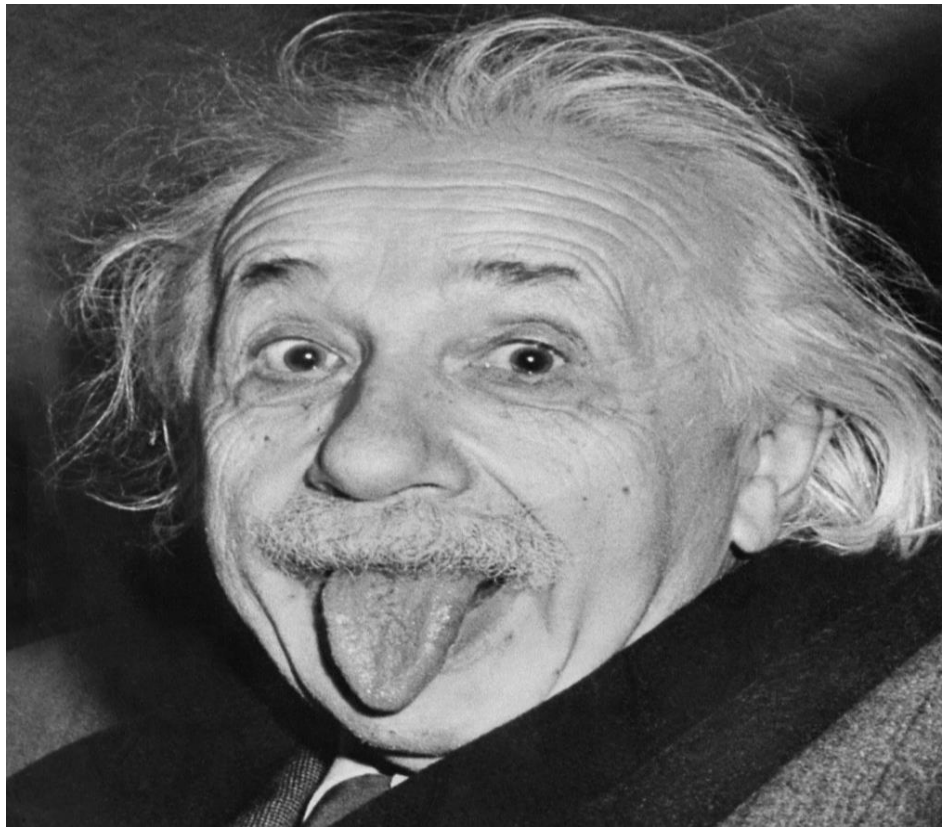
DataLab
Community

TÉCNICAS PARA UN MEJOR COMPUTER VISION

- Dr. Rubén Alvarez

- *"Everything human beings can imagine; nature has already created…"*
  - -Albert Einstein.



WHAT IS COMPUTER VISION?

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- Humans use our eyes and our brains to see and visually perceive the world around us. Computer Vision is the science that aims to provide a similar, if not better, capability to a machine or computer.

COMPUTER VISION

1. Optics and 3D Reconstruction
2. Image Processing
3. Machine Learning in images

COMPUTER VISION

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1. **Optics and 3D Reconstruction**
2. Image Processing
3. Machine Learning in images

OPTICS AND 3D RECONSTRUCTION

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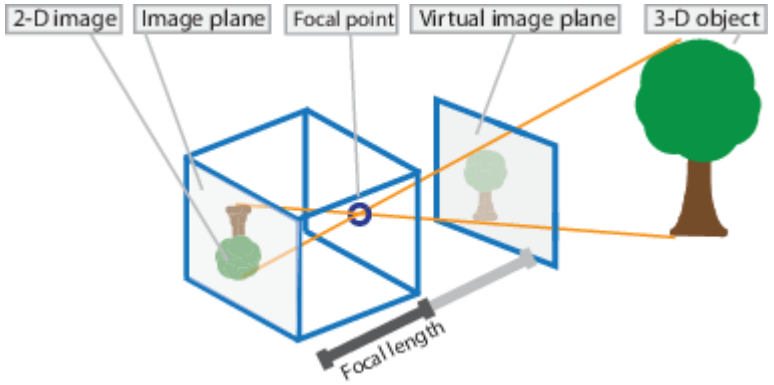

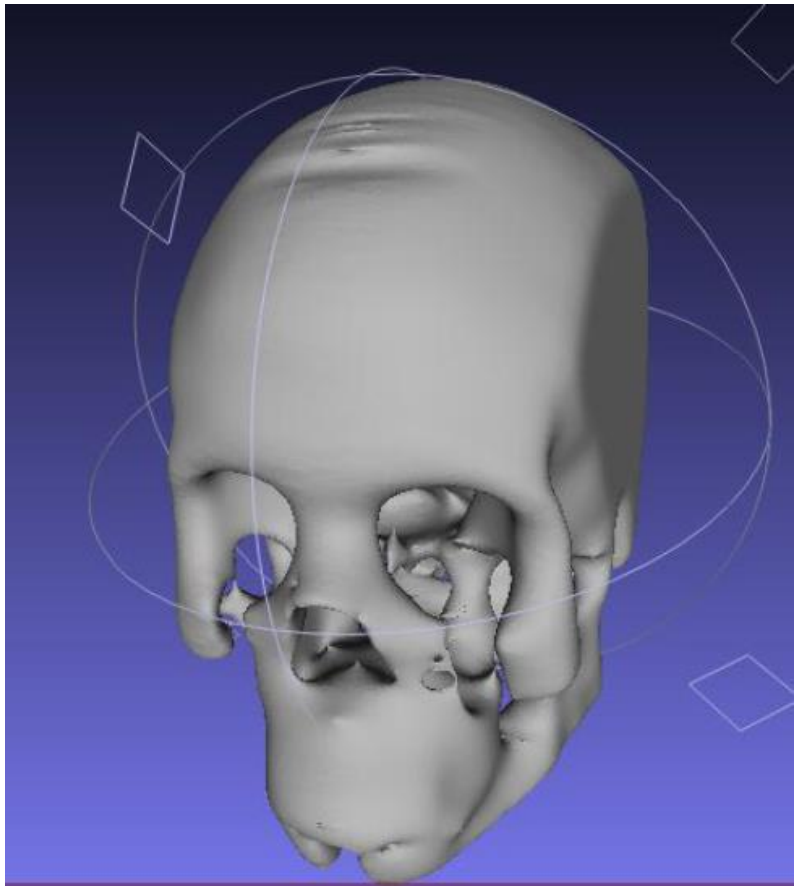

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COMPUTER VISION

3D CLOUD SAMPLES

COMPUTER VISION

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1. Optics and 3D Reconstruction
2. **Image Processing**
3. Machine Learning in images

IMAGE PROCESSING

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COMPUTER VISION

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1. Optics and 3D Reconstruction
2. Image Processing
3. **Machine Learning in images**

OBJECT RECOGNITION

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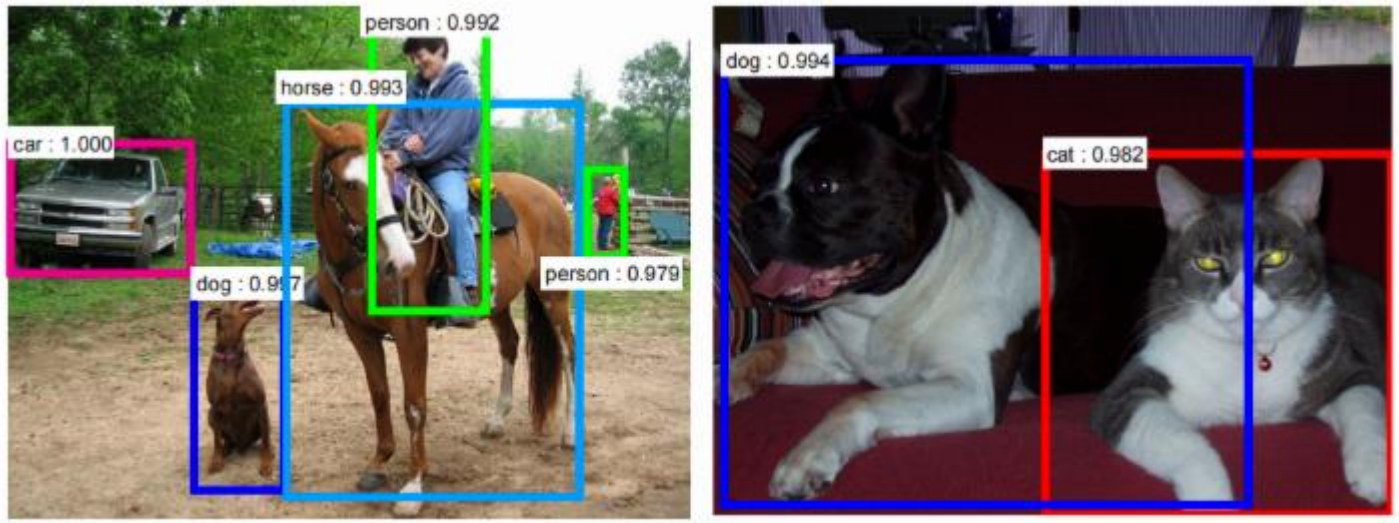

SEGMENTATION

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(c) Semantic segmentation

(d) Instance segmentation

STYLE TRANSFER

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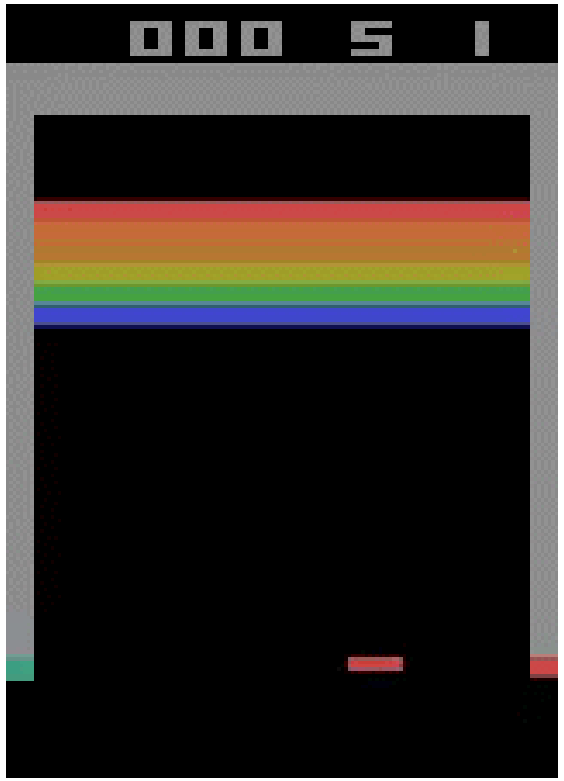
VIDEO GAMES



VIDEO GAMES

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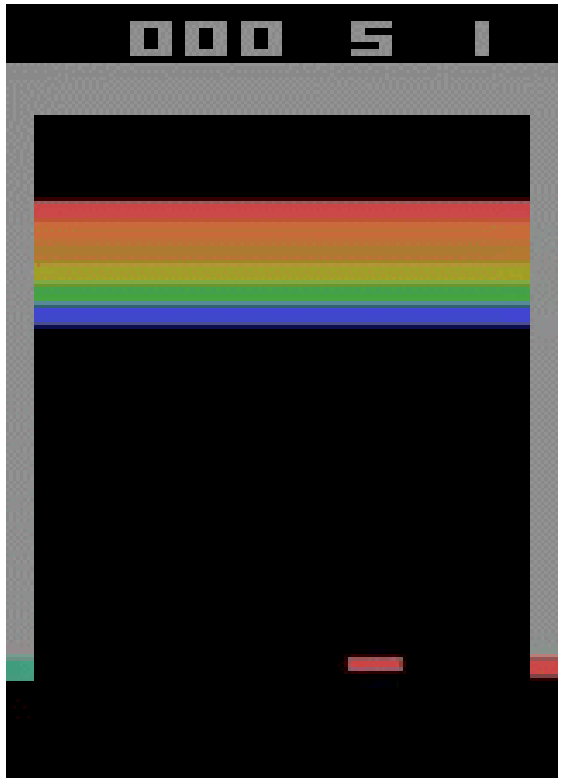

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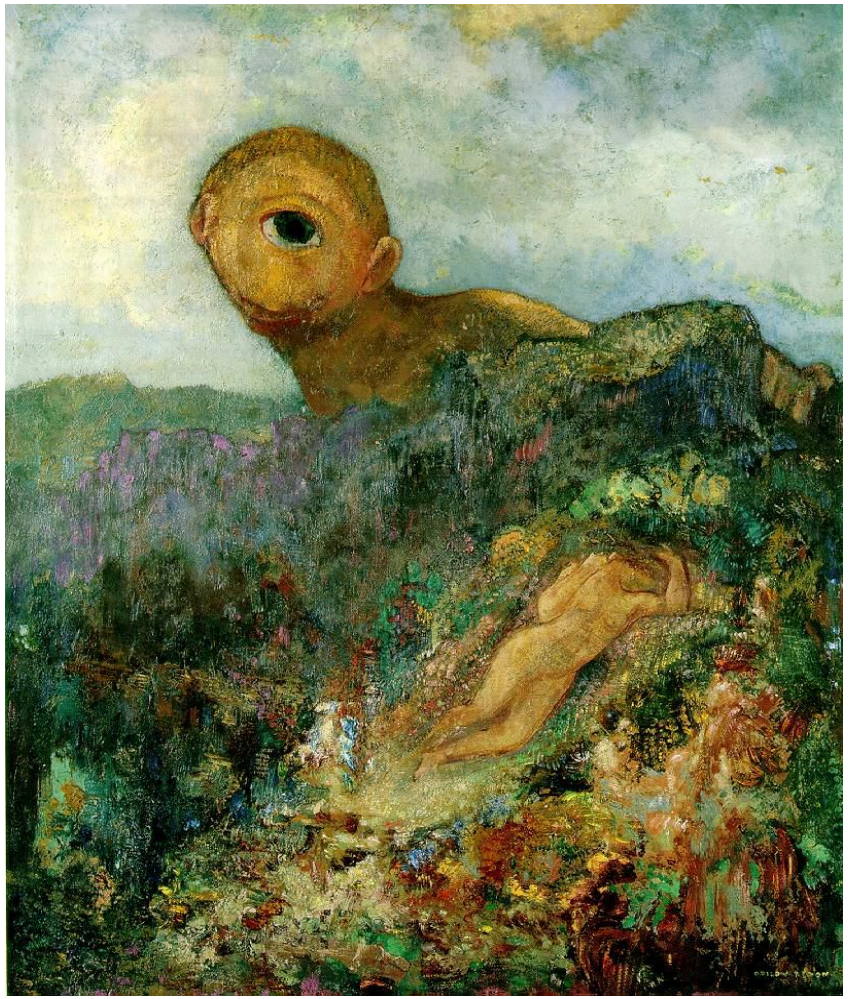
COMPUTER VISION

PERCEPCIÓN 3D

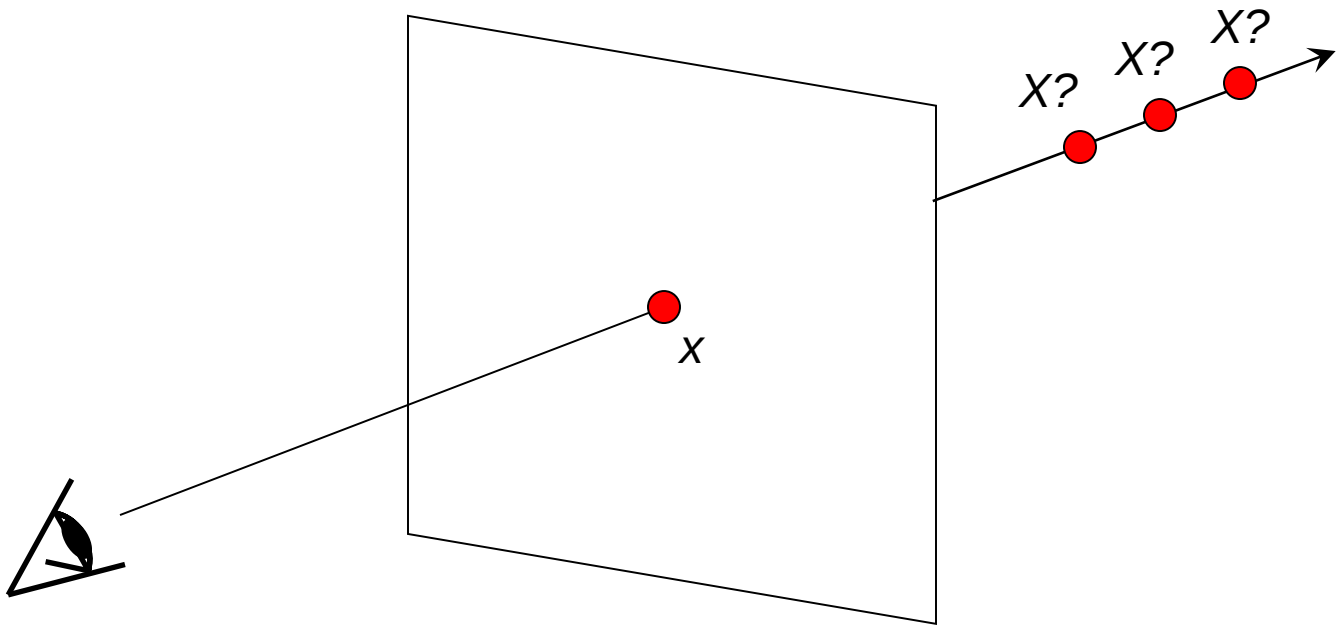
SINGLE-VIEW GEOMETRY



Odilon Redon, *Cyclops*, 1914

OUR GOAL: RECOVERY OF 3D STRUCTURE

- Is recovering the structure of an image unambiguous?



