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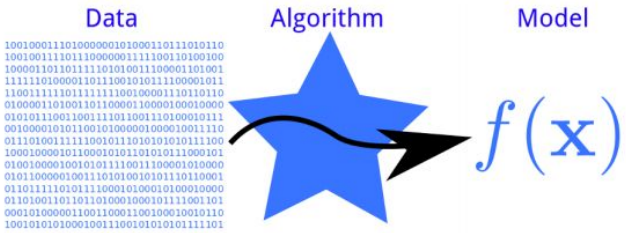
Τεχνητά νευρωνικά δίκτυα και ευφυή υπολογιστικά συστήματα

Εισαγωγη 2021

Μηχανική μάθηση

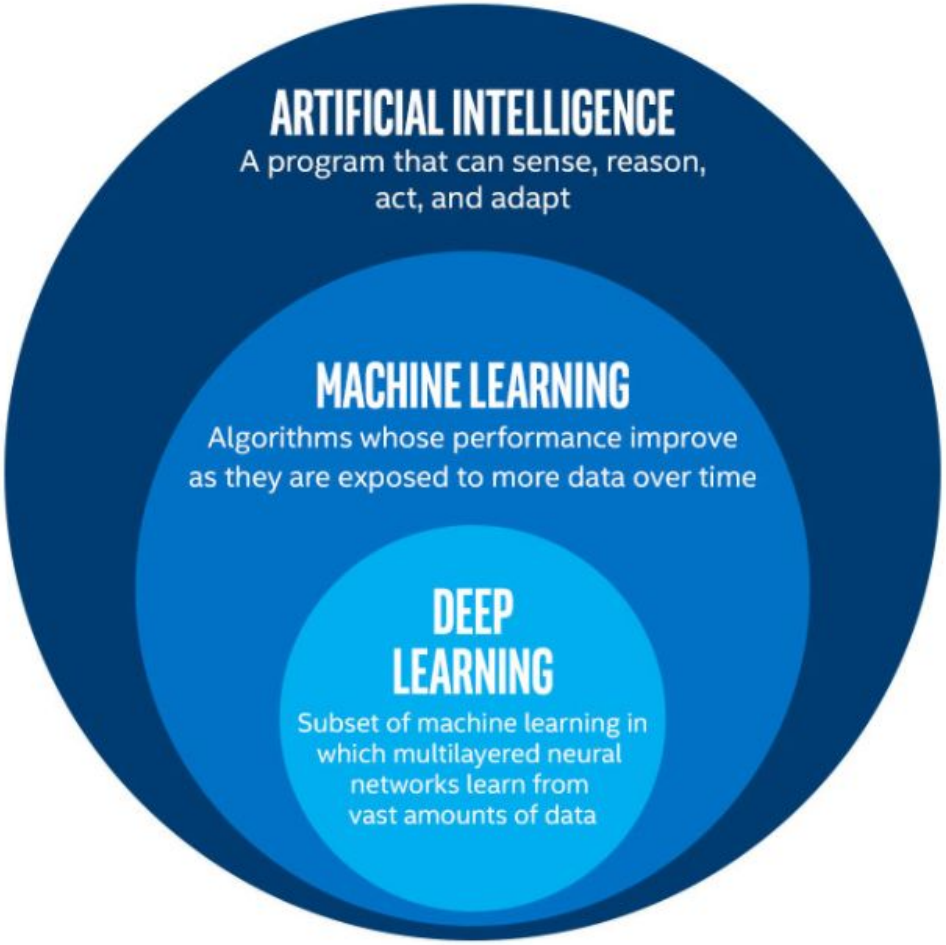
The subfield of computer science that "gives computers the ability to learn without being explicitly programmed".
(Arthur Samuel, 1959)



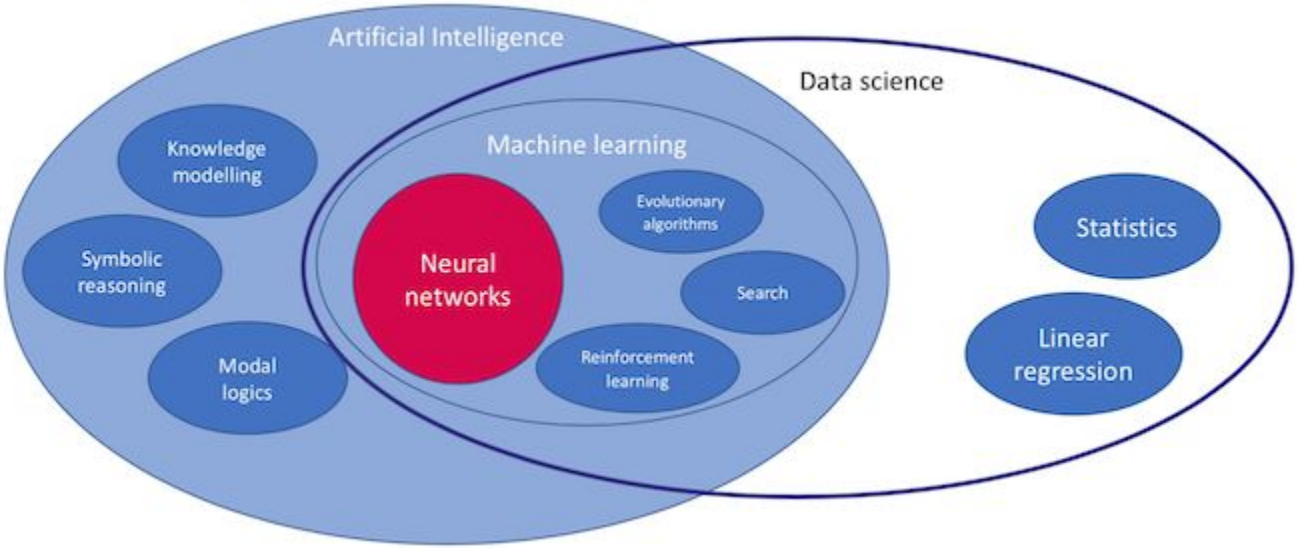
Ορισμός προβλήματος μάθησης

Ένα πρόγραμμα υπολογιστή *μαθαίνει* από μία εμπειρία E ως προς μια κλάση εργασιών T και ένα μέτρο επίδοσης P, αν η επίδοσή του σε εργασίες της κλάσης T, όπως αποτιμάται από το μέτρο P, βελτιώνεται με την εμπειρία E.

