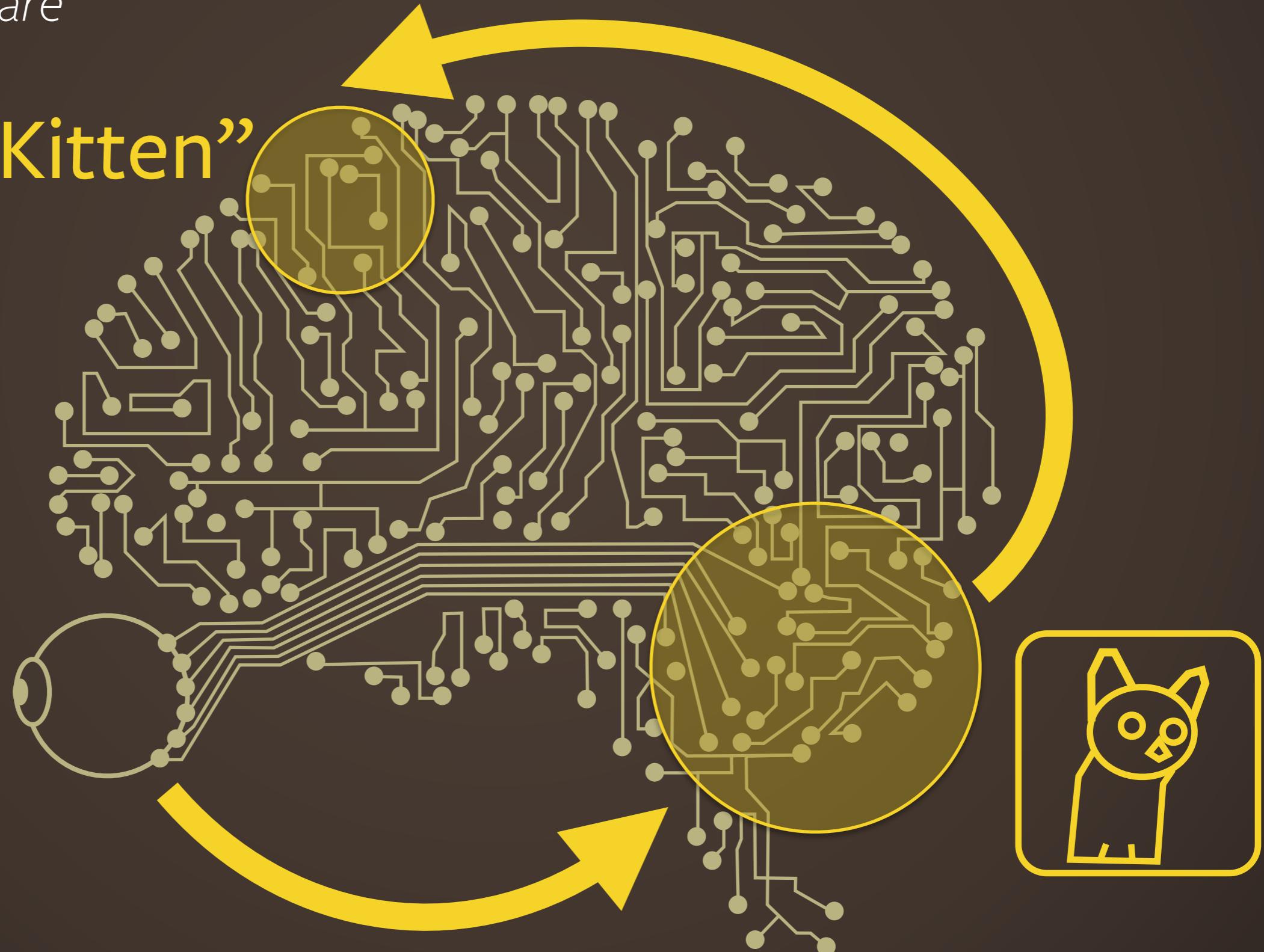


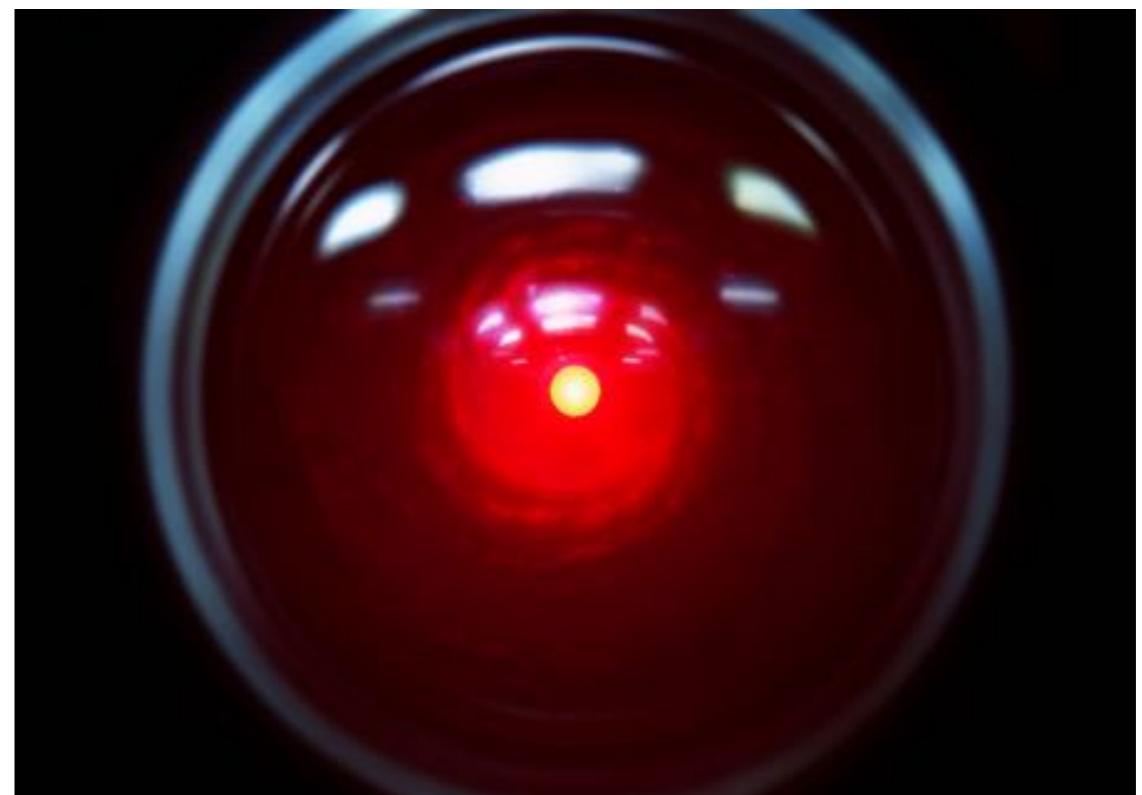
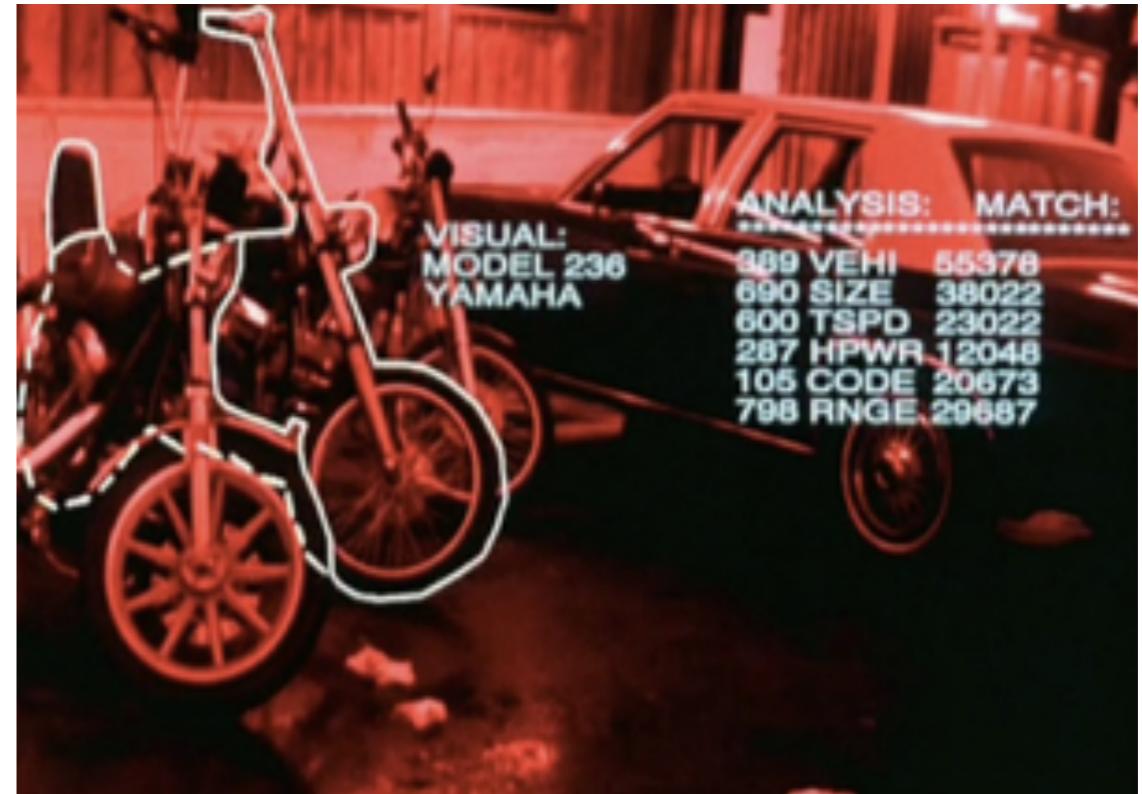
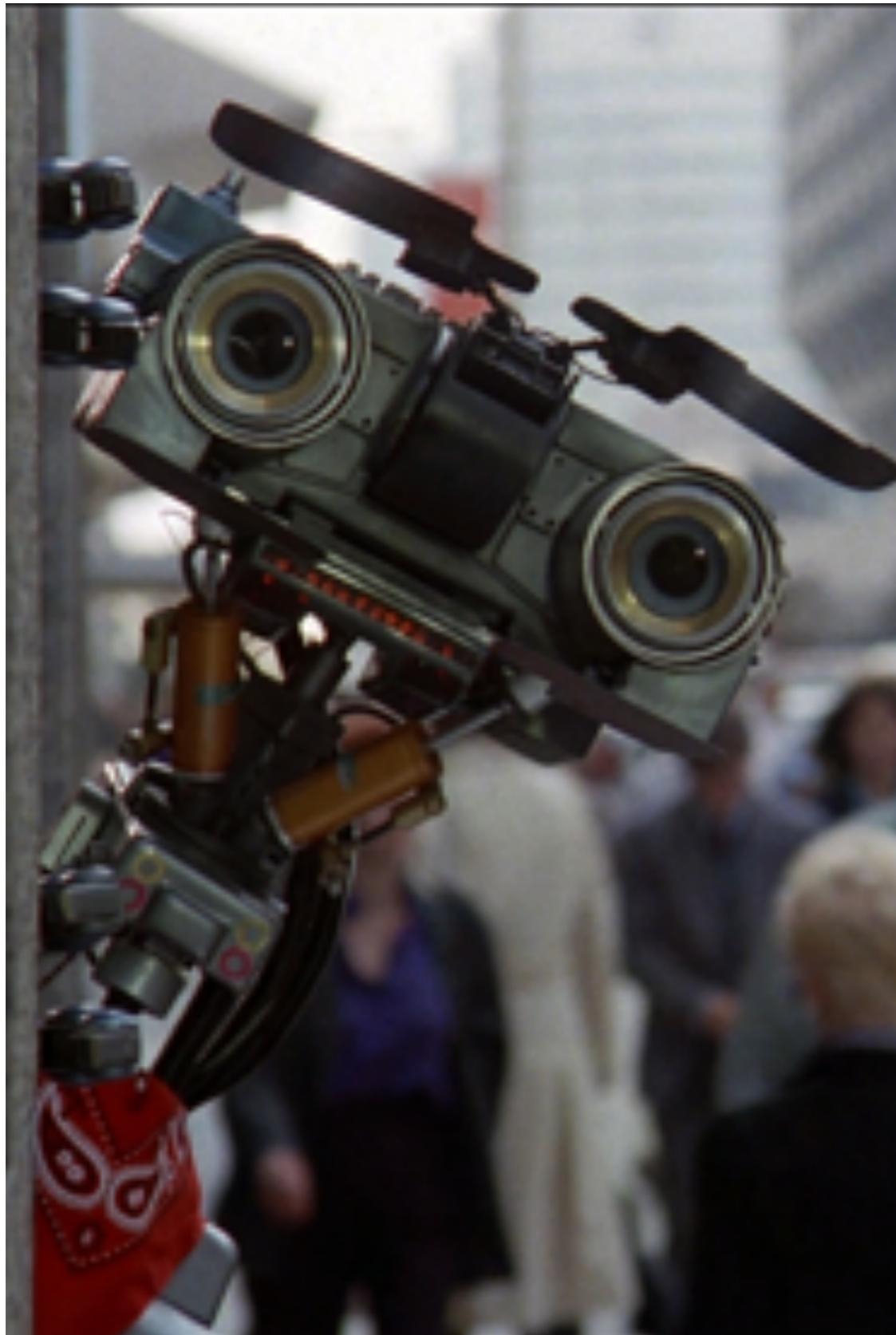
Teaching machines to see

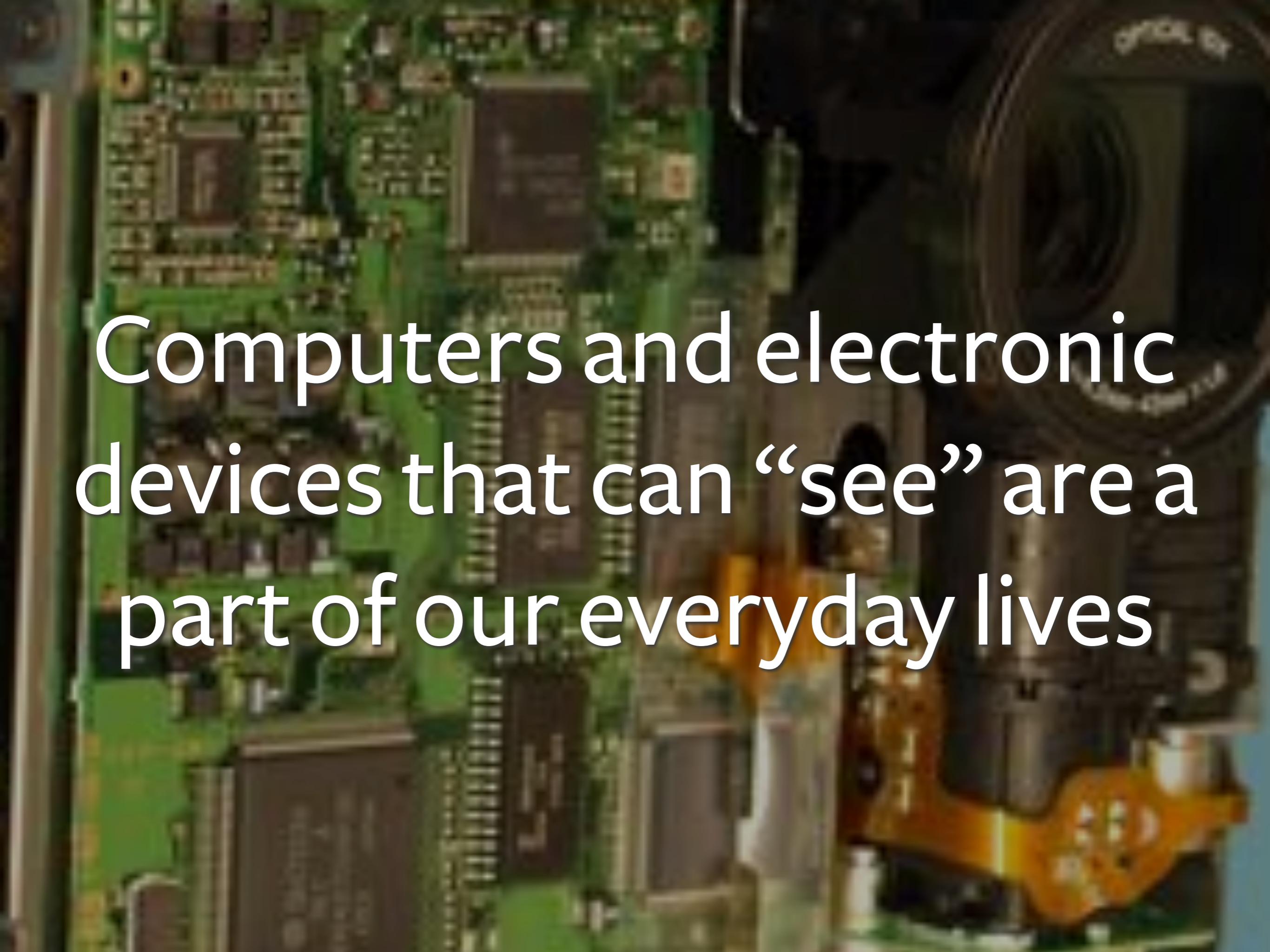
Dr Jonathon Hare



“Kitten”







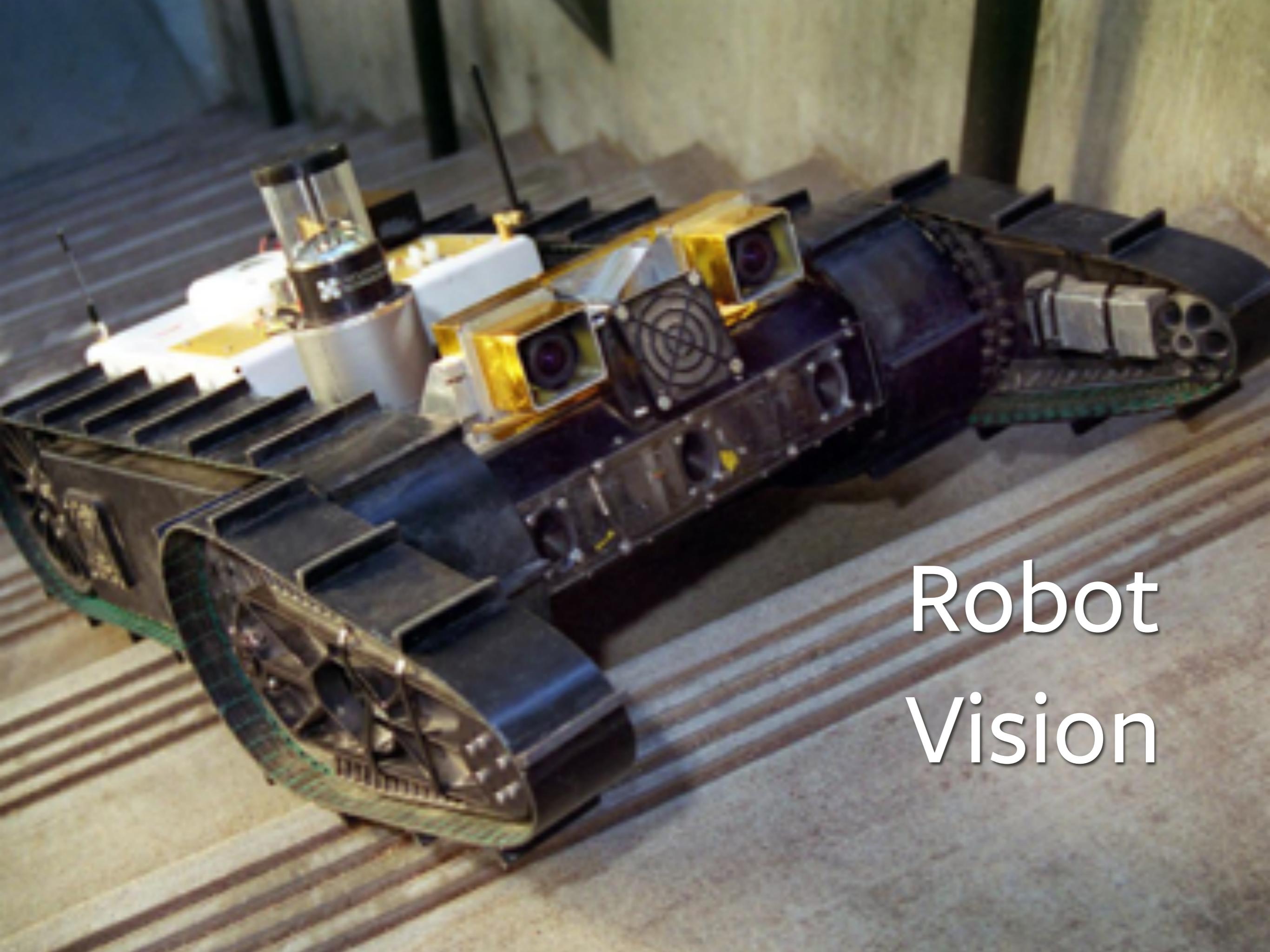
Computers and electronic devices that can “see” are a part of our everyday lives



