Artificial Intelligence

Introduction

Course Details

- Instructor
- Sadullah Karimi; MSc in Computer Science and Engineering Specialized NLP, Machine Learning and Deep Learning

- Grading
- Programming projects (3) 35%
- Homework set (3): 15%
- Midterm 20%
- Final 30%

Table of Contents

WHAT IS AI?

- ✓ We call ourselves Homo sapiens —man the wise— because our intelligence is so important to us.
- ✓ The field of artificial intelligence, or AI, goes further still:
  - **ARTIFICIAL INTELLIGENCE**: it attempts not just to understand but also to build intelligent entities.
- ✓ AI currently encompasses a huge variety of sub-fields, 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.

★★★ AI is regularly cited as the “field I would most like to be in” by scientists in other disciplines ★★★

- A system is rational if it does the "right thing," given what it knows.

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)

Figure 1.1 Some definitions of artificial intelligence, organized into four categories.

Acting humanly: The Turing Test approach

The **Turing Test**, proposed by Alan Turing TURING TEST (1950).

A computer passes the test if a human interrogator, after posing some written questions, cannot tell whether the written responses come from a person or from a computer.

Essential Capabilities for AI

- ✓ **Natural Language Processing (NLP):**
  - Enables successful communication in English and other languages.
- ✓ **Knowledge Representation:**
  - Stores and manages acquired knowledge.
- ✓ **Automated Reasoning:**
  - Uses stored information to answer questions and derive new insights.
- ✓ **Machine Learning:**
  - Adapts to new circumstances, detects patterns, and extrapolates information.
- ✓ **Computer Vision:**
  - Perceives and interprets visual information about objects.
- ✓ **Robotics:**
  - Manipulates objects and moves in physical environments.

Alan Turing's Legacy

✓ **Turing Test:**
- Introduced in 1950, a test to assess a machine's ability to exhibit intelligent behavior indistinguishable from that of a human.

✓ **Concept of Universal Computing:**
- Proposed the concept of a universal computing machine (Turing machine), which laid the foundation for modern computers.

✓ **Impact on AI:**
- Turing's ideas and tests remain foundational in the development and evaluation of artificial intelligence.

✓ **Recognition:**
- His contributions continue to shape AI research, philosophy, and ethics, influencing fields beyond computing.

Understanding Human Thinking

✓ **Defining Human-like Thinking:**
- Essential to establish criteria for determining if a program thinks like a human.

✓ **Cognitive Science:**
- Integrates AI models and psychological experiments.
- Constructs precise and testable theories about human cognition.

✓ **Early Confusions in AI:**
- **Approach Confusion:** Authors debated whether a task-performing algorithm equated to human-like performance, or vice versa.

Development of Logical Reasoning

- ✓ **Aristotle (384–322 BC):**
  - Codified "right thinking" with syllogism, establishing foundational logic.
- ✓ **Evolution of Logic:**
  - **Syllogism:** Formal reasoning process based on deductive logic.
  - **Logicist Approach:** Systematic study and application of logical principles.
- ✓ **Contrast with Arithmetic:**
  - **Arithmetic Notation:** Limited to statements about numbers, unlike logic which deals with broader reasoning.
- ✓ **Advancements in Computing:**
  - **1965:** Development of programs capable of solving problems described in logical notations.

Acting rationally: The rational agent approach

✓ **Definition of an Agent:**

- An agent is something that acts, deriving from the Latin "agere," meaning to do.

✓ **Computer Agents:**

- Expected to operate autonomously and perceive their environment.

Rational Agent:

- Acts to achieve the best outcome or, in uncertain conditions, the best expected outcome.

Philosophical Inquiries

- ✓ **Formal Rules and Valid Conclusions:**
  - **Logic:** Formal rules are used in logic to draw valid conclusions deductively.
- ✓ **Mind and Physical Brain:**
  - Philosophy of Mind: Investigates how mental processes arise from physical brain activities.
- ✓ **Source of Knowledge:**
  - **Epistemology:** Explores the origins and nature of knowledge.
- ✓ **Knowledge to Action:**
  - **Practical Philosophy:** Examines how knowledge influences decision-making and action.