Ευφυή υπολογιστικά συστήματα



Ευφυή υπολογιστικά συστήματα



Συμβολική ΤΝ - Στατιστική - Μηχανική Μάθηση

Symbolic AI	Mathematical/Statistical AI	Machine Learning Approach
"Let us sit down with the world's best chess player, Ekpe Okorafor, and put his knowledge into a computer program"	"Let us simulate all the different possible moves and the associated outcomes at each single step and go with the most likely to win"	**"Let us show millions of examples or real life and simulated games (won and lost) to the program, and let it learn from experience"**

TN vs MM

Traditional AI techniques

- **Static** – hard-coded set of steps and scenarios
- **Rule Based** – expert knowledge
- **No generalization** – handling special cases is difficult

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Machine Learning

- **Dynamic** – evolves with data, finds new patterns
- **Data driven** – discovers knowledge
- **Generalization** – adapts to new situations and special cases

Χαρακτηριστικά ανθρώπινου εγκεφάλου

Ελλείψεις αρχιτεκτονικής von Neumann

- Μαζική παραλληλία
- Κατανεμημένη αναπαράσταση
- Κατανεμημένη επεξεργασία
- Ανοχή σε σφάλματα, αστοχίες
- Αφαίρεση
- Γενίκευση
- Προσαρμοστικότητα
- Μάθηση

Πότε χρησιμεύει η Μηχανική Μάθηση

Tasks programmers can't describe

Hand writing

Cognitive Reasoning

Complex multidimensional problems that can't be solved by numerical reasoning

Weather Forecasting

Health Care Outcomes

Network Intrusion

Movie Recommendation

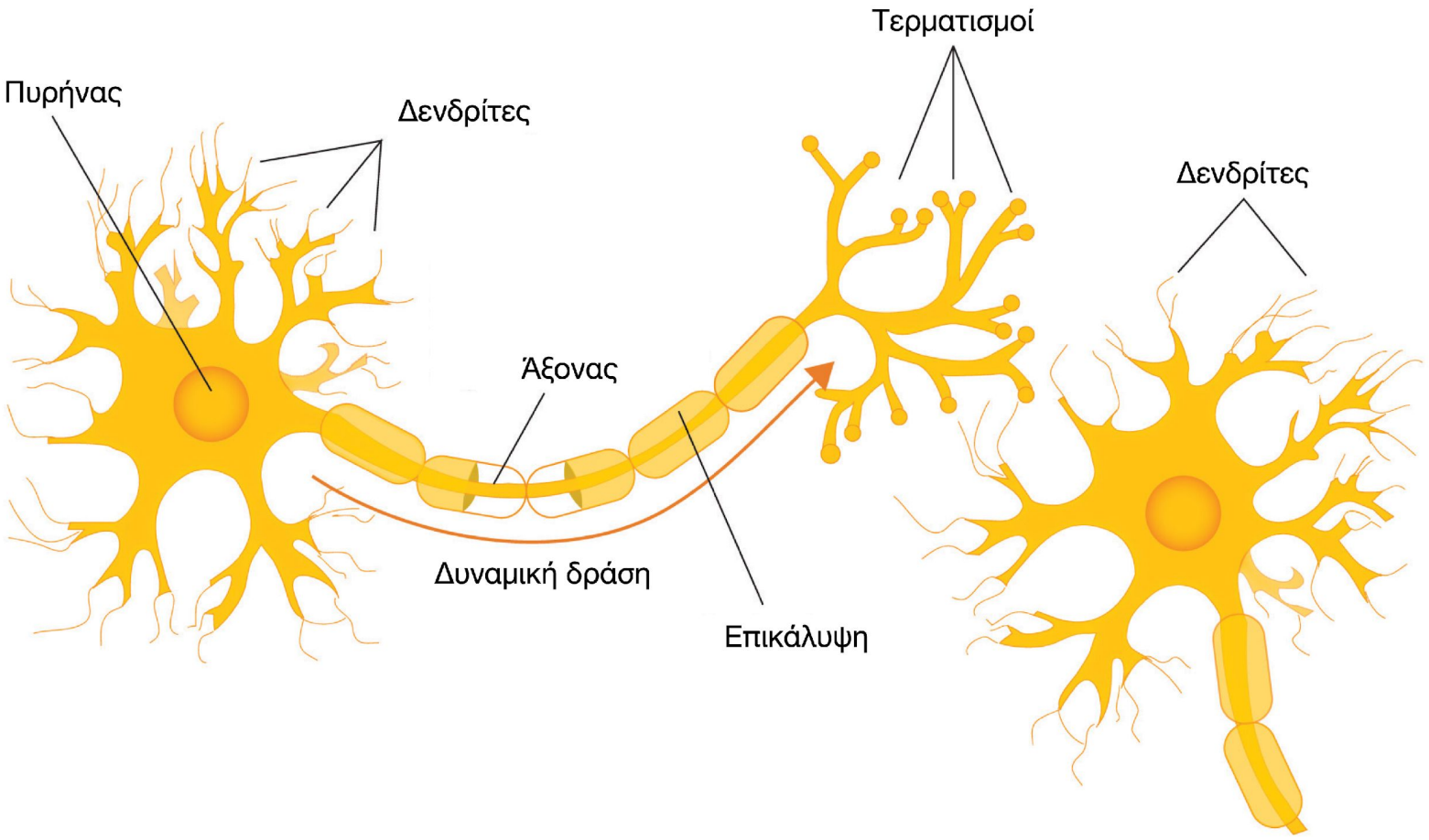
Τεχνητά νευρωνικά δίκτυα

Χαρακτηριστικά μοντελοποίησης

- Κατανόηση και μοντελοποίηση βιολογικών λειτουργιών
- Προσπάθεια εφαρμογής αρχών βιολογικού εγκεφάλου (δομικά στοιχεία, αρχιτεκτονική, λειτουργικότητα)
- Υλοποιησιμότητα (πραγματιστική προσέγγιση)

- Απλές υπολογιστικές μονάδες
- Μεγάλος αριθμός συνδέσεων (connectionism)
- Παράλληλη κατανεμημένη επεξεργασία και προσαρμογή

