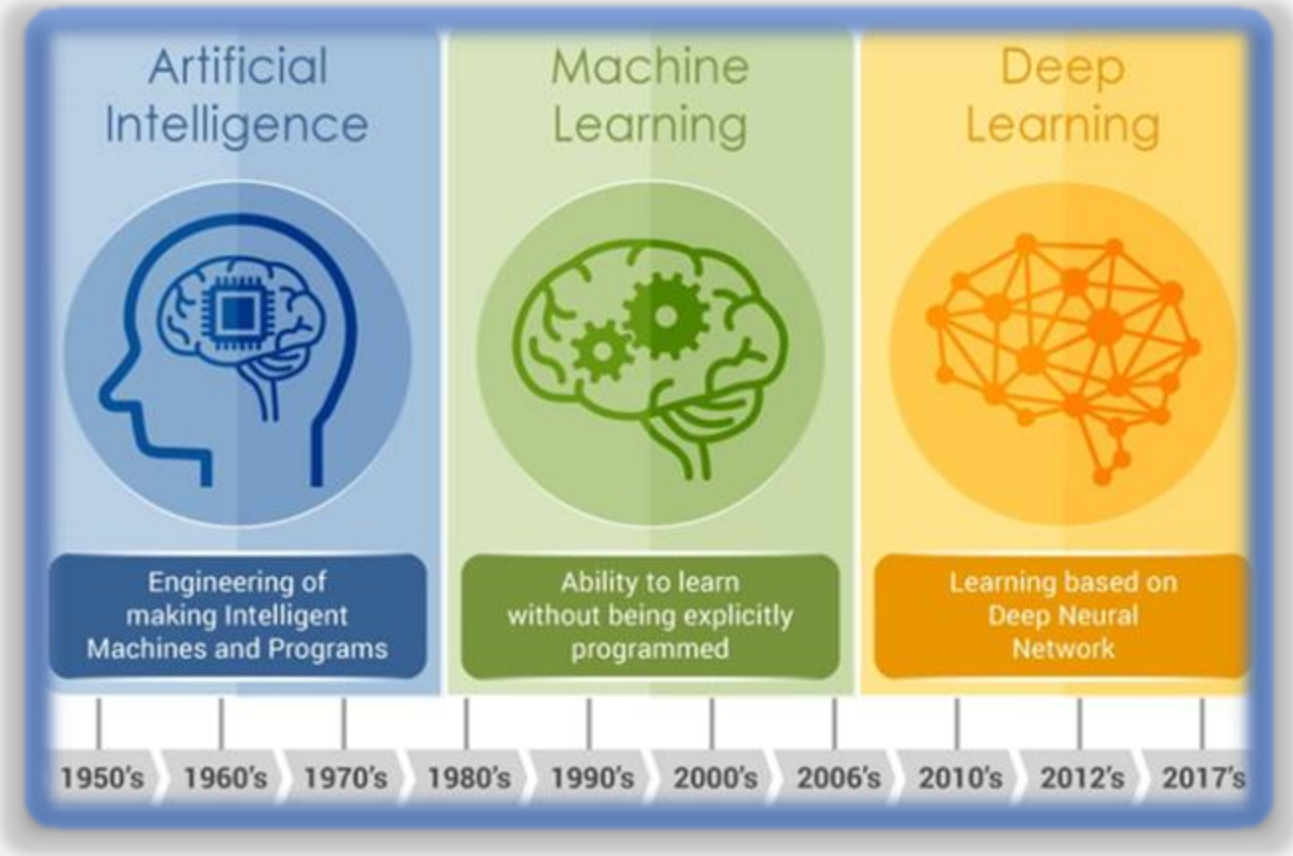
CENG 3511 Artificial Intelligence

Week 1

Introduction to Artificial Intelligence



Instructor
Bekir Taner Dinçer

Teaching Assistant
Selahattin Aksoy

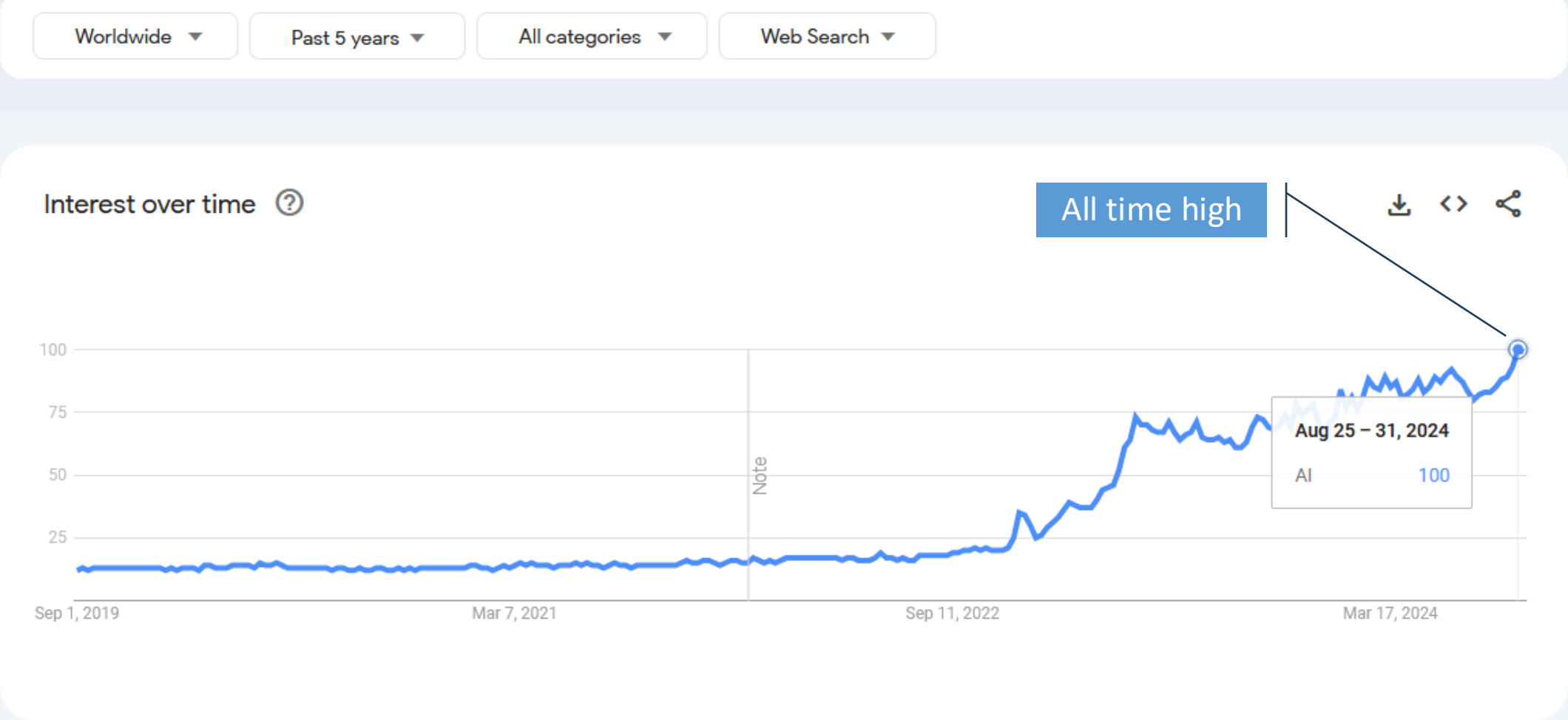
MUĞLA SITKI KOÇMAN UNIVERSITY
COMPUTER ENGINEERING

2024 – FALL

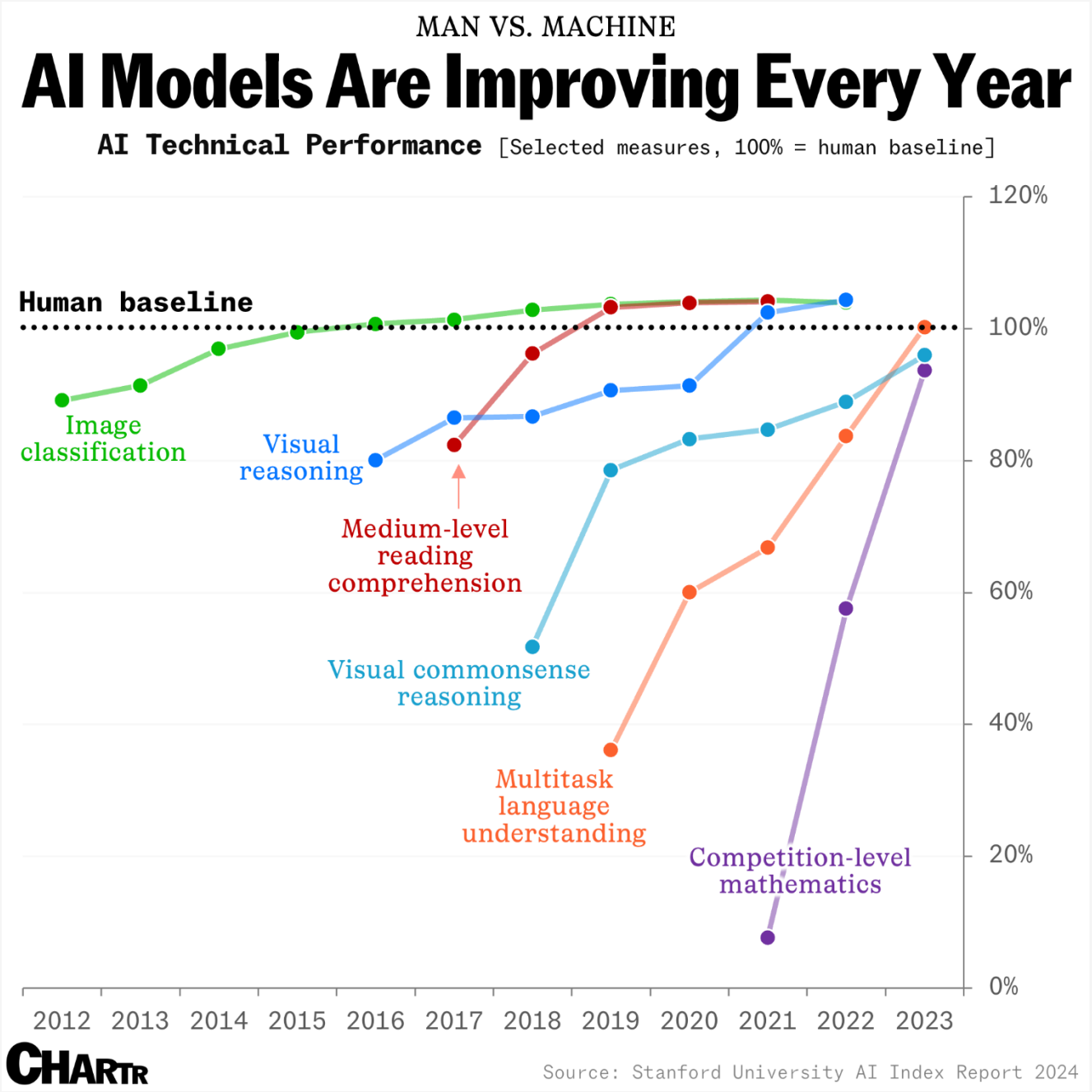
Course Introduction

Course Info, Textbooks, Billboard, Content, Schedule (Syllabus), etc.

Interest in Artificial Intelligence Worldwide



Where are we now?



Where are we now?

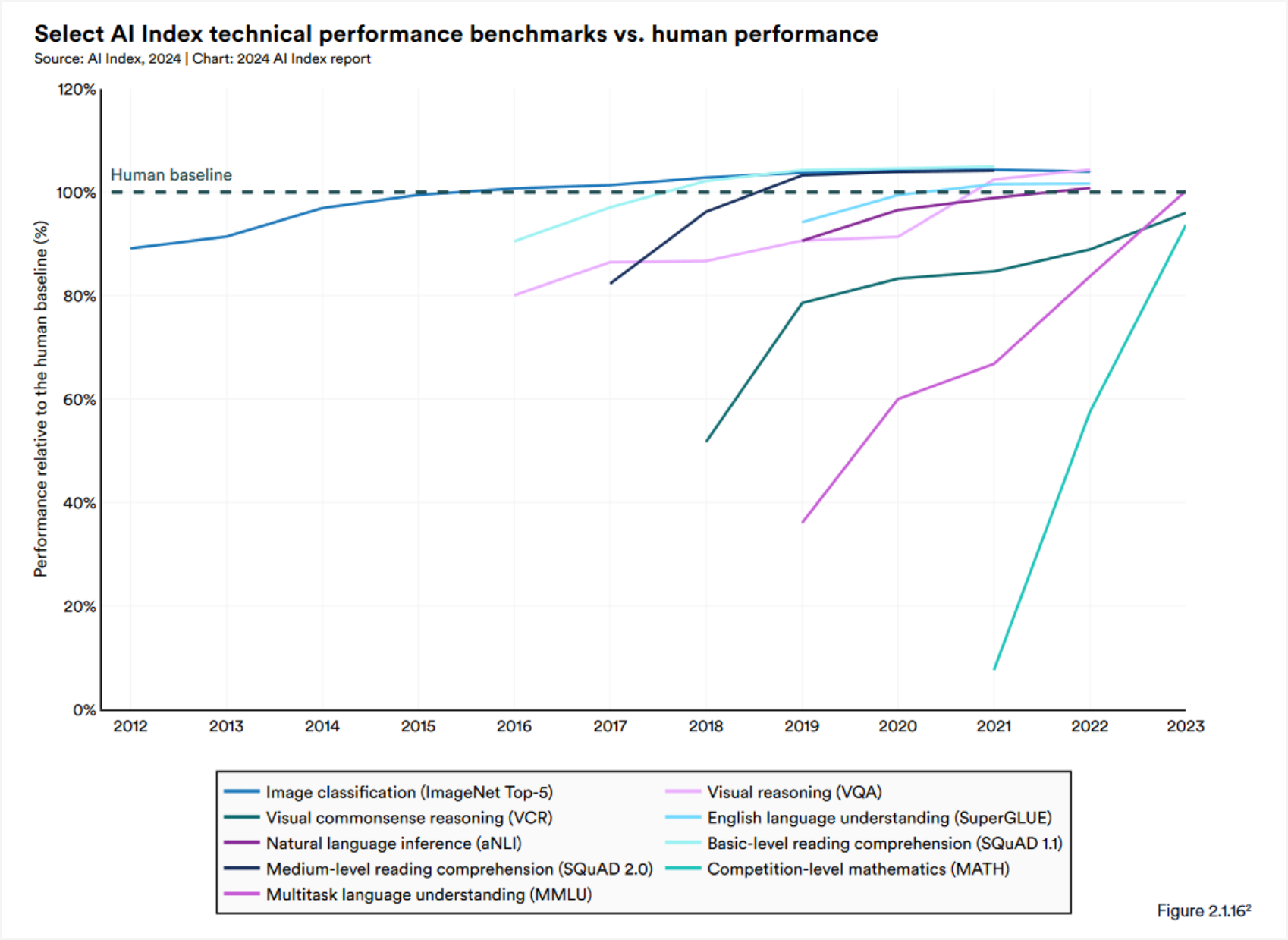


Figure 2.1.16[2]

Nestor Maslej, Loredana Fattorini, Raymond Perrault, Vanessa Parli, Anka Reuel, Erik Brynjolfsson, John Etchemendy, Katrina Ligett, Terah Lyons, James Manyika, Juan Carlos Niebles, Yoav Shoham, Russell Wald, and Jack Clark, "*The AI Index 2024 Annual Report*," AI Index Steering Committee, Institute for Human-Centered AI, Stanford University, Stanford, CA, April 2024.

Course Info

This course aims to equip you with a solid understanding of Artificial Intelligence (AI) principles and their practical applications.

Key learning outcomes includes:

- Understanding of AI fundamentals: such as agents, problem-solving, search, optimization, knowledge representation, reasoning, machine learning, and neural networks.
- Apply AI techniques to real-world problems: you will develop the ability to apply AI techniques to solve real-world problems and make informed decisions.
- Develop problem-solving skills: You will develop the ability to analyze problems, identify potential AI solutions, and implement them effectively.
- Critical thinking: You will learn to analyze and evaluate AI systems and their potential applications.
- Understand the limitations and ethical implications of AI: You will recognize the challenges and potential biases associated with AI systems, and consider ethical implications in AI development.