OUR GOAL: RECOVERY OF 3D STRUCTURE

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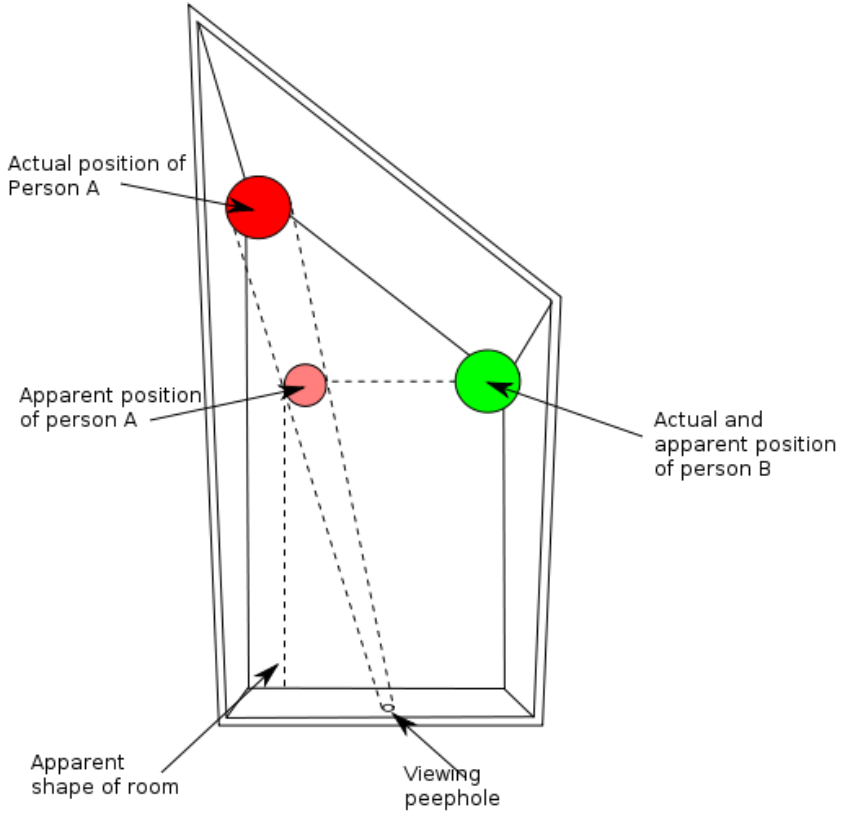
- What about perspective?

AMES ROOM


Actual position of
Person A
Apparent position
of person A
Actual and
apparent position
of person B
Apparent
shape of room
Viewing
peephole

AMES ROOM

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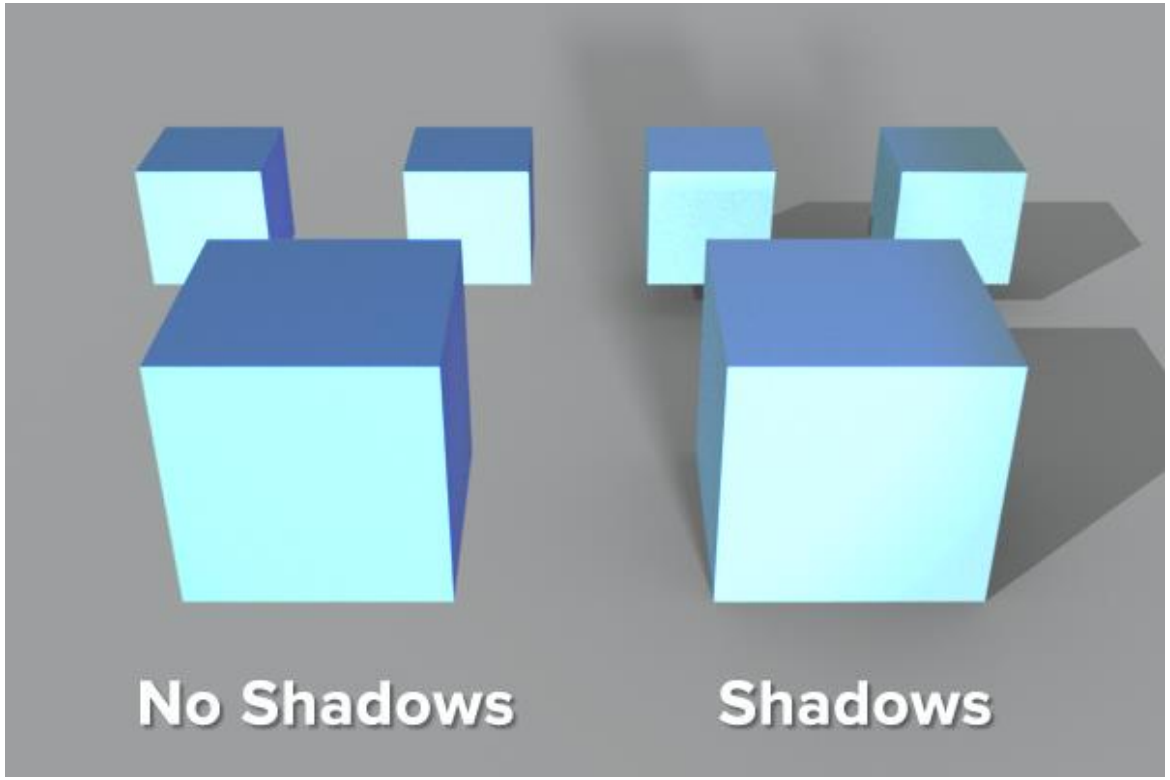
VIRTUAL REALITY LIGHTING



RAY TRACING

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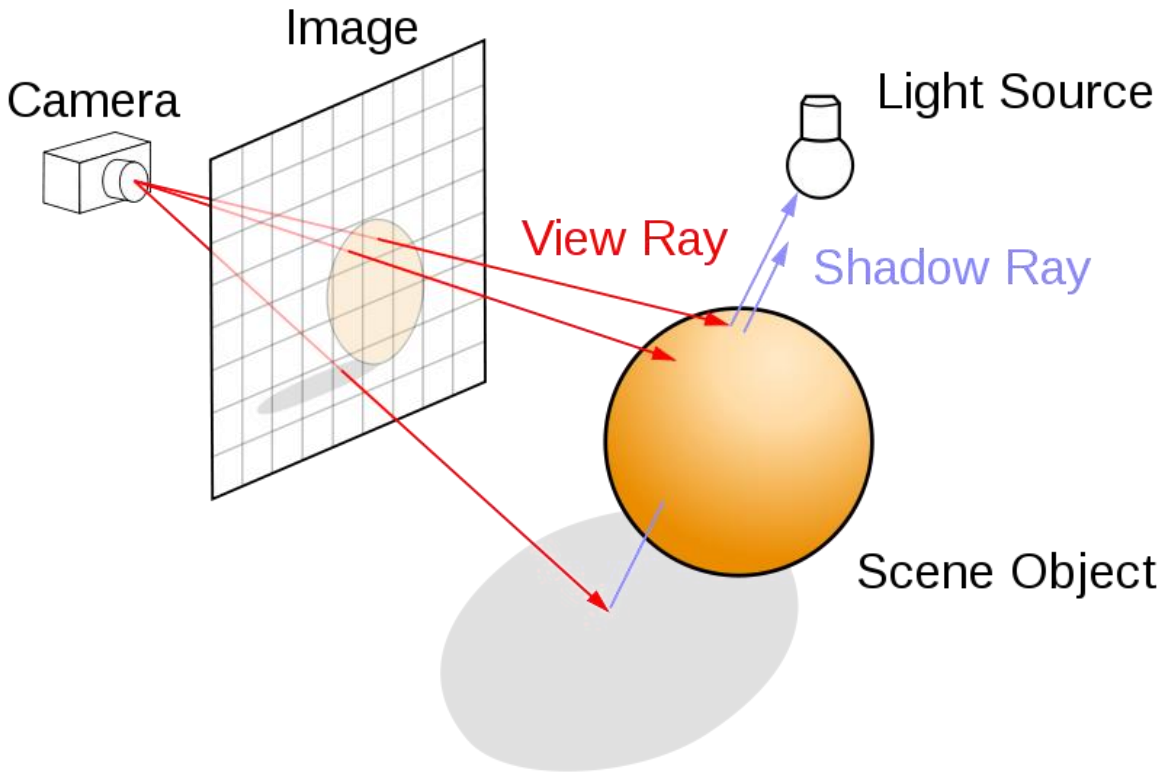

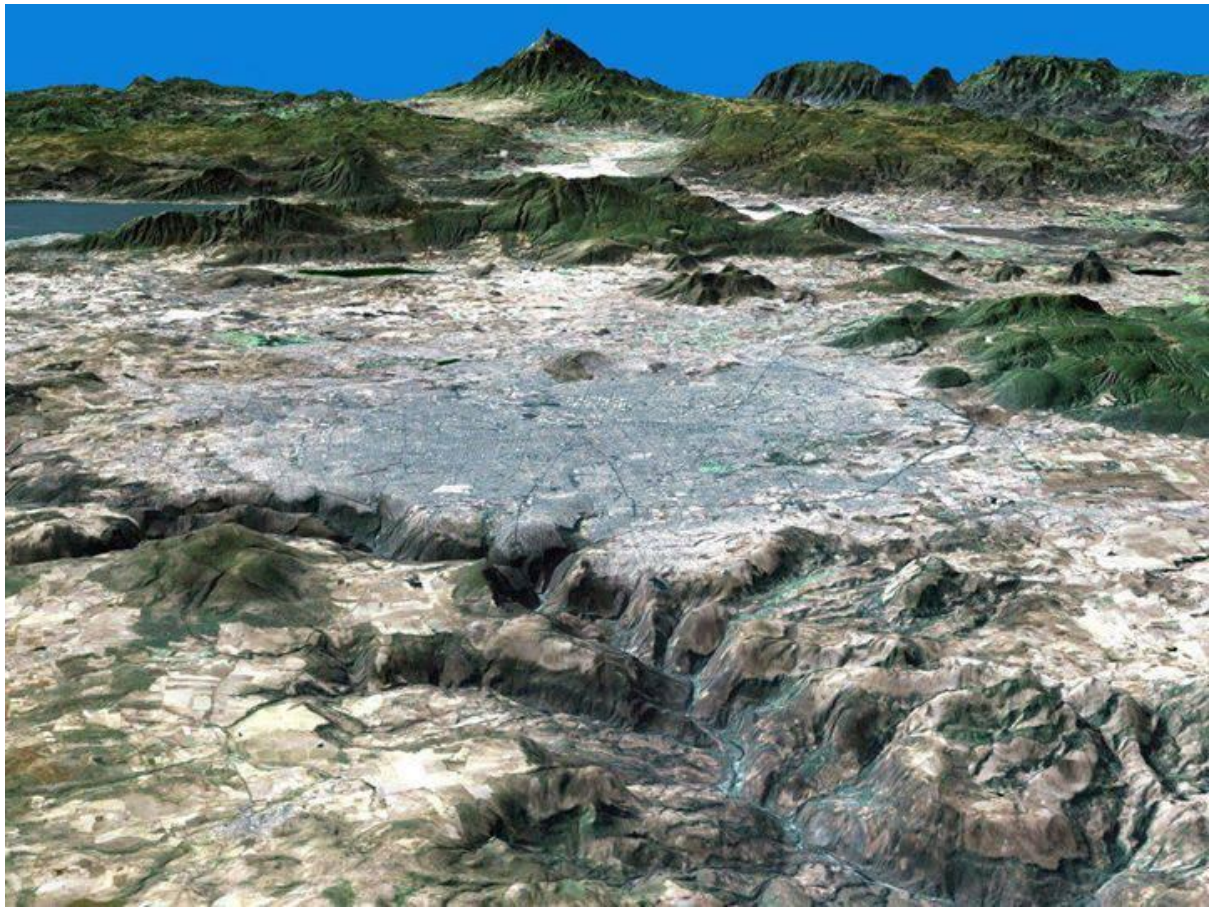

WHAT IF WE JUST WORK WITH THE CENTER OF THE LENS?

