Lecture Notes
PART II

CmpE 258
Spring 2023

March 21 (Tue).

Midterm is scheduled on the 23rd (Thu). 1 hr Exame.
16:30–17:30
Then 15 minutes for prep & Uploading the file.

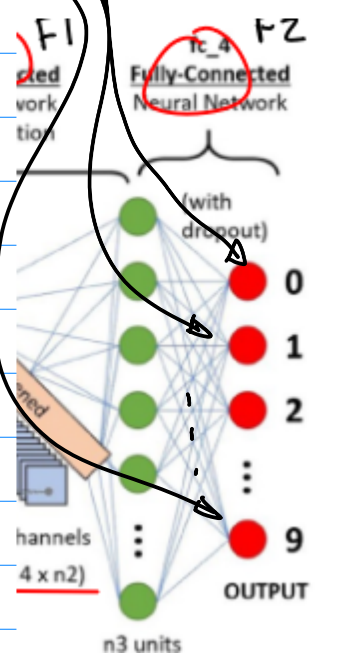
Example: Softmax Activation Function. MNIST CNN

Output from Each Neuron:

$$f(z_1) = \frac{e^{z_1}}{\sum_{j=1}^{10} e^{z_j}} \quad \ldots (4)$$

for Digit "0" (1st Output)

And



Note:

Dimension

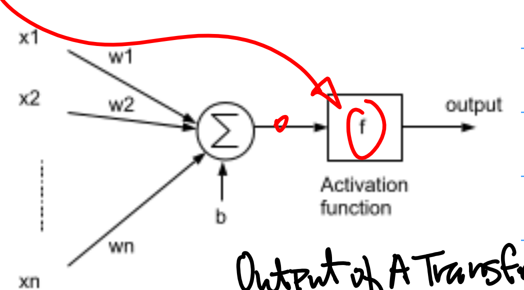
$$\sigma(\mathbf{z})_i = \frac{e^{z_i}}{\sum_{j=1}^{K} e^{z_j}} \quad \text{for } i = 1, \ldots, K \text{ and } \mathbf{z} = (z_1, \ldots, z_K) \in \mathbb{R}^K. \quad \ldots (1)$$

Let K=1

1° $f(z)$ Notation

$$f(z_2) = \frac{e^{z_2}}{\sum_{j=1}^{10} e^{z_j}} \quad \text{for Digit "1" (2nd output)} \quad \ldots (5)$$

⋮



Output of A Transfer function

$$f(z_{10}) = \frac{e^{z_{10}}}{\sum_{j=1}^{10} e^{z_j}} \quad \text{for Digit "9" (10th o/p)}$$

2° Index

$$f(z_i) = \frac{e^{z_i}}{\sum_{j=1}^{K} e^{z_j}} \quad \ldots (2)$$

if Add Eqn (1) + Eqn (2) + ...

$$f(z_1) + f(z_2) + \cdots + f(z_{10})$$

$$= \frac{e^{z_1}}{\sum_{j=1}^{10} e^{z_j}} + \frac{e^{z_2}}{\sum_{j=1}^{10} e^{z_j}} + \cdots\cdots + \frac{e^{z_{10}}}{\sum_{j=1}^{10} e^{z_j}}$$

Total No. of Output Neurons = K
for Hand Written Digits Recognition
K = 10;

where

Property 1.

$$\sum_{j=1}^{K} e^{z_j} = e^{z_1} + e^{z_2} + \cdots + e^{z_K} \geq e^{z_i} \quad \ldots (3)$$

$$= \frac{\sum_{j=1}^{10} e^{z_j}}{\sum_{j=1}^{10} e^{z_j}} = 1. \quad \ldots (6)$$

The softmax function takes as input a vector z of K real numbers, and normalizes it into a probability distribution consisting of K probabilities proportional to the exponentials of

$$f(z_i) = \frac{e^{z_i}}{\sum_{j=1}^{K} e^{z_j}}$$

See Eqn (6).

Now, move to the 2nd Half of DCNN.

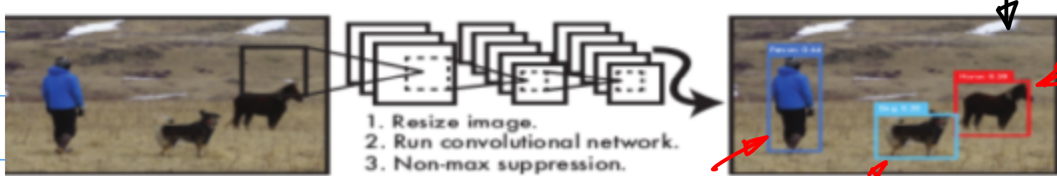
2022F-108a-Yolo-architecture-loss-function-2022-10-10.pdf

Typical Classification/Recognition Results are in Bounding Boxes

://arxiv.org/pdf/1506.02640v5.pdf
h Divvala, Ross Girshick, Ali Farhadi
, Allen Institute for AI ,Facebook AI Research http://pjreddie.com/yolo/

You Only Look Once:
Unified, Real-Time Object Detection

Joseph Redmon, Santosh Divvala, Ross Girshick, Ali Farhadi
University of Washington, Allen Institute for AI, Facebook AI Research
http://pjreddie.com/yolo/



del runs at 45 FPS. A smaller version, Fast YOLO, runs astounding 155
tperforms DPM (deformable parts models) and R-CNN.