Industrial Vision







Robot
Vision



<http://vimeo.com/39404736>



Digital Image Processing

AI AND THE EYE

- COMPUTER VISION AS IMAGE PROCESSING
INFORMATION
- FROM SCENES TO OBJECTS
RECOGNITION AND UNDERSTANDING
- III MACHINE LEARNING
- Practical Implementations in Computer Vision
- PRACTICAL DIGITAL IMAGE PROCESSING
- ARTIFICIAL INTELLIGENCE METHODS
- Artificial Intelligence: An Integrating Approach
- Introduction to UNIX and Linux
- Applied Numerical Methods for Digital Computation
- Data Structures and C Programs

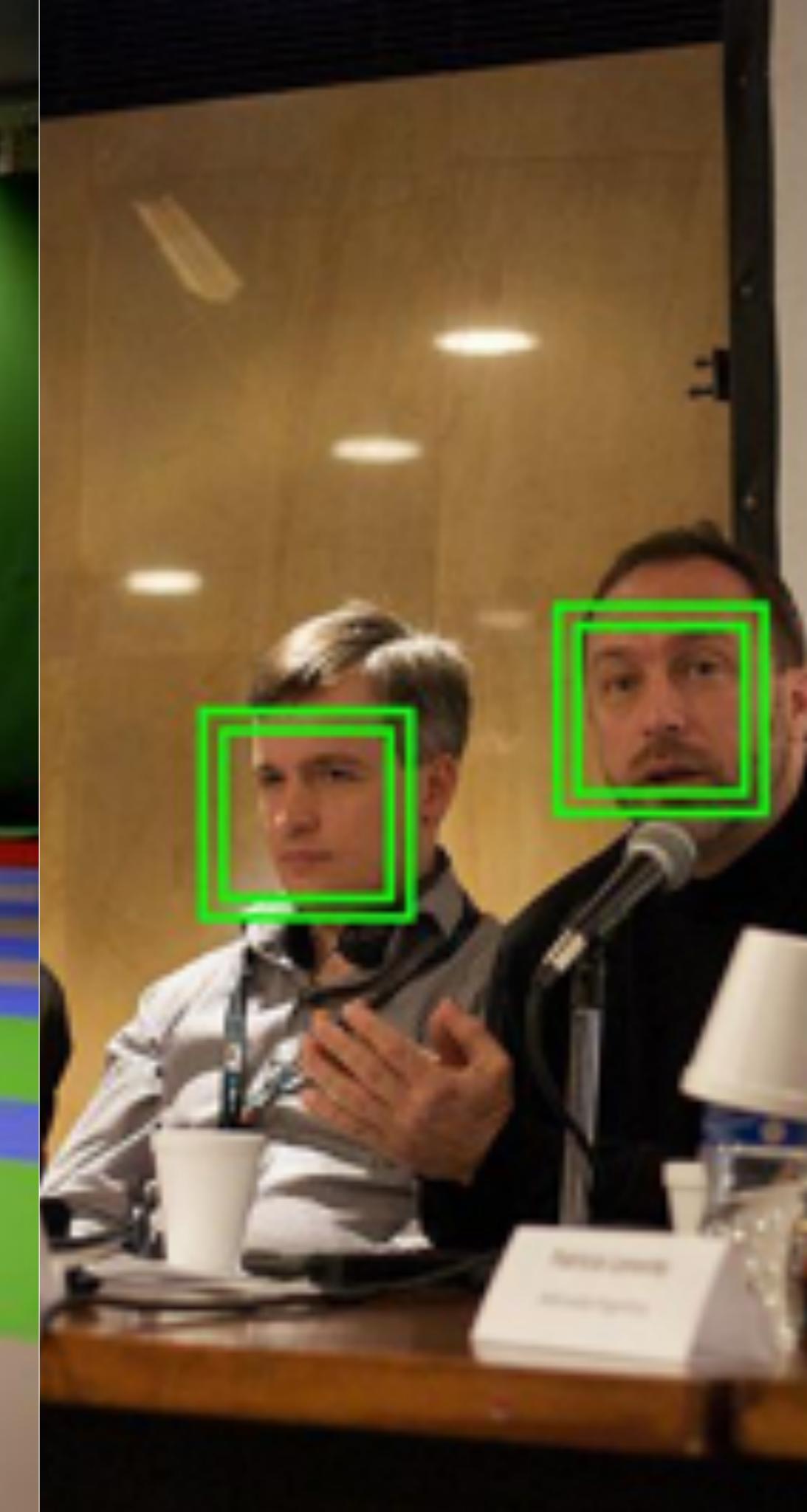
Vision in
your
pocket





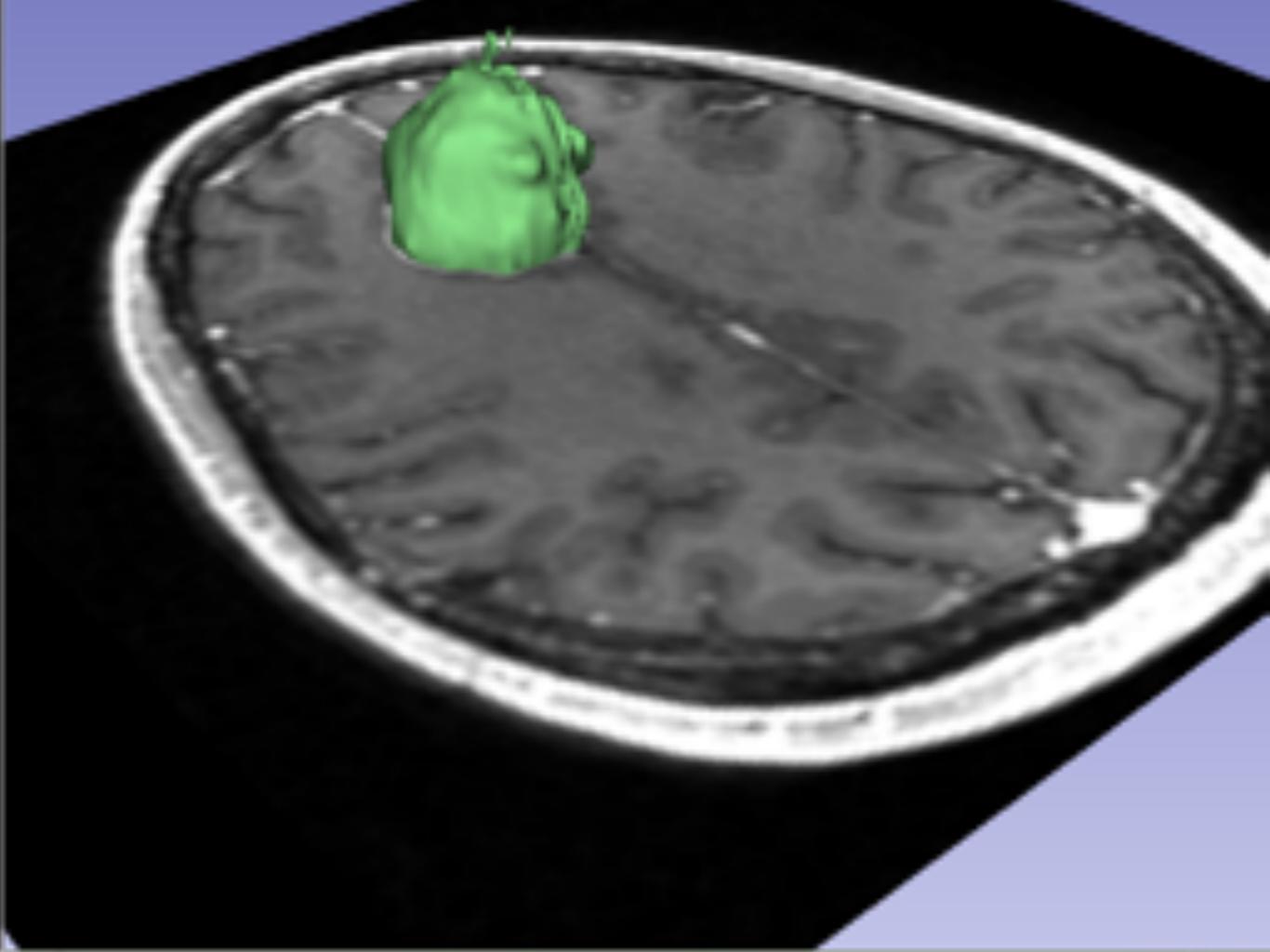
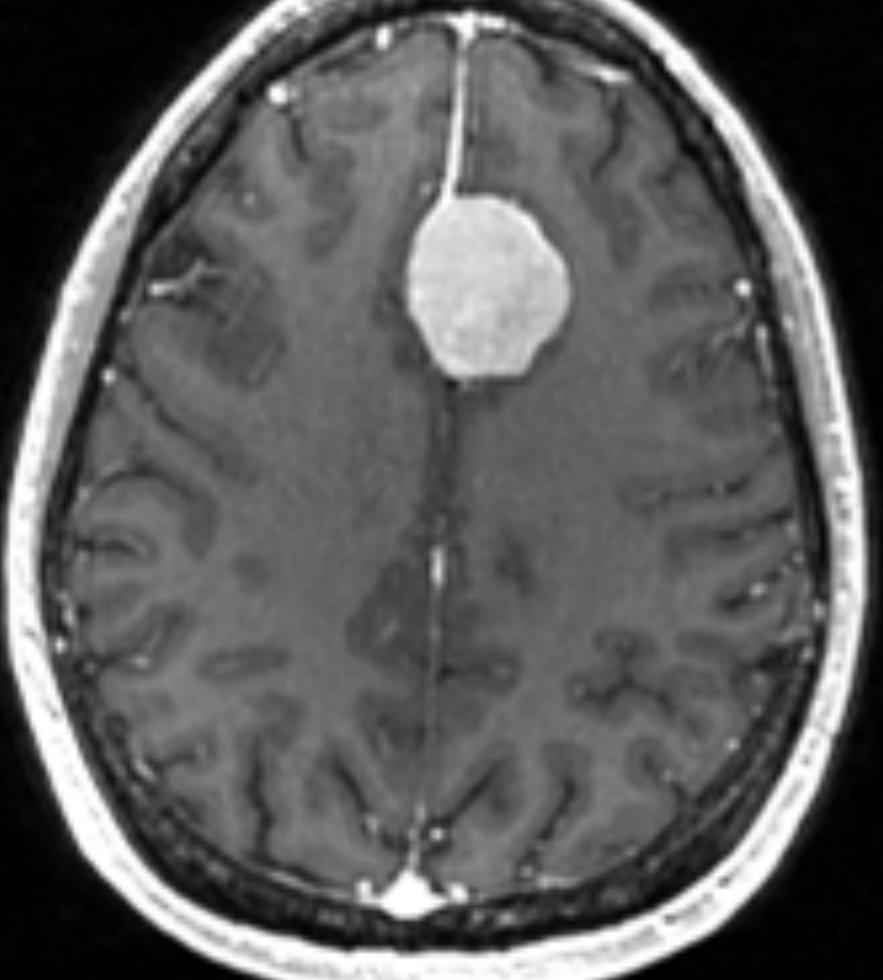


Vision all
around



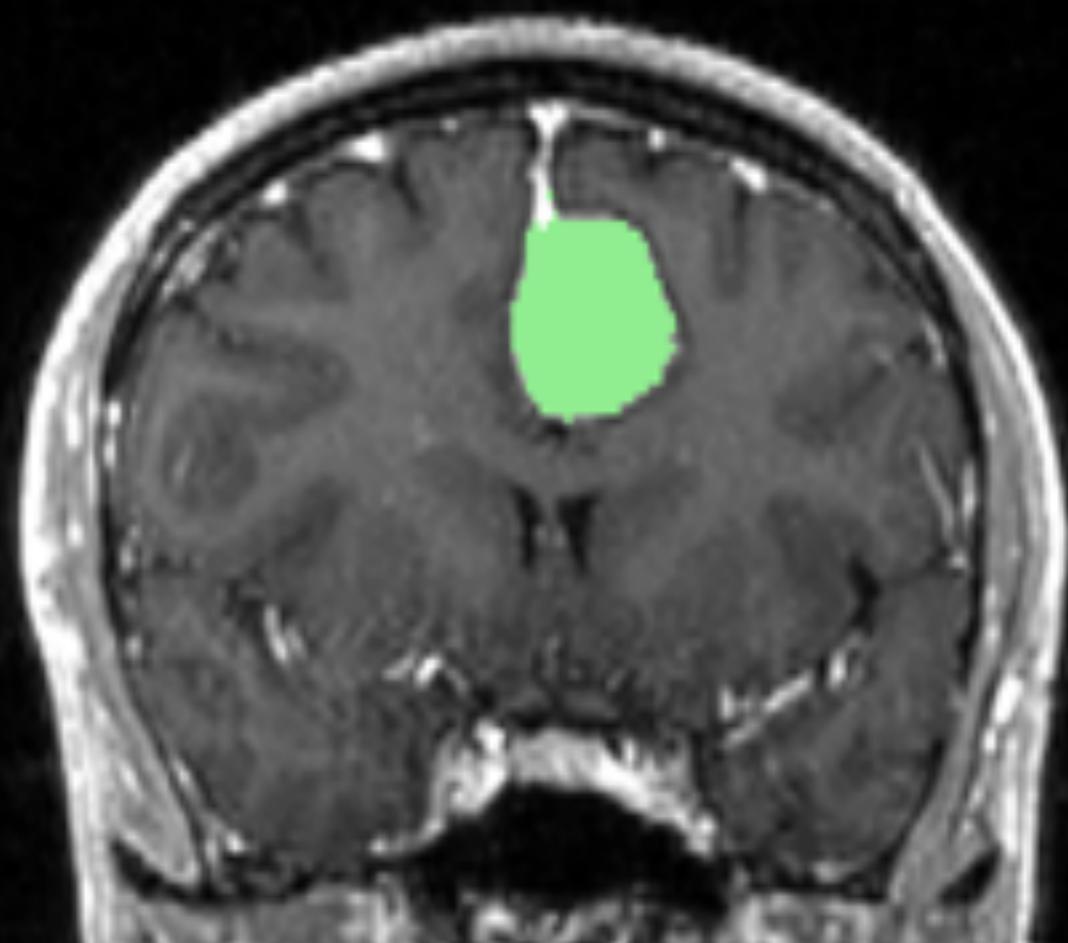
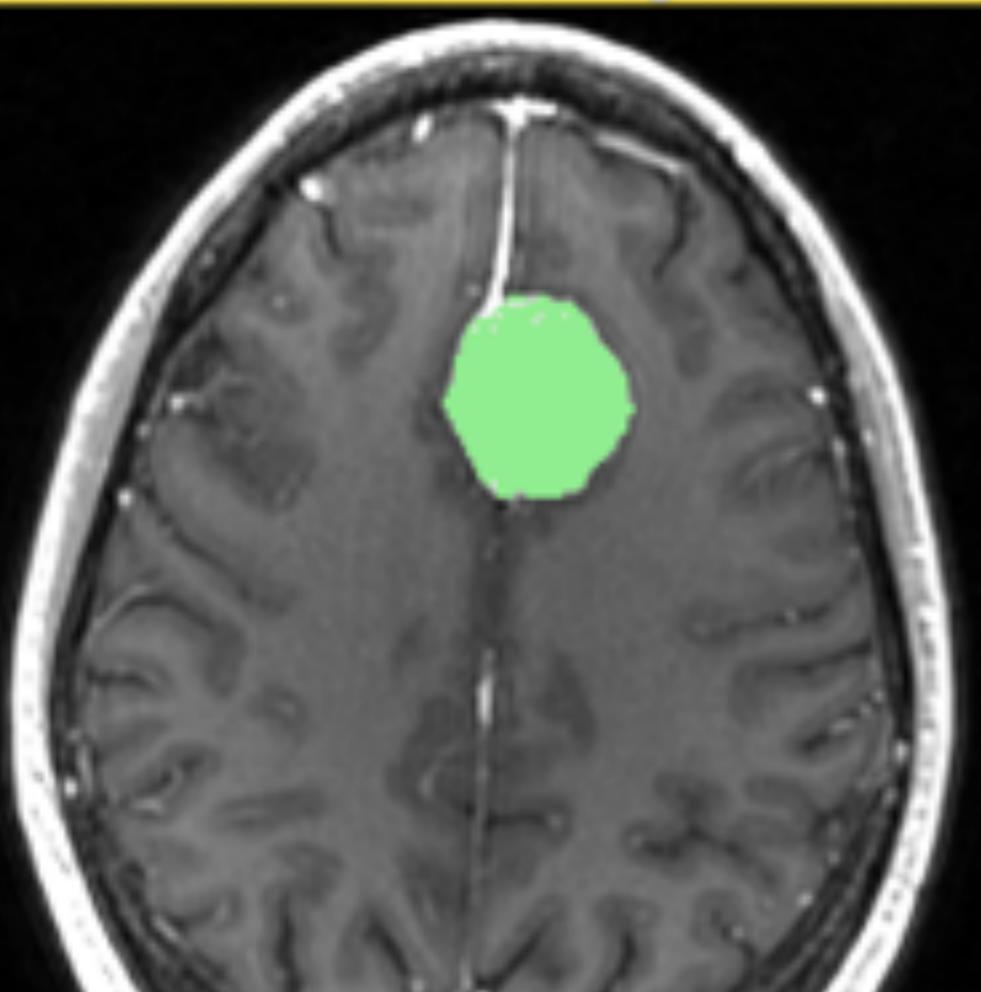
Medical Vision

