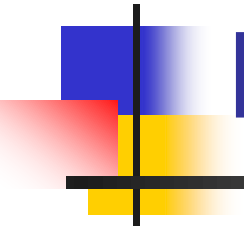
Convolutional Neural Network



Dr. Ash Pahwa

OC R User's Group

September 24, 2019

Bio: Dr. Ash Pahwa

- Ph.D. Computer Science
- Website: www.AshPahwa.com
- Affiliation
  - California Institute of Technology, Pasadena
  - UC Irvine
  - UCLA
  - UCSD
  - Chapman University: Adjunct
- Field of Expertise
  - Machine Learning, Deep Learning, Digital Image Processing, Database Management, CD-ROM/DVD
- Worked for
  - General Electric, AT&T Bell Laboratories, Oracle, UC Santa Barbara

Caltech Course

Deep Learning with TensorFlow

SCHEDULE

Classes are held Saturdays, 8:00 AM to 5:00 PM, on the Caltech campus in Pasadena, California.

	Spring 2019	Add to Cart
Deep Learning with TensorFlow	April 6, 13, 20	Register

INSTRUCTOR

Ash Pahwa, PhD

What are you looking at?

What are you seeing?

Who are you going to Believe? Me or your own eyes

Groucho Marx

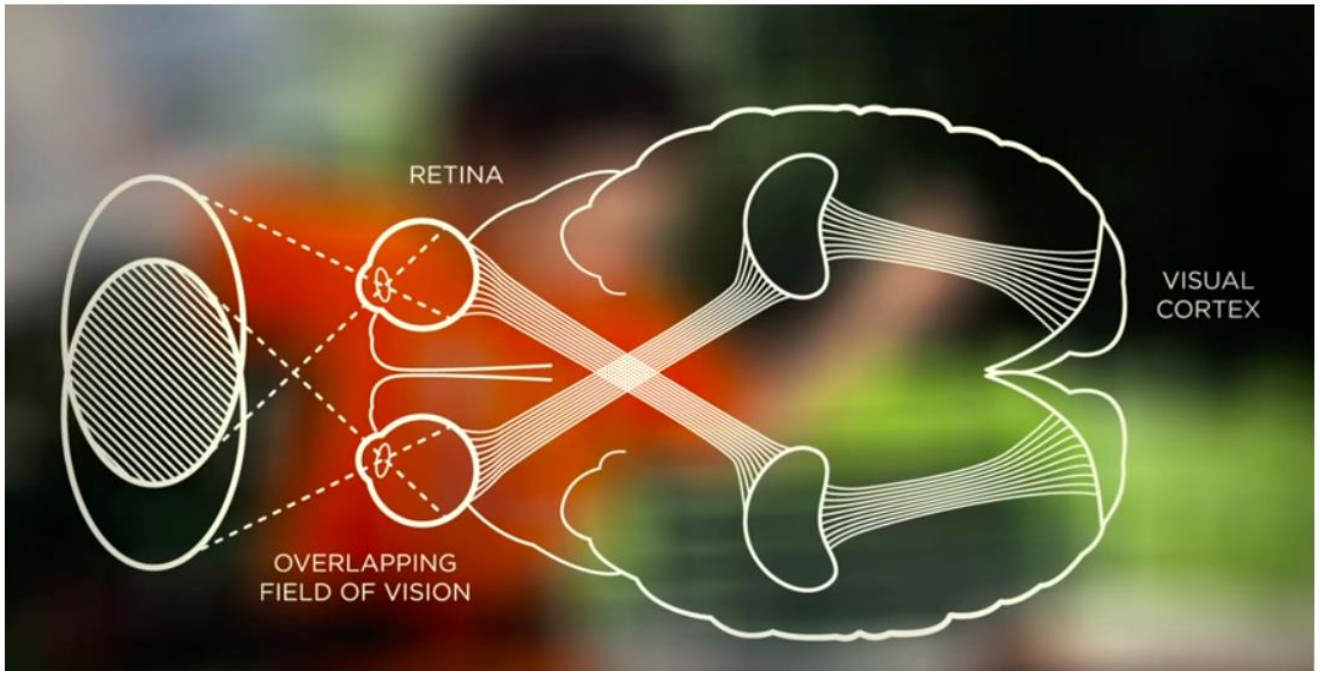
https://www.youtube.com/watch?v=cHxGUe1cjzM

What are you looking at?

What are you seeing?

Human Vision
* Eyes + Brain to Understand Images

Autonomous Cars
* Camera + Neural Networks with Deep Learning



Hubel & Wiesel

- 1960 - 1970
- Experimented with the Visual Systems of cats
- Cats retina responded to stripes but not on spots
- Biological visual system respond to edges
- John Hopkins School of Medicine
- Noble prize in Physiology in 1981

David H. Hubel

Torsten Wiesel (left) and Hubel (right), co-recipients of the 1981 Nobel Prize in Physiology or Medicine for their discoveries concerning information processing in the visual system, 1980

Born	David Hunter Hubel February 27, 1926 Windsor, Ontario, Canada
Died	September 22, 2013 (aged 87) Lincoln, Massachusetts, US
Nationality	American-Canadian[1]
Alma mater	McGill University
Known for	Visual system
Spouse(s)	Ruth Izzard (m. 1953)
Awards	Louisa Gross Horwitz Prize (1978) Dickson Prize (1980) Nobel Prize in Physiology or Medicine (1981) ForMemRS (1982)[2][3]
Scientific career	
Fields	Neurophysiologist
Institutions	Johns Hopkins School of Medicine Harvard University

