CSE419 – Artificial Intelligence and Machine Learning 2021

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https://github.com/FurkanGozukara/CSE419-Artificial-Intelligence-and-Machine-Learning-2020

Lecture 1

Introduction

Composed from Asst. Prof. Dr. Senem Kumova Metin's Resources

Source: https://cs.pomona.edu/~dkauchak/classes/f13/cs451-f13/lectures/

Dictionary Definitions of Intelligence

- “The ability to use memory, knowledge, experience, understanding, reasoning, imagination and judgment in order to solve problems and adapt to new situations.” AllWords Dictionary, 2006

- “The ability to learn or understand or to deal with new or difficult situations” (Merriam Webster)

- “The capacity for understanding; ability to perceive and comprehend meaning” (Collins)

- “The ability to acquire and apply knowledge and skills” (Oxford Dictionary, 2006)

Overview of Artificial Intelligence (AI) (1/3)

- **Artificial intelligence (AI)**
  - Computers with the ability to mimic or duplicate the functions of the human brain
  - The term was coined in 1956 by John McCarthy at the Massachusetts Institute of Technology
- **Artificial intelligence systems**
  - The people, procedures, hardware, software, data, and knowledge needed to develop computer systems and machines that demonstrate the characteristics of intelligence

Overview of Artificial Intelligence (AI) (2/3)

- **Intelligent behavior**
  - Learn from experience
  - Apply knowledge acquired from experience
  - Handle complex situations
  - Solve problems when important information is missing
  - Determine what is important
  - React quickly and correctly to a new situation
  - Understand visual images
  - Process and manipulate symbols
  - Be creative and imaginative
  - Use heuristics

Design methodology and goals

The exciting new effort to make computers thinks … *machine with minds,* in the full and literal sense" (Haugeland 1985)	"The study of mental faculties through the use of computational models" (Charniak et al. 1985)
"The art of creating machines that perform functions that require intelligence when performed by people" (Kurzweil, 1990)	A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes" (Schalkol, 1990)

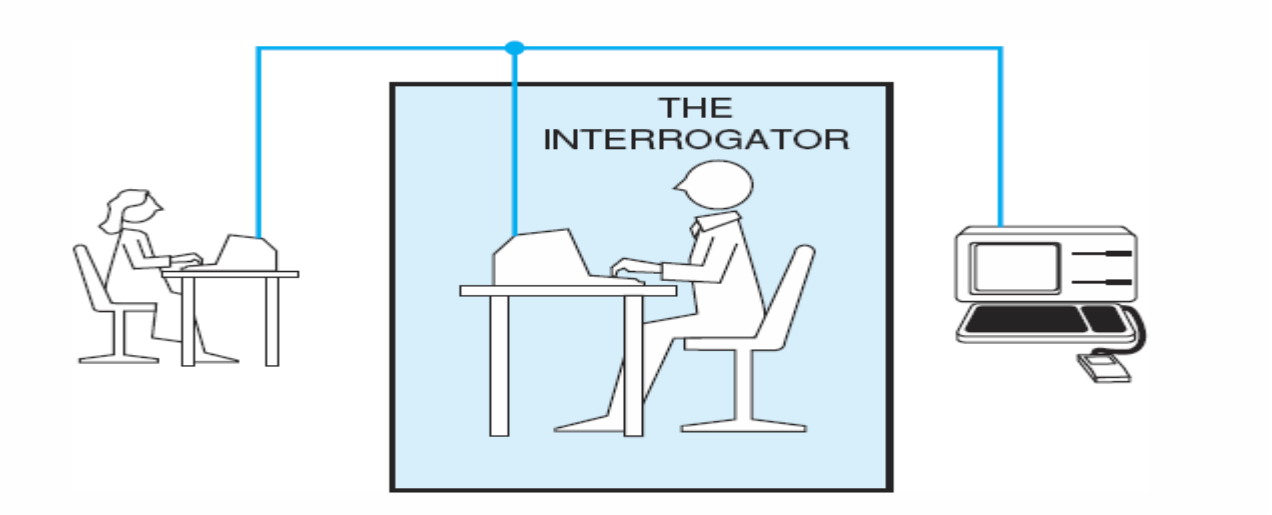
Systems that think like humans	Systems that think rationally
Systems that act like humans	Systems that act rationally

Systems that act like humans

- Behaviorist approach.
- Not interested in how you get results, just the similarity to what human results are.
- **ELIZA:** one of the first chatterbots and one of the first programs capable of attempting the Turing Test.
  - Turing Test: a test for intelligence in a computer, requiring that a human being should be unable to distinguish the machine from another human being by using the replies to questions put to both.

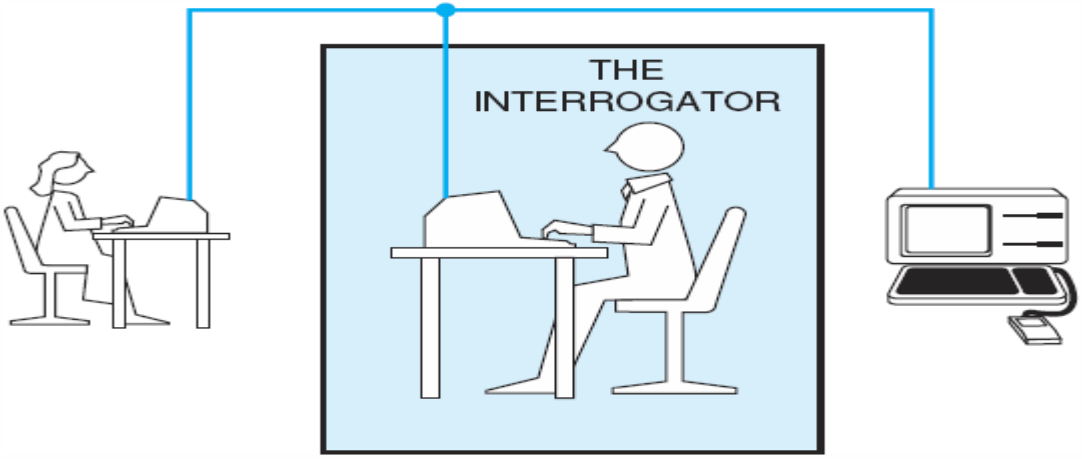
Acting Humanly: The Turing Test

- Alan Turing's 1950 article *Computing Machinery and Intelligence* discussed conditions for considering a machine to be intelligent