The Foundation of Artificial Intelligence

✓ **Definition of AI:**

- AI refers to the simulation of human intelligence in machines that are programmed to think and learn like humans.

✓ **Historical Milestones:**

- **1950s:** Alan Turing proposes the Turing Test and foundational concepts of AI.
- **1960s-1970s:** Early developments in symbolic AI and expert systems.
- **1980s-1990s:** AI winter and resurgence with neural networks and machine learning.
- **2000s-Present:** Rapid advancements in deep learning, reinforcement learning, and AI applications.

Early Calculating Machines

✓ **Wilhelm Schickard (1592–1635):**

- Constructed the first known calculating machine around 1623.

✓ **Blaise Pascal (1623–1662):**

- Invented the Pascaline in 1642, capable of addition and subtraction.

✓ **Gottfried Wilhelm Leibniz (1646–1716):**

- Developed a more advanced calculator, adding multiplication, division, and roots.

Mathematics: Formalizing Rules and Computations

Mathematical development really began with the work of George Boole (1815–1864)

✓ **Formal Rules for Valid Conclusions:**

- Logic and deductive reasoning principles.

✓ **Scope of Computations:**

- Operations expand from basic arithmetic to complex mathematical functions.

✓ **Uncertain Information: Reasoning Approaches**

- Methods to handle uncertainty, including probability theory and Bayesian reasoning.

Evolution of Algorithms

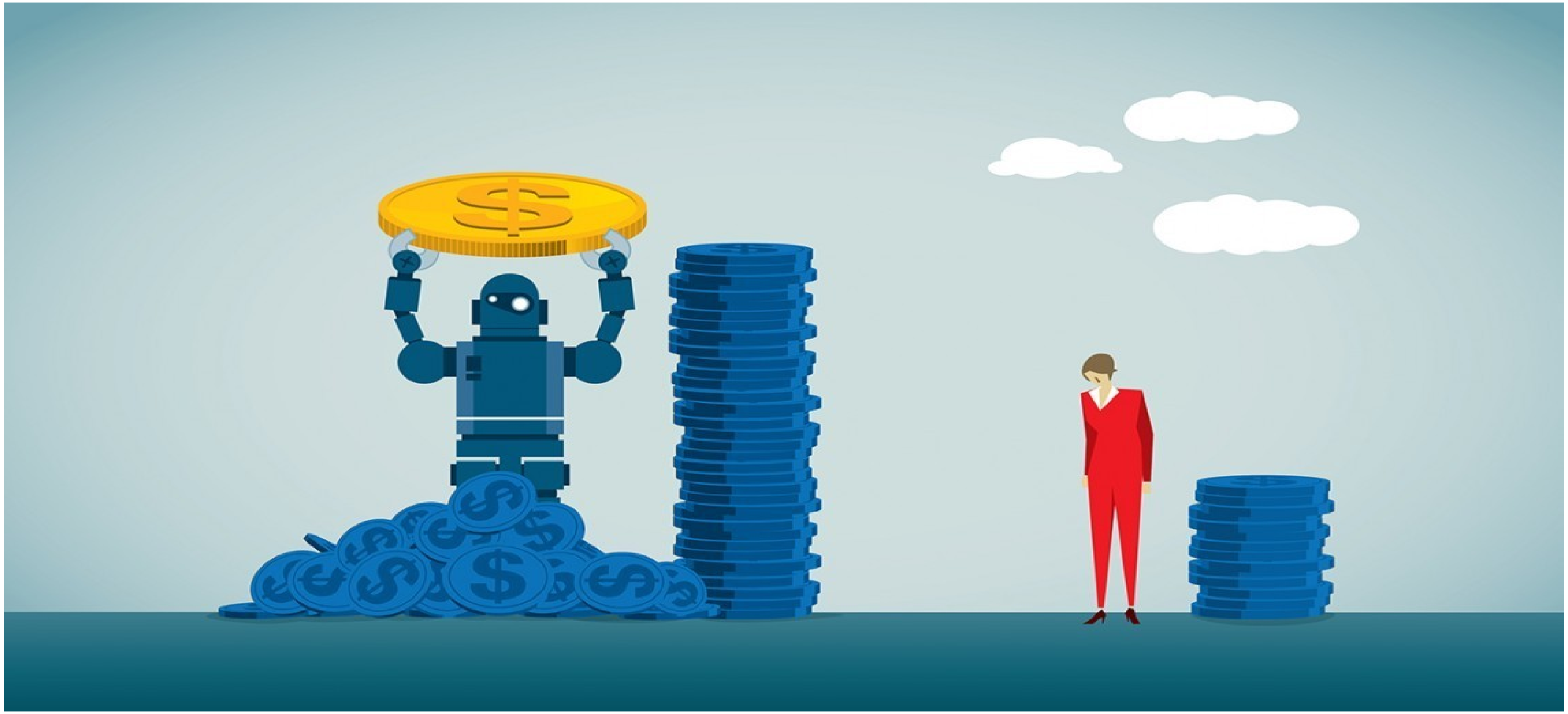
- ✓ **Ancient Roots:**
  - Euclid’s algorithm for greatest common divisors.
- ✓ **9th Century Influence:**
  - Al-Khwarizmi introduced algorithms alongside Arabic numerals and algebra to Europe.
- ✓ **Logical Deduction:**
  - Boole and others developed algorithms for logical reasoning.
- ✓ **Formalization:**
  - Late 19th century efforts to formalize mathematical reasoning.
- ✓ **Gödel’s Insights:**
  - **1930:** Effective procedures in first-order logic by Frege and Russell.
  - **1931:** Limits of deduction demonstrated by Kurt Gödel.

