CS6482

Deep Reinforcement Learning

A: Introduction, Symbolic AI.

J.J. Collins

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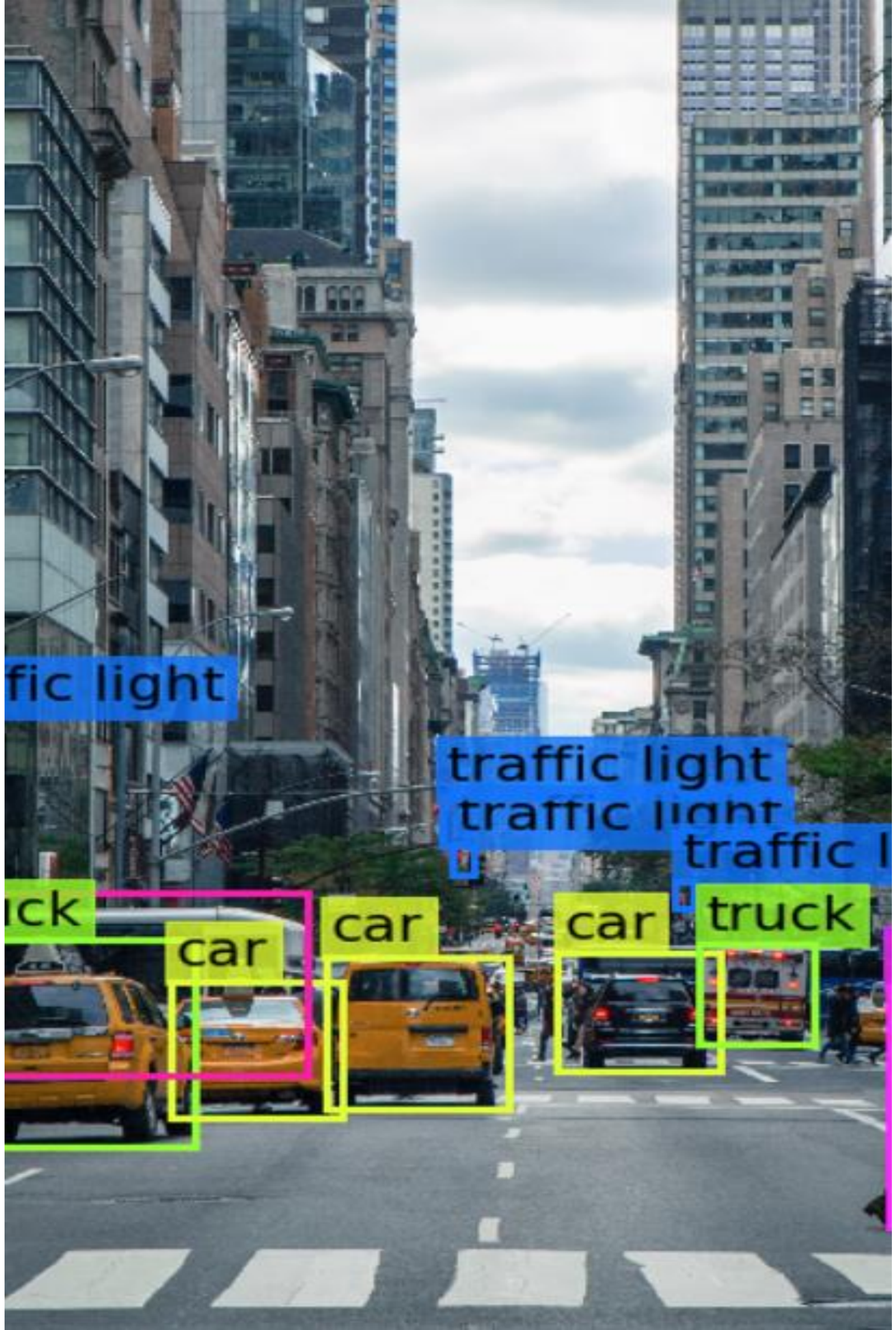

Objectives

- ❑ Introduce the lecturer
- ❑ Outline assessment instruments
- ❑ Walkthrough syllabus and recommended texts
- ❑ Some thoughts on AI and ML

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The Lecturer

- J.J. Collins
- j.j.Collins@ul.ie
- LM121 Computer Science Course Director
- Teaching: Neural Computing, Deep Learning, Software Architecture.
- Research:
  - Evolutionary Algorithmss for automatic parallelisation of sequential code,
  - Previous work in Reinforcement Learning, Robotics, Computer Vision, Business Process Orchestration and Service Level Agreements (SLAs)

2. Assessment Instruments

1. **20% In-Person Midterm Week 6**

2. **17% CNN project**
   - Individual.
   - Distributed Week 4, due week 7

1. **27% Deep Reinforcement Learning project**
   - Team-based submission.
   - Distributed Week 7, due week 12

4. **36% In-Person Final Exam**

Repeat: 100% Exam

2. Schedule

- Tutorials starting **Week 4**.

- Office Hours
  - Email with a request for either online OR in-person meeting with a list of 3 preferred dates/times, cannot be Tuesday or Thursday.

- ALWAYS put CS6482 in the subject.

2. Module Background: Texts

- Aurelien Geron. Hands-on machine learning with Scikit-learn, Keras, and TensorFlow : concepts, tools, and techniques to build intelligent Systems, 2nd Edition. 2019. O'Reilly.
- Ian Goodfellow, Yoshua Bengio, and Aaron Courville. *Deep Learning* . 2016. The MIT Press.

- Richard Sutton and Andrew Barto. Reinforcement Learning, 2nd Edition. 2018. The MIT Press.
- Lapan, Maxim (2018) *Deep Reinforcement Learning Hands-On: Apply modern RL methods, with deep Q-networks, value iteration, policy gradients, TRPO, AlphaGo Zero and more. 2018*. Packt Publishing Ltd,

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- Many Research Papers

2. Syllabus

- **Part 1: Artificial Neural Networks (5 weeks)**
  - Introduction to the computational model of a neuron.
    - Models of Learning: Hebian, Boltzman, supervised, unsupervised, and reinforcement learning.
  - Learning in the Perceptron and its limitations.
  - Backpropagation in the Multilayer Perceptron.
  - Cross validation, generalisation, over-fitting, and analysis of the output. Hopfield networks.
  - Deep learning paradigms such as Convolutional Neural Networks, Long Short Term Memory, and Recurrent Neural Networks.
  - Concepts such as Dropout and Batch Normalisation will be introduced.