Figure 1: The YOLO Detection Sy
image to 448 × 448, (2) runs a co
network, and (3) thresholds the re

Then, we would like to Achieve Semantic Segmentation.

Pixel by pixel Based Segmentation/Detection/Recognition

Part II (After the midterm) → Semantic Segmentation.
April 4 (Tue)
Road map: Yolo (You-Only-Look-ONCE)

{ Project Assignment = Yolo Implementation
Due 2½ weeks. April 20th. (Thursday)

CmpE258

Spring 2023

Homework (In-Class Presentation)

Requirements Due April 6 (Thu).

1° One Paragraph Description (Abstract) of the proposed Semester-Long Project.

2° Title

Team members: First Name, LastName, Major

Team Coordinator.

Contact E-mail.

3° Abstract Part.

Objective(s): a) What is the proposed work;

b) What is the Coding / Training / Testing Task involved in the project?

c) Anticipated Result? And deliverable?

d) Tools, platform, Programming Language Version, T.F., Pytorch, ChatGPT etc.

Also, Define Python Packages, OpenCV.

Example: On Yolo.

Ref:

2022F-106-README-Tiny-Yolo4-GP...

Note 1: Readme for Yolo github 34 ~~Installation & Testing~~ for the project.

Title: README Tiny Yolo v4 GPU Ubuntu

Document Number: 105-1b

CTI One Corporation

Table 1a. Document History

2022-10-6	Establish this document, document archive: (base) harry@workstation:~/yolo-2022-10-19$	YY

1. Setup YOLO v4 environment

1.1. Clone the GitHub folder;

$ git clone https://github.com/pythonlessons/TensorFlow-2.x-YOLOv3.git

1.2. Create YAML file for building the YOLO v4 Anaconda environment;

Create TensorFlow-2.x-YOLOv3/conda-gpu.yml as the following;

==

name: yolov4-gpu

Ref: Introduction

2022F-108a-Yolo-architecture-loss-function-2022-10-10.pdf

Base-Line Ref for Yolo Technique

2022S-112-yolo-paper.pdf

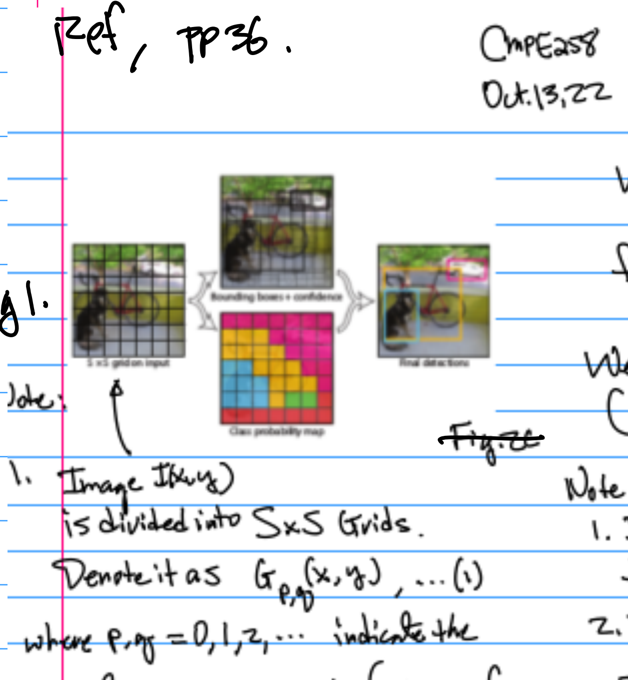
You Only Look Once:
Unified, Real-Time Object Detection

Joseph Redmon*, Santosh Divvala*†, Ross Girshick¶, Ali Farhadi*†
University of Washington*, Allen Institute for AI†, Facebook AI Research¶
http://pjreddie.com/yolo/

Lecture Notes: Base Line Ref / Requirements.

2022F-101-cmpe258-note-2022-11-1.pdf

Example: Notations for YoLo.


Ref, PP36.

CmpE258
Oct.13,22

Fig 1.

Note:

~~Fig.2e~~

1. Image I(x,y) is divided into S×S Grids.
Denote it as $G_{p,q}(x,y)$, ... (1)
where p, q = 0, 1, 2, ... indicate the

1) Image $I(x,y)$. with Resolution

M × N

No. of col. No. of Rows.

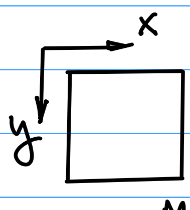


Fig.1b.

Divide $I(x,y)$ into S×S Grids.

