INTELLIGENZA ARTIFICIALE

INTRODUZIONE ALLE RETI NEURALI

Corsi di Laurea in Informatica, Ing. Gestionale, Ing. Informatica, Ing. di Internet

(a.a. 2021-2022)

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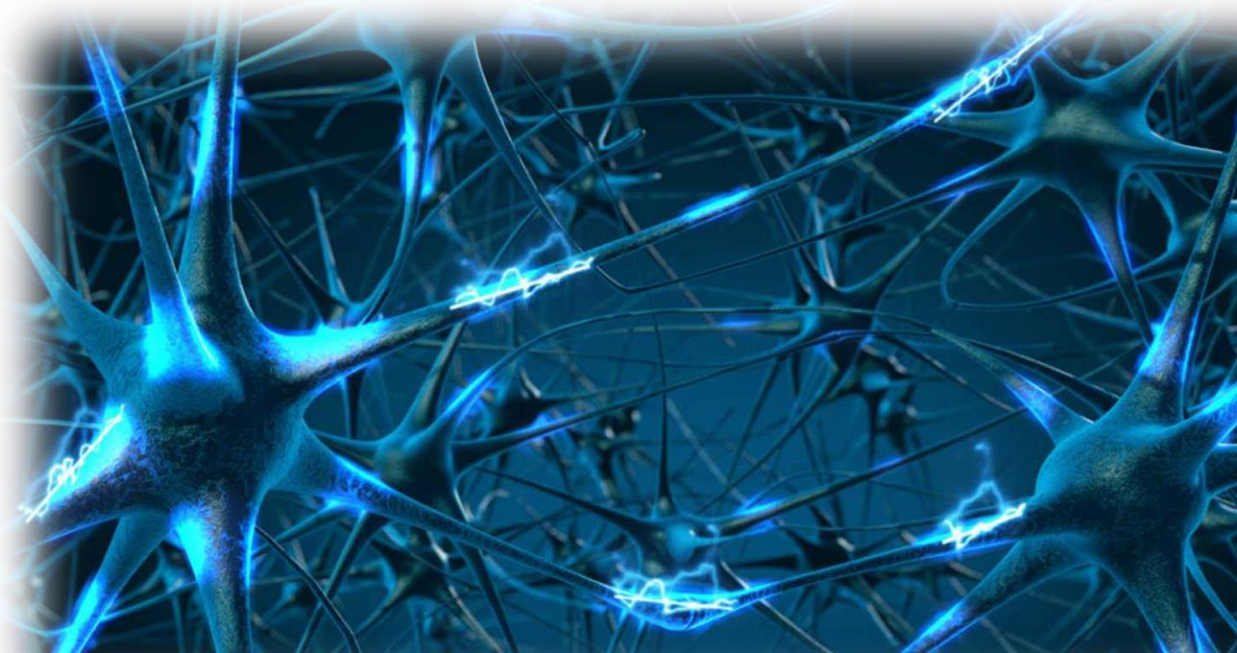
(*) dalle *slides* di S. Russel



Overview (AIMA chpt. 18.1-18.4)

- Agents & machine learning
- Learning from examples:
  - Complexity and Expressiveness
  - The definition of model selection
- An example: Decision Tree learning
  - Recursive search among Boolean formulas
  - Attribute Selection in DT: Information Gain
- Learning methodology: design, experiment/ evaluation and model selection
  - Cross validation

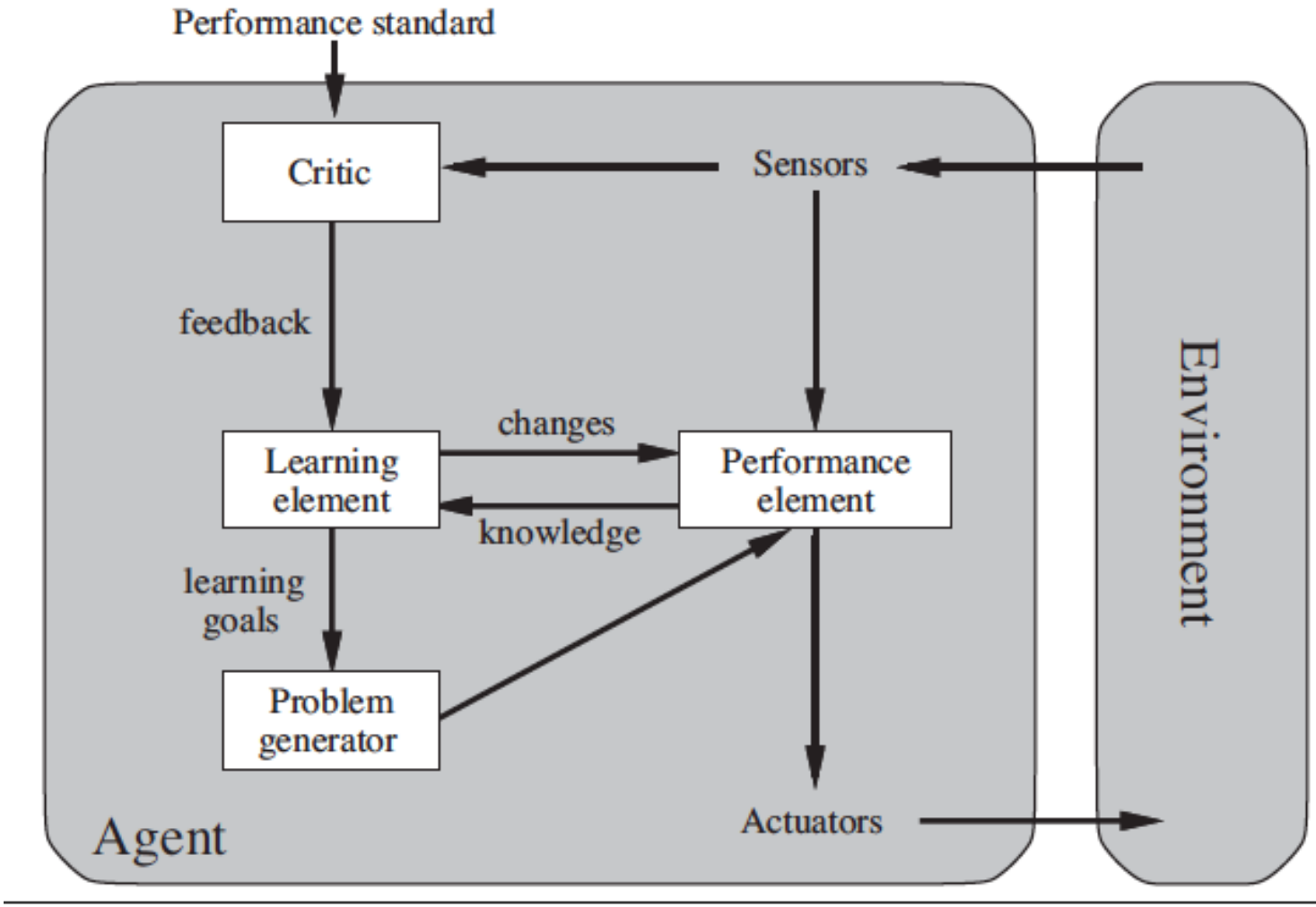
Introduction to machine learning

- Introduction to machine learning
  - When appropriate and when not appropriate
  - Task definition

  - Learning methodology: design, experiment, evaluation
  - Learning issues: representing hypothesis

  - Learning paradigms
    - Supervised learning
    - Unsupervised learning
    - Reinforcement learning

AIMA learning architecture



Machine learning: definition

- *A computer program is said to **learn** from experience E with respect to some class of tasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E* [Mitchell]
- Problem definition for a learning agent
  - Task T
  - Performance measure P
  - Experience E