Evolution of Probability

- ✓ **Origins:**
  - Gerolamo Cardano (1501–1576) framed probability, linking it to gambling outcomes.
- ✓ **17th Century Advancements:**
  - Blaise Pascal (1623–1662) showed predictive capabilities in gambling.
  - Pierre Fermat (1601–1665) collaborated on early probability theory.
- ✓ **Integration into Sciences:**
  - Probability became essential in quantitative sciences for handling uncertainties and incomplete theories.
- ✓ **Further Developments:**
  - James Bernoulli (1654–1705) and Pierre Laplace (1749–1827) advanced theory and introduced statistical methods.
- ✓ **Bayesian Revolution:**
  - Thomas Bayes (1702–1761) introduced Bayes’ rule for updating probabilities with new evidence.
  - Fundamental to modern uncertain reasoning in AI systems.

Economics

- ✓ How should we make decisions so as to maximize payoff?
- ✓ How should we do this when others may not go along?
- ✓ How should we do this when the payoff may be far in the future?



Neuroscience

✓How do brains process information?

✓The ability of the brain to elaborate new connections and neuronal circuits—neuroplasticity—underlies all learning.

✓How Neuroscience Helps Us Understand the Mind and Brain.

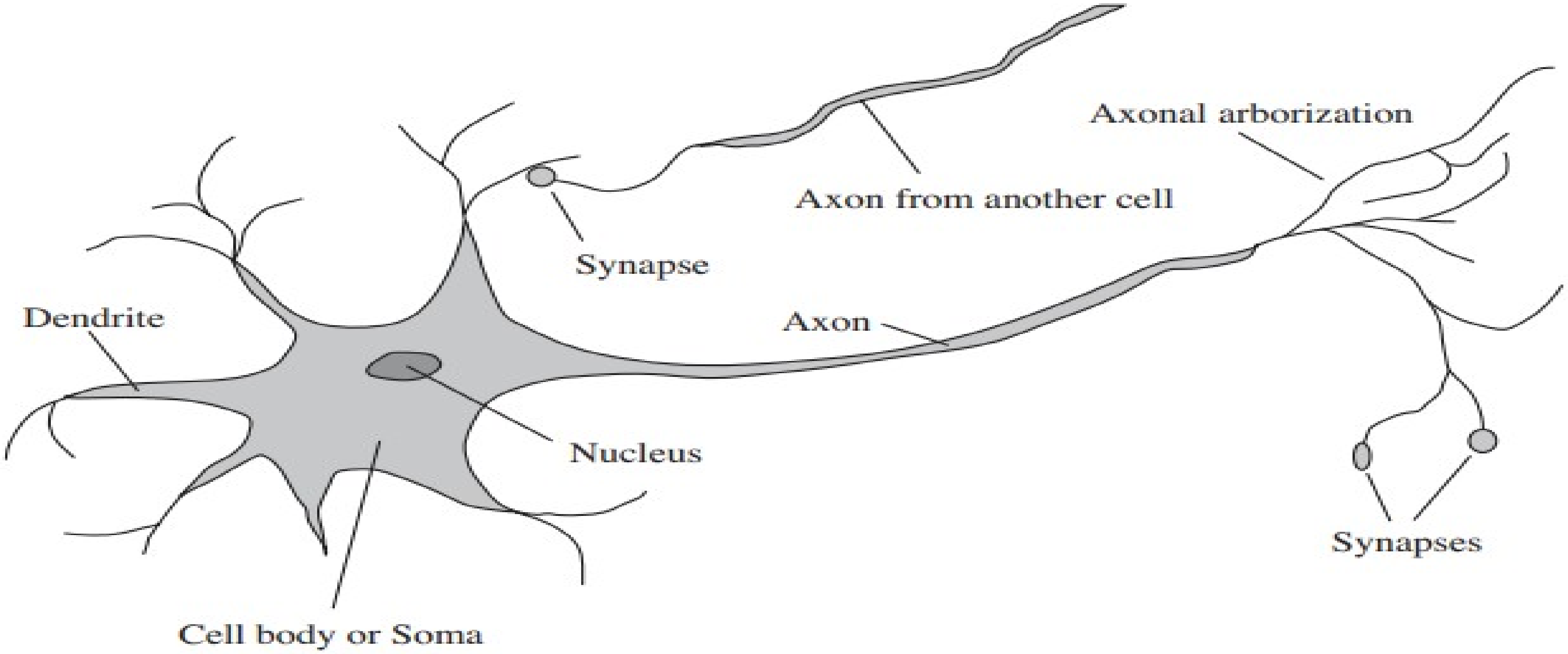


Figure 1.2 The parts of a nerve cell or neuron. Each neuron consists of a cell body, or soma, that contains a cell nucleus. Branching out from the cell body are a number of fibers called dendrites and a single long fiber called the axon. The axon stretches out for a long distance, much longer than the scale in this diagram indicates. Typically, an axon is 1 cm long (100 times the diameter of the cell body), but can reach up to 1 meter. A neuron makes connections with 10 to 100,000 other neurons at junctions called synapses. Signals are propagated from neuron to neuron by a complicated electrochemical reaction. The signals control brain activity in the short term and also enable long-term changes in the connectivity of neurons. These mechanisms are thought to form the basis for learning in the brain. Most information processing goes on in the cerebral cortex, the outer layer of the brain. The basic organizational unit appears to be a column of tissue about 0.5 mm in diameter, containing about 20,000 neurons and extending the full depth of the cortex about 4 mm in humans).

	Supercomputer	Personal Computer	Human Brain
Computational units	10^4 CPUs, 10^{12} transistors	4 CPUs, 10^9 transistors	10^{11} neurons
Storage units	10^{14} bits RAM	10^{11} bits RAM	10^{11} neurons
	10^{15} bits disk	10^{13} bits disk	10^{14} synapses
Cycle time	10^{-9} sec	10^{-9} sec	10^{-3} sec
Operations/sec	10^{15}	10^{10}	10^{17}
Memory updates/sec	10^{14}	10^{10}	10^{14}

