Introduction to Robotics
CSE 461

Class Topic: Introduction to Convolutional Neural Network

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Last Class

What is machine Learning

Neural Network

Mother Law of Machine Learning

$$w1 * x1 + w2 * x2 + w3 * x3 = y$$

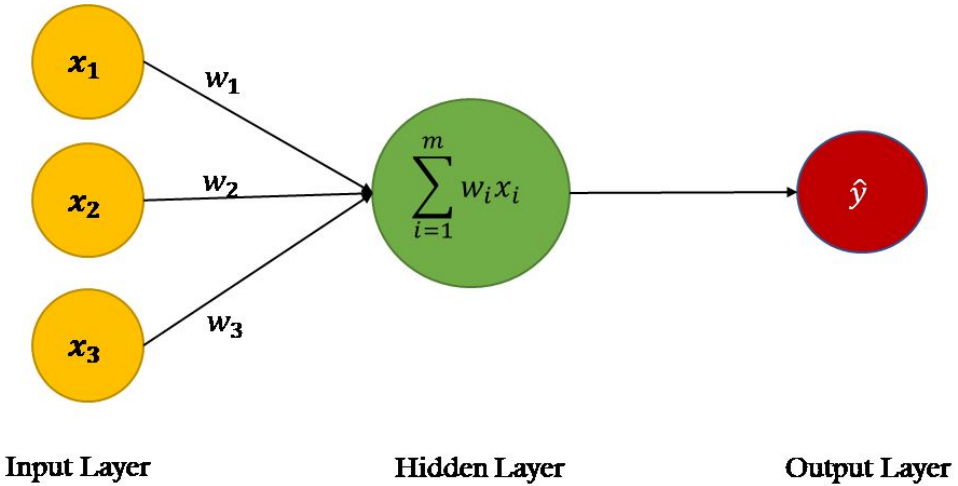
x1, x2, ..., xn = Features

w1, w2, ..., wn = Weights

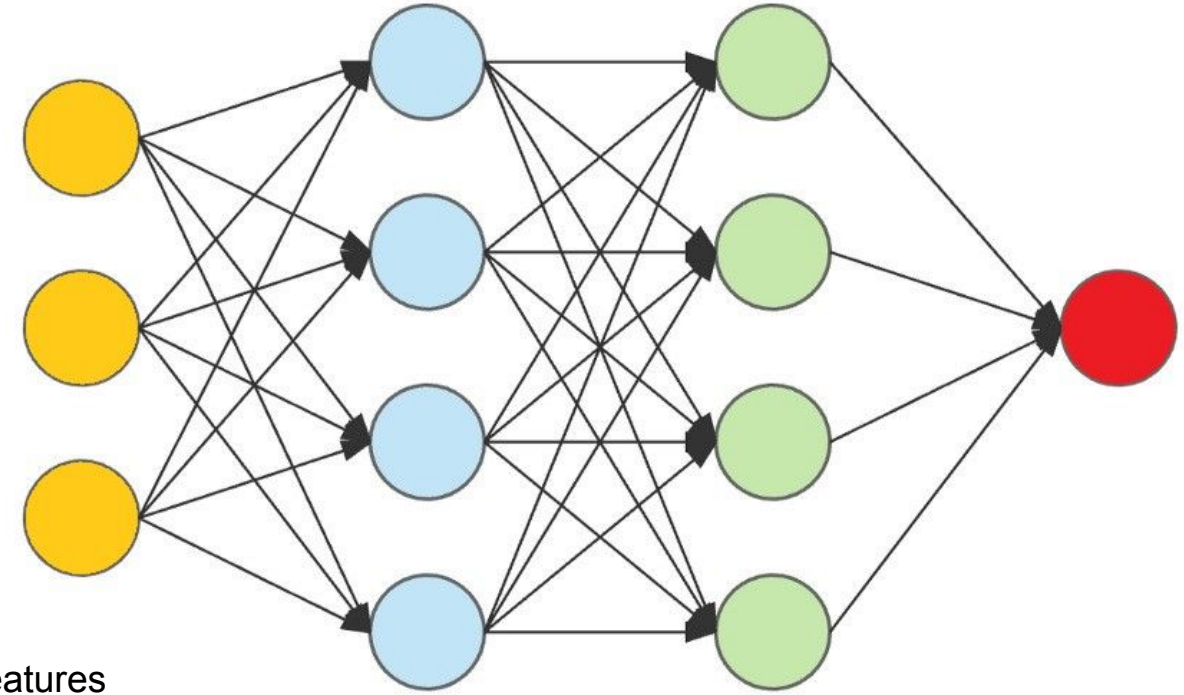
y = output/ target

Neural Network

$$w1 * x1 + w2 * x2 + w3 * x3 = y$$



Neural Network



Predictions/
decisions

Features

Hidden Layers

Two types

1. Features are given (Handcrafted Features)
2. Raw Data is given not features

Out[33]=

Sepal.Length	Sepal.Width	Petal.Length	Petal.Width	Species
5.1	3.5	1.4	0.2	setosa
4.9	3.	1.4	0.2	setosa
4.7	3.2	1.3	0.2	setosa
4.6	3.1	1.5	0.2	setosa
5.	3.6	1.4	0.2	setosa
5.4	3.9	1.7	0.4	setosa
4.6	3.4	1.4	0.3	setosa
5.	3.4	1.5	0.2	setosa
4.4	2.9	1.4	0.2	setosa
4.9	3.1	1.5	0.1	setosa