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MOVE INFORMATION FROM 3D TO 2D

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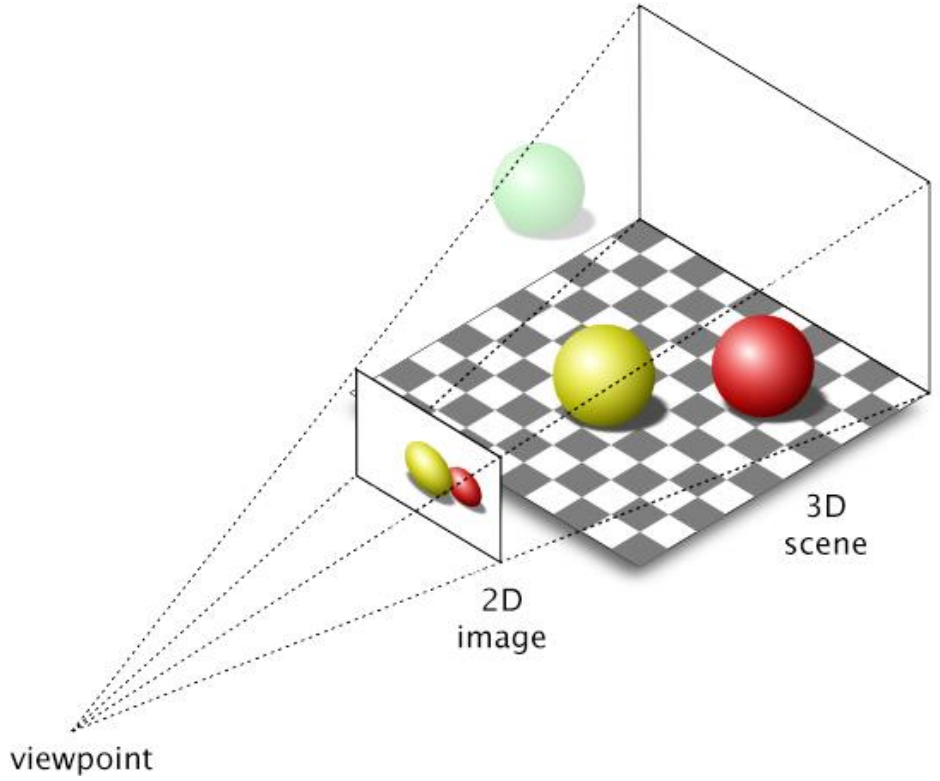
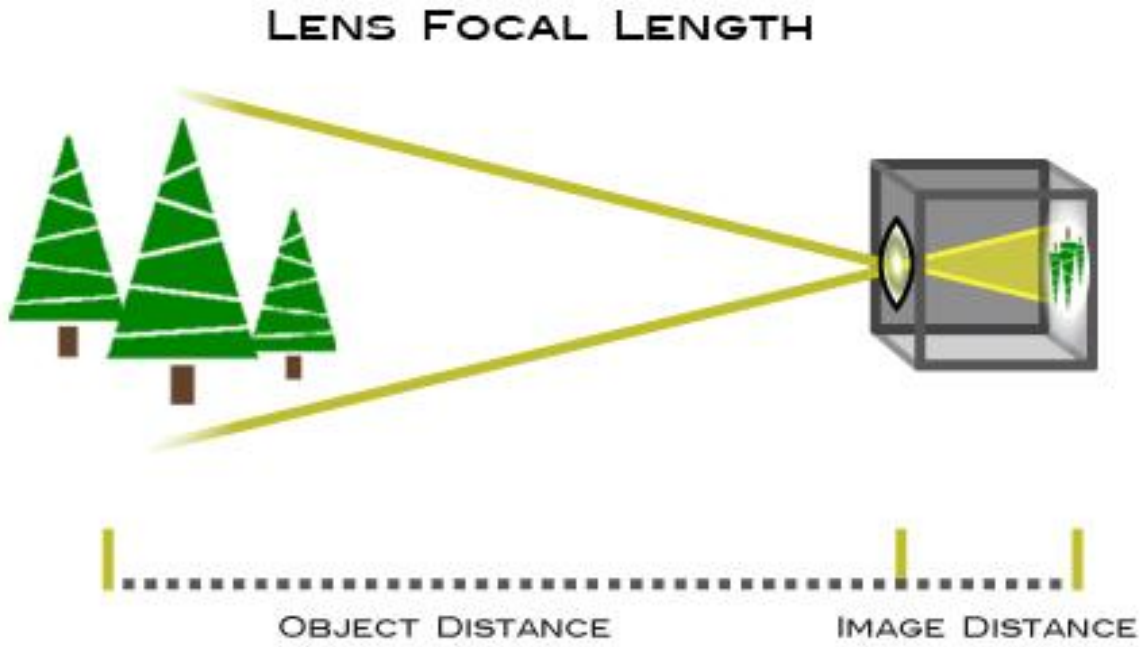


DOES OPENNESS MATTER?

- In the case of the above drawing, is it important to enter the dimensions of that opening where the light enters the box?



DOES OPENNESS MATTER?

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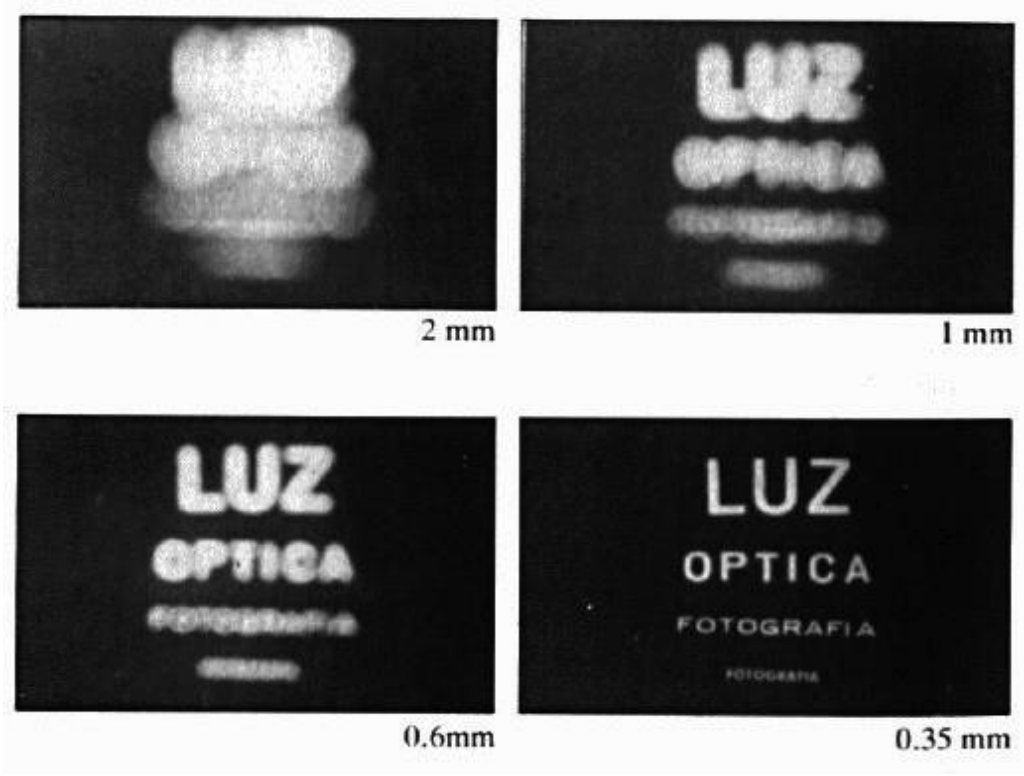

OPENNESS AND DEPTH ARE CORRELATED

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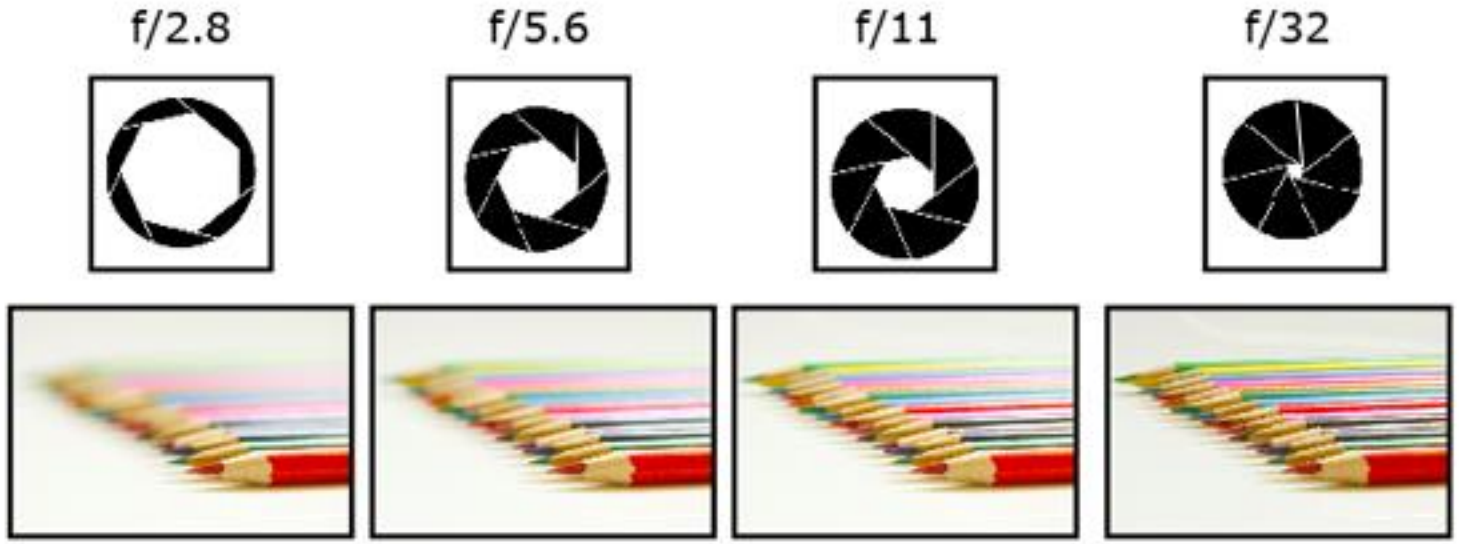
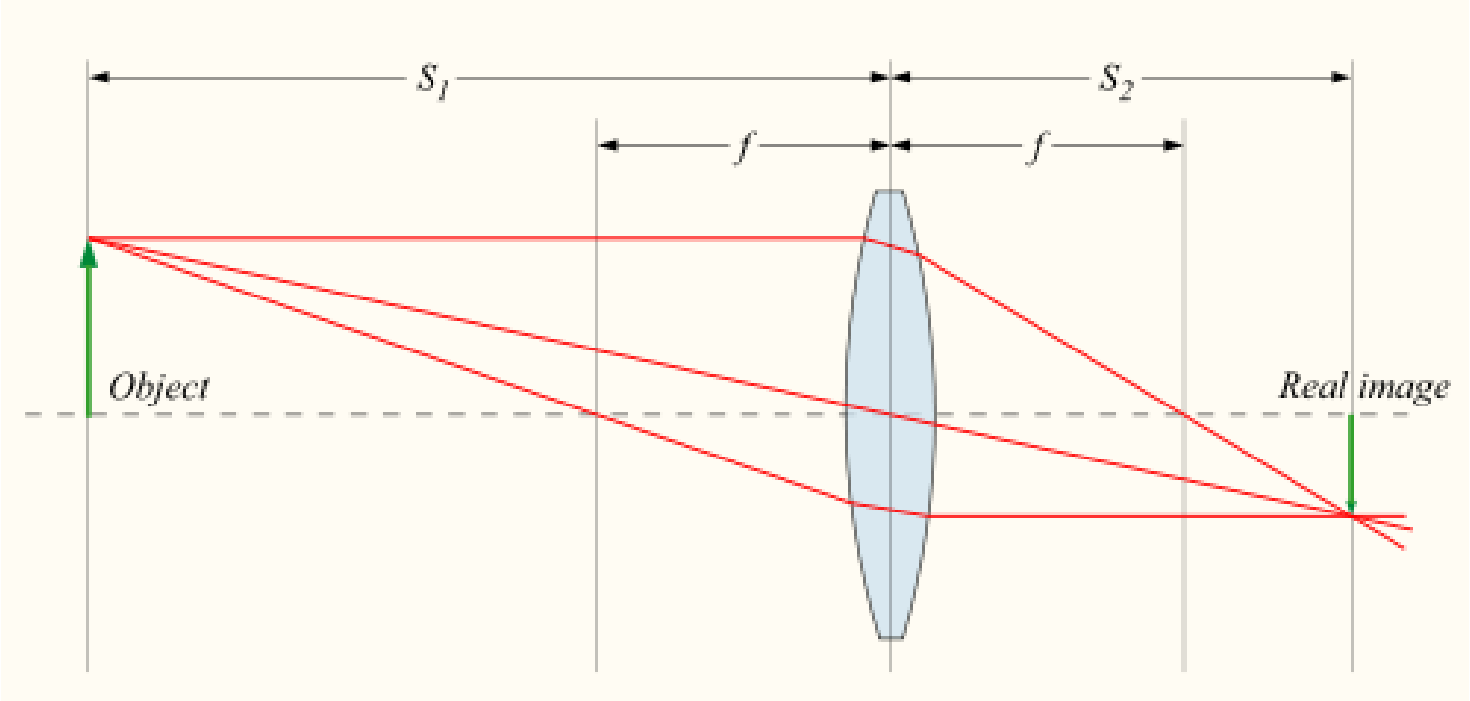


THIN LENSES

- Gaussian Law $\frac{1}{Z} + \frac{1}{z} = \frac{1}{f}$



CAMERA CALIBRATION

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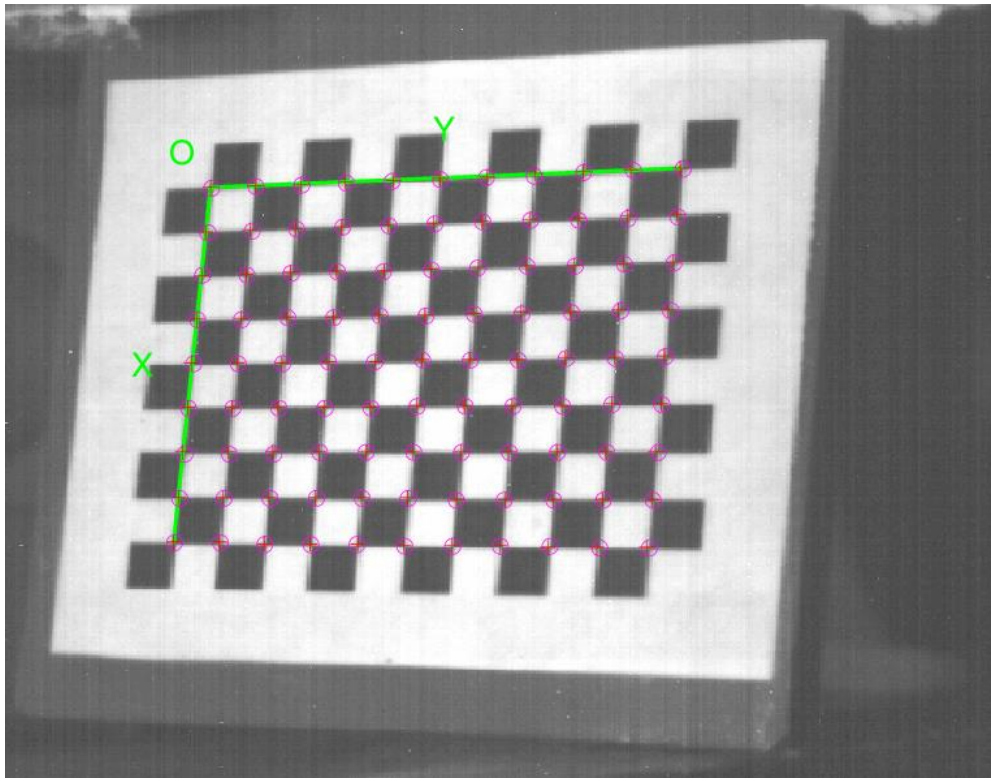
- $$\begin{pmatrix} p_{xi} \\ p_{yi} \\ 1 \end{pmatrix} = \begin{pmatrix} \frac{f}{dx} & -\rho\frac{f}{dy} & c_{xi} \\ 0 & \frac{f}{d_y} & c_{yi} \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} X_w \\ Y_W \\ Z_W \end{pmatrix}$$