Course Info

- **Quizzes (30%):** Weekly quizzes focusing on key concepts and fundamentals of AI algorithms and techniques, and occasional assignments focusing on implementing and analyzing different AI algorithms and techniques.
- **Midterm Exam (30%):** Covers the theoretical concepts learned in the first half of the course.
- **Final Exam & Final Project (40%):** A final exam covering the whole theoretical concepts learned throughout the course, and a comprehensive project applying AI principles to a real-world problem of your choice.

Course Info

Course resources (check official LMS, dys.mu.edu.tr)

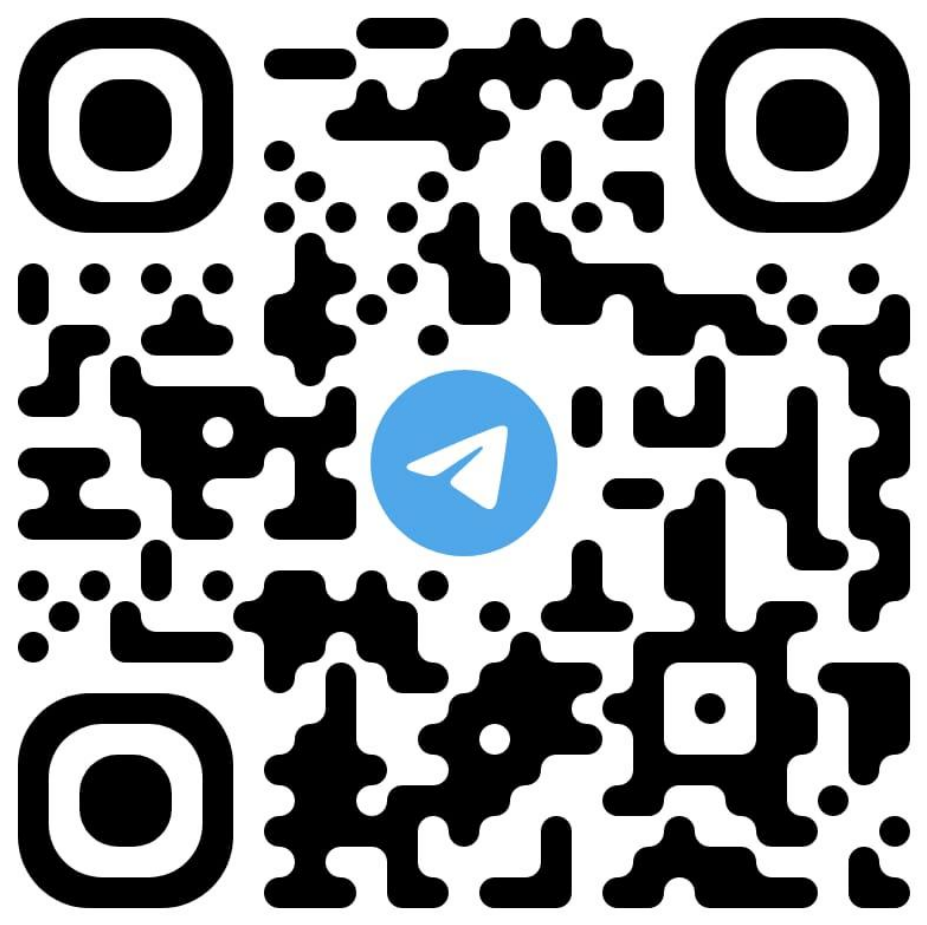
- **Textbooks**:
  - *Artificial Intelligence: A Modern Approach* by Stuart Russell, Peter Norvig
  - *Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow* by Aurélien Géron
  - *Deep Learning with Python* by François Chollet
  - *Speech and Language Processing* by Daniel Jurafsky, James H. Martin
- **Software**:
  - Python, scikit-learn, TensorFlow, PyTorch, Jupyter notebooks, etc.
  - Google Colab, work@tech (https://workat.tech/), Hacker Rank,
- **Additional Resources**:
  - Online tutorials and datasets (e.g., Kaggle, UCI Machine Learning Repository)

Course Billboard & Announcements

Telegram group name

CENG 3511 AI (2024-Fall)

(Invite link is in dys.mu.edu.tr)



Course Content

1. Search and Optimization

- **Algorithmic thinking**: This involves understanding the underlying logic, breaking down problems into smaller steps, and using appropriate data structures and control flow.

2. Knowledge Representation and Reasoning

- **Knowledge representation:** Explores how AI systems can understand and process information.
- **Reasoning:** Focuses on how AI can use that knowledge to make intelligent decisions.

3. Statistical AI

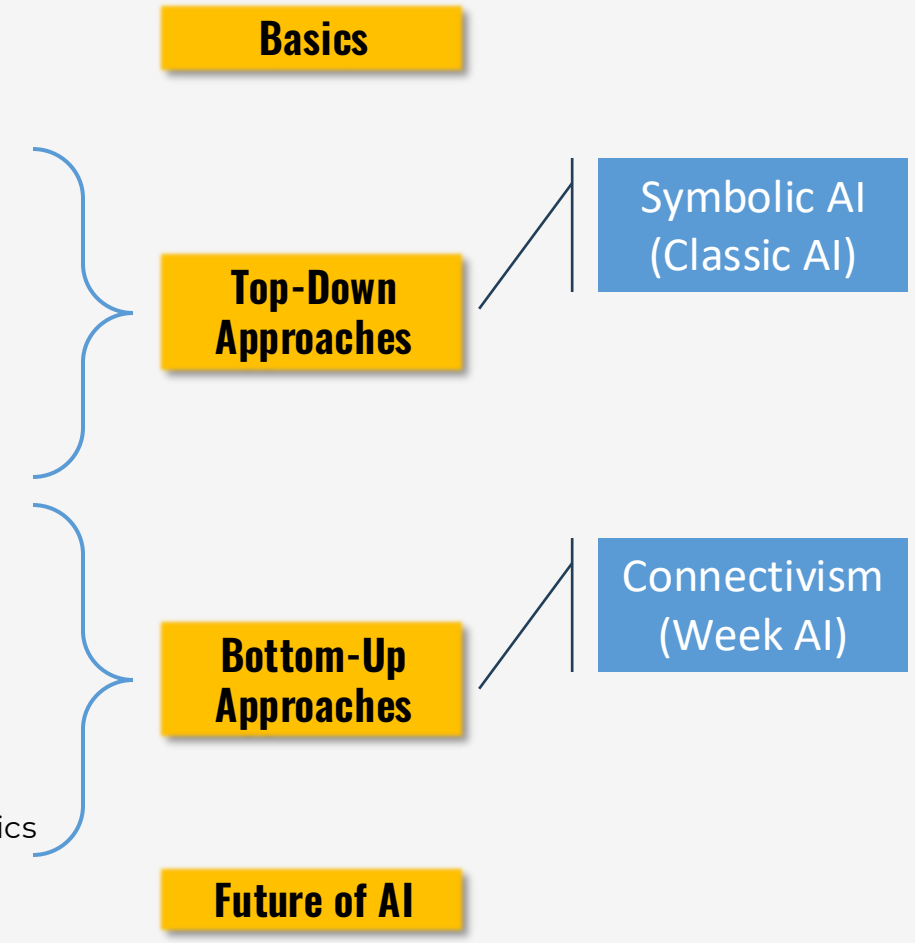
- **Data-Driven Approaches:** Shift from knowledge-based to data-driven approaches

- **Machine Learning**
  - Linear Regression
  - Logistic Regression
  - Support Vector Machines (SVMs)
  - Decision Trees,
  - k-Nearest Neighbors (k-NNs)
  - Ensemble Methods: Bagging, Boosting, Random Forests

- **Neural Networks**
  - Convolutional (CNNs)
  - Recurrent (RNNs)
  - Generative Models (GANs and VAEs)
  - Transformers (LLMs)
  - Transfer Learning & Fine Tuning
  - Reinforcement Learning

Course Schedule

- **Weeks 1-2**: Introduction to AI
  - Week 1: Introduction to AI (Today!!)
  - Week 2: Intelligent Agents and Problem Solving
- **Weeks 3-5**: Search and Optimization
  - Week 3: Advanced Search Techniques
  - Week 4: Constraint Satisfaction Problems (CSPs)
  - Week 5: Optimization and Metaheuristics
- **Weeks 6-8**: Knowledge Representation and Reasoning
  - Week 6: Logic and Knowledge Representation
  - Week 7: Ontologies and Semantic Networks
  - Week 8: Reasoning Under Uncertainty
- **Weeks 9-12**: Machine Learning & Neural Networks
  - Week 9: Introduction to Machine Learning
  - Week 10: Introduction to Neural Networks
  - Week 11: Deep Learning I
  - Week 12: Deep Learning II
- **Weeks 13**: Applications of AI
  - Week 13: AI in Vision, Speech, Audio Processing and Robotics
- **Weeks 14**: Future Directions, Ethics and Wrap-up
  - Week 14: Emerging AI Technologies, Ethics, AI and Society



Learning Outcomes

Knowledge: Understand the historical development of AI, various paradigms, their strengths, and limitations.

Skills: Become proficient in Python programming for AI applications, utilizing libraries like *NumPy*, *Pandas*, *scikit-learn*, *TensorFlow*, and *PyTorch*.

Application: Apply AI techniques to solve real-world problems and develop practical projects.

Critical Thinking: Analyze the ethical and societal implications of AI, recognizing its potential benefits and challenges.

Industry Experts & Guest Lectures

- Cem Ayyıldız
  - GHOM Ltd.
  - Using AI/ML to enhance wireless security in 6G networks
- Aydın Gülgün
  - AG Robotik ArGe Yazılım
  - Using AI/ML methods for 3D Design & Production
- Izzet Pembeci
  - Guest lecture.

Academic Integrity & Ethics

- Don't **copy-paste** codes in projects from the internet.
- Don't **copy-paste** codes from AI
  - Doing so, **will result in a 0 score** and you'll immediately fail.
- This class encourages the use of templates, use of AI and collaboration, as long as you clearly indicate (give reference to) when you use external resources

and

be sure the main part of the work is your own.

Today's Objectives

- What AI is and about.
- Learn about the types of AI
- How to formulate AI problems
- Overview of key AI subfields

What is Artificial Intelligence

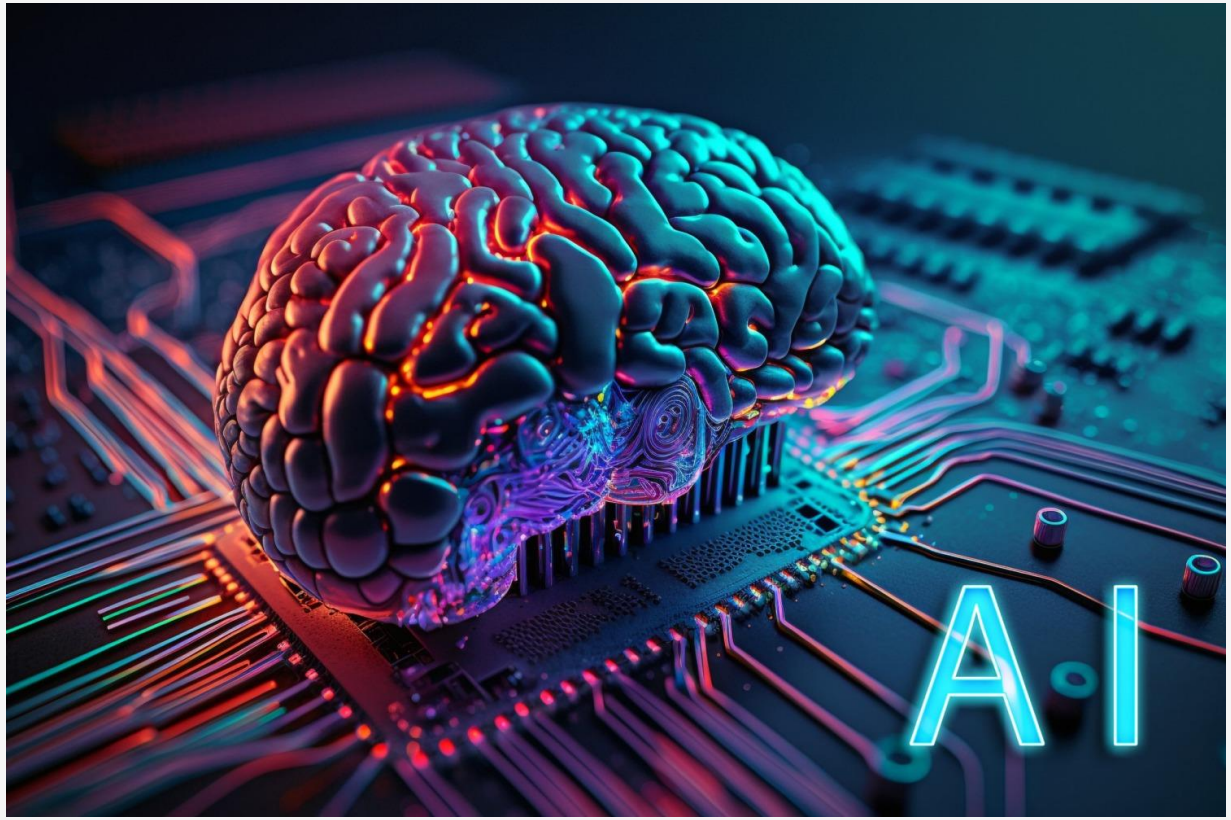
What is Artificial Intelligence (AI)?

Definition of AI:

- The **simulation of human (natural) intelligence processes** by machines, especially computer systems.

Key Components

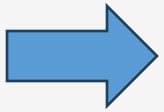
- **Learning**: Acquiring **knowledge** and skills through experience.
- **Reasoning**: Applying knowledge and skills to solve problems and **make decisions**.
- **Self-correction**: Identifying and correcting errors in its own performance.



What is Artificial Intelligence (AI)?

Definition of AI:

- The **simulation of human (natural) intelligence processes** by machines, especially computer systems.



But what is Natural Intelligence?

Key Components

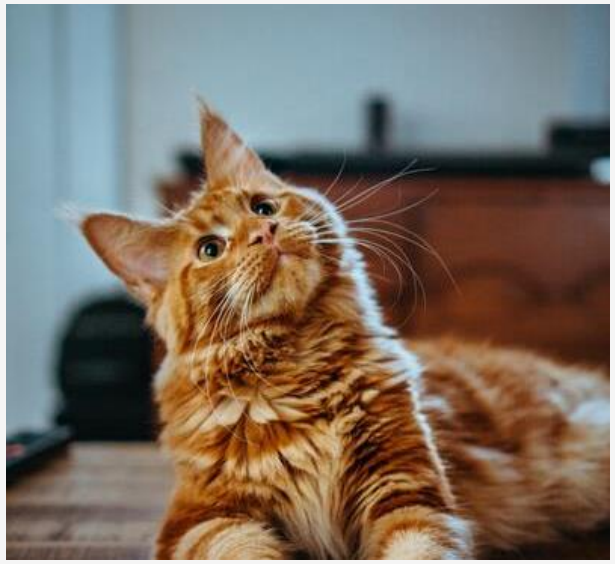
- **Learning**: Acquiring **knowledge** and skills through experience.
- **Reasoning**: Applying knowledge and skills to solve problems and **make decisions**.
- **Self-correction**: Identifying and correcting errors in its own performance.

What is Natural Intelligence?

- One of the problems when dealing with the term **Intelligence** is that there is no clear definition of this term.
- One can argue that intelligence is connected to **abstract thinking**, or to **self-awareness**, but we cannot properly define it.