Μοντέλο βιολογικού νευρώνα



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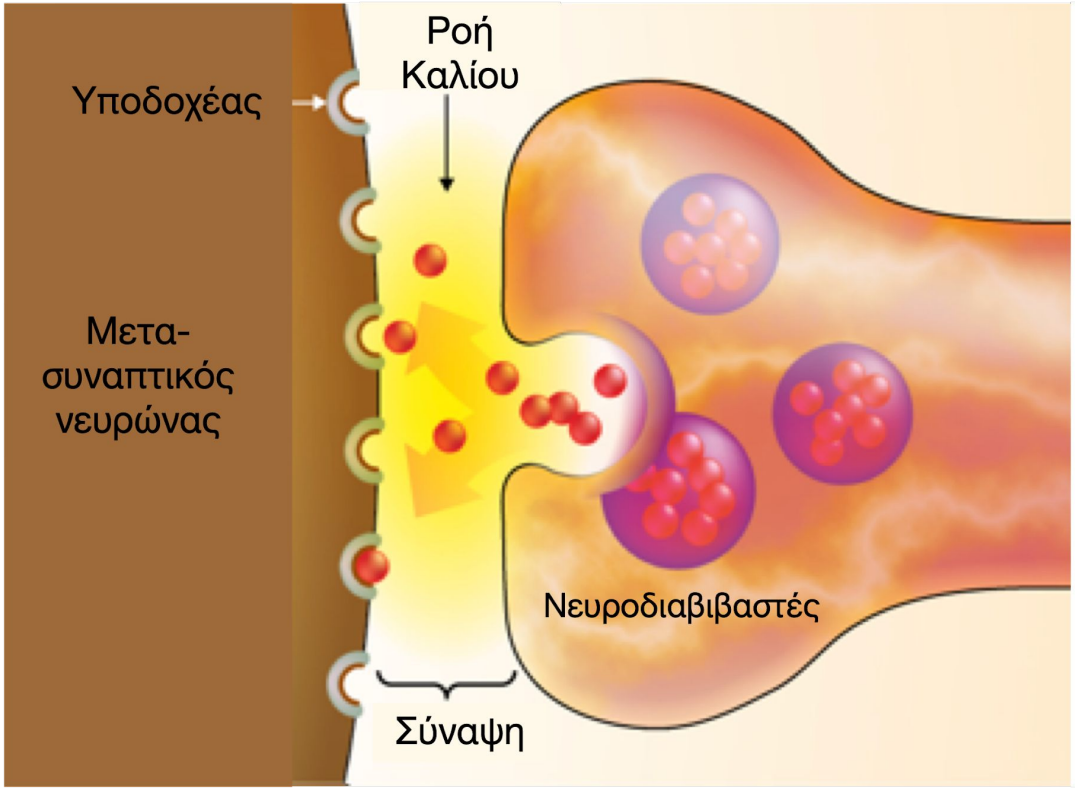
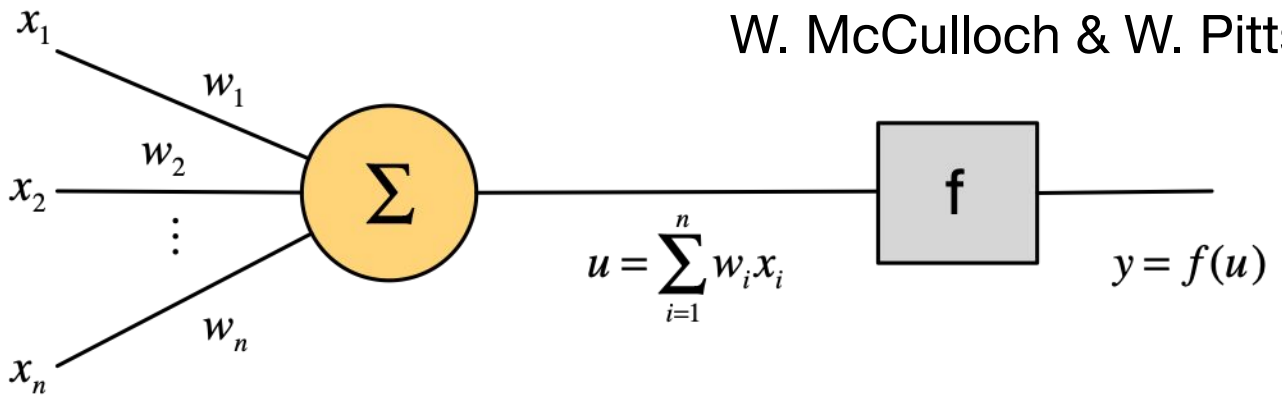


Μοντέλο βιολογικού νευρώνα

Χαρακτηριστικά

- 10^{11} νευρώνες
- 10^{15} συνάψεις
- Χαμηλές ταχύτητες (msec)
- Τοπικός έλεγχος

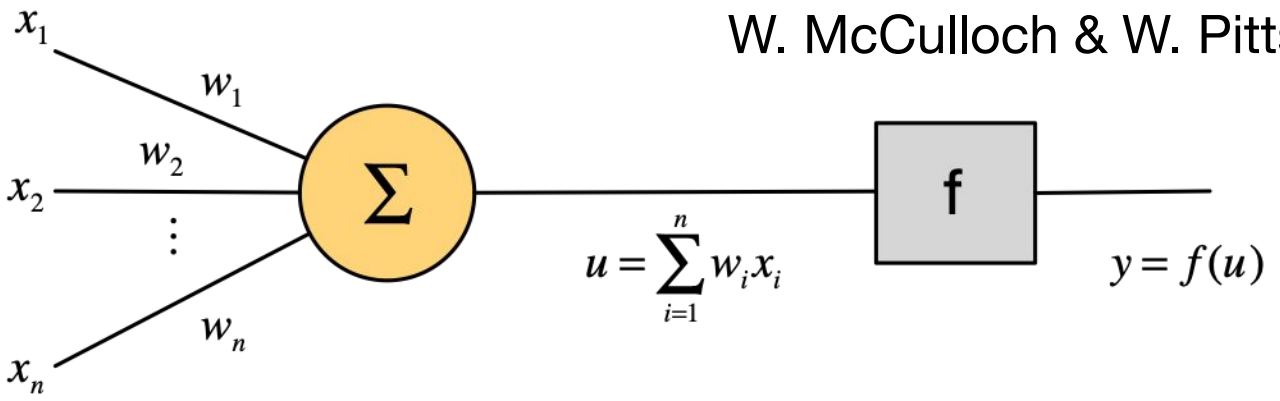
Μοντέλο τεχνητού νευρώνα



W. McCulloch & W. Pitts (1943)

- x_i, w_i, y Είσοδοι, βάρη, έξοδος
- u Αναλυτικό γινόμενο διανυσμάτων εισόδου-βαρών
- f Συνάρτηση ενεργοποίησης