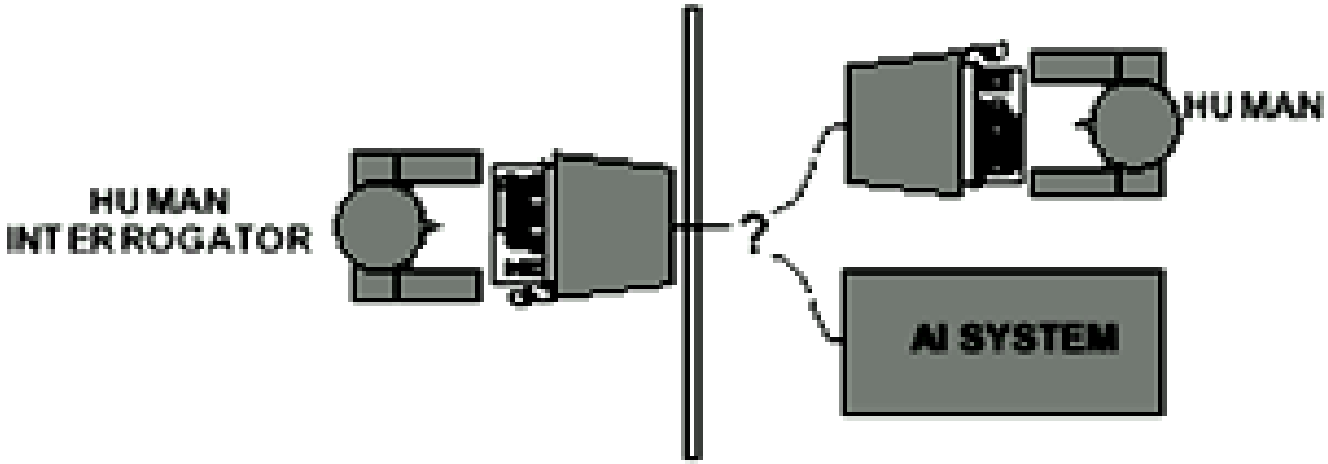


Acting Humanly: The Turing Test

- Interrogator asks questions of two “people” who are out of sight and hearing. One is a human, the other one a machine.
- 30mins to ask whatever she/he wants.
- To determine only through questions and answers which is which.
- If the interrogator cannot distinguish between human and computer, the machine has passed the test!



Acting Humanly: The Turing Test

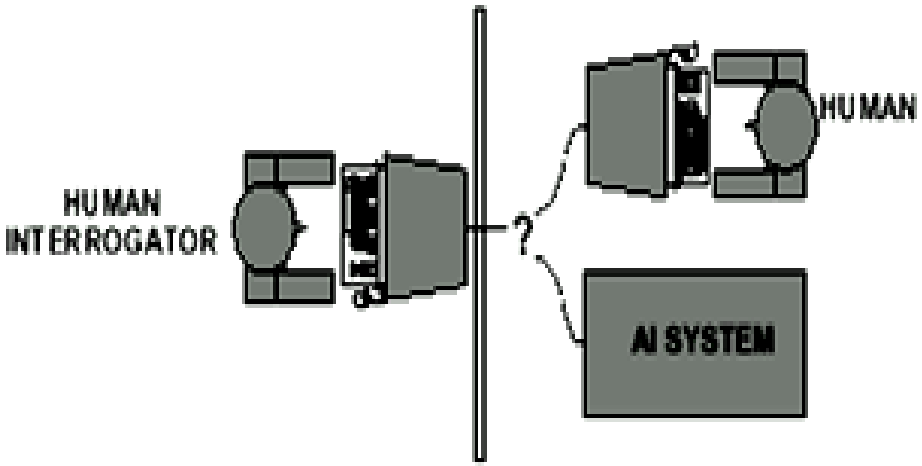


- Computer needs to possess:
  - Natural language processing
  - Knowledge representation
  - Automated reasoning
  - Machine learning

What would a computer need to pass the Turing test?

- **Natural language processing**: to communicate with examiner.
- **Knowledge representation**: to store and retrieve information provided before or during interrogation.
- **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.

Acting Humanly: The Full Turing Test



Problems:

1) Turing test is not reproducible, constructive, and amenable to mathematic analysis.

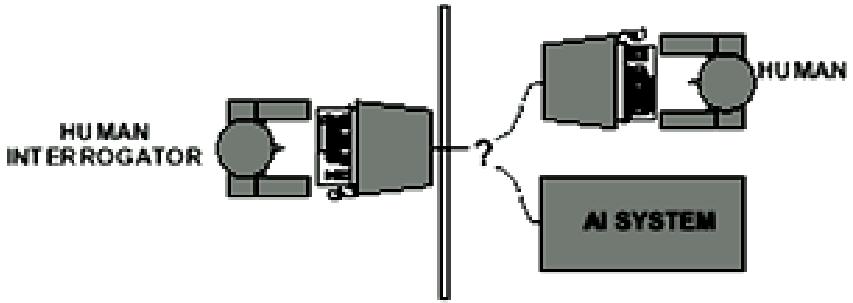
2) What about physical interaction with interrogator and environment?

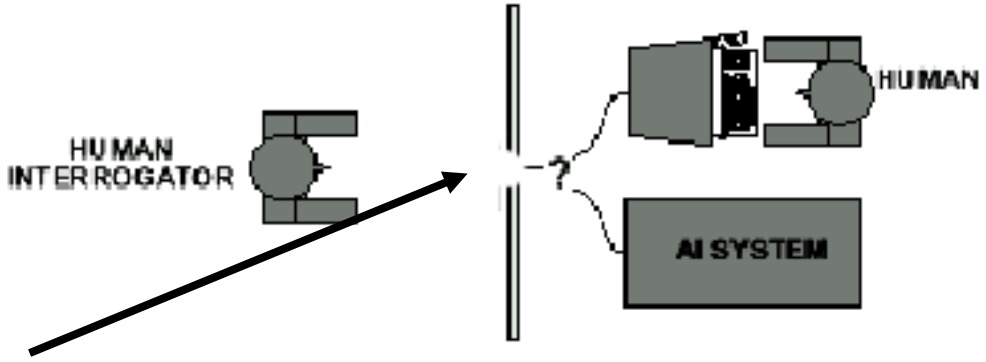
- **Total (Full) Turing Test**: Requires physical interaction and needs perception and actuation.

Acting Humanly: The Full Turing Test

- Computer needs to possess:
  - Natural language processing
  - Knowledge representation
  - Automated reasoning (AR)
  - Machine learning (MR)

  and
  - Computer Vision
  - Robotics





Trap door

What would a computer need to pass the full Turing test?

- **Natural language processing**
- **Knowledge representation**
- **Automated reasoning (AR)**
- **Machine learning (MR)**

- **Vision :** to recognize the examiner's actions and various objects presented by the examiner.
- **Robotics :** to manipulate objects and move about

Systems that think like humans

- Focus not just on behavior and I/O, look at reasoning process.
- Computational model should reflect "how" results were obtained.
- **GPS (General Problem Solver):** Goal not just to produce humanlike behavior (like ELIZA), but to produce a sequence of steps of the reasoning process that was similar to the steps followed by a person in solving the same task.

Thinking Humanly: Cognitive Science

- Thinking like a human → Determining how humans think …

- Cognitive science brings together theories and experimental evidence to model internal activities of the brain

Systems that think rationally

- Formalize the reasoning process, producing a system that contains logical inference mechanisms that are provably correct, and guarantee finding an optimal solution.

- This brings up the question: How do we represent information that will allow us to do inferences?

Thinking Rationally: Laws of Thought

- Aristotle (~ 450 B.C.) attempted to codify "right thinking"
  What are correct arguments/thought processes?

- E.g., "Socrates is a man, all men are mortal; therefore Socrates is mortal"

- The Law of Thought approach initiated the field called LOGIC…

Thinking Rationally: Laws of Thought

Problems:

1) **Uncertainty:** Not all facts are certain (e.g., *the flight might be delayed).*

   It is not easy to take informal knowledge and state in formal terms required by logical notation , particularly when the knowledge is less than 100% certain

2) **Resource limitations:**
   - Not enough time to compute/process
   - Insufficient memory/disk/etc
   - etc.

Systems that act rationally

- For a given set of inputs, tries to generate an appropriate output that is not necessarily correct but gets the job done.