Torsten Wiesel

At a conference in 2011

Born	Torsten Nils Wiesel 3 June 1924 (age 93) Uppsala, Sweden
Nationality	Swedish
Alma mater	Karolinska Institute
Known for	Visual system
Spouse(s)	Lizette Mususa Reyes (m. 2008) Jean Stein (m. 1995; div. 2007) Ann Yee (m. 1973; div. 1981) Teeri Stenhammar (m. 1956; div. 1970)
Awards	Louisa Gross Horwitz Prize (1978) Dickson Prize (1980) Nobel Prize in Physiology or Medicine (1981)[1] ForMemRS (1982)[2][3] National Medal of Science[4] (2005)
Scientific career	
Institutions	Johns Hopkins School of Medicine Rockefeller University Harvard University

The Nobel Prize in Physiology or Medicine 1981

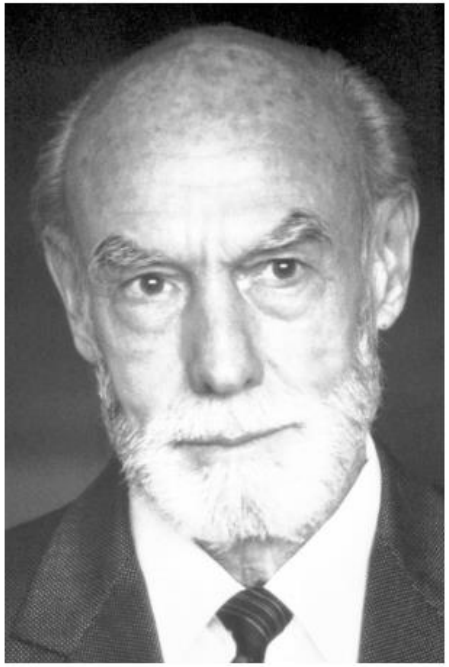


Photo from the Nobel Foundation archive.

Roger W. Sperry

Prize share: 1/2

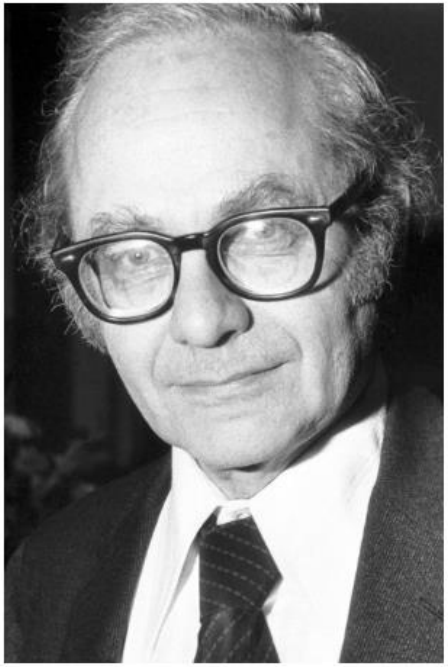


Photo from the Nobel Foundation archive.

David H. Hubel

Prize share: 1/4

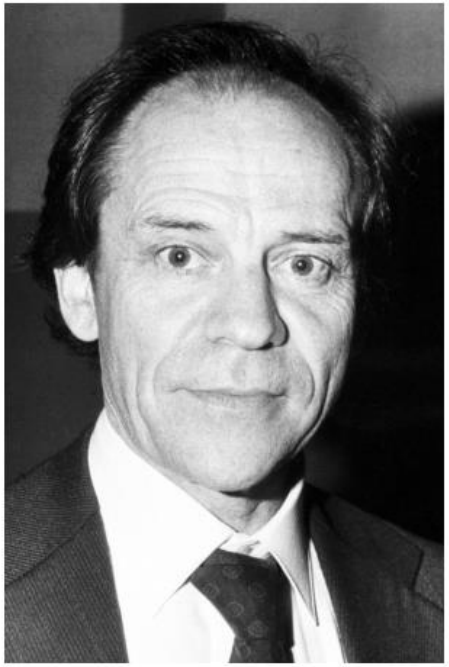


Photo from the Nobel Foundation archive.

Torsten N. Wiesel

Prize share: 1/4

Cat Experiment

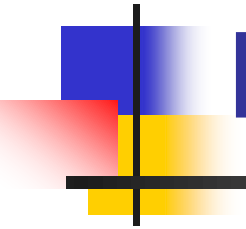
- Hubel and Wiesel Cat Experiment
- https://www.youtube.com/watch?v=IOHayh06LJ4

Professor Hubel
Harvard Medical School

- Hubel & Wiesel 1: Intro
- https://www.youtube.com/watch?v=y_l4kQ5wjiw

Edge Detection by Eye

- Hubel & Wiesel - Cortical Neuron - V1
- https://www.youtube.com/watch?v=8VdFf3egwfg