Designing a learning system

1. Choosing the training experience
   - Examples of best moves, games outcome …
2. Choosing the target function
   - board-move, board-value, …
3. Choosing a representation for the target function
   - linear function with weights (hypothesis space)
4. Choosing a learning algorithm for approximating the target function
   - A method for parameter estimation

Inductive learning

- Simplest form: learn a function from examples

f is the target function

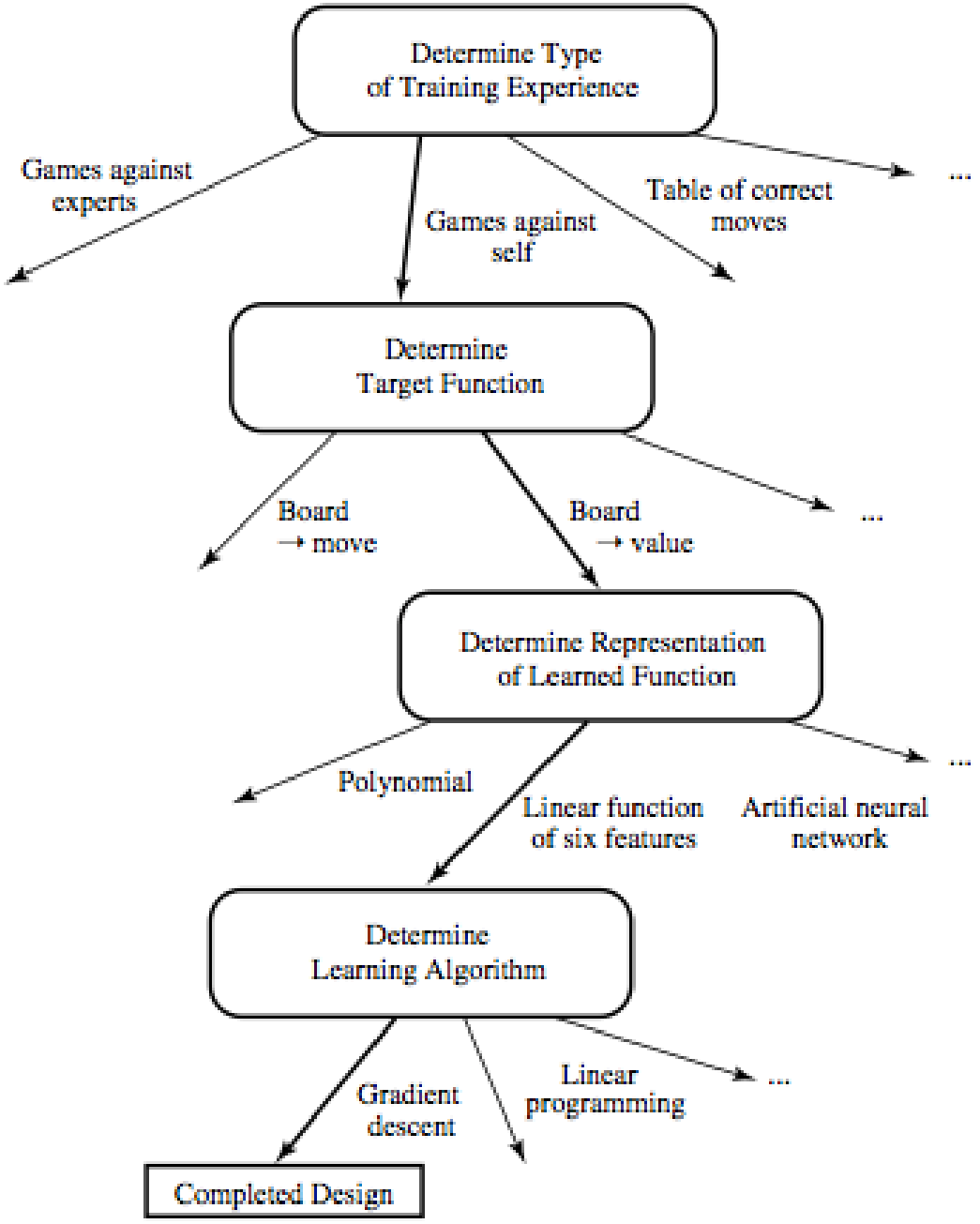
An example is a pair (*x*, *f(x)*)

Problem: find a hypothesis *h*
such that $h \approx f$
given a training set of examples

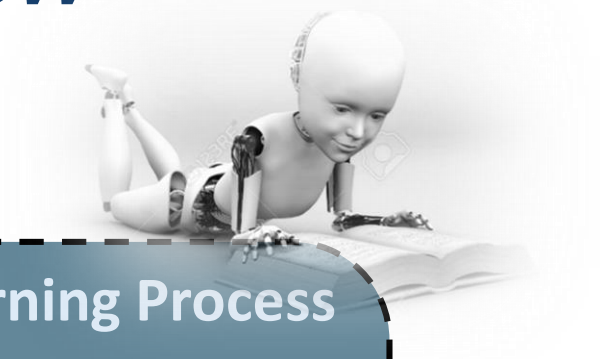
(This is a highly simplified model of real learning:
- Ignores prior knowledge
- Assumes examples are given)