1. Some data column may not a good feature.
2. Some data column may need to be transformed.

Out[33]=

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4.6	3.1	1.5	0.2	setosa
5.	3.6	1.4	0.2	setosa
5.4	3.9	1.7	0.4	setosa
4.6	3.4	1.4	0.3	setosa
5.	3.4	1.5	0.2	setosa
4.4	2.9	1.4	0.2	setosa
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5.4	3.9	1.7	0.4	setosa
4.6	3.4	1.4	0.3	setosa
5.	3.4	1.5	0.2	setosa
4.4	2.9	1.4	0.2	setosa
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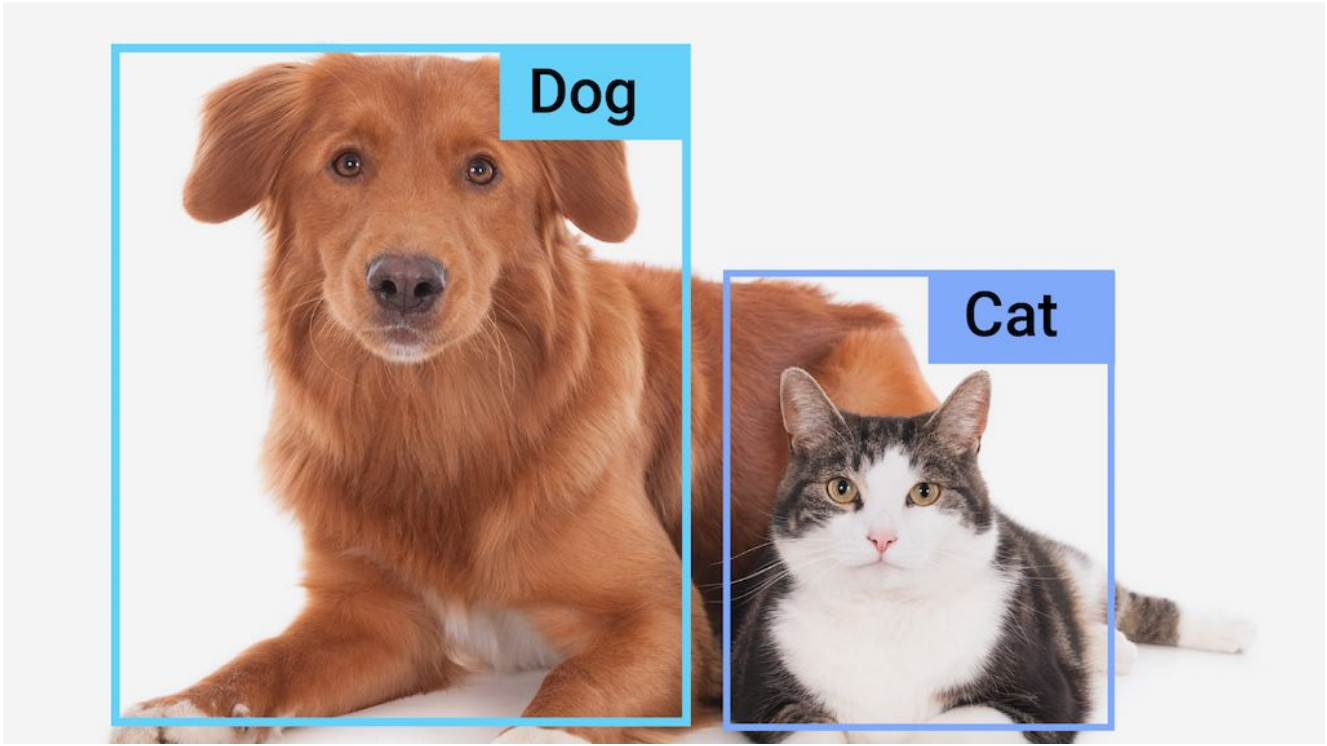
1. We can do it by our hand (Handcrafted)
2. Neural network does this automatically (Deep Learning)

Deep Learning

Deep learning is a type of machine learning based on artificial neural networks in which multiple layers of processing are used to extract progressively higher level features from data.