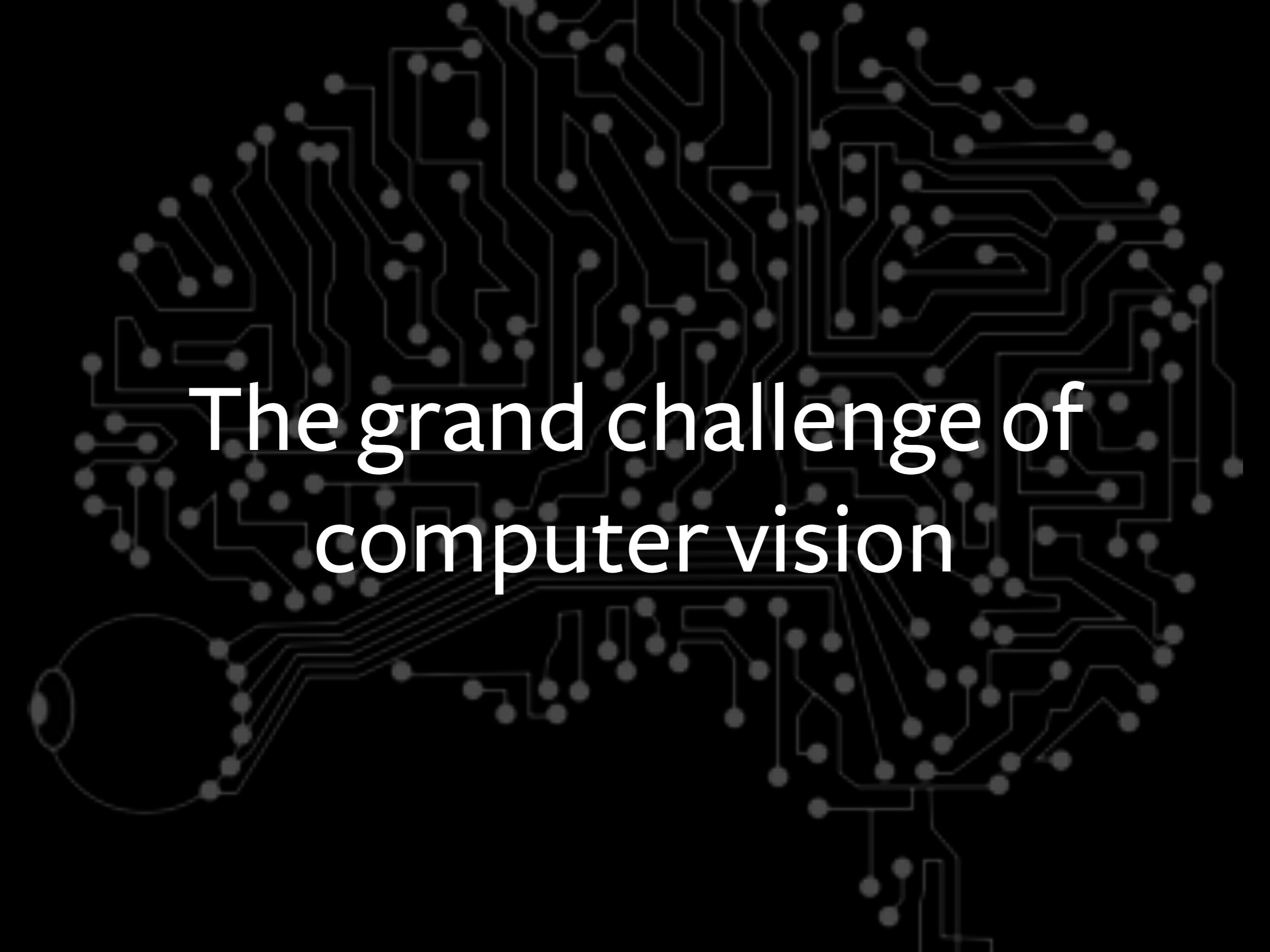




S: 23.80 G: 4

A: 19.22





The grand challenge of
computer vision

Computer Vision research has always
been inspired by the way humans
“see” and perceive the world



WHEN A USER TAKES A PHOTO,
THE APP SHOULD CHECK WHETHER
THEY'RE IN A NATIONAL PARK...

SURE, EASY'G'S LOOKUP
GIMME A FEW HOURS.

...AND CHECK WHETHER
THE PHOTO IS OF A BIRD.

I'LL NEED A RESEARCH
TEAM AND FIVE YEARS.



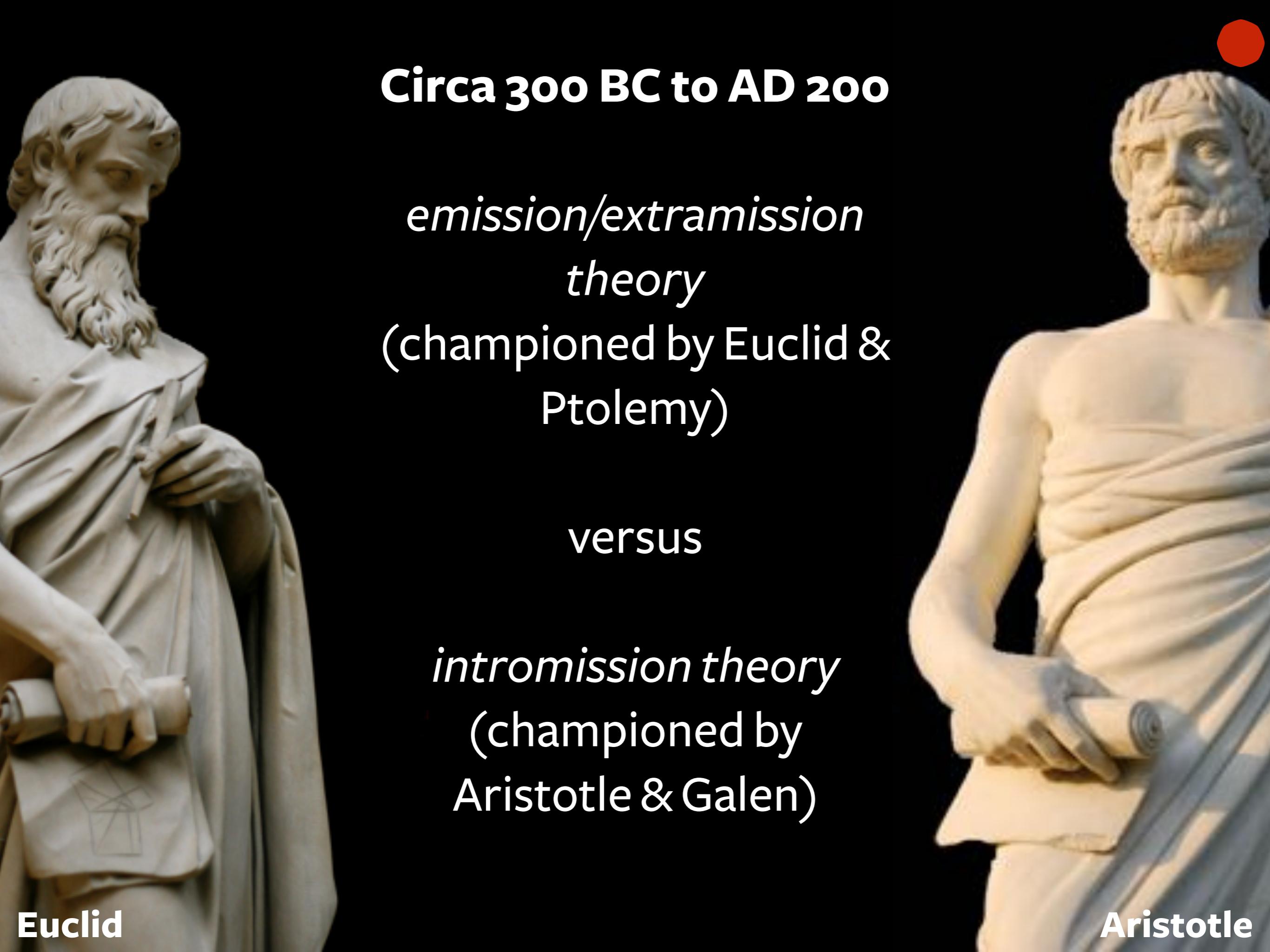
IN CS, IT CAN BE HARD TO EXPLAIN
THE DIFFERENCE BETWEEN THE EASY
AND THE VIRTUALLY IMPOSSIBLE.



A potted history of our understanding of:

- Biological Vision
 - Computation
- Machine Learning
- Computer Vision





Circa 300 BC to AD 200

*emission/extramission
theory*
(championed by Euclid &
Ptolemy)

versus

intromission theory
(championed by
Aristotle & Galen)

OPTICAE

THEATRVS

ALHAZENI

AKA IBN

AL-HAYTHAMI

AD 1000

EDITION DE L'ACADEMIE
DE PARIS

VITELLONIS

THEATRVS PICTORUM

LONDINI

EDITION DE L'ACADEMIE
DE PARIS

PARISIENSIS LIBRARIA



Circa AD 100 - 1000

Understanding of the visual system gross anatomy

Circa AD 1500

Foveal and peripheral vision



“The function of the human eye ... was described by a large number of authors in a certain way. But I found it to be completely different.”

—Leonardo Da Vinci

1642

Pascal's mechanical adder



Blaise Pascal

1801

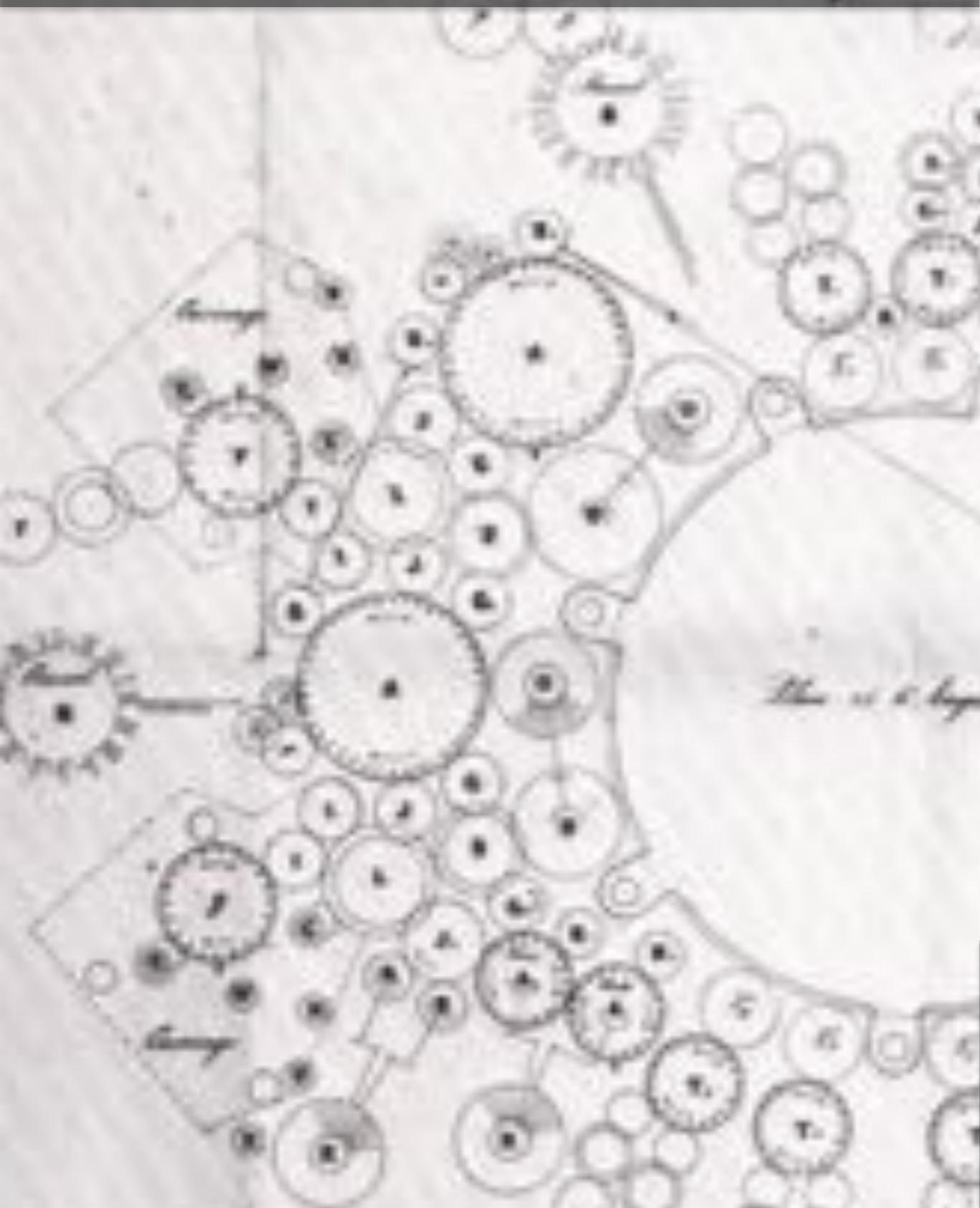
Jacquard Loom - first use of stored instructions



**Joseph Marie
Jacquard**

1837

Babbage's Analytical Engine - the
first general purpose computer



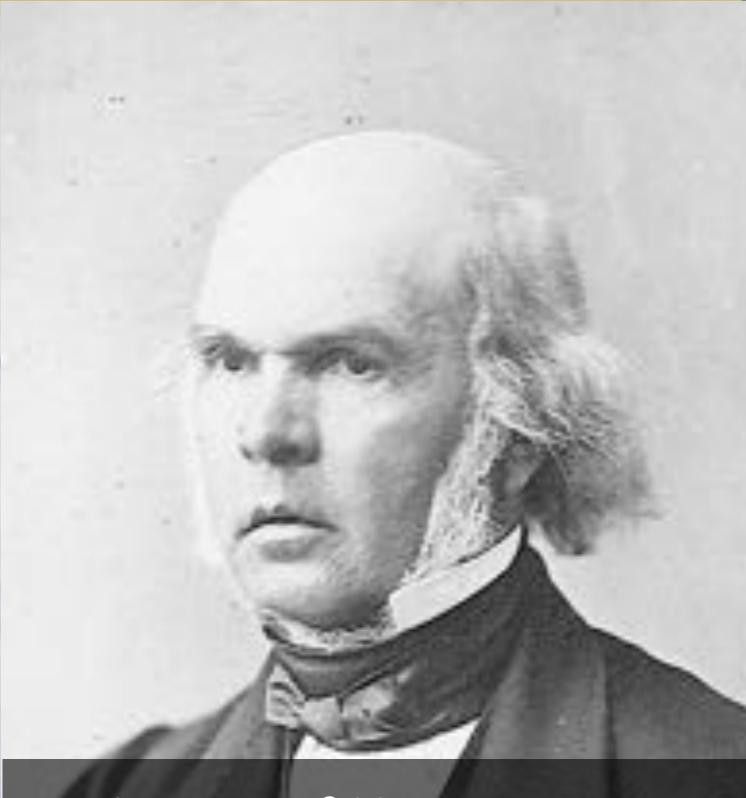
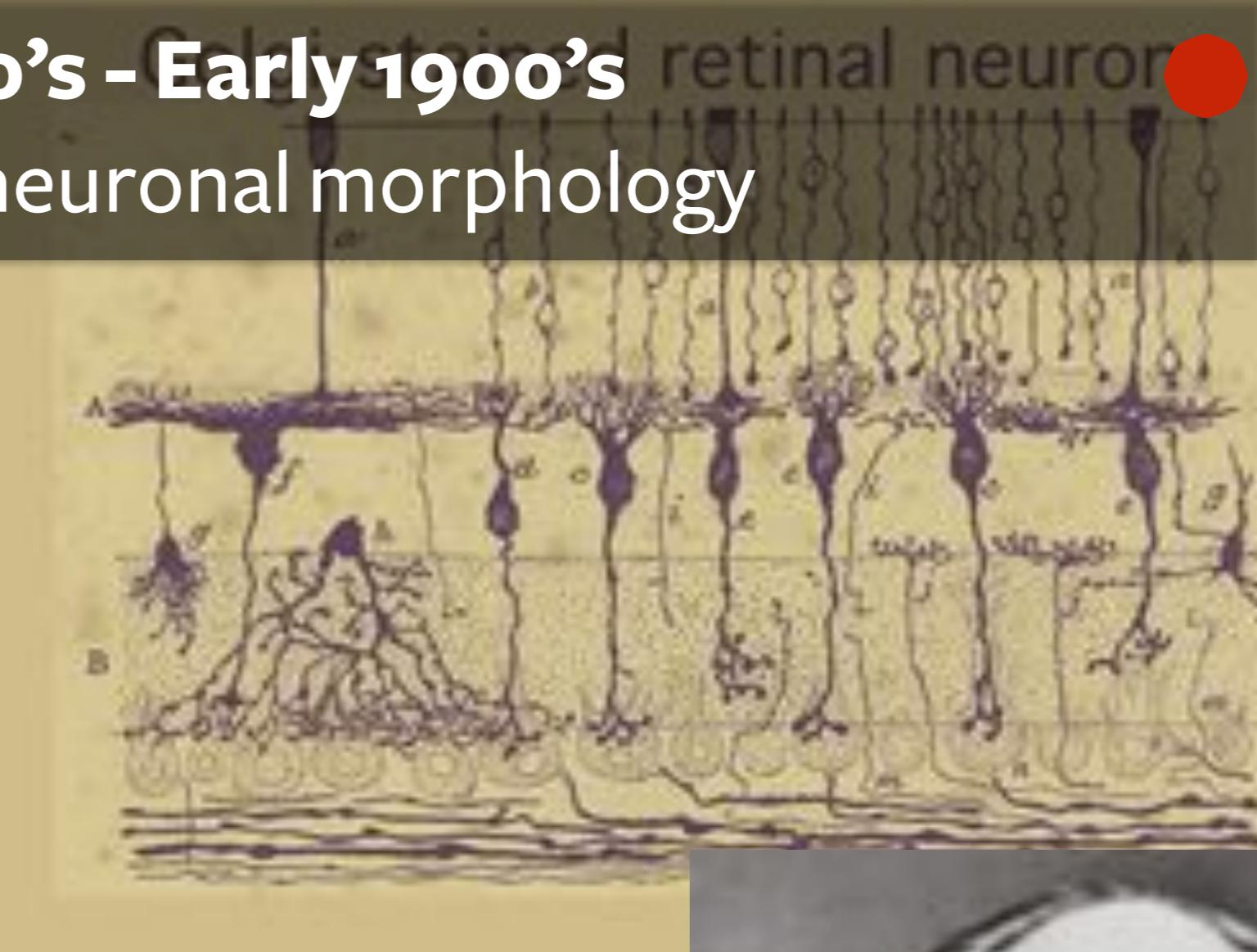
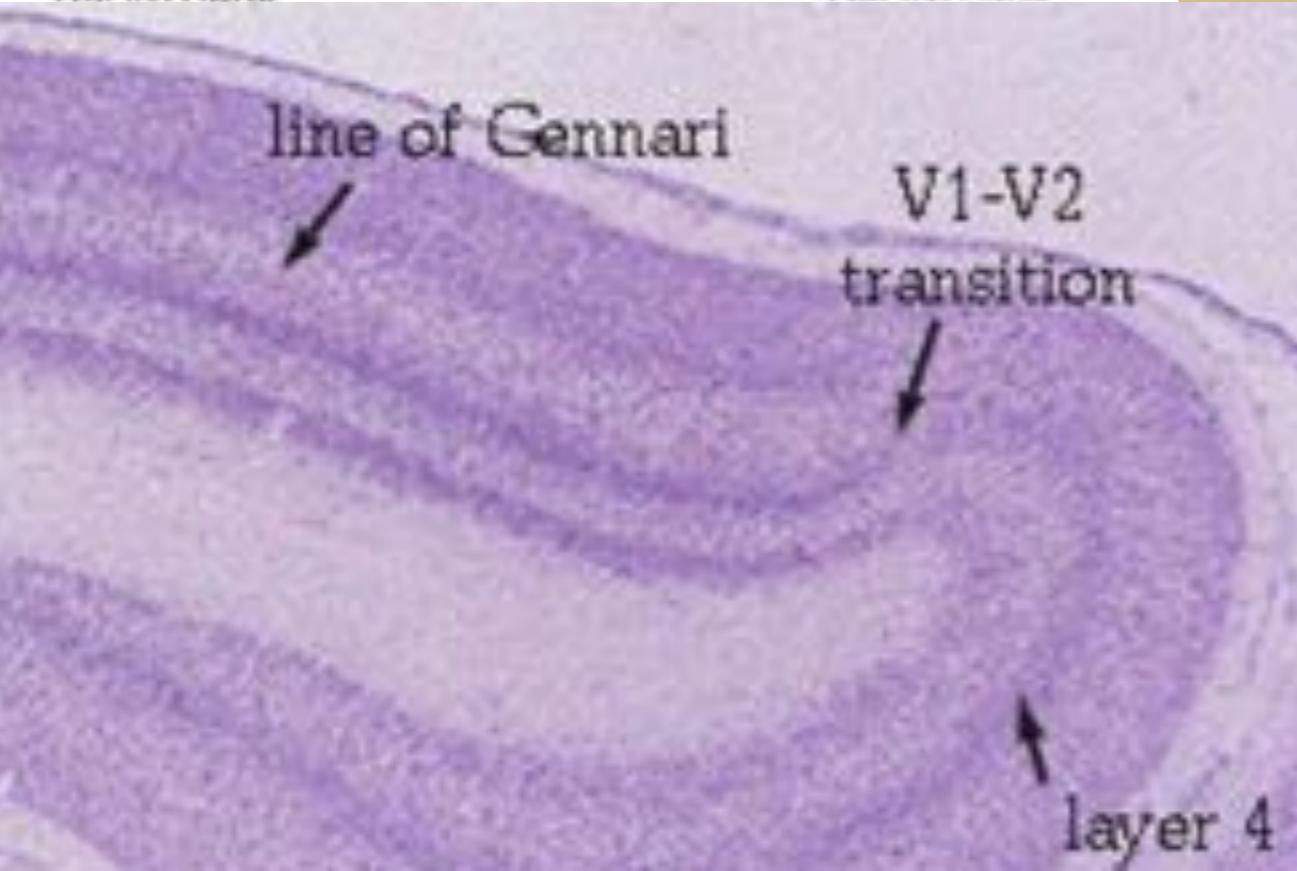
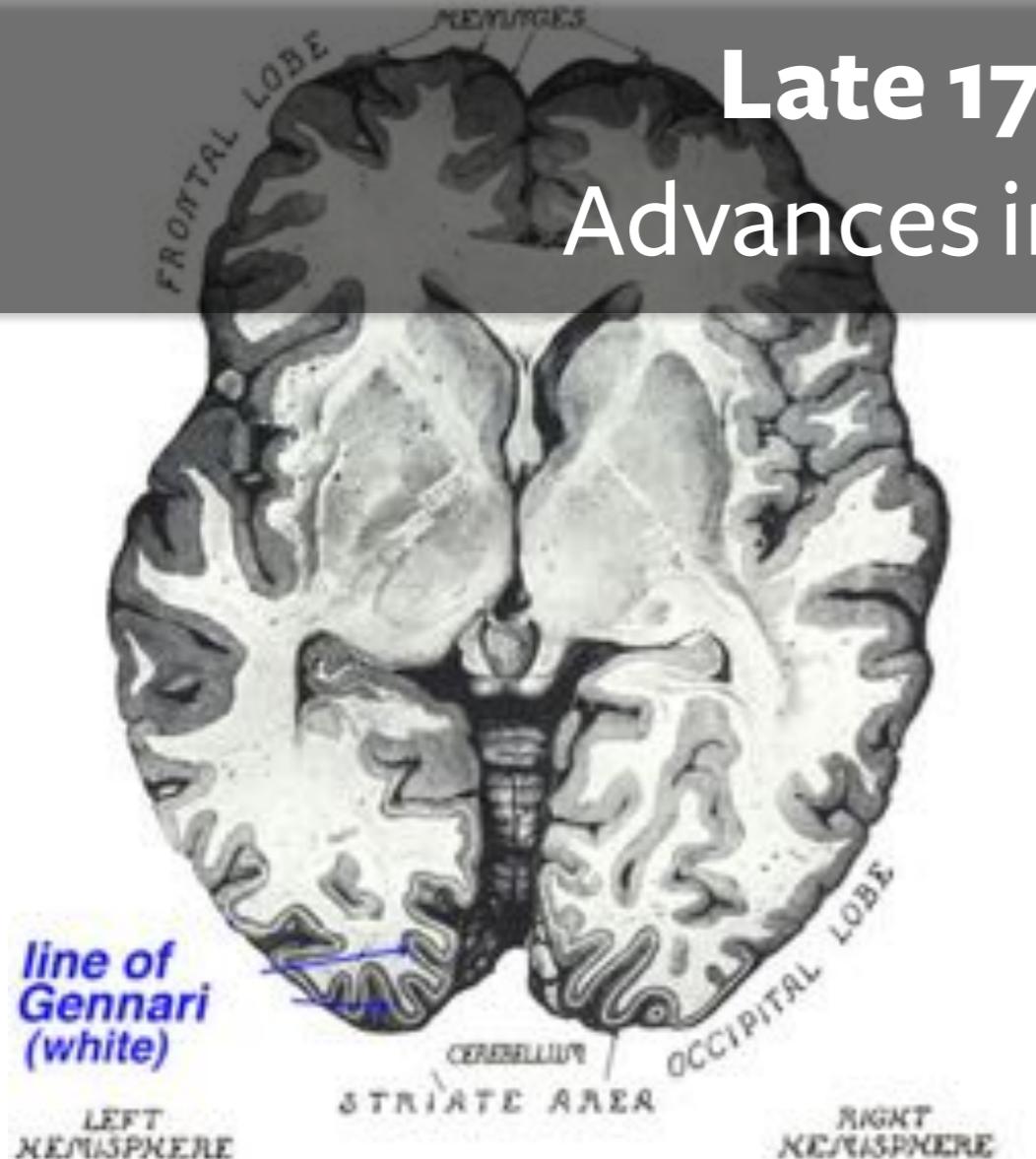
Number of Operation	Nature of Operation	Variables acted upon
1.	\times	$^1V_2 \times ^1V_3$ $^1V_4, ^1V$
2	-	$^1V_4 - ^1V_1$ 2V_4
3	+	$^1V_5 + ^1V_1$ 2V_5
4	\div	$\div ^2V_4$
5	\div	$^1V \div ^1V_2$
6	-	$^0V_{18} - 1$
7	-	$^1V_3 - ^1V_1$
8	+	$^1V_2 + ^0V$
9	\div	$^1V_6 + ^1V_7$
10	\div	$^1V_{12} + ^1V_{13}$
11	\div	$^1V_{12} + ^1V_{13}$