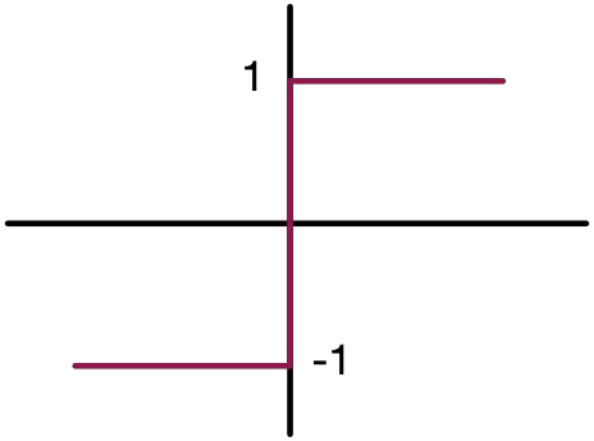
Μοντέλο τεχνητού νευρώνα



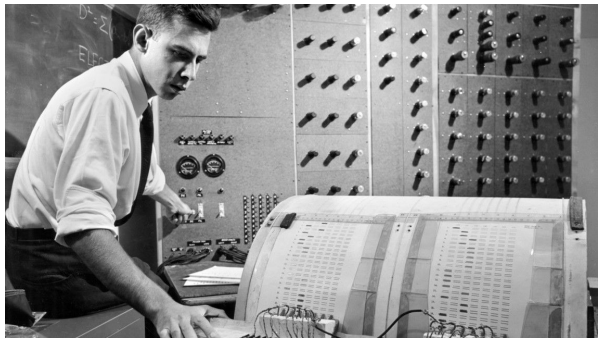
W. McCulloch & W. Pitts (1943)

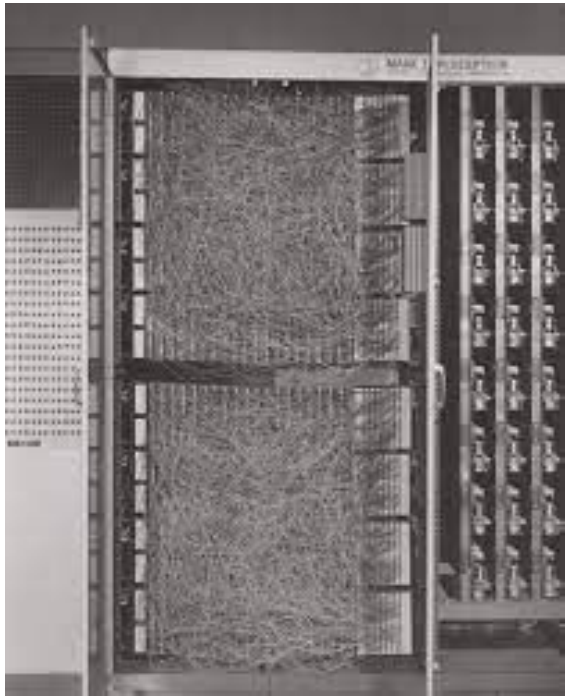
Συναρτήσεις ενεργοποίησης

- Βηματική
- Σιγμοειδής
- Υπερβολική εφαπτομένη
- Κατωφλίου



Perceptron (Rosenblatt, 1958)





Perceptron

1958 New York Times...

NEW NAVY DEVICE LEARNS BY DOING

Psychologist Shows Embryo of Computer Designed to Read and Grow Wiser

WASHINGTON, July 7 (UPI) —The Navy revealed the embryo of an electronic computer today that it expects will be able to walk, talk, see, write, reproduce itself and be conscious of its existence.

The embryo—the Weather Bureau's $2,000,000 "704" computer—learned to differentiate between right and left after fifty attempts in the Navy's demonstration for newsmen.

The service said it would use this principle to build the first of its Perceptron thinking machines that will be able to read and write. It is expected to be finished in about a year at a cost of $100,000.

Dr. Frank Rosenblatt, designer of the Perceptron, conducted the demonstration. He said the machine would be the first device to think as the human brain. As do human beings, Perceptron will make mistakes at first, but will grow wiser as it gains experience, he said.

Dr. Rosenblatt, a research psychologist at the Cornell Aeronautical Laboratory, Buffalo, said Perceptrons might be fired to the planets as mechanical space explorers.

Without Human Controls

The Navy said the perceptron would be the first non-living mechanism "capable of receiving, recognizing and identifying its surroundings without any human training or control."

The "brain" is designed to remember images and information it has perceived itself. Ordinary computers remember only what is fed into them on punch cards or magnetic tape.

Later Perceptrons will be able to recognize people and call out their names and instantly translate speech in one language to speech or writing in another language, it was predicted.

Mr. Rosenblatt said in principle it would be possible to build brains that could reproduce themselves on an assembly line and which would be conscious of their existence.

In today's demonstration, the "704" was fed two cards, one with squares marked on the left side and the other with squares on the right side.

Learns by Doing

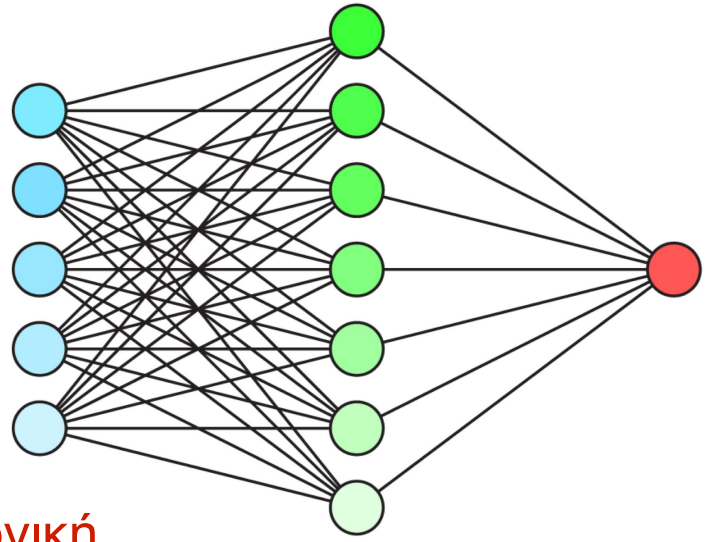
In the first fifty trials, the machine made no distinction between them. It then started registering a "Q" for the left squares and "O" for the right squares.