Let’s Do object detection



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4.9	3.1	1.5	0.1	setosa

Out[33]=

Cat

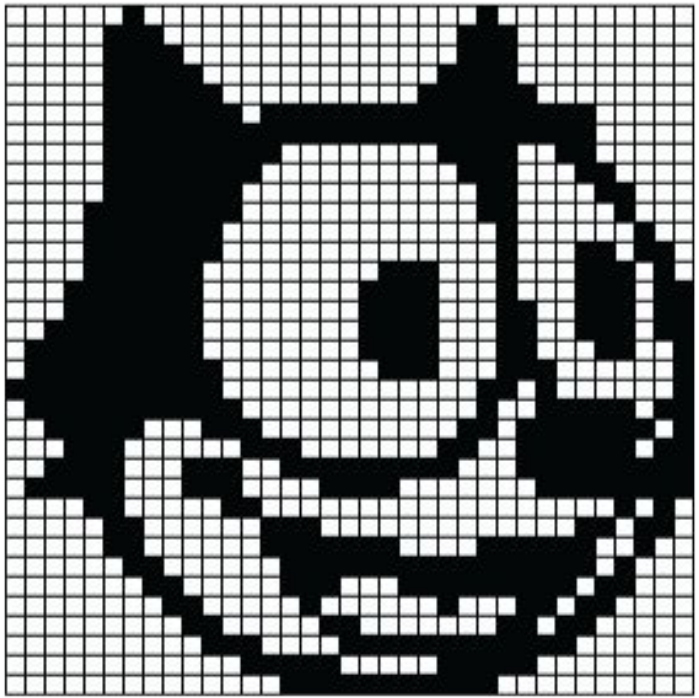
Cat

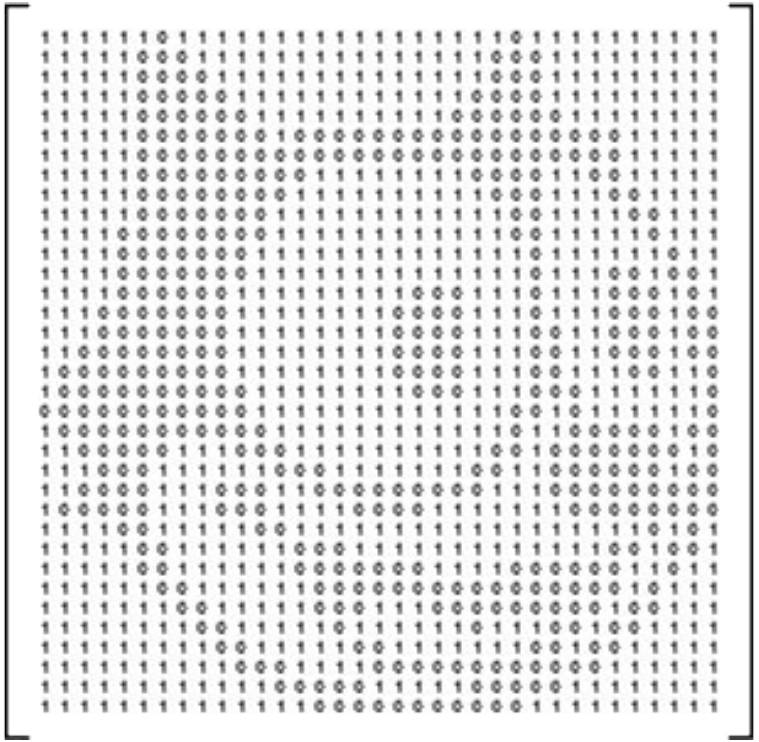
Dog

Dog

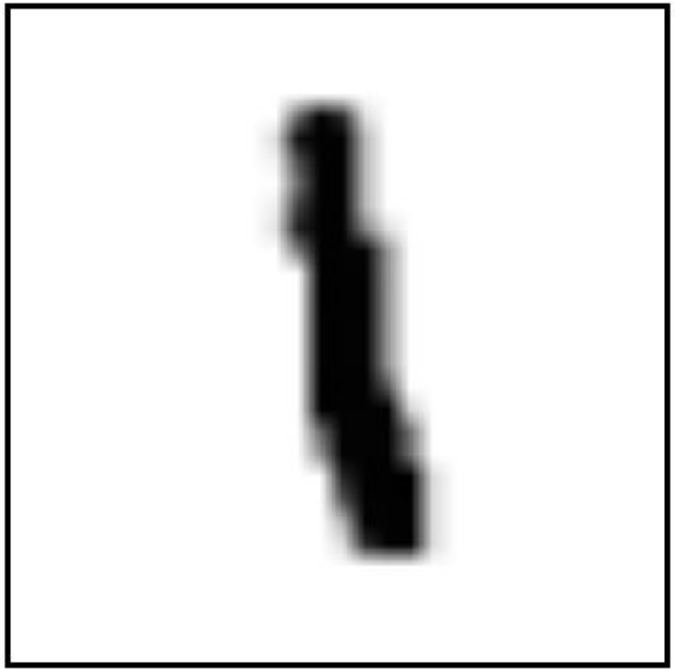
Features ??

Image?