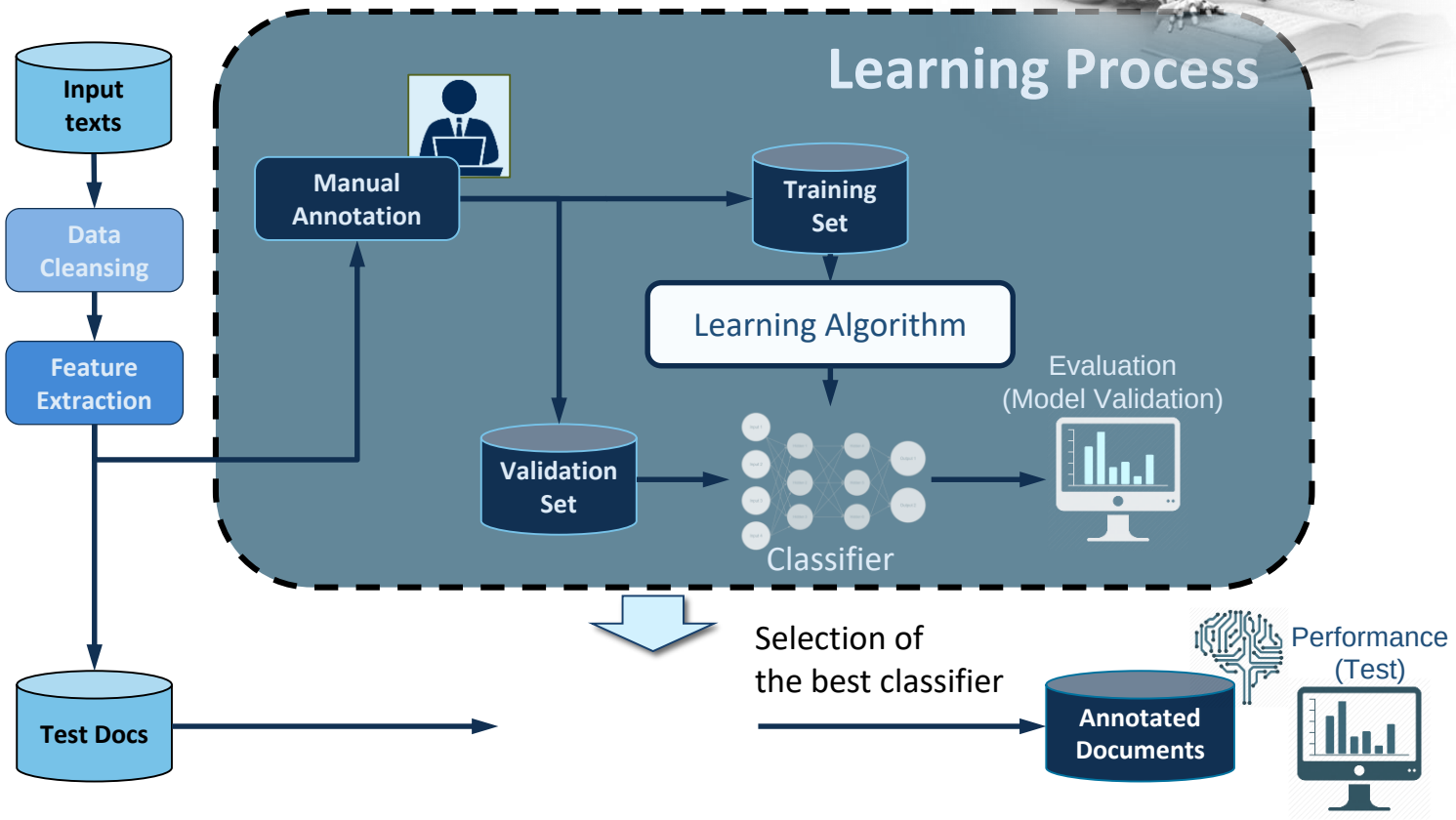
Design of a learning system

Mitchell, 1997



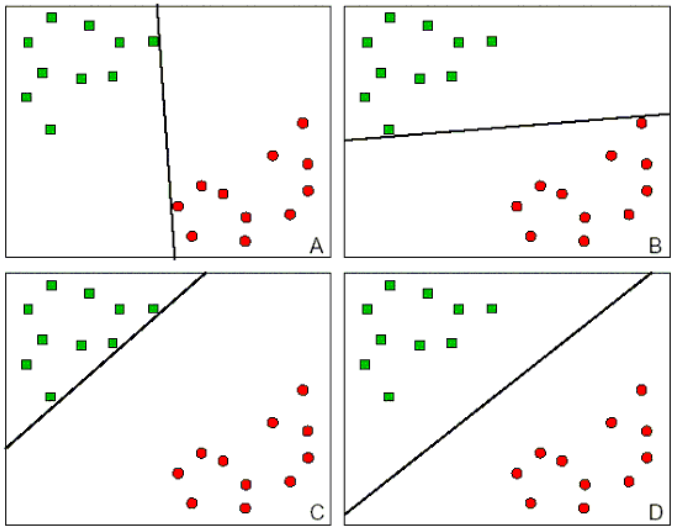
Machine Learning workflow





Metodi di ML: selezione dei modelli

- **Approcci discriminativi**
  - Lineari
  - h(x) = sign(**W** · **x** + b)

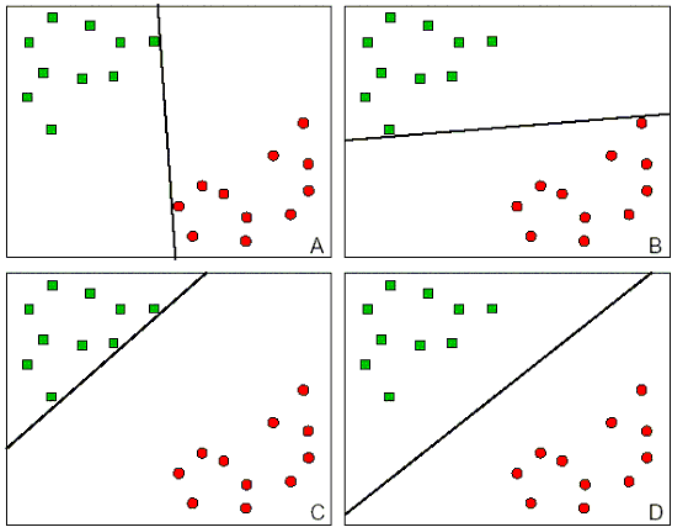


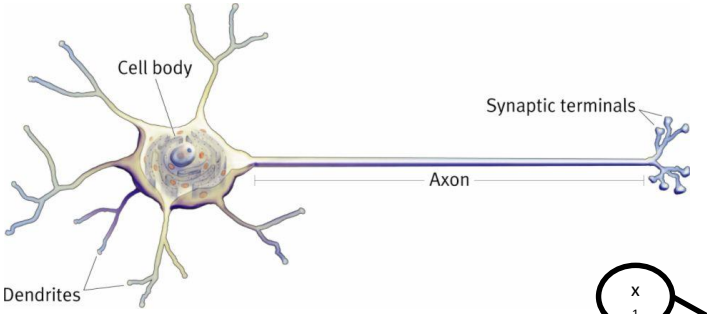
  - Approcci probabilistici
    - Stima delle probabilità $p(\mathcal{C}_k|\mathbf{x})$ attraverso un training set
    - Modello generativo ed uso della inversione Bayesiana

$$p(\mathcal{C}_k|\mathbf{x}) = \frac{p(\mathbf{x}|\mathcal{C}_k)p(\mathcal{C}_k)}{p(\mathbf{x})}.$$

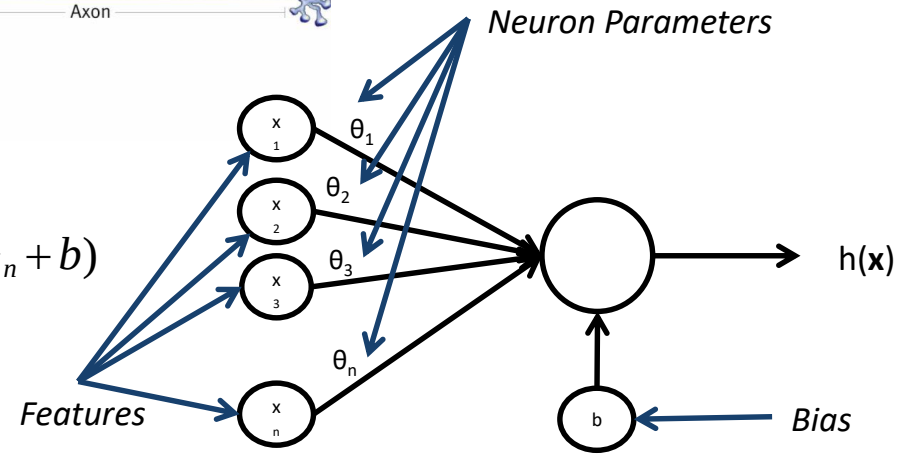
Perceptron (Rosenblatt, 1958)

- Linear Classifier mimicking a neuron

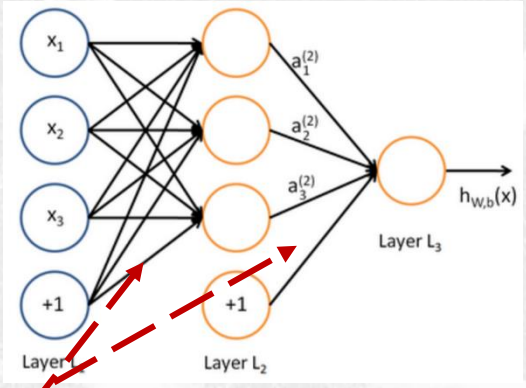




$$h(\vec{x}) = g(\sum_n \theta_n x_n + b)$$



Adding Layers …



- From simple linear laws …

$$h(\vec{x}) = g(\vec{x};\vec{\theta},b) = g(\sum_n \theta_n x_n + b)$$

- to feedforward structures. It can be made dependent on a sequence of functions $g^{(1)}$ and $g^{(2)}$, …, $g^{(k)}$ that give rise to a structured hypothesis:

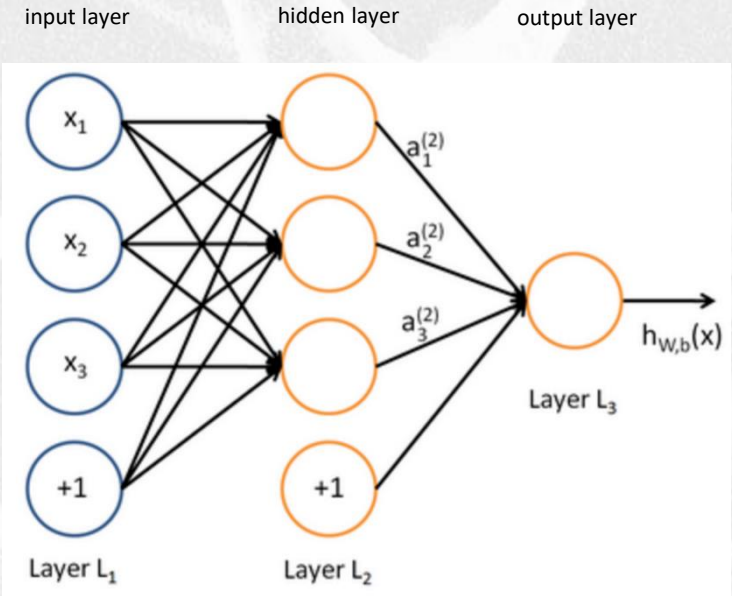
$$h(\vec{x}) = g^{(2)}(g^{(1)}(\vec{x};\vec{\theta}^{(1)},b^{(1)});\vec{\theta}^{(2)},b^{(2)}) =$$
$$= W^{(2)}g^{(2)}(g^{(1)}(W^{(1)}\cdot\vec{x}+b^{(1)})+b^{(2)}$$

- Hidden layers

$$h^{(1)}(\vec{x}) = g^{(1)}(W^{(1)}\vec{x}+b^{(1)})$$

Neural Networks

- Each circle represent a **neuron** (or unit)
  - 3 **input**, 3 **hidden** and 1 **output**
- n_l=3 is the number of layers
- s_l denotes the number of units in layer l
- Layers:
  - Layer l is denoted as L_l
  - Layer l and l+1 are connected by a matrix $W^{(l)}$ of parameters
    - $W^{(l)}_{i,j}$ connects neuron j in layer l with neuron i in layer $l+1$
- $b^{(l)}_i$ is the *bias* associated to neuron I in layer l+1

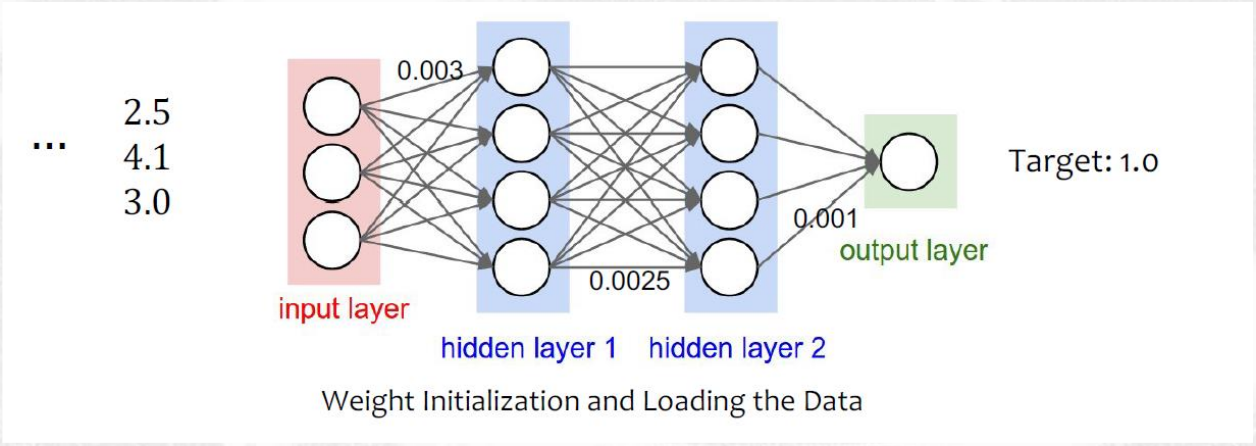


Training MLPs: Back-propagation

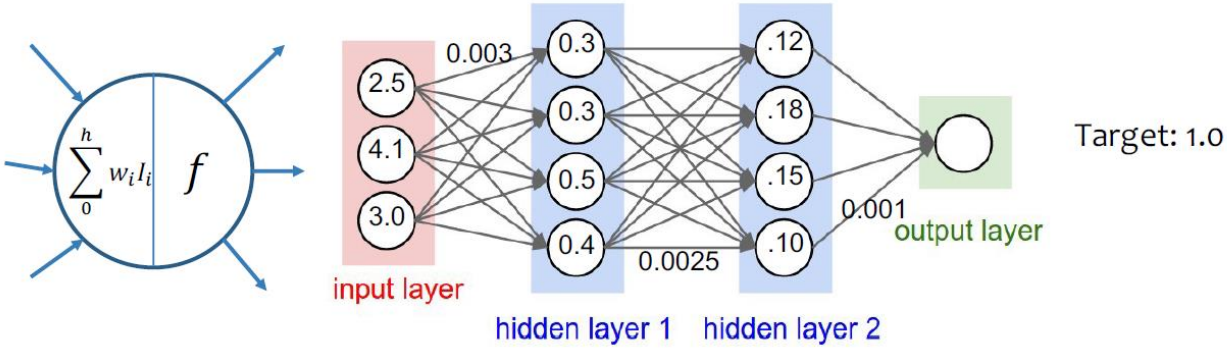
- How are parameters of the tw-layer network, i.e. *W, w* and *c, b* defined?
- This is the role of the training algorithm for which:

$$f(\boldsymbol{x}; \boldsymbol{W}, \boldsymbol{c}, \boldsymbol{w}, b) = \boldsymbol{w}^\top \max\{0, \boldsymbol{W}^\top \boldsymbol{x} + \boldsymbol{c}\} + b \approx f^*(\boldsymbol{x}).$$

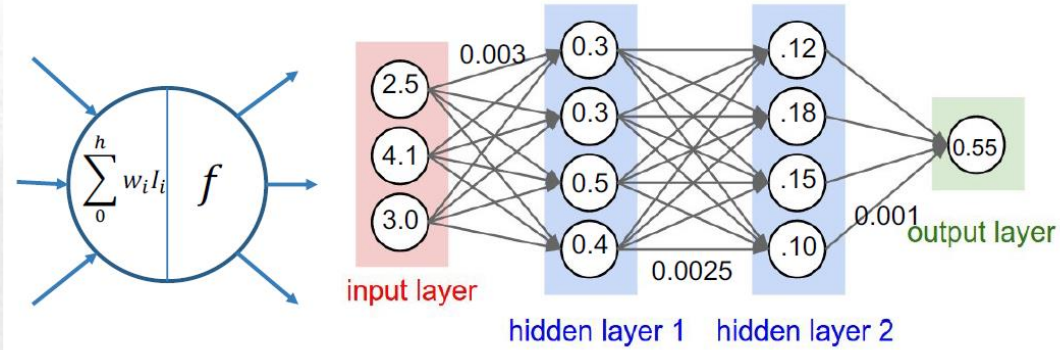
- The learning process in MLPs is based on two notions:
  - The optimization local to individual neurons
  - The adjustments to the overall network by propagation backwards from the output (where the error manifests) through all the hidden layers.



