Intelligence: An Introduction

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What is Intelligence ?

- The concept of intelligence has been the subject of much debate and research over the years, and different theories have emerged to explain its nature and measurement.
- Intelligence can be defined as the ability to learn, understand, reason, adapt, and solve problems.
- It encompasses a wide range of cognitive abilities, including perception, memory, attention, language, creativity, and reasoning.
- Intelligence is not limited to any specific domain or task but is a general mental ability that allows individuals to function effectively in a variety of contexts.

Types of Intelligence

- **Emotional intelligence:** Ability to recognize and understand one's own emotions and the emotions of others, and to use this information to guide thinking and behavior, e.g.,
  - Empathy: ability to understand and share the feelings of others, and to respond in a way that shows care and respect.
- **Social intelligence:** Ability to understand and navigate social situations, and to use this knowledge to build and maintain positive relationships with others, e.g.,
  - Persuasion and influence: ability to persuade and influence others through effective communication and interpersonal skills.
- **Logical-mathematical intelligence:** Ability to reason logically and abstractly, and to use mathematical and scientific concepts to solve problems, e.g.,
  - Scientific thinking: ability to use the scientific method to gather and analyze data, and to draw valid conclusions based on evidence.

What is Artificial Intelligence ?

- Definition:
  - Field of CS that focuses on creating machines that can perform tasks that would typically require human-level intelligence to complete.
- Examples of tasks that AI can perform
  - Visual perception, speech recognition, decision-making, and language translation
- How AI works:
  - Developing algorithms and computer programs that can learn and improve their performance over time through the use of large amounts of data and feedback mechanisms.
- Potential impact of AI
  - Revolutionizing industries and transforming the way we live and work
- Future of AI
  - Rapidly growing field with new advancements and applications emerging all the time.

What is Artificial Intelligence ?

- Discipline that systematizes and automates intellectual tasks to create machines that:

Act like humans	Act rationally
Think like humans	Think rationally

Movie Time

[How artificial intelligence will change your world in 2019, for better or worse]

Characteristics of Intelligent Systems

1. **Learning:** Ability to improve performance based on experience
    a. Example: A machine learning algorithm that improves its accuracy over time as it processes more data.
2. **Adaptability:** Ability to adjust to new situations
    a. Example: An autonomous vehicle that can adjust its driving behavior based on changing road and weather conditions.
3. **Reasoning:** Ability to make decisions based on available information
    a. Example: An expert system that suggests a treatment plan based on a patient's symptoms.
4. **Creativity:** Ability to generate new and innovative ideas
    a. Example: A natural language generation system that can write creative and engaging stories.

Components of an Intelligent System

1. **Input Interface:** Allows the user or the system to input data into the intelligent system.
    a. Various forms such as voice commands, text input, sensor data, or images.
2. **Knowledge Base:** Stores the knowledge or information required for the system to make intelligent decisions.
    a. The knowledge can be represented in various forms such as rules, facts, or statistical models.
3. **Inference Engine:** Uses the knowledge base to reason and make decisions based on the input data.
    a. It applies various techniques such as deduction, induction, or abduction to draw conclusions from the available information.
4. **Output Interface:** Presents the results or decisions of the system to the user or another system.
    a. Various forms such as text output, visualizations, or actions performed by the system.

IS Components IS: Virtual Assistant

1. **Input Interface:** Voice commands [Hey Siri!]
2. **Knowledge Base:** User's calendar, contacts, and preferences, as well as general knowledge about the world such as weather forecasts, news headlines, or restaurant reviews.
3. **Inference Engine:** Applies various techniques such as natural language processing, machine learning, and rules-based reasoning to understand the user's input and provide appropriate responses.
   a. For example, if the user asks "What's the weather like today?"
      i. the system might use speech recognition to transcribe the question,
      ii. parse the text to extract the relevant keywords ("weather", "today"), and
      iii. query a weather service to retrieve the forecast for the user's location.
4. **Output Interface:** Speech
   a. "The forecast for today is sunny with a high of 28 degrees"