2. Syllabus

- **Part 2 Reinforcement Learning Basics(4 weeks)**
  - Markov Decision Processes
  - State and Action Value Policies.
  - Reinforcement Learning (RL) paradigms such as Dynamic Programming (DP), Monte Carlo (MC), and Temporal Difference Methods such as Q Learning.
  - Deep RL: DQN.

- **Part 3 Advanced Topics in RL (3 weeks)**
  - Policy Gradient Methods
  - Monte Carlo Tress Search

Know your history

A look a Symbolic AI

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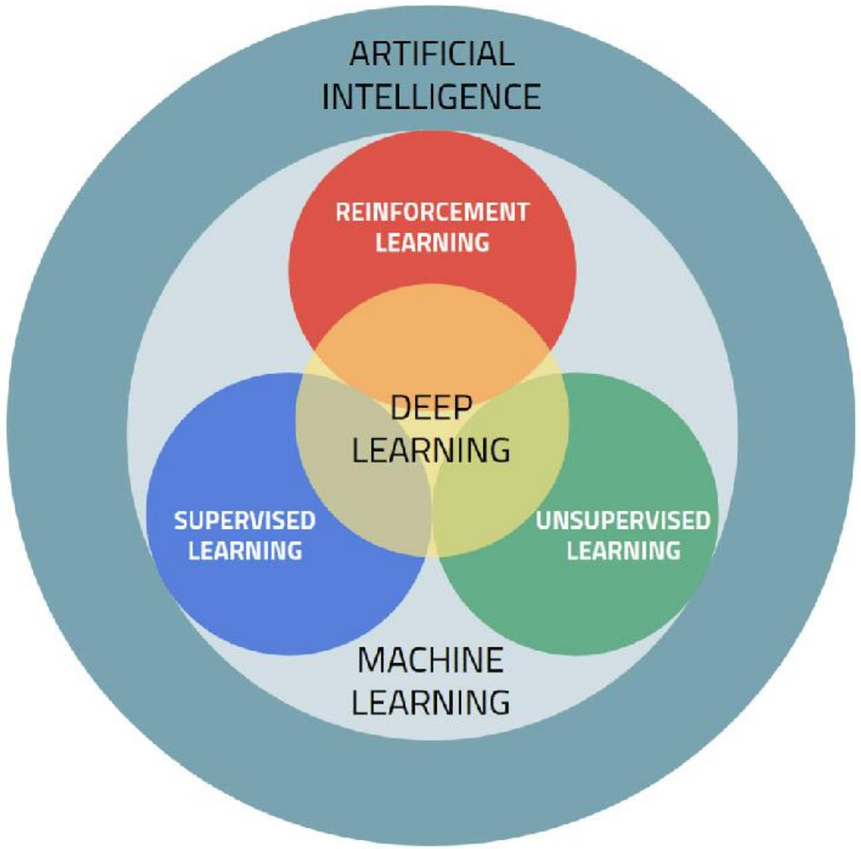
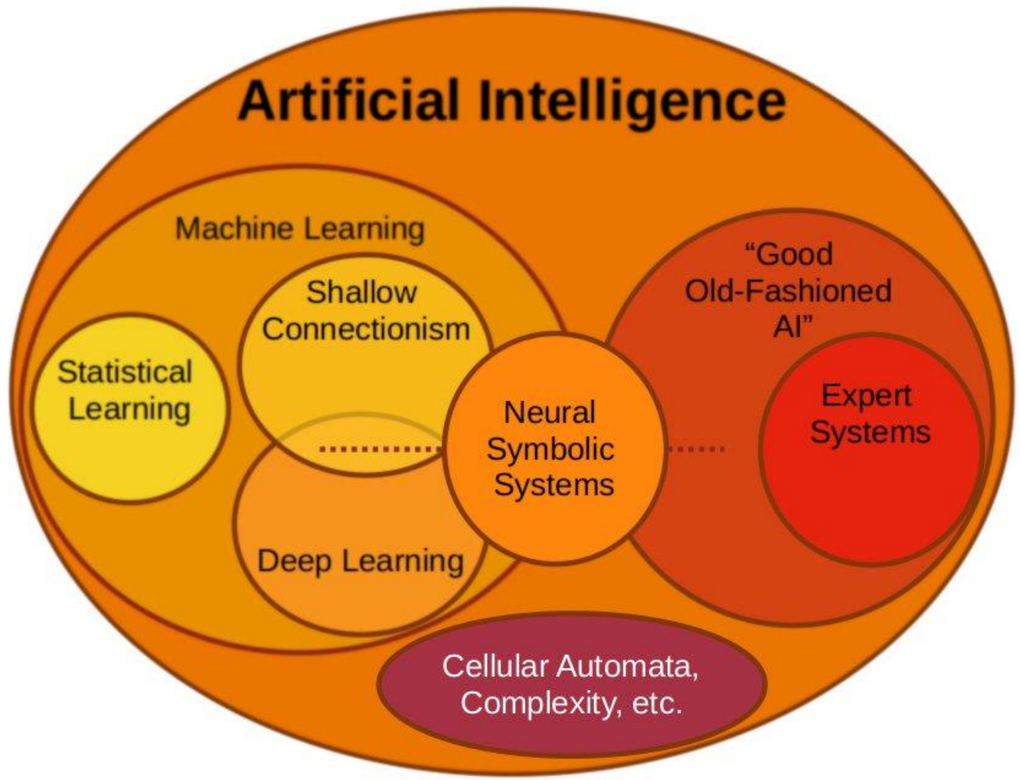
Two of Many Maps of the Discipline



www.researchgate.net/publication/357234810_Artificial_intelligence_machine_learning_for_chemical_sciences



www.exxactcorp.com/blog/Deep-Learning/difference-between-ai-machine-learning-and-deep-learning