COMPUTER VISION

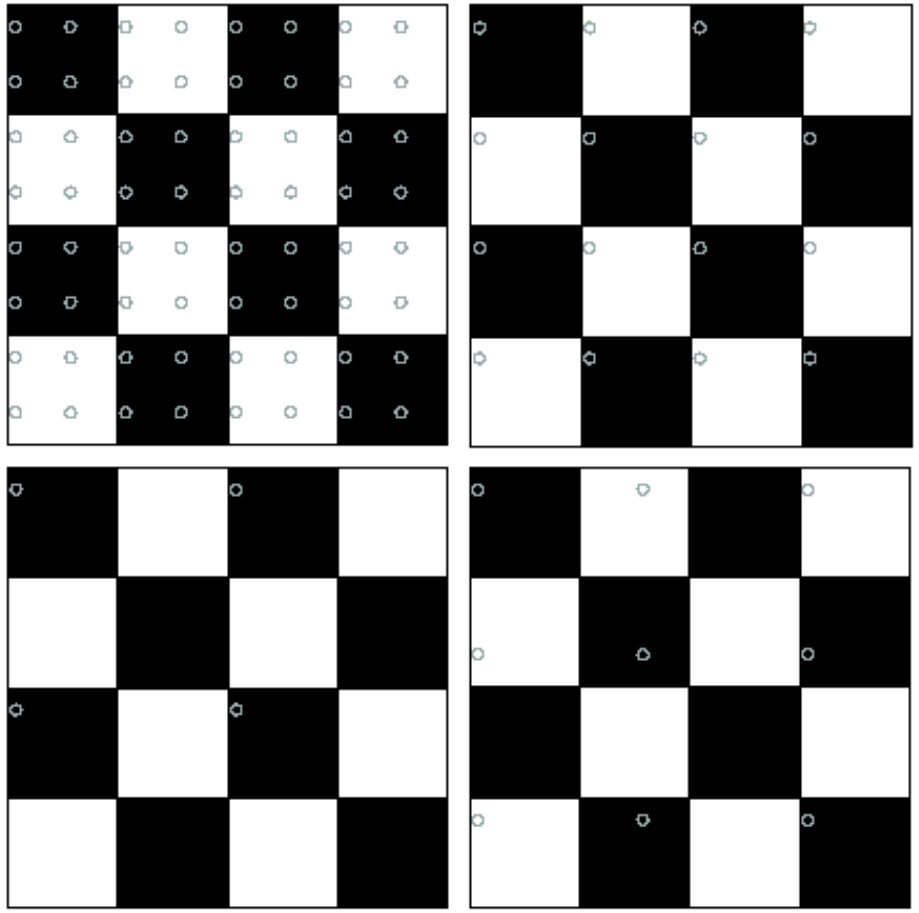
DEMO ARUCO

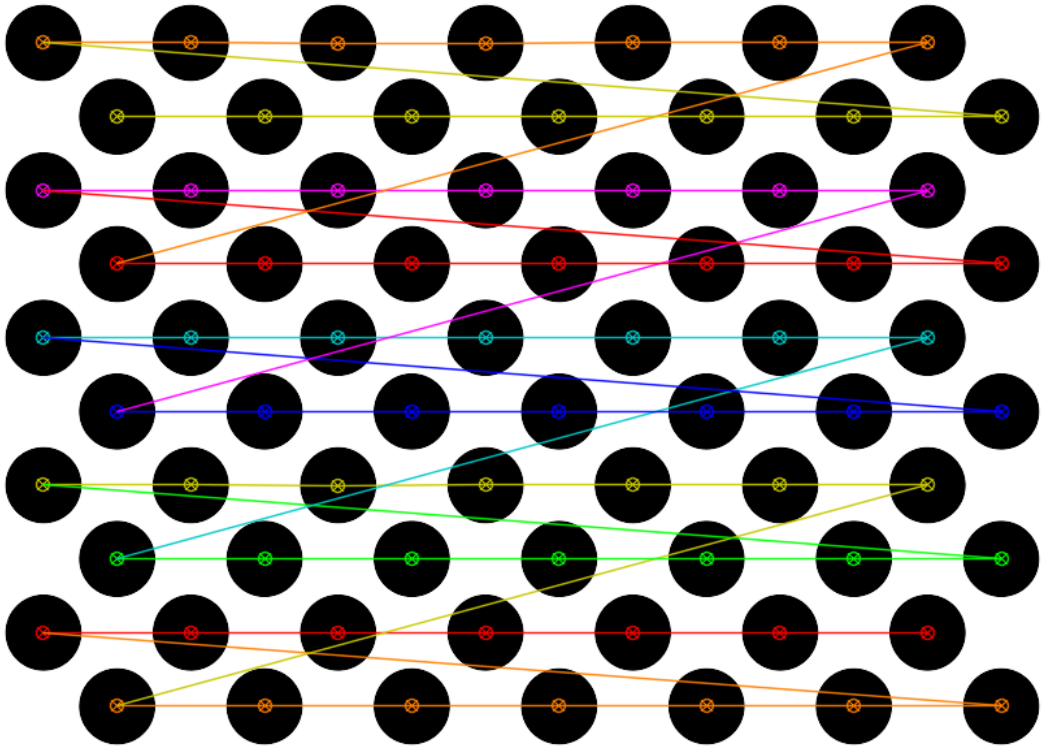
CHECKERBOARD



CHECKERBOARD

DataLab Community





FEATURE MATCHING

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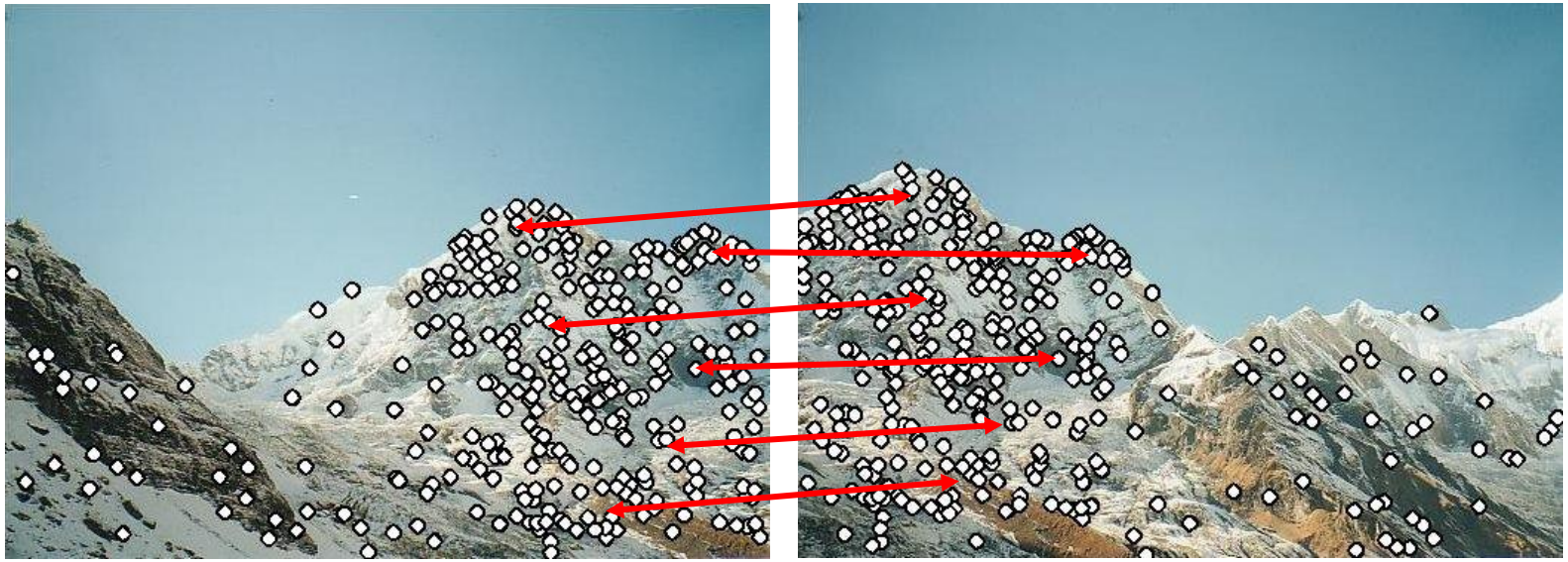

COMPUTER VISION

DEMO MATCHING

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WHAT IS CONVOLUTION?

REMEMBER...

AVERAGE FILTER

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- Then for a neighborhood of 3...

$$\frac{1}{9}\begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$$

AND IN PICTURES...

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$F[x, y]$

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	0	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	0	0	0	0	0	0	0
0	0	90	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

$G[x, y]$

	0								

AND IN PICTURES...

DataLab Community

$F[x, y]$

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	0	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	0	0	0	0	0	0	0
0	0	90	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

$G[x, y]$

	0	10							

AND IN PICTURES...

DataLab Community

$F[x, y]$

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	0	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	0	0	0	0	0	0	0
0	0	90	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

$G[x, y]$

	0	10	20						

AND IN PICTURES...

DataLab Community

$F[x, y]$

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	0	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	0	0	0	0	0	0	0
0	0	90	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

$G[x, y]$

	0	10	20	30					

AND IN PICTURES...

DataLab Community

$F[x, y]$

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	0	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	0	0	0	0	0	0	0
0	0	90	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

$G[x, y]$

	0	10	20	30					

AND IN PICTURES...

DataLab Community

$F[x, y]$

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	0	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	0	0	0	0	0	0	0
0	0	90	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

$G[x, y]$

	0	10	20	30	30	30	20	10	
	0	20	40	60	60	60	40	20	
	0	30	60	90	90	90	60	30	
	0	30	50	80	80	90	60	30	
	0	30	50	80	80	90	60	30	
	0	20	30	50	50	60	40	20	
	10	20	30	30	30	30	20	10	
	10	10	10	0	0	0	0	0	

WHAT IS CONVOLUTION?

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$$(f * g)(t) = \int_{-\infty}^{\infty} f(\eta) g(t - \eta)\, d\eta$$

WHAT IS CONVOLUTION?

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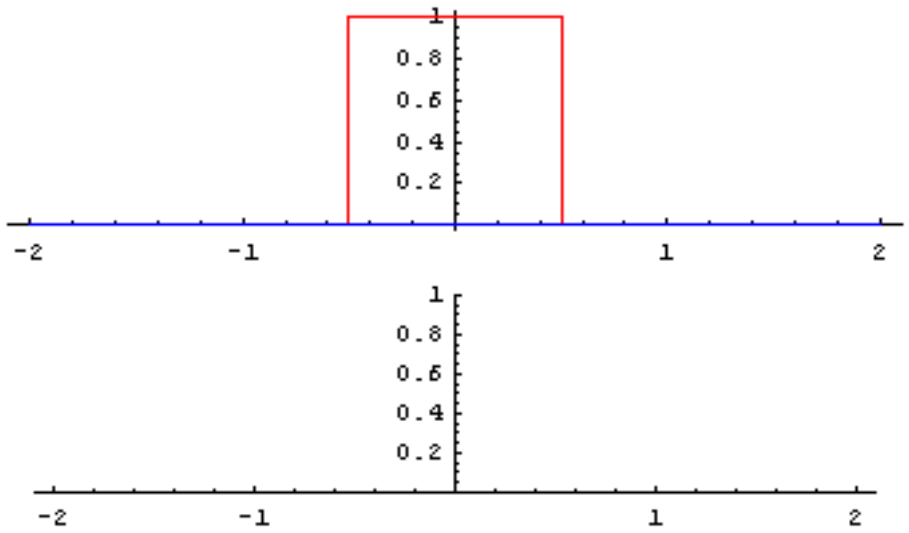
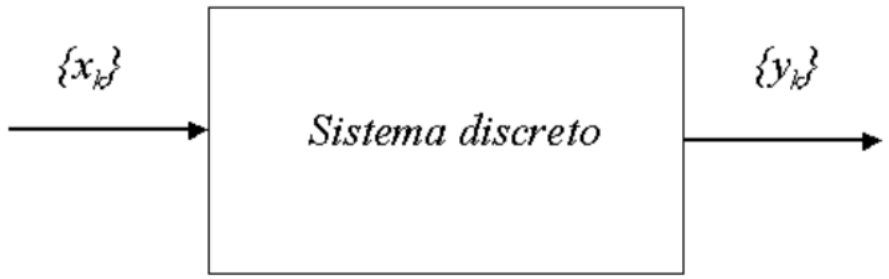


WHY THE CONVOLUTION?



WHY THE CONVOLUTION?

- Filtros FIR (Finite Impulse Response)
- Filtros IIR (Infinite Impulse Response)

CONVOLUTION THEOREM

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$$\mathcal{F}(f * g) = F(\omega)G(\omega)$$

FILTERS IN WAVE NUMBER DOMAIN

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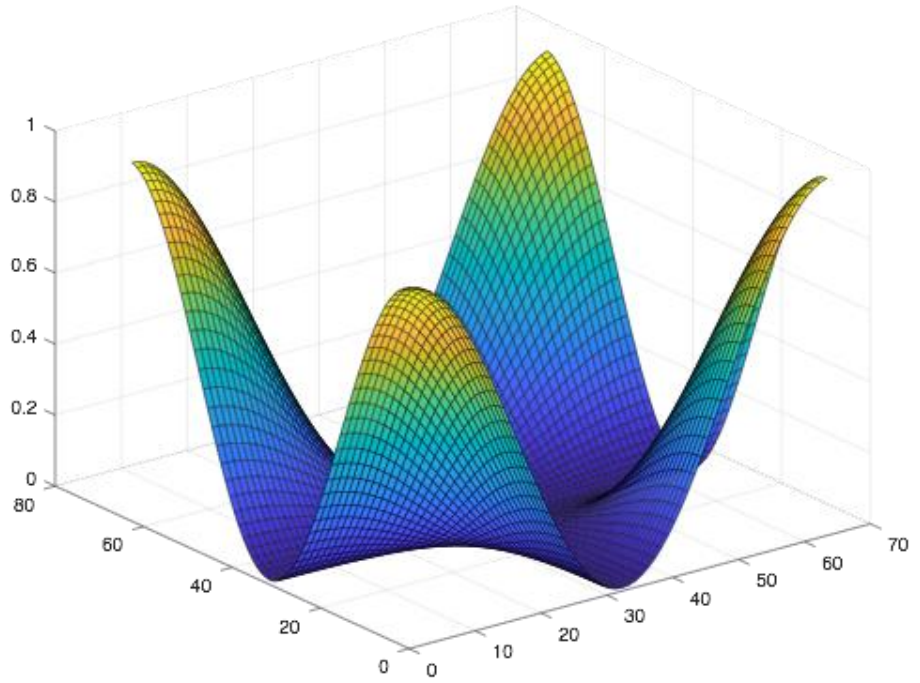
$$\frac{1}{16}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$