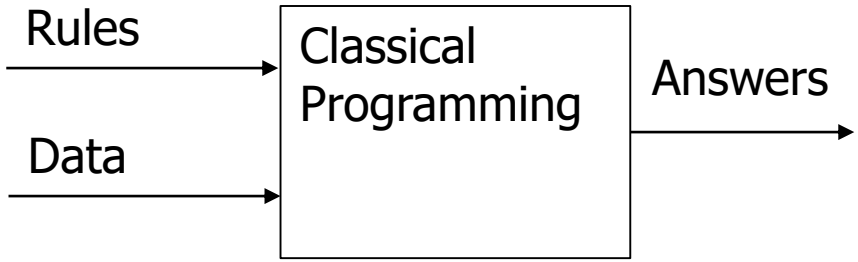


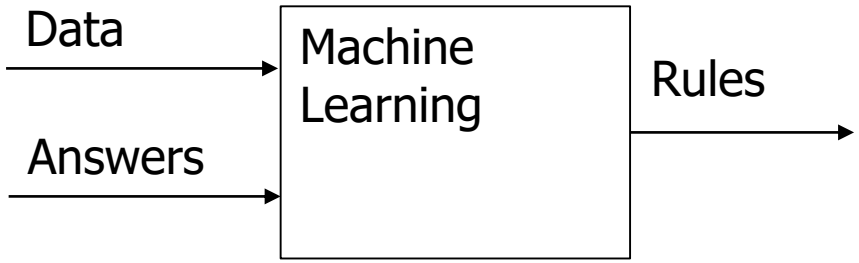
Machine Learning and Deep Learning

Neural Networks

Problems that can use Neural Networks

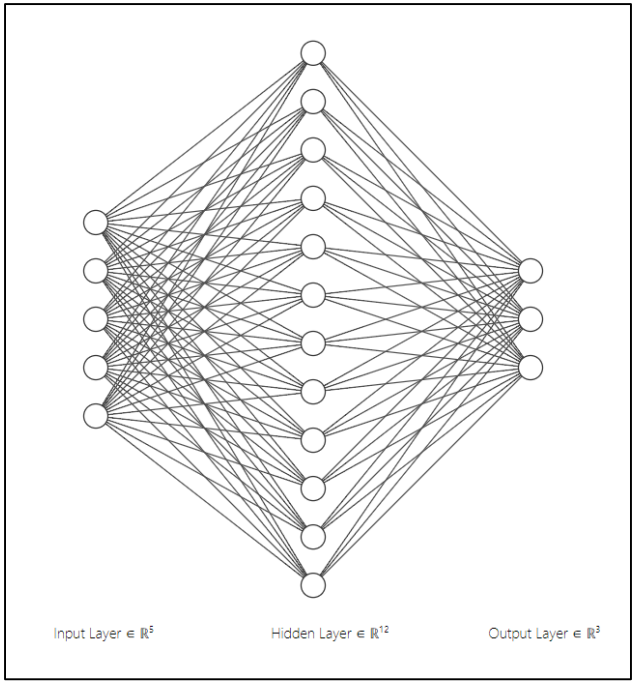
- For simple problems we can define the rules
  - We can automate the process
  - Write software
- For complex problems
  - We cannot define the rules
  - Object recognition in an image
- To solve these types of problems
  - We provide data and the answers
  - System will create the rules