1842

Ada Lovelace writes the first
computer program

Late 1700's - Early 1900's

Advances in neuronal morphology



Jules Baillarger



Santiago
Ramón y Cajal

1930's

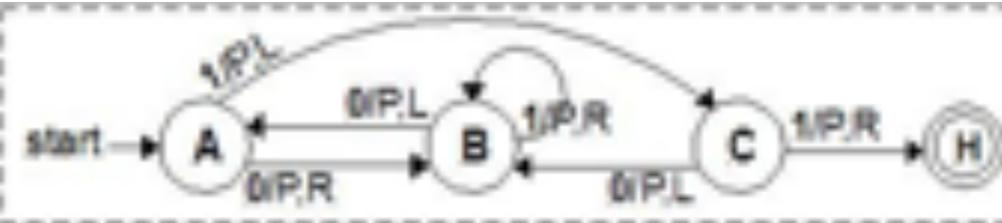
Gestalt Laws of Perceptual Grouping



1936

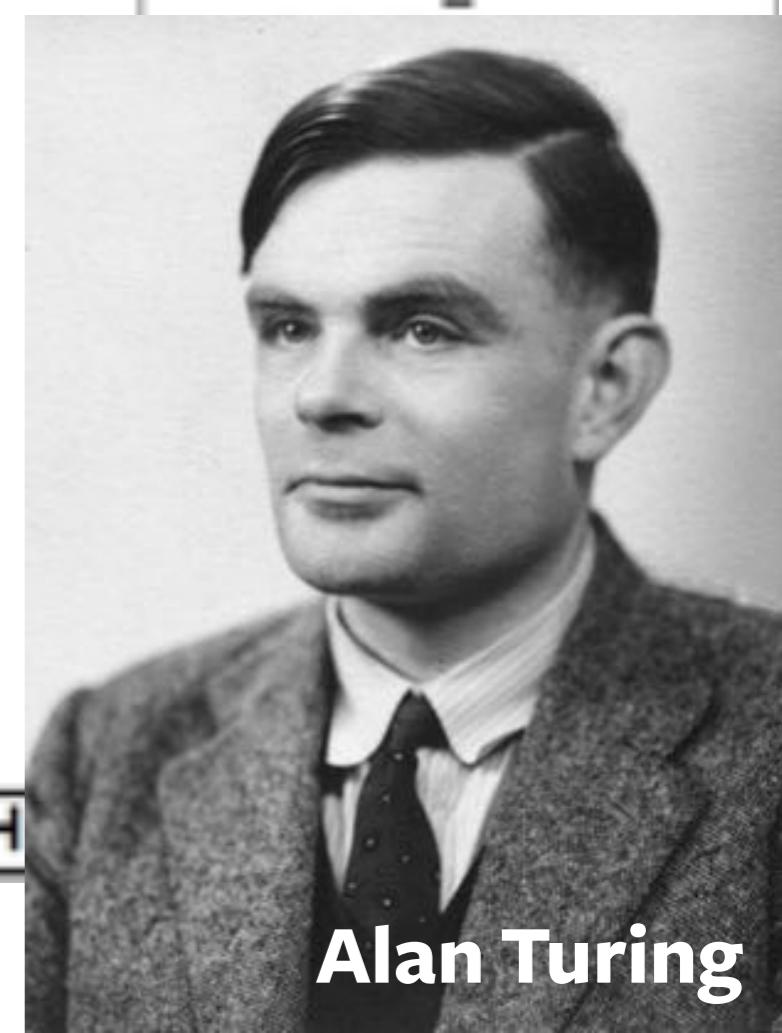
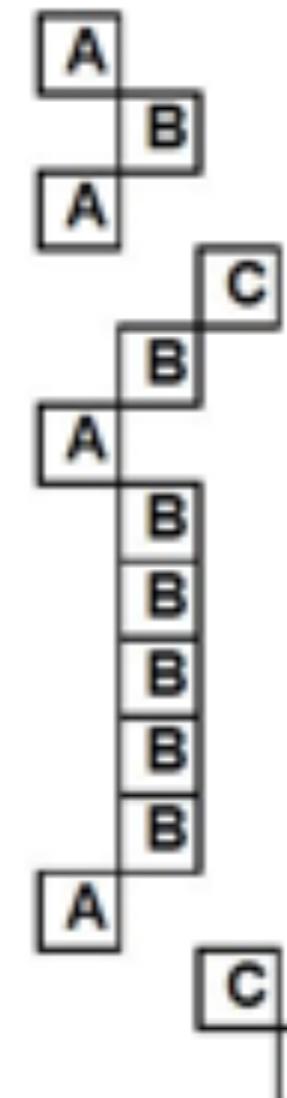
Turing machine

3-state busy beaver:



Sequence	Instruction	Head	Instruction: A B C H
1	A	0000000000000000	A 0
2	B	0000000000000000	B 0 1
3	A	0000000001000000	1 A 1
4	C	0000001100000000	
5	B	0000111000000000	
6	A	0001111000000000	
7	B	0000111110000000	
8	B	0000011111000000	
9	B	0000001111110000	
10	B	0000000111111100	
11	B	000000001111111100	
12	A	0000000011111111100	
13	C	00000001111111111000	
14	H	00000011111111110000	

time →

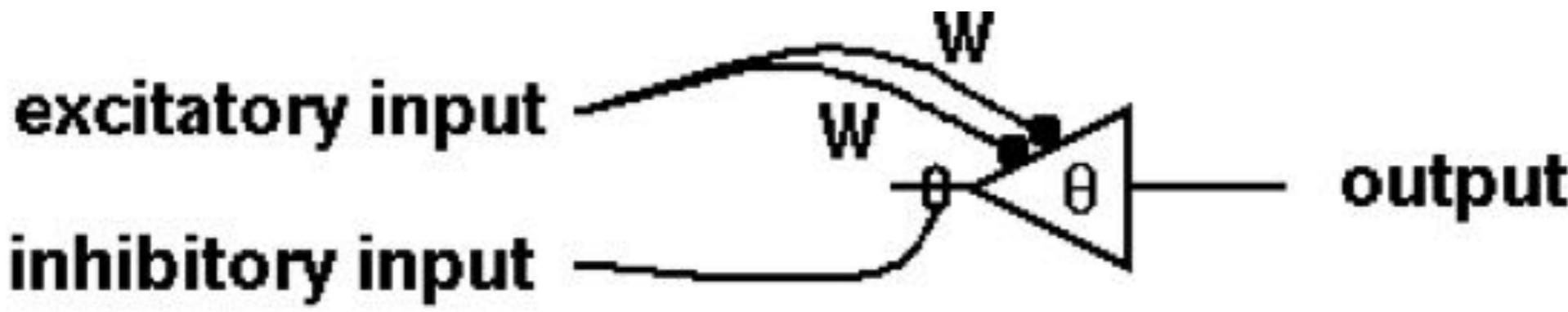


Alan Turing

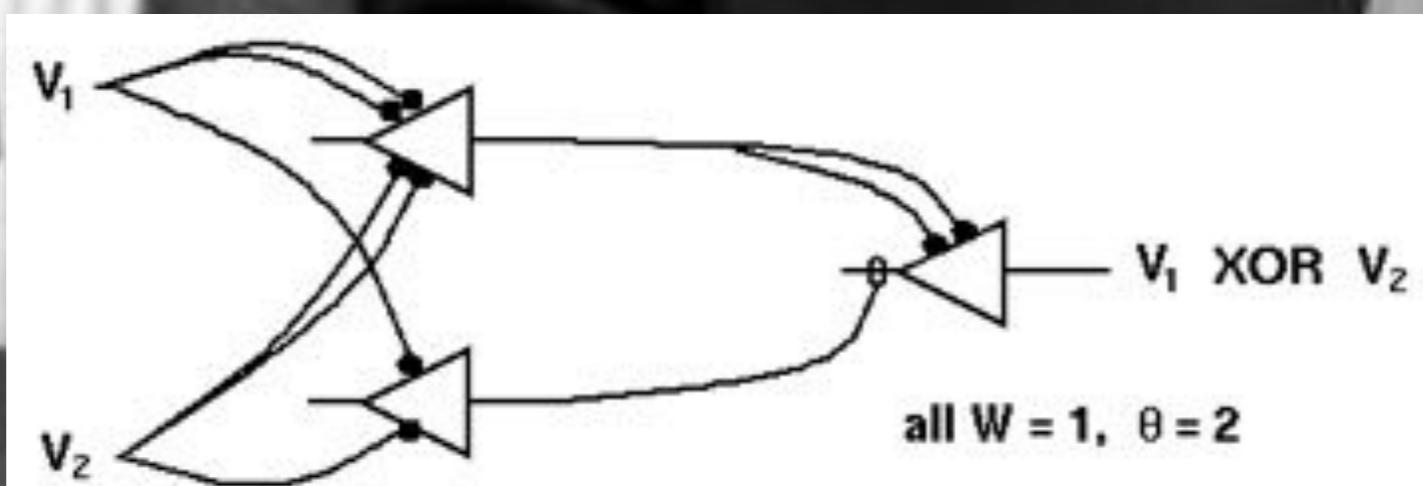
1943

McCulloch-Pitts Artificial Neuron

$$V_i = \begin{cases} 1 & : \sum_j W V_j \geq \theta \text{ AND no inhibition} \\ 0 & : \text{otherwise} \end{cases}$$



