Università di Verona

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Machine Learning & Artificial Intelligence

Preliminary news

Introduction

Vittorio Murino

About the teachers

Prof. Vittorio Murino
Ca’ Vignal 2, floor 1, room 1.60
email: vittorio.murino@univr.it

Q&A: Monday, between or after the classes
or, better, on demand (ask by email)

Dr. Geri Skenderi, *Tutor*
Ca’ Vignal 2, floor -2, room 141
email: geri.skenderi@univr.it
Q&A: on demand (ask by email)

The teacher

- Prof. Vittorio MURINO

- Department of Computer Science
  Ca’ Vignal 2, I floor, studio n. 1.60 (east side)
  email: vittorio.murino@univr.it
  Telephone: 045 802 7996

- Reception (in the studio):
  - preferably by appointment agreed by email
  - Monday, ore 14:30 – 15:30 or after the class (from 17:30)

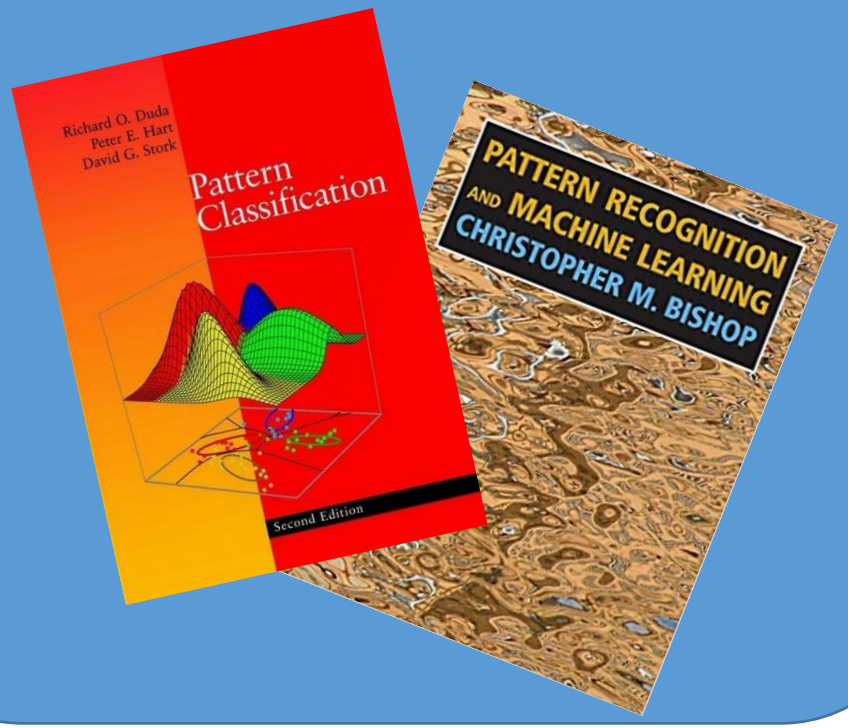
General information

- Theoretical and practical course : theory 7 cfu (48h) + lab 2 cfu (24h), with Python.
- Propedeuticity: Probability and Statistics, it would not be bad to have followed also course of Image Processing.
- Teaching materials: course slides (Italian/English), suggested books, articles.
- Any seminars of external teachers are included in the course material.
- Reference laboratory: VIPS (Vision, Image Processing & Sound).

  Info: http://vips.sci.univr.it

About the course

THEORY (48 hours)



LABORATORY (24 hours)

python™

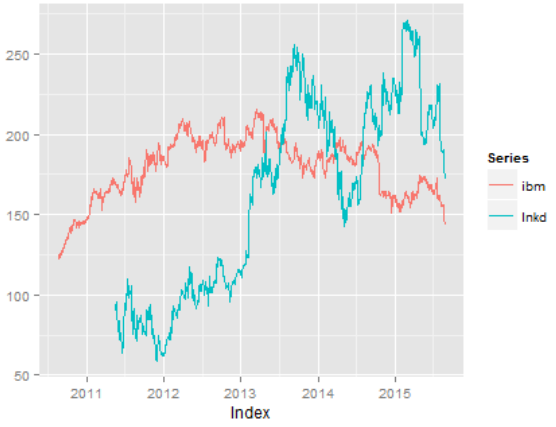
scikit learn

kaggle

Exam

- Exam: project, with written technical report and oral presentation (with ppt)
  - 2 people max, 3 people for more complex projects (to be agreed with the teacher)
  - The project exposition includes an assessment of the knowledge of the course contents.
  - Possible oral short for rounding
  - Possibility of joint project with similar courses, by agreement with the teachers.
  - Dissertation (Master thesis)

About the project and exam



Course objectives

- The course aims to provide the **theoretical foundations** and describe the main **methodologies** related to Machine Learning and Pattern Recognition and, more generally, to Artificial Intelligence.
- In particular, the course will deal with the methods of **analysis**, **recognition** and **automatic classification** of data of any type, typically called *patterns*.
- These disciplines are at the basis, are used, and often complement many other disciplines and application areas of wide diffusion, such as **computational vision, robotics, image processing, data mining, analysis and interpretation of medical and biological data, bioinformatics, biometrics, video surveillance, speech and text recognition**, and many others.
- More precisely, the methodologies that will be introduced in the course are often an integral part of the aforementioned application areas, and constitute their **"intelligent"** part with the ultimate goal of understanding (classifying, recognizing, analyzing) data, whatever being the process of interest (whether they are signals, images, strings, categorical, or other types of data).