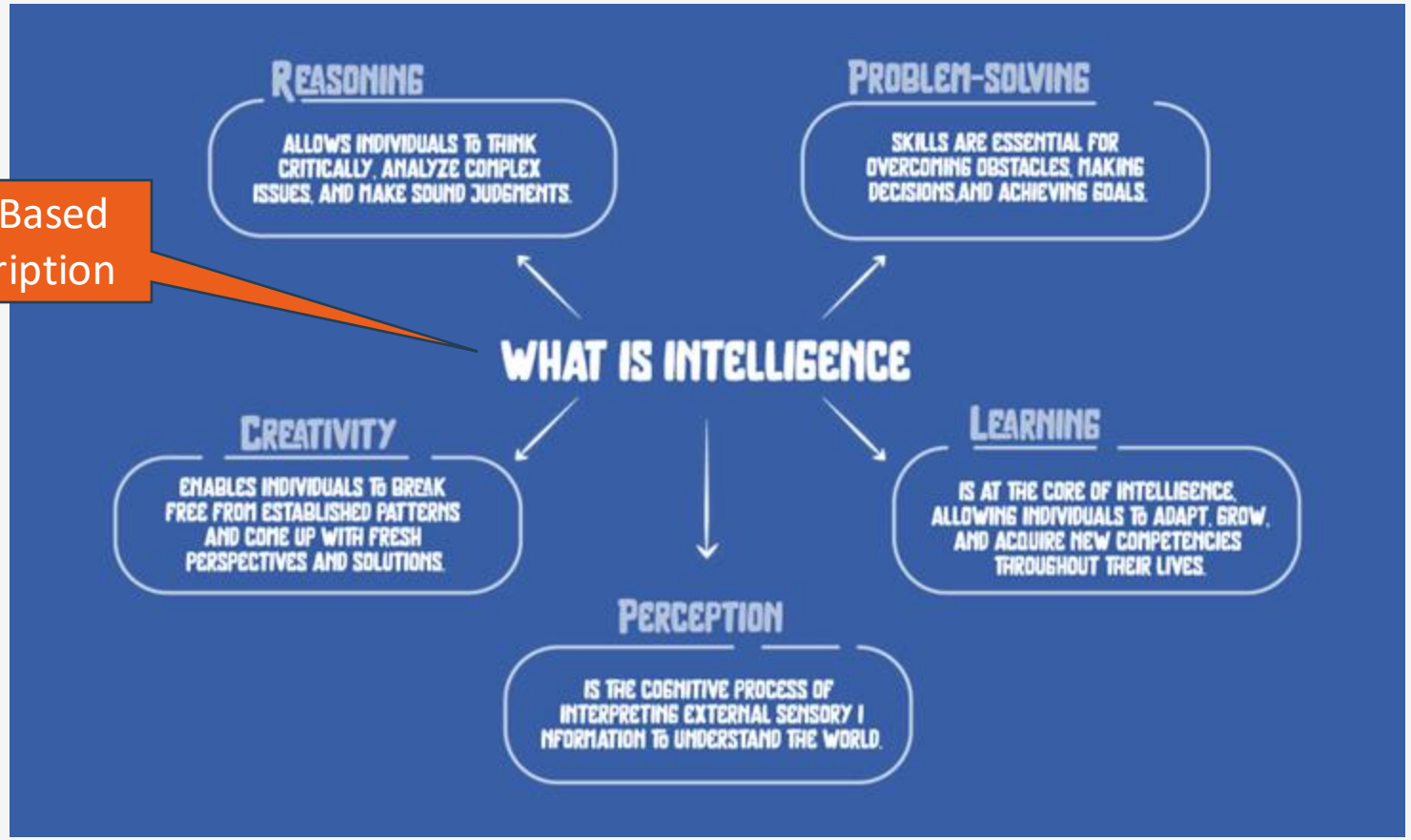
➢ The term "intelligence" is open to interpretation, as demonstrated by the question "Is a cat intelligent?".
  - Different individuals may have varying perspectives on this matter due to the absence of a universally agreed-upon standard for measuring intelligence.
  - Even if you believe such a standard exists, attempting to administer an IQ test to a cat…

❑ Think for a minute about how you define intelligence.
  ? Is a crow who can solve a maze and get at some food intelligent?
  ? Is a child intelligent?



What is Natural Intelligence to a Functional POV

Skill-Based Description



An intelligent being shows intelligent behavior and to do that it:

- ✓ Perceives
- ✓ Learns
- ✓ Reasons (Decision Making)
- ✓ Solves Problems
- ✓ and creates new …

What is Natural Intelligence to Cognitive Psychology

Cognitive Psychology, Fourth Edition, Robert J. Sternberg
Chapter 13

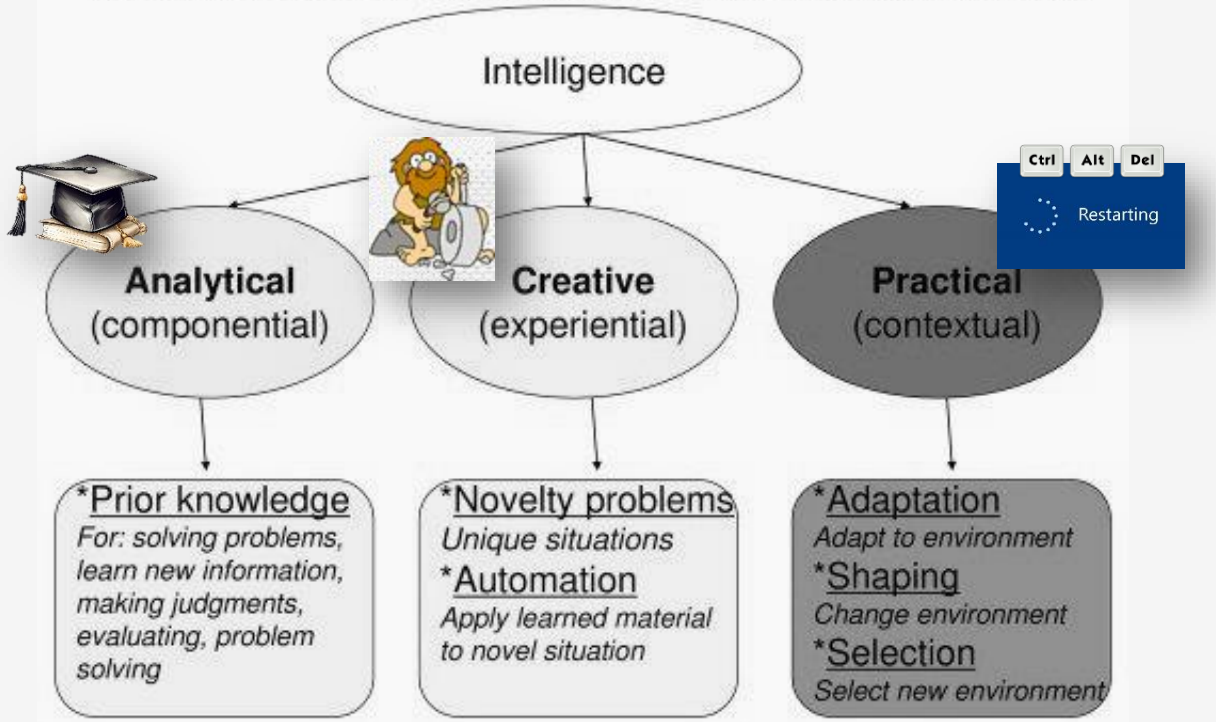
Sternberg's Triarchic Theory

- Emphasizes how 3 types of abilities work together to create intelligent behavior

Triarchic Theory

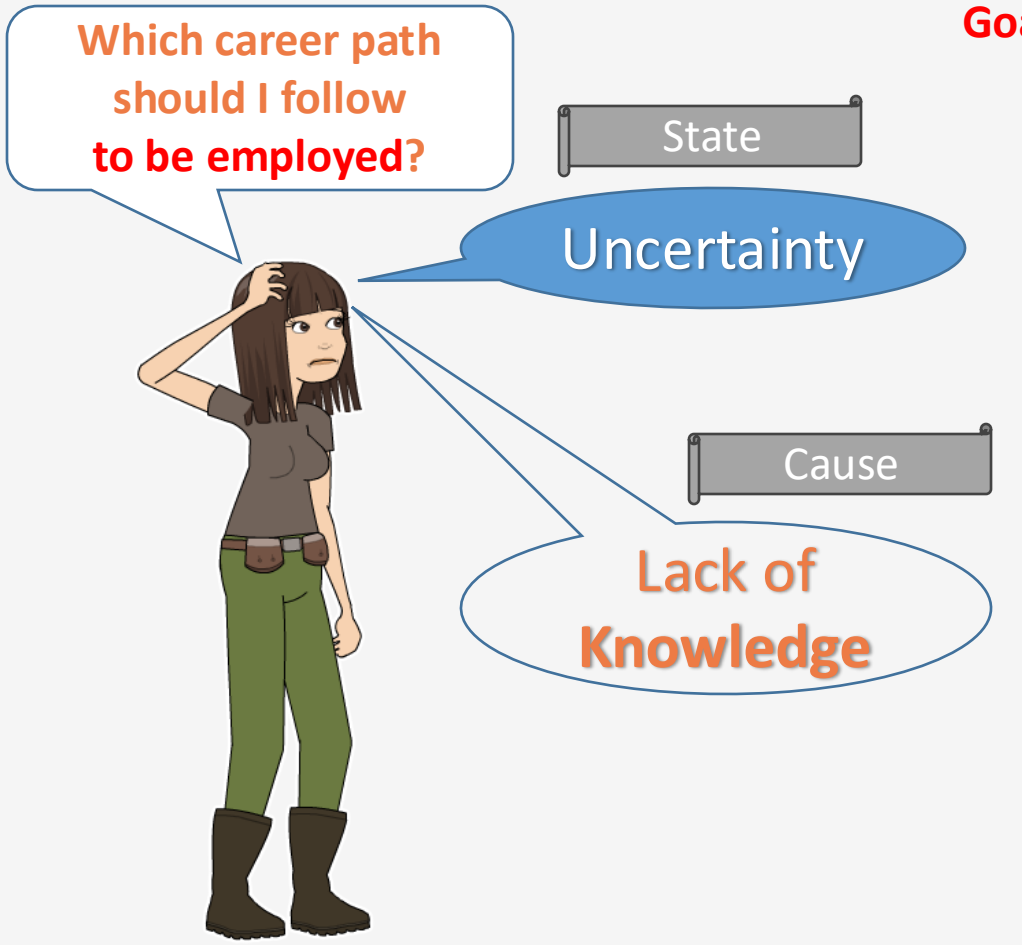
Analytical	**Creative**	**Practical**
Compare, Evaluate & Analyze	Insights, Synthesis, Adapting in unique situations	Dealing with Everyday tasks Relating to world

STERNBERG'S TRIARCHIC THEORY OF INTELLIGENCE (I)



Intelligent Behavior: A Working Example

Goal: “to be employed”



Intelligent Behavior!

Goal: “to be employed”

Which career path should I follow to be employed?

Uncertainty

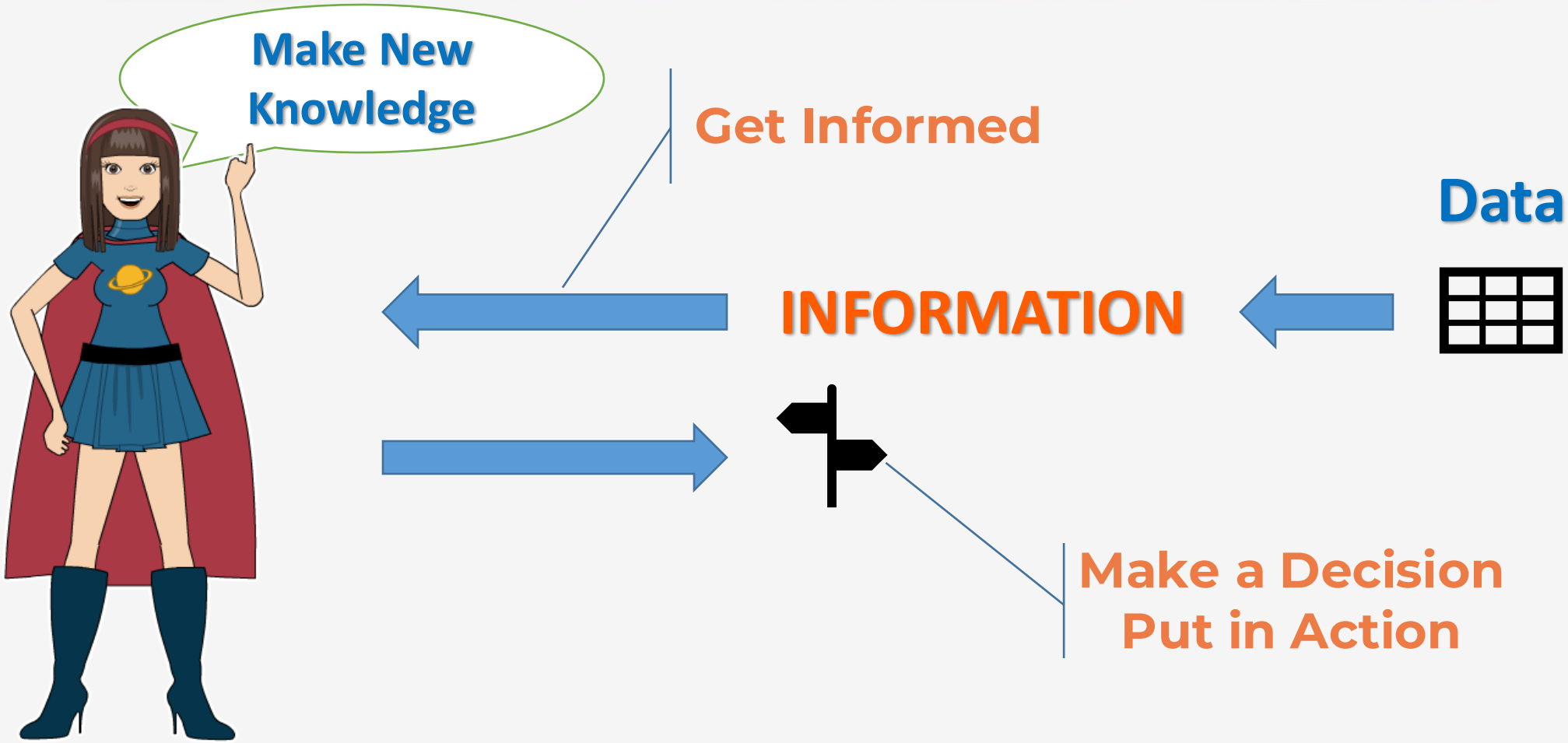
Data

INFORMATION

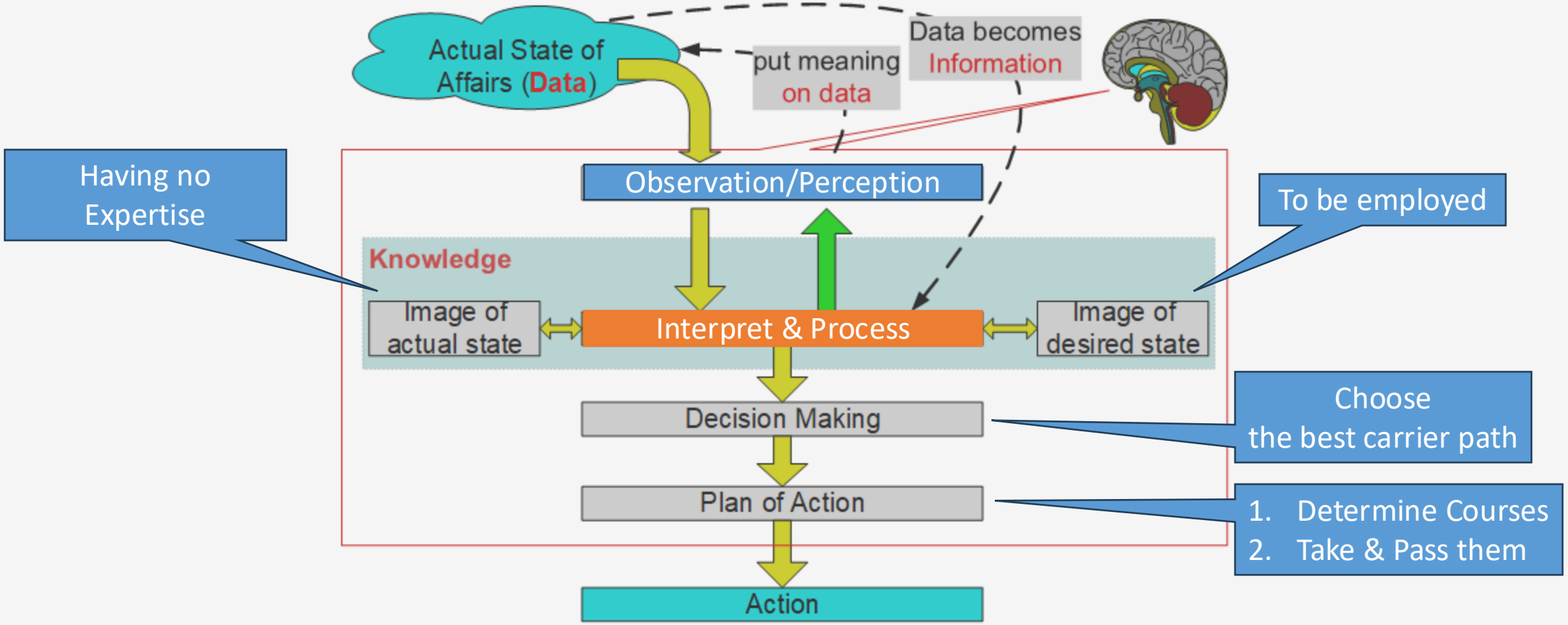
Collect Data

Put Meaning (Interpret)