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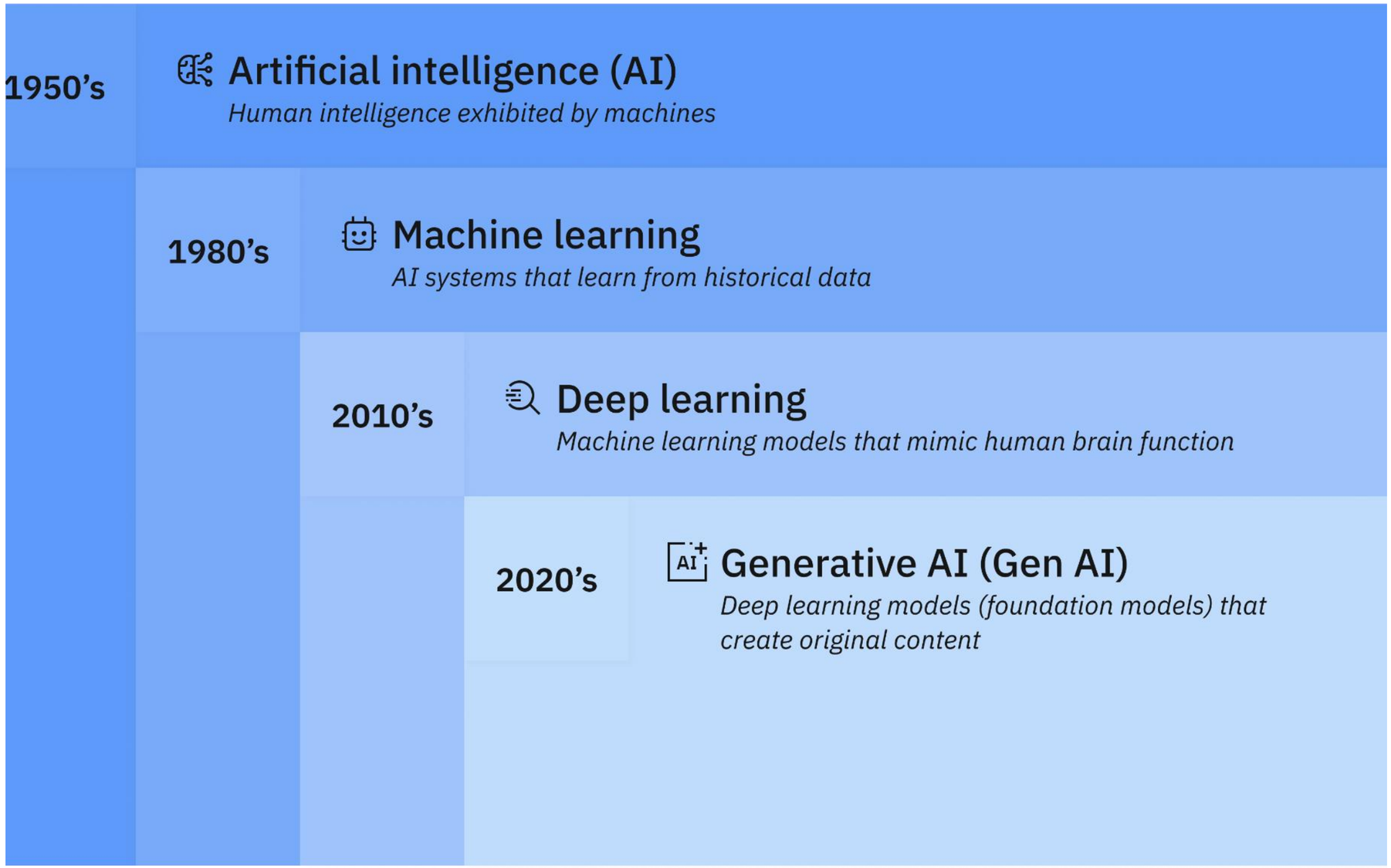

https://www.ibm.com/topics/artificial-intelligence

History of Artificial Intelligence

1956: The Dartmouth Conference, organized by John McCarthy, Marvin Minsky, Nathaniel Rochester, and Claude Shannon, is often considered the birth of AI.

1950s: Symbolic AI emerged in the 1950s with pioneers like **Allen Newell** and **Herbert A. Simon**

They developed the **Logic Theorist**, the first AI program, which could prove mathematical theorems using symbolic manipulation

Symbolic AI, also known as "good old-fashioned AI" (GOFAI), is an approach to artificial intelligence that relies on explicit rules and symbols to represent knowledge and perform reasoning.

It was one of the earliest paradigms in AI research and dominated the field from the 1950s through the 1980s.

Success

- **1960s: Researchers focused on developing systems that could perform tasks like theorem proving, language understanding, and problem-solving. Notable programs included the General Problem Solver (GPS) and SHRDLU**

- **1970s: The field saw significant advancements with the development of expert systems, which aimed to capture human expertise in specific domains**

Characteristics of Symbolic AI

Symbol Manipulation: Symbolic AI operates by manipulating symbols that represent objects, actions, and relationships in the world. These symbols are explicitly defined and manipulated according to a set of rules.

Rule-Based Systems: It uses predefined rules, often in the form of logical statements, to infer new information, make decisions, and solve problems. Expert systems are a prime example, where domain-specific knowledge is encoded in the form of "if-then" rules.

Logic and Reasoning: Symbolic AI heavily relies on formal logic and reasoning. Techniques like propositional logic, predicate logic, and first-order logic are used to represent and process knowledge.

Explicit Knowledge Representation: Knowledge is represented explicitly in structured forms such as semantic networks, frames, and ontologies. This makes it easy to understand and modify the knowledge base.

Based on theories from cognitive science, logic, etc.

Symbolic AI: Examples

- **Expert Systems: These systems use a vast set of rules to mimic the decision-making abilities of a human expert in a specific domain. For example, MYCIN - diagnosing bacterial infections.**
- **Natural Language Processing: Early NLP systems like ELIZA (the Rogerian psychotherapist simulator) used pattern matching and symbolic rules to simulate conversations.**
- **Theorem Proving: Programs like the** Logic Theorist **and Prolog-based systems were designed to prove mathematical theorems using logical reasoning.**

