

# Image Processing

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*Version 1.0*



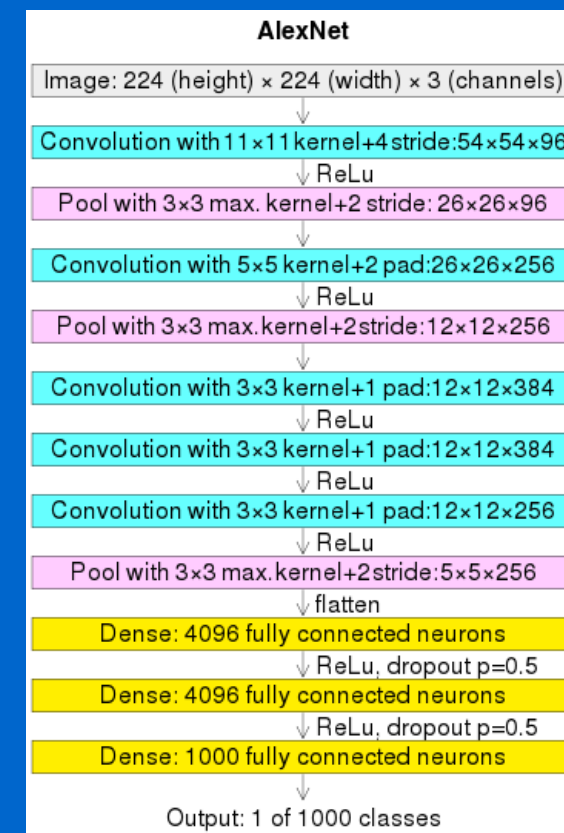
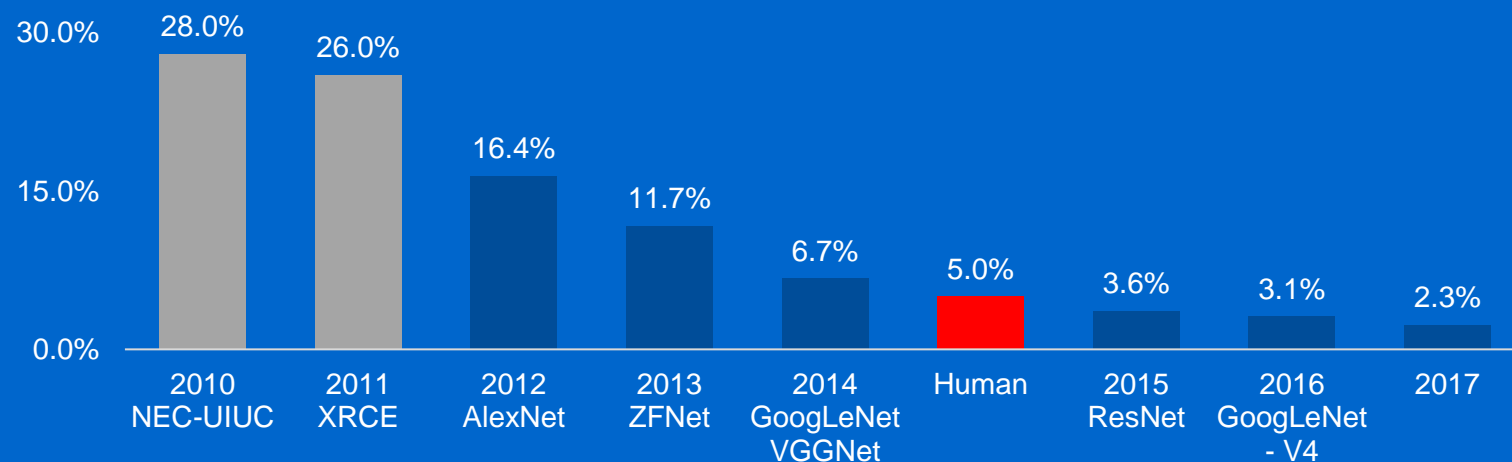
# Images are unstructured data

- A very high number of low information inputs
  - High number: 100x100 pixel image has 10K pixels!
  - Low information: Each pixel contains very little information about the image (e.g., objects)
- Deep learning networks are a breakthrough in image processing
  - Learn features from raw pixel data (e.g., edges)
  - “Deep” because it has many hidden layers. Networks with 100s of layers are common.