- Rational and sufficient (“satisficing” methods, not “optimal”).

Acting Rationally: The Rational Agent Approach

- Rational behavior: Doing the right thing!
- The right thing: That which is expected to maximize the expected return
- Provides the most general view of AI because it includes:
  - Correct inference ("Laws of thought")
  - Uncertainty handling
  - Resource limitation considerations (e.g., reflex vs. deliberation)
  - Cognitive skills (NLP, AR, knowledge representation, ML, etc.)
- <u>Advantages:</u>
  1) More general
  2) Its goal of rationality is well defined

Acting Rationally: The Rational Agent Approach

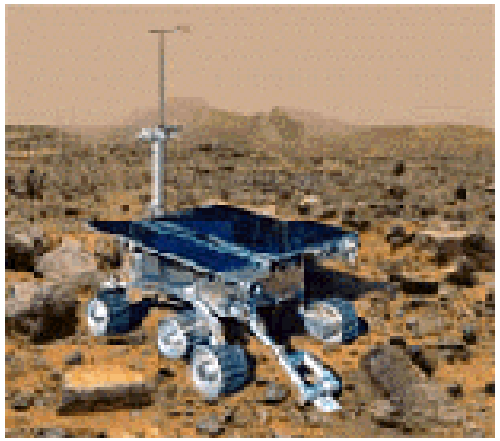
- An agent is something that acts

- A **computer agent** is a program that
  - operates under autonomous control,
  - perceives the environment,
  - persists over a prolonged time period,
  - adapts to change,
  - is capable of taking another's goal

- A **rational agent** is the agent that acts so as to achieve best outcome or when there is uncertainty the best expected outcome.

Why study AI?

Labor



Science

Google

YAHOO!

Search engines

Medicine/
Diagnosis

Appliances

What else?

Applications of AI

- **Game Playing**
  Defeating best MOBA players

- **Speech Recognition**
  PEGASUS spoken language interface to American Airlines' EAASY SABRE reservation system, which allows users to obtain flight information and make reservations over the telephone. The 1990s has seen significant advances in speech recognition so that limited systems are now successful.

- **Computer Vision**
  - Face recognition programs in use by banks, government, etc.
  - The ALVINN system from CMU autonomously drove a van from Washington, D.C. to San Diego (all but 52 of 2,849 miles), averaging 63 mph day and night, and in all weather conditions.
  - Handwriting recognition, electronics and manufacturing inspection, photo interpretation, baggage inspection, reverse engineering to automatically construct a 3D geometric model.

Applications of AI

- Expert Systems
  - Application-specific systems that rely on obtaining the knowledge of human experts in an area and programming that knowledge into a system.

- Diagnostic Systems
  - Microsoft Office Assistant provides customized help by decision-theoretic reasoning about an individual user.
  - MYCIN system for diagnosing bacterial infections of the blood and suggesting treatments.
  - Pathfinder medical diagnosis system, which suggests tests and makes diagnoses.

Applications of AI

- Financial Decision Making
  - Credit card companies, mortgage companies, banks, and the U.S. government employ AI systems to detect fraud and expedite financial transactions.
  - Systems often use learning algorithms to construct profiles of customer usage patterns, and then use these profiles to detect unusual patterns and take appropriate action.
- Classification Systems
  - Put information into one of a fixed set of categories using several sources of information. E.g., financial decision making systems.
  - NASA developed a system for classifying very faint areas in astronomical images into either stars or galaxies with very high accuracy by learning from human experts' classifications.

Applications of AI

- Mathematical Theorem Proving
  - Use inference methods to prove new theorems.
- Natural Language Understanding
  - Google's translation of web pages. Translation of Caterpillar Truck manuals into 20 languages. (Note: One early system translated the English sentence "The spirit is willing but the flesh is weak" into the Russian equivalent of "The vodka is good but the meat is rotten.")

Applications of AI

- Scheduling and Planning
  - Automatic scheduling for manufacturing.
  - DARPA's DART system used in Desert Storm and Desert Shield operations to plan logistics of people and supplies.
  - American Airlines rerouting contingency planner.
  - European space agency planning and scheduling of spacecraft assembly, integration and verification.
- Robotics and Path planning
  - NASA’s Rover mission.
- Biology and medicine
  - Modeling of cellular functions, analysis of DNA and proteins.
- and…

How to achieve AI?

- How is AI research done?
- AI research has both theoretical and experimental sides. The experimental side has both basic and applied aspects.
- There are two main lines of research:
  - One is biological, based on the idea that since humans are intelligent, AI should study humans and imitate their psychology or physiology.
  - The other is phenomenal, based on studying and formalizing common sense facts about the world and the problems that the world presents to the achievement of goals.
- The two approaches interact to some extent, and both should eventually succeed. It is a race, but both racers seem to be walking. [**John McCarthy]**

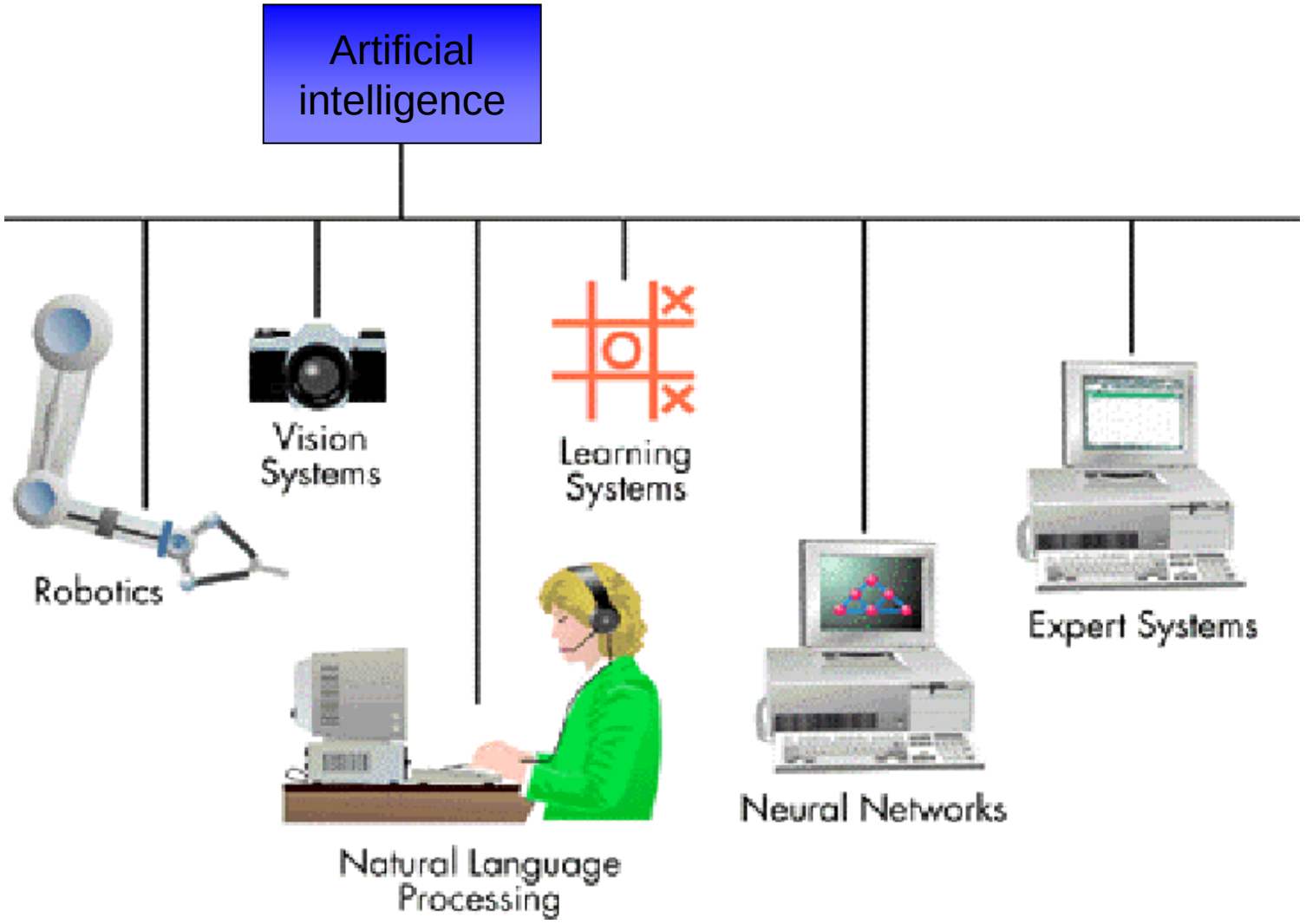
Major Branches of AI (1/3)