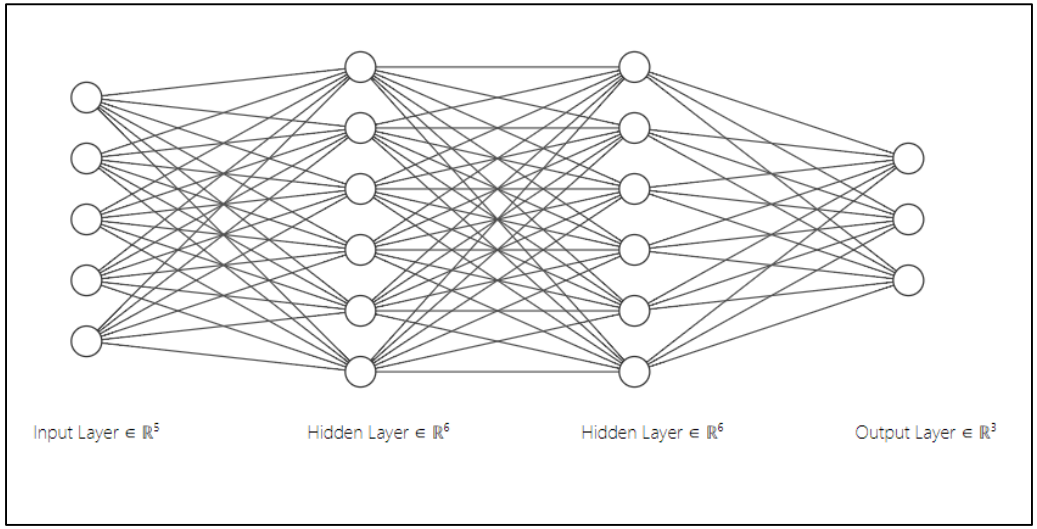
Shallow and Deep NN

Shallow Neural Network



Input layer: 5 nodes
Hidden layer: 12 nodes
Output layer: 3 nodes

Deep Neural Network

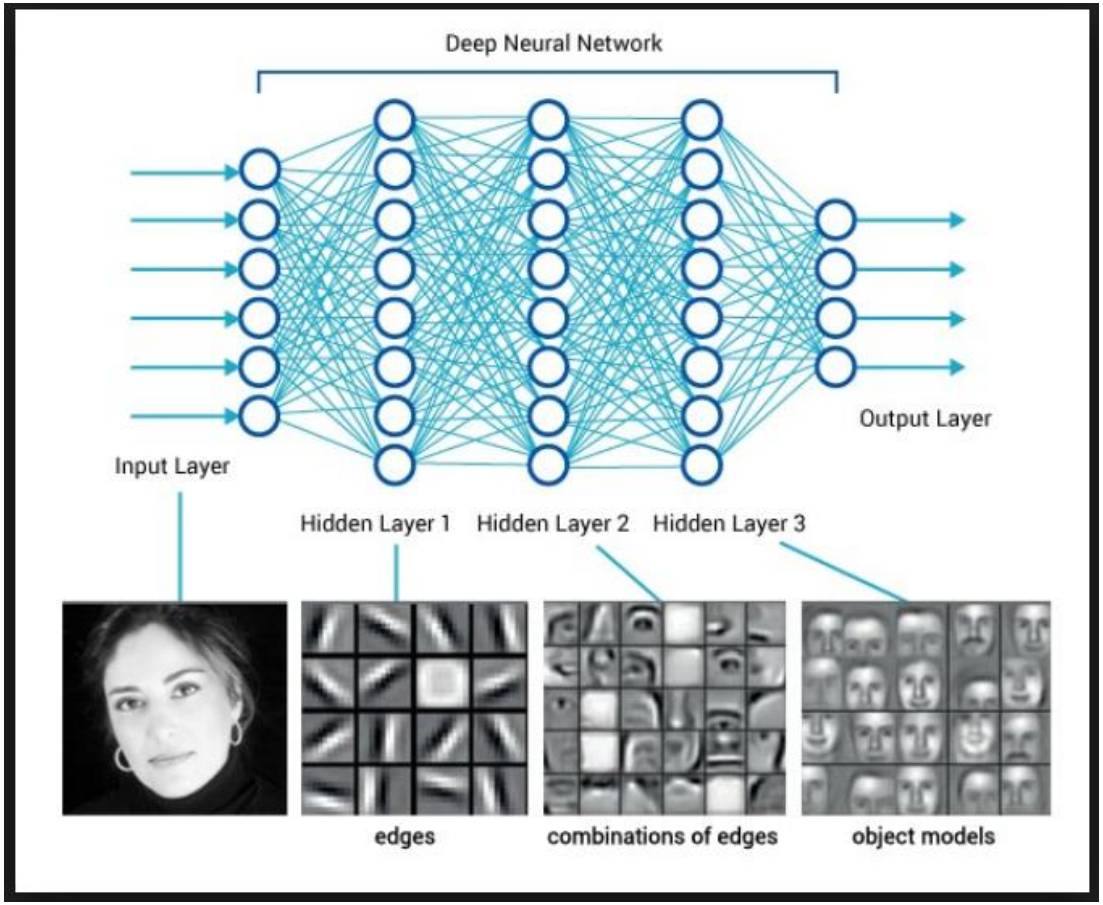


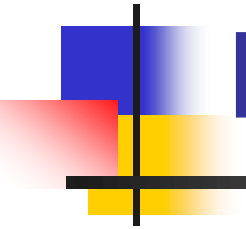
Input layer: 5 nodes
Hidden layer 1: 6 nodes
Hidden layer 2: 6 nodes
Output layer: 3 nodes

More layers usually provides more efficient and accurate representation of data

Deep Neural Network

- Every layer of the DNN allows a more sophisticated build-up
  - From simple elements
  - To more complex ones





Motivations for CNN

Convolutional Neural Network

Neocognitron
Developer of Convolution Neural Network
K. Fukushima

- Neocognitron: Artificial Neural Network : 1980
- Kunihiko Fukushima received a B.Eng. degree in electronics in 1958 and a PhD degree in electrical engineering in 1966 from Kyoto University, Japan.
- Professor
  - Osaka University
  - University of Electro-Communications
  - Tokyo University of Technology
  - Kansai University

Kunihiko Fukushima

Senior Research Scientist, Fuzzy Logic Systems Institute (Iizuka, Fukuoka, Japan)
E-mail: fukushima@m.ieice.org

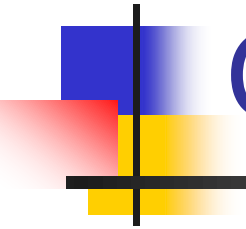
Turing Award: 2019: Announced on March 27, 2019

Artificial-intelligence pioneers win $1 million Turing Award

From left, computer scientists Yoshua Bengio, Geoffrey Hinton and Yann LeCun were awarded the 2018 Turing Award for their work on neural networks. (Maryse Boyce; Keith Penner; Facebook/Association for Computing Machinery)

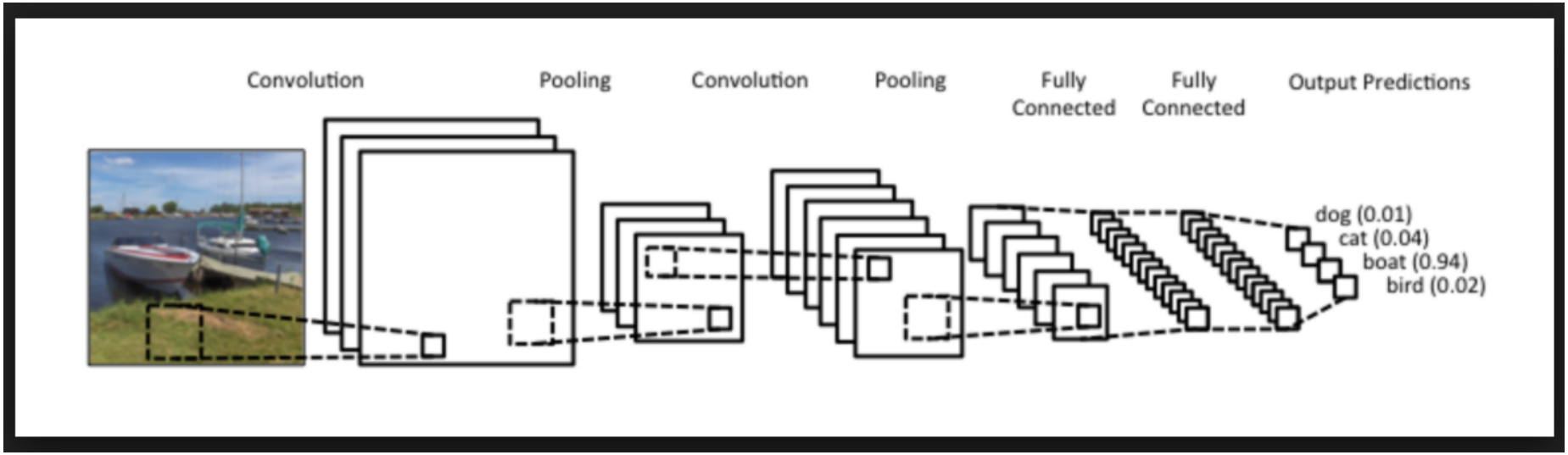
Birth of Deep Learning BigData

- Fei-Fei Li (Stanford) created ImageNet
  - Contains 14 million images of 20,000 categories
- These images were classified by Mechanical Turk workers on Amazon
- For pennies per image, labeled each one