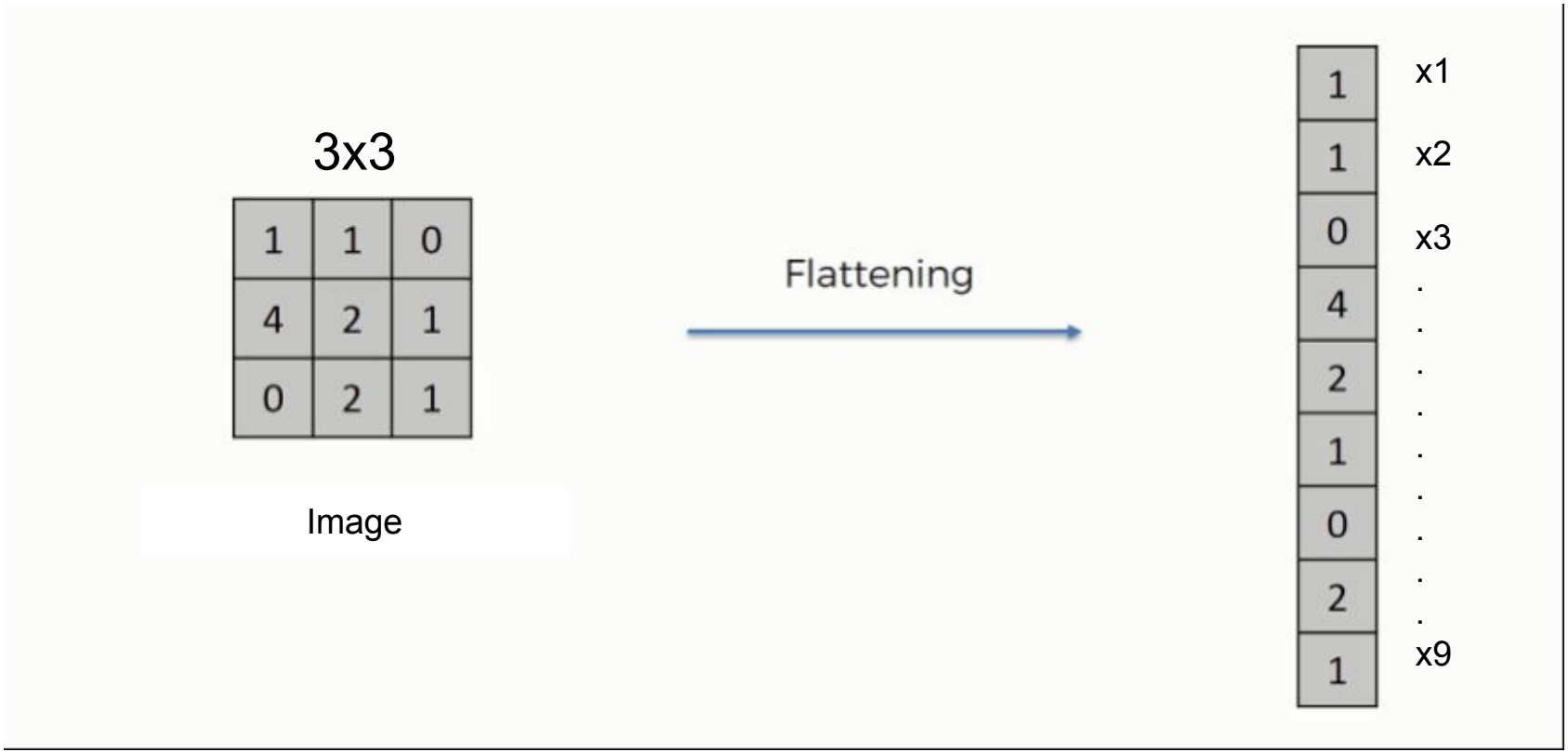


35x35

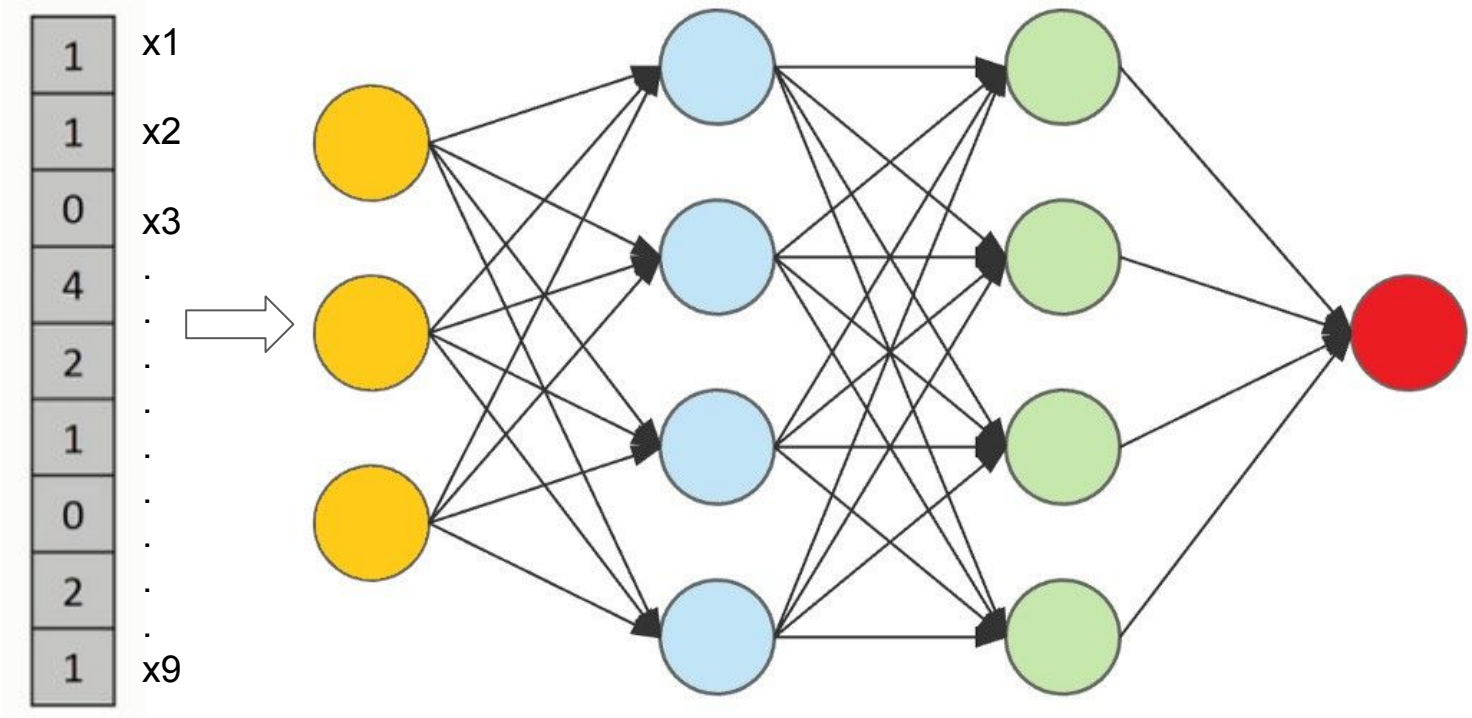


$\approx$

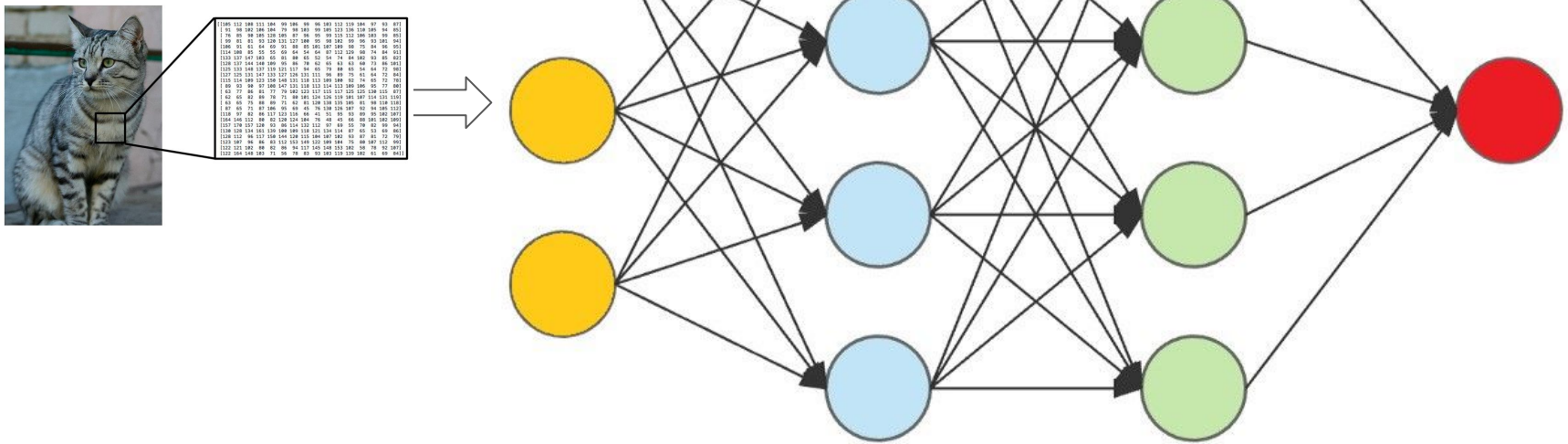
$$
\begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & .6 & .8 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & .7 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & .7 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & .5 & 1 & .4 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & .4 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & .4 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & .7 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & .9 & 1 & .1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & .3 & 1 & .1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
$$