Weight Initialization and Loading the Data

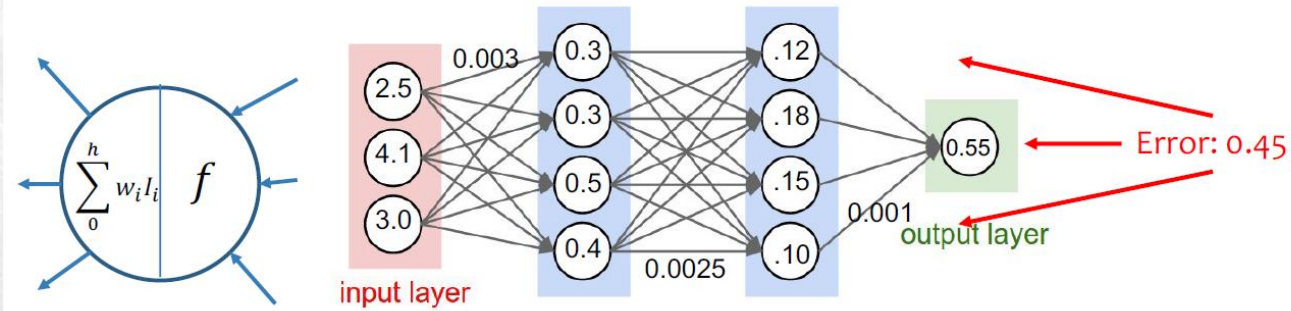


Going forward (Regularization, Dropout, Batch Normalization, …)



Target: 1.0

$Loss\ Function: (T - O) \Rightarrow Loss: 0.45$

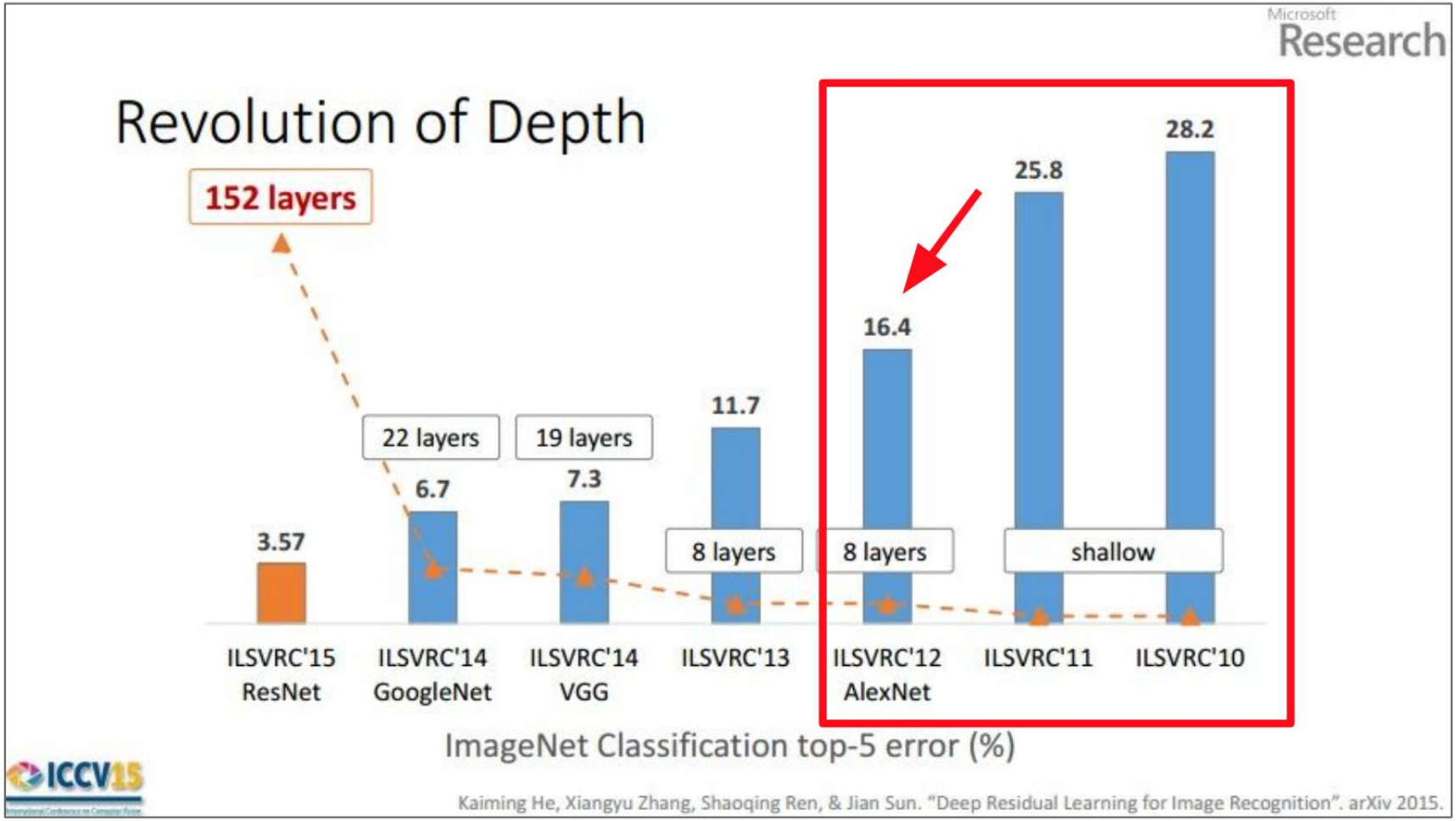


Updating the weights using Backpropagation $\frac{\partial E}{\partial w_j^i}$

How to induce the hypothesis *h* from examples

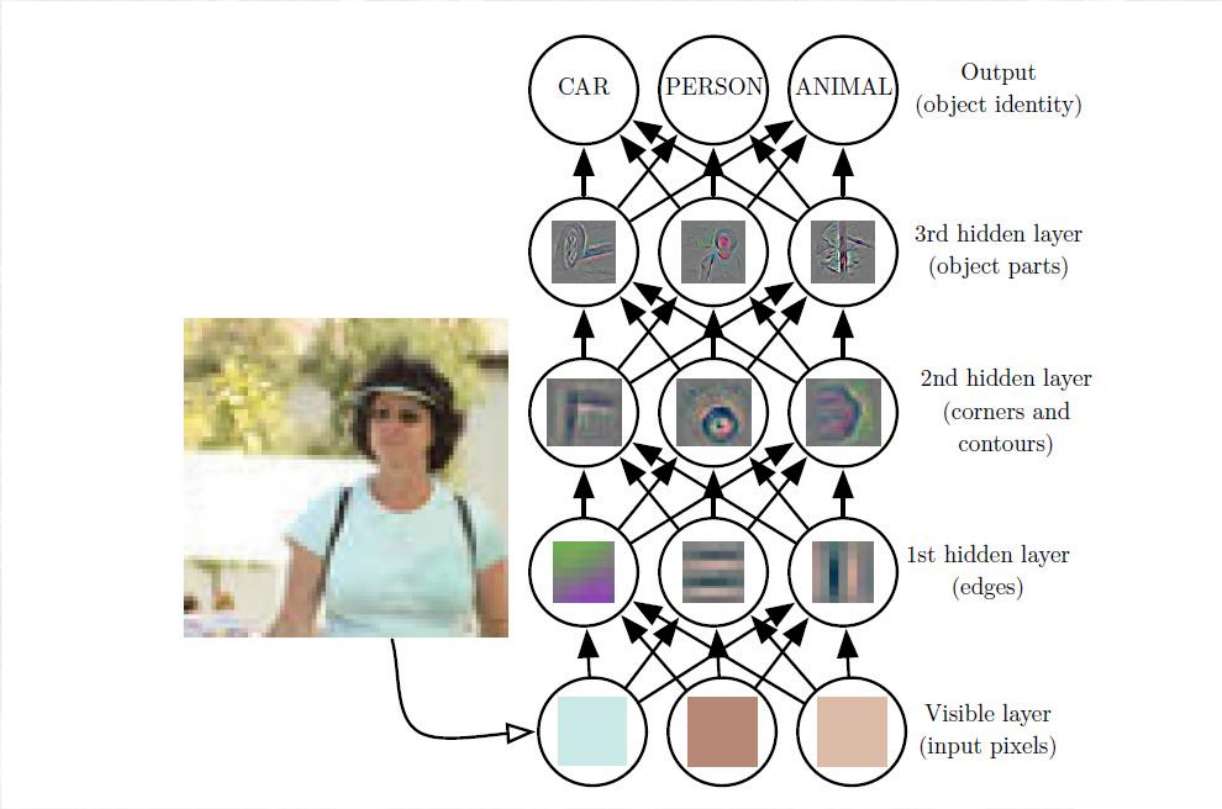
- Learn the parameters ϑ and b
- To find these we look at the past data (i.e. training data) optimizing an objective function
- Objective function: the error we make on the training data
  - the sum of differences between the decision function h and the label y
  - also called Loss Function or Cost Function