Course objectives

- Starting from the type of sensed data, the entire analysis pipeline will be considered, such as
  - the extraction and selection of characteristics (*features*);
  - supervised and unsupervised learning methods,
  - parametric and non-parametric analysis techniques,
  - validation protocols,
  - recent deep learning techniques: basic notions, and some advanced topics with case studies.
- In conclusion, the course aims to provide the students with a set of **theoretical foundations** and **algorithmic tools** to address the problems that can be encountered in strategic and innovative industrial sectors such as those involving robotics, cyber physical systems, (big) data mining, digital manufacturing, visual inspection of products/production processes, and automation in general.

Syllabus

Theoretical foundations and main methods devoted to data analysis, not necessarily images – Statistical Pattern Recognition

Provide a basis for the recent Deep Learning techniques

- Introduction to the course: pattern recognition, machine learning and artificial intelligence. Systems and applications.
- Bayes decision theory
- Parameter estimation and nonparametric methods
- Linear, nonlinear classifiers and discriminant functions
- Linear transformations, Fisher method, feature extraction and selection, Principal Component Analysis
- Kernel methods and Support Vector Machines

Syllabus

Theoretical foundations and main methods devoted to data analysis, not necessarily images – Statistical Pattern Recognition

Provide a basis for the recent Deep Learning techniques

- Artificial neural networks
- Unsupervised classification methods, clustering, mixtures models and Expectation-Maximization algorithm
- Analysis of sequential data and Hidden Markov Models
- Deep learning: basic notions, advanced topics and case studies.
- Selected application examples