Warren
McCulloch



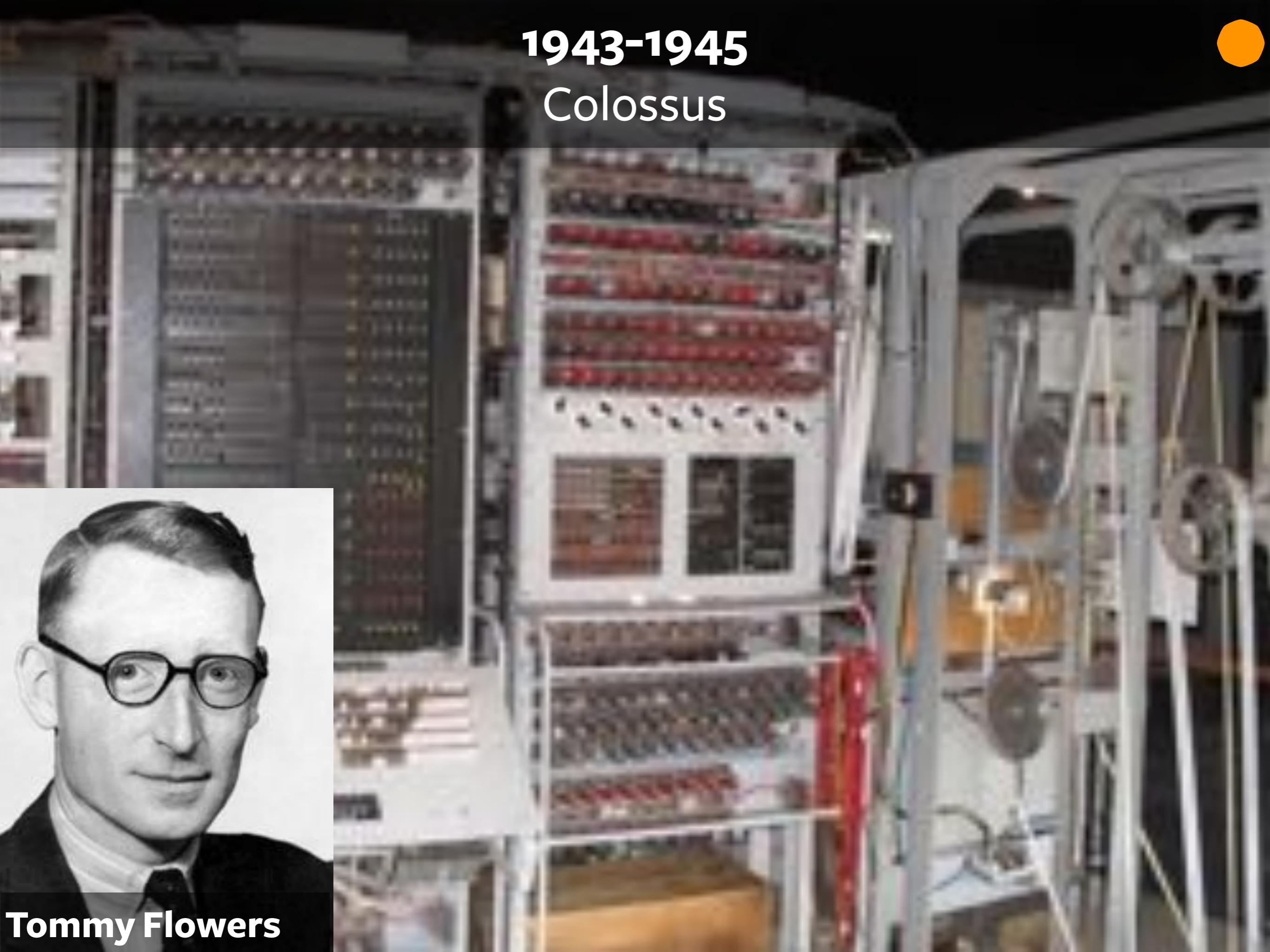
Walter
Pitts

1943-1945

Colossus



Tommy Flowers



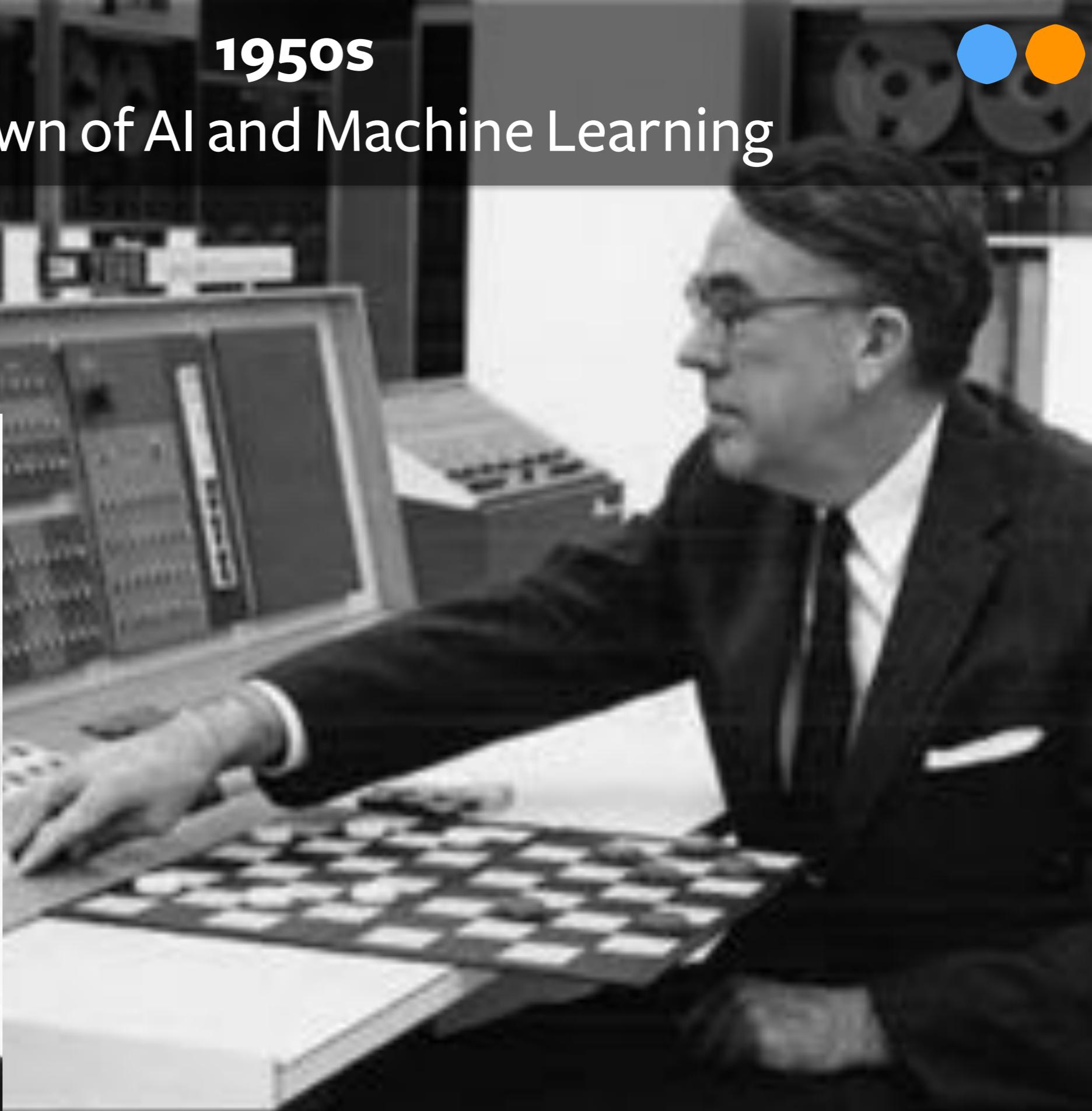
1950s



The dawn of AI and Machine Learning



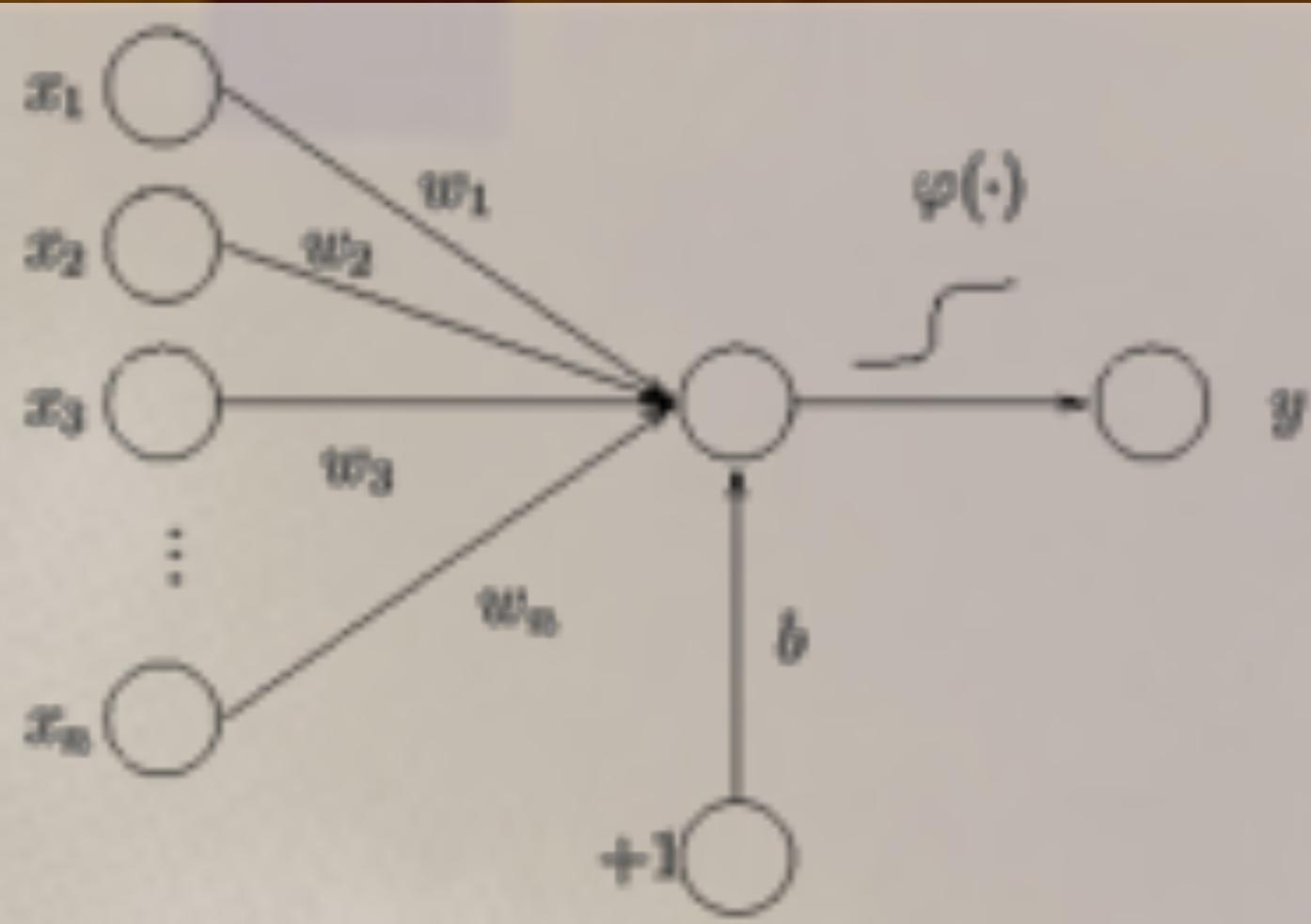
Christopher Strachey



Arthur Samuel

1958

Rosenblatt's Perceptron



Frank Rosenblatt

$$y = \varphi\left(\sum_{i=1}^n w_i x_i + b\right) = \varphi(\mathbf{w}^T \mathbf{x} + b)$$



MARK I

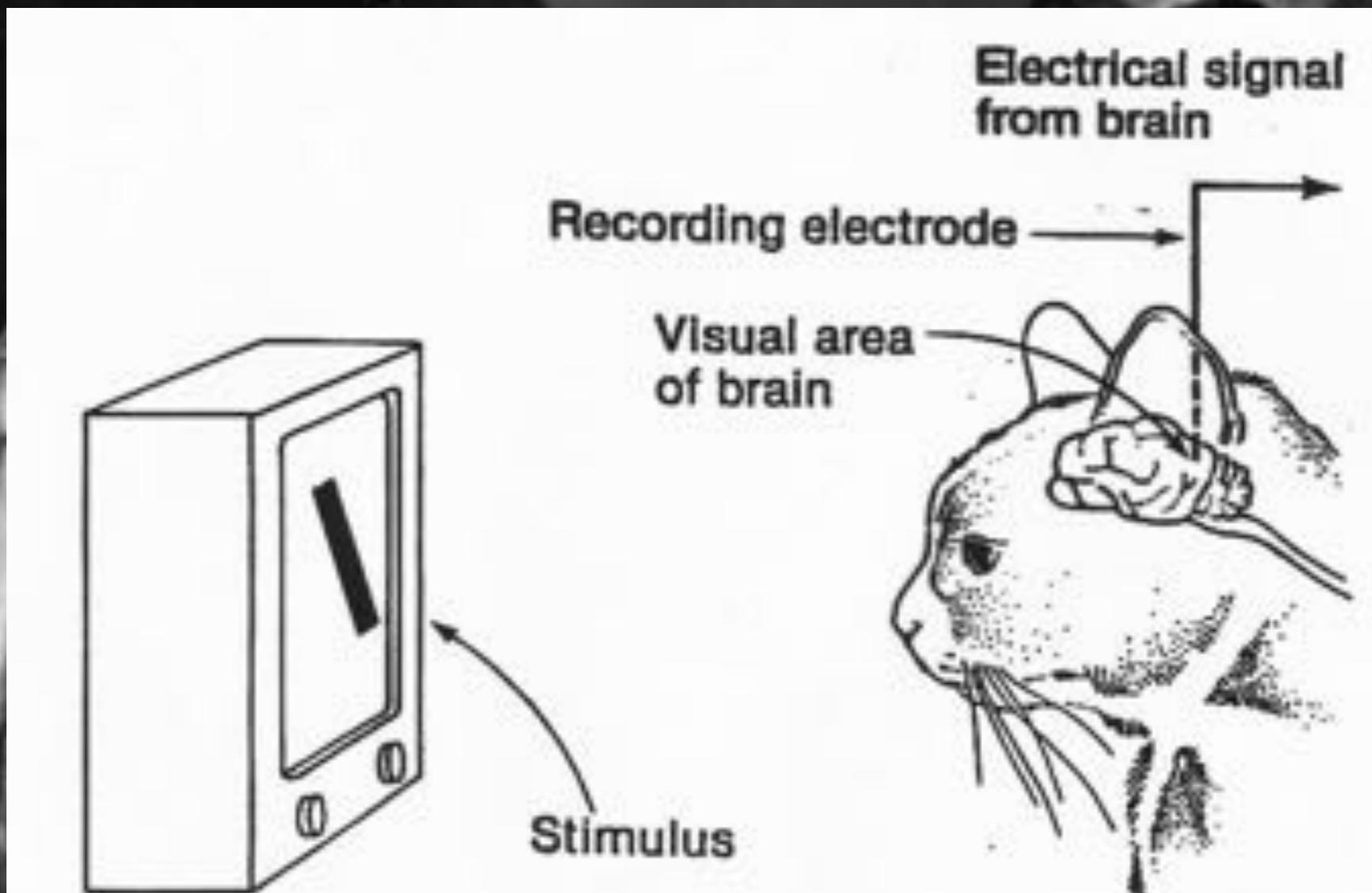
PERCEPTION
RECOGNITION



Structure	Description of decision regions	Exclusive-OR problem	Classes with mismatched regions	General region shapes
	Half plane bounded by hyperplane			
	Arbitrary complexity limited by number of hidden units			
	Arbitrary complexity limited by number of hidden units			

1959

Receptive Fields of Single Neurons in the Cat's Striate Cortex



David
Hubel

Torsten
Wiesel



1966

Computer vision "summer project"

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
PROJECT MAC

Artificial Intelligence Group
Vision Memo. No. 100.

July 7, 1966

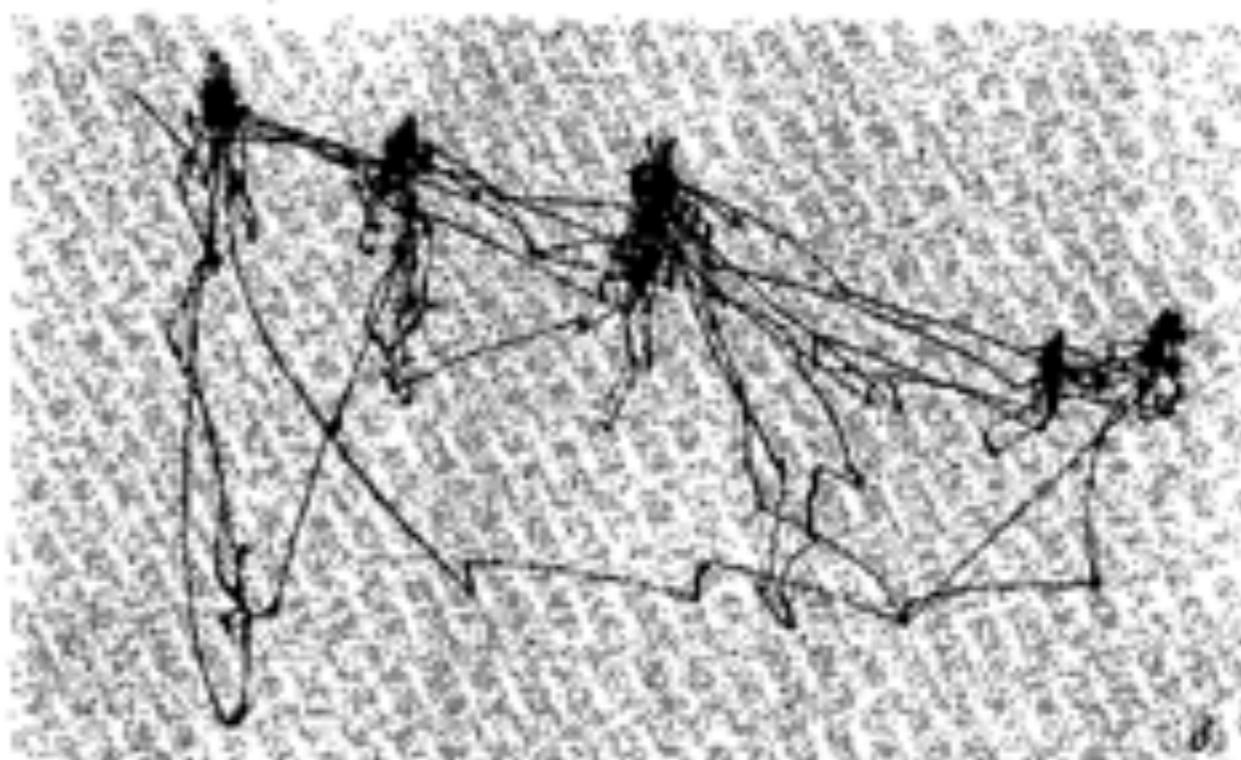
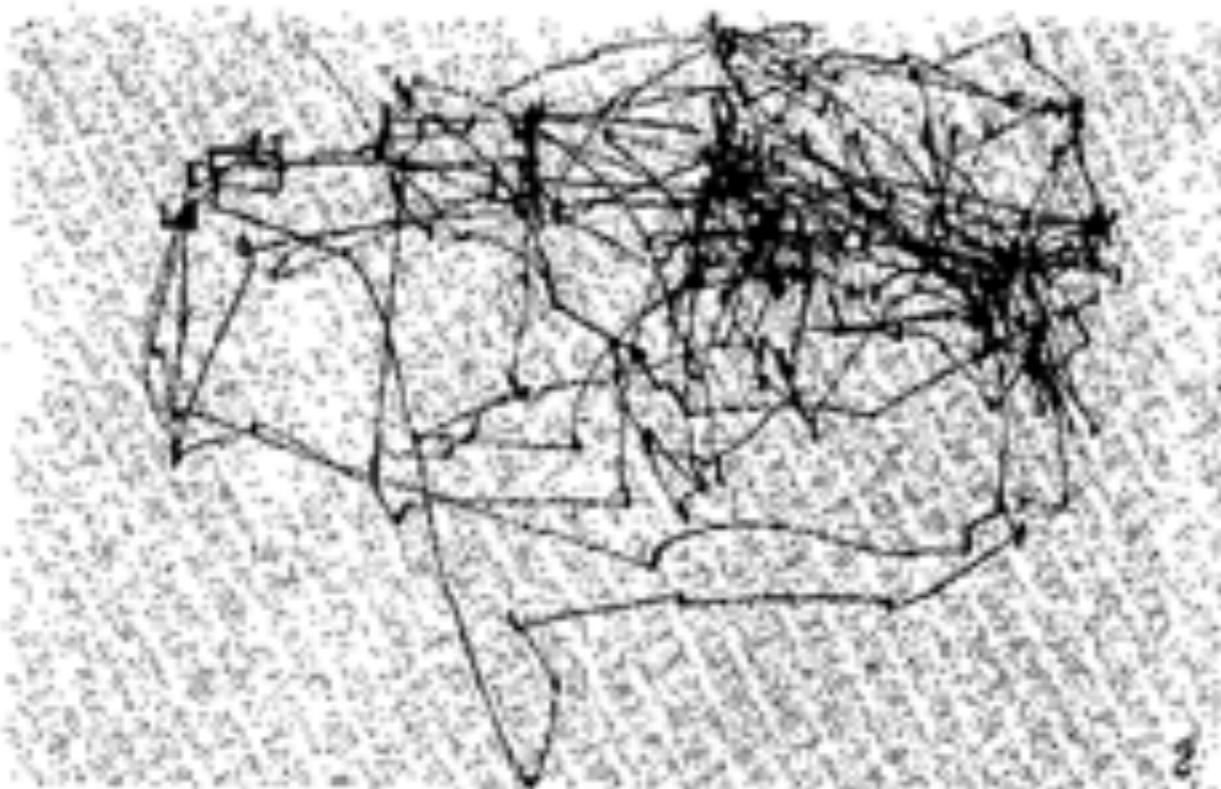
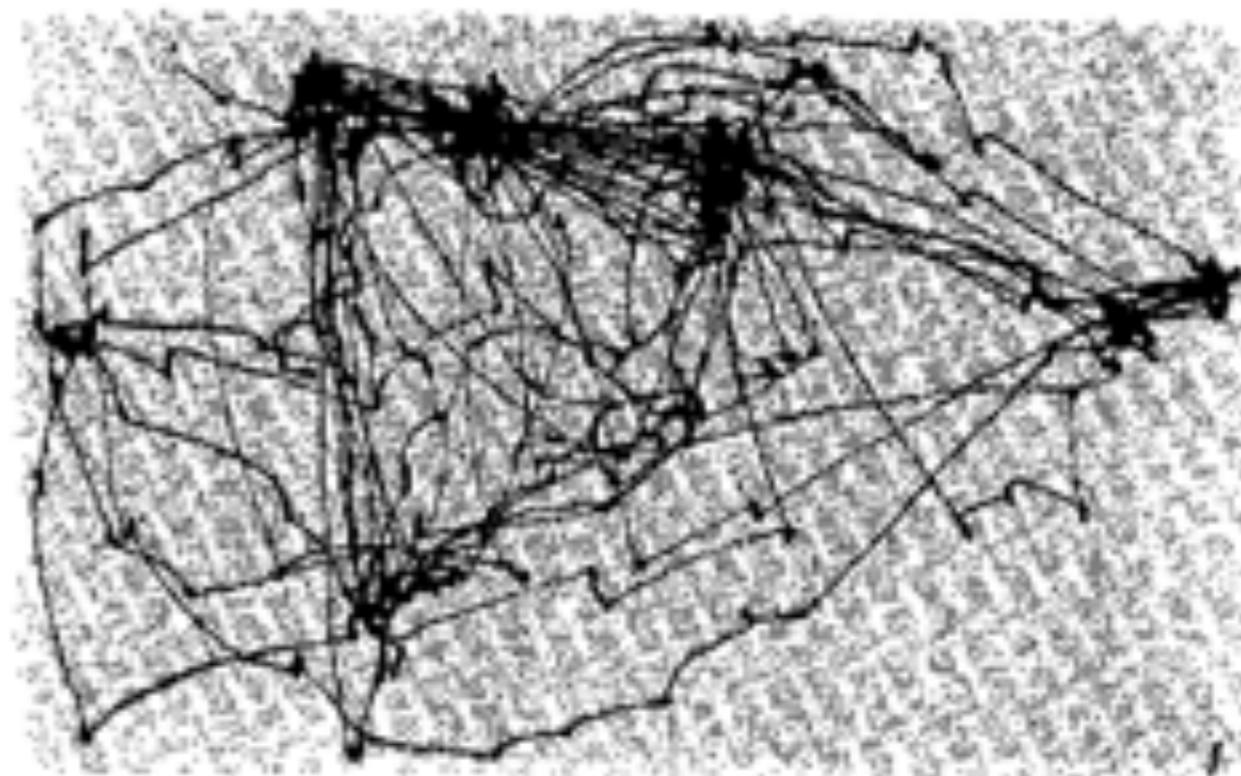
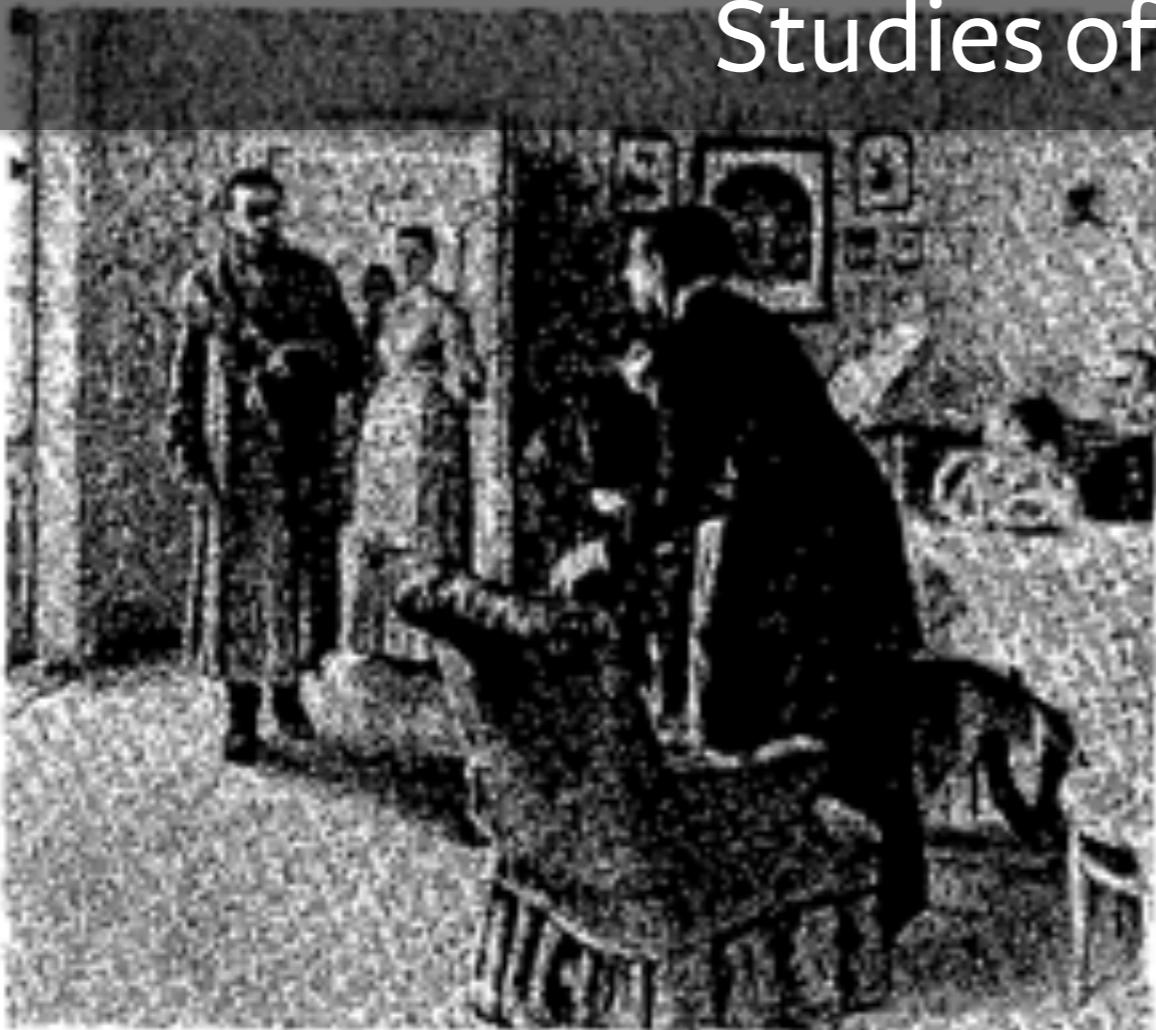
THE SUMMER VISION PROJECT