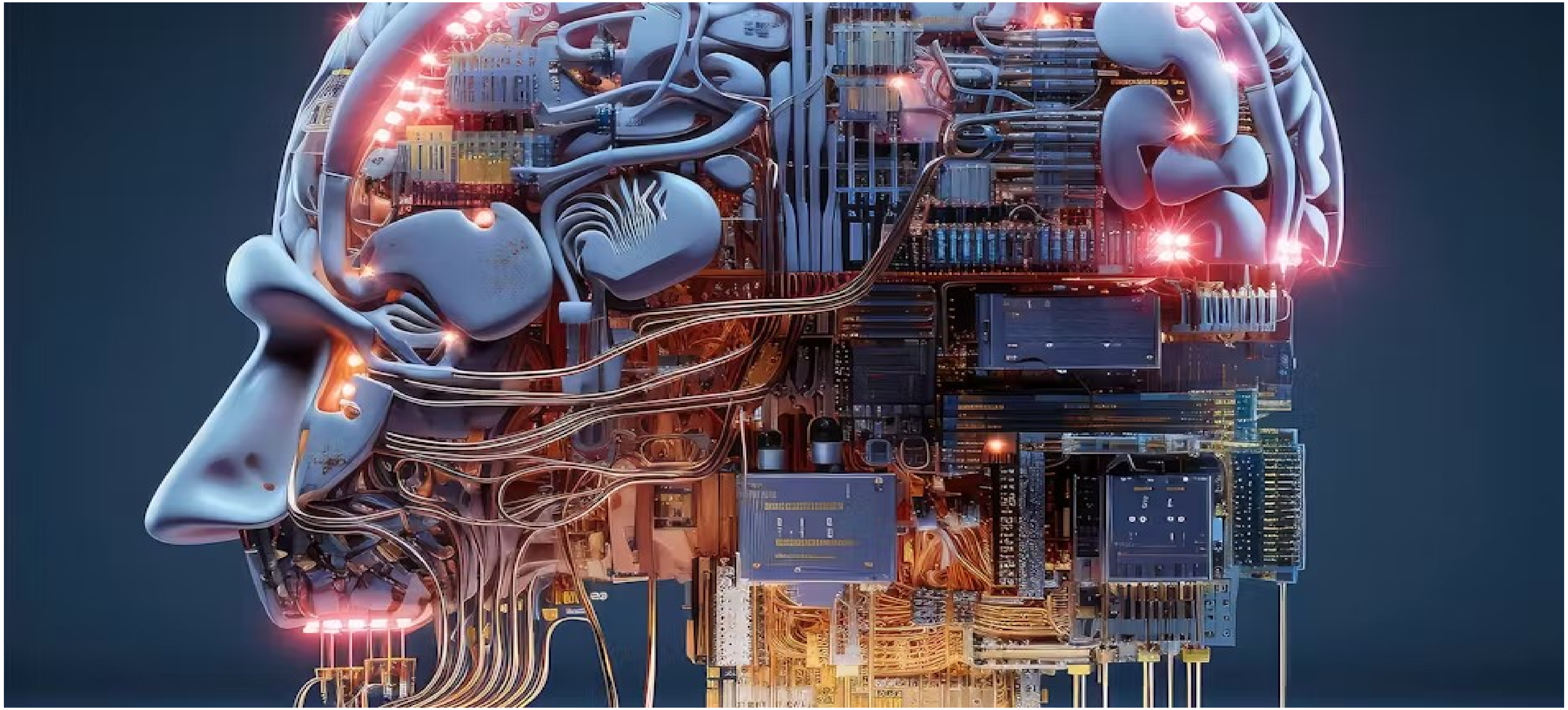
Figure 1.3 A crude comparison of the raw computational resources available to the IBM BLUE GENE supercomputer, a typical personal computer of 2008, and the human brain. The brain's numbers are essentially fixed, whereas the supercomputer's numbers have been increasing by a factor of 10 every 5 years or so, allowing it to achieve rough parity with the brain. The personal computer lags behind on all metrics except cycle time.

Psychology

- ✓ How do humans and animals think and act?
- ✓ Psychologists adopted the idea that humans and animals can be considered information processing machine.
- ✓ AI creates new jobs as "data science", "AI teaching", "data labeling", etc