Most Amazing Milestones So Far

- 1997 – Deep Blue defeats world chess champion Garry Kasparov

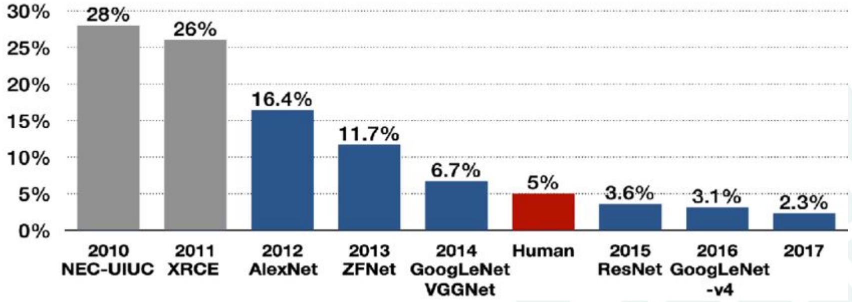
- 2005 – The DARPA Grand Challenge
- A $2 million prized race for autonomous vehicles across 100+ kms off-road terrain in the desert.

Stanford Racing Team's leader Sebastian Thrun

Most Amazing Milestones So Far

- 2011 – IBM Watson's Jeopardy! Victory
- The final tally was $77,147 to Mr. Jennings's $24,000 and Mr. Rutter's $21,600.

- 2015 – Machines "see" better than humans
- Largescale image recognition contest for classifying 50,000 high-resolution color images into 1,000 categories.
- The model is considered to have classified a given image correctly if the target label is one of the model's top 5 predictions.



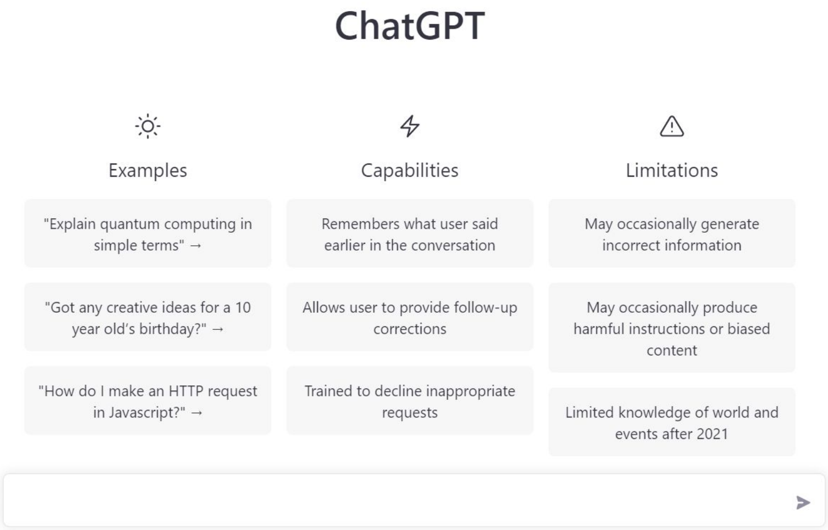
Most Amazing Milestones So Far

- 2016 – AlphaGo created by Deep Mind (now a Google subsidiary) defeated world Go champion Lee Sedol over five matches.