Convolution Operation

Convolution Neural Network



Input Image / Filter
Output Image

a_{00}	a_{01}	a_{02}	a_{03}	a_{04}	a_{05}
a_{10}	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}
a_{20}	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}
a_{30}	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}
a_{40}	a_{41}	a_{42}	a_{43}	a_{44}	a_{45}
a_{50}	a_{51}	a_{52}	a_{53}	a_{54}	a_{55}

f_{00}	f_{01}	f_{02}
f_{10}	f_{11}	f_{12}
f_{20}	f_{21}	f_{22}

$m \times n = 3 \times 3$

c_{00}	c_{01}	c_{02}	c_{03}	c_{04}	c_{05}
c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}
c_{20}	c_{21}	c_{22}	c_{23}	c_{24}	c_{25}
c_{30}	c_{31}	c_{32}	c_{33}	c_{34}	c_{35}
c_{40}	c_{41}	c_{42}	c_{43}	c_{44}	c_{45}
c_{50}	c_{51}	c_{52}	c_{53}	c_{54}	c_{55}

Spatial Filtering

a_{00} f_{00}	a_{01} f_{01}	a_{02} f_{02}	a_{03}	a_{04}	a_{05}
a_{10} f_{10}	a_{11} f_{11}	a_{12} f_{12}	a_{13}	a_{14}	a_{15}
a_{20} f_{20}	a_{21} f_{21}	a_{22} f_{22}	a_{23}	a_{24}	a_{25}
a_{30}	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}
a_{40}	a_{41}	a_{42}	a_{43}	a_{44}	a_{45}
a_{50}	a_{51}	a_{52}	a_{53}	a_{54}	a_{55}

c11 =
(f00 * a00) +
(f01 * a01) +
(f02 * a02) +
(f10 * a10) +
(f11 * a11) +
(f12 * a12) +
(f20 * a20) +
(f21 * a21) +
(f22 * a22)

Spatial Filtering

a_{00}	a_{01}	a_{02}	a_{03}	a_{04}	a_{05}
a_{10}	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}
a_{20}	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}
a_{30}	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}
a_{40}	a_{41}	a_{42}	a_{43}	a_{44}	a_{45}
a_{50}	a_{51}	a_{52}	a_{53}	a_{54}	a_{55}

f_{00} f_{01} f_{02}
f_{10} f_{11} f_{12}
f_{20} f_{21} f_{22}

c12 =
(f00 * a01) +
(f01 * a02) +
(f02 * a03) +
(f10 * a11) +
(f11 * a12) +
(f12 * a13) +
(f20 * a21) +
(f21 * a22) +
(f22 * a23)

Example - Input Image / Filter

1	4	6	10	14	12
18	20	26	25	13	10
6	5	4	3	1	2
2	4	5	10	12	26
38	25	49	24	26	30
2	40	36	44	25	13

1	2	1
2	4	2
1	2	1

m x n = 3 x 3

Example - Output Image

1	4	6	10	14	12
18	20	26	25	13	10
6	5	4	3	1	2
2	4	5	10	12	26
38	25	49	24	26	30
2	40	36	44	25	13