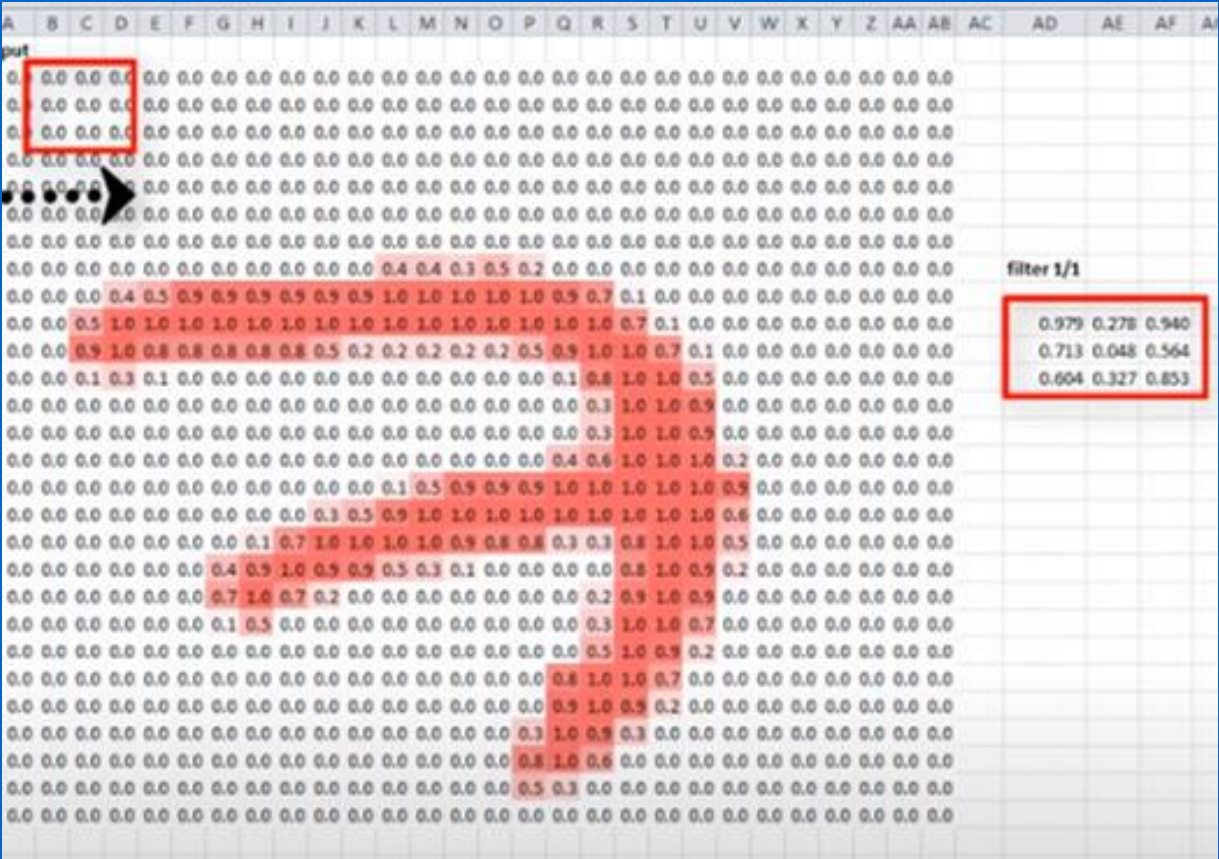
# AlexNet

- Breakthrough in image processing performance
- Announced at 2012 ImageNet Competition
- 2015: ResNet has over 100 layers!



# Convolutional Neural Network

Unlike traditional neurons, output is a matrix.



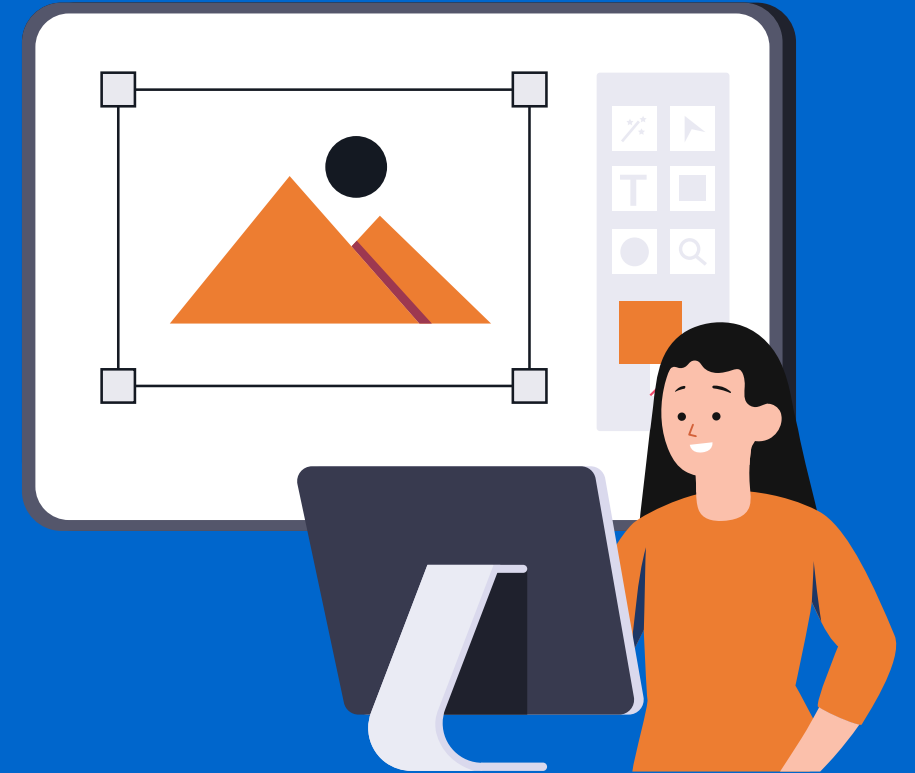
# A 'convolution' simply multiplies the pixels

Breakthrough: In the 1990s, the filter matrix was created by hand.  
Today, a CNN *learns* the weights.

<table><tbody><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td></tr></tbody></table>	0	1	0	0	1	0	0	1	0	x	<table><tbody><tr><td>25</td><td>200</td><td>25</td></tr><tr><td>25</td><td>225</td><td>25</td></tr><tr><td>25</td><td>225</td><td>25</td></tr></tbody></table>	25	200	25	25	225	25	25	225	25	$\begin{aligned} &0*25 + 1*200 + 0*25 + \\ &0*25 + 1*225 + 0*25 + \\ &0*25 + 1*225 + 0*25 \\ &= 650 \end{aligned}$
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Filter matrix that is good at identifying center vertical lines (we will see why shortly)		Pixel values	Sum = 650; this is higher than for any other arrangement of the filter matrix, because pixel values are highest in central column																		

# The convolution filter sweeps through the entire image

- The matrix moves across the image.
- A filter can detect local features such as: horizontal lines, curves, borders.
- These local features can then be passed on to further convolutional layers which can then build global features: bird's legs, texture.



# Pooling layer

- Downsamples convolutional layer
- Most common types
  - Max pooling
  - Average pooling