FILTERS IN WAVE NUMBER DOMAIN

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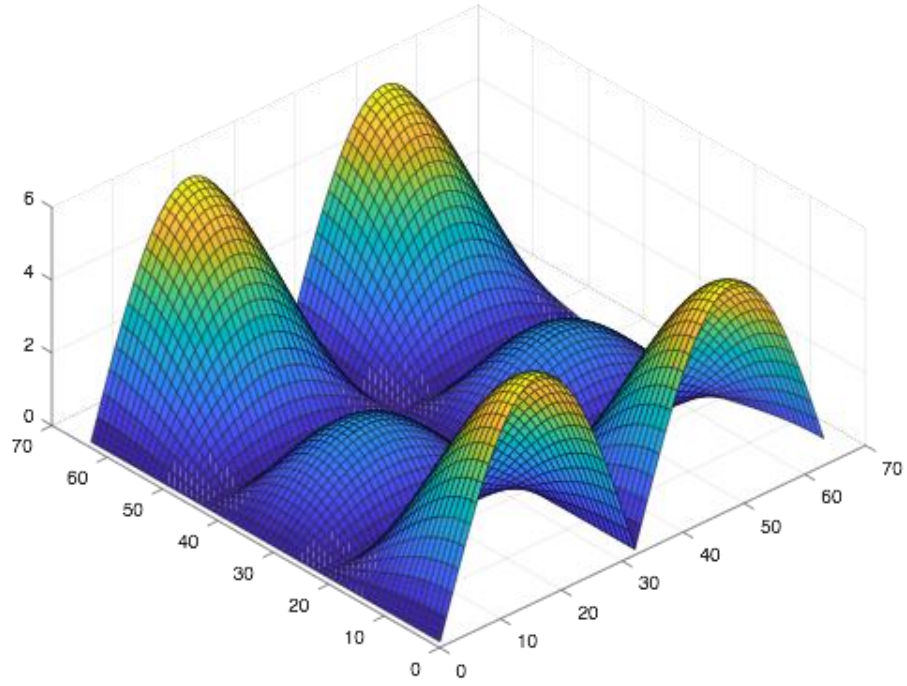
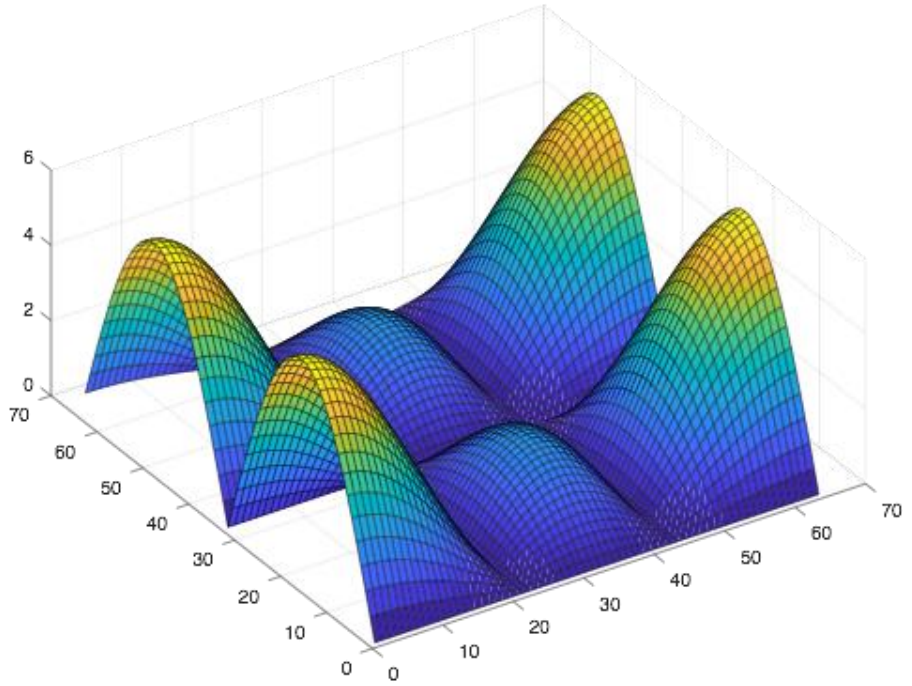
$$\begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$$



FILTERS IN WAVE NUMBER DOMAIN

$$\begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$



COMPUTER VISION

DEMO EDGES

IMAGE PROCESSING VS CNN

COMPUTER VISION

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CONVOLUTIONAL NEURAL NETWORKS

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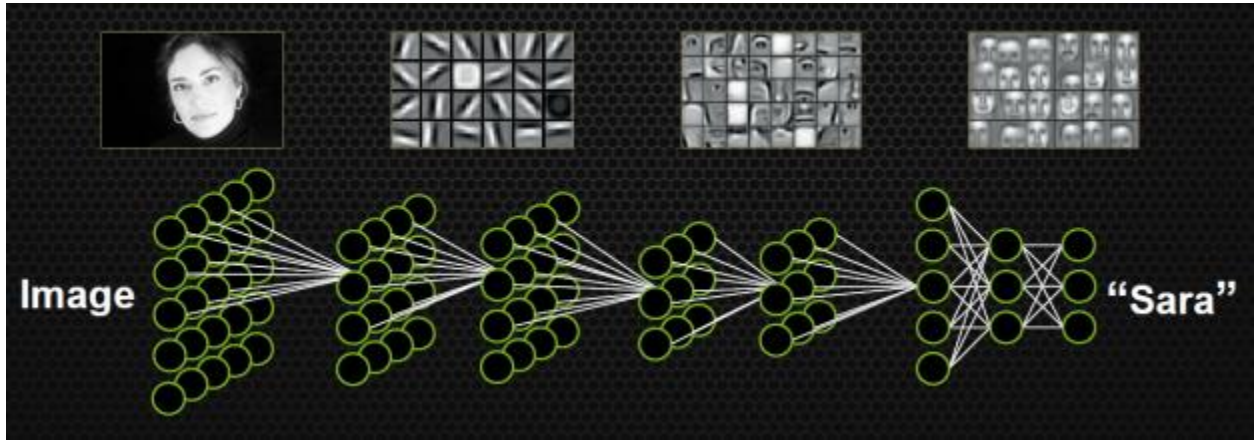

CNN

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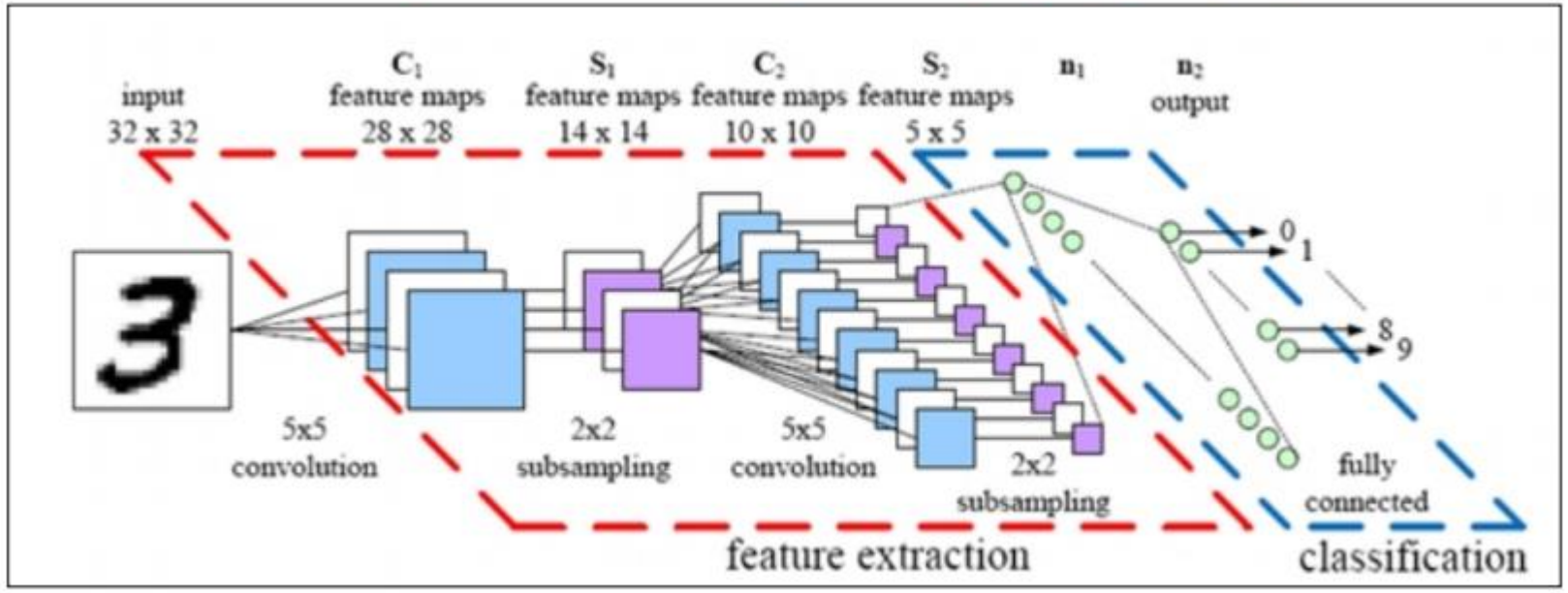

ARCHITECTURE OF A CNN

- Convolutional Layer
- Pooling Layer
- Flatten Layer
- Activation Layer
- Fully Connected Layer
- …

CONVOLUTIONAL NEURAL NETWORKS

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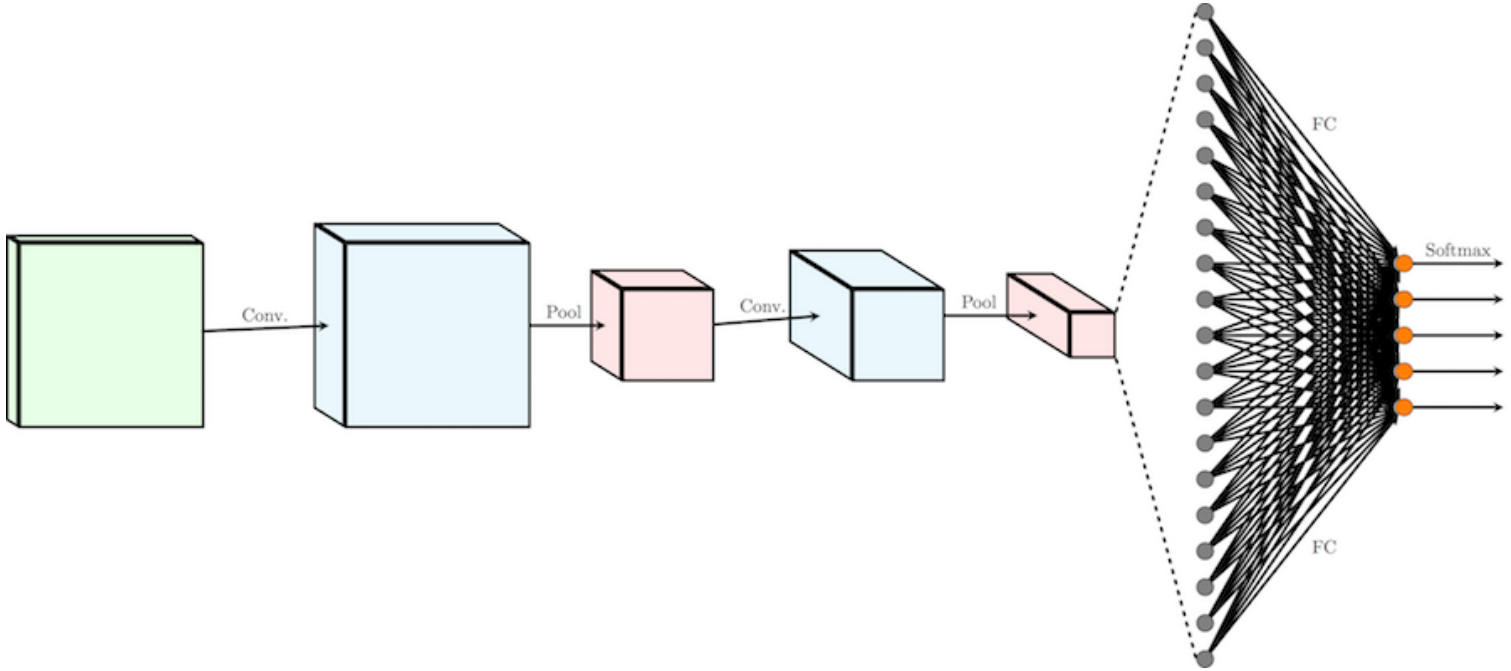
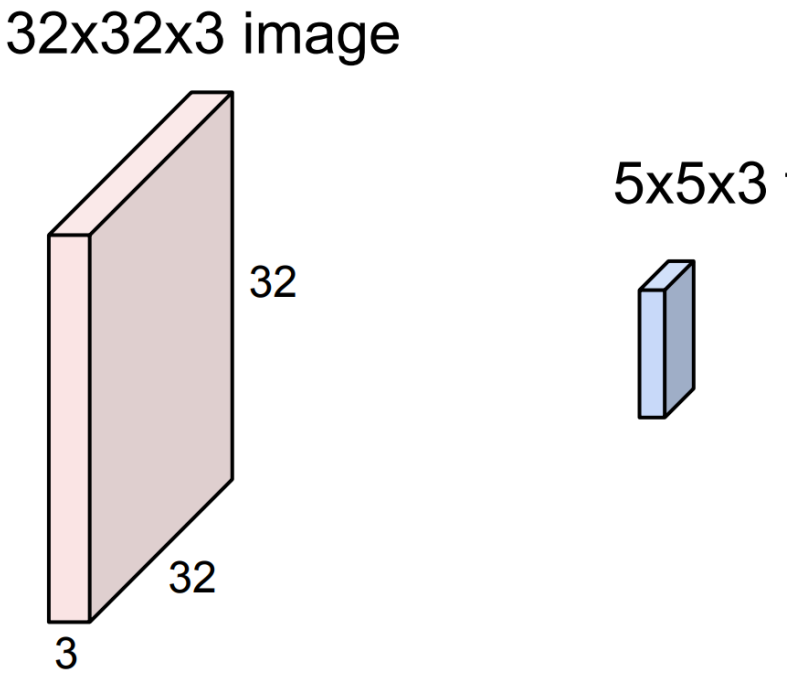
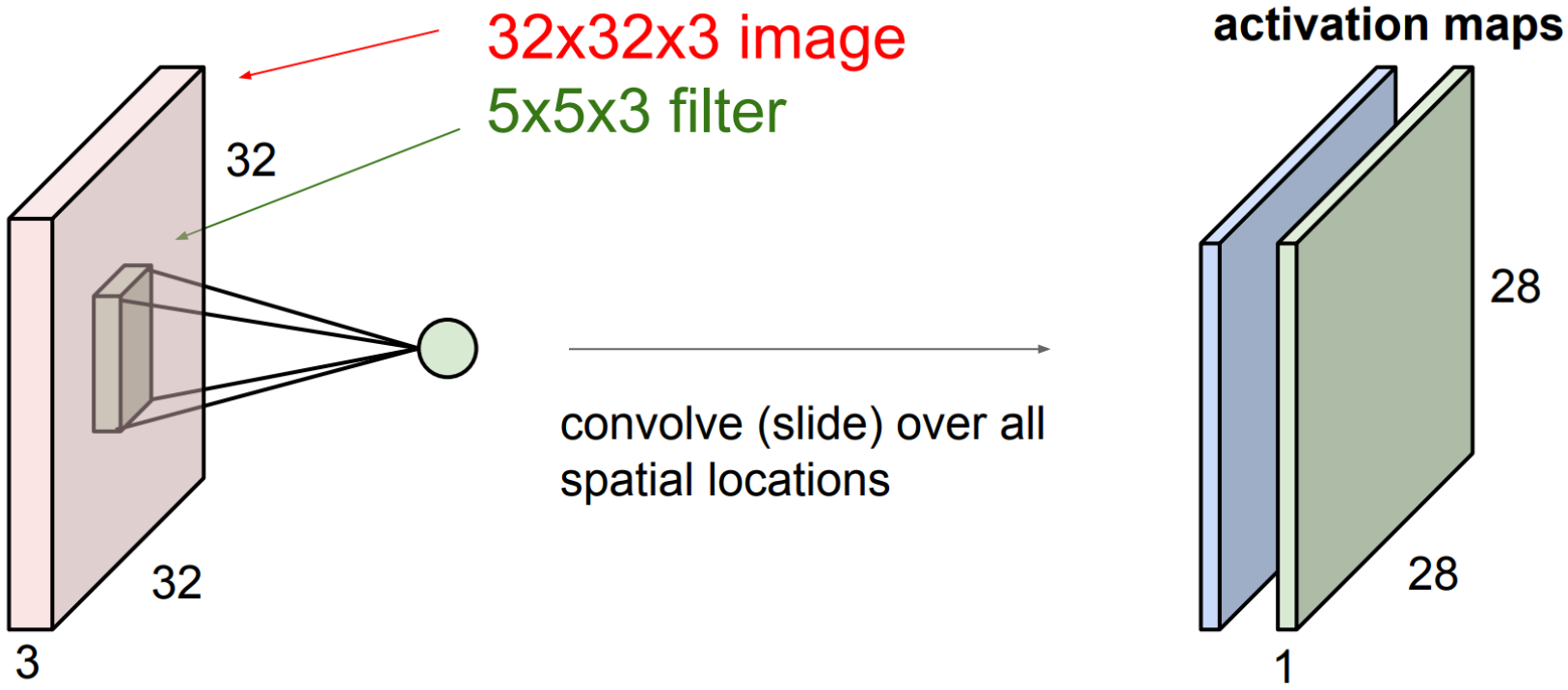