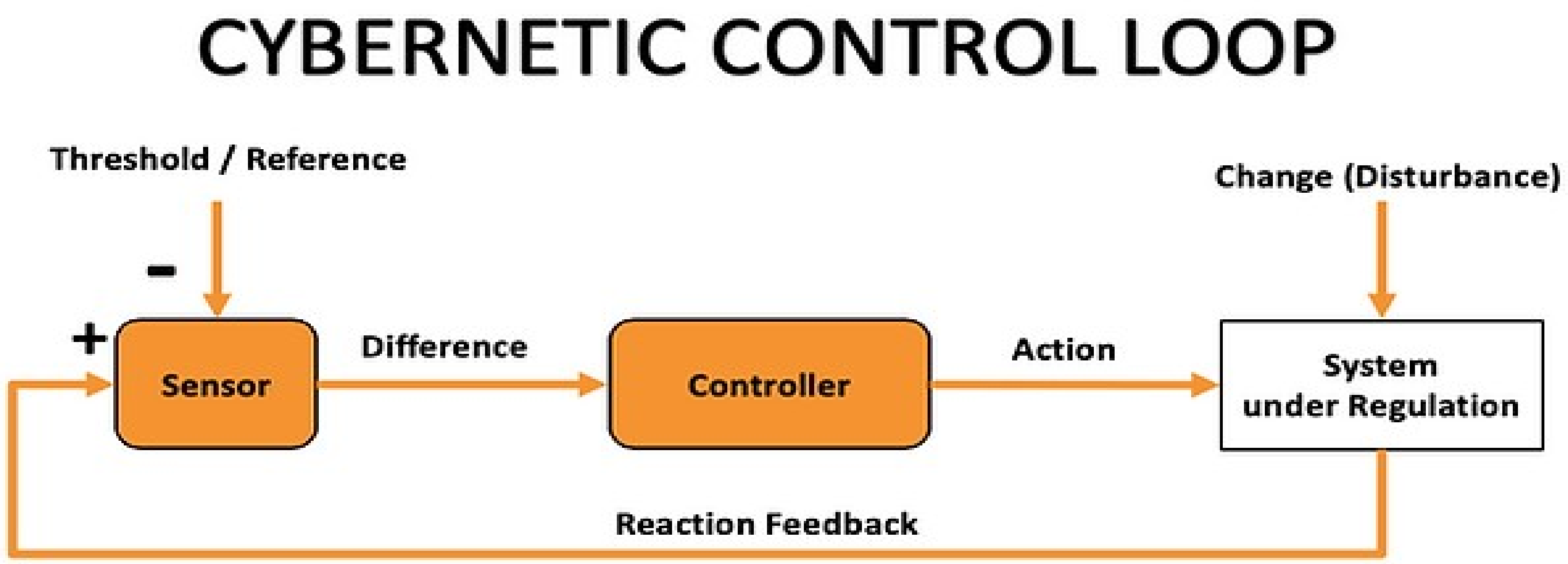
Computer engineering

- ✓ How can we build an efficient computer?



Control theory and cybernetics

✓ How can artifacts operate under their own control?