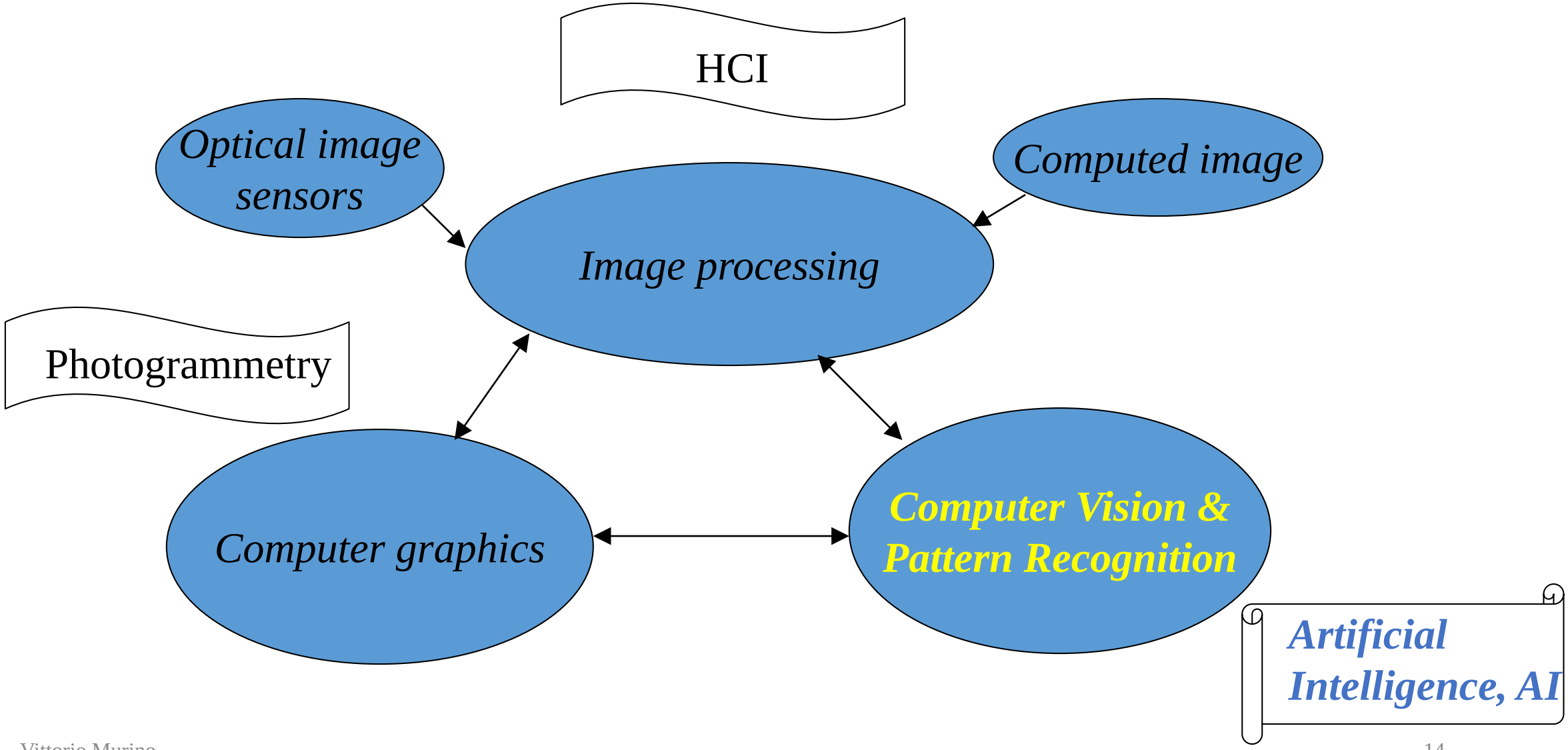
Books

- R. Duda, P. Hart, D. Stork
  Pattern Classification, Wiley, 2001.
- C.M. Bishop
  Pattern Recognition and Machine Learning, Springer, 2006.
- S. Theodoridis, K. Koutroumbas
  Pattern Recognition, Academic Press, 1998.
- C.M. Bishop
  Neural Networks for Pattern Recognition, Oxford University Press, 1995.

Other books/material

- T. Hastie, R. Tibshirani, J. Friedman
  The Elements of Statistical Learning. Springer, 2001
- J.T. Tou, R.C.Gonzales
  Pattern Recognition Principles. Addison-Wesley, Publishing Co., Reading Mass., 1974.
- K. Fukunaga
  Introduction to Statistical Pattern Recognition. Academic Press Inc. 1990.
- Monographic articles, reviews
  … in Internet