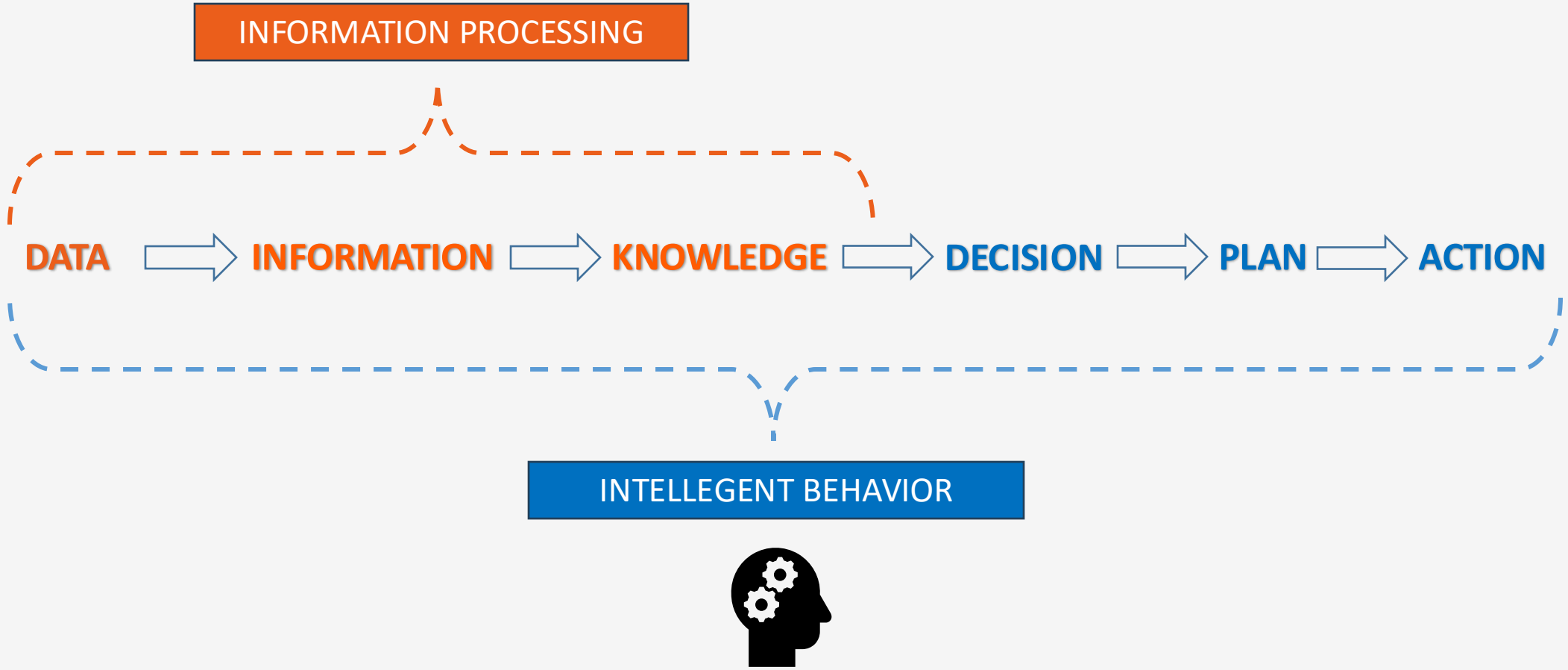
Intelligent Behavior!



Decision Making Process: Cognitive Science Perspective



Intelligent Behavior & Information Processing



Conclusion: What is Artificial Intelligence?

Information (Information Processing)
is the subject matter of
Information Science

Artificial Intelligence
is basically
Information Processing

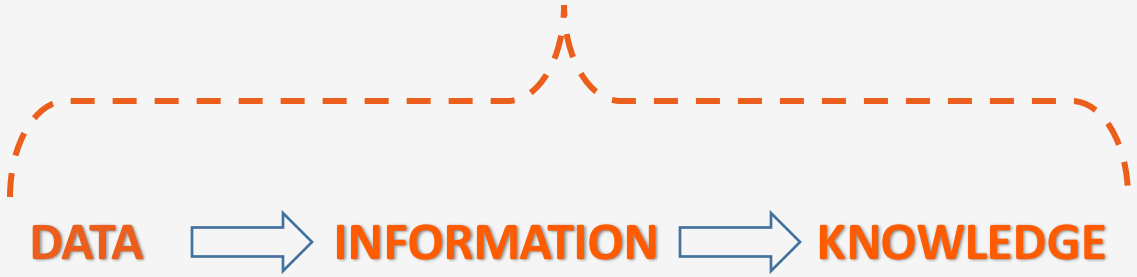
Computer Science Perspective

Computer Science is
about understanding
the theoretical foundations of computing
and
applying them to create practical solutions

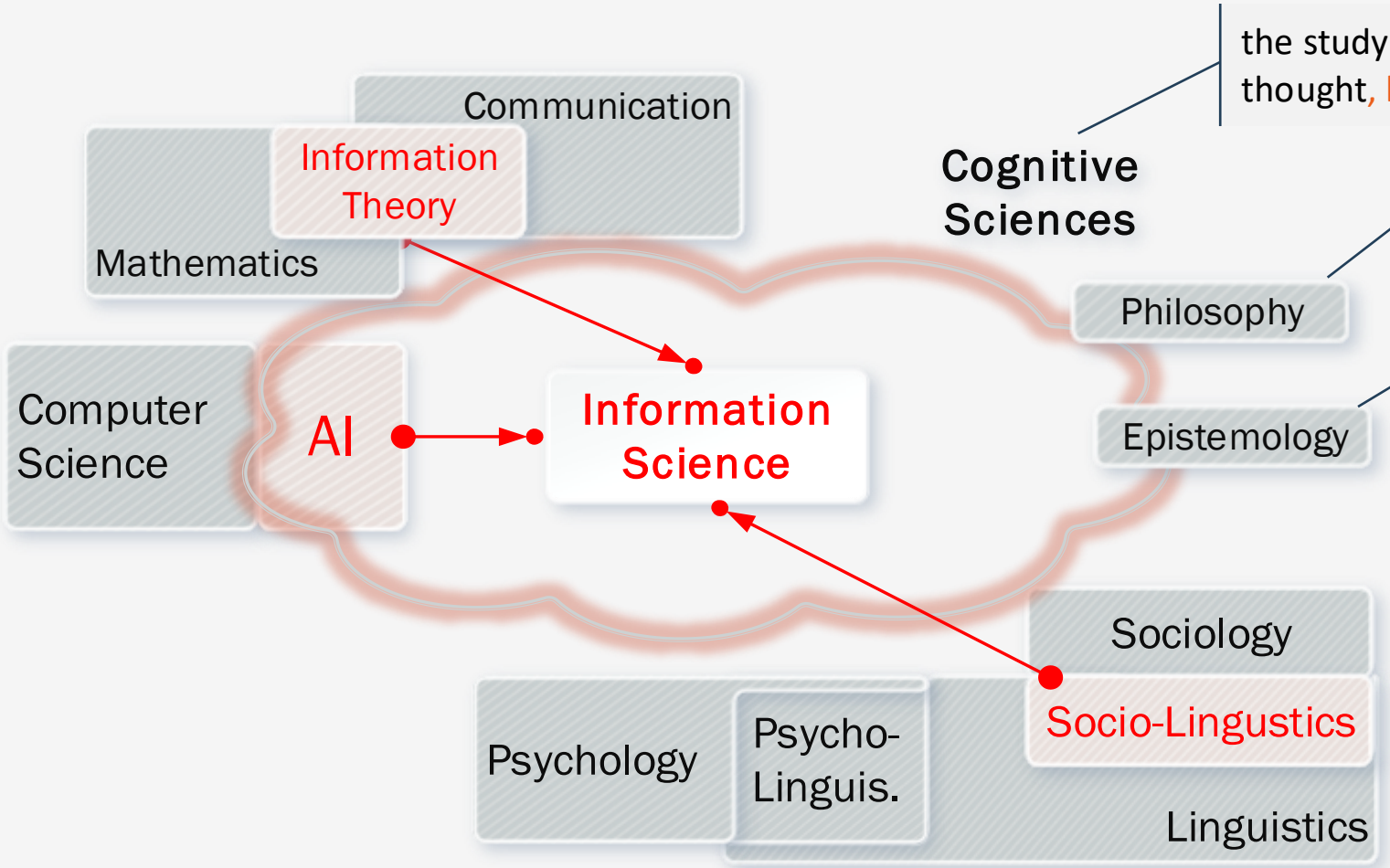
Cognitive Science Perspective

Cognitive Science is
the study of
thought, learning, and mental organization,
which draws on aspects of
psychology, linguistics, philosophy, and
computer modelling

INFORMATION PROCESSING



Information Science & Influencing Disciplines



Information Science:

- is a field that deals with the organization, storage, retrieval, and dissemination of information.
- It focuses on the study of how information is created, processed, and used in various contexts.

What is Information?

What is Information Processing?

Information Science: State-of-the-Art of AI

What Computers can only process

What only humans can process

DATA + MEANING = INFORMATION

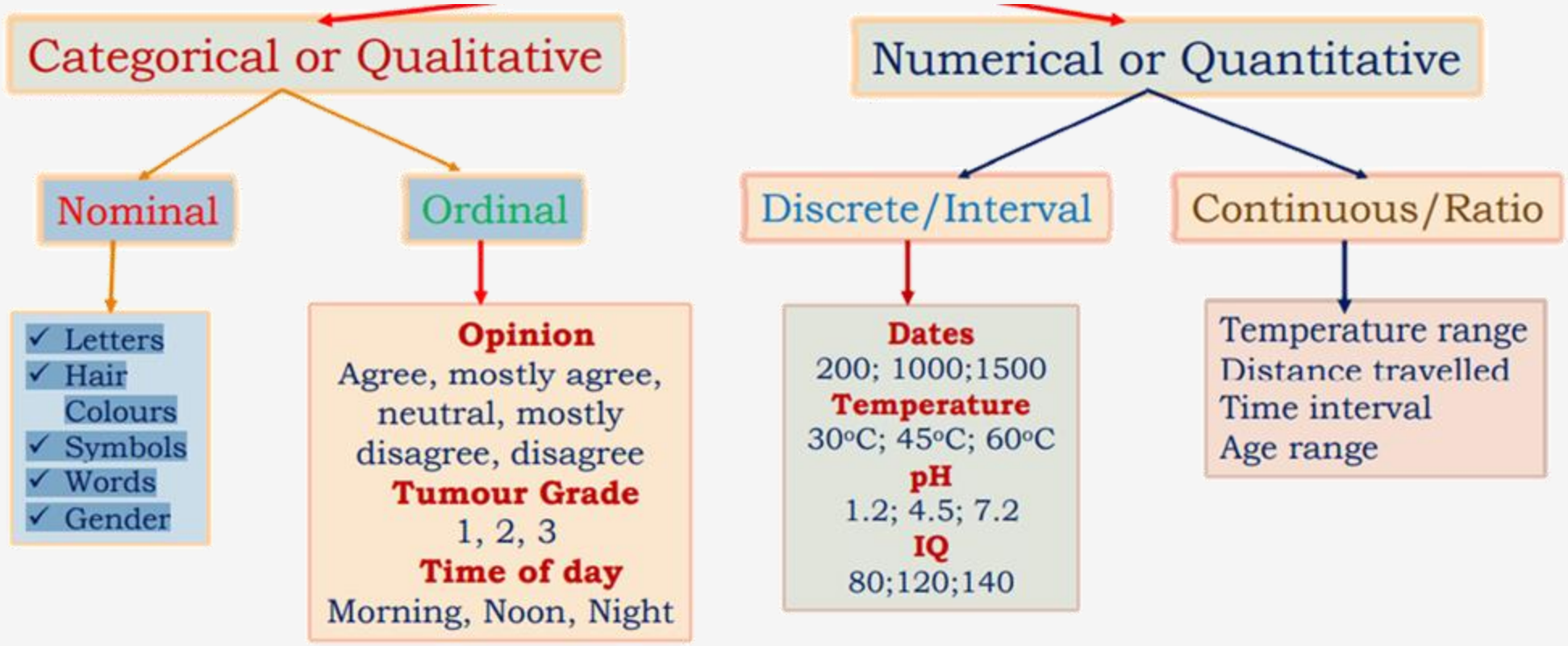
INFORMATION + PROCESSING = KNOWLEDGE

Information Science: Claim of AI

DATA + MEANING = INFORMATION

INFORMATION + PROCESSING = KNOWLEDGE

Information Science : Fundamentals – Types of Data?



Neither Order Nor Difference

Implies Order

Counted Items

Measured Characteristics

Information Science : Fundamentals – What is Data?

- Any quantities, characters, or symbols

  - 25, 100, 500, 1,000,000
  - 50 Male, 32 Female,
  - 50 cents, 1 dollar
  - 0.28 grams, 0.01 ounce,
  - etc.

✓ **Computers may perform operations** on Data

✓ **Data may be stored and transmitted** in the form of **electrical signals** and recorded on magnetic, optical, or mechanical recording media

Information Science : Fundamentals – What is Data?

- Data, on its own, make no sense without a context/meaning

Can 50 cents do that?

Information Science : Fundamentals – What is Data?

- Data, on its own, make no sense without a context/meaning

Can 50 cents do that?

If money,

- what 50 cents can buy
- can someone do something for 50 cents?

Information Science : Fundamentals – What is Data?

- Data, on its own, make no sense without a context/meaning

Can 50 cents do that?

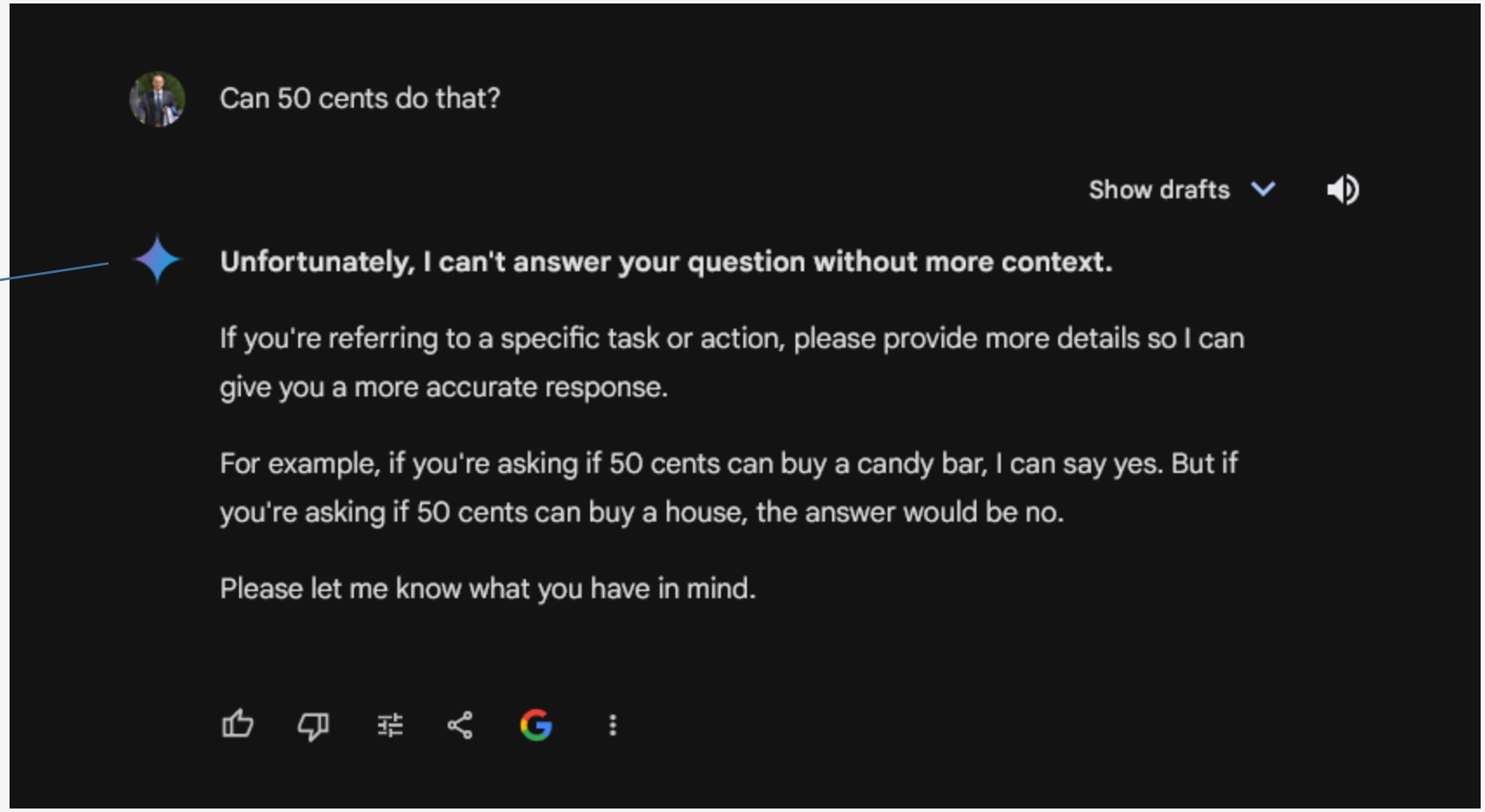
Nick Name of a Hip-Hop Singer / Rapper

- he can do anything he wants ☺

Information Science : Fundamentals – What is Data?