$$J(\theta, b) = \sum_{i=1}^{m} (h(x^{(i)}; \theta, b) - y^{(i)})^2$$



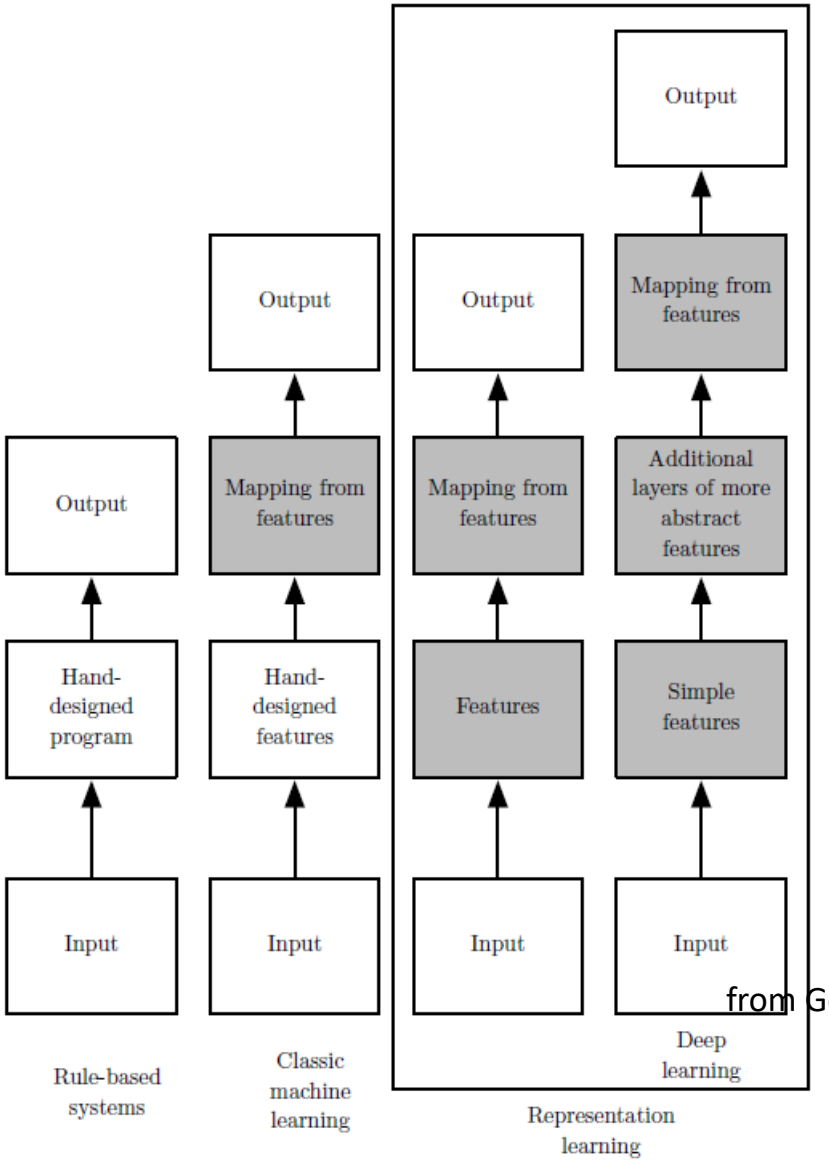
(slide from Kaiming He's recent presentation)

Rappresentazione e Apprendimento: il ruolo della profondità



Zeiler and Fergus (2014)