Images on the computer



A possible taxonomy

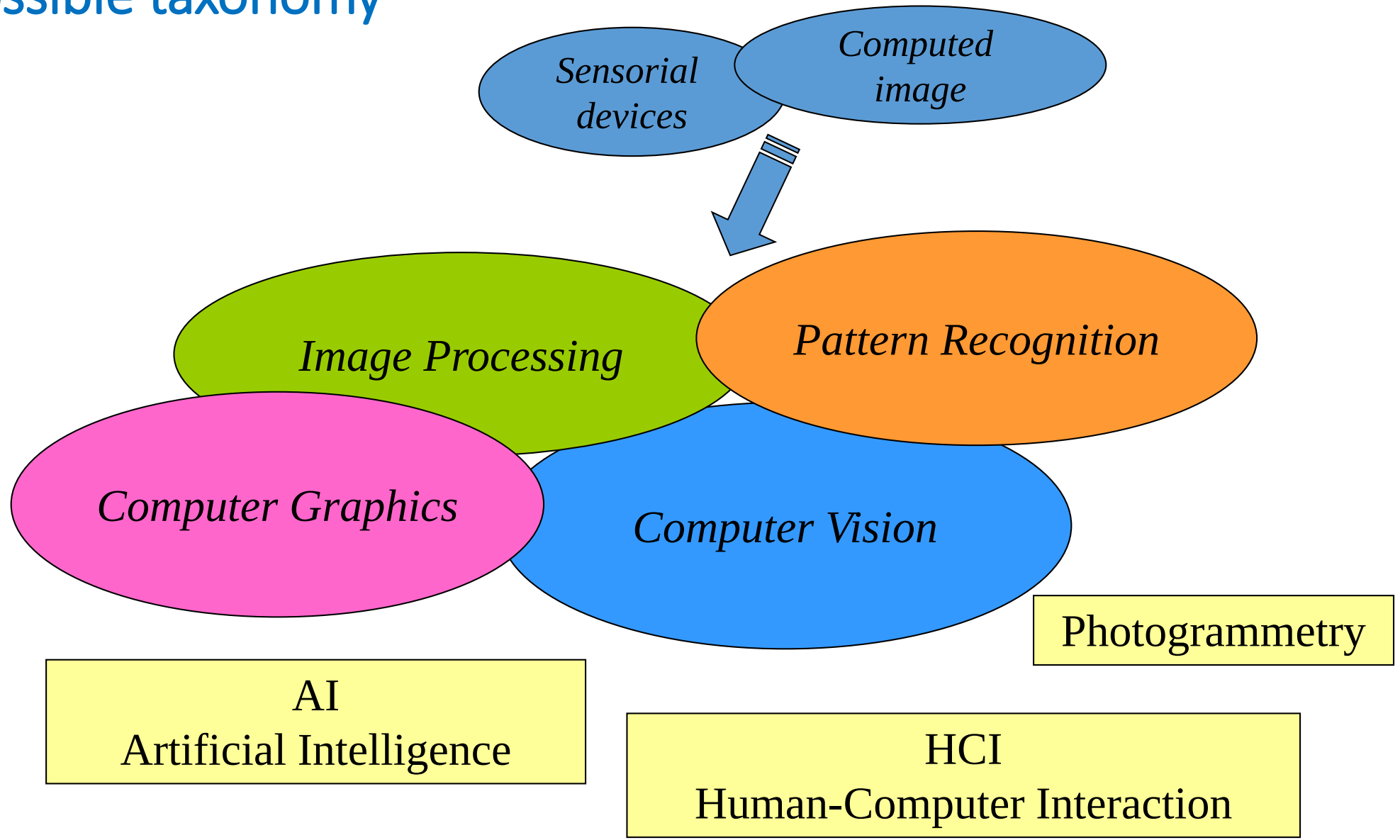


Image processing

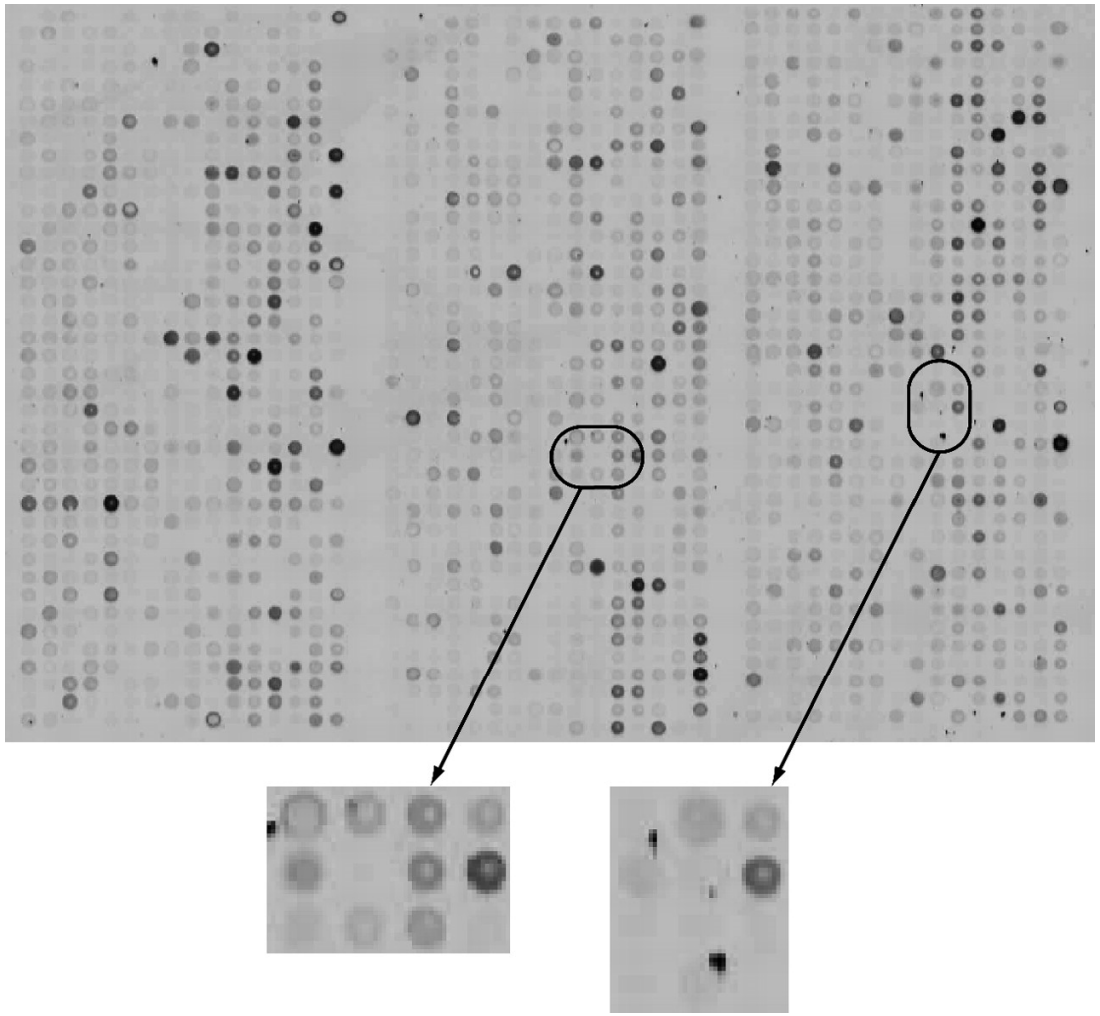
- **Manipulation** of an image in order to produce a new version of it – restoration, noise removal, filtering.
- Original image acquired from a physical sensor or *file*.
- Includes **image analysis**: perform calculations regarding specific aspects of the image itself (e.g., color).
- Important consequences for biomedical sciences and beyond: reconstruction by img MRI, SPECT, CT, ultrasound, etc., measurement analysis, diagnostic aid (with AI, PR), filtering and reinforcement, etc.