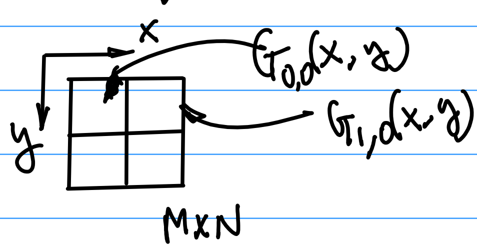
Each Grid is Denoted as

$$G_{pq}(x,y) \quad \ldots (1)$$

matches to x

where $p, q = 0, 1, 2, \ldots, S-1$

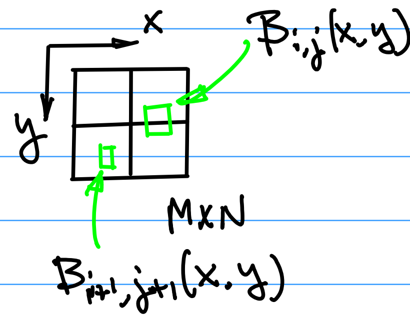
Fig 1c



2. Bounding Boxes $B_{ij}(x,y)$ ... (2)

i for x-direction; j for y-direction

Fig 1a



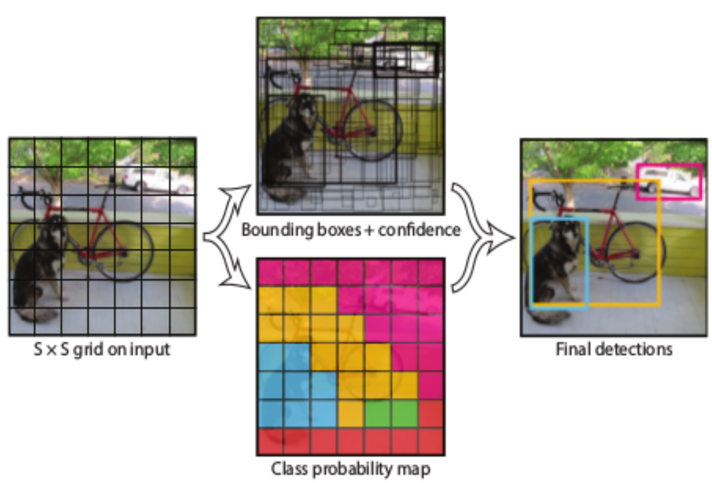
3. Five Parameters to define each Bounding Box.

(x, y) : Location of the top Left Corner of $B_{ij}(x,y)$

w, h : Width and Height of $B_{ij}(x,y)$

f : Confidency Level, Probability distribution to Describe the likelihood of the B.B (B^2) belongs to a certain Class of objects.

$$(x, y, w, h, f) \quad \ldots (3)$$



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Spring 2023

Note 1. a. (Grid) Gpq(x,y) Grid.

Figure 2: The Model. Our system models detection as a regression problem. It divides the image into an $S \times S$ grid and for each grid cell predicts B bounding boxes, confidence for those boxes, and C class probabilities. These predictions are encoded as an $S \times S \times (B * 5 + C)$ tensor.

b. $B_{ij}(x,y)$

Class probability.

Probability

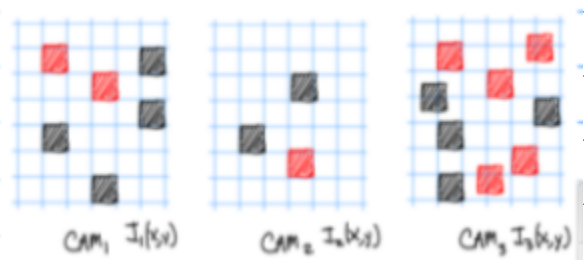
Confidency.

c. (x, y, w, h, f)

April 13 (Th).

Example: Discussion on Notation / Formulation.

Ref: 2022F-101-cmpe258-note-2022-11-1.pdf pp38



Camera 1: $I_1(x,y)$ Camera 2 $I_2(x,y)$ Cam 3. $I_3(x,y)$

$$R = RI_1 + RI_2 + RI_3 \quad \ldots (1)$$

for "Union" " $\cup$ "

R: Red Squares, Persons.
B: (Black) Vehicles.

Intersection. " $\cap$ "

Consider the probability of the event "R" (meaning Person(s) being Capture on any one of these images).

$$Prob(R) = Prob(RI_1) + Prob(RI_2) + Prob(RI_3) \quad \ldots (2)$$

$$I_1 \cap I_2 \cap I_3 = \phi \text{ (Empty set)}$$

Consider Each Individual Camera:

$$Prob(RI_1) = Prob(R/I_1)\, Prob(I_1) \quad \ldots (3a)$$

Similarly,

$$Prob(RI_2) = Prob(R/I_2)\, Prob(I_2) \quad \ldots (3b)$$

$$Prob(RI_3) = Prob(R/I_3)\, Prob(I_3) \quad \ldots (3c)$$

Rewrite Eqn (2):

$$Prob(R) = Prob(R/I_1)\, Prob(I_1) + Prob(R/I_2)\, Prob(I_2) + Prob(R/I_3)\, Prob(I_3) = \sum_{i=1}^{3} Prob(R/I_i)\, Prob(I_i) \quad \ldots (4)$$

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Ref: 2022S-112-yolo-paper.pdf

$$\Pr(\text{Class}_i|\text{Object}) * \Pr(\text{Object}) * \text{IOU}^{\text{truth}}_{\text{pred}} = \Pr(\text{Class}_i) * \text{IOU}^{\text{truth}}_{\text{pred}} \quad (1)$$

Example: pp36

Note 1. Conditional Probability. Prob(C_i)

Prob(C_i|Obj) Prob(Obj)

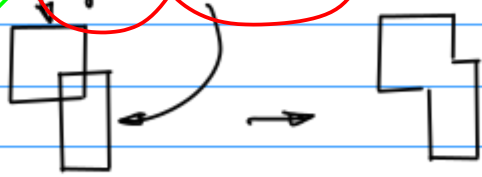
1. IOU (Intersection of Union)

Index for the purpose of Comparing 2 Bounding Boxes at a time

pp.37

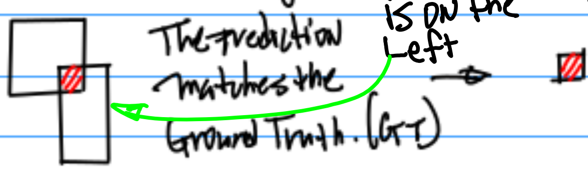
The Union of $B_{ij}(x,y)$ $B_{GT}(x,y)$ ← Note: "GT" Ground Truth.