Input Image

1	2	1
2	4	2
1	2	1

Filter

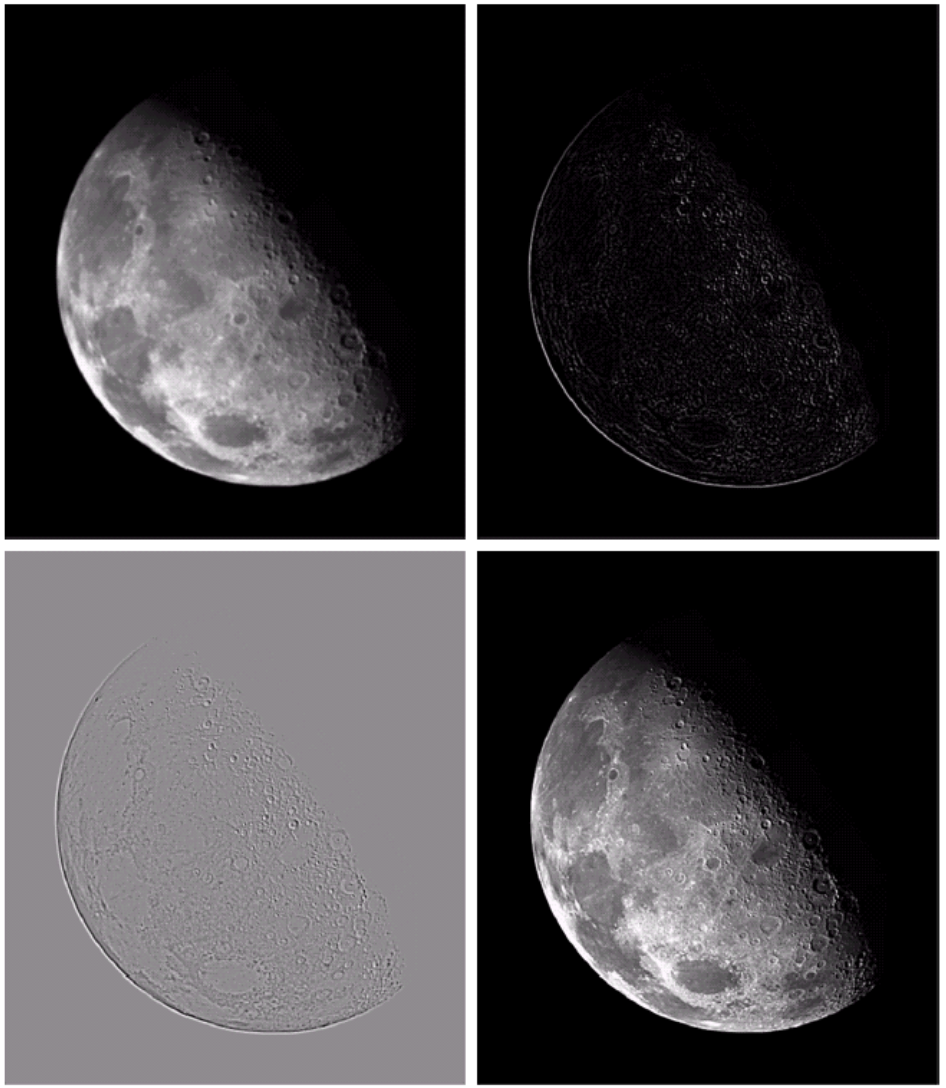
?	?	?	?	?	?
?	*203*	*236*	*229*	*179*	?
?	*139*	*153*	*148*	*135*	?
?	*187*	*211*	*208*	*233*	?
?	*407*	*474*	*432*	*379*	?
?	?	?	?	?	?

Output Image

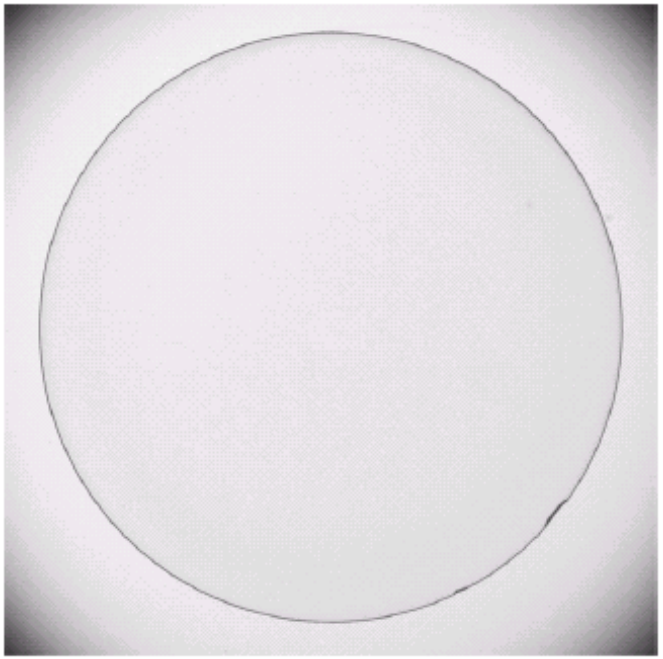
Laplacian Filter

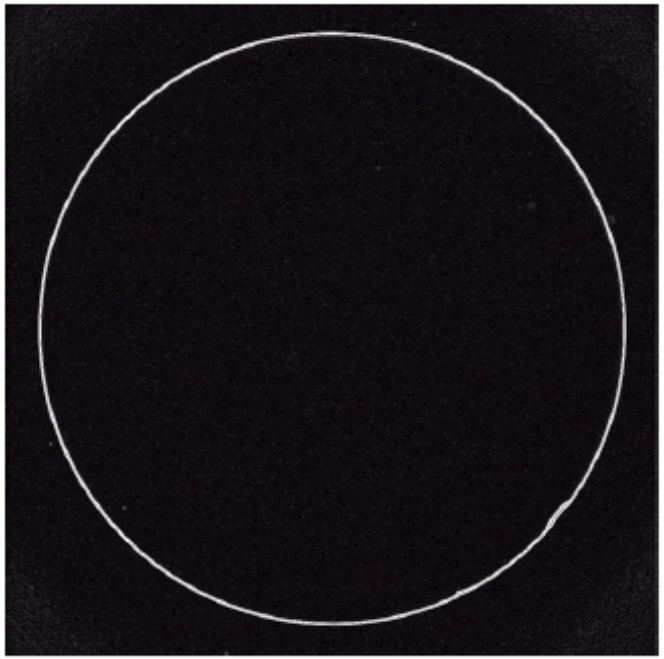
a b
c d

FIGURE 3.40
(a) Image of the North Pole of the moon.
(b) Laplacian-filtered image.
(c) Laplacian image scaled for display purposes.
(d) Image enhanced by using Eq. (3.7-5).
(Original image courtesy of NASA.)



Example: Sobel Filter





a b

FIGURE 3.45 Optical image of contact lens (note defects on the boundary at 4 and 5 o'clock). (b) Sobel gradient. (Original image courtesy of Mr. Pete Sites, Perceptics Corporation.)