- Perceptive system
  - A system that approximates the way a human sees, hears, and feels objects
- Vision system
  - Capture, store, and manipulate visual images and pictures
- Robotics
  - Mechanical and computer devices that perform tedious tasks with high precision
- Expert system
  - Stores knowledge and makes inferences

Major Branches of AI (2/3)

- Learning system
  - Computer changes how it functions or reacts to situations based on feedback
- Natural language processing
  - Computers understand and react to statements and commands made in a “natural” language, such as English
- Neural network
  - Computer system that can act like or simulate the functioning of the human brain

Major Branches of AI (3/3)



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

AI 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

AI State of the art

- Have the following been achieved by AI?
  - World-class chess playing
  - Playing table tennis
  - Cross-country driving
  - Solving mathematical problems
  - Discover and prove mathematical theories
  - Engage in a meaningful conversation
  - Understand spoken language
  - Observe and understand human emotions
  - Express emotions
  - …

Special Topics: An Introduction ☺

- Natural Language Processing
- Robotics
- Machine Learning
- Expert Systems
- Genetic Algorithms
- Information Retrieval
- Planning
- Vision
- Neural Networks

Natural Language Processing

- Natural Language Processing
  - Process information contained in natural language text.
  - Also known as Computational Linguistics (CL), Human Language Technology (HLT), Natural Language Engineering (NLE)
- Can machines understand human language?
  - Define ‘understand’
  - Understanding is the ultimate goal. However, one doesn’t need to fully understand to be useful.

Natural Language Processing

- Analyze, understand and generate human languages just like humans do.
- Applying computational techniques to language domain..
- To explain linguistic theories, to use the theories to build systems that can be of social use..
- Started off as a branch of Artificial Intelligence..
- Borrows from Linguistics, Psycholinguistics, Cognitive Science & Statistics.
- Make computers learn our language rather than we learn theirs

Natural Language Processing

- The input/output of a NLP system can be:
  - **written text**
  - **speech**
- To process written text, we need:
  - **lexical, syntactic, semantic knowledge about the language**
  - **discourse information, real world knowledge**
- To process spoken language, we need everything required to process written text, plus the challenges of speech recognition and speech synthesis.

NLP Applications

- Question answering
  - Who is the first Taiwanese president?
- Text Categorization/Routing
  - e.g., customer e-mails.
- Text Mining
  - Find everything that interacts with BRCA1.
- Machine (Assisted) Translation
- Language Teaching/Learning
  - Usage checking
- Spelling correction
  - Is that just dictionary lookup?

Robotics

- Word robot was coined by a Czech novelist Karel Capek in a 1920 play titled Rossum's Universal Robots (RUR)

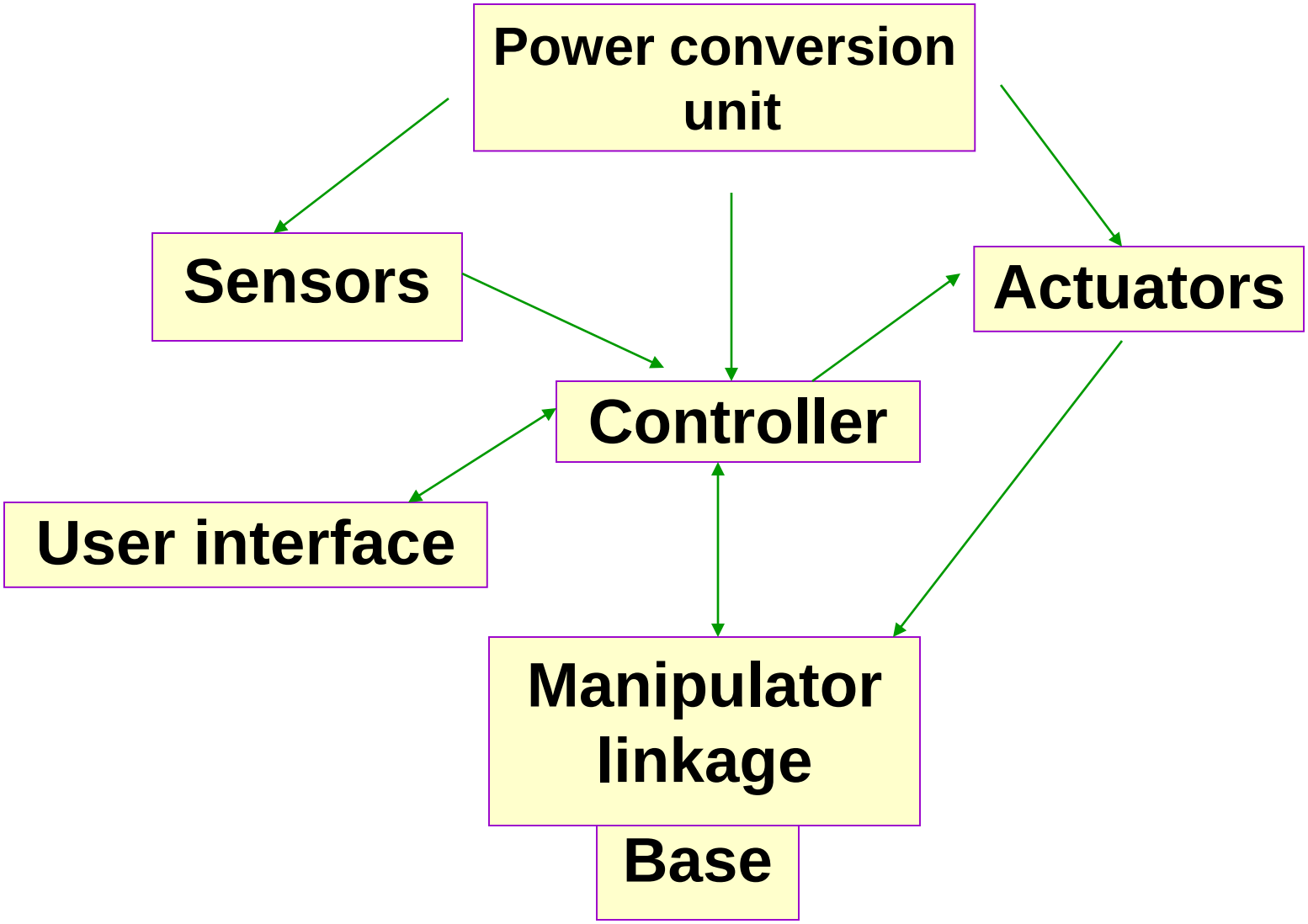
- Robota in Czech is a word for worker or servant

Karel Capek

Definition of robot:

A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks: Robot Institute of America, 1979

Robotics: Key Components



Robotics: What Can Robots Do?