Note: $B_{ij}(x,y)$ for the i,j B.B.



The Union

The Intersection of $B_{ij}(x,y)$, $B_{GT}(x,y)$ Fig 1



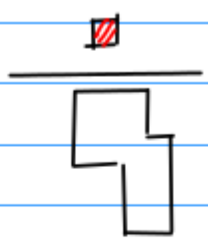
The prediction is on the Left matches the Ground Truth. (GT)

$$\text{IOU} = \frac{\text{Intersection of } B_{ij}(x,y) \text{ and } B_{GT}(x,y)}{\text{The Union of } B_{ij}(x,y) \text{ and } B_{GT}(x,y)}$$

... (5)

pp37

C =



~~... (1)~~

(IOU) Confidence, denoted as

Hand Calculation of IOU.

5. IOU (Intersection of Union).

Example. Illustration of IOU

Fig.3

Sol. First, find the Number of pixels of the $B_{ij}(x,y) \cap B_{GT}(x,y)$,

$B_{ij}(x,y) \cap B_{GT}(x,y) = 1$

then, Find the Union

$B_{ij}(x,y) \cup B_{GT}(x,y) =$
$N[B_{ij}(x,y)] + N[B_{GT}(x,y)]$
$- N[B_{ij}(x,y) \cap B_{GT}(x,y)]$
$= (3 \times 3) + (2 \times 4) - 1 = 9 + 8 - 1$
$= 17 - 1 = 16$

$\therefore$ IOU $= 1/16$

Now, from Eq (1) of the Ref. (Research Paper)

Note

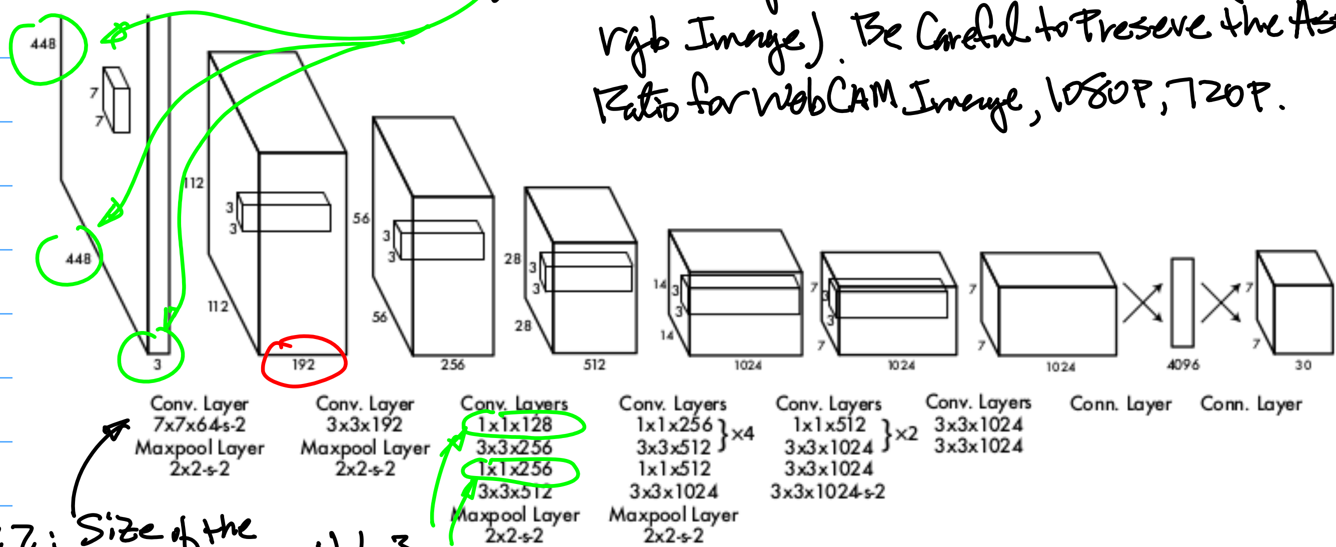
$$\Pr(\text{Class}_i|\text{Object}) * \Pr(\text{Object}) * \text{IOU}^{\text{truth}}_{\text{pred}} = \Pr(\text{Class}_i) * \text{IOU}^{\text{truth}}_{\text{pred}} \quad (1)$$

IOU truth ← "G.T." B.B.
IOU pred ← Predicted B.B.