Seymour Papert

The summer vision project is an attempt to use our summer workers effectively in the construction of a significant part of a visual system. The particular task was chosen partly because it can be segmented into sub-problems which will allow individuals to work independently and yet

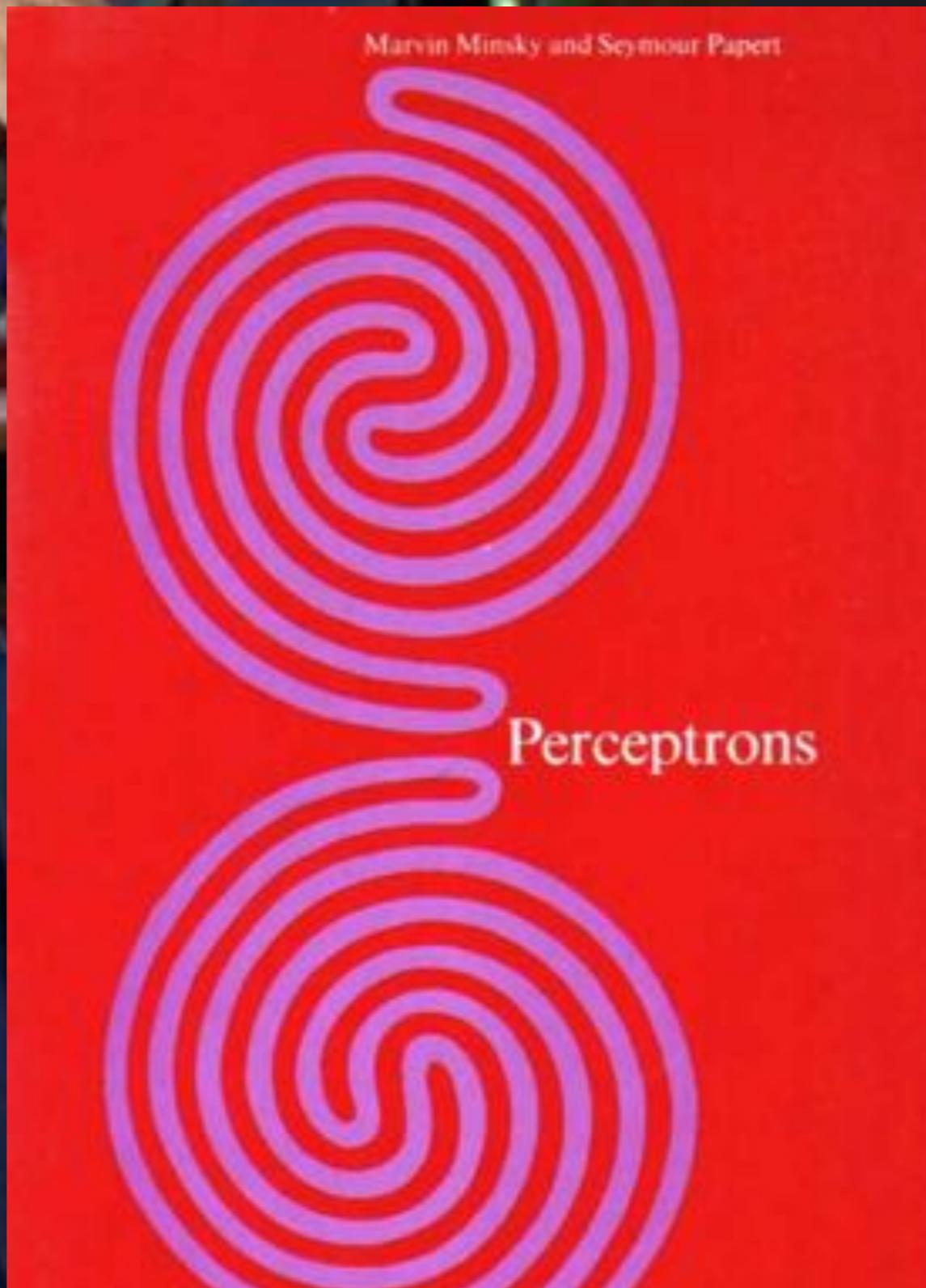
1960's

Studies of eye movement



1969

“Perceptrons” and the first AI Winter



Marvin Minsky

Seymour Papert

1970

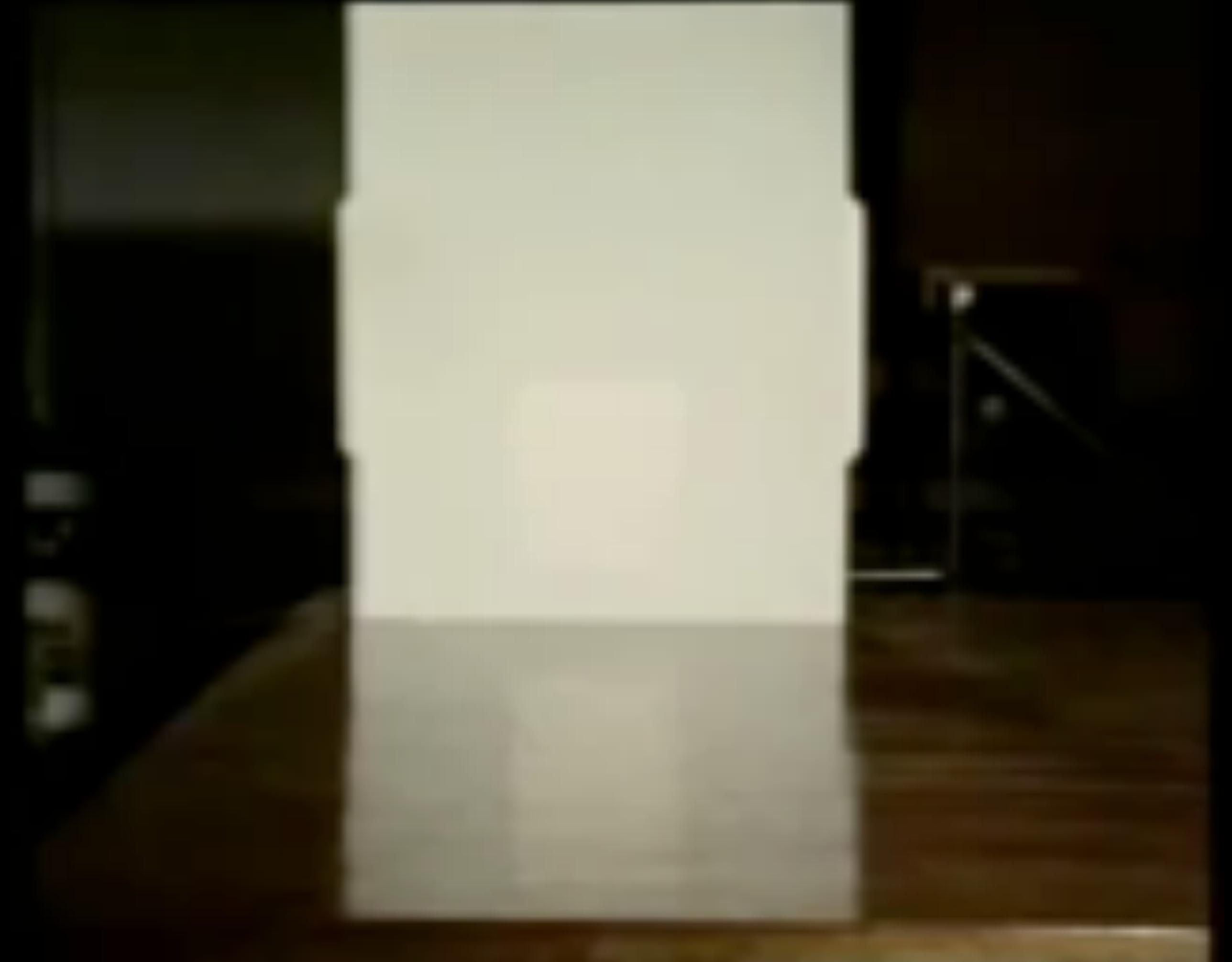
Is vision innate or acquired?



