

AN OVERVIEW OF AI, CYBERNETICS, & DYNAMIC SYSTEMS

Systems Sciences Foundations

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Outline

Kerox ↓

- 1 Basic Concepts of Artificial Intelligence
- 2 Basic Concepts of Cybernetics
- 3 Introduction to Dynamic Systems



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AI: Definitions and Main Goals

- **Artificial Intelligence (AI):** *Science and engineering* of making intelligent machines capable of performing tasks that normally require human intelligence.

- **Main Goals:**

- Automate reasoning and knowledge representation.
- Enable learning, perception, and adaptation.
- Achieve problem-solving in complex domains.

- **Scope:**

- Broad field spanning subtopics like machine learning, robotics, and cognitive modeling.



Maths
Biology
Physics

electronic
mechanic
materials



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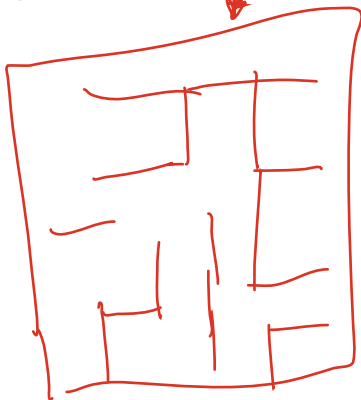
905 → Psyc. → Comp
Comp → Psyc.



AI Types and Learning Paradigms I

Symbolic vs. Subsymbolic AI:

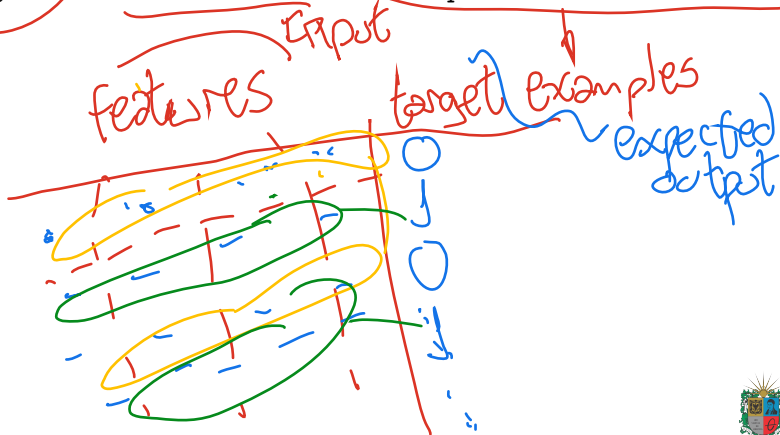
- *Symbolic (GOFAI):* Knowledge-based systems with logical rules.
- *Subsymbolic:* Neural networks that learn patterns from data.



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AI Types and Learning Paradigms II

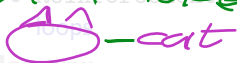
Machine Learning Types:

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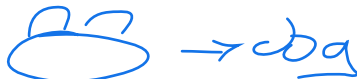
- Unsupervised: Discovering patterns or structures in unlabeled data.

data label (target)

cat



dog



AI Types and Learning Paradigms II

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- Supervised: **Mapping** inputs to outputs using **labeled data**.
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- **Glossary:**

- *Deep Learning, Decision Tree, Overfitting.*



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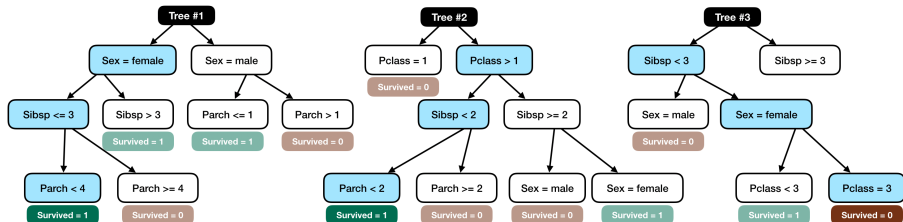
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Case Study: Titanic in Kaggle

Did the passenger survive?