YOLO

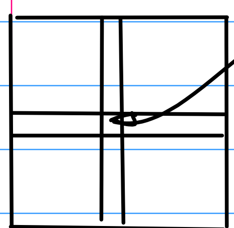
Example: Architecture :

Note 1. Input Image Resolution: 448x448x3 (Channels: rgb Image). Be Careful to Preserve the Aspect Ratio for WebCAM Image, 1080P, 720P.



Note 2: Size of the Kernel: 7x7, 64 of them.

Note 3. 1x1 Convolution is utilized here



Center of the KxK Kernel

KxK

Fig. 1

for KxK 2D Convolution, the output of the convolution. "Spatial Information", Neighbouring pixels under the KxK Kernel are Counted for (for feature extraction @ the Center of the Kernel)

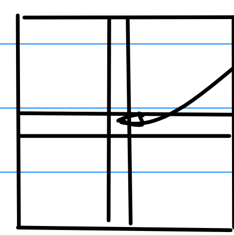
April 11 (Tue).

Presentation (Brief) on Each Team Project.

Example: Continuation on Math Formulation.

1x1 Convolution.

Note 1. Background on KxK Convolution.



Center of the KxK Kernel

KxK

Fig. 1

Output: 1 pixel

Input: KxK pixels.

Captures All Neighbouring Pixels at a time, And Produce One pixel Output.

Note 2. for each convolution kernel, the Convolution Conducted will result in One Output Feature Layer

/ 2022F-108a-Yolo-architecture-loss-function-

As we continue the Convolution Process, the Number of Output feature Layers will grow Significantly. Therefore, there's a need to Reduce the Number of Layers without missing crucial features.

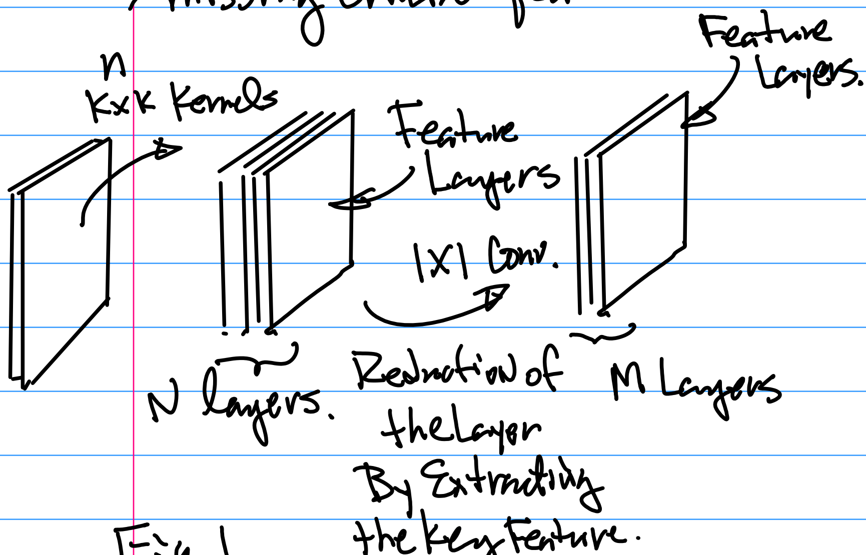
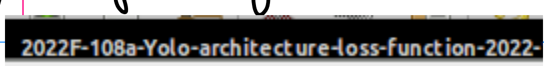


Fig. 1.

To Be Able to Extract/Preserve the Key features to Achieve Reduction of Layers. We are using the following Technique.



CMPE258
Spring 2023

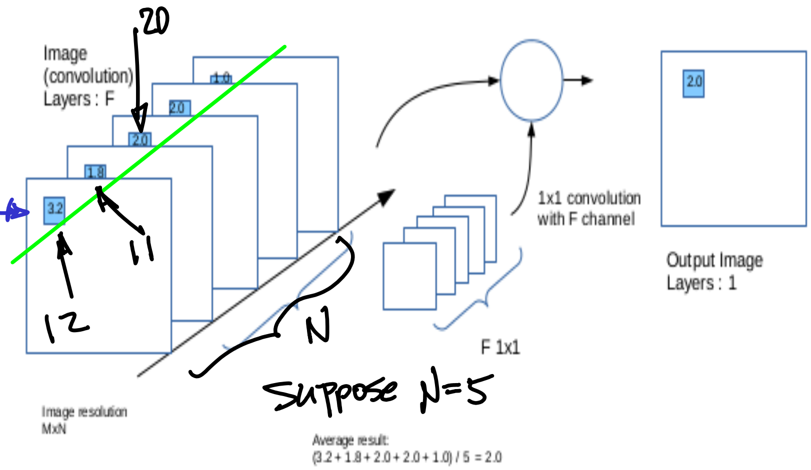
1x1 Convolution for Dimension Reduction and Pooling

The 1x1 convolution enables dimension reduction by reducing the number of channels in convolution layers

1. Suppose the input layers is C*H*W, where C is its channels. The 1x1 convolution generates one average result in shape H*W. The 1x1 (filter) is a vector of length C.
2. Now if you have F 1x1 filters, you get F layers of output, the output shape is F*H*W. For input layer C*H*W with F 1x1 convolution (with channel is C), you will get F*H*W layers.

Note 1.

One pixel across the entire stack of the feature layer.



Harry Li, Ph.D.