Colin Blakemore



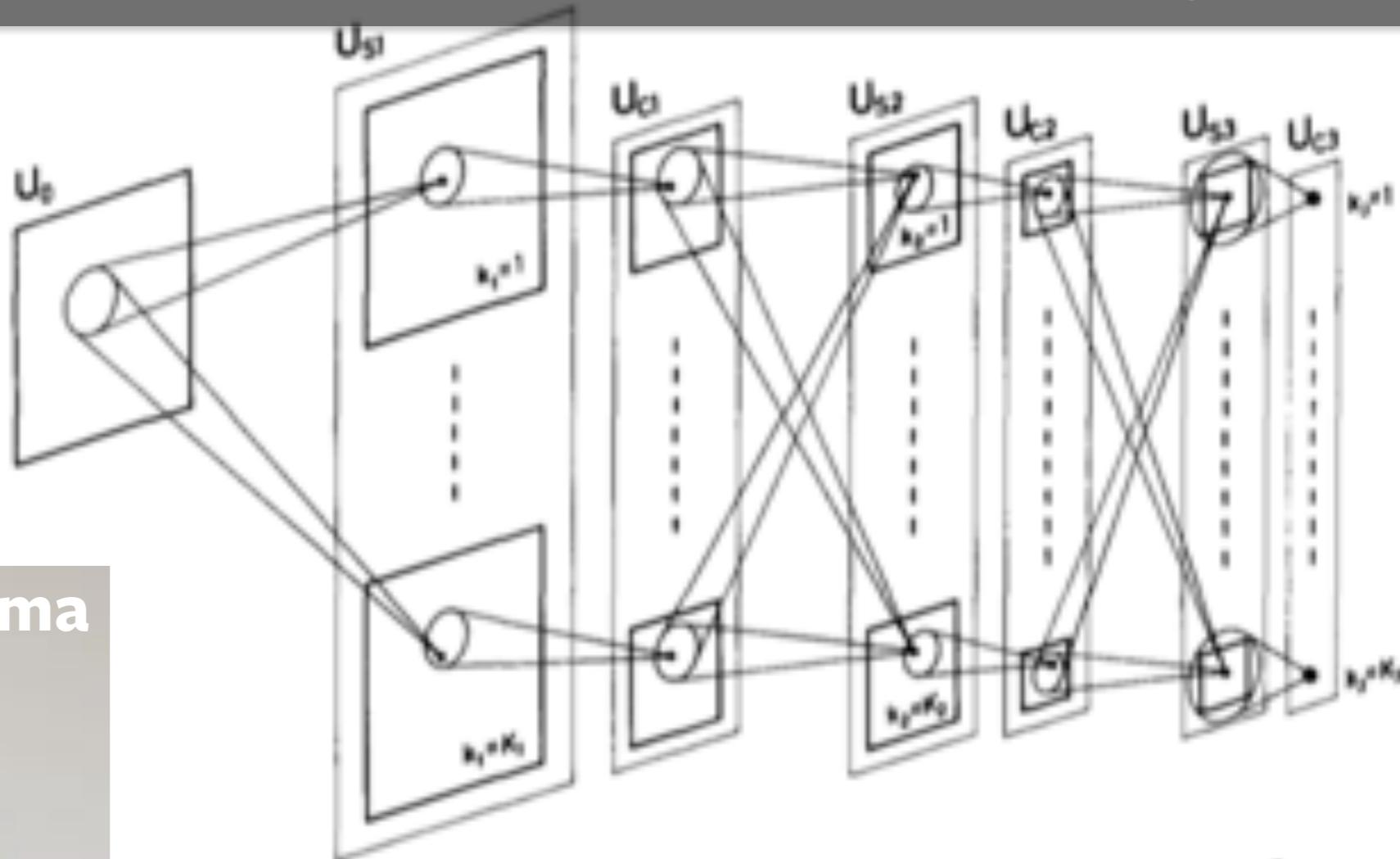
卷之三



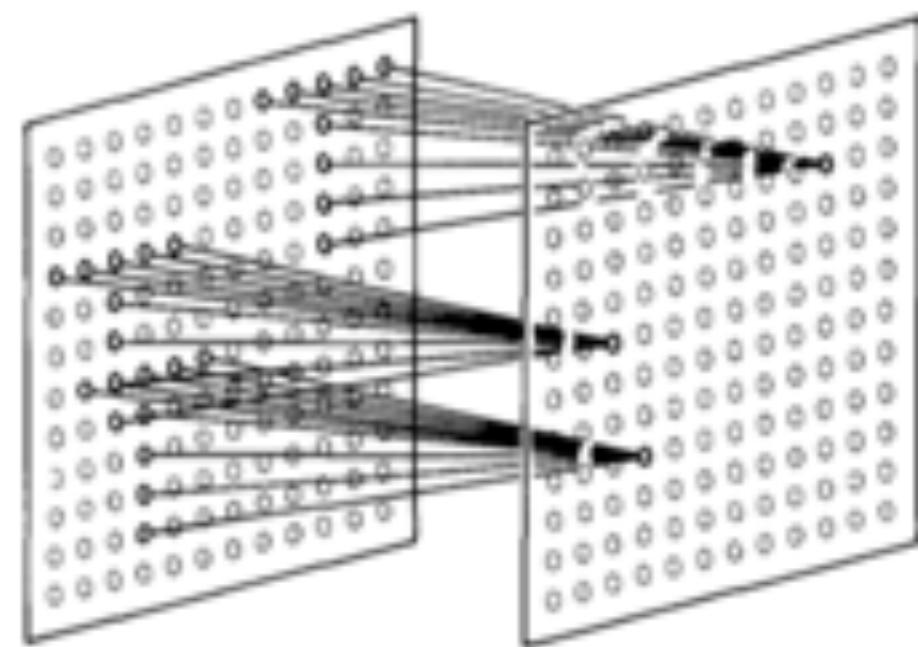
1979



Convolutional Neural Networks & Neocognitron



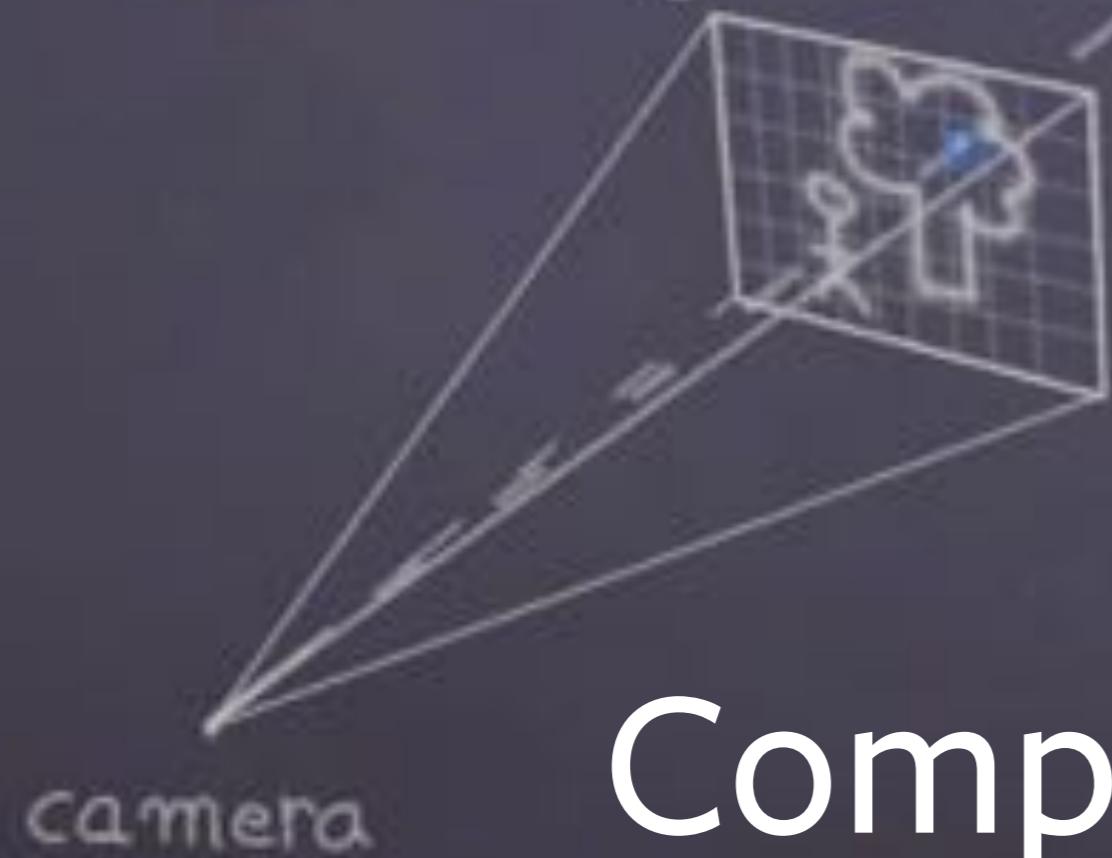
Kunihiko Fukushima



Computer Vision

3D World

2D Image



Computer vision
from the late 80's



camera

Classical approaches to computer vision take the following form:

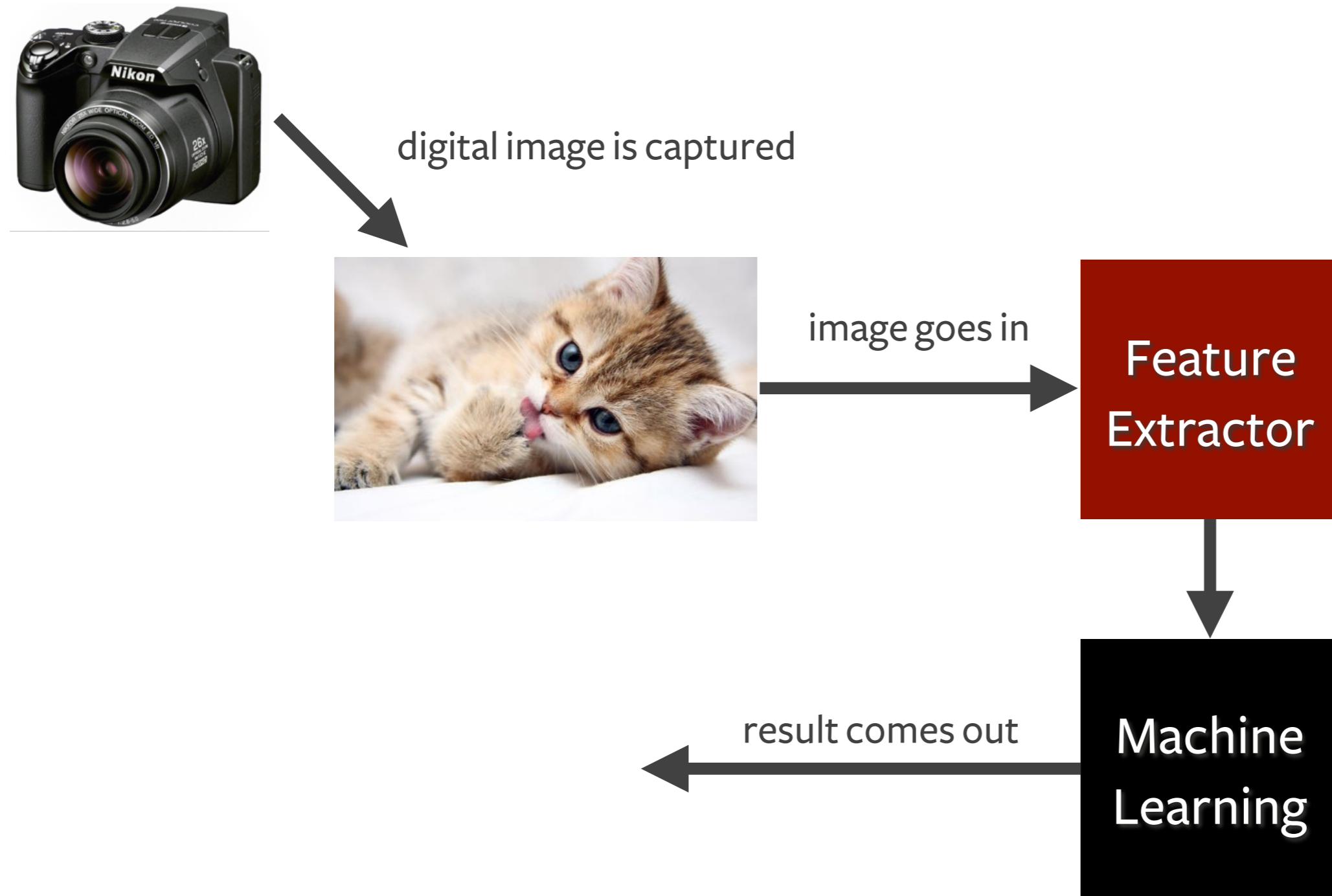
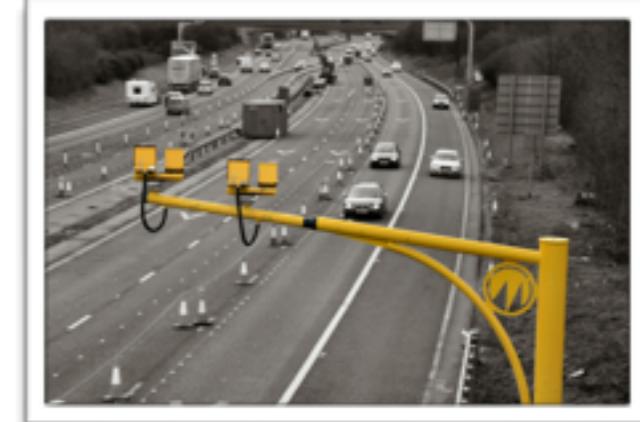
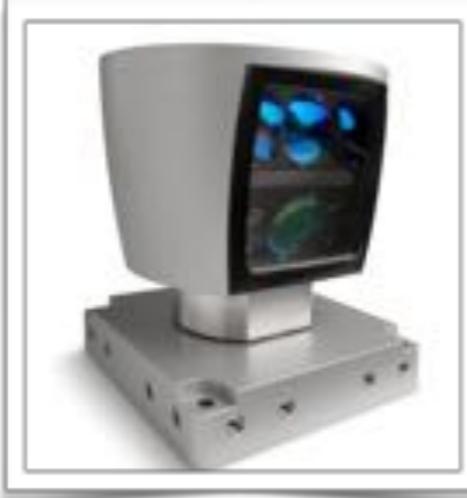


Image Acquisition



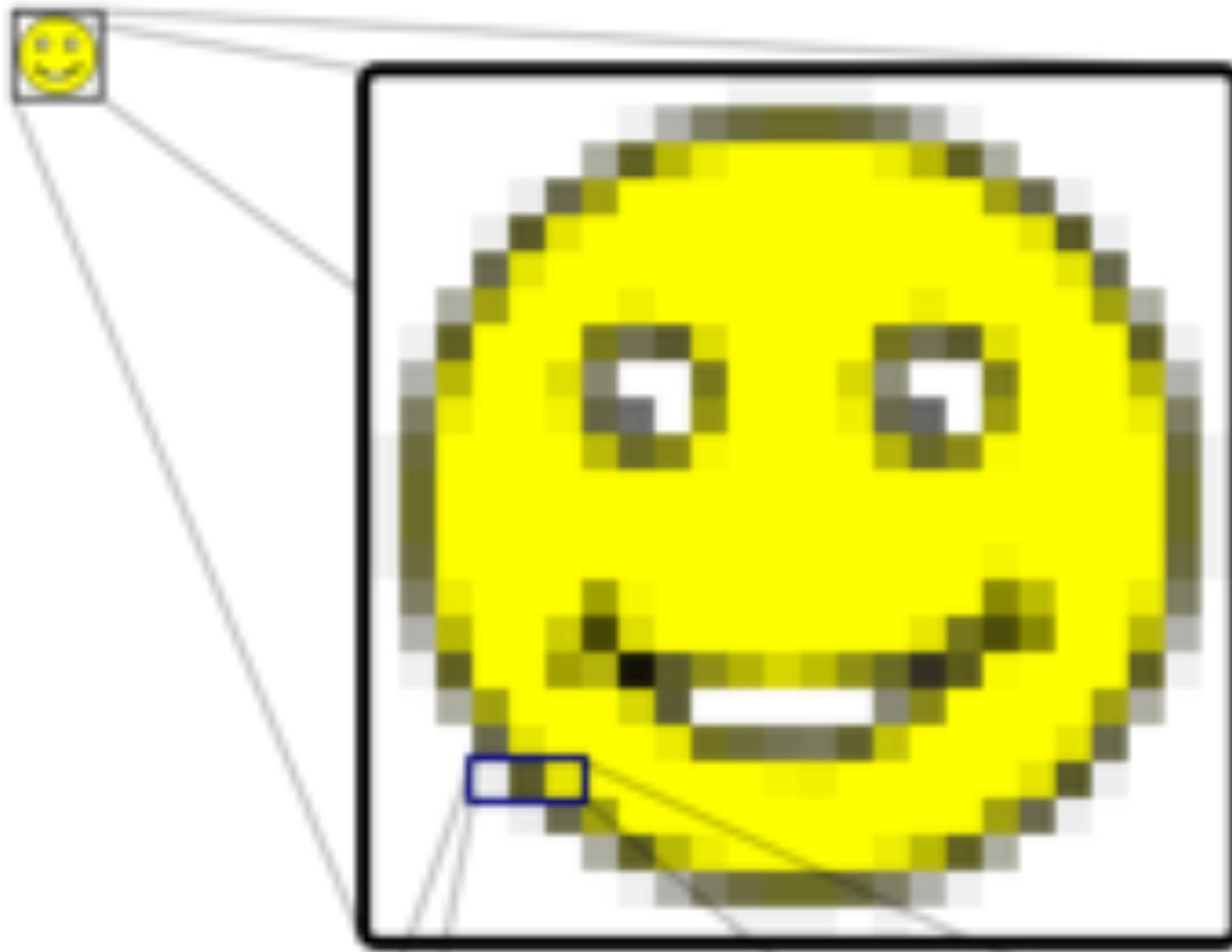


Grey-scale image

a “pixel”

1	2	3	4	1	1	2	1
2	2	3	2	1	2	2	1
3	1	38	39	37	36	3	1
4	1	45	44	41	42	2	1
1	2	43	44	40	39	1	3
2	1	39	41	42	40	2	1
1	2	1	2	2	3	1	1
1	2	1	3	1	1	4	2

Matrix representation



a “pixel”

R 93%	R 35%	R 90%
G 93%	G 35%	G 90%
B 93%	B 16%	B 0%

Engineered features



Low-level features:
“*Global features*”; edges; corners

High-level features:
“*Model-based features*”; objects;
feature combinations









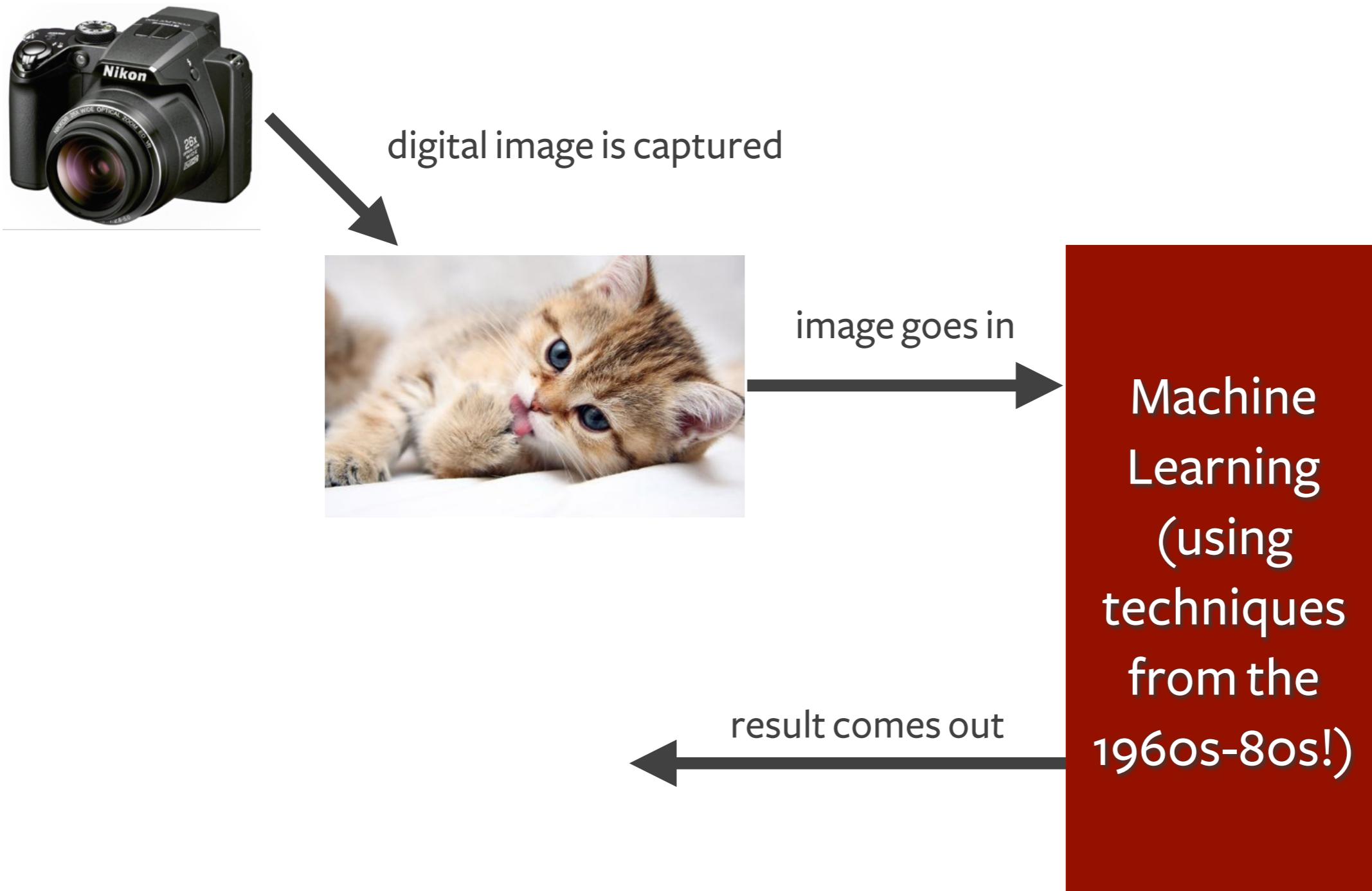




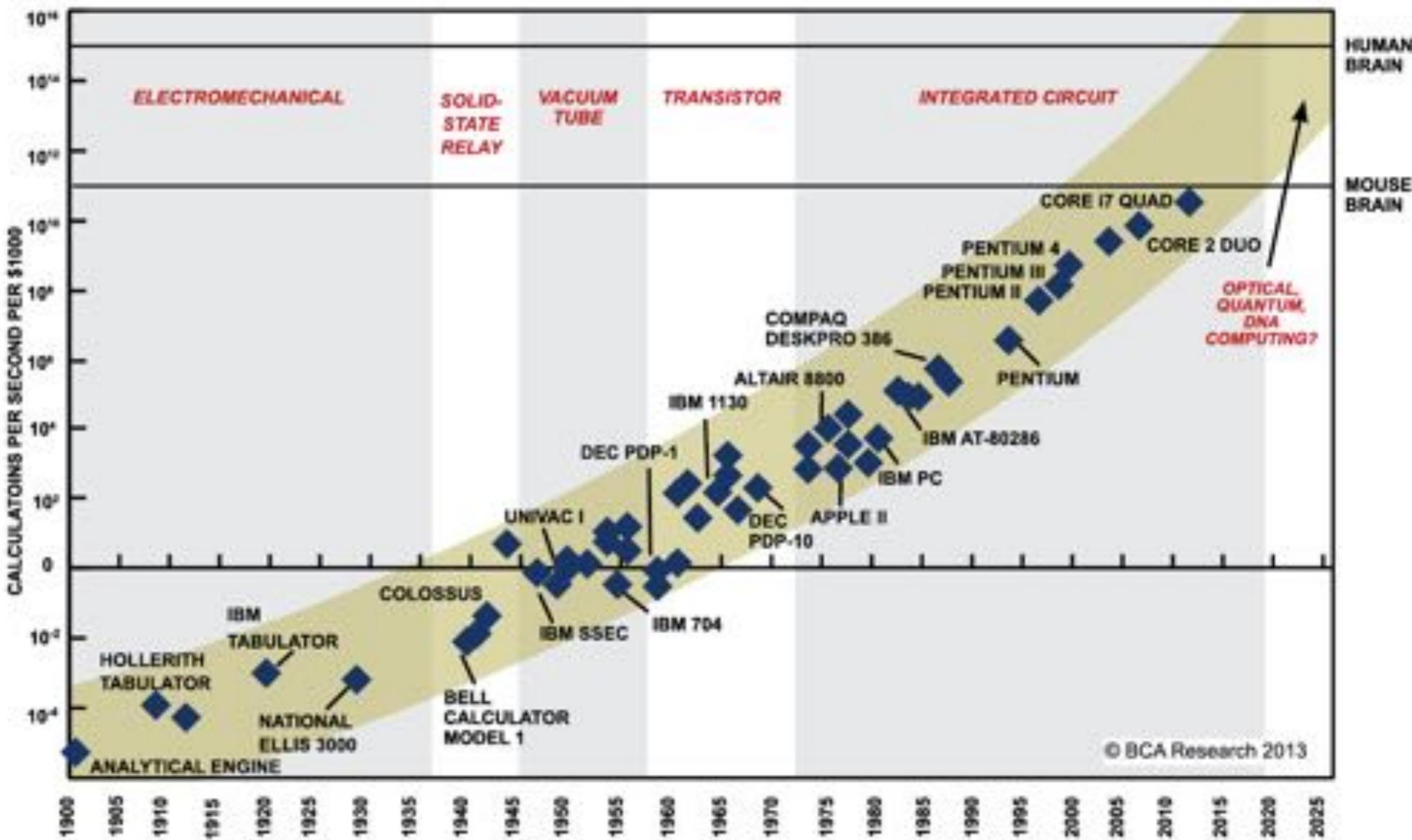
Vision in the last 10 years: *Feature Learning*