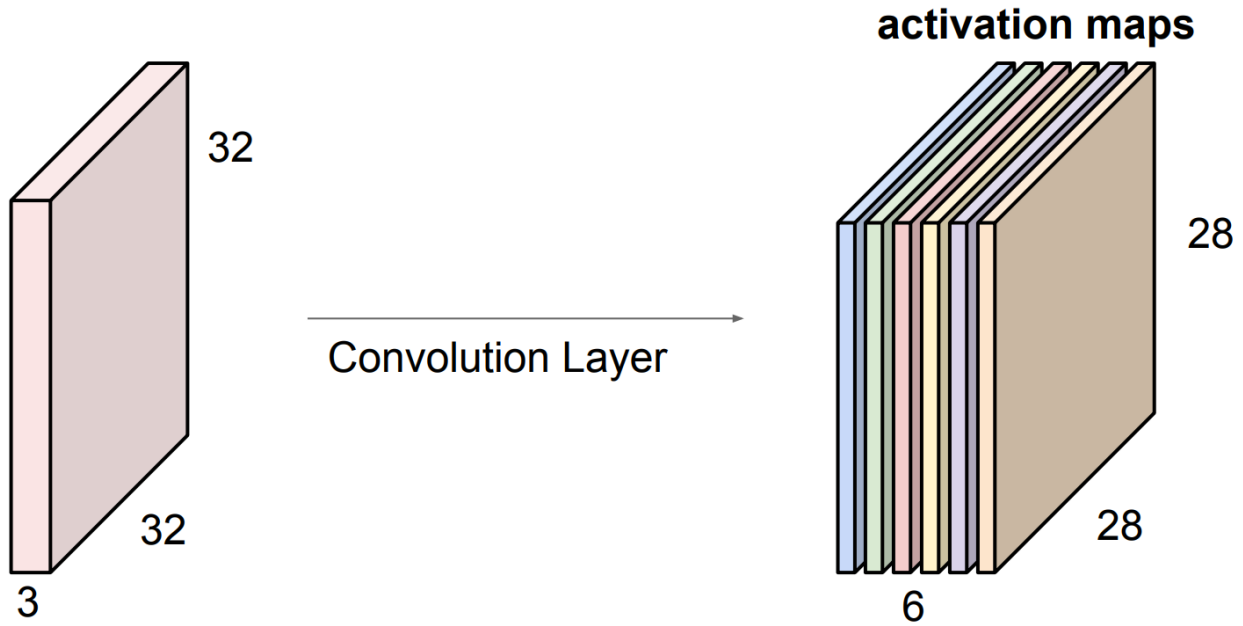
CONVOLUTIONAL LAYER



ACTIVATION MAP CNN



ACTIVATION MAP



We stack these up to get a “new image” of size 28x28x6!

CONVOLUTIONAL LAYER

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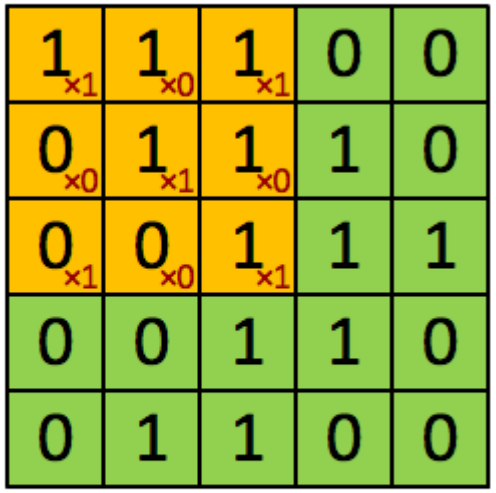
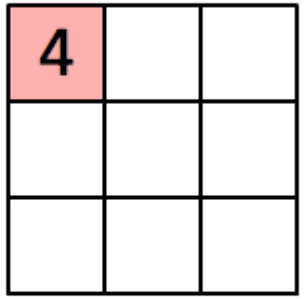


Image



Convolved Feature

CONVOLUTIONAL LAYER

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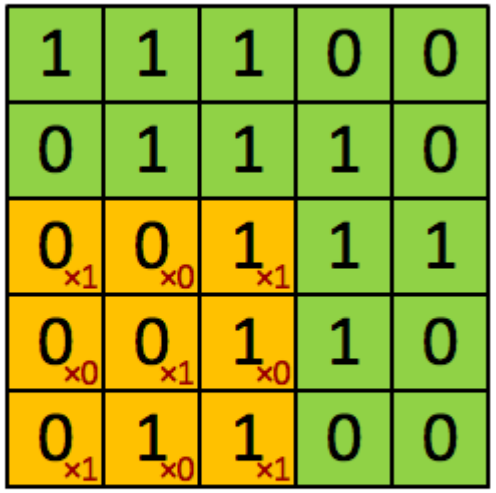
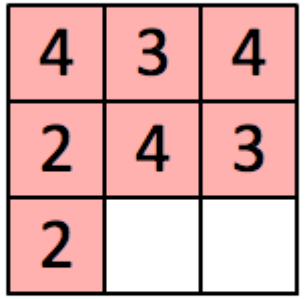


Image



Convolved Feature

POOLING LAYER

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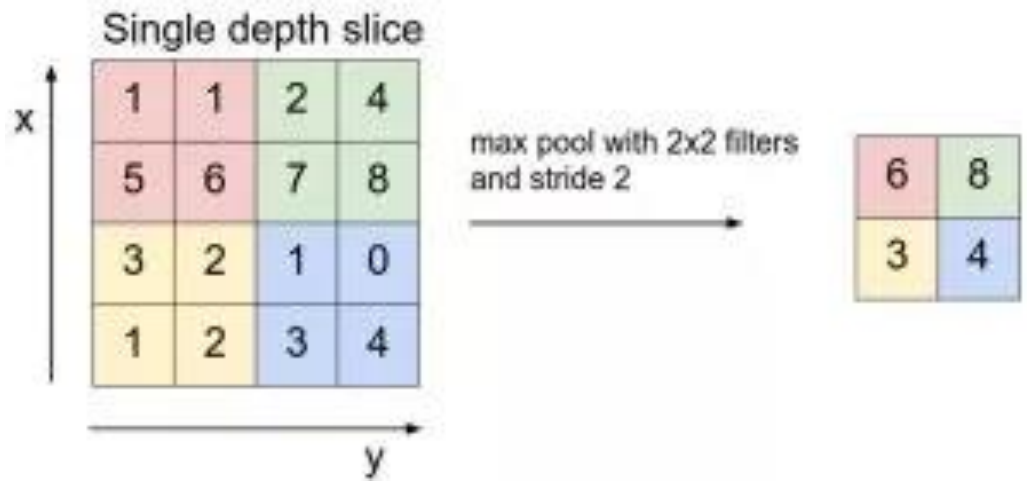
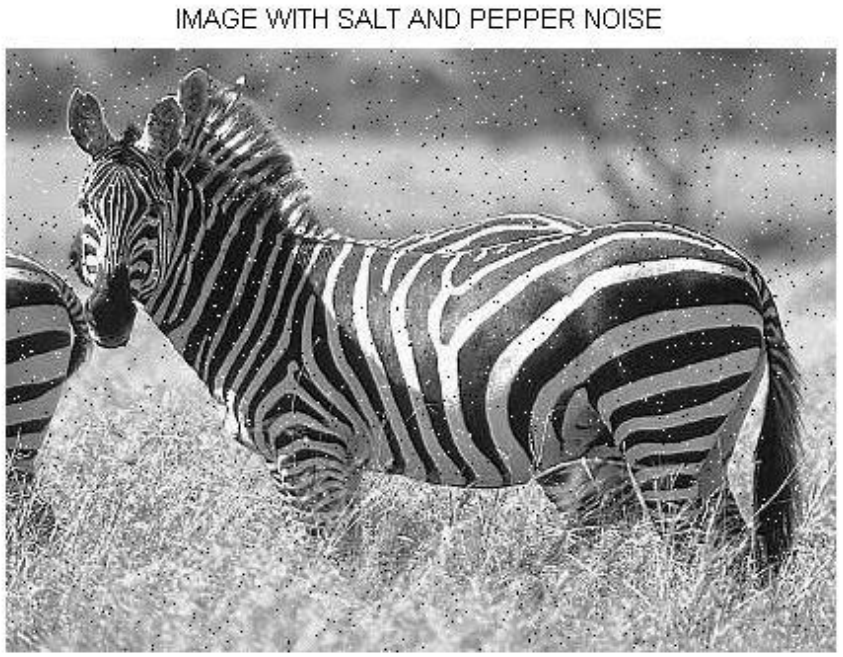
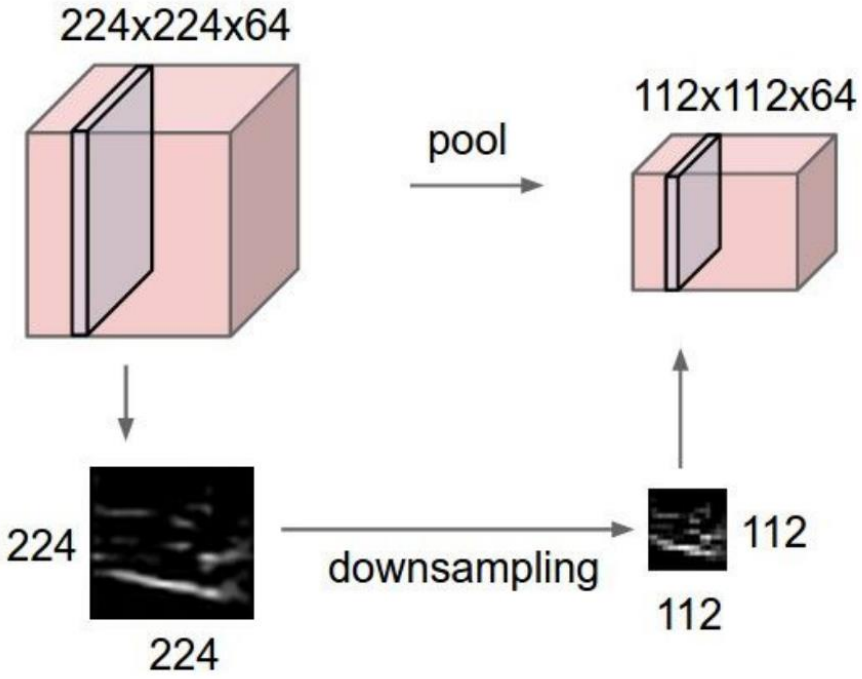