Industrial Robots

- Material handling
- Material transfer
- Machine loading and/or unloading
- Spot welding
- Continuous arc welding
- Spray coating
- Assembly
- Inspection

Material Handling Manipulator

Assembly Manipulator

Spot Welding Manipulator

NLP Applications

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Machine Learning

- Adapt to / learn from data
  - To optimize a performance function

Can be used to:

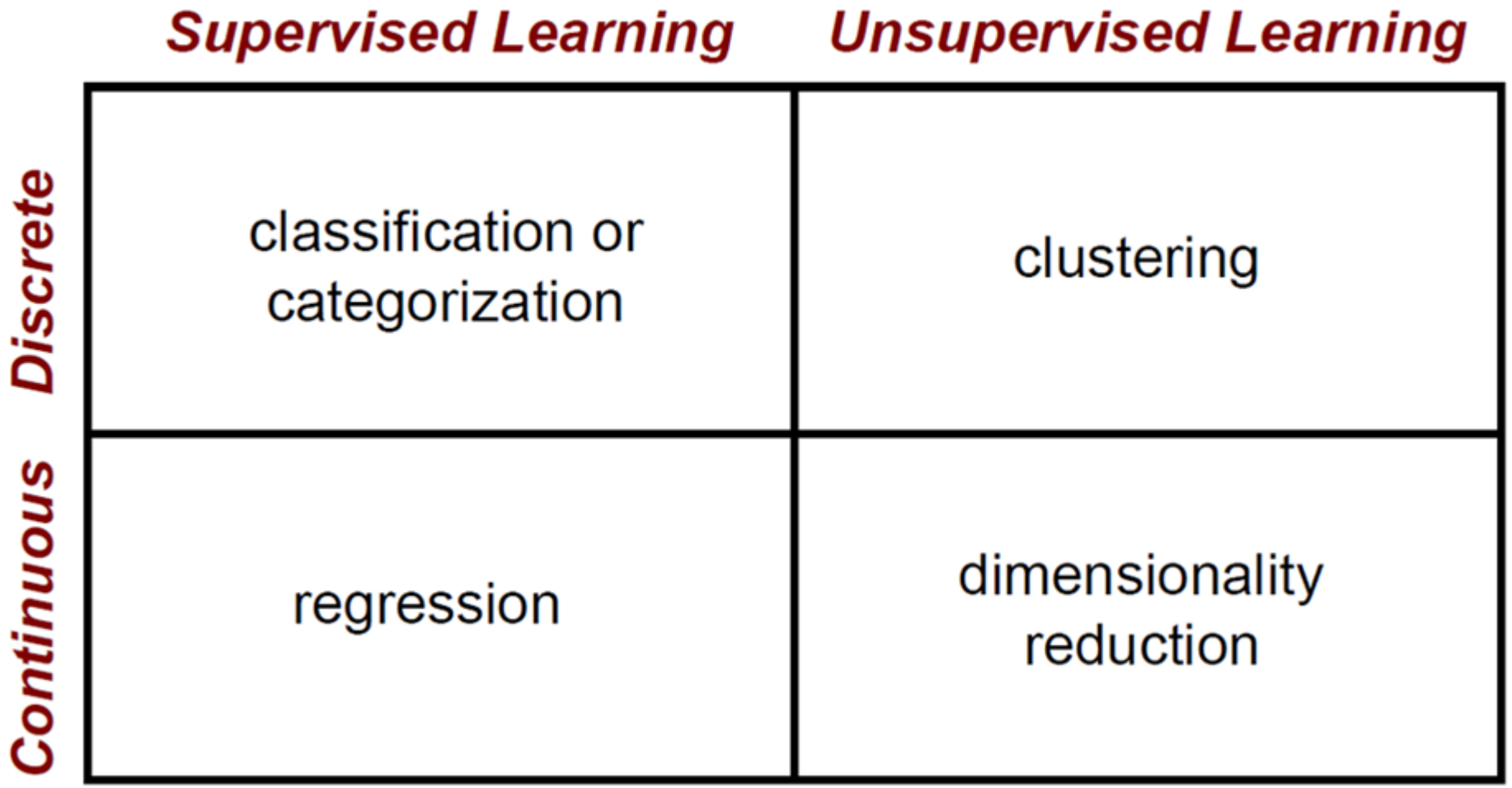
- Extract knowledge from data
- Learn tasks that are difficult to formalize
- Create software that improves over time

Machine Learning

- Machine learning is programming computers to optimize a performance criterion using example data or past experience.

- Learning is used when:
  - Human expertise does not exist (navigating on Mars),
  - Humans are unable to explain their expertise (speech recognition)
  - Solution changes in time (routing on a computer network)
  - Solution needs to be adapted to particular cases (user biometrics)

Machine Learning



Machine Learning : Classification: Applications

- Face recognition: Pose, lighting, occlusion (glasses, beard), make-up, hair style
- Character recognition: Different handwriting styles.
- Speech recognition: Temporal dependency.
  - Use of a dictionary or the syntax of the language.
  - Sensor fusion: Combine multiple modalities; e.g., visual (lip image) and acoustic for speech
- Medical diagnosis: From symptoms to illnesses
- Web Advertising: Predict if a user clicks on an ad on the Internet.
- etc.