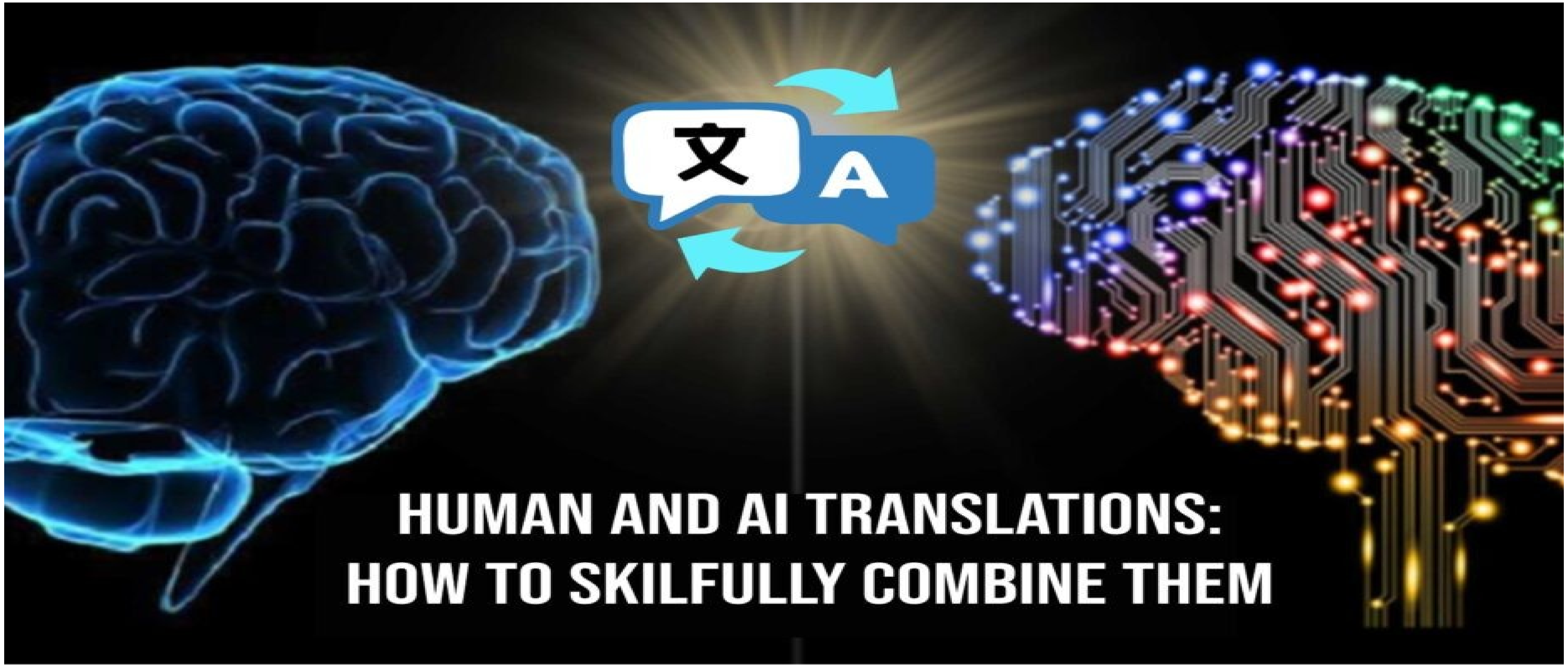
- When the variety or complexity of the environment exceeds the capacity of a system the environment will dominate
- The larger the variety of actions available to a control system, the larger the variety it is able to compensate
- The capacity of the control system cannot exceed the capacity as a channel of communication
- The response time of the control system must meet or exceed the speed of change