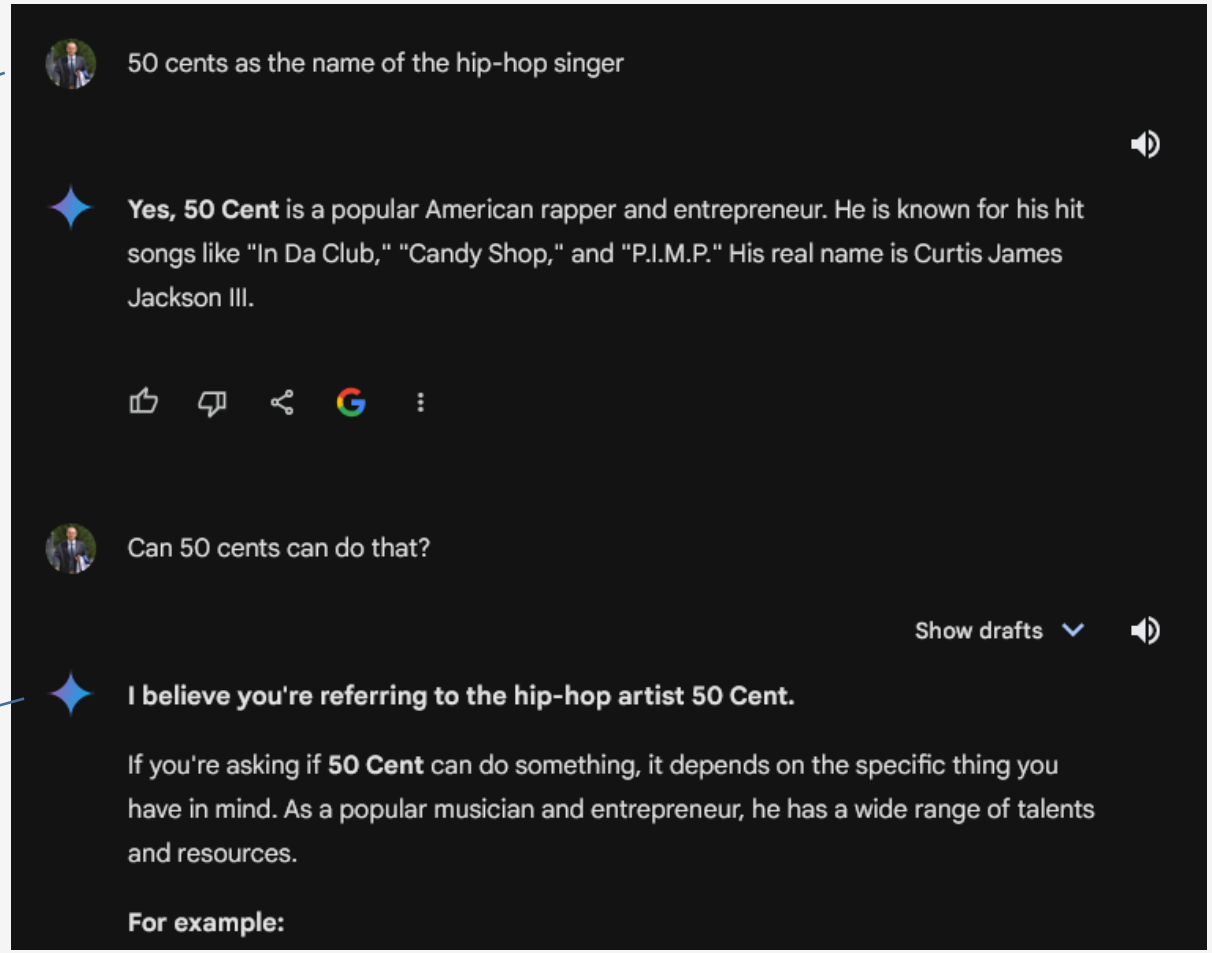
What Computers can only process

Google's Gemini



Information Science : Fundamentals – What is Data?

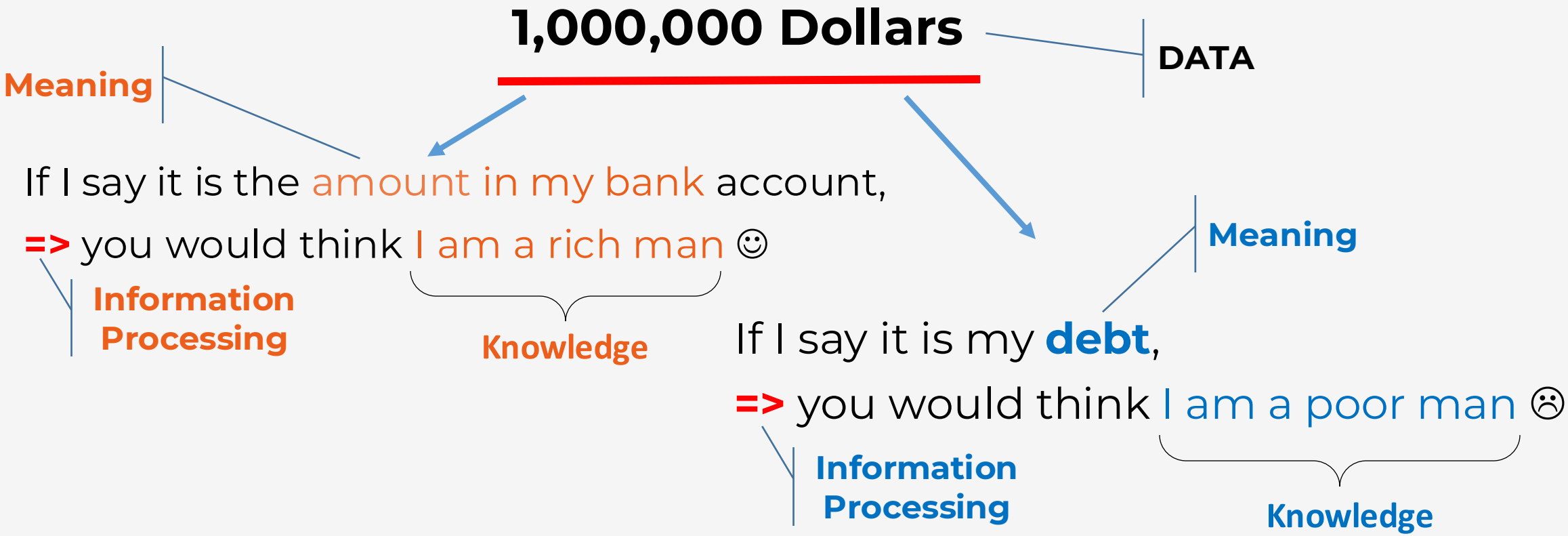
Provide meaning for “50 cents”



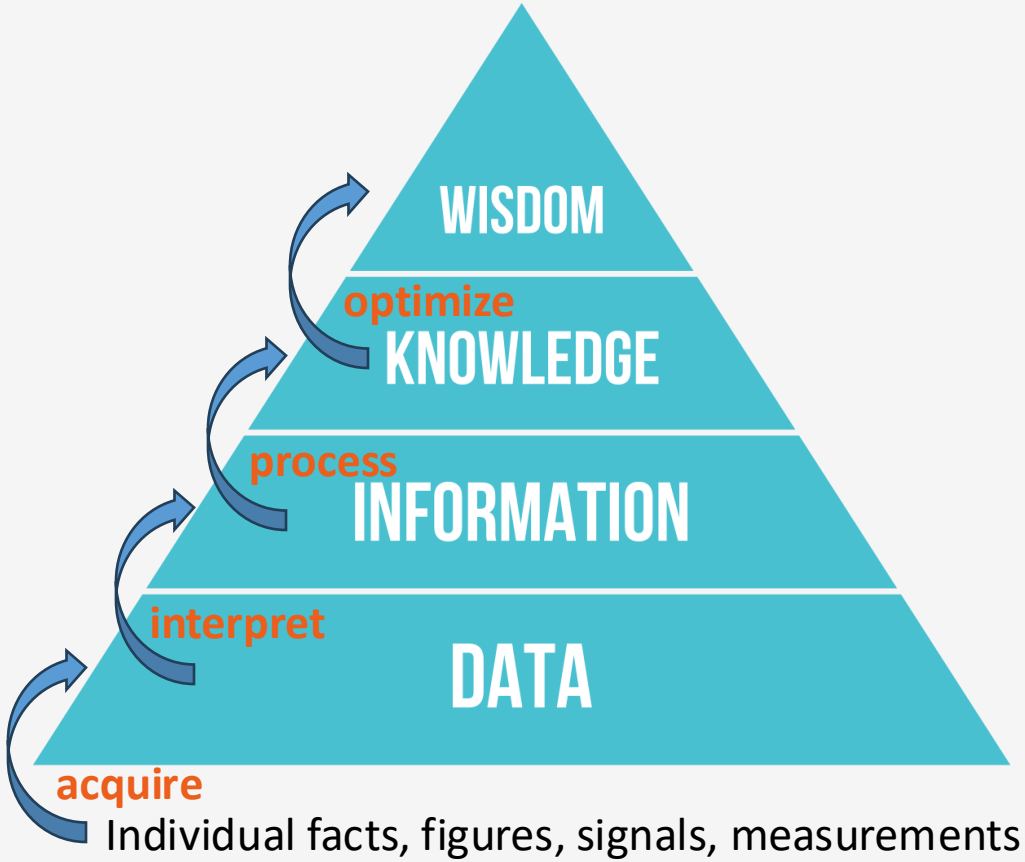
Google’s Gemini

Data vs Information vs Knowledge

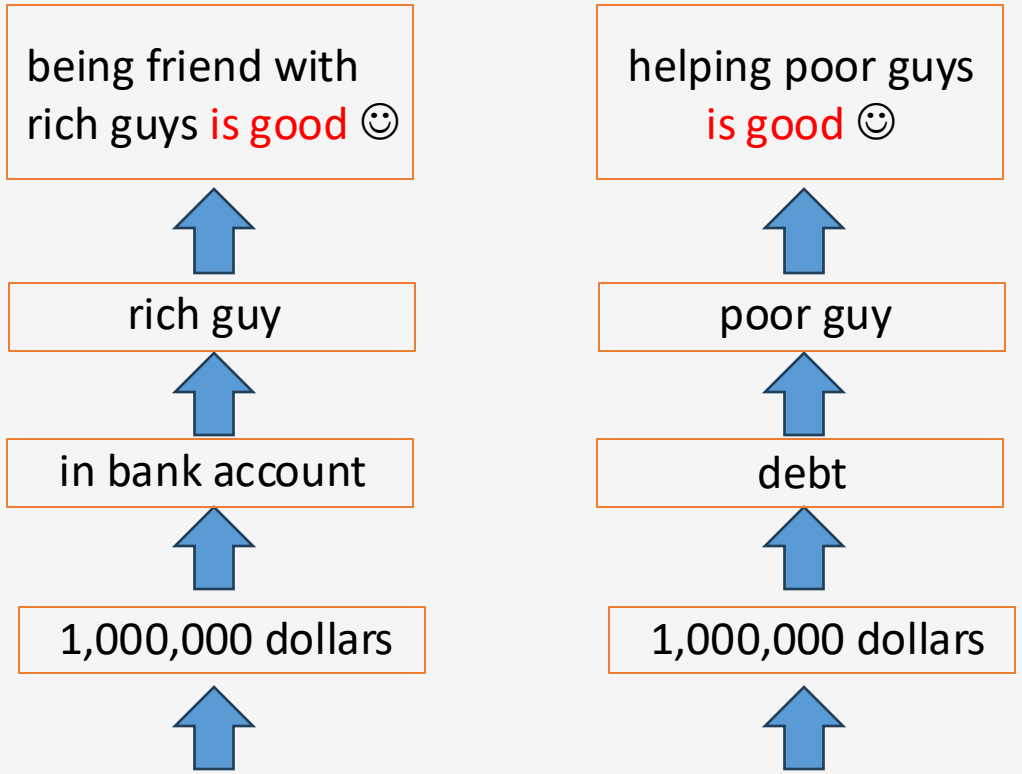
- Data, on its own, make no sense without a context/meaning



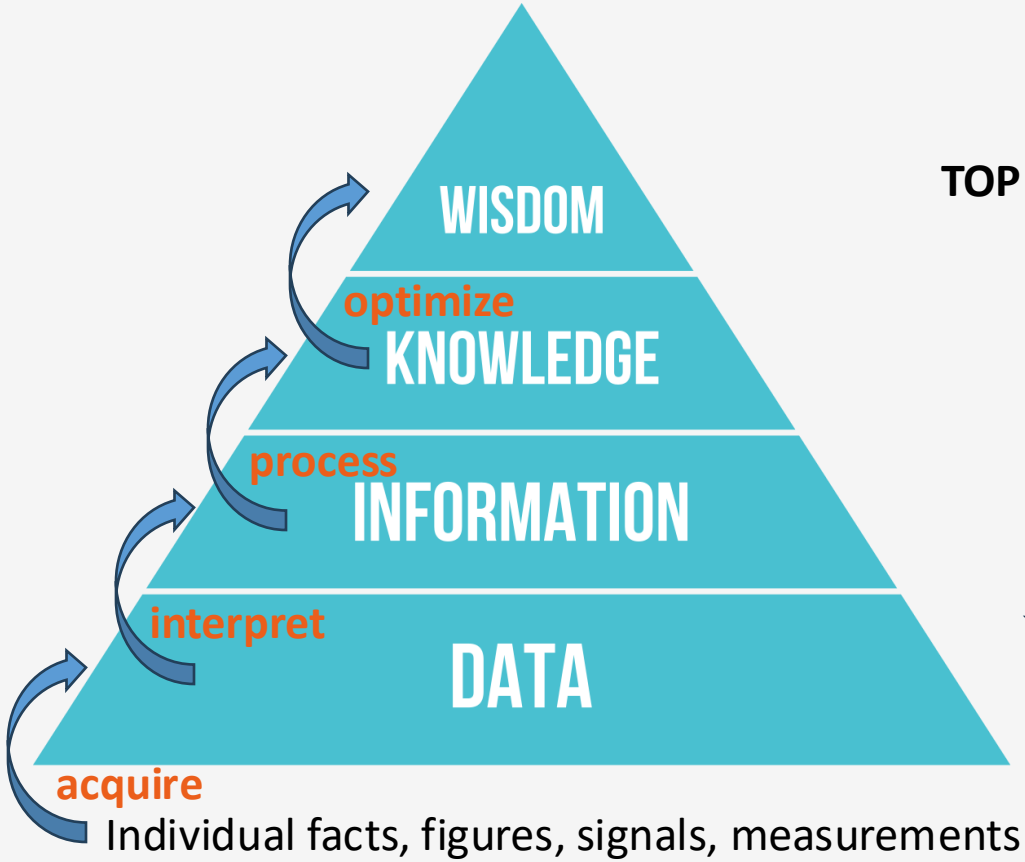
DIKW Pyramid



Individual facts, figures, signals, measurements



DIKW Pyramid



Individual facts, figures, signals, measurements

Artificial Intelligence Methods

Top-Down Methods (Theory-driven Approach)

TOP

Week 3 to 8

- Advanced search techniques
- Constraint satisfaction problems
- Optimization and metaheuristics
- Logic and knowledge representation
- Ontologies and semantic networks
- Reasoning under uncertainty

Bottom-Up Methods (Data-driven Approach)