Recent approaches to computer vision take the following form:



Moore's Law



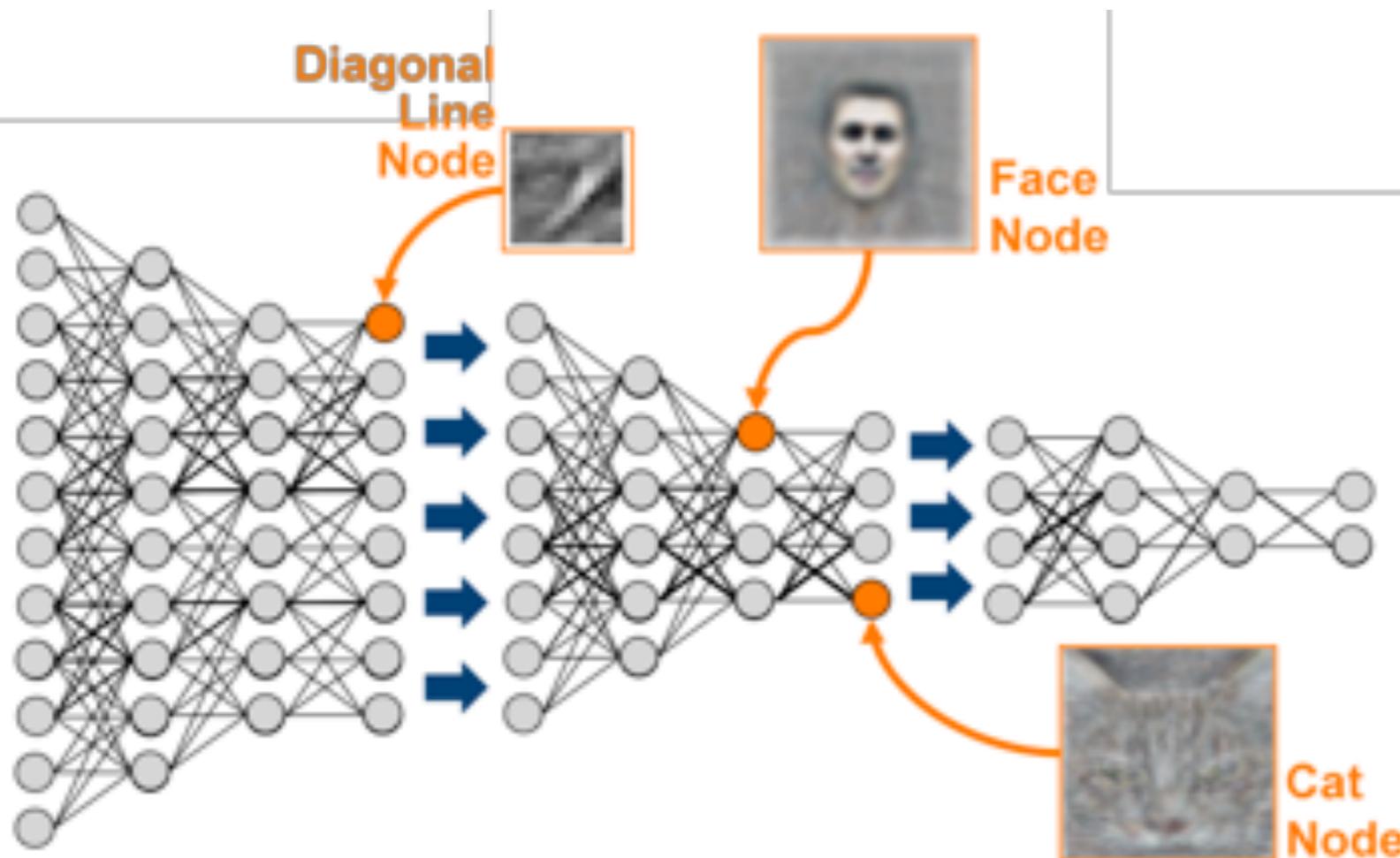
SOURCE: RAY KURZWEIL, "THE SINGULARITY IS NEAR: WHEN HUMANS TRANSCEND BIOLOGY", P.67, THE VIKING PRESS, 2005. DATAPoints BETWEEN 2000 AND 2012 REPRESENT BCA ESTIMATES.

© BCA Research 2013

The new Moore's Law: Computer's no longer get faster, just wider

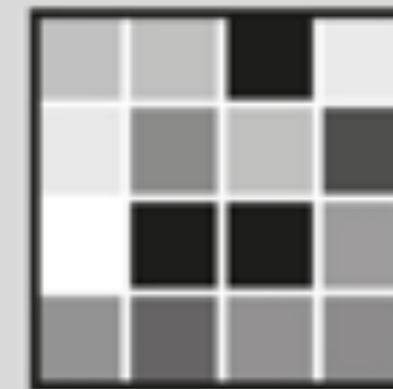


Deep learning: learning layers of features

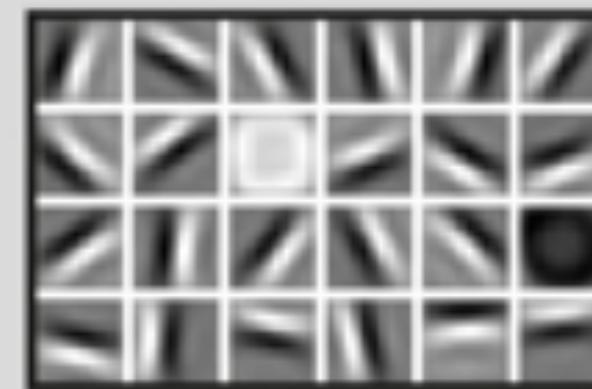


FACIAL RECOGNITION

Deep-learning neural networks use layers of increasingly complex rules to categorize complicated shapes such as faces.



Layer 1: The computer identifies pixels of light and dark.



Layer 2: The computer learns to identify edges and simple shapes.



Layer 3: The computer learns to identify more complex shapes and objects.



Layer 4: The computer learns which shapes and objects can be used to define a human face.



Do computers dream of electric sheep?

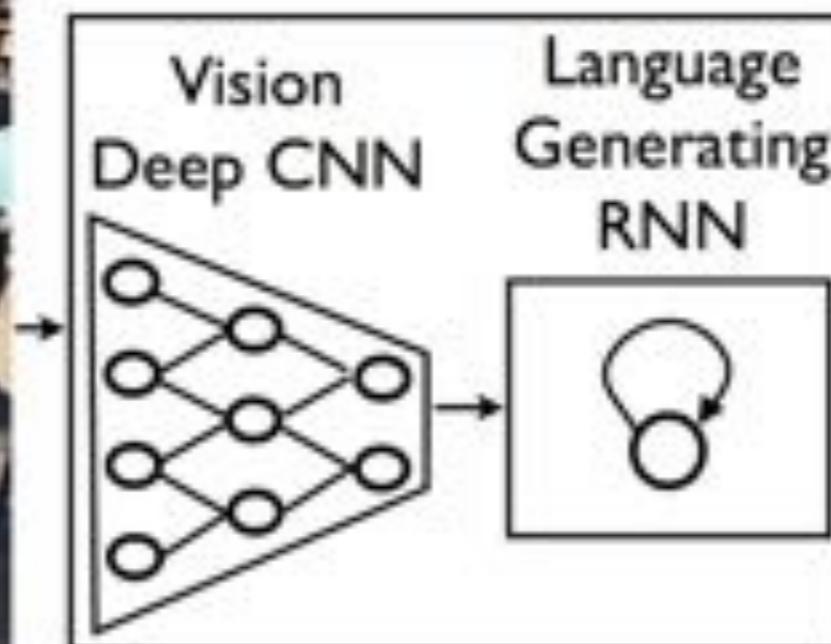
Inceptionism and Algorithmic Pareidolia







State-of-the-art computer vision: Recurrent networks for image captioning



**A group of people
shopping at an
outdoor market.**

**There are many
vegetables at the
fruit stand.**



“a man is climbing up a rock face”



“a motorcycle racer is driving a turn on a racetrack”



“a basketball player in a red uniform is trying to score a player in the air”

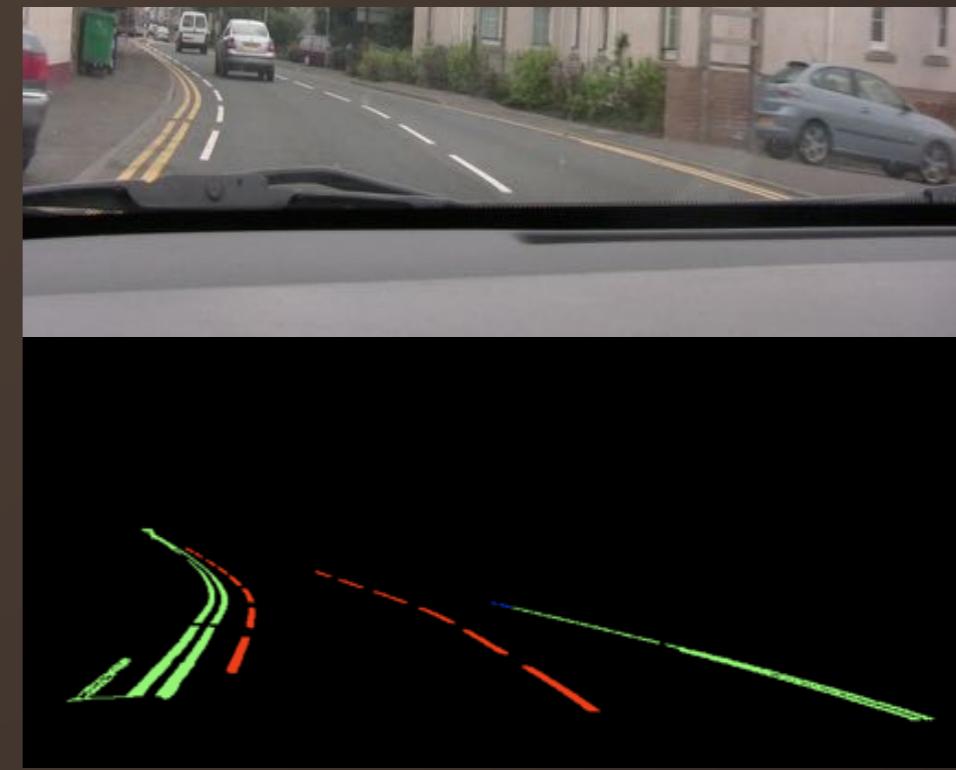
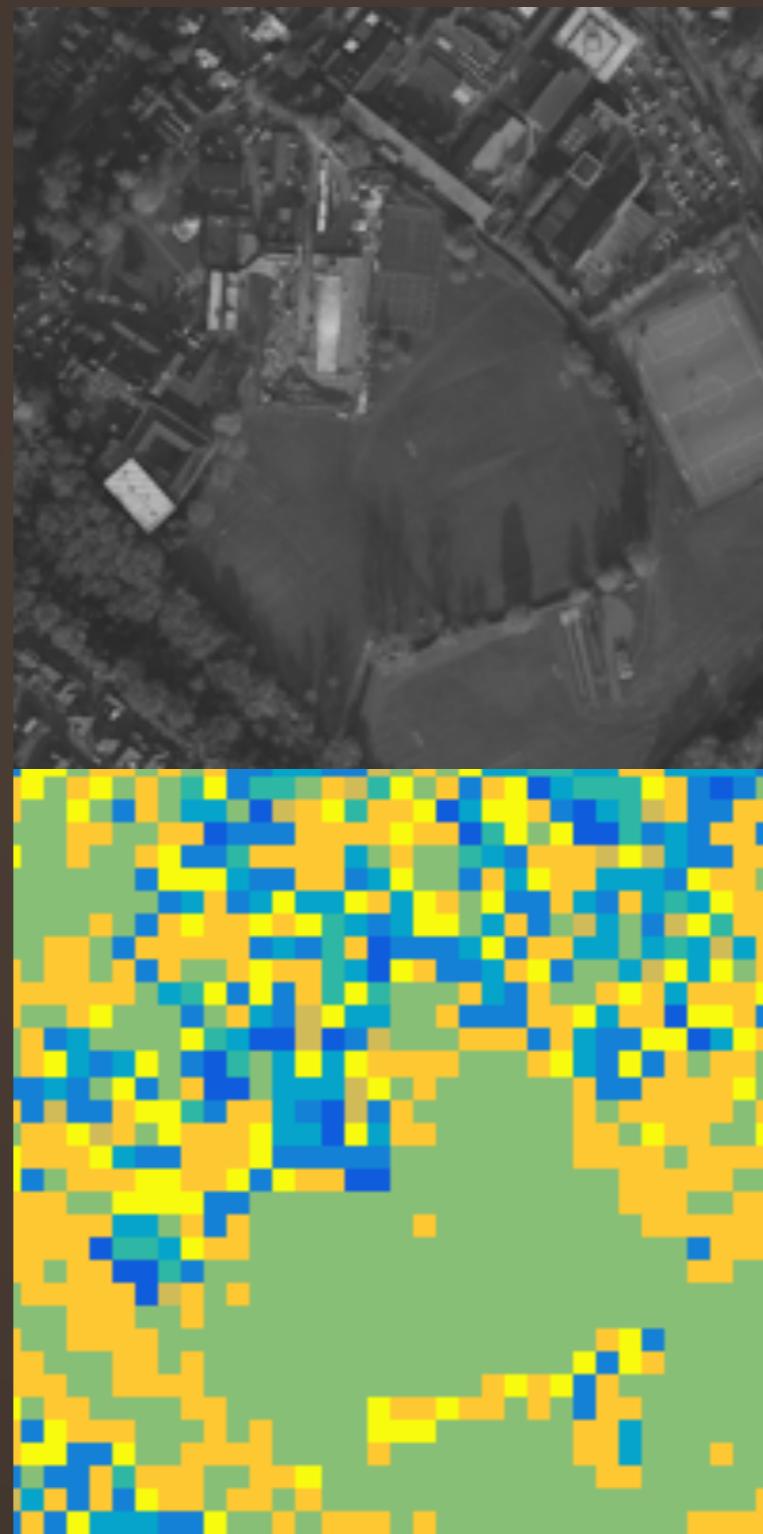


“a man in a red shirt is riding a bike on a snowy
hill”



“a surfer is jumping off a snowy hill”

Current Research Areas



Open questions
and future
directions



QUESTIONS

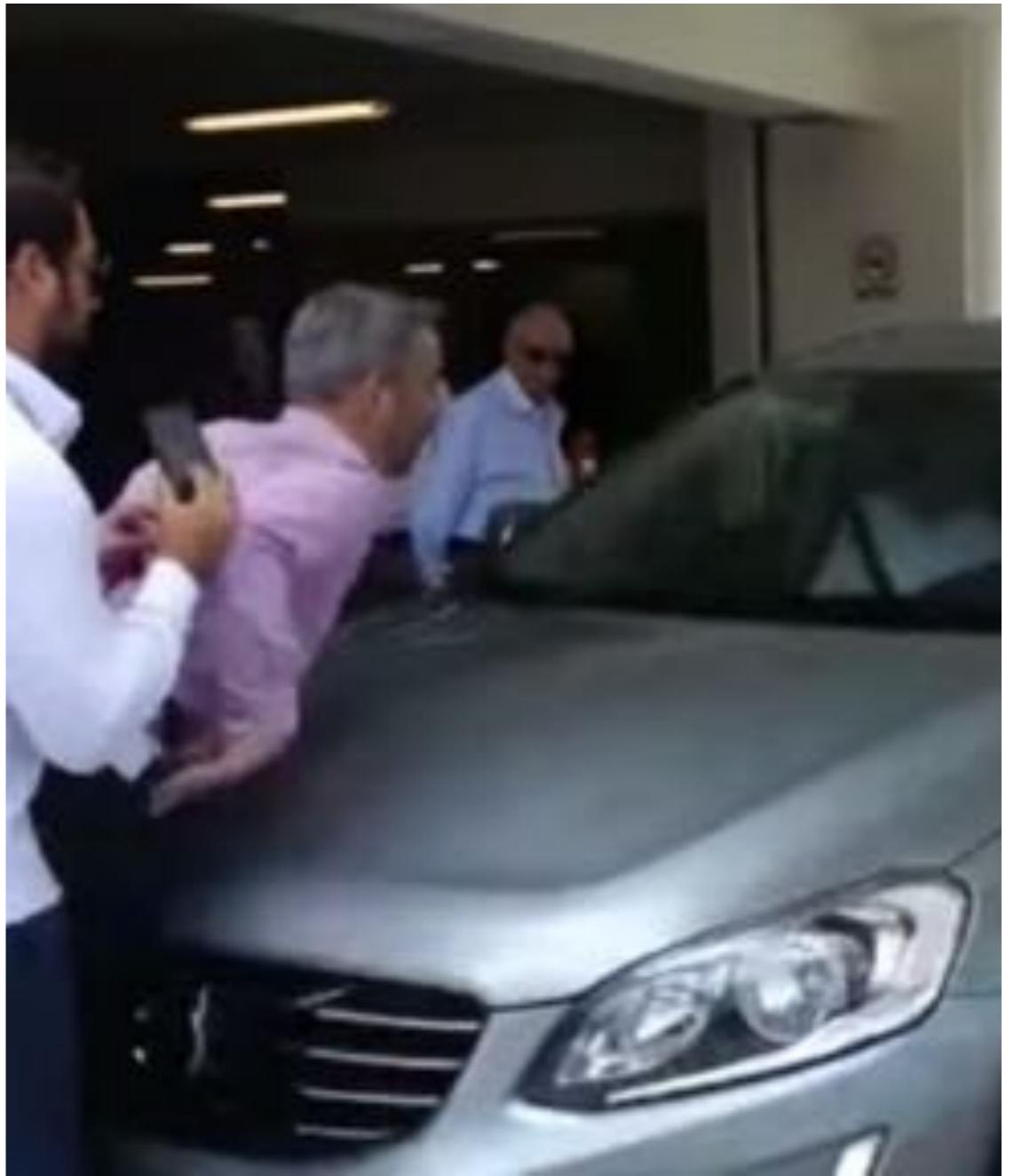
Technological issues

- Modern super-computers only come within a fraction of the computing power of the human brain.
- We still don't understand how the brain works, or what intelligence is.
- Humans don't need to see thousands of examples in order to learn to identify different types of object



Legal and ethical issues

- We still don't understand the brain; to do so inevitably means more animal experiments.
- With more and more pervasive use of vision technologies we're going to have to make difficult decisions.
 - Should the self-driving car optimise to preserve the life of its occupants or others?



Discussion & Questions