Max Pooling

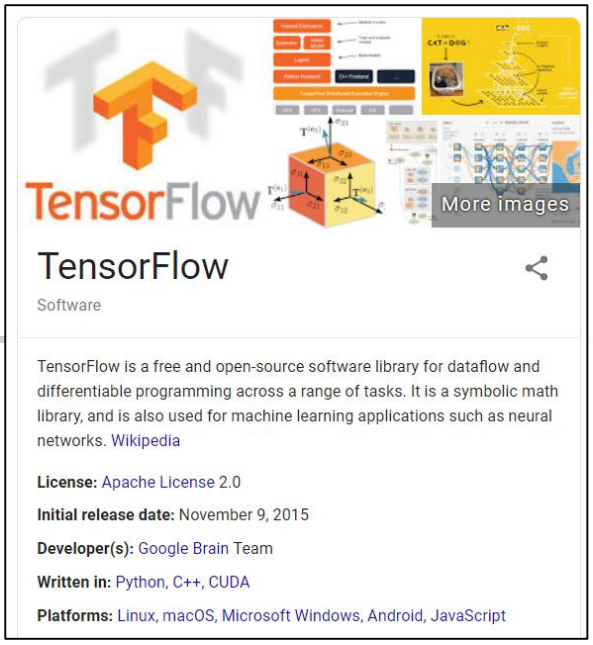
- Image Size = 4x4
- Filter size = 2x2
- Stride = 2

1	3	2	1
2	9	1	1
1	3	2	3
5	6	1	2

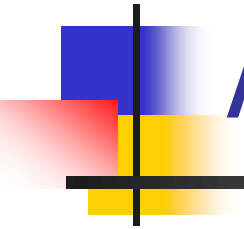
9	2
6	3

Tools for Deep Learning

- Backend
  - TensorFlow (Google)
  - Scikit-Learn (Google)
  - Theano (Univ of Montreal)
  - CNTK (Microsoft)
  - Torch + PyTorch (Facebook)
  - Caffe (UC Berkeley)
  - H2O

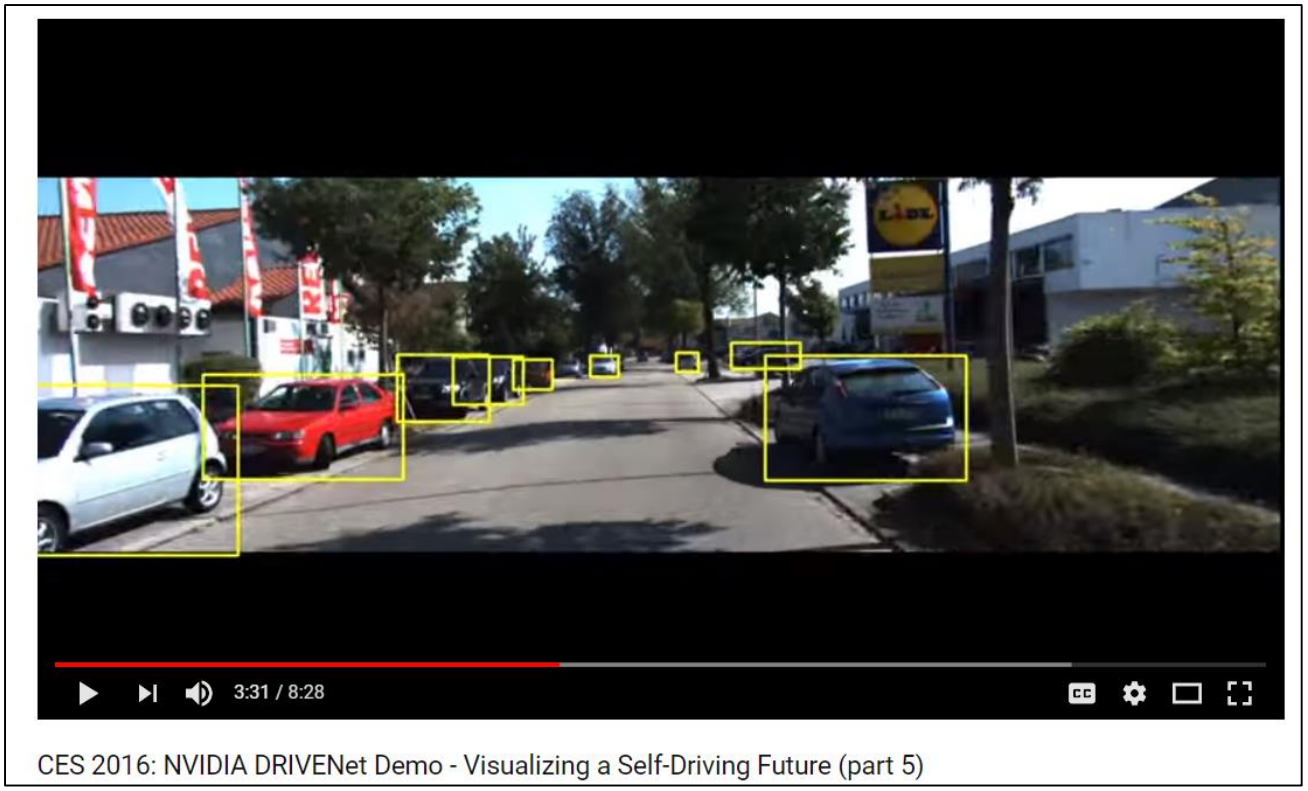


- Frontend
  - R
  - Keras/R
  - Python
  - Keras/Python
  - Apache MXNet (Amazon)