Reduction Requirement: Combine 5 (N=5) layers into 1 layer. To preserve the feature in this process. What is the technique

Question: To combine them (pixels at different layers) with equal contribution from Each layer?

$$\frac{1}{N}\left[I_1(x_1,y_1)+I_2(x_1,y_1)+\cdots+I_5(x_1,y_1)\right] \quad \cdots (1)$$

$$\frac{1}{N}I_1(x_1,y_1)+\frac{1}{N}I_2(x_1,y_1)+\cdots+\frac{1}{N}I_5(x_1,y_1)$$

April 12 (Th).

Example: 1x1 Convolution.

2022F-108a-Yolo-architecture-loss-function-2022-10-10.pdf

N=5

Average result:
(3.2 + 1.8 + 2.0 + 2.0 + 1.0) / 5 = 2.0

Pixel from Layer1

Pixel from Layer2

pixel from Layer N.

Note: The Average operation treats the feature Equally from Each Layer.

More General Case:

$$\alpha_1 I_1(x_i,y_i)+\alpha_2 I_2(x_i,y_i)+\cdots+\alpha_N I_N(x_i,y_i)$$

where $\alpha_1+\alpha_2+\cdots+\alpha_N=1 \quad \cdots (2)$

CMPE258
Spring 2023

Note: Project Assignment (10 pts)
on Object Recognition.
Due April 30th (Sunday, 11:59 pm).

CMPE258
YOLACT Semantic Segmentation and Comparison with YOLO
HL

PART I YOLO (5 points)

test run YOLO v4 based on the readme document given in the class githu

).com/hualili/opencv/blob/master/deep-learning-2022s/2022F-106-READ!
ı-YY-HL-v2-2022-10-20.pdf

nart phone to take record a 15 - 30 second video clip for YOLO v4 object

Note: To Config Anaconda Environment,
use the Pre-Created Configuration
files here, from the github

- 2022S-104b-conda-gpu.yml
- 2022S-104c-conda-cpu.yml

Then, Create conda environment → Next, Activate the conda Env.
config. file

$ conda env create -f conda-gpu.yml

$ conda activate yolo4-gpu

Then, perform the following task

1.5. Download Tiny YOLO v4 model files;

$ wget -P model_data
https://github.com/AlexeyAB/darknet/

1.6. Modify the configuration file, TensorFlow-2.x-YOLOv3/yolov3/configs.py;

==

13 YOLO_TYPE = "yolov4" # yolov4 or yolov3

37 TRAIN_YOLO_TINY = True

==

Now, To Run the Yolo Program.

The Env.

(1) 2.1. Activate the Anaconda environment

conda activate yolo4-gpu

(2) 2.2. Execute the demo program;

$ python detection_demo.py

Make the following modification to Run Yolo for the Video file Input. Need to modify the python Code,

3. Execute Tiny YOLO v4 with a video file

3.1. Modify TensorFlow-2.x-YOLOv3/detection_demo.py

Make Change by Replacing Image file input (Line 23) by Video file input (Line 24).

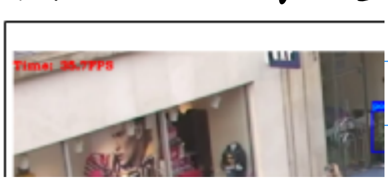
Then, Repeat the Same steps as you did for Yolo Execution with image input.

Note: Execution Speed,

$ python detection_demo.py

FPS is around 35 on RTX 2070.

FPS: Frames Per Second.



Be Sure to Record Video Clip(s) yourself for Yolo Testing, you Need to use these Videos in the future.

Example: Yolo Architecture.

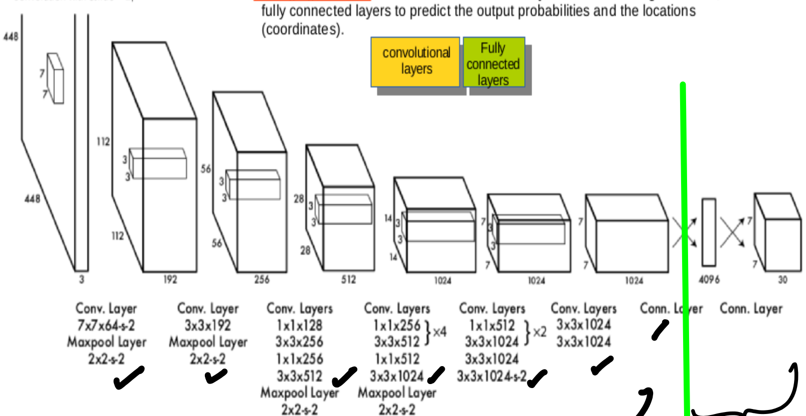
Note: 1° Understand the Composition of the Yolo Architecture. To Be Able to Describe the function(s) of Each Block;

2° Analyze the Parameter(s) of Each Block.

1. Input image size: 448x448x3; 2. Resolution reduction for feature extraction/abstraction Pooling and convolution with stride = 2;

Base Line Yolo Architecture

Design guideline: The block of convolutional layers to extract image features, the fully connected layers to predict the output probabilities and the locations (coordinates).



For Feature Extraction Convolutional Operations. Like/Similar to the Creation of high Dimensional feature Vectors.

$X(x_1, x_2, \cdots, x_n)$

For Classification

Note: Image/Video Input Should be Square with preservation of the Original Aspect Ratio.