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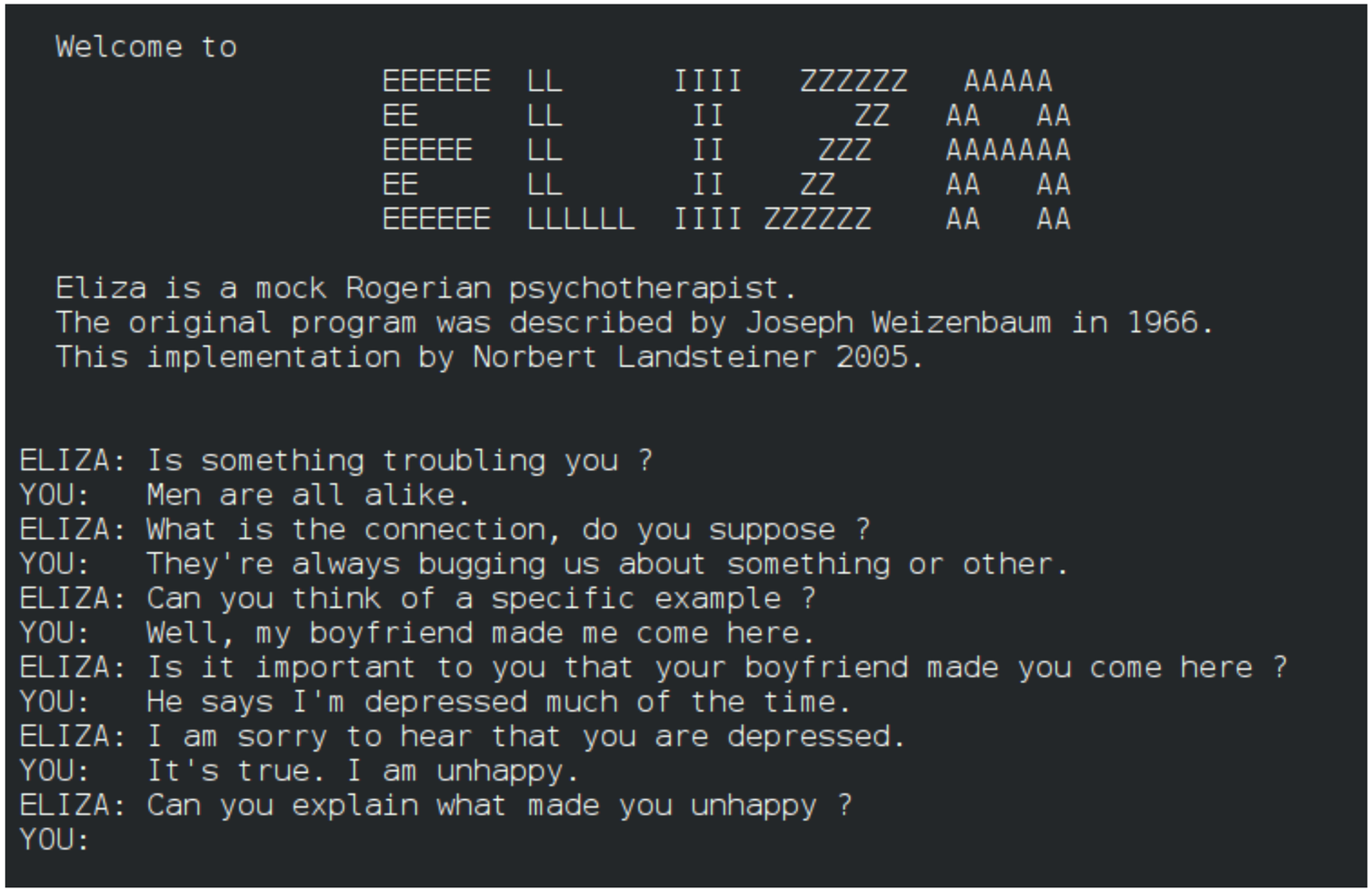
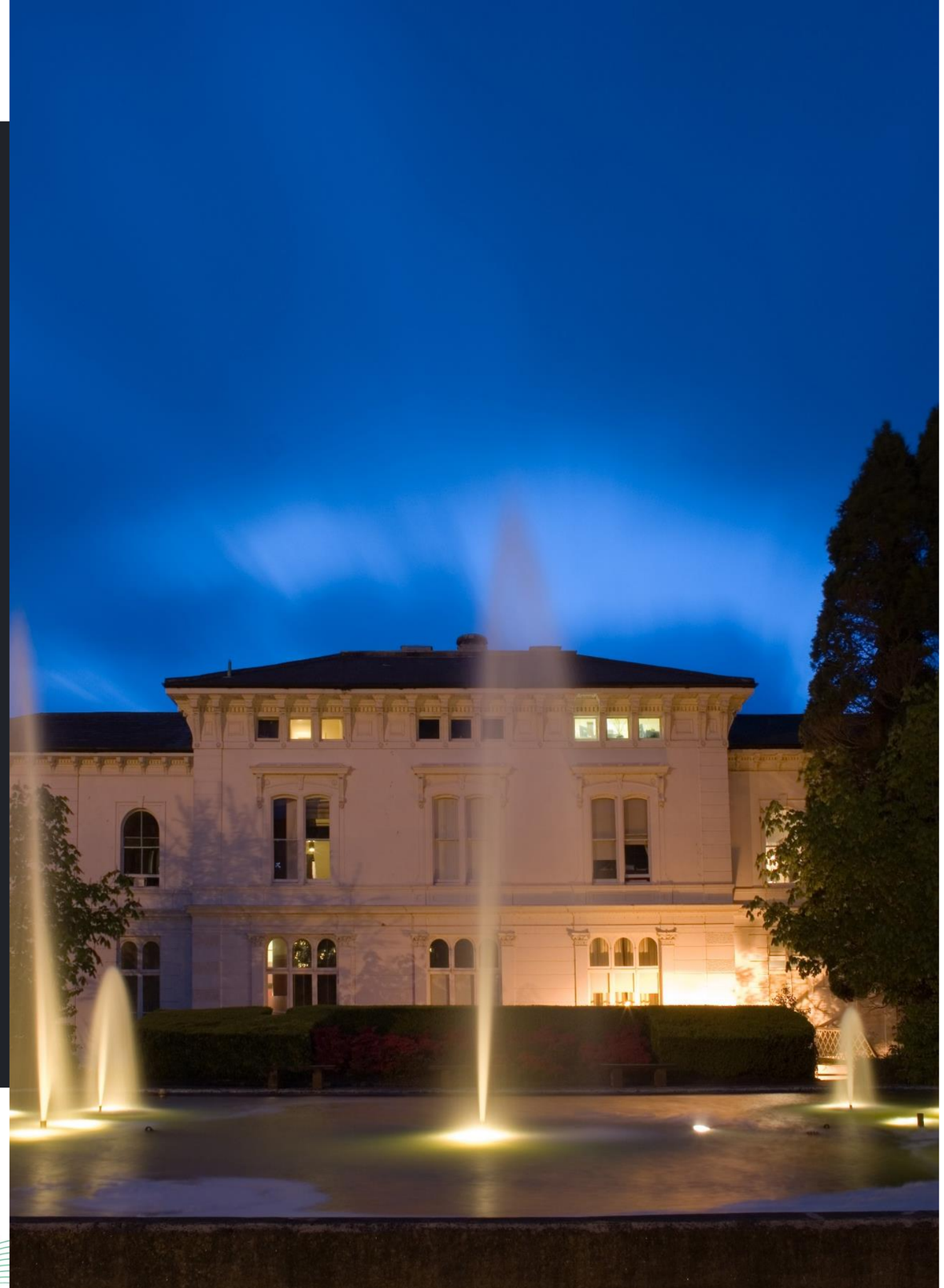
ELIZA



