

AN OVERVIEW OF AI, CYBERNETICS, & DYNAMIC SYSTEMS

Systems Sciences Foundations

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Outline

Kero x ↓

- 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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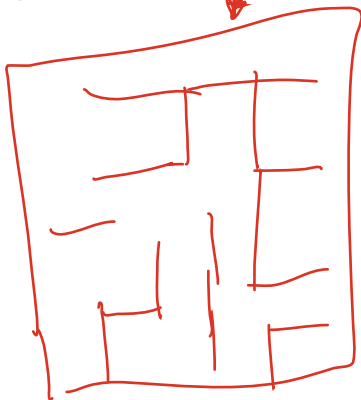
905 → Psyc. → Comp
Comp → Psyc.



AI Types and Learning Paradigms I

Symbolic vs. Subsymbolic AI:

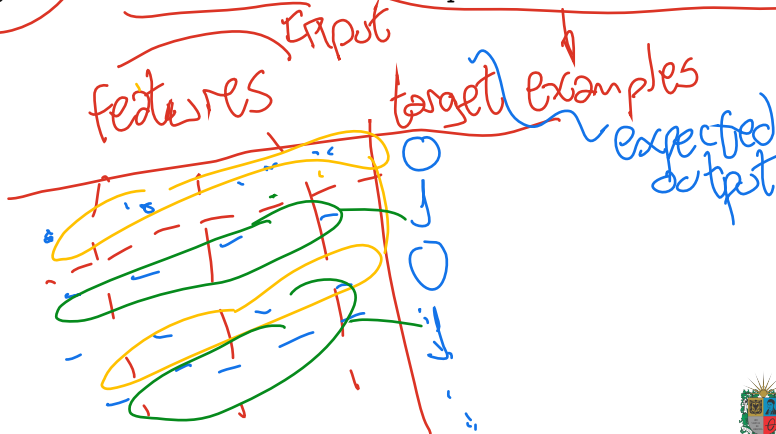
- **Symbolic (GOFAI):** Knowledge-based systems with logical rules.
- *Subsymbolic:* Neural networks that learn patterns from data.



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AI Types and Learning Paradigms II

Machine Learning Types:

- Supervised: Mapping inputs to outputs using labeled data.

- Unsupervised: Discovering patterns or structures in unlabeled data.

data label (target)

cat

cat - cat - cat

dog - dog - cat

dog

cat - cat - cat

dog - dog - cat

cat → cat

dog → dog

cat 70.7
dog 29.3



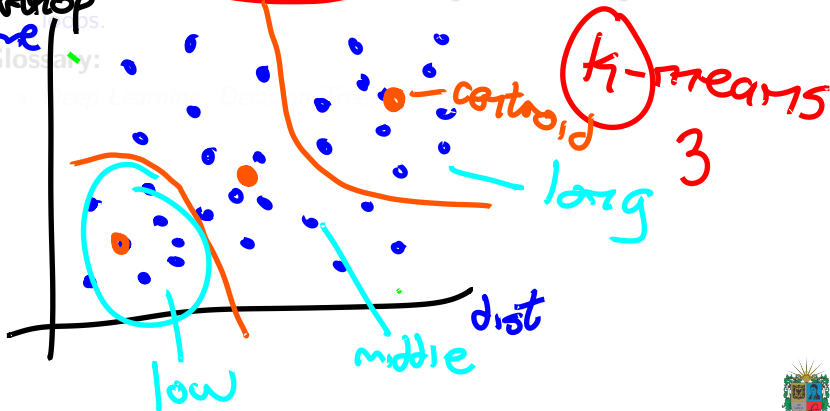
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Smartshop
line

Glossary:



AI Types and Learning Paradigms II

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- Supervised: **Mapping** inputs to outputs using **labeled** data.
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- Reinforcement Learning: Learning **actions** through reward feedback loops.