1. Input image size: 448x448x3; 2. Resolution reduction for feature extraction/abstraction Pooling and convolution with stride = 2;

CMPE258

Spring 2023

Stride = 1 Convolution.

"default" Version of Convolution.

Shift/move the Mask from Top left Corner Left to Right ONE pixel at a time, And Top to Bottom ONE Row at a time.

Stride = 2.

Shift/move the mask from Top left Corner Left to Right 2 pixel at a time, And Top to Bottom 2 Row at a time.

Example/Exercise Off-Line

Sub-Sampling + Convolution $\rightarrow$ Reduction of feature Layers

Group II Classes

April 18 (Tue)

Group II classes are those classes which meet TR, T, R, TWR, MTR, TRF, MTRF, MTWR, TWRF, RF, TF, TRS.

Regular Class Start Times	Final Examination Days	Final Examination Times
7:00 through 8:25 AM	Monday, May 22	7:15-9:30 AM
8:30 through 9:25 AM	Wednesday, May 17	7:15-9:30 AM
9:30 through 10:25 AM	Friday, May 19	9:45 AM-12:00 PM
10:30 through 11:25 AM	Tuesday, May 23	9:45 AM-12:00 PM
11:30 AM through 12:25 PM	Thursday, May 18	9:45 AM-12:00 PM
12:30 through 1:25 PM	Monday, May 22	12:15-2:30 PM
1:30 through 2:25 PM	Wednesday, May 17	12:15-2:30 PM
2:30 through 3:25 PM	Friday, May 19	2:45-5:00 PM
3:30 through 4:25 PM*	Tuesday, May 23	2:45-5:00 PM
4:30* through 5:25 PM*	Thursday, May 18	2:45-5:00 PM

1. Final Exam: May 18th

2. Presentation — Review

9th Tue | 11th Thu | 15th (Monday) Last Day | 18th (Th)

First 25 Names on the CMPE258

Example: $1\times1\times K$ Convolution

2022S-101-note-part2-cmpe258-2022-05-3.pdf

github.

Given 3 Feature Layers

$$\begin{bmatrix} 1 & 1 & 3 \\ 2 & 0 & -5 \\ 1 & 1 & 0 \end{bmatrix} \quad \begin{bmatrix} 2 & 0 & -1 \\ 1 & 0 & 2 \\ 0 & 0 & 1 \end{bmatrix} \quad \begin{bmatrix} 2 & 3 & 2 \\ 1 & 0 & 2 \\ 6 & 0 & 1 \end{bmatrix}$$

$F_1(x,y)$ $F_2(x,y)$ $F_3(x,y)$

3x3

3

1x1

Fig. 1a

$\downarrow$ Computation.

For Step 1. PP. 52

$$\begin{bmatrix} 1 & 1 & 3 \\ 2 & 0 & -5 \\ 1 & 1 & 0 \end{bmatrix} \quad \begin{bmatrix} 2 & 0 & -1 \\ 1 & 0 & 2 \\ 0 & 0 & 1 \end{bmatrix} \quad \begin{bmatrix} 2 & 3 & 2 \\ 1 & 0 & 2 \\ 6 & 0 & 1 \end{bmatrix}$$

Fig 1b

$$1*C_1 + 2*C_2 + 2*C_3 = \frac{1}{3}(1+2+2)$$

$$= 5/3$$

Step 2.

$$\begin{bmatrix} 1 & 1 & 3 \\ 2 & 0 & -5 \\ 1 & 1 & 0 \end{bmatrix} \quad \begin{bmatrix} 2 & 0 & -1 \\ 1 & 0 & 2 \\ 0 & 0 & 1 \end{bmatrix} \quad \begin{bmatrix} 2 & 3 & 2 \\ 1 & 0 & 2 \\ 6 & 0 & 1 \end{bmatrix}$$

$$1*C_1 + 0*C_2 + 3*C_3$$

$$= \frac{1}{3}(1+0+3) = 4/3$$

Fig 1c

CMPE258

Spring 2023

Architecture: 1° 1×1×K Convolution;

2° Stride = 2.

for Both Convolutions & Maxpool

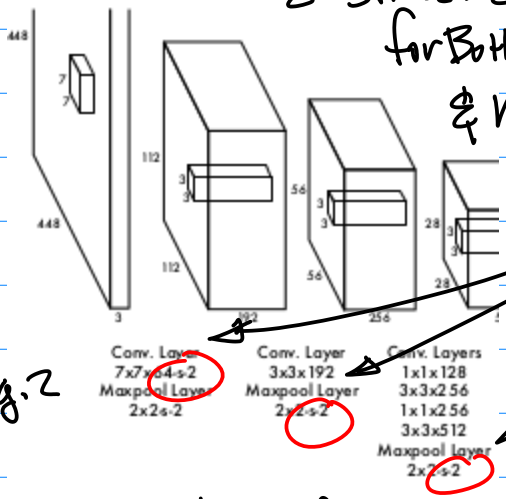


Fig. 2

Sub-Sampling: for the Reduction of Resolution.

Example for Stride = 2, for 1×1×K Convolution

$F_1(x,y)$			$F_2(x,y)$			$F_3(x,y)$		
1	1	3	2	0	-1	2	3	2
2	0	-5	1	0	2	1	0	2
1	1	0	0	0	1	6	0	1

Step 1. (Same as the previous example on pp 43).