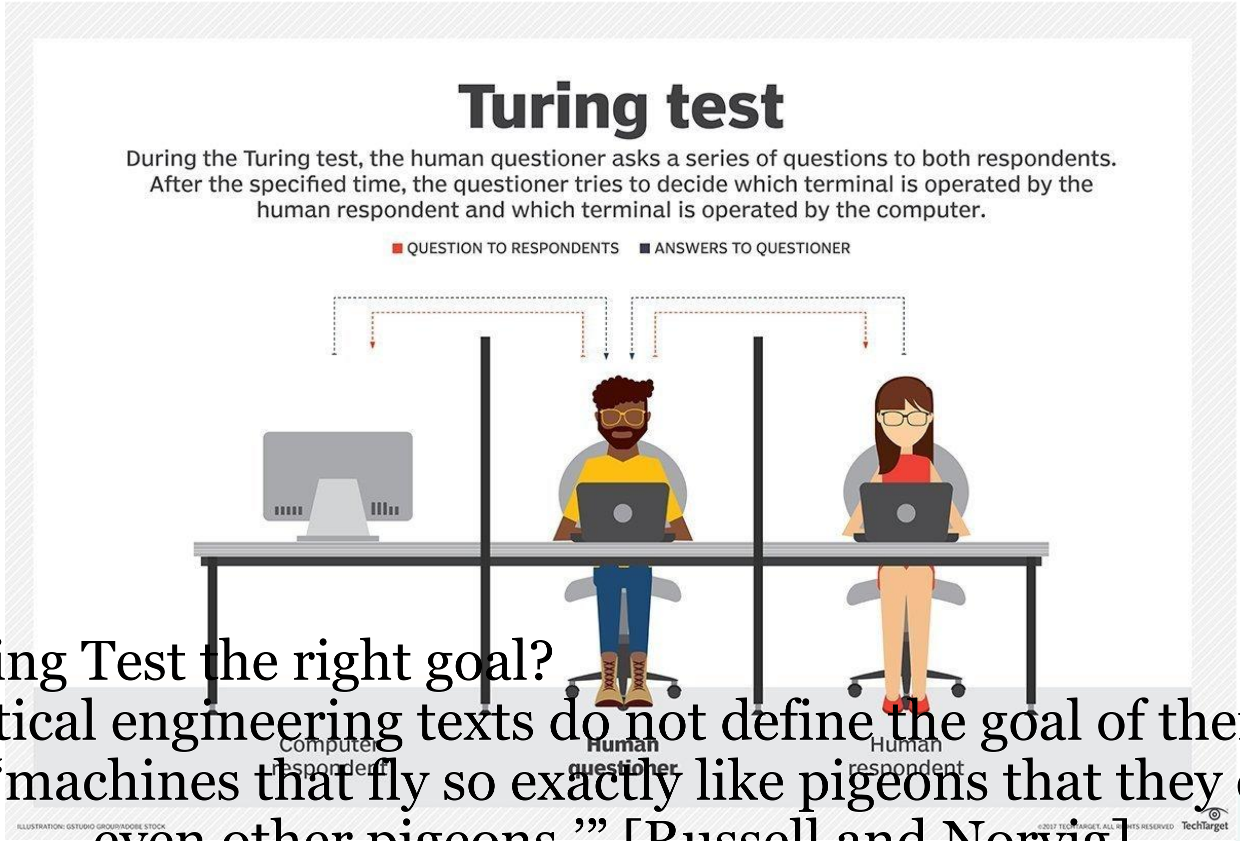
- There are over 100,000 possible opening moves in Go, compared to 400 in Chess, make the brute force approach impractical.

Most Amazing Milestones So Far

- 2020 – OpenAI created third iteration of the GPT (Generative Pre-trained Transformer) series of language models.
- Ability to understand and generate human-like language, making them useful for a wide range of applications such as language translation, content creation, and customer service.
- Advanced natural language processing techniques, deep learning, and massive amounts of training data to continuously improve their language skills.



Turing Test



- Is Turing Test the right goal?

"Aeronautical engineering texts do not define the goal of their field as making 'machines that fly so exactly like pigeons that they can fool even other pigeons.'" [Russell and Norvig]

Advantages of IS

1. **Efficiency:** IS can process vast amounts of data and information quickly and accurately, reducing the time and effort required for complex tasks.
   a. They can automate repetitive and mundane tasks, freeing up human workers to focus on more creative and strategic tasks.
   b. They can also work 24/7 without breaks or rest, providing continuous and uninterrupted service.
   c. Example: A customer service chatbot that can handle multiple inquiries simultaneously without waiting times, reducing the need for humans.
2. **Accuracy:** IS can perform tasks with a high degree of precision and accuracy, reducing errors and improving overall quality.
   a. They can also analyze data and information more objectively and consistently than humans, who may be subject to biases or variations.
   b. Example: A fraud detection system that can analyze transaction data and detect anomalies or suspicious patterns, reducing the risk of financial losses.

Advantages of IS

3. **Cost-effectiveness:** IS can often perform tasks at a lower cost than human workers, especially for tasks that are repetitive or require specialized knowledge or skills.
   a. They can also reduce the need for physical space and infrastructure, as well as lower the risk of human error and associated costs.
   b. They can also help organizations make better decisions by providing accurate and timely insights, which can lead to cost savings or revenue growth.
   c. Example: A supply chain optimization system that can analyze logistics data and suggest optimal routes and schedules, reducing transportation costs and improving delivery times.