3x3
1 1 0
4 2 1
0 2 1
Image
Flattening
1
1
0
4
2
1
0
2
1
x1
x2
x3
x9

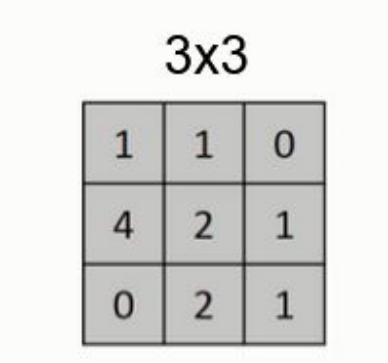
Pixels as Features



Pixels as Features



Problem with “Pixels as features”



3*3 = 9

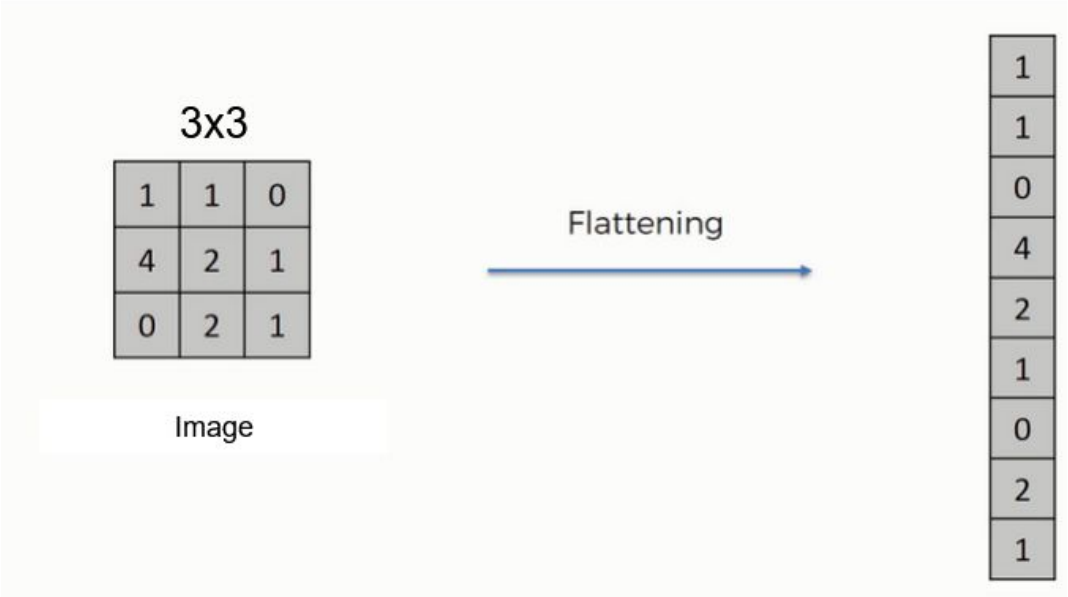
12x12 → 12*12 = 144

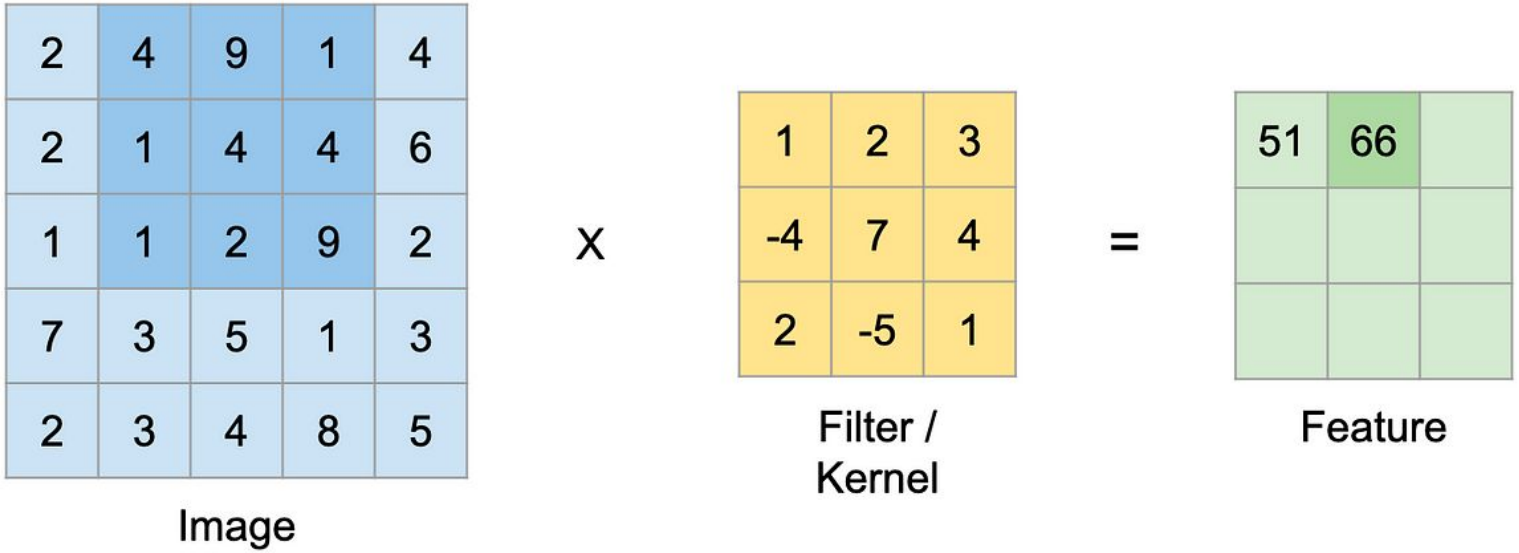