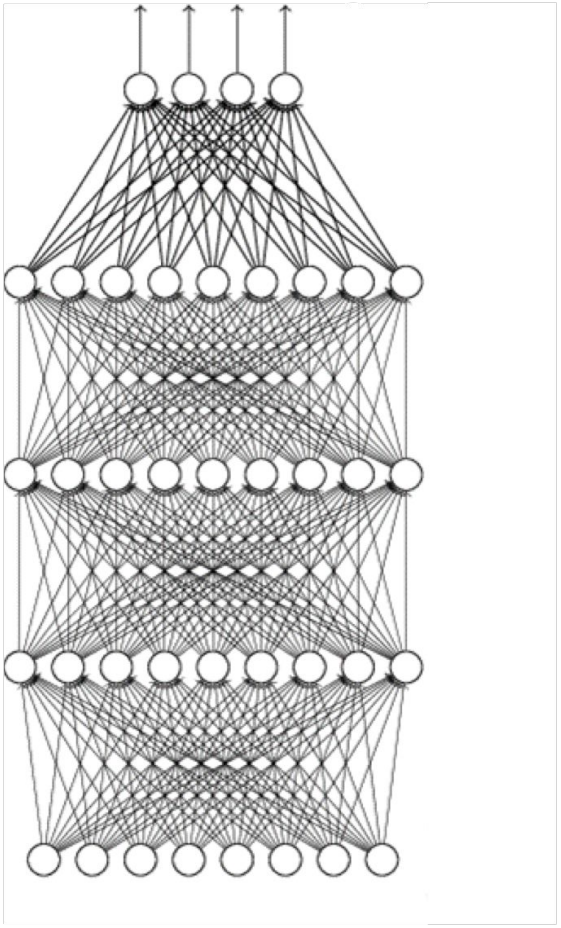
Dr. Rosenblatt said he could explain why the machine learned only in highly technical terms. But he said the computer had undergone a "self-induced change in the wiring diagram."

The first Perceptron will have about 1,000 electronic "association cells" receiving electrical impulses from an eye-like scanning device with 400 photo-cells. The human brain has 10,000,000,000 responsive cells, including 100,000,000 connections with the eyes.

Νευρωνικά δίκτυα - Βαθιά μάθηση

Συνδέσεις νευρώνων





Αρχιτεκτονική

- Στρώματα (layers)
- Πρόσθια τροφοδότηση (feedforward)
- Ανατροφοδότηση (feedback, recurrent)

Μάθηση στα νευρωνικά δίκτυα

Πρόβλημα

Δίνεται μία εμπειρία (συνήθως ένα σύνολο δεδομένων εισόδου-επιθυμητής εξόδου στην *επιβλεπόμενη* μάθηση, ή μόνο δεδομένα εισόδου και αξιολόγηση επίδοσης στη *μη-επιβλεπόμενη* μάθηση) και ζητείται ο προσδιορισμός των παραμέτρων του δικτύου (αρχιτεκτονική, βάρη συνάψεων), έτσι ώστε η επίδοσή του να είναι ικανοποιητική

Ζητήματα που προκύπτουν

- Υπάρχει λύση για τα συγκεκριμένα δεδομένα;
- Μπορεί να βρεθεί η λύση (αν υπάρχει);
- Αν υπάρχουν πολλές λύσεις, μπορεί να βρεθεί η καλύτερη;
- Μεθοδολογία (ανάπτυξη, αξιολόγηση επίδοσης κλπ)

Είδη της Μηχανικής Μάθησης

Supervised

Unsupervised

Reinforcement

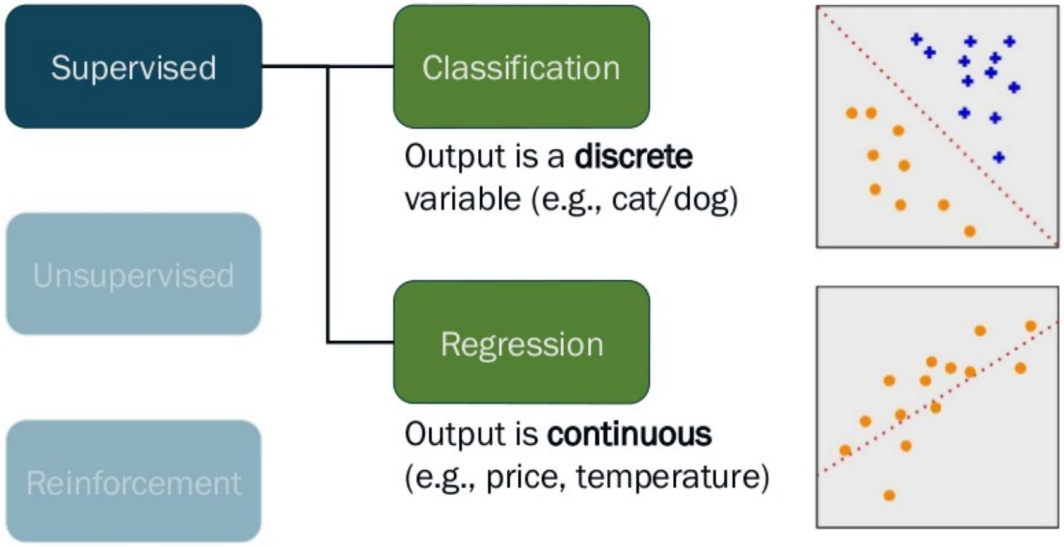
Learn through **examples** of which we know the desired output (what we want to predict).

Is this a cat or a dog?

Are these emails spam or not?

Predict the market value of houses, given the square meters, number of rooms, neighborhood, etc.

Είδη της Μηχανικής Μάθησης



Είδη της Μηχανικής Μάθησης

Supervised

Unsupervised

Reinforcement

There is **no *desired* output**. Learn something about the data. *Latent* relationships.

I have photos and want to put them in 20 groups.

I want to find anomalies in the credit card usage patterns of my customers.