Considerations on image processing

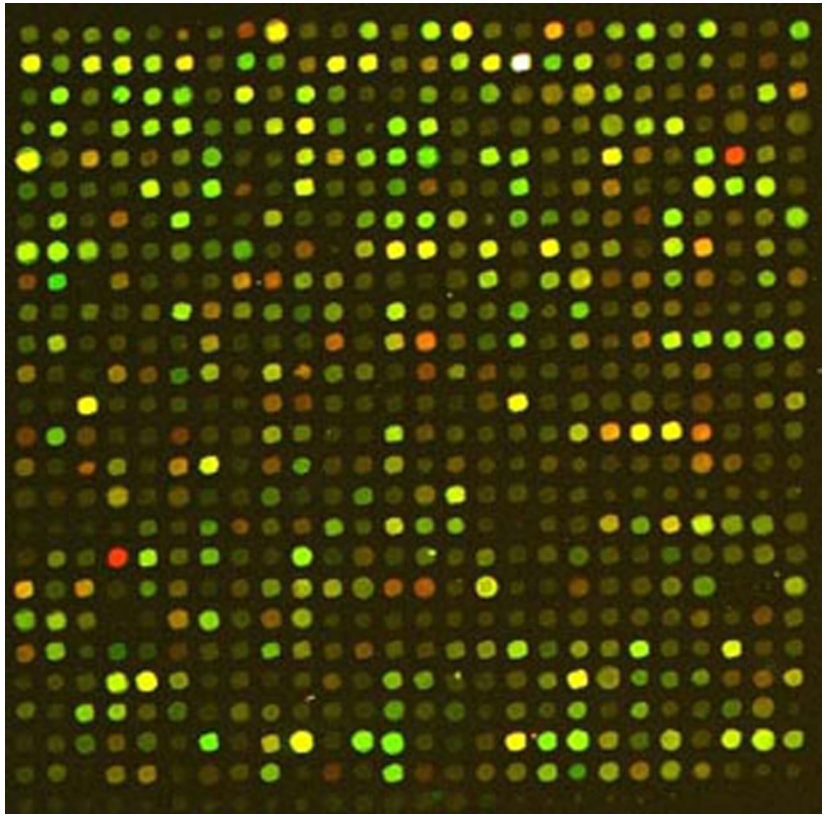
- It is the oldest discipline: dawn during World War II to quantify the effects of bombing
- In 1960 much is already developed, to improve satellite images – remote sensing
- Today, more migration to new applications than development of innovative methods
- The advent of powerful and affordable PCs and monitors makes it public
- It is often used in the service of *computer vision* and graphics (against *aliasing* and *sampling*)

Considerations on image processing

- In bioinformatics and bio-imaging:
  - Low-level image filtering for noise reduction
  - Image reinforcement and restoration for improving quality
  - Background subtraction (e.g., microarray imgs)
  - Image analysis
  - Segmentation (lesions, tissues, etc)
  - Detection (injury, etc.)
  - Registration (different modalities)
  - Classification (e.g. benign vs malignant)



Three blocks of one of the HIV raw images. The whole image contains 12 blocks. Each block is formed by 16 x 40 spots. At the bottom, we have enlarged two portions of the image containing several artifacts not caused by hybridization of the probes to the slide. Some spots are doughnut shaped with larger intensity on the perimeter of the spot



Computer vision

- **Set of computational techniques to estimate the geometric and dynamic properties of the 3D world from one or more images.**
- **Broadly speaking, extracting information** from an image to produce a **representation** or **description** of the scene
- It has inverse purposes to the graphics.
- More ambitious than image analysis. It would emulate the human visual system
- Derive 3-D information from 2-D images, assign labels, stimulate/guide actions

Pattern Recognition

- Difficult to identify, many overlaps with CVs
- Description and analysis of measurements made by physical or mental processes
  - requires a pre-processing phase to reduce noise and redundancy of measurements
  - use of available knowledge on the statistical and structural properties of the measures
- Often, it is identified with the classification (of numerical and symbolic data)
- New disciplines and applications make use of it: data mining, semantic web, intrusion detection