680x420 → 680*420 = 285,600

680x420x3 → 680*420*3 = 856,800

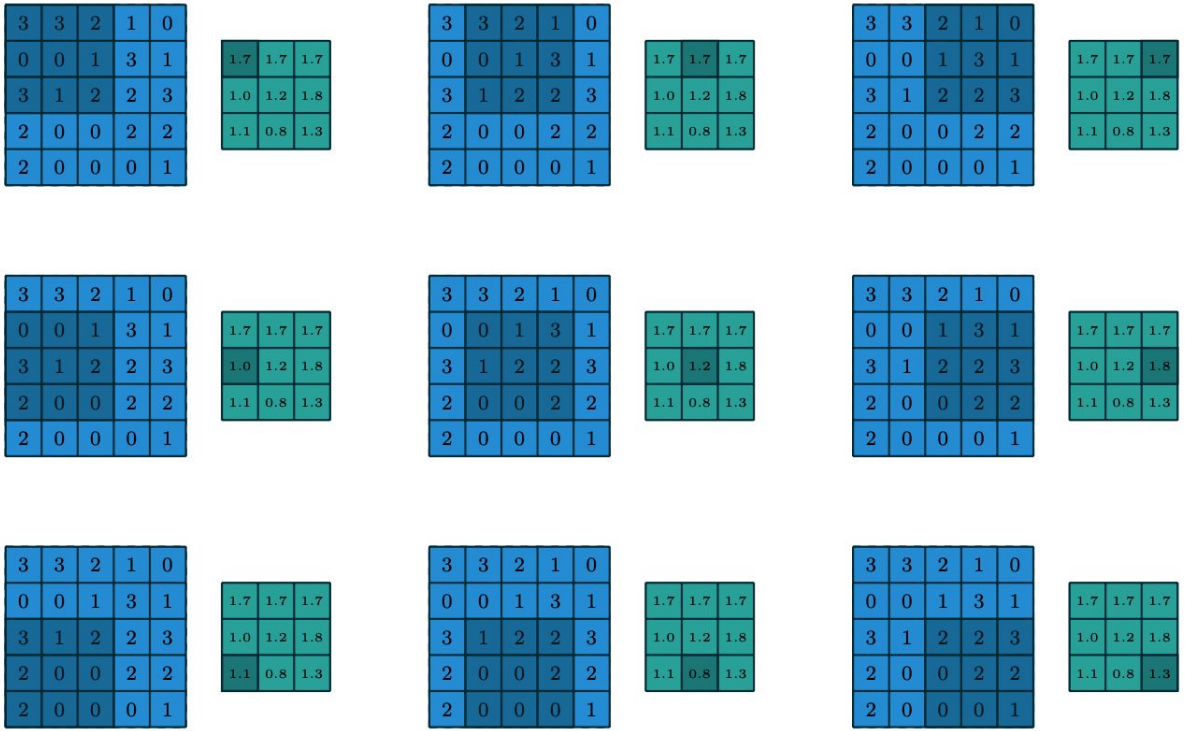
Problem with “Pixels as features”

No Structural Features

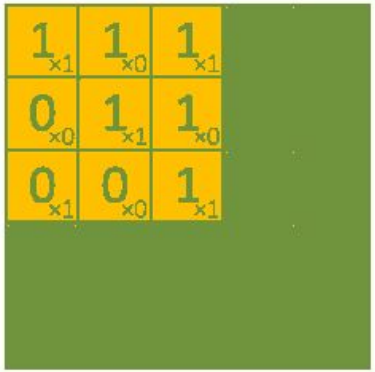



2 4 9 1 4
2 1 4 4 6
1 1 2 9 2
7 3 5 1 3
2 3 4 8 5
Image
X
1 2 3
-4 7 4
2 -5 1
Filter / Kernel
=
51 66
Feature