Worries about AI

1. **Job displacement:** AI may automate many jobs, leading to unemployment or underemployment.
    a. Example: Self-driving vehicles may lead to job displacement for human drivers, such as taxi and truck drivers.

2. **Bias and discrimination:** AI may perpetuate or amplify biases in society, leading to unfair treatment of certain groups.
    a. Example: Facial recognition systems have been shown to have higher error rates for people with darker skin tones, leading to potential bias and discrimination.

3. **Privacy and security:** AI may collect, use, or misuse personal data, putting individuals and organizations at risk.
    a. Example: Social media companies may use AI to collect and analyze user data for targeted advertising, raising concerns about privacy and data protection.

Worries about AI

4. **Autonomy and control:** AI may make decisions or take actions without human oversight or intervention, raising concerns about accountability and responsibility.
   a. Example: Autonomous weapons systems may make decisions to use lethal force without human intervention, raising concerns about accountability.

5. **Misuse and abuse:** AI may be used for malicious purposes, such as cyber attacks, surveillance, or warfare.
   a. Example: Deepfake technology can be used to create convincing fake videos or images, raising concerns about the potential for misuse and abuse.

6. **Human-AI interaction:** AI may change the way humans interact with each other and with technology, raising questions about social norms, ethics, and values.
   a. Example: Chatbots and virtual assistants may change the way we communicate

Worries about AI

7. **Dependence and addiction:** AI may become so integral to our lives that we become dependent or addicted to it, leading to negative consequences for mental and physical health.
   a. Example: Social media algorithms may be designed to keep users engaged and addicted to the platform, leading to potential negative impacts on mental health and well-being.

8. **Regulation and governance:** AI may require new laws, regulations, and ethical frameworks to ensure its safe and responsible development and use.
   a. Example: Governments and regulatory bodies may need to develop new regulations and ethical guidelines to ensure that AI is developed and used in a safe and responsible manner.

Lecture 2: Knowledge Representation

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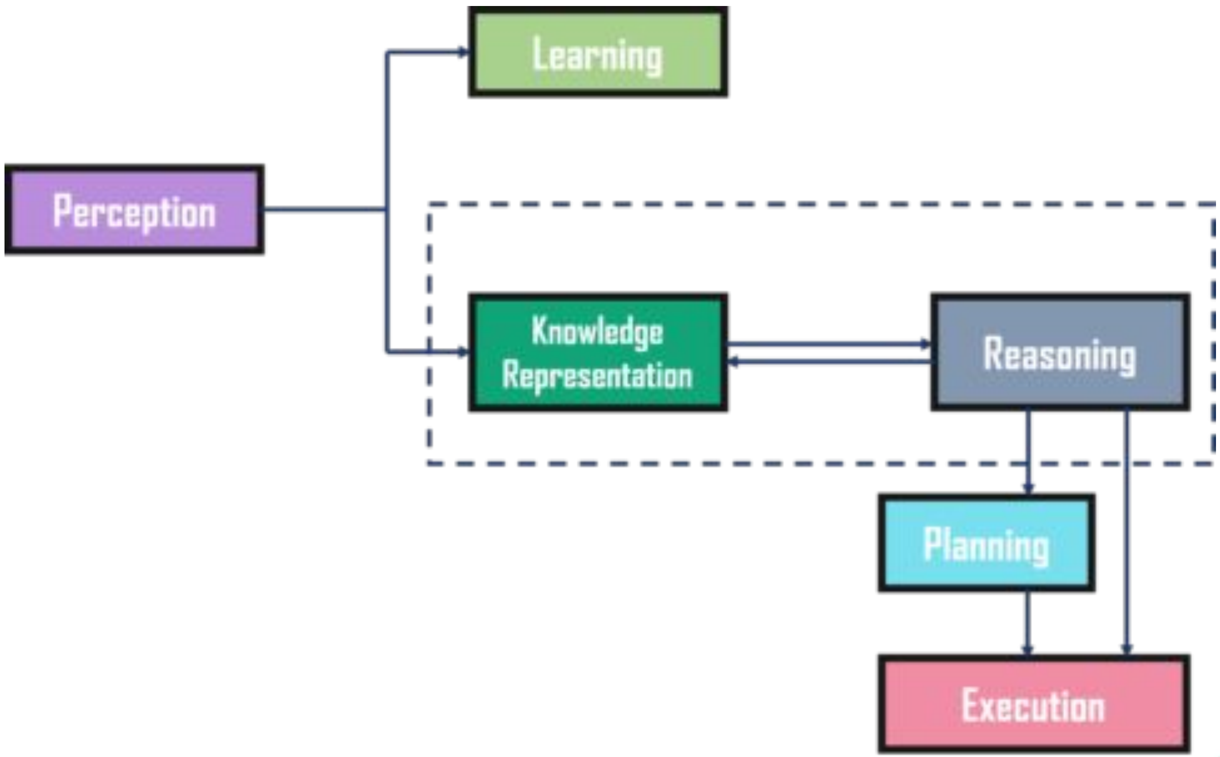
Knowledge Representation?