- By Unknown author - File:ELIZA conversation.jpg, Public Domain, https://commons.wikimedia.org/w/index.php?curid=99305439

Symbolic AI / ELIZA

- Eliza was an early natural language processing program developed by Joseph Weizenbaum between 1964 and 1967 at MIT
- Pattern Matching: Eliza used a pattern matching and substitution. It processed user inputs by matching them against predefined patterns and then substituted parts of the input to generate response
- **Scripts**: The program's language capabilities were provided by "scripts" written in a Lisp-like representation. These scripts contained the rules and patterns for generating responses.
- **DOCTOR Script**: The most famous script, DOCTOR, simulated a Rogerian psychotherapist. It used non-directional questions to reflect the user's statements back to them, creating the illusion of understanding
- Eliza is an example of symbolic AI.
- Symbolic AI relies on manipulating symbols and using explicit rules to represent knowledge and perform reasoning. Eliza used symbolic representations and pattern matching rules to simulate conversation with users.
- Eliza used a script-based approach where predefined patterns in the user's input were matched and transformed into responses based on these symbolic rules.
- This approach exemplifies the core principles of symbolic AI, which focus on explicit, rule-based processing rather than learning from data or statistical methods.

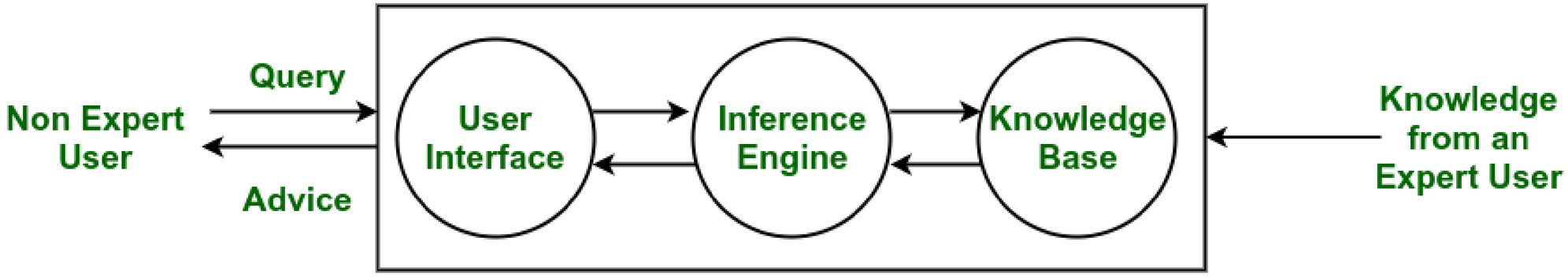


MYCIN

IF
- The site of the culture is blood
- The gram stain of the organism is negative
- The morphology of the organism is rod
- The patient has a serious burn

THEN
- ➢ There is suggestive evidence (0.4) that the identity of the organism is Pseudomonas

Expert Systems: classic symbolic reasoning

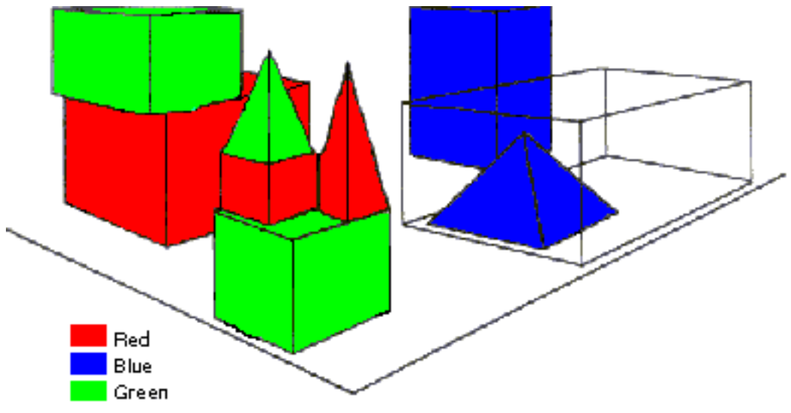


It process knowledge expressed in the form of rules and use symbolic reasoning in narrow domain.

- https://www.geeksforgeeks.org/what-are-the-different-components-of-an-expert-system/