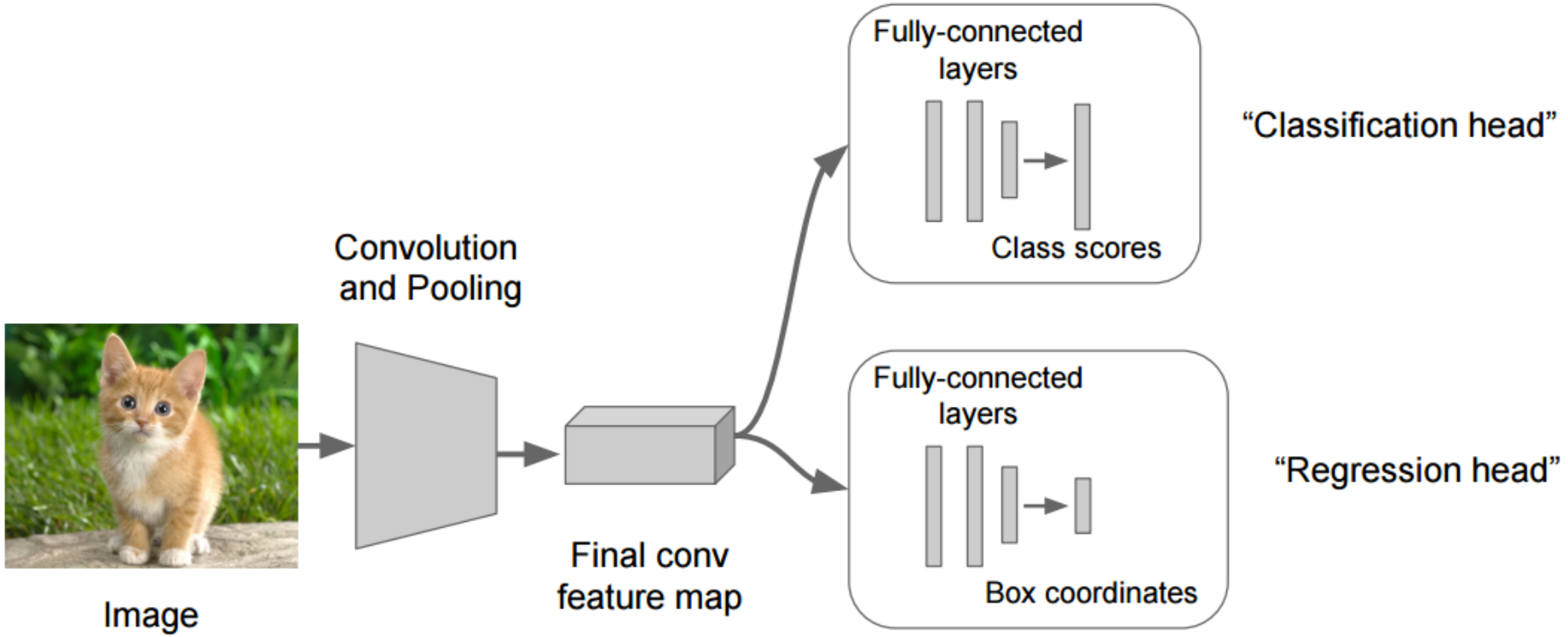
POOLING LAYER



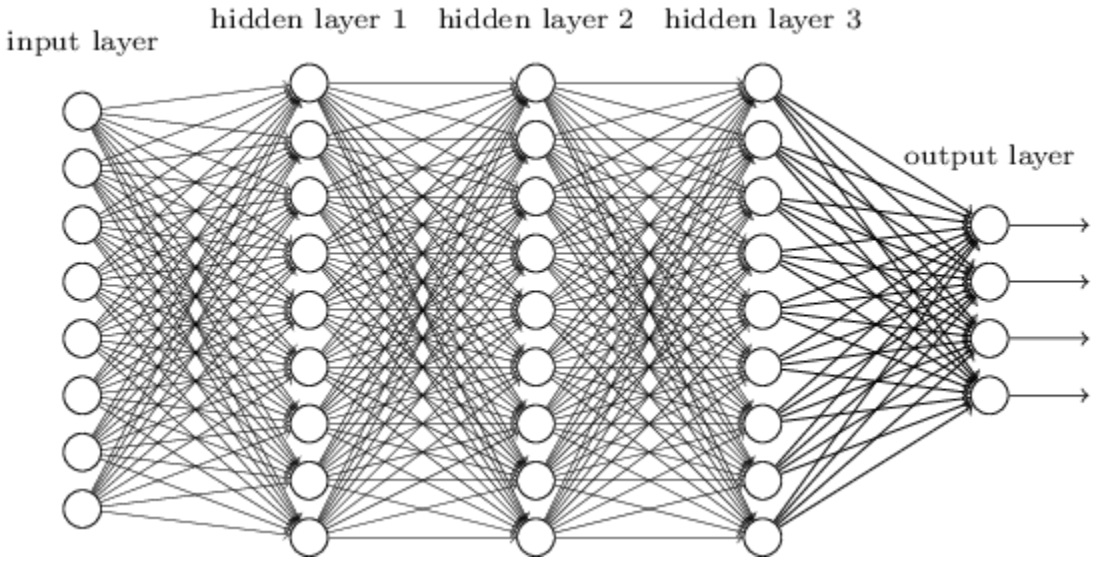
POOLING LAYER



FULLY CONNECTED LAYER



FULLY CONNECTED LAYER



DEEP LEARNING

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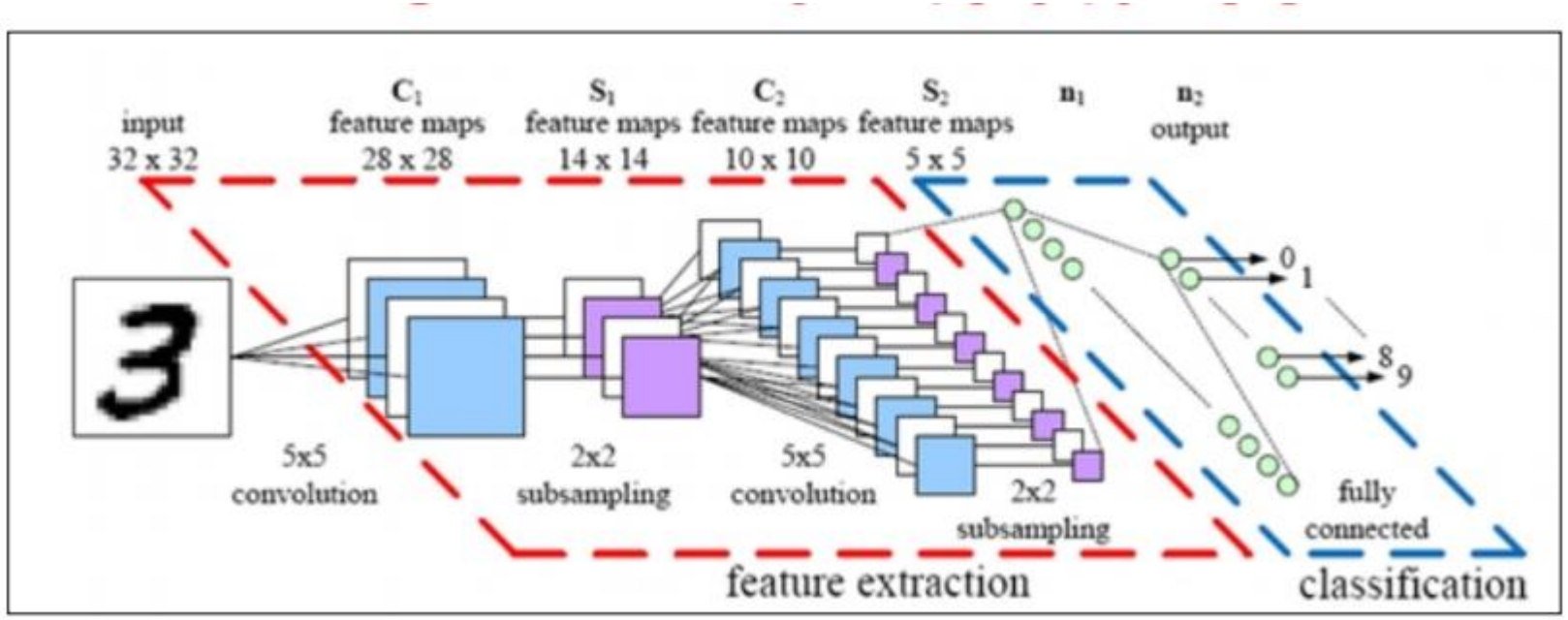

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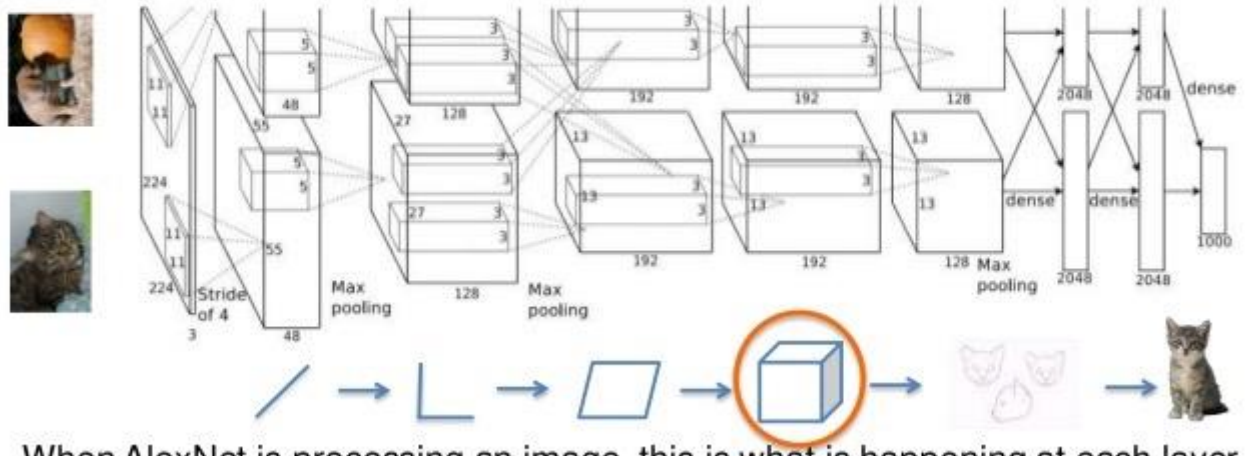
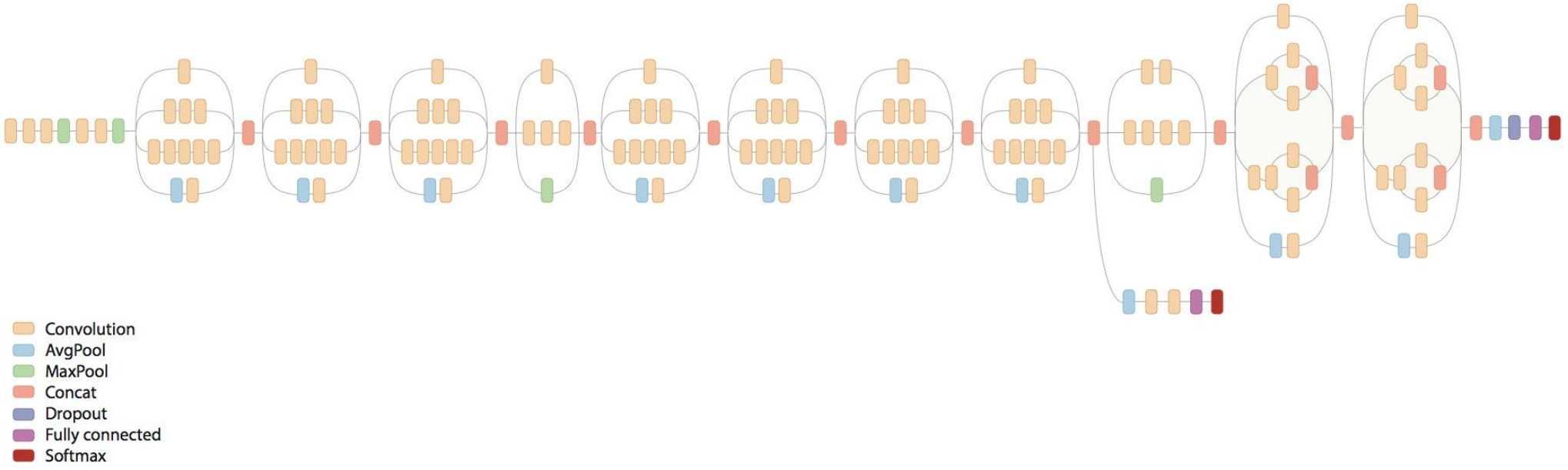
AlexNet (Krizhevsky et al. 2012)

The class with the highest likelihood is the one the DNN selects



When AlexNet is processing an image, this is what is happening at each layer.

INCEPTION V3



COMPUTER VISION

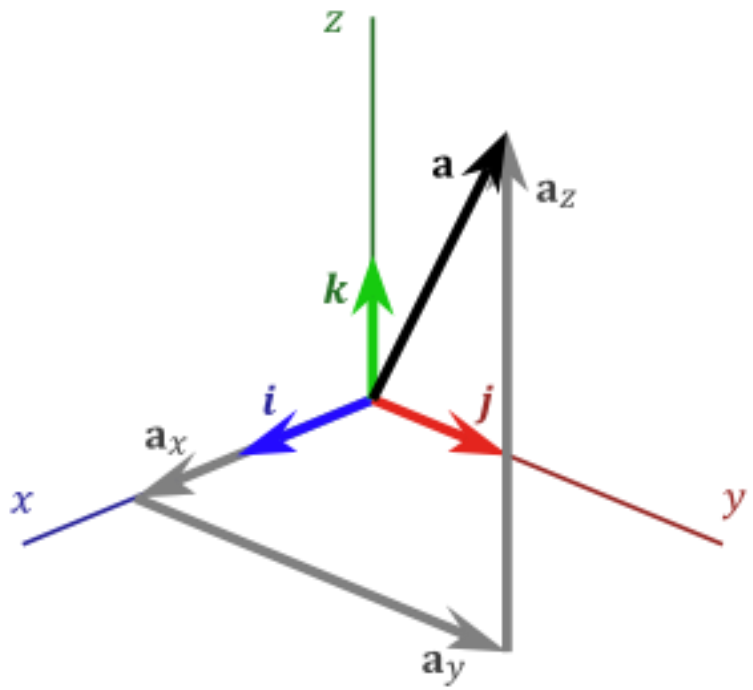
DEMO CNN

COMPUTER VISION

WHAT IS A TENSOR?

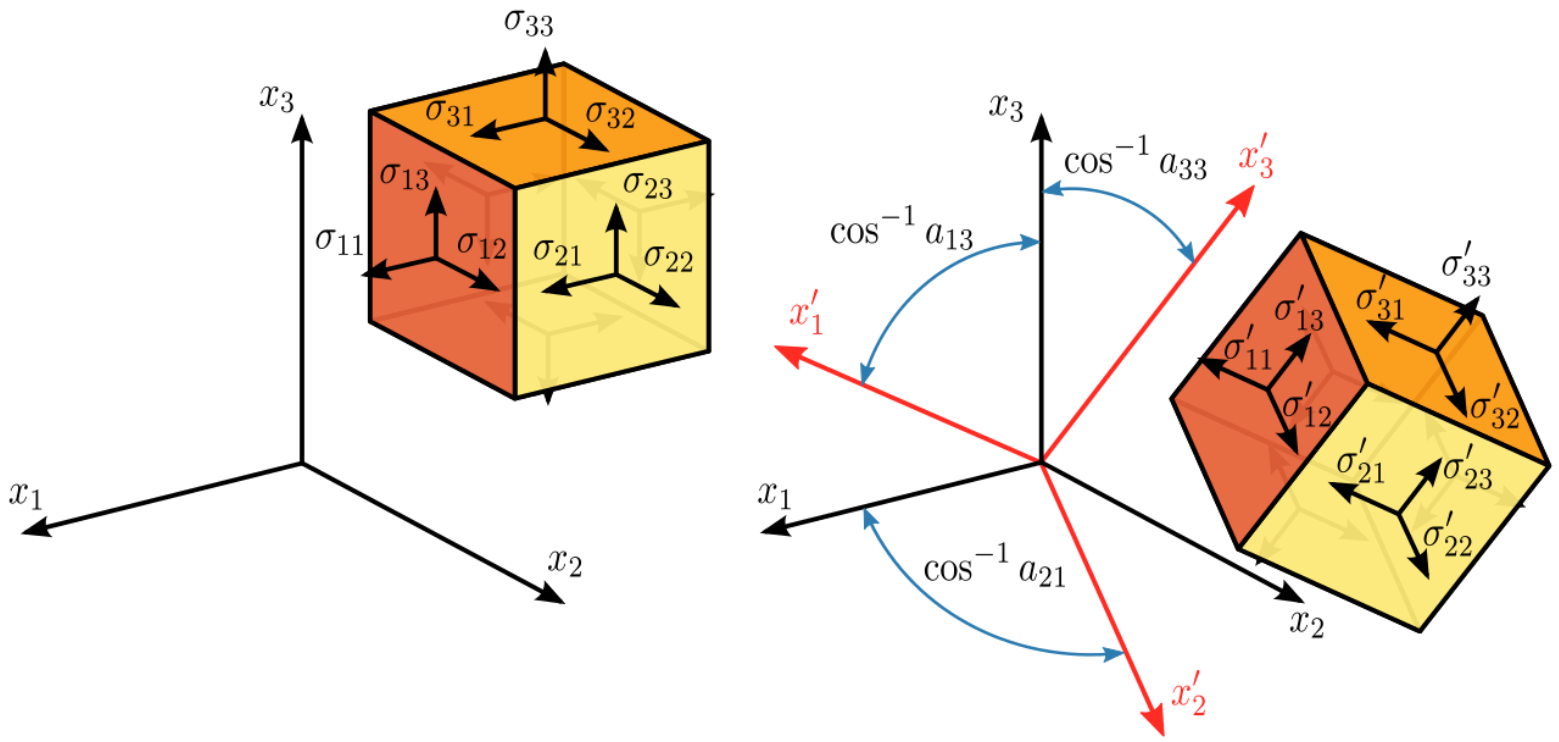
WHAT IS A TENSOR?

DataLab Community



WHAT IS A TENSOR?

DataLab Community



LILIAN LIEBER

DataLab Community

- Tensors
- “The facts of the universe”.

- *1886-1986*

LILIAN LIEBER

DataLab Community

- From "The Einstein Theory of Relativity"
- In n-dimensional space,
- a VECTOR has n components,
- a TENSOR of rank TWO has n^2 comp
- a TENSOR of rank THREE has n^3 comp
- and so on.