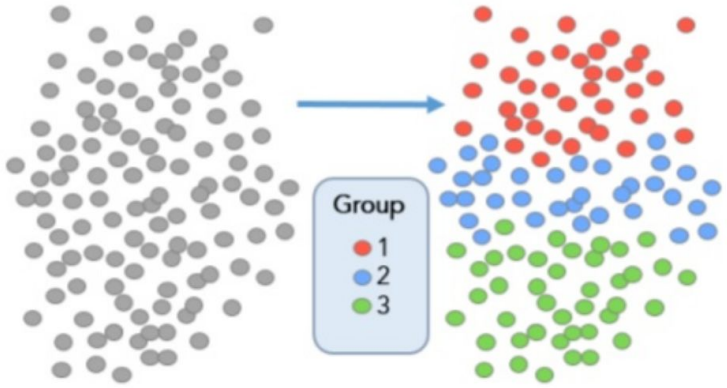
Είδη της Μηχανικής Μάθησης

Supervised

Unsupervised

Reinforcement

Useful for learning structure in the data **(clustering)**, hidden correlations, reduce dimensionality, etc.



Είδη της Μηχανικής Μάθησης

Supervised

Unsupervised

Reinforcement

An agent **interacts** with an **environment** and watches the result of the interaction.

Environment gives feedback via a positive or negative **reward signal**.

Νευρωνικά δίκτυα - Κατηγορίες

Επιβλεπόμενη μάθηση

- Πολυστρωματικά perceptron
- Δίκτυα RBF (Radial Basis Functions)
- LVQ (Learning Vector Quantisation)
- SVM (Support Vector Machines)

Μη επιβλεπόμενη μάθηση

- Ομαδοποίηση (Clustering)
- Δίκτυα Hopfield
- Ανταγωνιστικά δίκτυα
- Αυτοοργανούμενοι χάρτες Kohonen

Παραδείγματα αλγορίθμων ΜΜ

Supervised

- Linear classifier
- Naive Bayes
- Support Vector Machines (SVM)
- Decision Tree
- Random Forests
- k-Nearest Neighbors
- **Neural Networks (Deep learning)**

Unsupervised

- PCA
- t-SNE
- k-means
- DBSCAN

Reinforcement

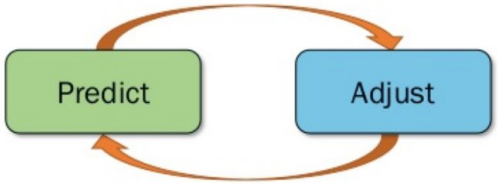
- SARSA–λ
- Q-Learning

Βιβλιοθήκες - Python

Επιλογή Αλγορίθμου και Εκπαίδευση

Goal of training: making the correct prediction as often as possible

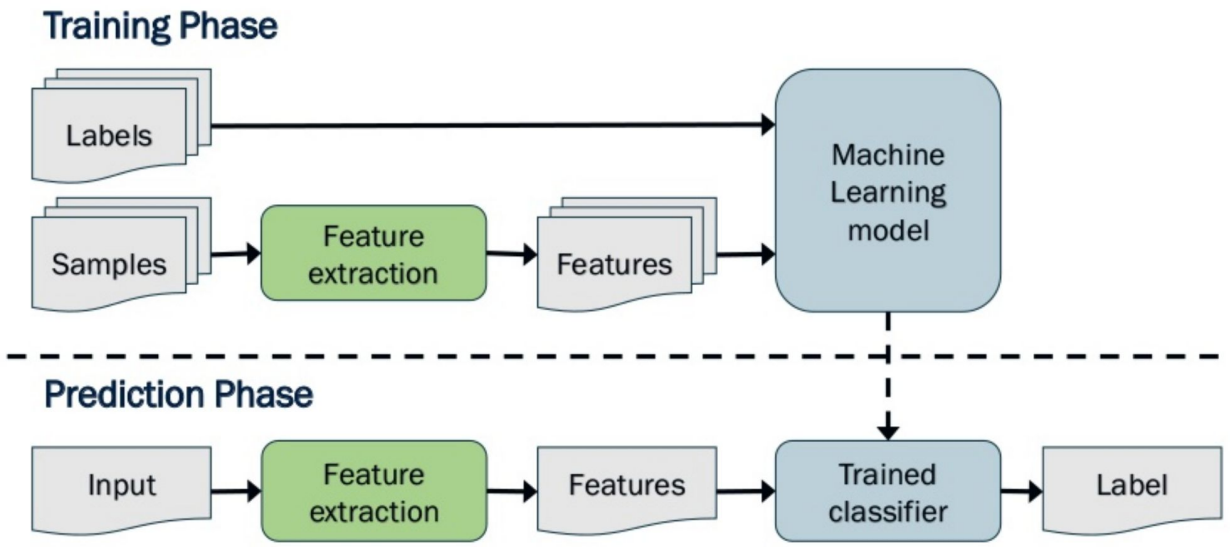
- Incremental improvement:



- Use of metrics for **evaluating** performance and comparing solutions
- **Hyperparameter tuning**: more an art than a science

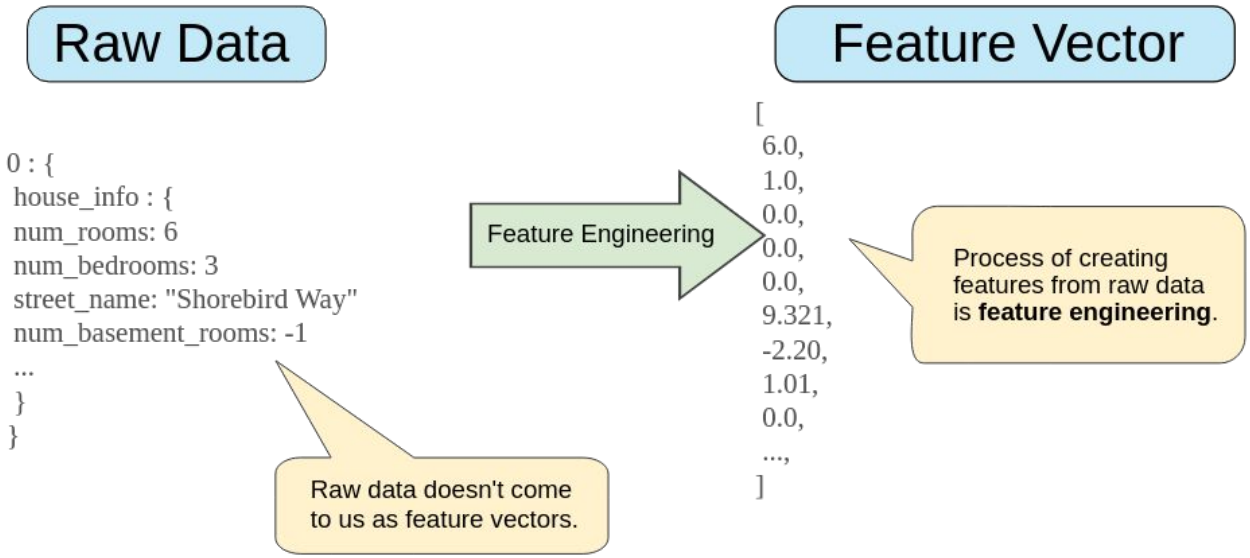
- Every ML algorithm has three components:
  - **Representation**
  - **Optimization**
  - **Evaluation**