• Glossary:



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Glossary:

- Deep Learning, Decision Tree, Overfitting

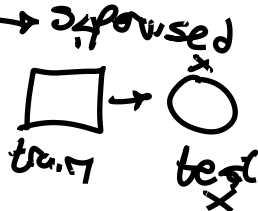
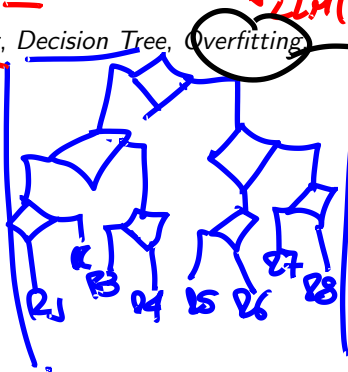
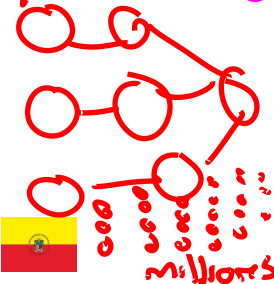
deep

AI - Machine = Deep Learning

LLM (GenAI)

Partial
m = derivative

$$f(x) = ax + b$$

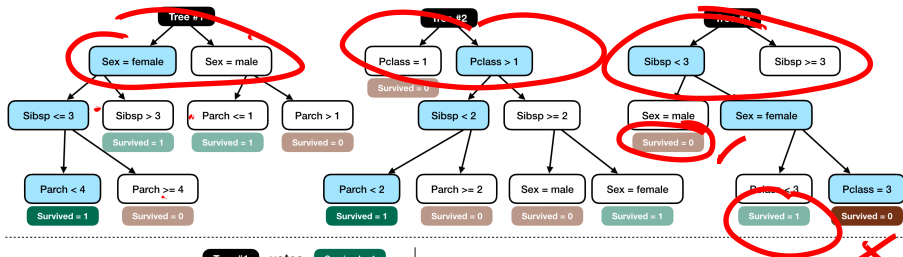


Case Study: Titanic in Kaggle

XGBoost *Gradient (Derivate)*

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:

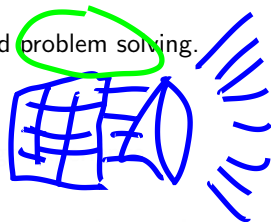
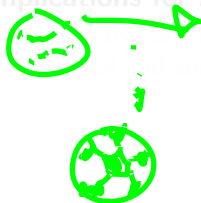
- Inspired AI research in learning, perception, and problem solving.

90's → Pro + Psy

Learning Theories:

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

• Implications for AI:



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• Implications for AI:

M1 → rate punish OS ✓

M2 → OS ✓

learn to avoid bad actions

Punish



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- **Learning Theories:**

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

- **Implications for AI:**

- Cognitive architectures simulate attention, learning, and reasoning
- Ethical and social implications of intelligent machines

Context (Feedback Cybernetics)



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- Cognitive architectures simulate attention, memory, and reasoning.
- Ethical and social concerns about AI-like systems.

Transformers → word → ^{map} remembered

Léonard salto on la cama.



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Discussion

- 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?

1000s, no rules

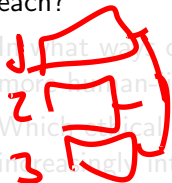
knowledge
↓
rules

data
↑ volume
- unbalanced

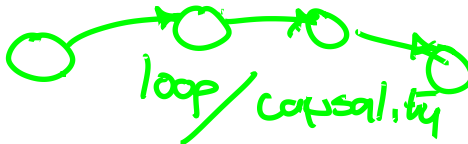
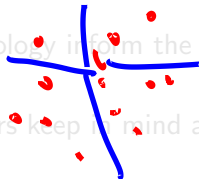


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compa
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- **AI in Art:**

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



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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 internal stability despite external changes (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 solutions, algorithms, and innovative system architectures.*



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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.
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- **Non-linearity:**

- 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:**

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- 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 machine learning for autonomous systems.
- Nonlinear control techniques for complex systems.



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Case Study: Lotka—Volterra model



Case Study: SIR model



Case Study: Bank — Event-Based Simulation



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- 2 Can you provide examples of real-world systems that exhibit chaotic behavior?
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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.

- **Dynamic Systems in Technology:**

- *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>



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FRANCISCO JOSÉ DE CALDAS