Machine Learning : Face Recognition

Training examples of a person

Test images

AT&T Laboratories, Cambridge UK
http://www.uk.research.att.com/facedatabase.html

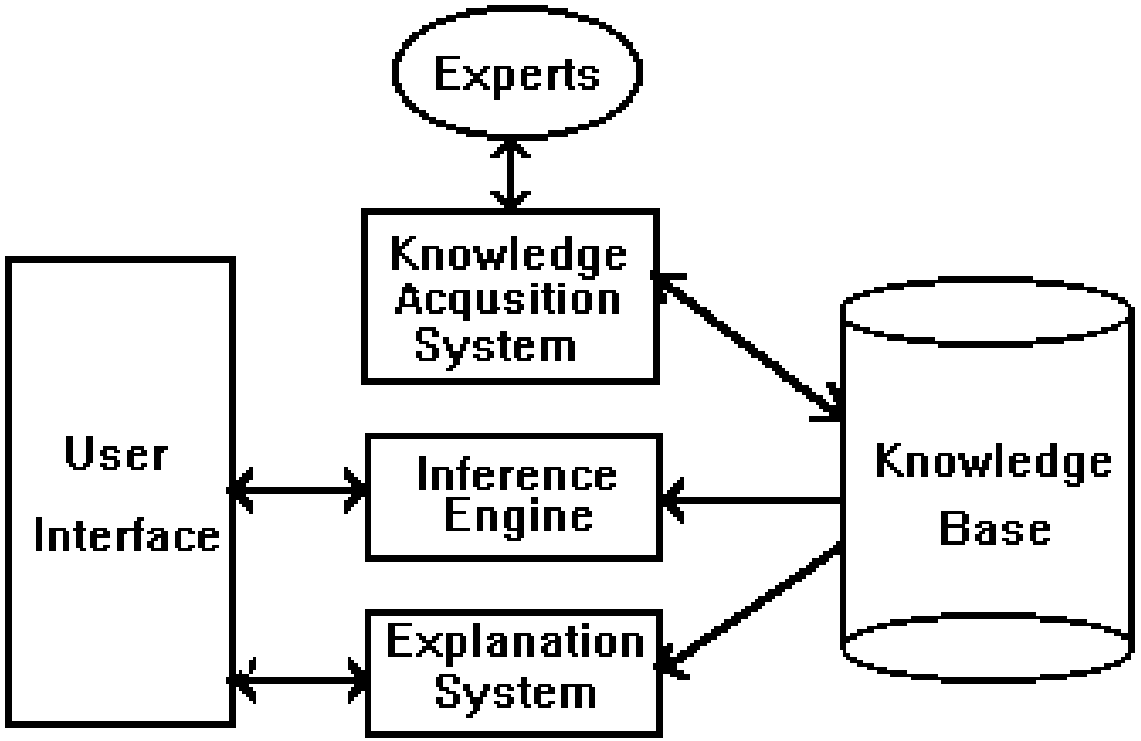
Expert Systems

- The term ***expert system*** is used in a paper by Alan Turing in 1937 related to a study in AI.

- ***An Expert System (ES)*** is a computer program that reasons using knowledge to solve complex problems. (Feigenbaum, 1992)

- Traditionally, computers solve complex problems by arithmetic calculations; and the knowledge to solve the problem is only known by the human programmer.

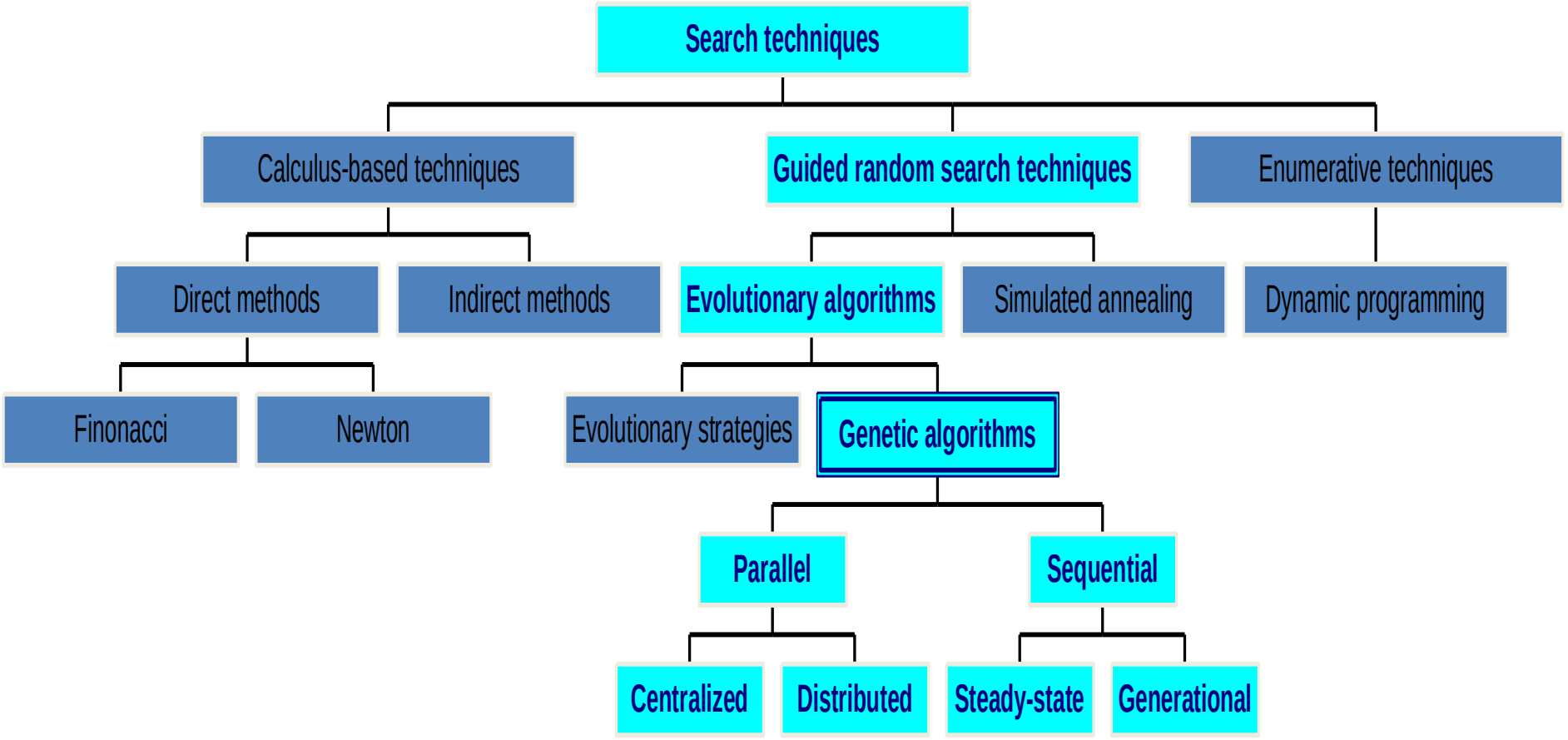
Expert Systems: Architecture



Genetic Algorithms

- A class of probabilistic optimization algorithms
- Inspired by the biological evolution process
- Originally developed by John Holland (1975)