Πρόβλεψη - Inference



Representation & Features

(αναπαράσταση και χαρακτηριστικά)



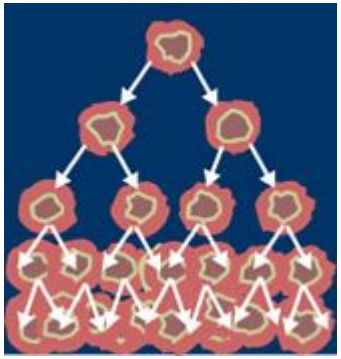
Datasets

Attribute Information:

1) ID number
2) Diagnosis (M = malignant, B = benign)
3-32)

Ten real-valued features are computed for each cell nucleus:

a) radius (mean of distances from center to points on the perimeter)
b) texture (standard deviation of gray-scale values)
c) perimeter
d) area
e) smoothness (local variation in radius lengths)
f) compactness (perimeter^2 / area - 1.0)
g) concavity (severity of concave portions of the contour)
h) concave points (number of concave portions of the contour)
i) symmetry
j) fractal dimension ("coastline approximation" - 1)



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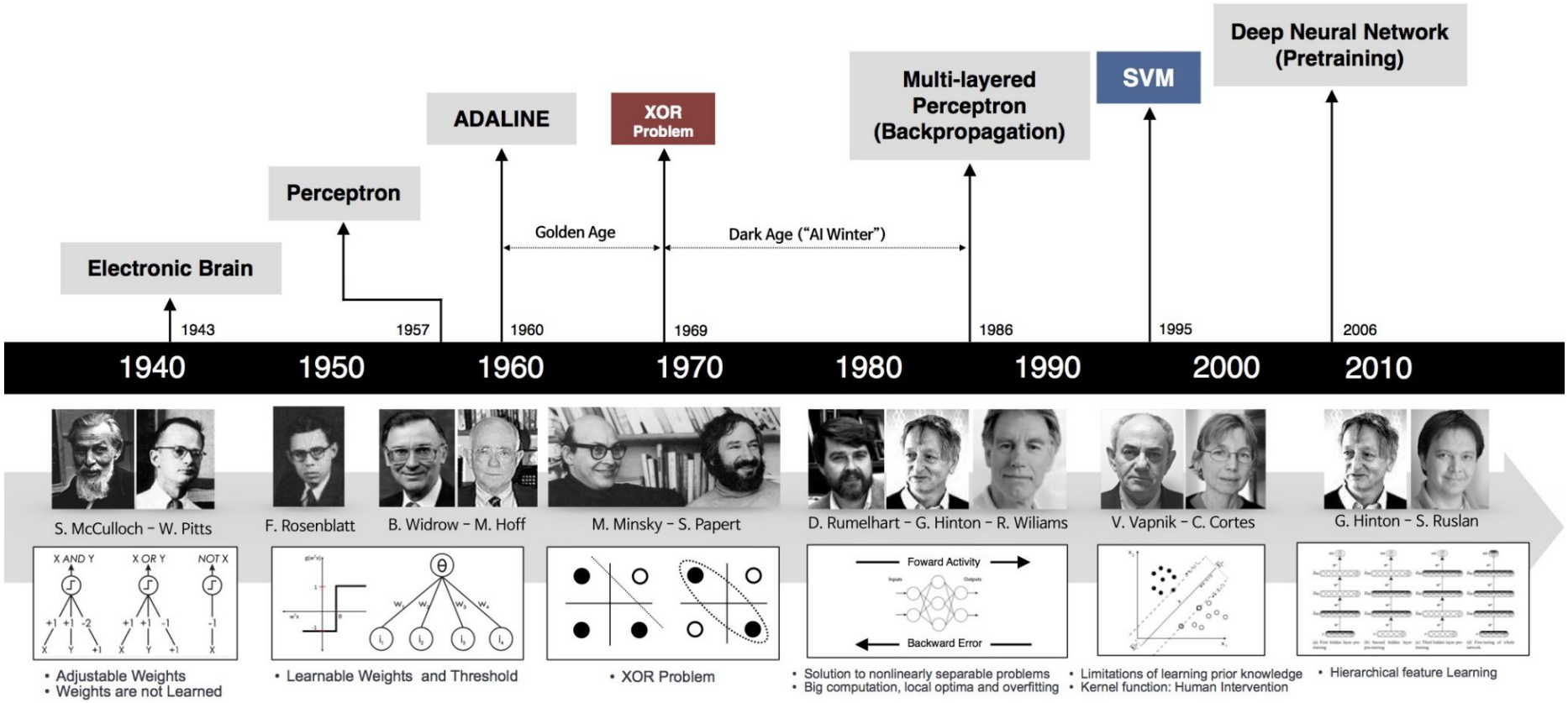
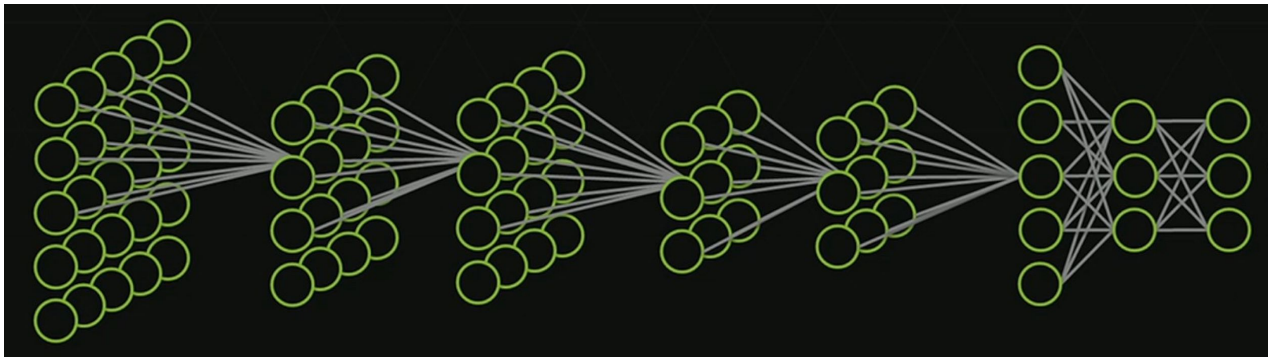
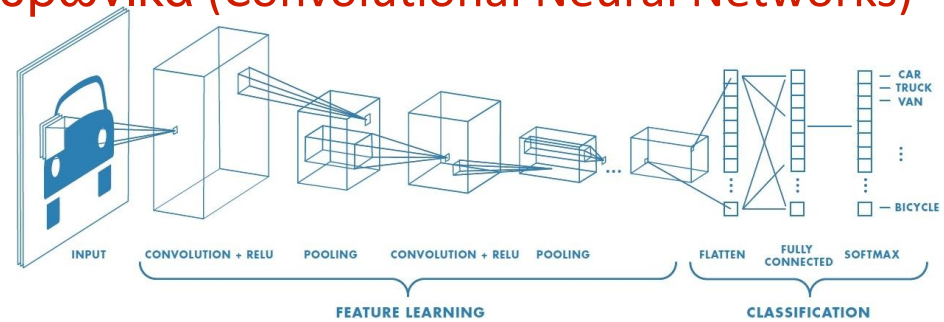