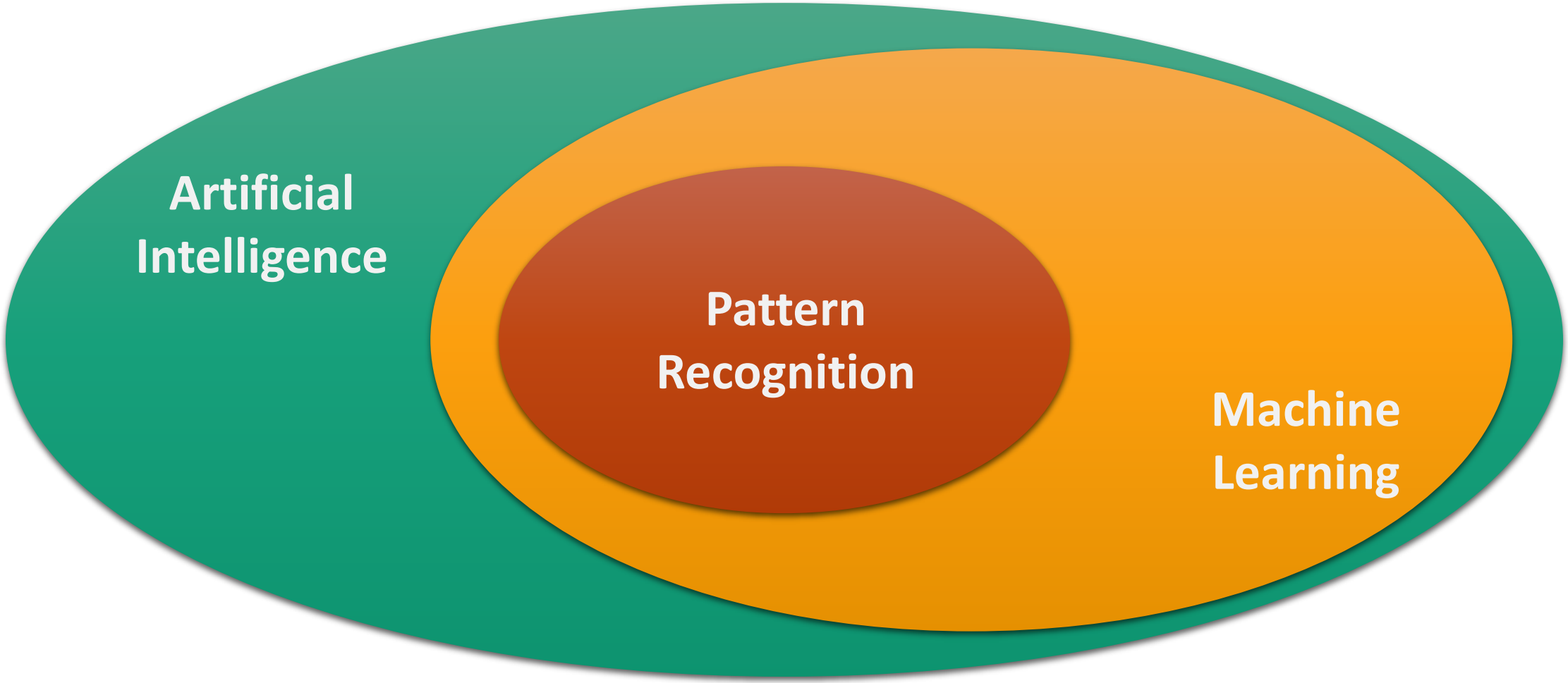
Pattern Recognition

- *Cluster analysis*
  - data analysis to find inter-relationships and discriminate in groups (without prior knowledge)
- Extraction and selection of *features*
  - reduce the dimensionality of the *pattern* (sets of measures)
- Classifying
  - Structural (syntactic language):
    - each pattern is expressed as a composition of primitives and an analogy is established between the pattern structure and the syntax of a language $\Rightarrow$ recognition seen as parsing (according to syntax rules)
  - Statistical

Considerations on CV & PR

- Image processing peer and older than graphics
- Broadly speaking it includes classification (*pattern recognition*)
- Difficulties and lack of solutions in many applications that need them
- It is often linked to a robotic function and is aimed at imitating human vision
- To date it is an open problem. In unconstrained cases, existing systems are not satisfactory
- **Knowledge** and **experience** are predominant factors in human vision

Where we are…


Artificial Intelligence
Pattern Recognition
Machine Learning

Machine Learning

~~Pattern Recognition~~

Pattern Recognition vs. Machine Learning

Pattern Recognition has its origins in engineering, whereas Machine Learning grew out of computer science. However, these activities can be viewed as two facets of the same field, …

Christopher M. Bishop

What is Machine Learning?

*I think that Machine Learning is about this broader notion of building computational artifacts that **learn over time based on experience**.*

*You have data, you do analysis on that data, you try to glean things from them using various kinds of computational structures: it's **computational statistics**!*

What does “learning” mean?