- *1886-1986*

IMAGE PROCESSING VS CNN

COMPUTER VISION

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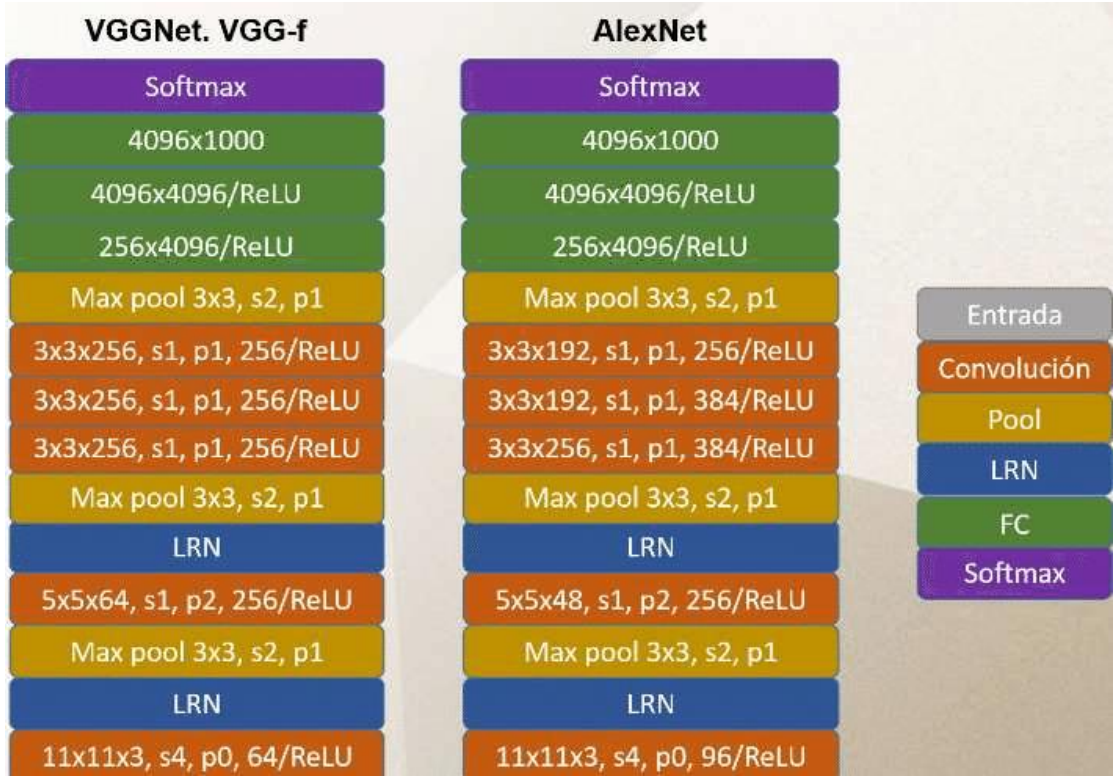
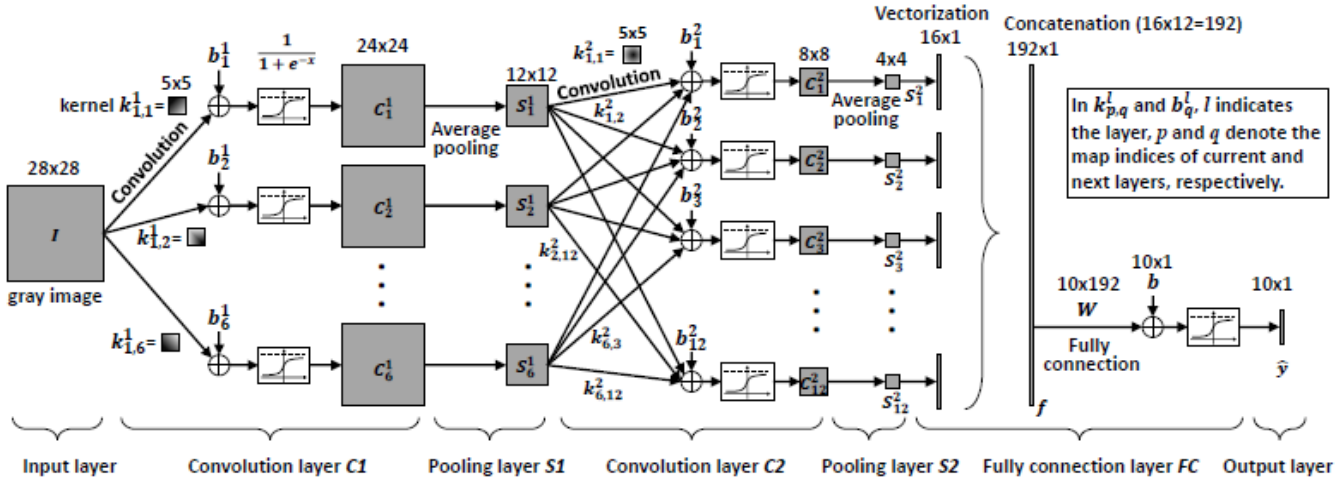
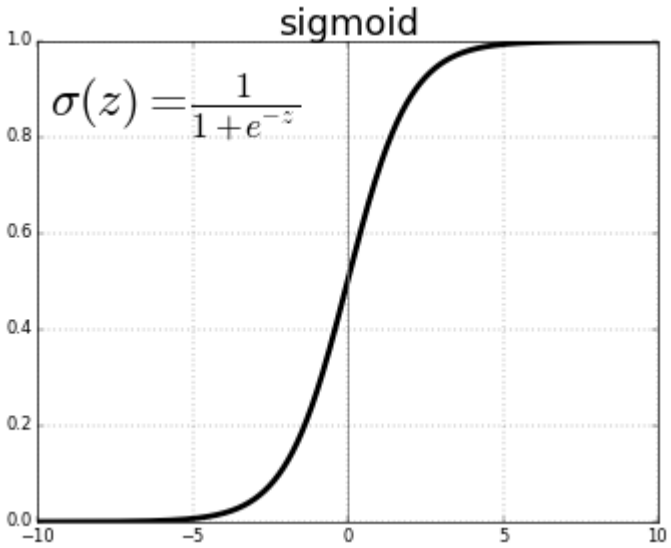
CNN ARCHITECTURE

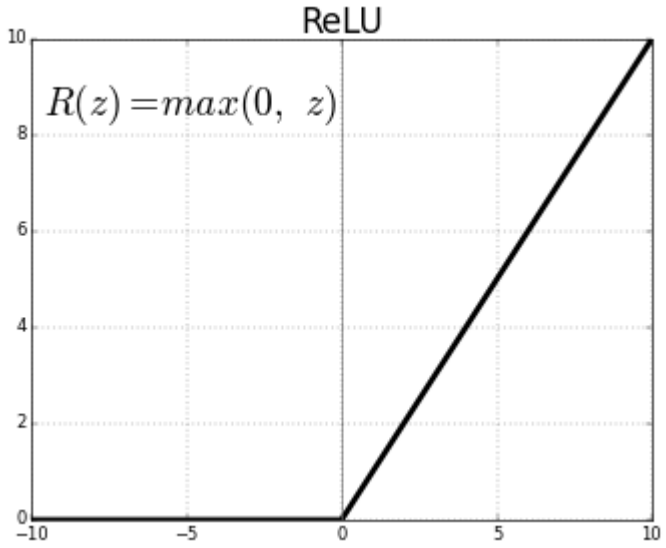


CNN ARCHITECTURE



RELU


sigmoid
$\sigma(z) = \frac{1}{1+e^{-z}}$
1.0
0.8
0.6
0.4
0.2
0.0
−10
−5
0
5
10


ReLU
$R(z) = max(0,\ z)$
10
8
6
4
2
0
−10
−5
0
5
10

IF WE LOOK CLOSELY AT THE "CONVOLUTION LAYER"

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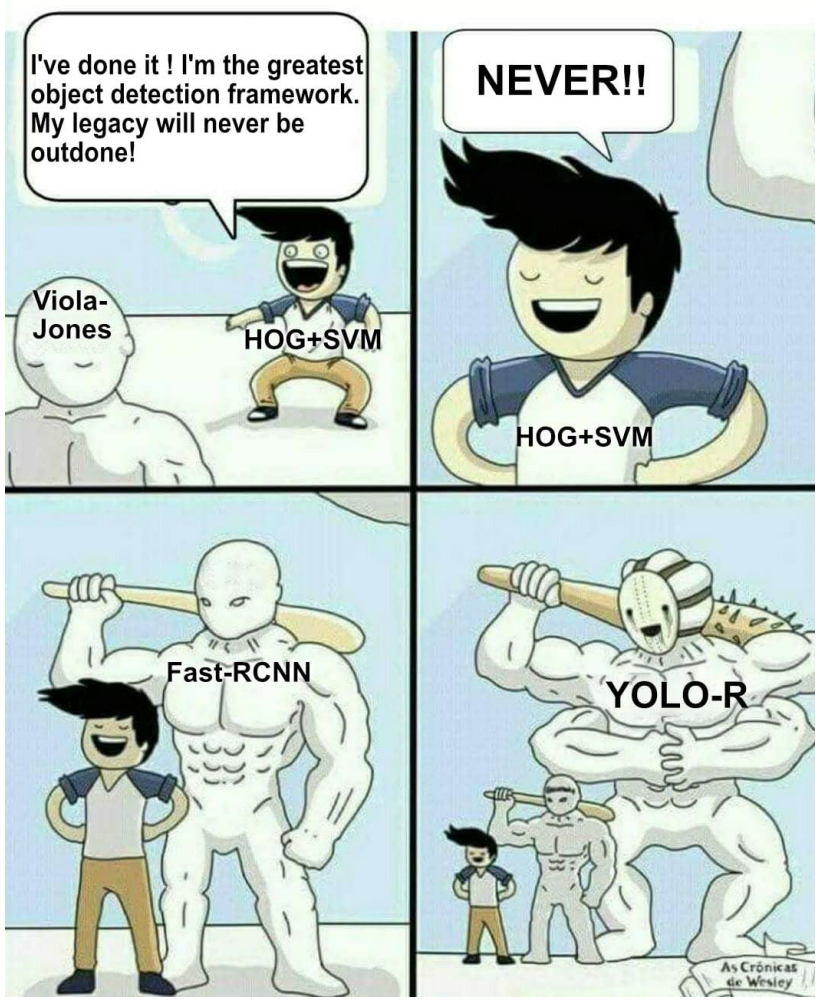
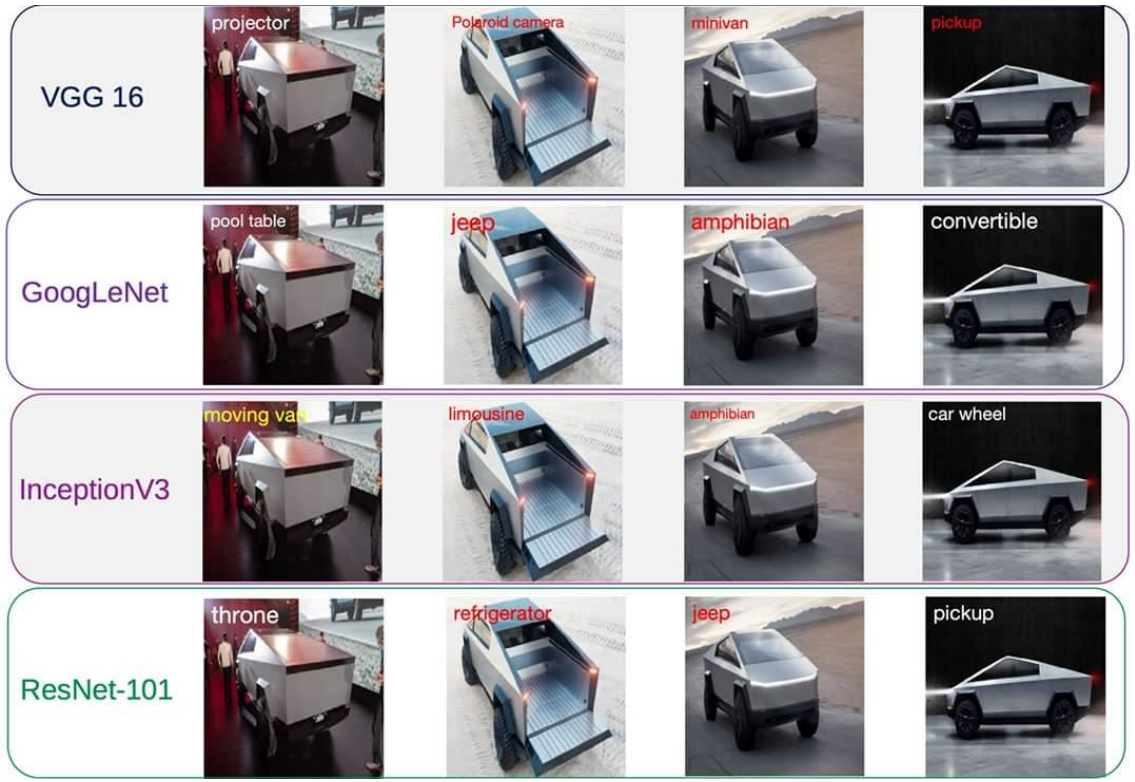
$$C_p^1(i,j) = \sigma\left(\sum_{u=-2}^{2}\sum_{v=-2}^{2} I(i-u, j-v)k_{1,p}^1(u,v) + b_p^1\right)$$


I've done it ! I'm the greatest object detection framework. My legacy will never be outdone!
Viola-Jones
HOG+SVM
NEVER!!
HOG+SVM
Fast-RCNN
YOLO-R
As Crônicas de Wesley

COMPUTER VISION

WHY DO YOU NEED SO MANY IMAGES FOR TRAINING?


VGG 16
projector
Polaroid camera
minivan
pickup
GoogLeNet
pool table
jeep
amphibian
convertible
InceptionV3
moving van
limousine
amphibian
car wheel
ResNet-101
throne
refrigerator
jeep
pickup

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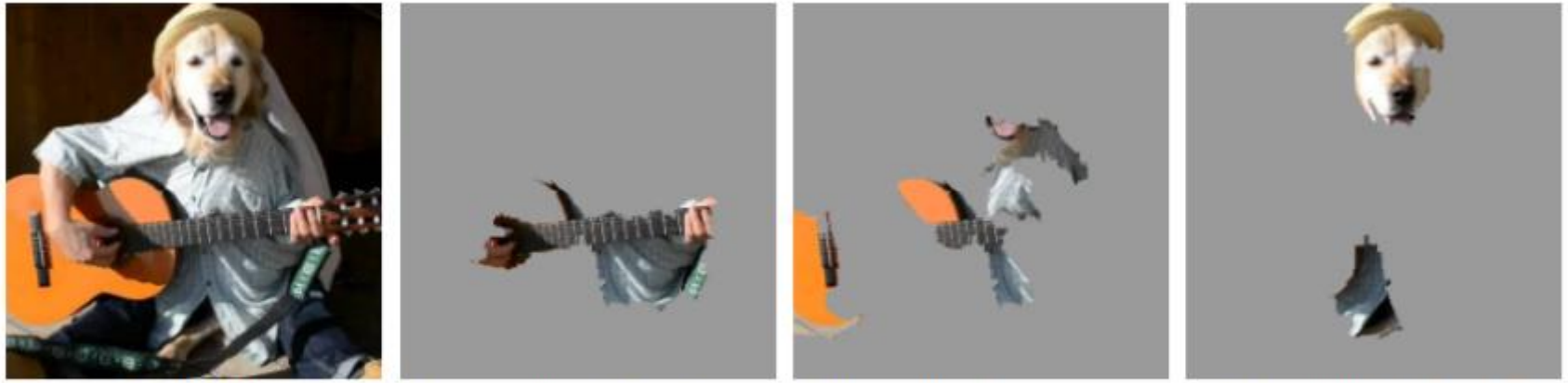
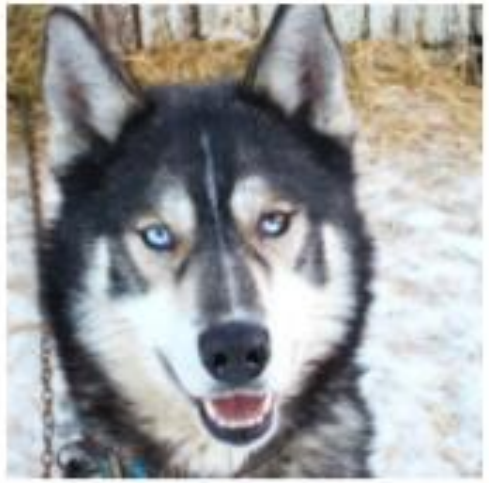
How to confuse machine learning



(a) Original Image (b) Explaining *Electric guitar* (c) Explaining *Acoustic guitar* (d) Explaining *Labrador*

Figure 4: Explaining an image classification prediction made by Google's Inception neural network. The top 3 classes predicted are "Electric Guitar" ($p = 0.32$), "Acoustic guitar" ($p = 0.24$) and "Labrador" ($p = 0.21$)



(a) Husky classified as wolf

(b) Explanation

Figure 11: Raw data and explanation of a bad model's prediction in the "Husky vs Wolf" task.

> “Those who can imagine anything, can create the impossible.”
>
> *-Alan Turing*

Questions?

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