† *Law of Requisite Variety – Ross Ashby (Cyberneticist)*

LEAN COMPLIANCE

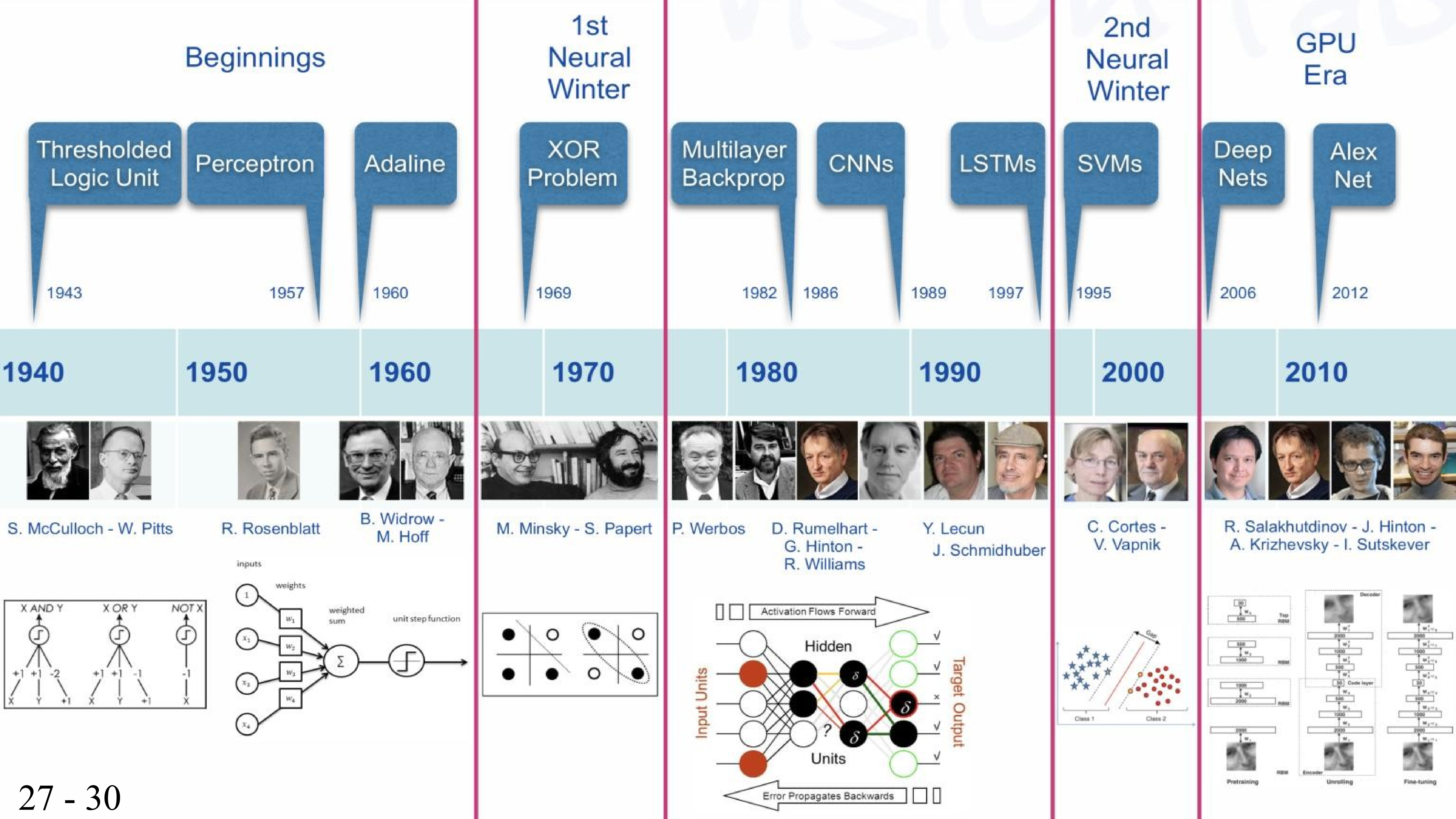
Linguistics

- ✓ How does language relate to thought?
- ✓AI Linguistics covers a number of related rubrics, including the AI behind the processing of speech, comprehension of written text (the next stage of optical character recognition), natural language processing, production of synthetic speech, chatbots and smart agents such as Siri or Alexa.



The history of artificial Intelligence

- ✓The birth of artificial intelligence (1956)
- ✓Princeton was home to another influential figure in AI, John McCarthy. After receiving his PhD there in 1951 and working for two years as an instructor, McCarthy moved to Stanford and then to Dartmouth College, which was to become the official birthplace of the field. McCarthy convinced Minsky, Claude Shannon, and Nathaniel Rochester to help him bring together U.S. researchers interested in automata theory, neural nets, and the study of intelligence.