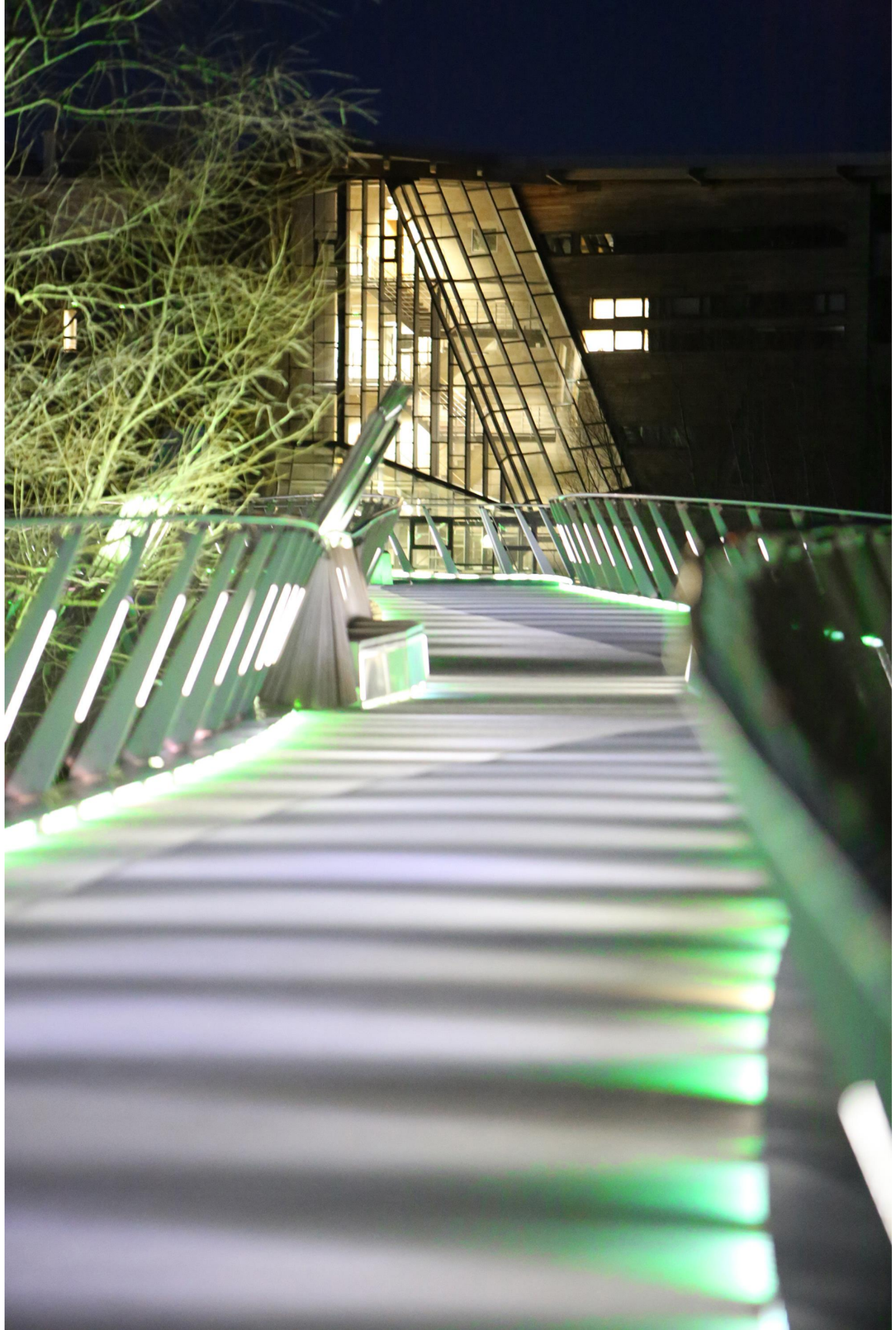
```
Rule from MYCIN Expert System
IF  the stain of the organism is gram-positive
AND the morphology of the organism is coccus
AND the growth conformation of the organism is clumps
THEN (0.7) the identity of the organism is staphyloccus.

Inference Engine used Backward Chaining from logic.

Does not learn with experience.
```

Terry Winograd: SHRDLU the Robot



(On the screen, the robot arm swings into action. Two red blocks are visible, one small, one large, as on figure above. The large one has a green cube stacked on top of it. The robot first transfers the green cube to the table top, and then picks up the red block.)

- **SHRDLU** is an early NLP program that was developed by Terry Winograd at MIT 1968-1970.
- Perception performed by the end user – inputs relative location of “blocks”
- It could perform only three actions: MOVETO a location, GRASP block, and UNGRASP the block currently in the hand.
- Thus SHRDLU, which accepted high-level commands, such as `put a red block on the green block', had to discover sequences of basic actions that would achieve its goals.
- It did this with a `Planner' program.
- Using a technique called backward chaining.



The Physical Symbol System Hypothesis (PSSH)

Proposed by **Allen Newell and Herbert A. Simon** in 1976.

It is a fundamental idea in **artificial intelligence (AI) and cognitive science**, suggesting that a **physical symbol system** is both **necessary and sufficient** for general intelligence.

The Physical Symbol System Hypothesis (PSSH)

A physical symbol system is a system that:

- **Creates, stores, manipulates, and interprets symbols.**
- **Uses rules and operations to transform symbols into new symbols.**
- **Operates in a physical medium (e.g., a computer or the human brain).**

The Physical Symbol System Hypothesis (PSSH)

Necessity and Sufficiency

•Necessity: Any system capable of general intelligence must be a physical symbol system.

•Sufficiency: A properly programmed physical symbol system can exhibit general intelligence.

The Physical Symbol System Hypothesis (PSSH)

Symbols and Symbol Manipulation

•Symbols represent objects, concepts, or ideas.

•Symbol structures are collections of symbols arranged in meaningful ways (e.g., sentences, equations).

•Symbol processing allows reasoning, learning, and problem-solving.

Know your history

Critiquing Symbolic AI

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3. History: Sense Plan Act (SPA) Cycle

Brooks, R. A., "Intelligence Without Representation", Artificial Intelligence Journal (47), 1991, pp. 139–159.

- Cartesian / Traditional / Old Artificial Intelligence based on SPA

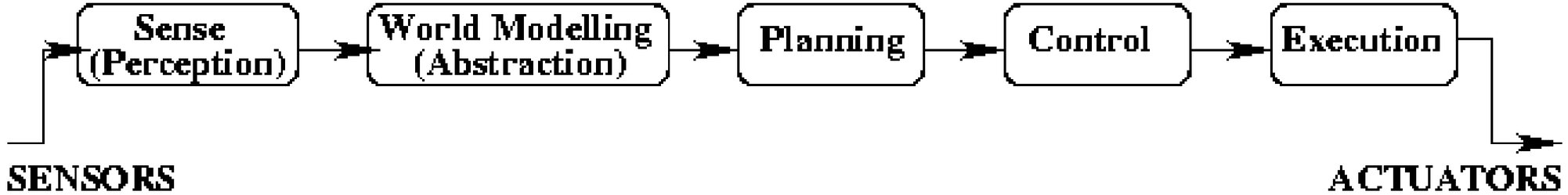

Fig: sense plan act (SPA) cycle – sequential processing.

- Rodney Brooks formerly of MIT has many problems with this

History: Sense Plan Act (SPA) Cycle

- Assume that humans are existence proof of intelligence (????).
  - Human level intelligence is not yet well understood.
- Robotics in the early days trying to emulate human intelligence using SPA.
  - Widespread failure.
  - Why?
- Brook's conclusion:
  - Explicit representations (symbols) and models of the world inhibit progress.
    - Symbolic AI
- Hypothesis: representation is the wrong unit of abstraction in building the bulkiest part of intelligent systems.

Situatedness and Embodiment

Single cell entities - 3.5 billion years ago.

Primates - 120 million years back.

Predecessors to great apes - 18 million years.

Man - 3.5 millions years.

Agriculture - 10,000 years old.