PassengerId	Pclass	Name	Sex	Age	SibSp	Parch	Ticket	Fare	Cabin	Embarked
893	3	Wilkes, Mrs. James (Ellen Needs)	female	47	1	0	363272	7		S



Tree #1 votes Survived = 1

Tree #2 votes Survived = 1

Tree #3 votes Survived = 0



Random forest predicts Survived = 1



Psychological Foundations of AI

- **Human Cognition and Behavior:**

- Inspired AI research in learning, perception, and problem solving.

- **Learning Theories:**

- *Behaviorism:* Learning as conditioning.
- *Constructivism:* Building mental models through experience.

- **Implications for AI:**

- How Cognitive Architectures Simulate Attention, Learning, and Problem Solving
- Detect and Model Cognitive States in the Systems



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- Expert systems capture human knowledge into machine systems.



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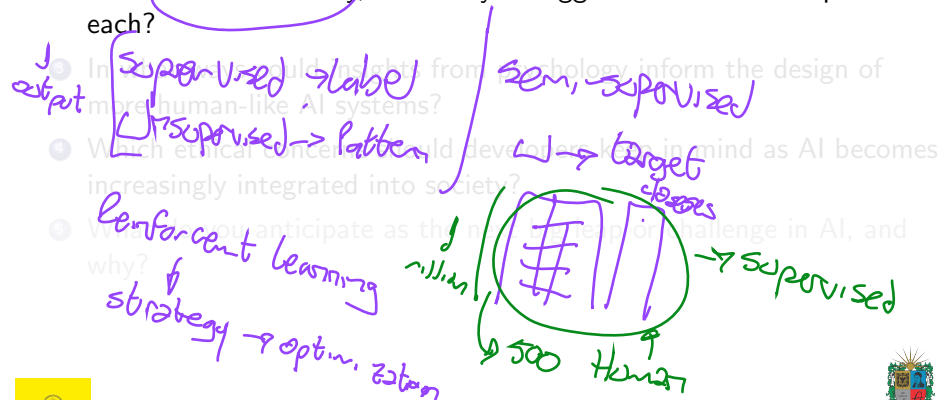
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- 1 What key differences separate symbolic (GOFAI) from subsymbolic (neural networks) approaches, and when might each be more suitable?
- 2 How do supervised, unsupervised, and reinforcement learning each handle data differently, and can you suggest real-world examples for each?
- 3 In what ways could insights from psychology inform the design of more human-like AI systems?
- 4 Which ethical concerns should developers keep in mind as AI becomes increasingly integrated into society?
- 5 What do you anticipate as the next big leap or challenge in AI, and why?



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- Handwritten notes and arrows:
- Control + feedback (with arrow pointing to question 3)
 - Cognitive/Tricks (with arrow pointing to question 3)
 - learning Paradigms (with arrow pointing to question 2)
 - neuro? (with arrow pointing to question 3)
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- Data exposure
- Privacy

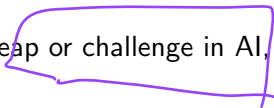
→ Deep voice / deep fake / Mrs. Information



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+ papers → 2017 → 2021
 + robots → hardware



Did you know?

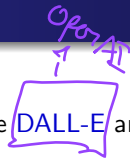
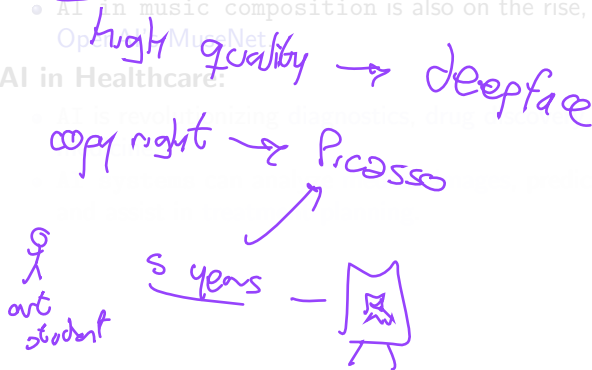
● AI in Art:

- AI-generated art is gaining popularity, with tools like **DALL-E** and **Midjourney**.