Beginnings
1st Neural Winter
2nd Neural Winter
GPU Era
Thresholded Logic Unit
1943
Perceptron
1957
Adaline
1960
XOR Problem
1969
Multilayer Backprop
1982
CNNs
1986
1989
LSTMs
1997
SVMs
1995
Deep Nets
2006
Alex Net
2012
1940
1950
1960
1970
1980
1990
2000
2010
S. McCulloch - W. Pitts
R. Rosenblatt
B. Widrow - M. Hoff
M. Minsky - S. Papert
P. Werbos
D. Rumelhart - G. Hinton - R. Williams
Y. Lecun
J. Schmidhuber
C. Cortes - V. Vapnik
R. Salakhutdinov - J. Hinton - A. Krizhevsky - I. Sutskever
X AND Y
X OR Y
NOT X
inputs
weights
weighted sum
unit step function
Activation Flows Forward
Hidden
Units
Input Units
Target Output
Error Propagates Backwards
Pretraining
Unrolling
Fine-tuning

The sate of the art

- ✓ Robotic vehicles
- ✓ Speech recognition
- ✓ Autonomous planning and scheduling
- ✓ Game playing
- ✓ Spam fighting
- ✓ Logistics planning
- ✓ Robotics
- ✓ Machine Translation

Thanks for your attention

Any questions?