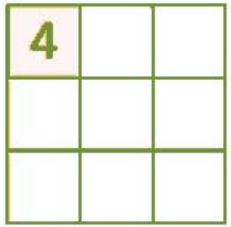
Convolution



Kernels



Image

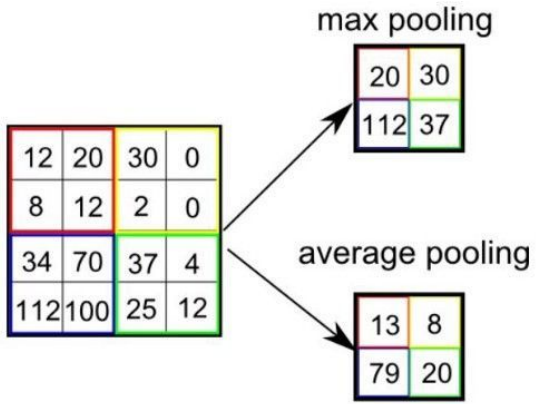


Convolved Feature

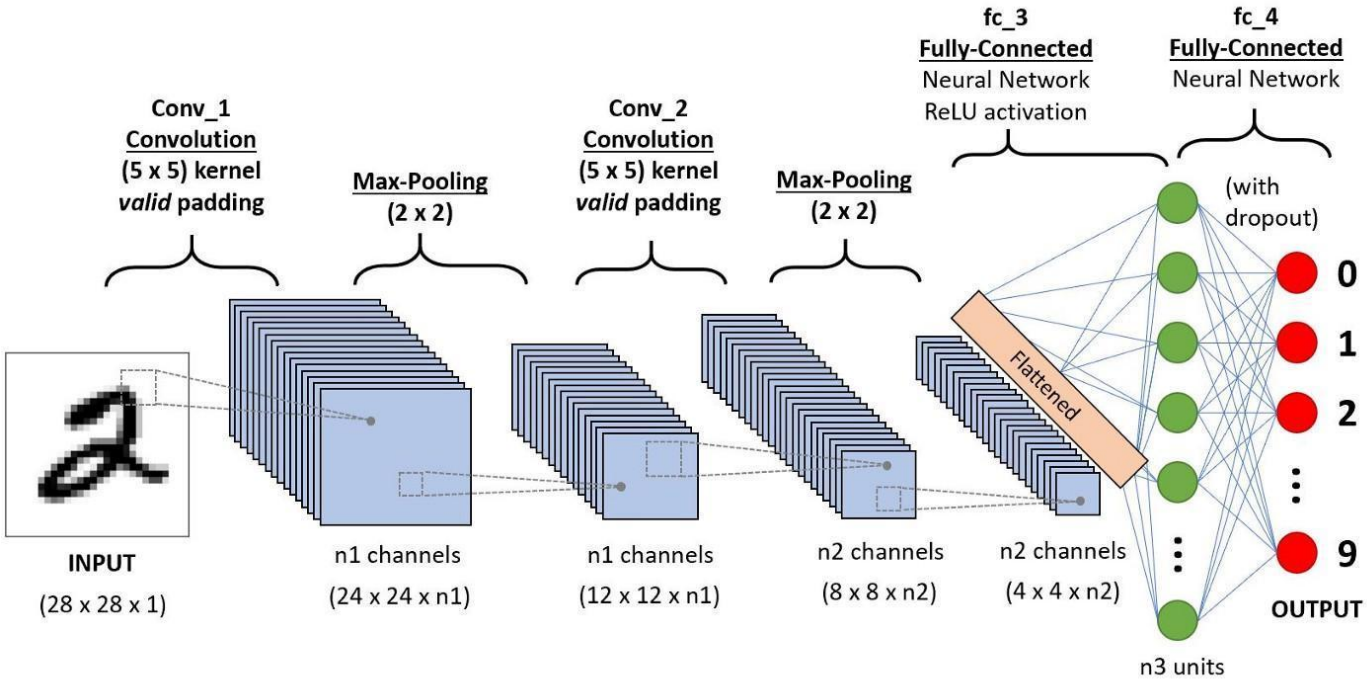
Operation	Filter	Convolved Image
Identity	$\begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$	
Edge detection	$\begin{bmatrix} 1 & 0 & -1 \\ 0 & 0 & 0 \\ -1 & 0 & 1 \end{bmatrix}$	
	$\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$	
	$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$	
Sharpen	$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix}$	
Box blur (normalized)	$\frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$	
Gaussian blur (approximation)	$\frac{1}{16}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$	

Pooling Layer

- Used for reducing the number of parameters in case of large images
- Also called Subsampling or Down sampling
- Retains major information
- Max pooling and average pooling are two types of pooling that are used



Architecture of CNNs



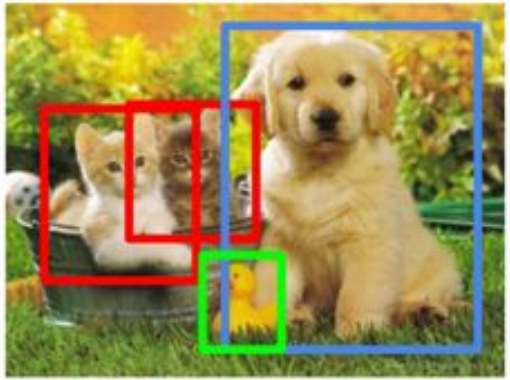
Classification

CAT

Classification + Localization

CAT

Object Detection



CAT, DOG, DUCK