Writing - less than 5000 years ago.

Suggests that reasoning, expert behaviour, etc. are all pretty simple once the essence of being is available.

Challenge is To Be

The ability to live in a dynamic environment.

Hypothesis: Mobility, acute vision, and the ability to carry out survival related tasks are the key to the construction of intelligent machines.

History: Sense Plan Act (SPA) Cycle

- Abstraction is good science.
- However, when applied to AI, inspires self-delusion.
- In Old AI, abstraction used to factor out motor skills and perception.
- These are the difficult tasks performed by biologically based intelligent systems.
- Example of Old AI: Winograd's Blocks world program.
  - All abstraction done by programmer i.e. state of the world specified as a set of facts (symbols).
  - Assumes that models used by programs are human-oriented.
  - Research indicates that perception is learned and a key aspect of intelligence.

3. History: Subsumption

- Control architecture for autonomous intelligent mobile robot platforms.

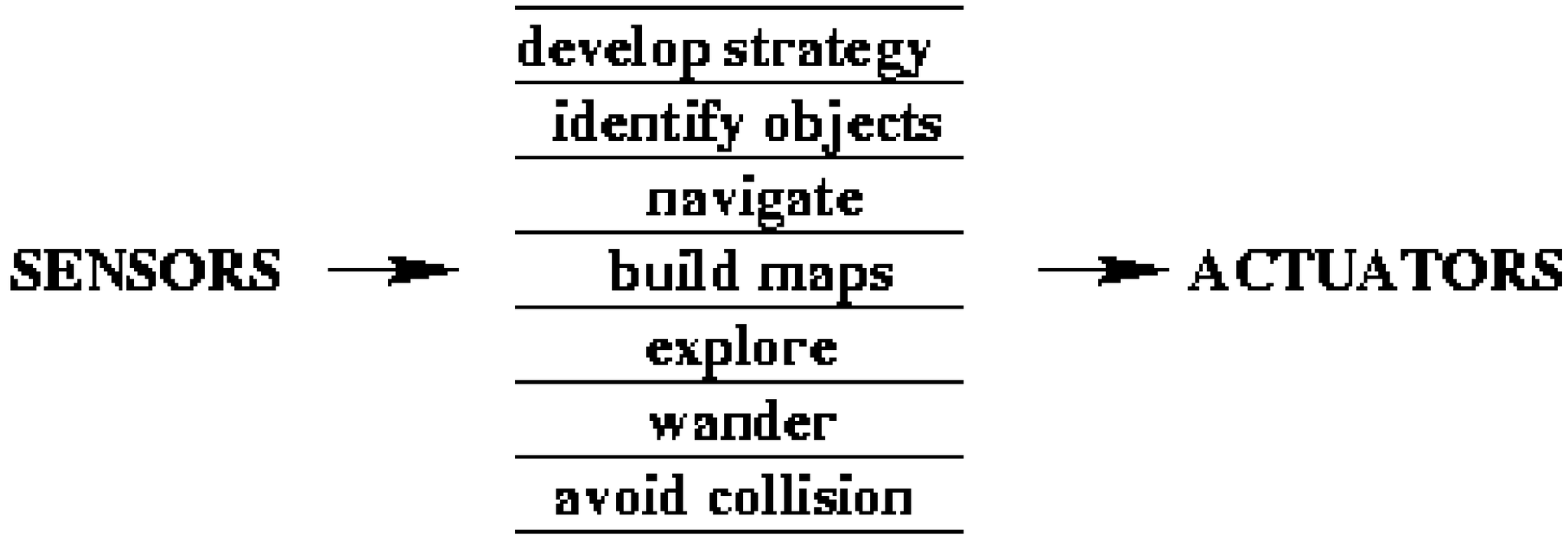

Fig: Brook's subsumption architecture using concurrent processing.

History: Subsumption

- Decomposition into parallel activities.
- Build incremental intelligence.
- No central representation with reduced emphasis on symbolism.
- Tight integration of sensory-motor loop.
- The world is the model - situatedness and embodiment.

Know your history

AI Winters

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1st AI Winters

Mid 70s - 1980s: The first AI Winter occurred due to unmet expectations and reduced funding.

The Lighthill Report (1973) UK criticized AI research, stating that AI systems were impractical for real-world use. Governments, including the US and UK, cut funding for AI research.

Symbolic AI systems could not scale. Symbolic systems were limited by computational power and knowledge representation issues.

2nd AI Winters

1987-1993: AI's second decline was due to failure of Expert Systems and Market Collapse. However, expert systems:

- **Were expensive to maintain.**
- **Couldn't handle uncertainty or adapt to new situations.**
- **Required manual updates and extensive rule creation.**
- **The Japanese Fifth Generation Computer Systems (FGCS) project failed to meet expectations.**

3rd AI Winters

1998-2010: AI's third decline was due to the slow progress of machine learning techniques like early neural networks and support vector machines. Neural networks suffered from:

1. **Lack of data: AI models required massive datasets.**
2. **Lack of computational power: had to use expensive HPC infrastructure.**
3. **Lack of funding: AI applications struggled to deliver commercial success, making investors hesitant.**

Know your history

Is GOFAI dead?

Novel uses of Symbolic AI

Enhancing Reasoning and Explainability:

•**Neuro-symbolic AI:** This field combines the strengths of neural networks (like LLMs) with symbolic reasoning. LLMs can be used to generate or extract symbolic representations of knowledge, which can then be used for logical reasoning and inference. This can improve the reasoning abilities of LLMs and make their decisions more explainable.

•**Knowledge Graphs:** Symbolic AI techniques can be used to create knowledge graphs, which represent relationships between concepts and entities. These knowledge graphs can be integrated with LLMs to provide them with structured knowledge and improve their understanding of the world.

Novel uses of Symbolic AI

Addressing Limitations of LLMs:

•**Hallucinations:** LLMs can sometimes generate incorrect outputs known as hallucinations. Symbolic AI can help mitigate this by providing constraints and rules that LLMs must adhere to, ensuring that their outputs are consistent with logical reasoning and factual knowledge.

•**Bias:** LLMs can inherit biases from their training data. Symbolic AI can help identify and mitigate these biases by providing a framework for explicitly representing and reasoning about ethical considerations and fairness.

Novel uses of Symbolic AI

Amazon AWS posted “Prevent Factual Errors From LLM Hallucinations With Mathematically Sound Automated Reasoning Checks (Preview)” by Antje Barth, AWS Amazon blog, December 3, 2024.