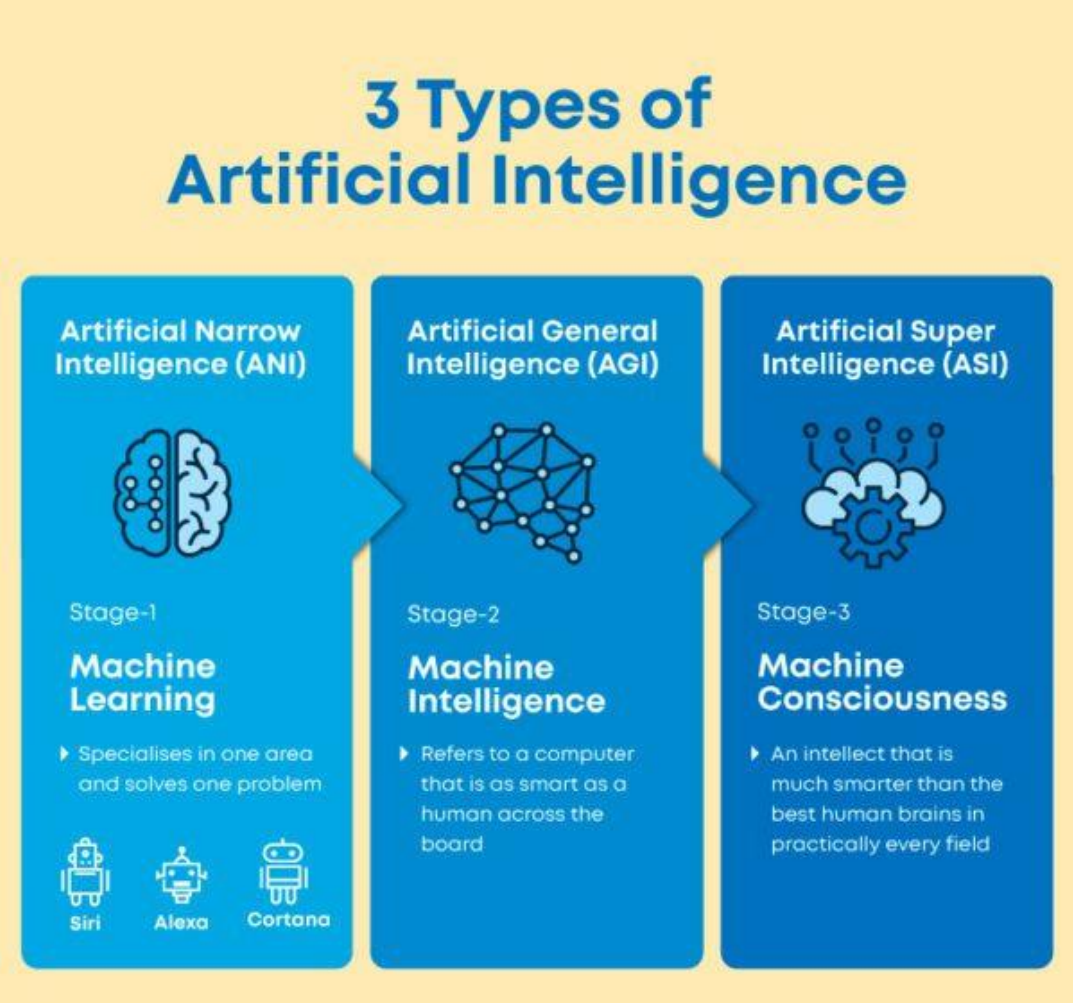
Week 9 to 13

- Machine Learning
- Neural Networks
- Deep Learning

BOTTOM

Types of Artificial Intellegence

Types of Artificial Intelligence (w.r.t Capability)



Weak AI (ANI)	Strong AI (AGI)
Weak AI refers to AI systems that are designed and trained for a specific task or a narrow set of tasks.	Strong AI, or Artificial General Intelligence (AGI), refers to AI systems with human-level intelligence and understanding.
These AI systems are not generally intelligent; they excel in performing a predefined task but lack true understanding or consciousness.	These AI systems have the ability to perform any intellectual task that a human being can do, adapt to different domains, and possess a form of consciousness or self-awareness.
Examples of weak AI include virtual assistants like Siri or Alexa, recommendation algorithms used by streaming services, and chatbots that are designed for specific customer service tasks.	Achieving Strong AI is a long-term goal of AI research and would require the development of AI systems that can reason, learn, understand, and adapt across a wide range of tasks and contexts.
Weak AI is highly specialized and does not possess human-like cognitive abilities or general problem-solving capabilities beyond its narrow domain.	Strong AI is currently a theoretical concept, and no AI system has reached this level of general intelligence

Types of Artificial Intelligence: Current State-of-the-Art

What we have today Week AI

Three types of Artificial Intelligence

Artificial Narrow Intelligence (ANI)	Stage-1	Machine Learning	Specialises in one area and solves one problem
Artificial General Intelligence (AGI)	Stage-2	Machine Intelligence	Refers to a computer that is as smart as a human across the board
Artificial Super Intelligence (ASI)	Stage-3	Machine Consciousness	An intellect that is much smarter than the best human brains in pratically every field

Examples of Week AI

- **Digital Voice Assistants**: **Siri** (Apple), **Alexa** (Amazon), and **Google Assistant** (Google) are designed to perform specific tasks such as setting reminders, answering questions, or providing weather updates.
- **Recommendation engines**: Mostly in e-commerce services, like **Netflix** and **Amazon**. These systems analyze user behavior, preferences, and historical data to provide personalized suggestions.
- **Image and Speech Recognition**: facial recognition technology in social media platforms, speech-to-text applications, and image recognition tools used in security systems.
- **Chatbots**: to handle specific queries or tasks. These bots are designed to understand and respond to user input within a predefined context.
- **Autonomous vehicles**: AI that enables vehicles to run without a human driver is considered weak AI.

Discussion

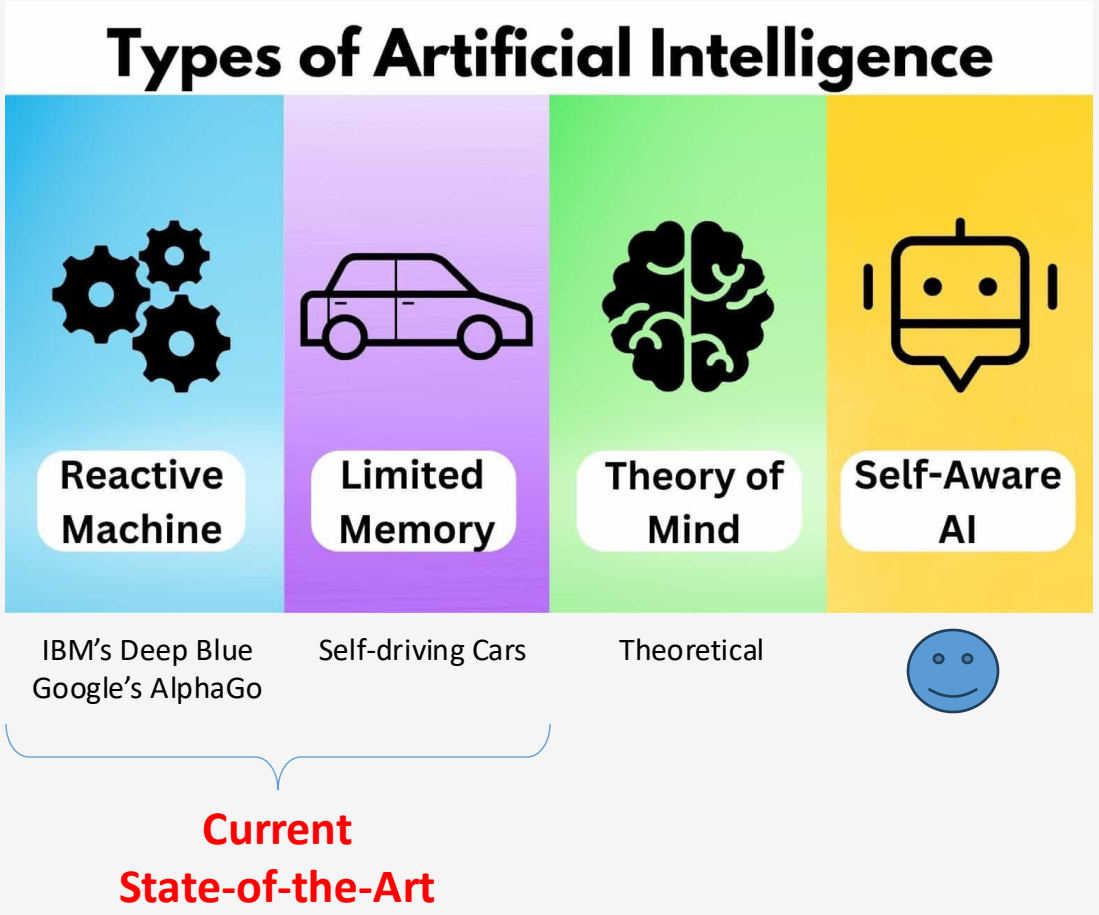
- Consider the following examples, are they of Week AI type?:
  - ❑ **Large Language Models**: OpenAI's ChatGPT, Google's LaMDA, Meta's Llama.
  - ❑ **Medical Diagnosis Systems**: systems that analyze medical images (like X-rays, MRIs, or CT scans) to assist doctors in identifying diseases or abnormalities.
  - ❑ **Machine translation tools**: These tools can translate text from one language to another, though their accuracy can vary depending on the complexity of the text and the languages involved.
  - ❑ **AI opponents in video games**: These AI systems are designed to provide a challenging opponent for human players. They can adapt their strategies based on the player's actions and make decisions within a defined game context.

Discussion

- Consider the following examples, are they of Week AI type?:
  - **Large Language Models**: OpenAI's ChatGPT, Google's LaMDA, Meta's Llama.
  - **Yes**
    - **Lack general intelligence**: They are designed for specific tasks, such as generating text or translating languages. They don't possess the broader cognitive abilities of human intelligence.
    - **Are limited by their training data**: Their responses are based on the data they were trained on. If they encounter a prompt or question outside their training data, they may struggle to provide accurate or relevant answers.
    - **Don't understand the world in the same way humans do**: They can process information and generate text, but they don't have the same understanding of the world as a human being.

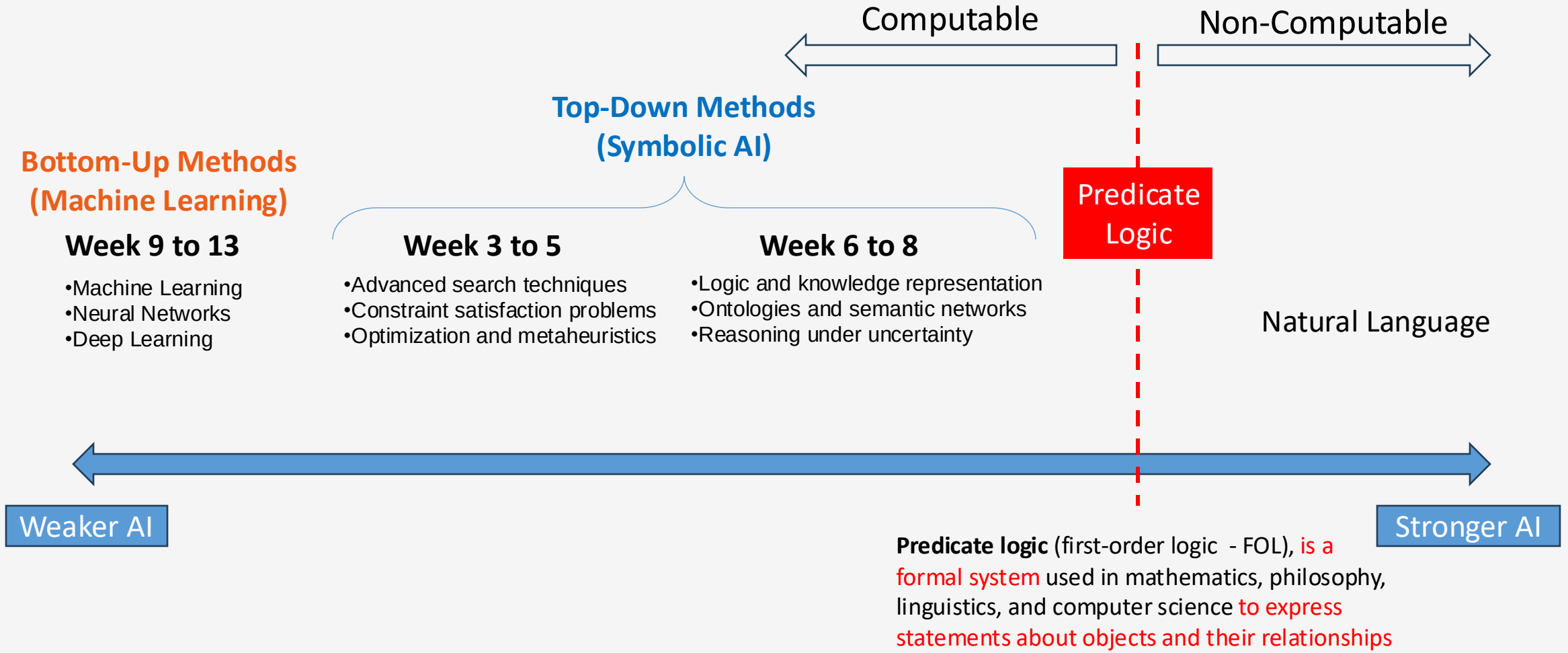
- ❑ **Medical Diagnosis Systems**: systems that analyze medical images (like X-rays, MRIs, or CT scans) to assist doctors in identifying diseases or abnormalities.
- ❑ **Machine translation tools**: These tools can translate text from one language to another, though their accuracy can vary depending on the complexity of the text and the languages involved.
- ❑ **AI opponents in video games**: These AI systems are designed to provide a challenging opponent for human players. They can adapt their strategies based on the player's actions and make decisions within a defined game context.

Types of Artificial Intelligence (w.r.t. Functionality)



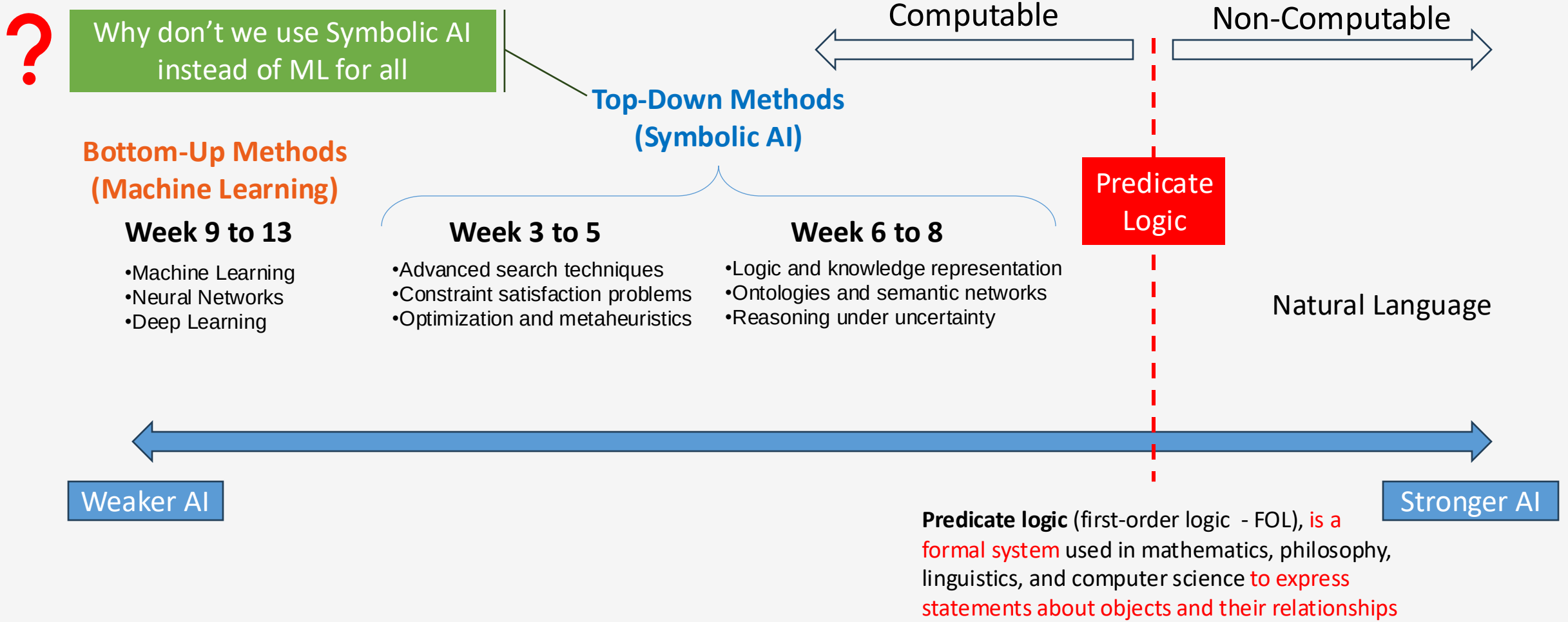
- **Reactive Machines** : most fundamental type of AI, stores no memories or past experience for future actions: IBM's Deep Blue system (Chess) and Google's AlphaGo.
- **Limited Memory**: can store past experience or some data for a short period of time: Self-driving car.
- **Theory of mind**: should be able to understand human emotions, people, beliefs, and be able to interact socially as humans do.
- **Self-awareness**: the future of artificial intelligence, possessing consciousness, sentiments, and self-awareness, and will be smarter than human mind.