Fig. 3a

$C_1*1 + C_2*2 + C_3*2$

$= \frac{1}{3}(1+2+2) = 5/3$

Step 2. Stride = 2

$C_1*3 + C_2*(-1) + C_3*2 = \frac{1}{3}(3-1+2)$

$= 4/3$

$F_1(x,y)$			$F_2(x,y)$			$F_3(x,y)$		
1	1	3	2	0	-1	2	3	2
2	0	-5	1	0	2	1	0	2
1	1	0	0	0	1	6	0	1

Fig. 3b

Next Step:

$C_1*1 + C_2*0 + C_3*6 = \frac{1}{3}(1+0+6) = 7/3$

$F_1(x,y)$			$F_2(x,y)$			$F_3(x,y)$		
1	1	3	2	0	-1	2	3	2
2	0	-5	1	0	2	1	0	2
1	1	0	0	0	1	6	0	1

Example: github. Fig. 3c

2022S-112-yolo-paper.pdf

Consider Class Probability Map.

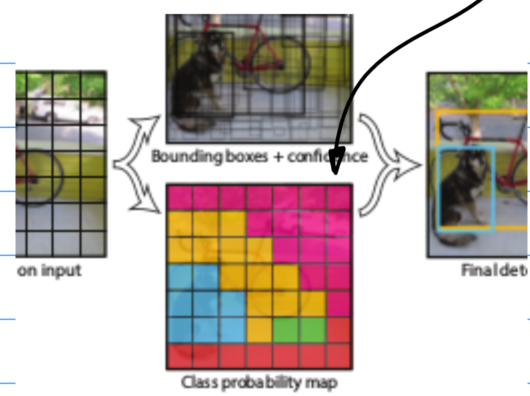


Fig. 4

Probability Distribution over a given image

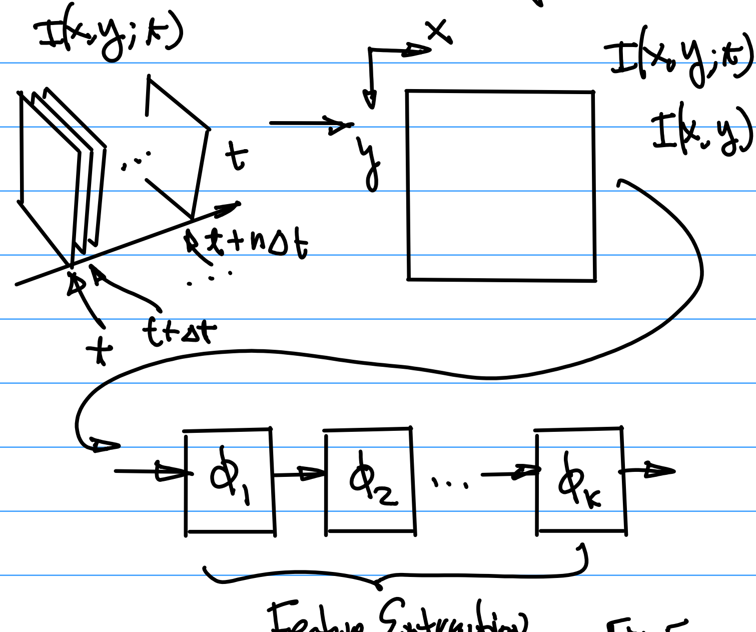


Fig. 5

Feature Vector

$$\underline{X}(\underbrace{x_1, x_2, \cdots, x_M}_{\text{Features}}; (x, y))$$

Pixel Location

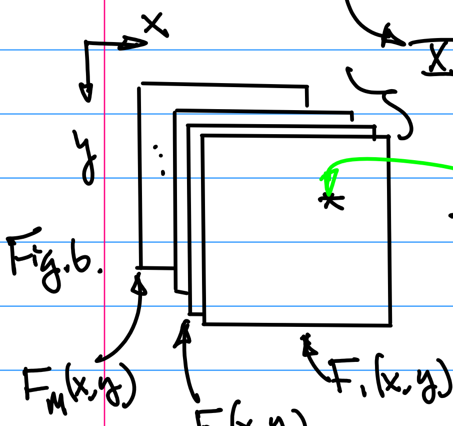


Fig. 6.

Feature Layers.

$$\underline{X}(x_1, x_2, \cdots, x_M; (x, y))$$

$$\downarrow$$

$$\underline{X}(x_1, x_2, \cdots, x_M)$$

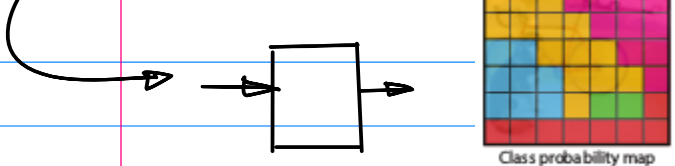


Fig. 7 Classifier

For Further Development, see

2022S-114c-KmeanCluster-v3-2022-4-19.pdf

Example: Activation Function.

"Leaky"

$$\phi(x) = \begin{cases} x, & \text{if } x > 0 \quad \cdots (1a) \\ 0.1x, & \text{otherwise} \quad \cdots (1b) \end{cases}$$