Learning Multiple Components

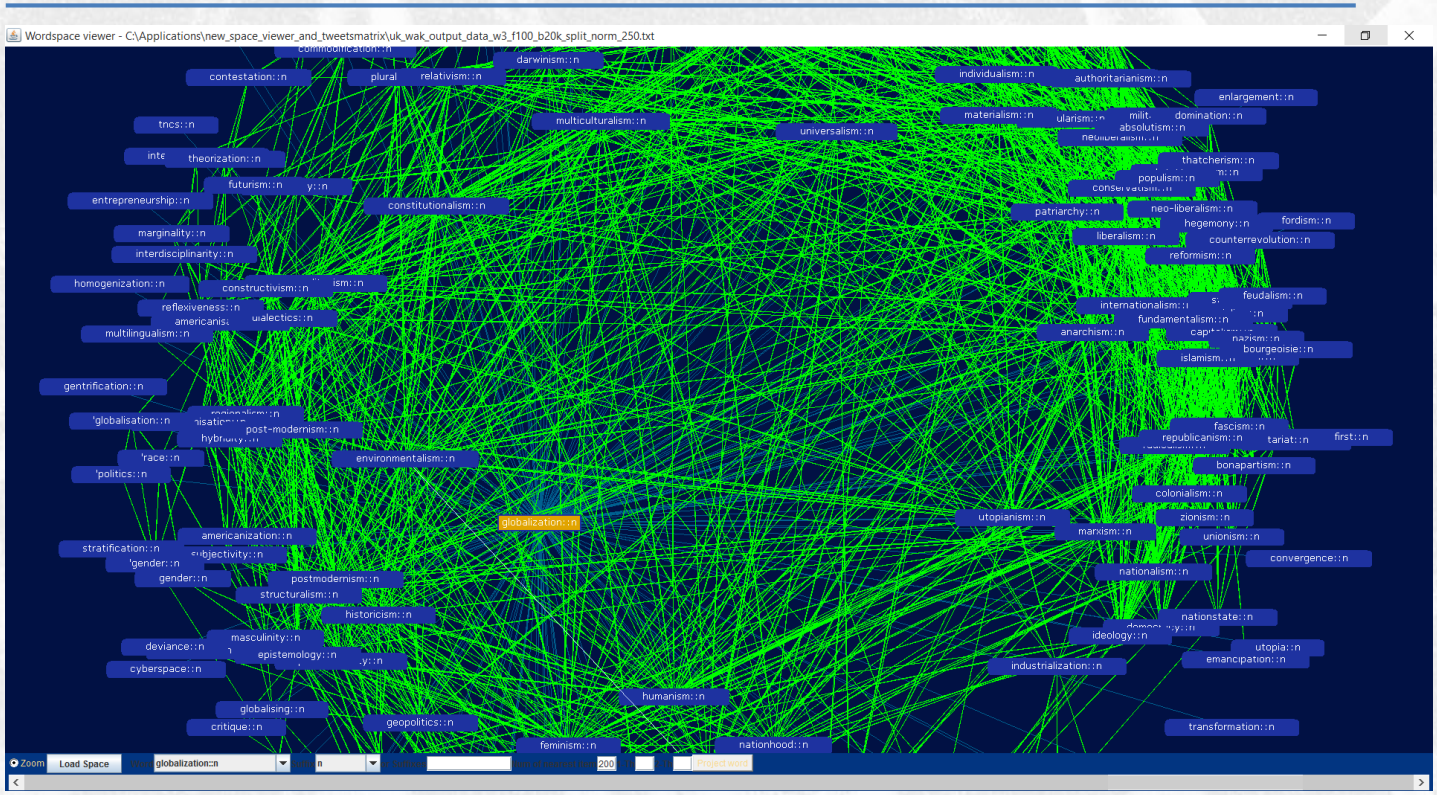


from Goodfellow et al., DL MIT book

Applicazioni delle reti neurali

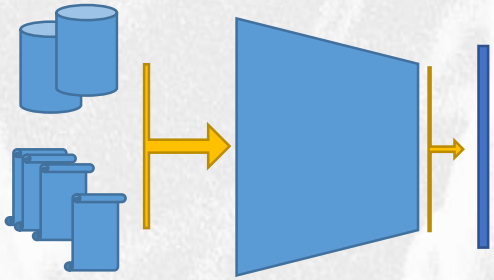
- Acquisizione Automatica di Lessici Semantici da testi (non annotati)
  - Modelli linguistici del linguaggio scritto (Italiano, Inglese, …)
  - Modelli vettoriali della semantica lessicale
  - Sistemi di pre-addestramento per la inizializzazione dei classificatori supervised (ad es. Machine Translation systems)
- Riconoscimento di oggetti o di pattern (ad es. emozioni dai visi) nelle immagini
- Acquisizione integrata di conoscenza da immagini, video e testi scritti
- Sistemi di Question Answering o Dialogo su immagini

Knowledge Acquisition & Lexical Embeddings con le Reti Neurali



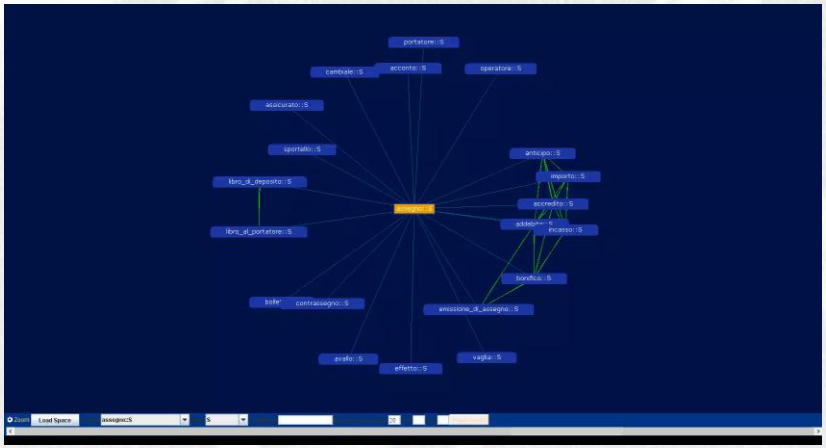
Wordspaces: Encoding & Domain Corpora

(No Use of Annotated Examples)