Deep Neural Network (Pretraining)
SVM
Multi-layered Perceptron (Backpropagation)
XOR Problem
ADALINE
Perceptron
Electronic Brain
Golden Age
Dark Age ("AI Winter")
1943
1957
1960
1969
1986
1995
2006
1940
1950
1960
1970
1980
1990
2000
2010
S. McCulloch - W. Pitts
F. Rosenblatt
B. Widrow - M. Hoff
M. Minsky - S. Papert
D. Rumelhart - G. Hinton - R. Wiliams
V. Vapnik - C. Cortes
G. Hinton - S. Ruslan
X AND Y
X OR Y
NOT X
Foward Activity
Backward Error
• Adjustable Weights
• Weights are not Learned
• Learnable Weights and Threshold
• XOR Problem
• Solution to nonlinearly separable problems
• Big computation, local optima and overfitting
• Limitations of learning prior knowledge
• Kernel function: Human Intervention
• Hierarchical feature Learning

Σύγχρονα νευρωνικά δίκτυα

Πολυεπίπεδες αρχιτεκτονικές (βαθιά νευρωνικά δίκτυα)



Συνελικτικά νευρωνικά (Convolutional Neural Networks)



Turing Award 2019

TECHNOLOGY

The New York Times

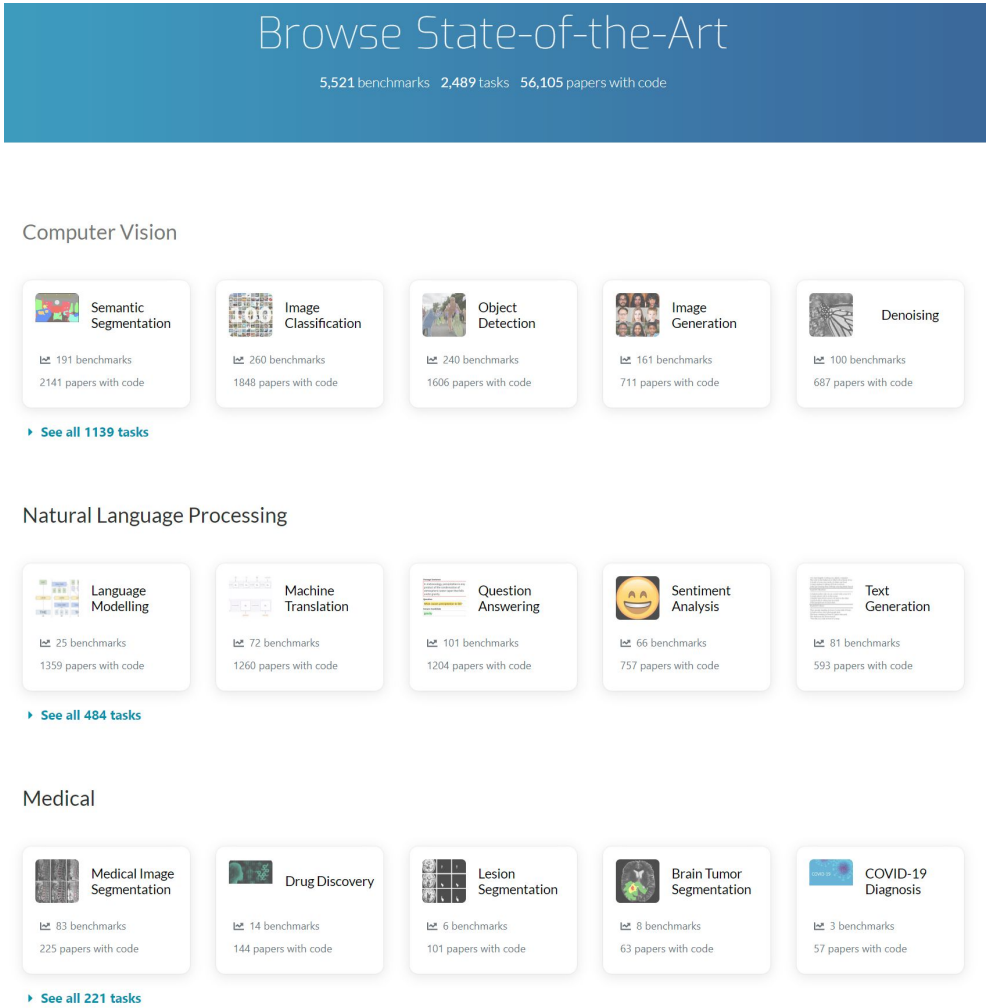
Turing Award Won by 3 Pioneers in Artificial Intelligence

From left, Yann LeCun, Geoffrey Hinton and Yoshua Bengio. The researchers worked on key developments for neural networks, which are reshaping how computer systems are built. From left, Facebook, via Associated Press; Aaron Vincent Elkaim for The New York Times; Chad Buchanan/Getty Images

Η εποχή της Μηχανικής Μάθησης

- Περισσότερα δεδομένα - Internet
- Αλγοριθμικές “εξελίξεις”
- Αλματώδης βελτίωση hardware
- Καλές βιβλιοθήκες (λογισμικό)
- **Strong AI vs Weak AI**

Computer Vision και NLP είναι τα πεδία με τα περισσότερα tasks



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