Know your history

Shallow Connectionism

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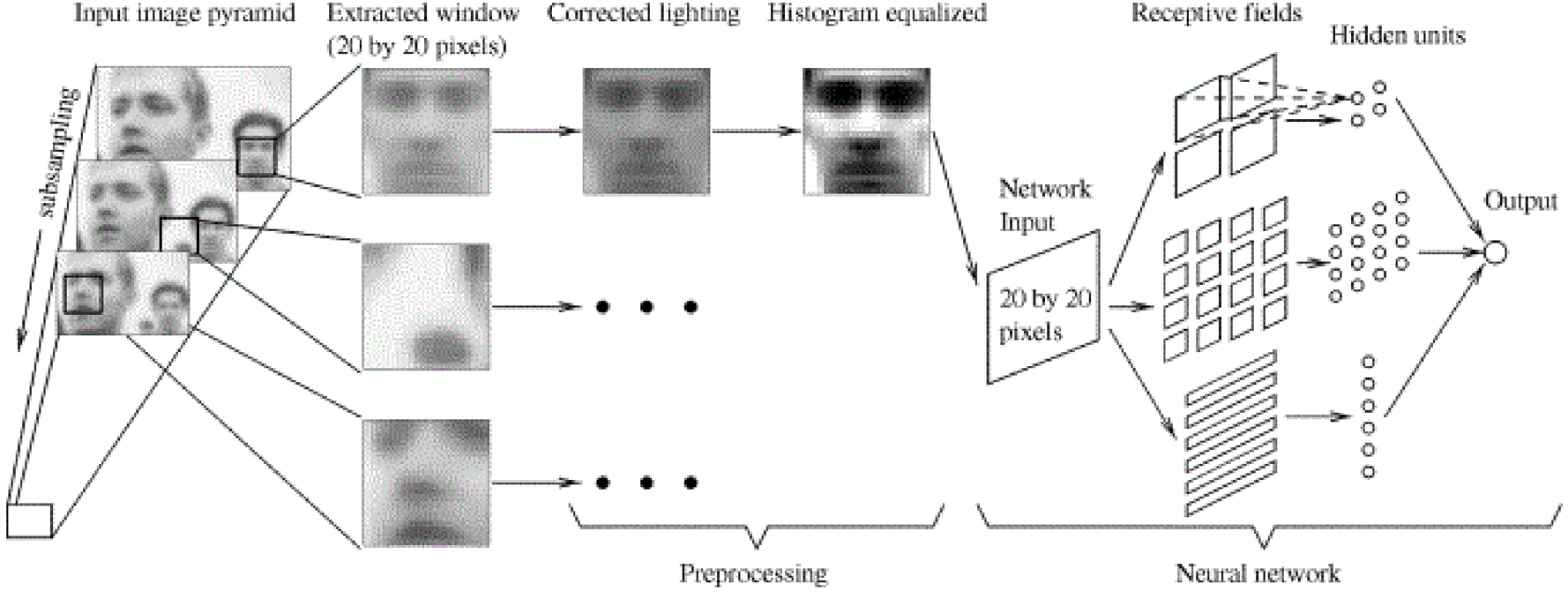
3. History: Computer Vision

- H. Rowley, S. Baluja, and T. Kanade. Neural Network Based Face Detection. IEEE Trans on Pattern Analysis and Machine Intelligence (PAMI), 20(1):23-38, January 1998.



3. History: Autonomous Vehicles

D. Pomerlau. ALVINN: An Autonomous Land Vehicle in a Neural Network, NIPS Letters, 1989.

[Courtesy of Dean Pomerleau]

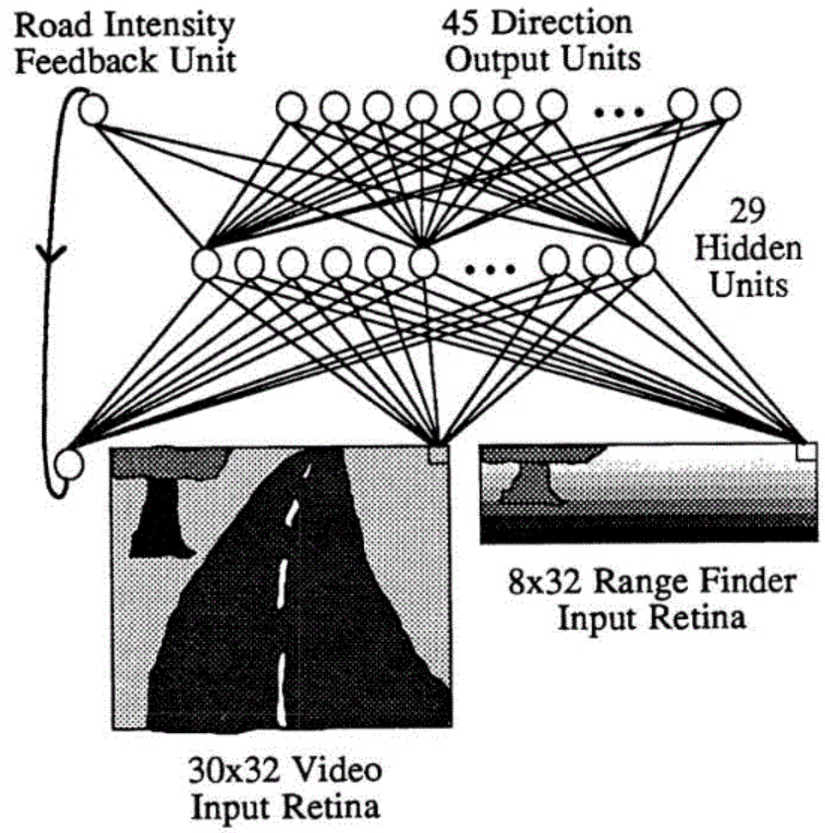


Figure 1: ALVINN Architecture

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Exercises

- ❑ What is intelligence?
- ❑ Distinguish AI from Machine Learning.
- ❑ What is PSSH.
- ❑ Briefly describe ELIZA, SHDRLU, MYCIN, OR Logic Theorist.
- ❑ Critique Symbolic AI

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Exercises

- Explain the use of receptive fields in Rowley's neural architecture for face detection (1997)?
- Critique Rowley et al. Face detector
- Critique Pomerlau's ALVINN
- What caused the third AI winter?

Thank you

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