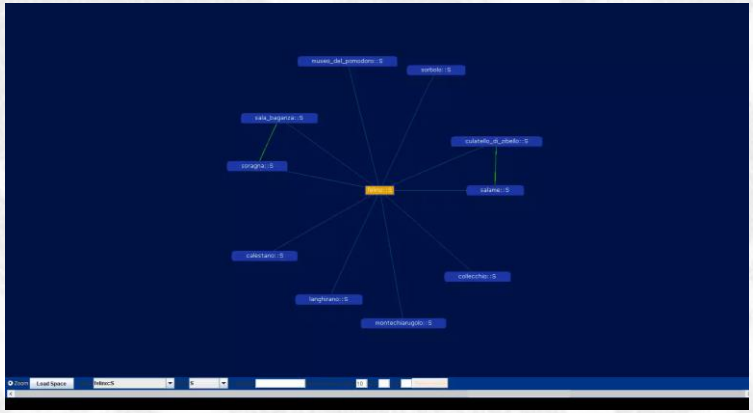


Encoding: vector-based lexicon

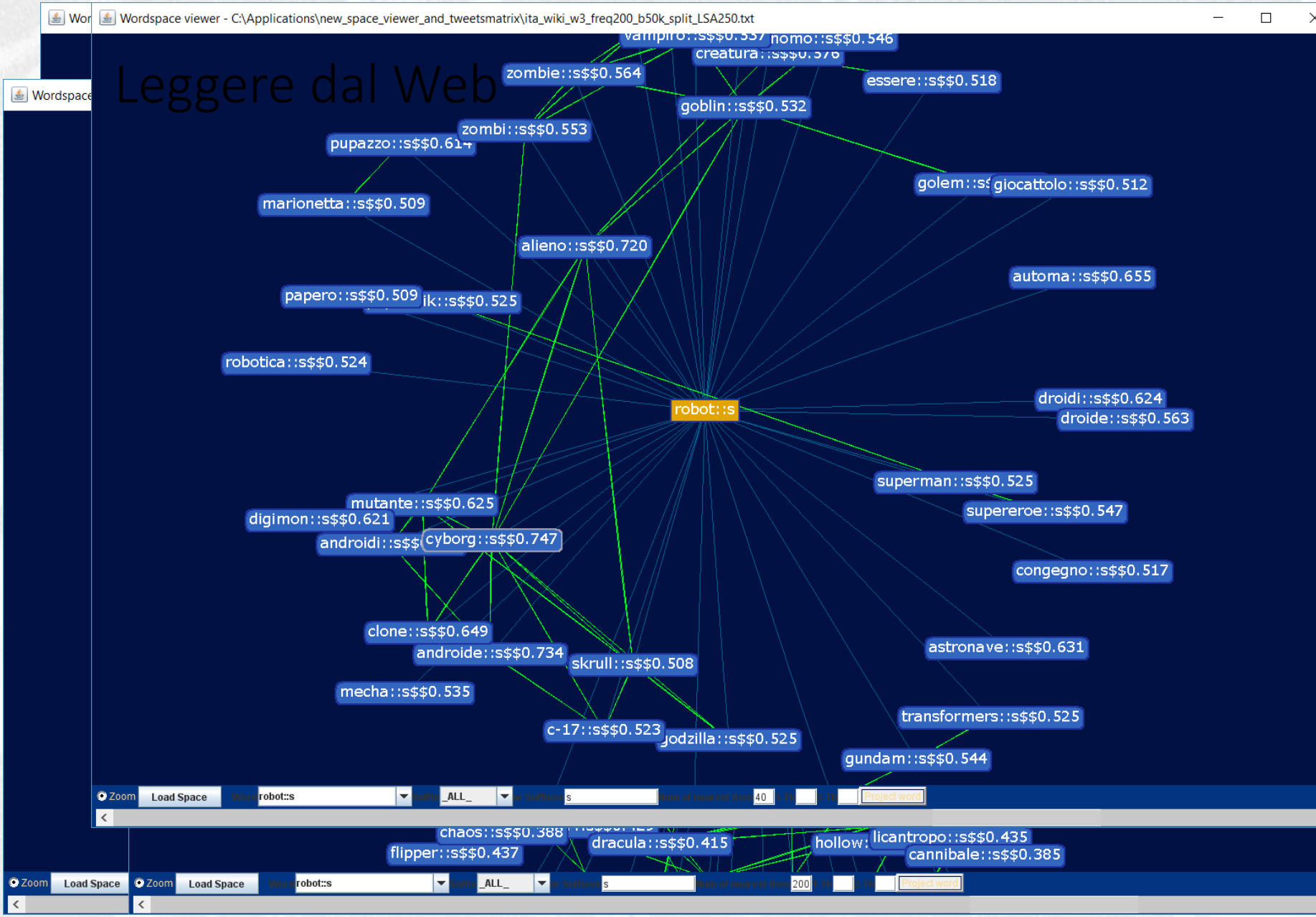
Monte Paschi Siena



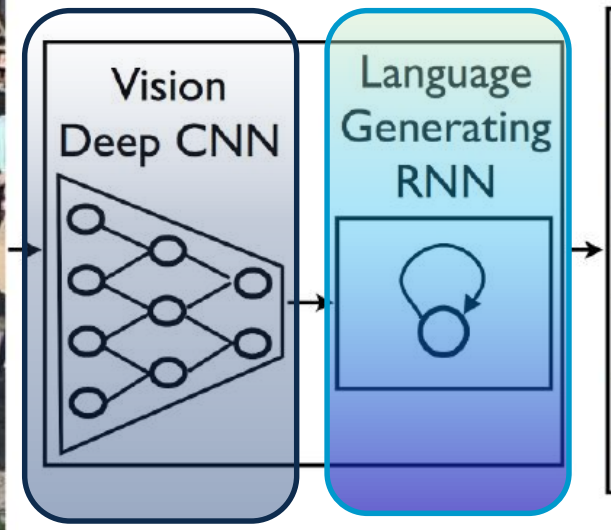
Parma



AkerSolution
(Subsea oil)


Wordspace viewer - C:\Applications\new_space_viewer_and_tweetsmatrix\ita_wiki_w3_freq200_b50k_split_LSA250.txt
Leggere dal Web
zombie::s$$0.564
essere::s$$0.518
goblin::s$$0.532
zombi::s$$0.553
marionetta::s$$0.509
giocattolo::s$$0.512
alieno::s$$0.720
automa::s$$0.655
papero::s$$0.509
robotica::s$$0.524
robot::s
droidi::s$$0.624
droide::s$$0.563
superman::s$$0.525
supereroe::s$$0.547
mutante::s$$0.625
digimon::s$$0.621
cyborg::s$$0.747
congegno::s$$0.517
clone::s$$0.649
androide::s$$0.734
skrull::s$$0.508
astronave::s$$0.631
mecha::s$$0.535
transformers::s$$0.525
c-17::s$$0.523
gundam::s$$0.544
dracula::s$$0.415
licantropo::s$$0.435
flipper::s$$0.437
cannibale::s$$0.385
Zoom
Load Space
robot::s
ALL
Project word

Automatic image captioning: neural networks *at work*



A group of people shopping at an outdoor market.

There are many vegetables at the fruit stand.

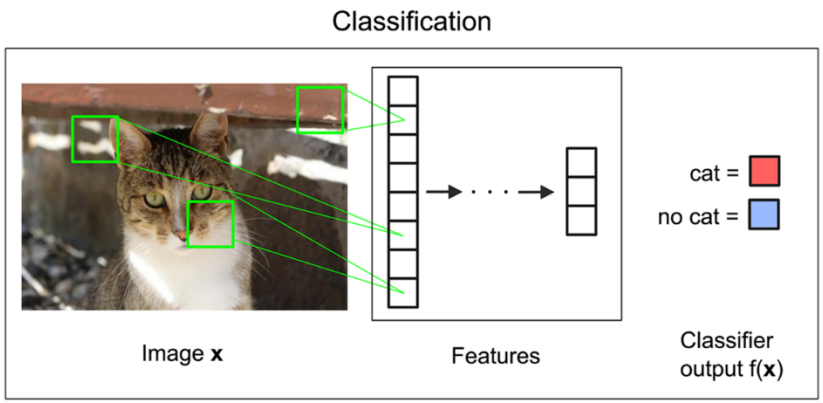
… training a neural network for italian

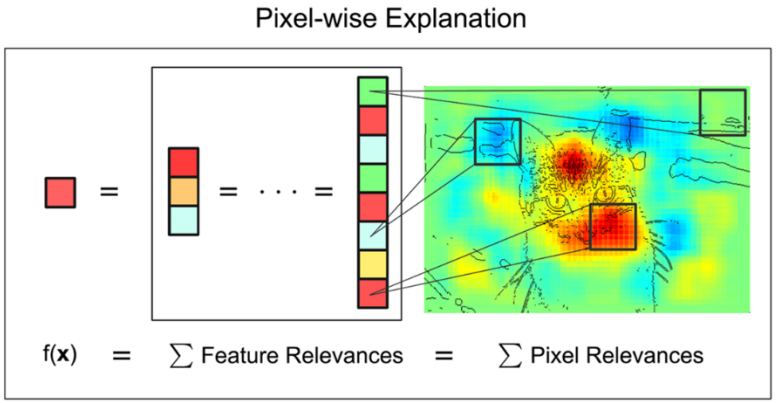
Uno scuolabus giallo parcheggiato sul lato della strada.

Un uomo che cavalca un cavallo su una strada cittadina.

Un segnale di stop che si siede su un angolo di strada.

Explainability: decisions vs. Activation states



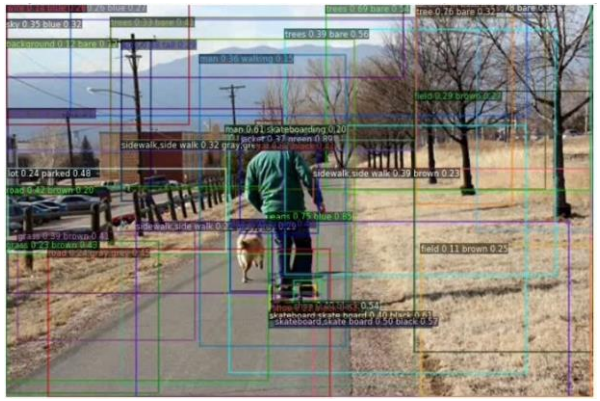


A(0.99)

A(1.00)

Visual QA

- Task:
  - Data una immagine che descrive una situazione o un evento rispondere a domande in LN verso i contenuti dell'immagine, basata sulla comprensione delle relazioni spaziali e semantiche tra gli elementi concettuali dell'immagine
- Tecnologia:
  - Convolutional Autoencoders, Recurrent neural networks and trasformer-based inferences
  - Two languages: ITA/ENG
  - ….



- Demo: VQA in italiano ed inglese: Demo_GQA.mp4

Relationship with other areas of AI

- Neural networks for **faster inference over large knowledge bases** wrt to logical approaches
- Neural networks for **high quality and cost-effective complex tasks**
  - Pattern recognition
  - Language and Image/Video processing
  - Complex rewriting tasks, e.g. Machine Translation
- **Learning to acquire knowledge**
  - Machine Reading for QA
  - Fast Indexing an retrieval from large document bases or Web sources
- Processing **Time** Series
  - Predictive Analuìytics tasks that depend on time
  - Sequence labeling tasks
- Complex inference on ***hybrid*** (i.e structured and unstructured) ***data***

Riferimenti Bibliografici

- *AIMA,* Chapter 18
- READING. *Machine Learning*, Tom Mitchell, Mc Graw-Hill International Editions, 1997 (Cap 3).

- L'Algoritmo Definitivo, Pedro Domingos, Bollato Boringhieri, 2016