Knowledge Representation?

- What?
  - The process of representing knowledge in a way that can be interpreted and used by machines
  - Knowledge representation involves transforming knowledge into a structured format that can be processed and manipulated by computer programs

- Why is important?
  - Enables computers to reason, learn and make decisions based on knowledge
  - Helps in solving complex problems
  - Facilitates knowledge sharing and reuse

Types of Knowledge Representation?

- **Logic-based representation:** uses formal logic to represent knowledge, e.g., propositional logic, predicate logic
- **Semantic networks:** represent knowledge as nodes and links between them, e.g., concept maps
- **Frames and scripts:** organize knowledge into hierarchical structures with attributes and values, e.g., object-oriented programming
- **Rule-based systems:** represent knowledge as a set of rules or conditional statements, e.g., expert systems

Logic Representation: Propositional

- Uses formal logic to represent knowledge, e.g., propositional logic, predicate logic.
- Propositional logic is a type of logic-based representation that uses statements or propositions to represent knowledge.
    - Each proposition is either true or false.
- Example: All dogs are mammals
- Dog(x) -> Mammal(x)
    - where x is a variable that represents any dog.

Logic Representation: Predicate

- Predicate logic is another type of logic-based representation that uses predicates or relations to represent knowledge.
- Predicates can take one or more arguments, called terms, which can be constants, variables, or other predicates.
- Predicate logic is more expressive than propositional logic and can be used to represent more complex knowledge.
- Example: All dogs are mammals
- For all x, if Dog(x), then Mammal(x)
  - where x is a variable that represents any dog,
  - Dog is a predicate that represents the concept of being a dog, and Mammal is a predicate that represents the concept of being a mammal.
  - This logical statement means that if something is a dog, then it is also a mammal.

Logic: Pros and Cons

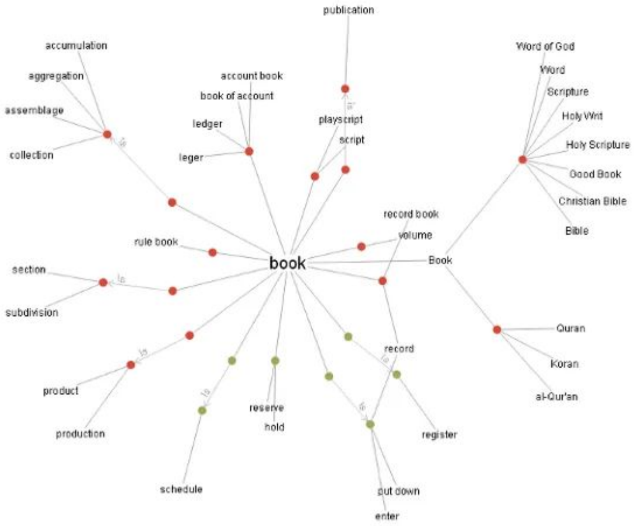
- **Advantages:**
  - Provides a formal and precise way to represent knowledge and reason about it.
  - Well-suited for tasks that involve deductive reasoning, such as automated theorem proving and decision-making.
  - Can be used to represent complex knowledge and relationships between concepts.
- **Disadvantages:**
  - Can be limiting for tasks that involve uncertain or incomplete knowledge, as it assumes a binary true/false representation of knowledge.
  - Can be difficult and time-consuming to create logic-based representations, as they often require extensive knowledge engineering.
  - May not be suitable for tasks that require more flexible or nuanced reasoning, such as natural language understanding or common-sense reasoning.