AI Methods/Tasks wrt Types/Levels of AI



Predicate logic (first-order logic - FOL), is a formal system used in mathematics, philosophy, linguistics, and computer science to express statements about objects and their relationships

AI Methods/Tasks wrt Types/Levels of AI



Predicate logic (first-order logic - FOL), is a formal system used in mathematics, philosophy, linguistics, and computer science to express statements about objects and their relationships

Symbolic AI vs Machine Learning

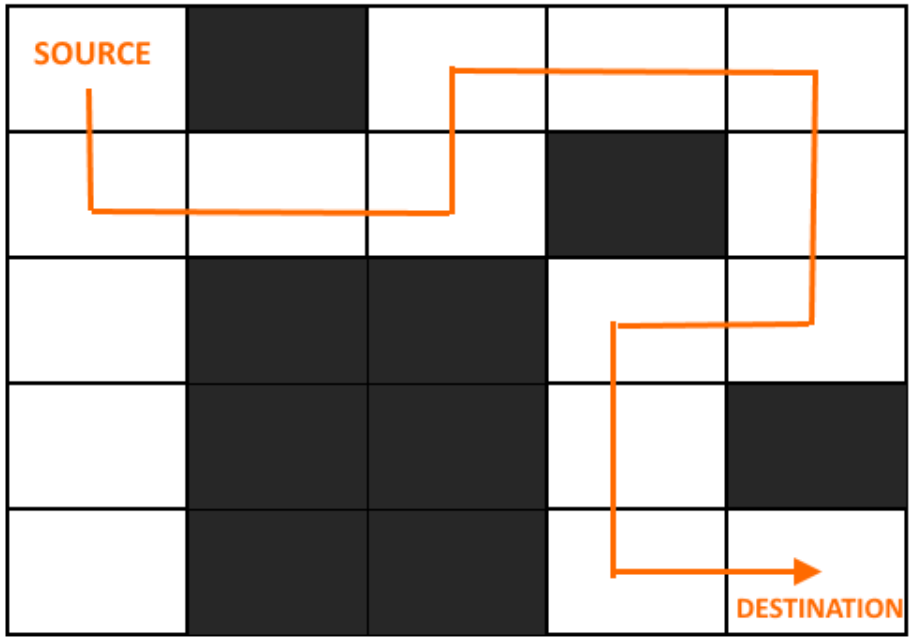
Aspect	Symbolic AI	Weak AI (Machine Learning)
Interpretability	*High, based on explicit rules and logic*	*Low, especially in deep learning (black box issue)*
Scalability	*Low, difficult to scale to complex tasks*	*High, can handle vast amounts of data*
Generalization	*Low, brittle and rule-bound*	*High, generalizes from data*
Learning Capability	*No learning, relies on manually encoded rules*	*Learns from data*
Adaptability	*Low, not flexible in dynamic environments*	*High, adapts to new tasks*
Knowledge Representation	*Structured, explicit (ontologies, logic)*	*Lacks explicit knowledge representation*
Data Requirements	*Low, but requires manual rule creation*	*High, large datasets are often needed*
Consistency	*High, deterministic and predictable*	*Can be inconsistent, especially with noisy data*

Problem Formulation in AI

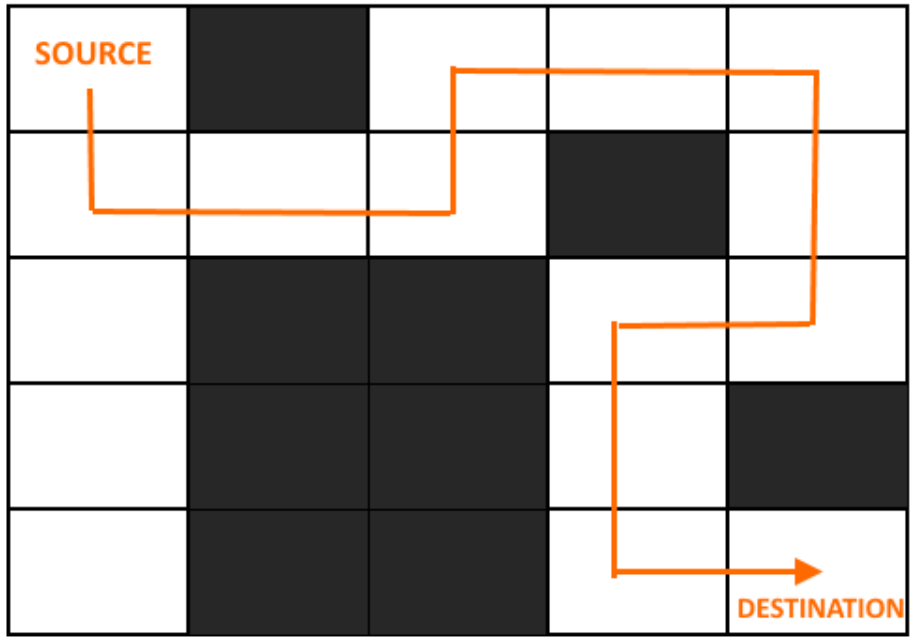
Problem Formulation: Basics

Components of a Problem

- **State space**: The set of all possible states of a problem
- **Initial state**: The starting point of a problem
- **Actions**: The operations that can be performed to change the state
- **Goal state**: The desired outcome of the problem
- **Solution**: A sequence of actions that transforms the initial state into the goal state.



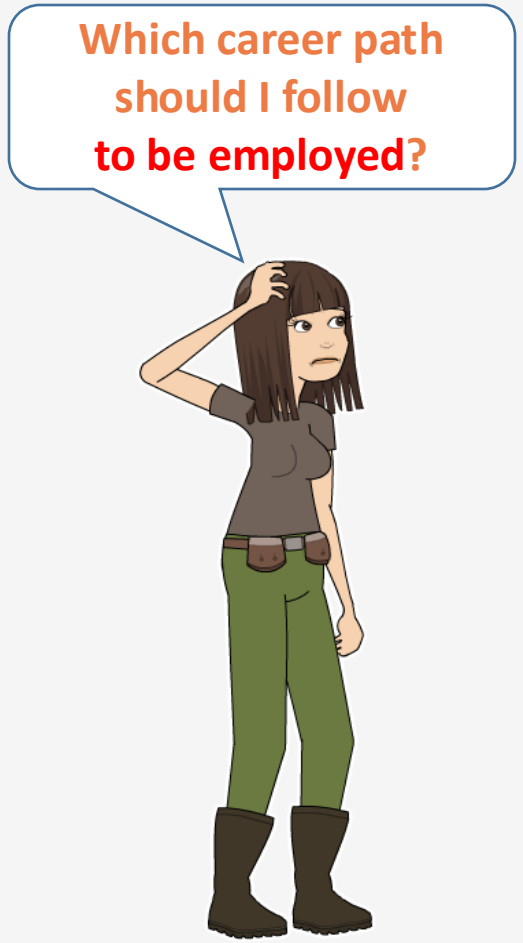
Problem Formulation: Maze Navigation



Components of a rat in a maze problem

- **State space**: Locations within the maze
- **Initial state**: The starting point of the maze
- **Actions**: move up, down, left, right
- **Goal state**: Reaching the exit, finding the cheese, etc.
- **Solution**: We'll learn during the course.

Problem Formulation: Carrier Path Selection



Components of carrier path selection

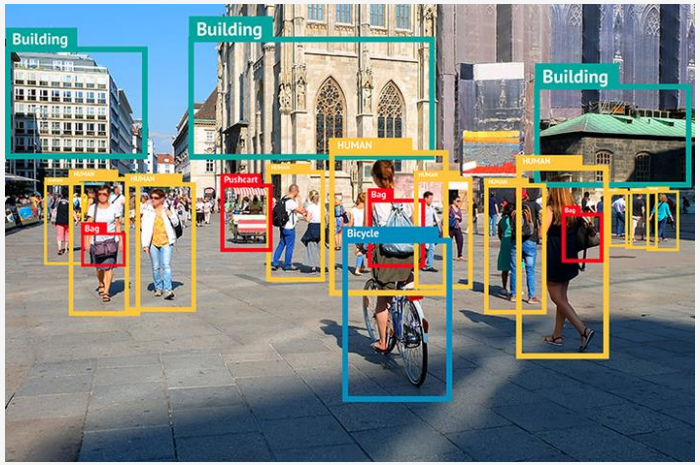
- **State space**: ?
- **Initial state**: ?
- **Actions**: ?
- **Goal state**: ?
- **Solution**: ?

Real World Problems

Real-world problems are, by nature, complex

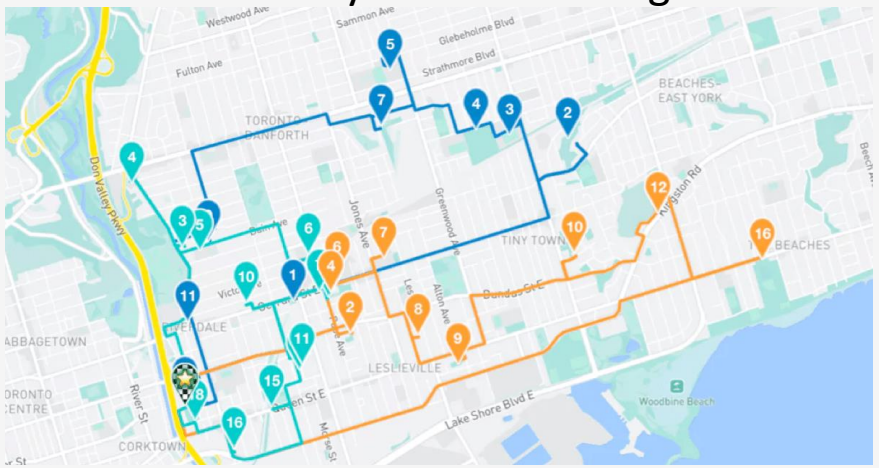
We need to simplify/model them to work on

Object Detection



Flight Route Planning

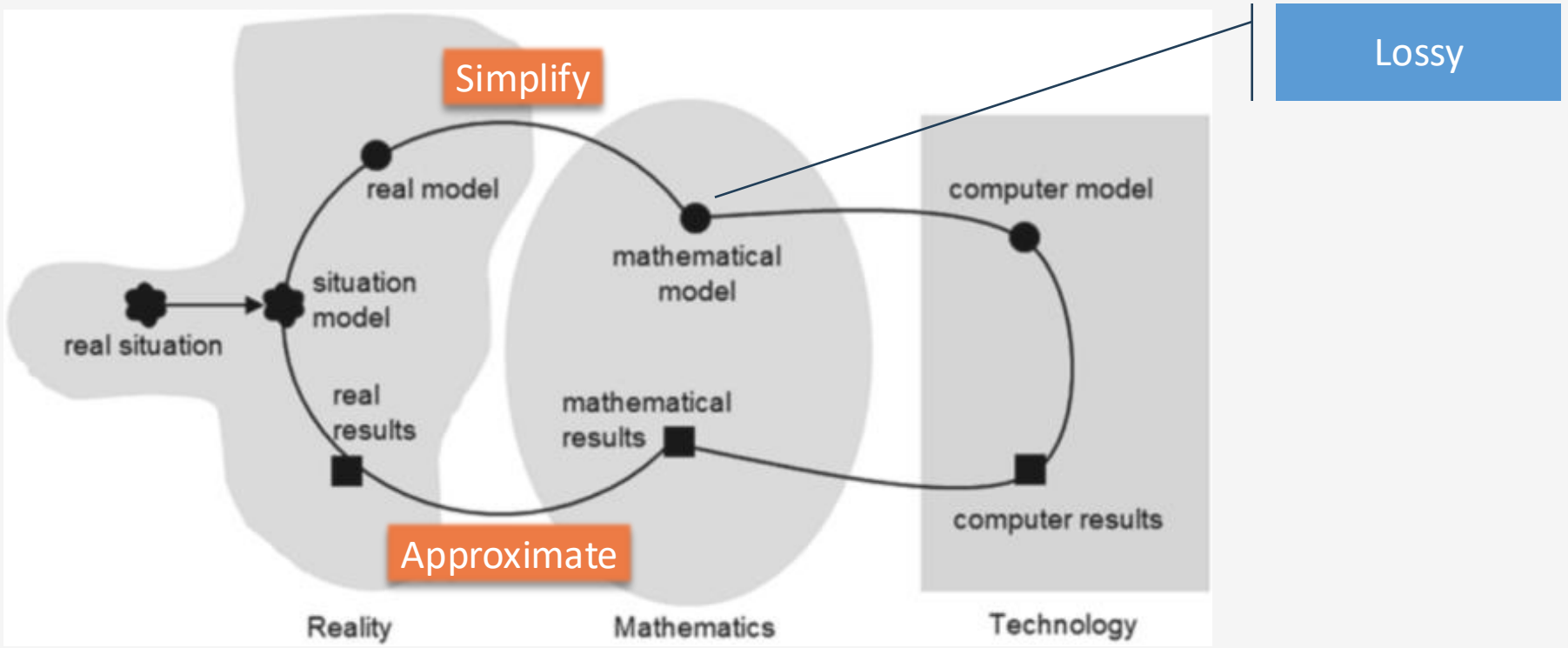
Delivery Route Planning



Real World Problems

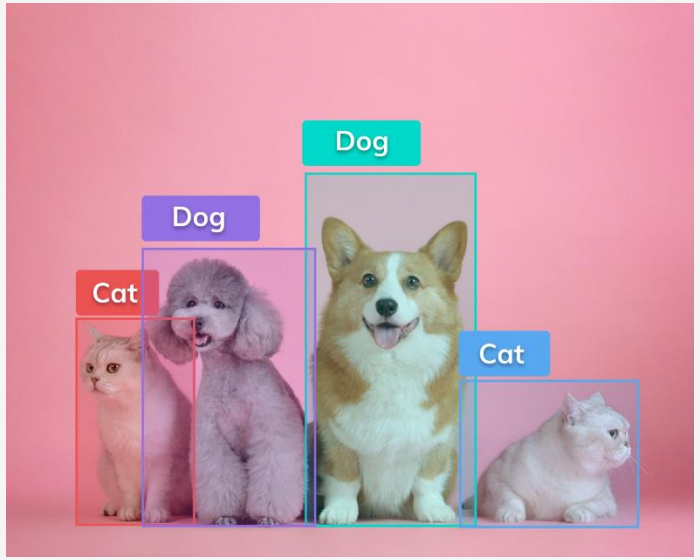
Real-world problems are, by nature, complex