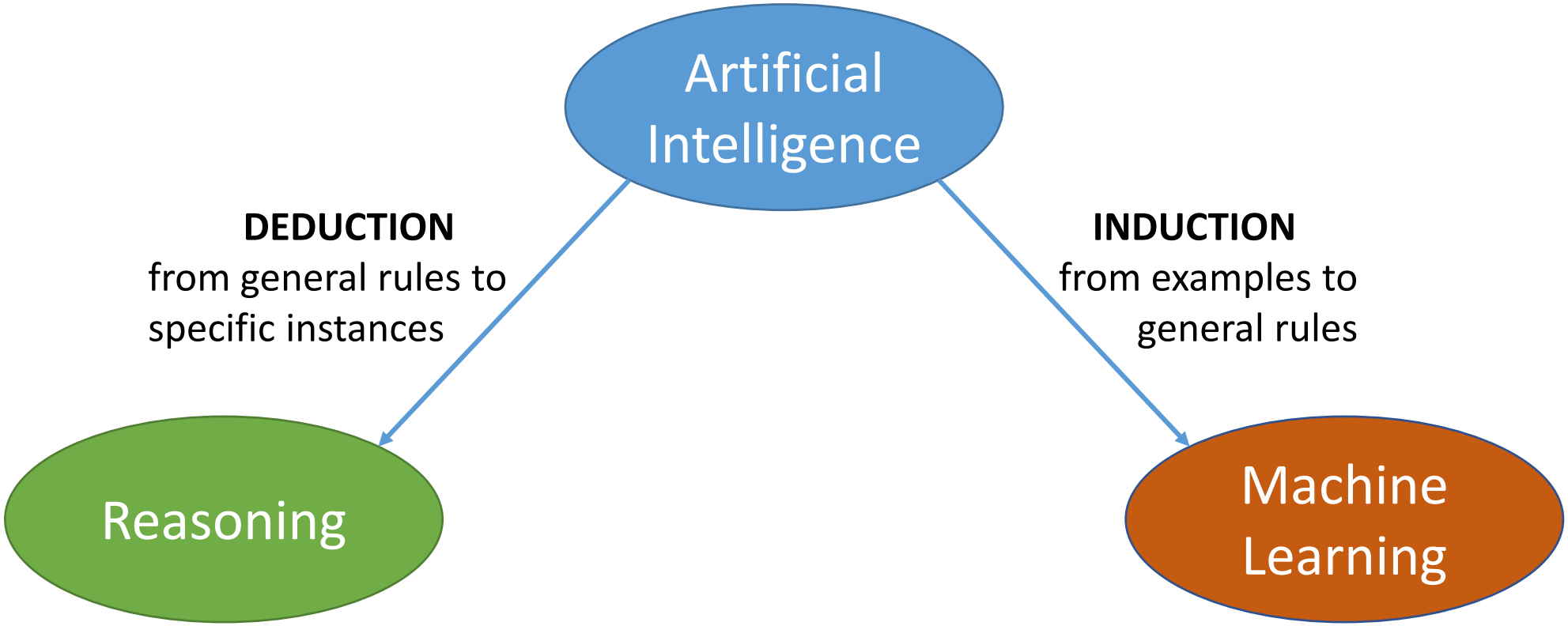
*A computer program is said to learn from experience **E** with respect to a task **T** and performance measure **P** if its performance at task **T**, as measured by **P**, improves with experience **E**.*

Tom M. Mitchell

Types of learning

- **Supervised learning**: given a set of pairs $[\mathbf{x}, y]$ ruled by $y = f(\mathbf{x})$, the goal is to find an approximate function $\hat{f}(\mathbf{x})$ so that given a new $\mathbf{x}$ we can guess $y = \hat{f}(\mathbf{x})$.
- **Unsupervised learning**: given a set of data $[\mathbf{x}]$, the goal is to find a function $f(\mathbf{x})$ that gives a compact representation of the given set.
- **Reinforcement learning**: given a set of triplets $[\mathbf{x}, a, r]$ ruled by $r = f(a|\mathbf{x})$, the goal is to find a mapping $\mathbf{x} \rightarrow a$ such that the reward r is maximum.

Artificial Intelligence vs. Machine Learning



Indeed, AI is covering all aspects related to intelligence, from perception to action, passing through learning and reasoning

Artificial Intelligence

- The field of **Artificial Intelligence**, or **AI**, goes further still: it attempts not just to understand but also to *build* intelligent entities.
- Work started in earnest soon after World War II, and the name itself was coined in 1956.
- **AI** currently encompasses a huge variety of subfields, ranging from the general (*learning and perception*) to the specific, such as playing chess, proving mathematical theorems, writing poetry, driving a car on a crowded street, and diagnosing diseases.
- **AI** is relevant to any intellectual task, it is truly a universal field.