Semantic networks

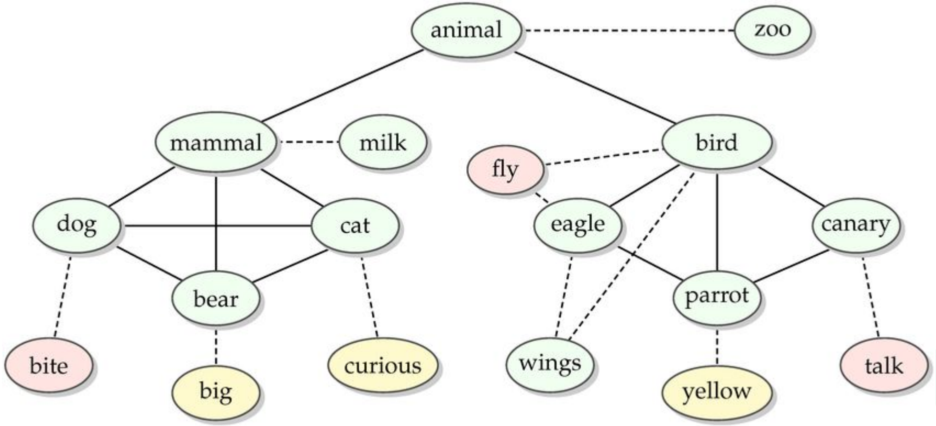
- Semantic networks provide a graphical representation of knowledge, making it easier to understand and visualize.
- Represents knowledge as nodes and links between them, e.g., concept maps.
- Nodes represent concepts or objects, and links represent relationships between them.
- They can represent complex relationships between concepts and objects.
- Suppose we want to represent knowledge about different types of food and their relationships to each other.
    - We can use a semantic network to represent this knowledge.
- For example, we can represent the concept of "pizza" as a node in the network, with links to other nodes representing related concepts such as "cheese", "tomato sauce", "pepperoni", etc.

Semantic networks

- They are useful in natural language processing, information retrieval, and knowledge-based systems.
- Examples:



WordNet: a lexical database that organizes English words into synsets (sets of synonyms)



Cyc: a large-scale knowledge base that contains a vast amount of common sense knowledge

Semantic networks: Pros and Cons

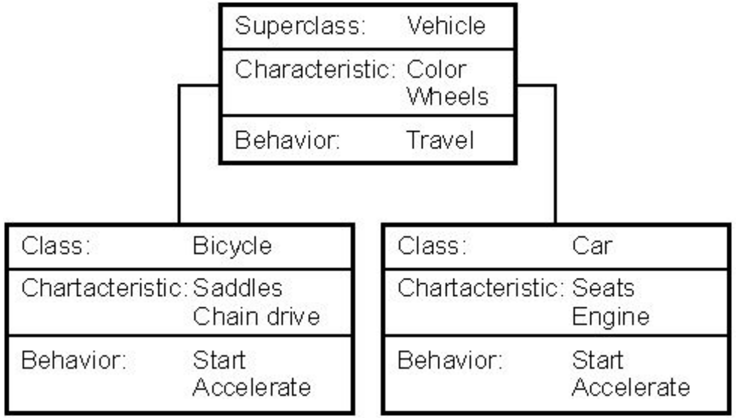
- Advantages:
  - **Easy to understand and interpret:** Graphical representation that is easy for humans to understand and interpret.
  - **Useful for taxonomies and hierarchies**
  - **Support inheritance and default reasoning:** Semantic networks can support inheritance, where properties of parent nodes are automatically inherited by child nodes.
- Disadvantages:
  - **Limited expressive power:** Limited in their expressive power and may not be able to represent complex relationships or contexts.
  - **Can be difficult to scale:** As the number of concepts and relationships in a semantic network grows, it can become difficult to manage and maintain.
  - **Can be ambiguous:** The same concept may be represented by different nodes in different parts of the network, leading to ambiguity and inconsistency.