Applications of CNN

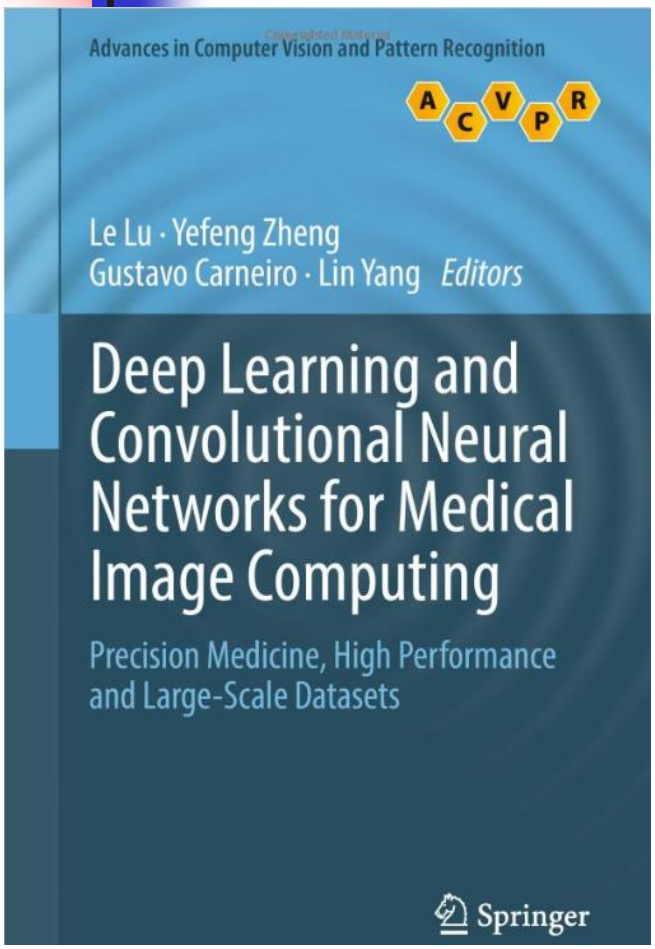
Nvidia
Video of Object Detection



- https://www.youtube.com/watch?v=HJ58dbd5g8g

Level 5 Autonomous Car

Deep Learning in Medical Image Computing



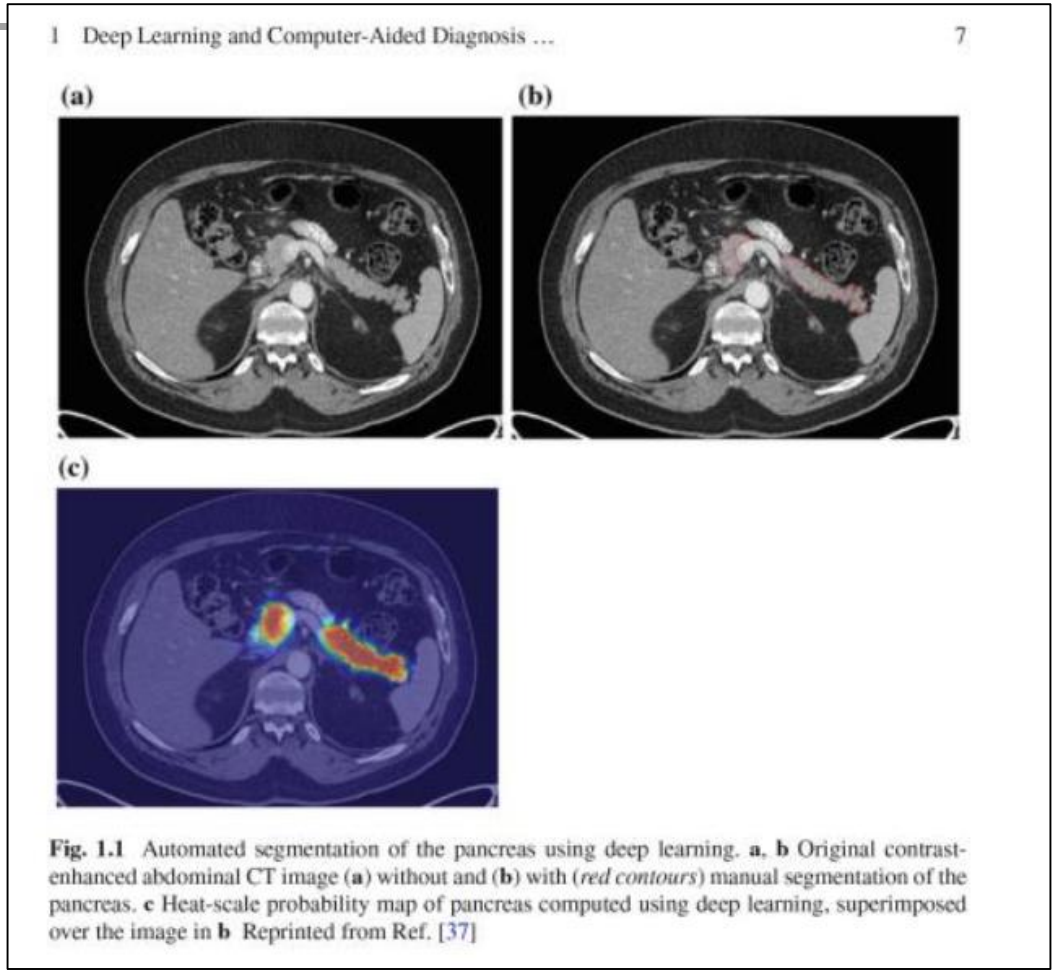


Fig. 1.1 Automated segmentation of the pancreas using deep learning. **a**, **b** Original contrast-enhanced abdominal CT image (**a**) without and (**b**) with (*red contours*) manual segmentation of the pancreas. **c** Heat-scale probability map of pancreas computed using deep learning, superimposed over the image in **b** Reprinted from Ref. [37]