Genetic Algorithms

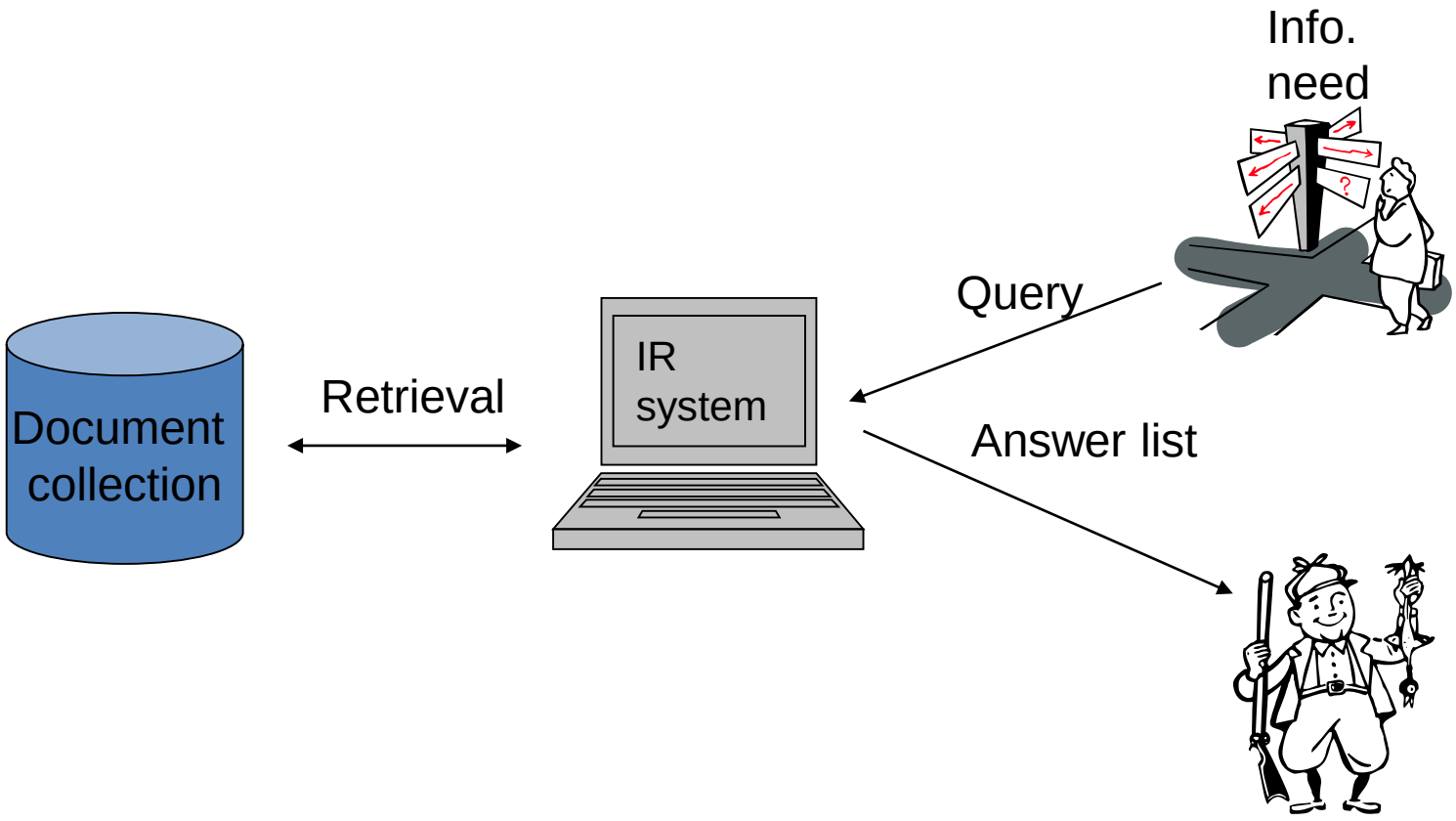


Genetic Algorithms : Some GA Application Types

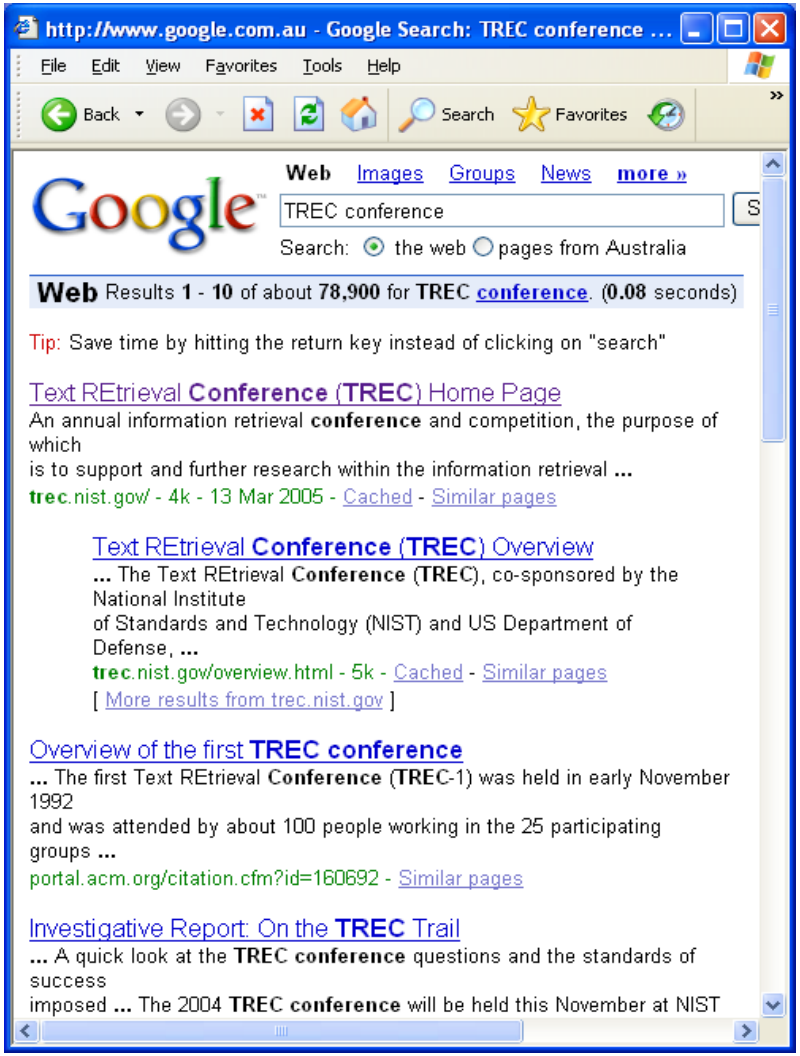
Domain	Application Types
Control	gas pipeline, pole balancing, missile evasion, pursuit
Design	semiconductor layout, aircraft design, keyboard configuration, communication networks
Scheduling	manufacturing, facility scheduling, resource allocation
Robotics	trajectory planning
Machine Learning	designing neural networks, improving classification algorithms, classifier systems
Signal Processing	filter design
Game Playing	poker, checkers, prisoner's dilemma
Combinatorial Optimization	set covering, travelling salesman, routing, bin packing, graph colouring and partitioning

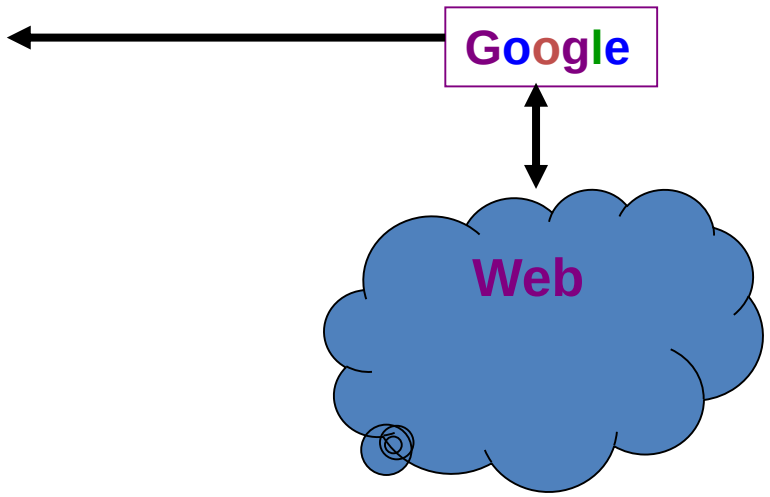
Information Retrieval (IR)

Goal = find documents *relevant* to an information need from a large document set