- AI in music composition is also on the rise, with systems like OpenAI's MuseNet.

● AI in Healthcare:

- AI is revolutionizing diagnostics, drug discovery, and personalized medicine.



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synt.

musicians



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- AI systems can analyze medical images, predict patient outcomes, and assist in treatment planning.

Images + data

patient → E2S6/d



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Google Healthcare → source
AWS medical AI



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Cybernetics: Definitions and History

- **Cybernetics:** Study of **communication** and **control** in living beings and machines.
- **Norbert Wiener (1948):** Formalized the term, focusing on **feedback systems**.
- **Applications:**
 - Robotics, AI, management science, social systems analysis.



Control Mechanisms in Cybernetics

- **Feedback Loops:** *Adjust* system behavior based on comparing outputs to goals.
- **Types of Control:**
 - Open-loop: No output-based feedback (*simple, less adaptive*).
 - Closed-loop: Uses sensors or feedback signals (*PID control, fuzzy logic*).
- **Homeostasis:**
 - Maintaining equilibrium with the environment (e.g., temperature regulation).



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Study Case: Thermostat System



Relation with AI

- **Cybernetics + AI:**

- Early *AI research* leveraged cybernetic principles of **feedback** and **adaptation**.
- **Reinforcement Learning** is a prime example of a **feedback-driven method**.

- **Self-Regulatory Systems:**

- *Agents continuously update their states based on environmental feedback.*
- *Examples: Autonomous robots, adaptive software agents.*

- **Interdisciplinary Insights:**

- *Combining AI and cybernetics fosters novel insights, models, and innovative problem solutions.*



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- Artists use **cybernetic principles** to create **interactive installations**.
- Examples include **responsive sculptures** and **generative art**.

- **Cybernetics in Nature:**

- Natural systems exhibit cybernetic principles, like *feedback loops in ecosystems*.
- Understanding these systems can inform *sustainable practices*.



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Definitions and System Characteristics

- **Dynamic System:**

- **System** whose state **evolves** over time based on inputs, initial conditions, and internal feedback.

- **Inputs vs. Outputs:**

- **Inputs:** Exogenous factors driving system change.
- **Outputs:** Responses or changes in the observable state.

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- Many dynamic systems contain complex interdependencies that are non-linear.



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Chaos Theory and Sensitivity

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- Studies how **small variations** in **initial conditions** can *lead* to large differences in **outcomes**.
- Butterfly Effect exemplifies **extreme sensitivity**.

- **Implications:**

- Long-term predictions become *difficult* in chaotic regimes.
- Planning requires robust control methods to handle uncertain or volatile behaviors.



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Dynamic Systems Analysis and Design

- **Modeling Approaches:**

- Ordinary Differential Equations (ODEs), agent-based models, simulation.

- **Stability and Equilibria:**

- Fixed points, limit cycles, chaotic attractors.
- Understanding stable vs. unstable dynamics.

- **Problem-Solving Approaches:**

- Control system identification and model-based control design.
- Adaptive control and reinforcement learning.
- Nonlinear control techniques for autonomous systems and robotics.



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Case Study: Lotka—Volterra model



Case Study: SIR model



Case Study: Bank — Event-Based Simulation



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- **Dynamic Systems in Nature:**

- *Ecosystems, weather patterns, and population dynamics* are all examples of **dynamic systems**.
- Understanding these systems can help us **predict** and **manage** environmental changes.

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- *Robotics, control systems, and networked systems* are all examples of **dynamic systems**.
- *Advances in these fields are driving innovation in AI and cybernetics.*



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Conclusion

- **Systems Sciences Foundations** merges AI, cybernetics, and dynamic systems.
- Provides **frameworks** for modeling, understanding, and controlling complex behaviors.
- **Preparatory step** for deeper explorations: advanced ML, multi-agent cybernetic architectures, and real-world system simulations.



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Thanks!

Questions?



Repo: <https://github.com/EngAndres/ud-public/tree/main/courses/systems-sciences-foundations>