Artificial Intelligence

Thinking Humanly	**Thinking Rationally**
"The exciting new effort to make computers think . . . *machines with minds*, in the full and literal sense." (Haugeland, 1985) "[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning . . ." (Bellman, 1978)	"The study of mental faculties through the use of computational models." (Charniak and McDermott, 1985) "The study of the computations that make it possible to perceive, reason, and act." (Winston, 1992)
Acting Humanly	**Acting Rationally**
"The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil, 1990) "The study of how to make computers do things at which, at the moment, people are better." (Rich and Knight, 1991)	"Computational Intelligence is the study of the design of intelligent agents." (Poole *et al.*, 1998) "AI . . . is concerned with intelligent behavior in artifacts." (Nilsson, 1998)

Artificial Intelligence

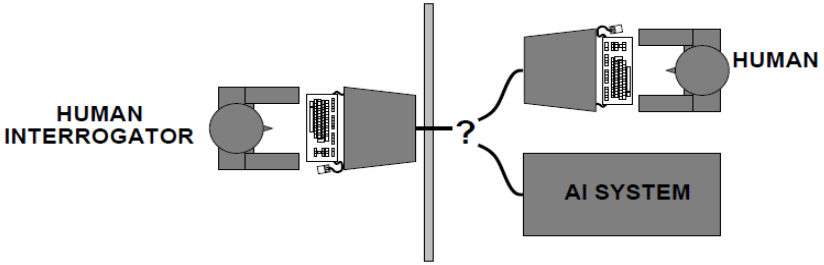
- **Thinking humanly**: cognitive science, information processing psychology, requires (neuro)scientific theories of internal activities of the brain, from behaviour to neural correlates and vice versa
- **Thinking rationally**: laws of thoughts, normative rather than descriptive, notation and rules of derivation for thoughts, from math and philosophy to modern AI
- **Acting rationally**: rational behaviour, doing the right thing, maximising goal achievement, not necessarily involve thinking (e.g., blinking reflex)
  - *Aristotele*: every art and every enquiry, and similarly every action and pursuit, is thought to aim at some good

Artificial Intelligence

Acting humanly:
Turing Test

Turing (1950) "Computing machinery and intelligence":

- "Can machines think?" $\longrightarrow$ "Can machines behave intelligently?"
- Operational test for intelligent behavior: the Imitation Game



- Predicted that by 2000, a machine might have a 30% chance of fooling a lay person for 5 minutes
- Anticipated all major arguments against AI in following 50 years
- Suggested major components of AI: knowledge, reasoning, language understanding, learning

Problem: Turing test is not reproducible, constructive, or amenable to mathematical analysis

Artificial Intelligence

- A computer would need to possess the following capabilities:
  - **natural language processing** to enable it to communicate successfully in English;
  - **knowledge representation** to store what it knows or hears;
  - **automated reasoning** to use the stored information to answer questions and to draw new conclusions;
  - **machine learning** to adapt to new circumstances and to detect and extrapolate patterns.
  - **computer vision** for understanding visual scenes by image/videos
  - **robotics**, to manipulate objects

Total Turing Test

Artificial Intelligence

- Rational agents

An agent is an entity that perceives and acts

Abstractly, an agent is a function from percept histories to actions:

$$f : \mathcal{P}^* \rightarrow \mathcal{A}$$

For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance

Caveat: computational limitations make perfect rationality unachievable
$\rightarrow$ design best program for given machine resources

Artificial Intelligence: AI prehistory

Philosophy	logic, methods of reasoning
	mind as physical system
	foundations of learning, language, rationality
Mathematics	formal representation and proof
	algorithms
	computation, (un)decidability, (in)tractability
	probability
Psychology	adaptation
	phenomena of perception and motor control
	experimental techniques (psychophysics, etc.)
Linguistics	knowledge representation
	grammar
Neuroscience	physical substrate for mental activity
Control theory	homeostatic systems, stability
	simple optimal agent designs

Artificial Intelligence: a little history

1943	McCulloch & Pitts: Boolean circuit model of brain
1950	Turing's "Computing Machinery and Intelligence"
1952–69	Look, Ma, no hands!
1950s	Early AI programs, including Samuel's checkers program,
	Newell & Simon's Logic Theorist, Gelernter's Geometry Engine
1956	Dartmouth meeting: "Artificial Intelligence" adopted
1965	Robinson's complete algorithm for logical reasoning
1966–74	AI discovers computational complexity
	Neural network research almost disappears
1969–79	Early development of knowledge-based systems
1980–88	Expert systems industry booms
1988–93	Expert systems industry busts: "AI Winter"
1985–95	Neural networks return to popularity
1988–	Resurgence of probabilistic and decision-theoretic methods
	Rapid increase in technical depth of mainstream AI
	"Nouvelle AI": ALife, GAs, soft computing

Artificial Intelligence: a little history

Deep Learning

- Convolutional Neural Networks (CNN)
  - LeCun, Bottou, Bengio, Haffner, *Proceedings of the IEEE*, 1998
- Deep Belief Nets
  - Hinton et al., *Neural Computation*, 2006
- Auto-encoder
  - Hinton & Salakhutdinov, *Science*, 2006