We need to simplify/model them to work on



Real World Problems

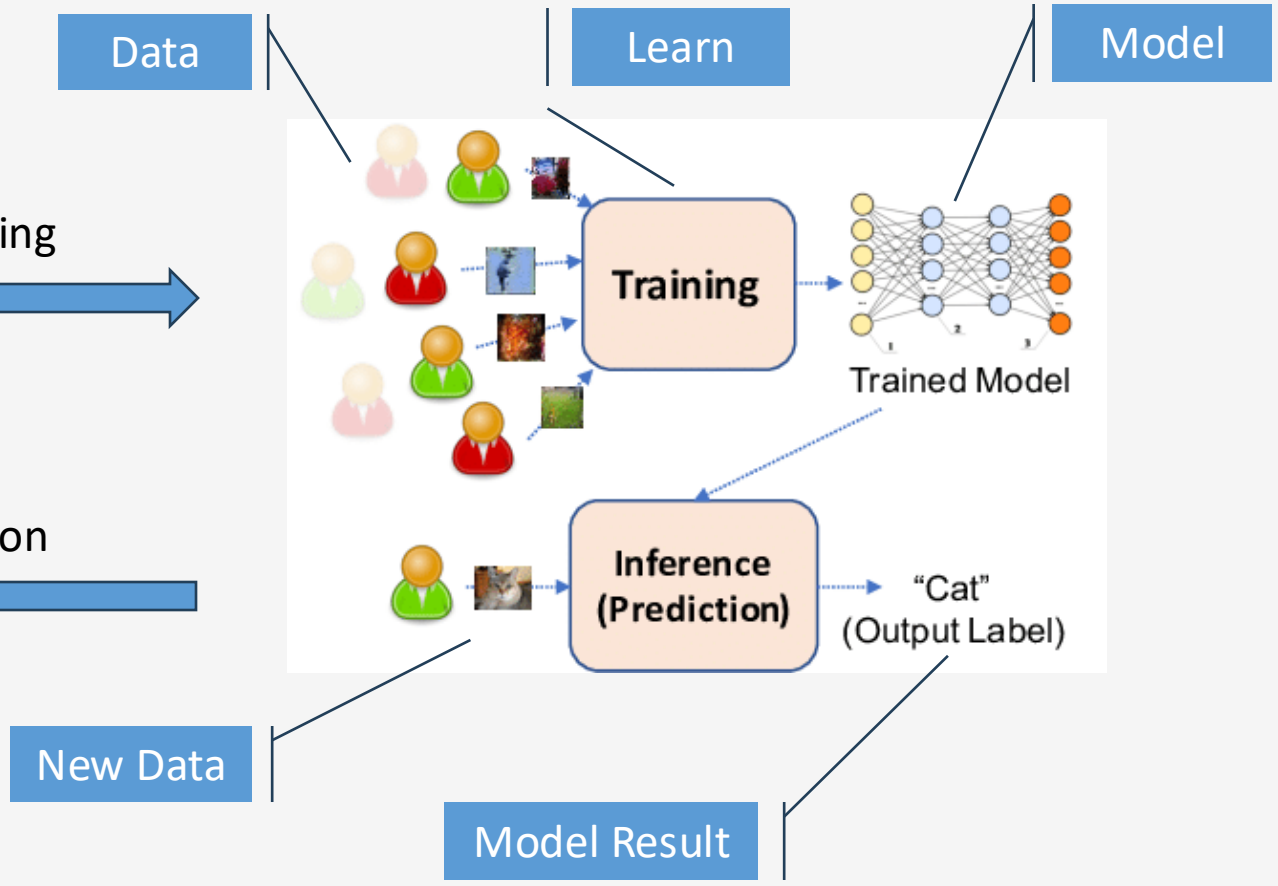
Real-world Problem



Modelling

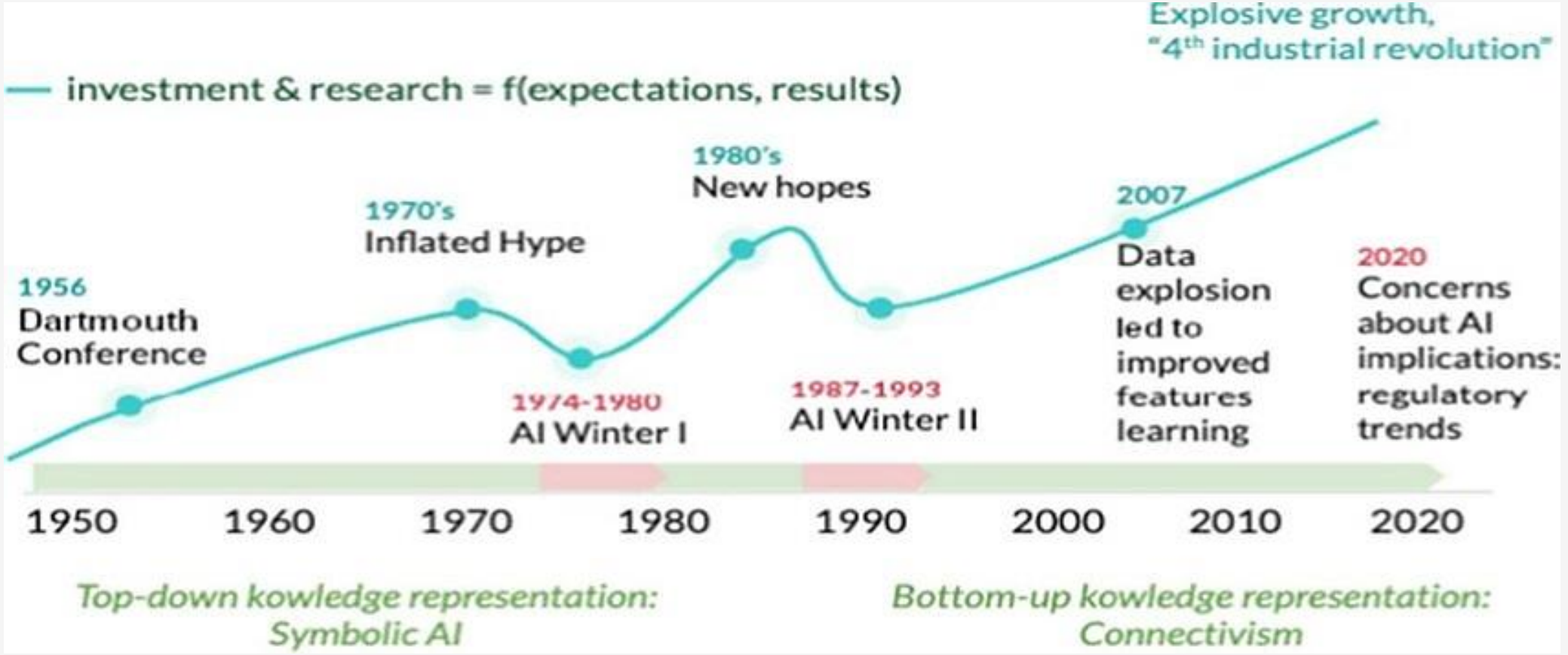
Validation

Solution to the Problem



History of AI

History of AI: at first glance



Groumpos, Peter. (2023). A Critical Historic Overview of Artificial Intelligence: Issues, Challenges, Opportunities and Threats. Artificial Intelligence and Applications. 1. 10.47852/bonviewAIA3202689.

Assignment

- Reading:
  - Chapter 1 of *Artificial Intelligence: A Modern Approach* (Stuart Russell, Peter Norvig)

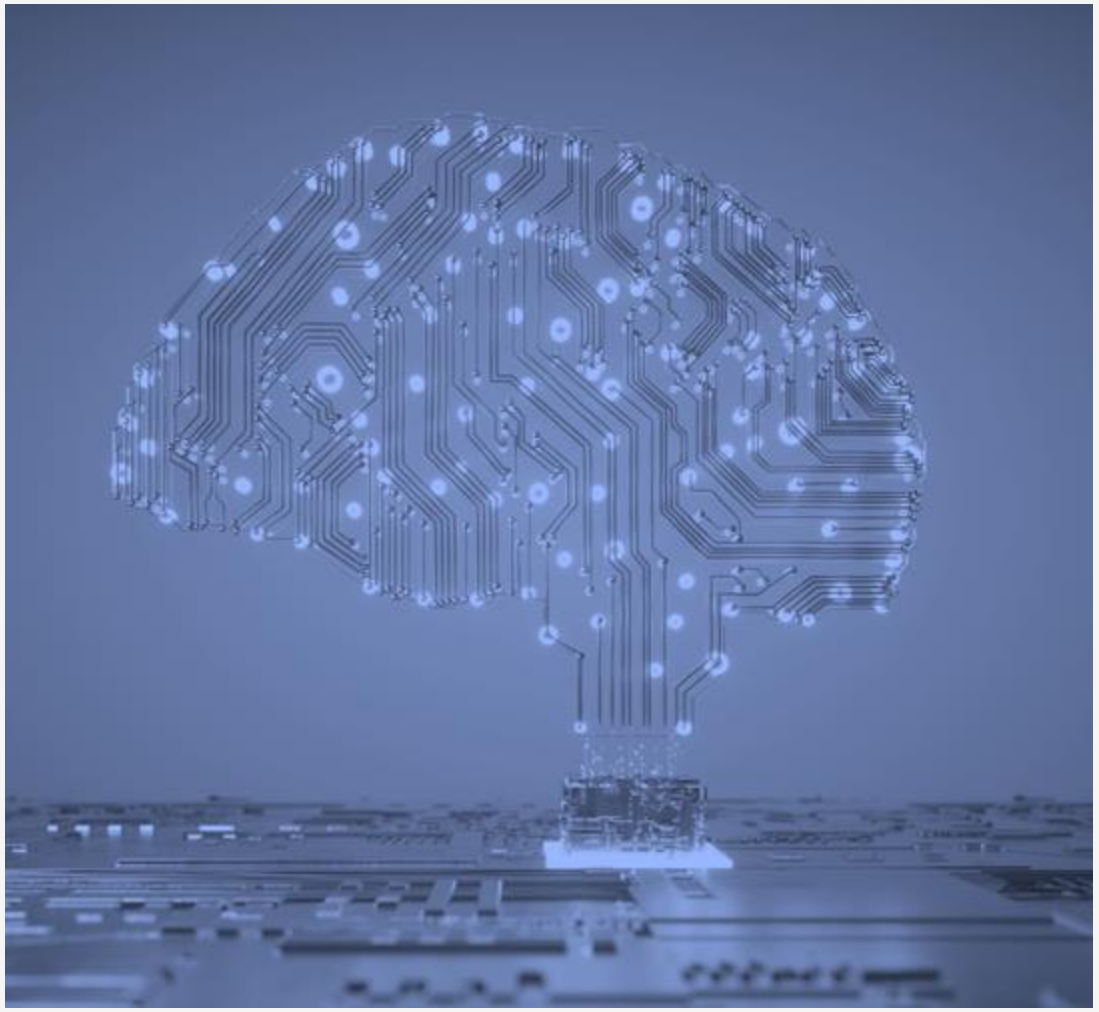
- **Create a timeline of key events in the history of artificial intelligence**, highlighting the major breakthroughs, setbacks, and trends that have shaped the development of AI.

Guidelines is in **dys.mu.edu.tr**

AI Subfields

Robotics, Natural Language Processing, Computer Vision, Expert Systems.

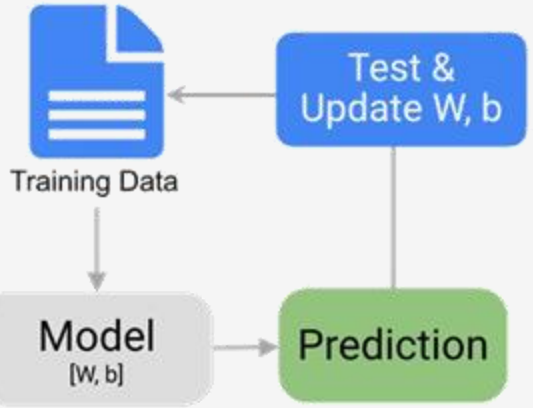
AI Subfields



1. Machine Learning (ML)
2. Natural Language Processing (NLP)
3. Robotics
4. Computer Vision
5. Expert Systems

Machine Learning

- Algorithms that allow computers to learn from data and improve their performance over time.



Applications:

- **Recommendation systems**: Suggesting products or content based on user preferences.
- **Image recognition**: Identifying objects and scenes in images.
- **Natural language processing**: Processing and generating human language.
- **Medical diagnosis**: Assisting doctors in diagnosing diseases.
- **Autonomous vehicles**: Enabling cars to drive themselves.
- …

Natural Language Processing (NLP) – CENG 3526

- The ability of computers to understand, interpret, and generate human language.

CENG 3538

Tasks:

- **Machine translation**: Translating text from one language to another.
- **Text summarization**: Creating a concise summary of a longer text.
- **Sentiment analysis**: Determining the emotional tone of a text.
- **Question answering**: Answering questions based on a given text.
- **Chatbots**: Creating conversational agents that can interact with humans.
- …

Applications:

- **Customer service**: Providing automated customer support.
- **Information retrieval**: Finding relevant information from large datasets.
- **Language learning**: Assisting language learners.
- **Content creation**: Generating creative text, such as poetry or news articles.
- **Social Media Analysis**: Identifying groups of people with similar interests or beliefs.
- **Education**: Tailoring educational content to individual student needs.
- …

Robotics: Key Components

The design, construction, and operation of robots.

Key components:

- **Mechanical structure:** The physical body of the robot, including its joints, limbs, and sensors.
- **Control system:** The software and hardware that control the robot's movements and actions.
- **Sensors:** Devices that collect information about the robot's environment, such as cameras, microphones, and touch sensors.
- **Actuators:** Devices that enable the robot to move and interact with its environment, such as motors and hydraulic cylinders.

Robotics: Types

The design, construction, and operation of robots.

Types:

- **Industrial robots:** Used in manufacturing and other industrial settings to perform repetitive tasks.
- **Service robots:** Designed to assist humans in various tasks, such as healthcare, domestic chores, and entertainment.
- **Autonomous robots:** Robots that can operate independently without human intervention.

Robotics: Applications

The design, construction, and operation of robots.

Applications:

Manufacturing: Assembly, welding, painting, and other tasks.

Healthcare: Surgery, rehabilitation, and patient care.

Exploration: Space exploration, underwater exploration, and search and rescue missions.

Entertainment: Toys, games, and theme parks.

Agriculture: Farming, harvesting, and livestock management.

Computer Vision: Key Components

The ability of computers to interpret and understand visual information from the real world.

Key components:

- **Image acquisition:** Capturing images or videos using cameras or other sensors.
- **Image preprocessing:** Enhancing the quality of images and removing noise.
- **Feature extraction:** Identifying important features in images, such as edges, corners, and textures.
- **Object detection:** Locating objects within images or videos.
- **Object recognition:** Identifying the type or category of an object.
- **Image segmentation:** Dividing images into different regions or objects.

Computer Vision: Applications

Applications:

- **Autonomous vehicles:** Enabling cars to perceive their surroundings and navigate safely.
- **Medical imaging:** Analyzing medical images, such as X-rays, MRIs, and CT scans.
- **Facial recognition:** Identifying individuals based on their facial features.
- **Augmented reality:** Overlaying digital information on top of the real world.
- **Robotics:** Enabling robots to interact with their environment and perform tasks.

Expert Systems

Computer systems that emulate the decision-making ability of human experts.

Key components:

- **Knowledge base:** A collection of facts, rules, and other information relevant to the domain of expertise.
- **Inference engine:** A mechanism for reasoning about the knowledge base and drawing conclusions.
- **User interface:** A means for interacting with the expert system.

Expert Systems

Types:

- **Rule-based systems:** Systems that use rules to represent knowledge and infer conclusions.
- **Case-based reasoning systems:** Systems that use past cases to solve new problems.
- **Neural network systems:** Systems that use artificial neural networks to represent knowledge and infer conclusions.

Expert Systems

Applications:

- **Medicine:** Diagnosing diseases, recommending treatments, and providing medical advice.
- **Finance:** Analyzing financial data, making investment decisions, and providing financial advice.
- **Engineering:** Designing products, troubleshooting problems, and providing technical support.
- **Legal:** Analyzing legal documents, providing legal advice, and assisting with legal research.
- **Education:** Providing tutoring, answering questions, and grading assignments.

Next Week

Intelligent Agents and Problem Solving

Reading:

Chapter 3-4 of
Artificial Intelligence: A Modern Approach

Topics:

- **Intelligent Agents**: Different types (simple reflex, model-based, goal-based, utility-based, learning) and their behaviors.
- **Rationality and Environments**: Concepts of rationality in AI and various environment types (fully vs. partially observable, deterministic vs. stochastic, episodic vs. sequential, static vs. dynamic, discrete vs. continuous).
- **Problem Solving by Search**: Introduction to search problems, state spaces, and basic search strategies (DFS, BFS).

Lab:

- **Agent Implementation**: Create simple reflex and model-based agents using ***Python***.
- **Environment Classification**: Analyze real-world scenarios and categorize them based on environment types.
- **Search Algorithm Implementation**: Implement DFS and BFS to solve search problems and compare their performance.
- **Agent Integration**: Incorporate search strategies into agent decision-making processes.

Next Week

Lab session requirements

Prepare Programming Environment

- Online
  - Jupyter Notebook - Google Colab
    - https://colab.research.google.com
- Offline
  - Install VSCode with python plugins
  - Install python3

* Instructions is in https://dys.mu.edu.tr