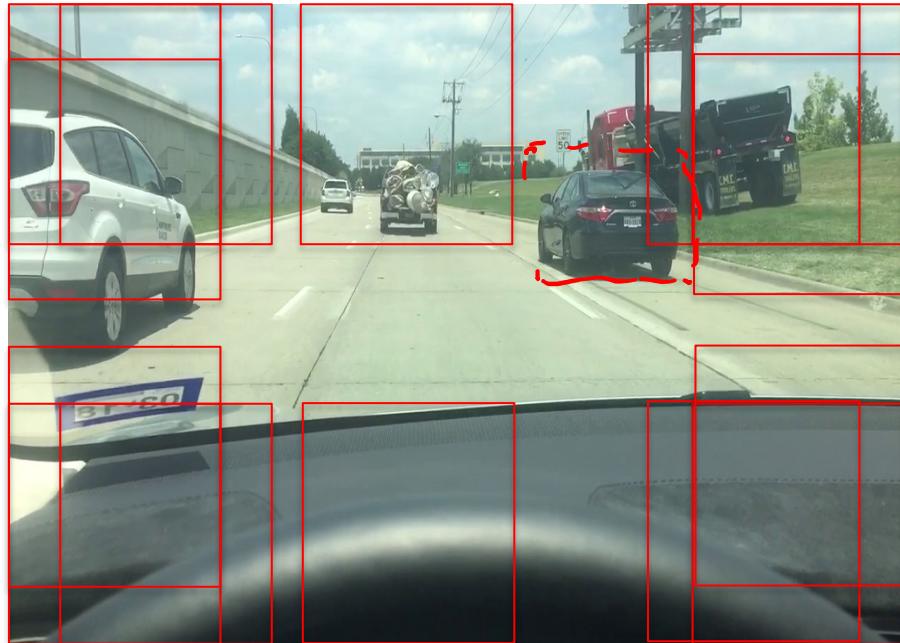


# Convolutional Sliding Windows



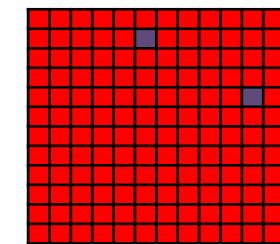
Overfeat: Integrated recognition, localization and detection using convolutional networks.  
Sermanet, P., Eigen, D., Zhang, X., Mathieu, M., Fergus, R., & LeCun, Y. (2013).