Information Retrieval

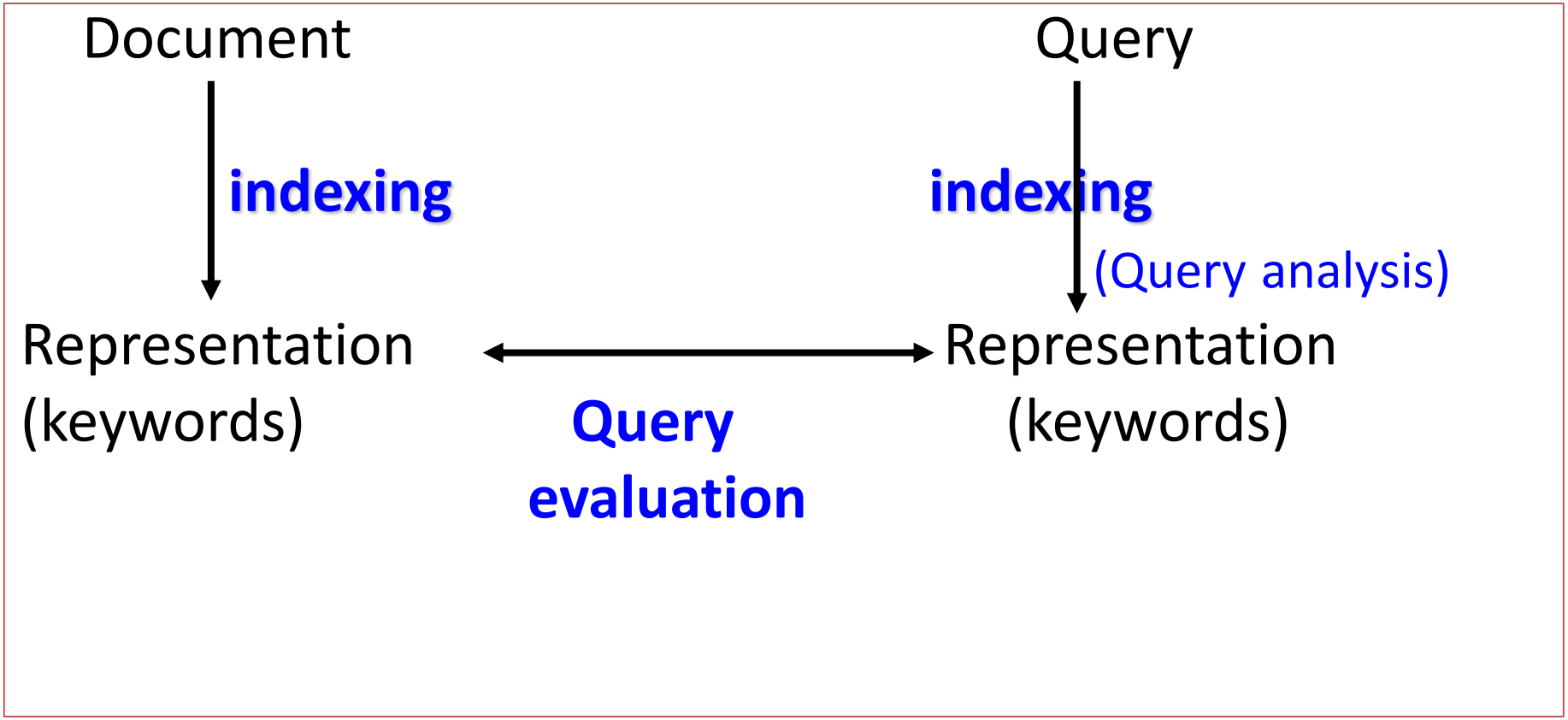




IR: Possible approaches

1. String matching (linear search in documents)
   - Slow
   - Difficult to improve
2. Indexing (*)
   - Fast
   - Flexible to further improvement

IR: Indexed Based IR Systems



Planning

- The task of coming up with a sequence of actions that will achieve a goal is called planning.
- It contains both how to take actions in the world (the search based problem solving agents) and how to represent objects, relations and so on (the logical planning agents).
- Scheduling + Game Playing

Computer Vision

Make computers understand images and video.

What kind of scene?

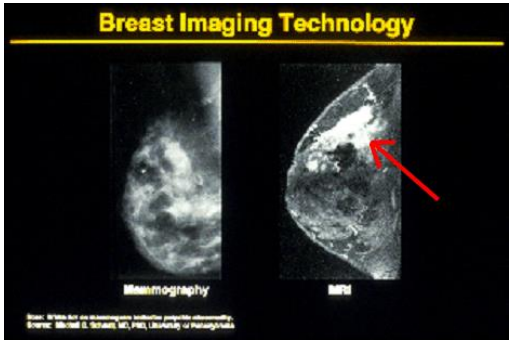
Where are the cars?

How far is the building?

…

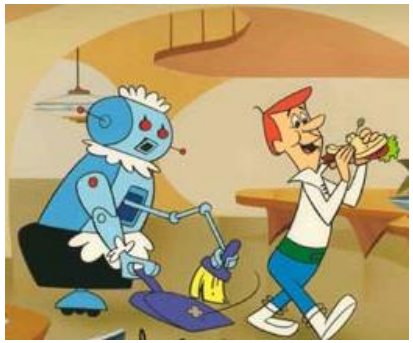
Why computer vision matters

Safety



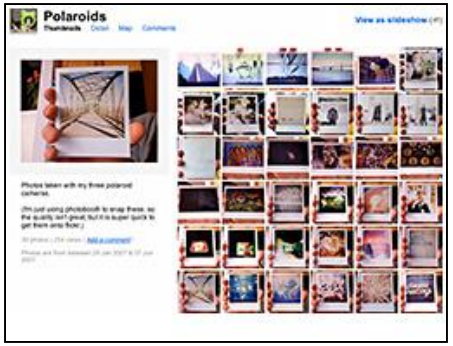
Health

Security



Comfort

Fun



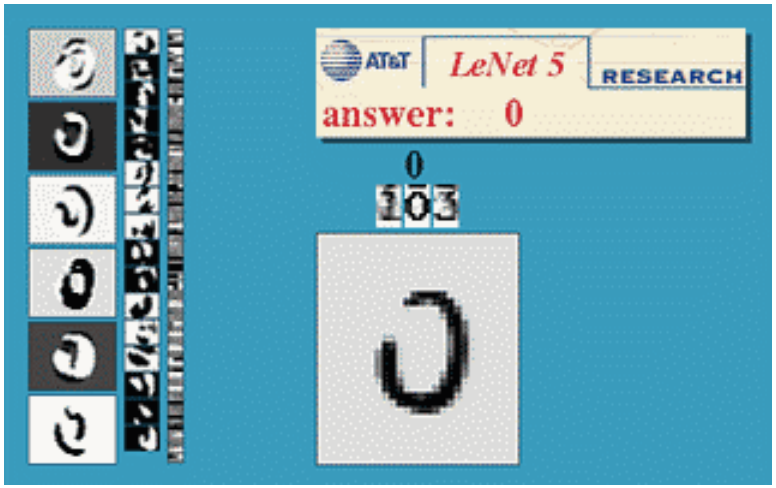
Access

Computer Vision :

Optical character recognition (OCR)

Technology to convert scanned docs to text

- If you have a scanner, it probably came with OCR software



Digit recognition, AT&T labs
http://www.research.att.com/~yann/

License plate readers
http://en.wikipedia.org/wiki/Automatic_number_plate_recognition

Computer Vision : Face detection

- Many new digital cameras now detect faces
  - Canon, Sony, Fuji, …

Neural Networks

- A mathematical model to solve engineering problems
  - Group of highly connected neurons to realize compositions of non linear functions
- Tasks
  - Classification
  - Discrimination
  - Estimation
- 2 types of networks
  - Feed forward Neural Networks
  - Recurrent Neural Networks