# OverFeat



100x100x3

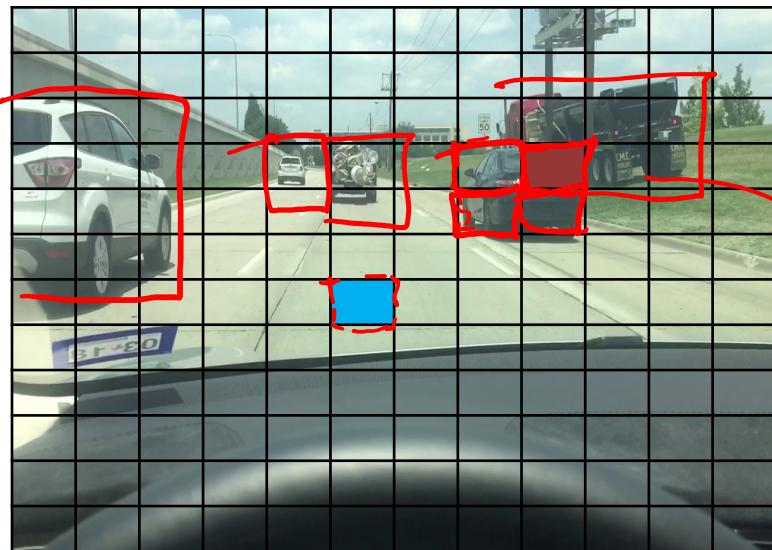
OverFeat



50x50x1

# YOLO – You Only Look Once

## Detection: Classification with Grids



100x100x3

CNN →

19x19x5

100

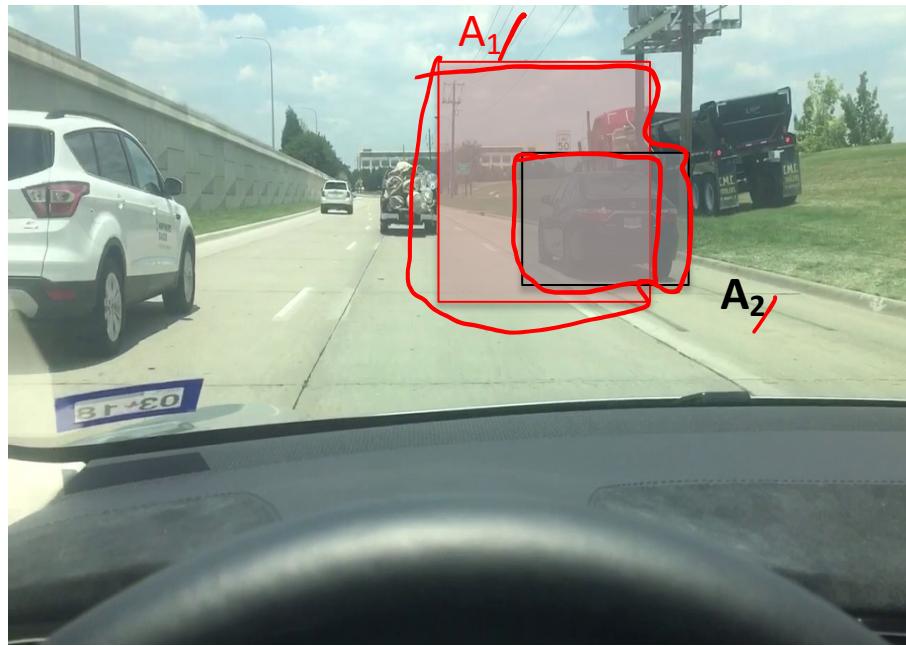
Per each grid cell

y =	pc
	bx
	by
	bw
	bh

0.6
0.1
0.9
2
2

0.1
-
-
-
-

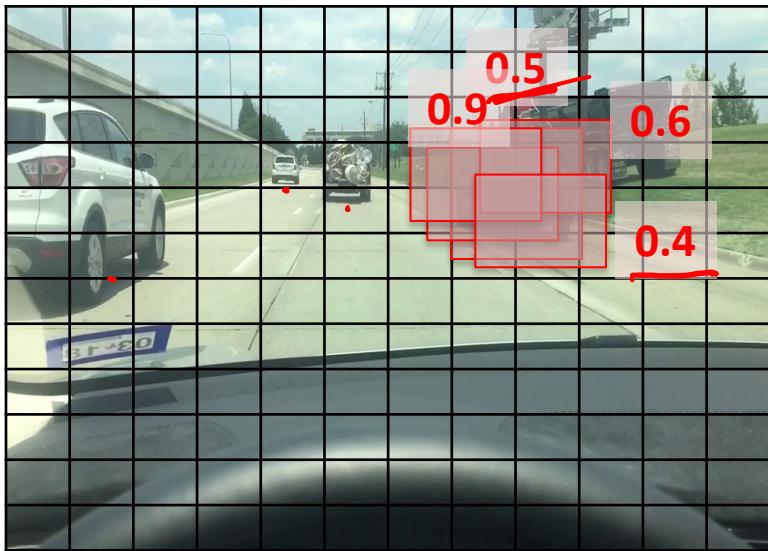
# Intersection Over Union (IoU)



$$\text{IoU} = \frac{A_1 \cap A_2}{A_1 \cup A_2}$$

$\geq 0.5$

# Non-max Suppression



- Discard all boxes with  $\underline{pc} < \underline{pthresh} (0.6)$

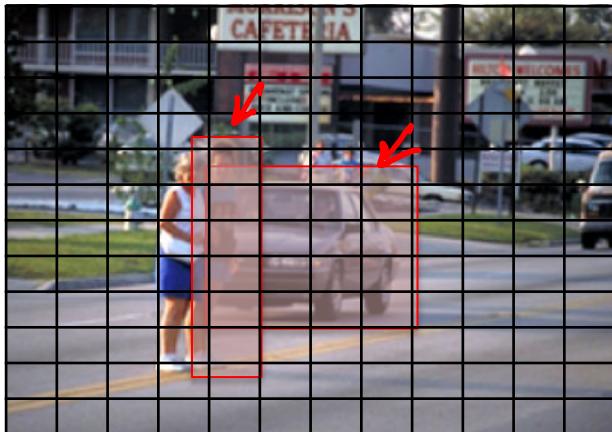
While boxes remained:

- pick the box with largest pc
- discard any box with  $IoU > Itresh$

b

# YOLO – You Only Look Once

Multi-object Real Time detection



Anchor boxes

Per each  
grid cell  
 $y =$

<b>pc1</b>
bx
by
bw
bh
c1
c2
<b>pc2</b>
bx
by
bw
bh
c1
c2



Ross Girshick  
Facebook AI



Ali Farhadi  
UW CSE

CNN

100x100x3



19x19x14 + non-max suppression

Redmon, J., Divvala, S., Girshick, R., & Farhadi, A, You only look once: Unified,  
real-time object detection. CVPR 2016

# Summary

- CONV, POOL Fundamental Operations → FC
- Extensions
  - Skip Connections
    - Residual
  - BCONV
    - Inception
  - FCONV

Res Nets