Frames and scripts

- A type of knowledge representation technique that represents knowledge as hierarchical structures of frames or schemas.
- Frames represent concepts or objects, while scripts represent sequences of events or actions.
- Frames organize knowledge into a set of attributes or properties and their values, representing objects and concepts.
- Frames and scripts are often used in natural language understanding and other AI applications.

Example: Frames and scripts

- Suppose we want to represent knowledge about different types of vehicles, such as cars, trucks, and buses.
  - We can use frames to represent this knowledge.
- For example, we can create a frame for the concept of "car" that includes attributes such as "make", "model", "color", "year", and "number of doors".
  - Each instance of the frame would represent a specific car, with values for each attribute.



Object-oriented Programming

Frames and scripts: Pros and Cons

- Advantages:
  - Used to represent complex and detailed knowledge, including both attributes and relationships between concepts.
  - Easily extended and modified, allowing for new knowledge to be added without major restructuring of the existing knowledge.
  - Used to represent knowledge in a more natural and intuitive way than other types of knowledge representation, particularly for tasks such as natural language understanding.
- Disadvantages:
  - Computationally expensive to process and reason about, particularly for large or complex knowledge bases.
  - Prone to ambiguity and inconsistency, particularly when representing complex relationships between concepts or when multiple frames or scripts overlap or contradict each other.

Rule-based systems

- Rule-based systems represent knowledge as a set of rules that specify conditions and actions.
- Rules are often represented as if-then statements or production rules.
- Rule-based systems are often used in expert systems and other AI applications.
- Example:
- **Expert System:** A rule-based expert system for diagnosing medical conditions might have rules such as
  - "If the patient has a fever and a sore throat, then diagnose them with strep throat".
  - Another rule might be "If the patient has a rash and joint pain, then diagnose them with Lyme disease".

Example: Rule-based systems

- **Fraud detection systems:** These systems use a set of rules to identify patterns of behavior that are consistent with fraud, such as unusual spending patterns or multiple purchases in different locations within a short period of time.
- **Traffic control systems:** These systems use a set of rules to determine which traffic lights should be green, yellow, or red based on factors such as traffic volume and pedestrian crossings.
- **Manufacturing control systems:** Some manufacturing plants use rule-based systems to control the production process. For example, a plant that produces steel may use a set of rules to adjust the temperature and pressure of the furnace based on the type of steel being produced and the desired quality of the final product.

Example: Pros and Cons

- **Advantages:**
  - Can be written in a clear and concise way.
  - Can be used to model complex decision-making processes, such as in medical diagnosis or financial planning.
  - Can be used to encode expert knowledge, making it accessible to non-experts.
- **Disadvantages:**
  - Can be difficult to scale to large knowledge bases, since the number of rules can become unwieldy.
  - Can be inflexible, since they rely on pre-defined rules and may not be able to adapt to changing situations.
  - Can suffer from uncertainty and ambiguity, since rules may be incomplete or contradictory.

Ontology

- Ontologies are a way of representing knowledge by specifying a set of concepts and the relationships between them.
  - An ontology can be thought of as a structured vocabulary for a particular domain or subject area.
- Used to integrate knowledge from multiple sources and represent it in a consistent and coherent way.
- Allow for reasoning about the relationships between concepts, such as inferring new knowledge based on existing knowledge.
- Can be used to represent knowledge in a wide range of domains, such as biology, medicine, finance, and more.
- Examples:
  - Gene Ontology and FOAF Ontology
- Typically represented using a formal language, such as the Web Ontology Language (OWL).

How to Choose?

- **Expressiveness:** More expressive techniques are better suited for representing complex and abstract knowledge.
- **Ease of use:** Techniques that are intuitive and easy to learn are preferred, especially for applications that involve a large number of knowledge sources.
- **Scalability:** Techniques that can scale to large knowledge bases are preferred for applications that involve big data or knowledge-intensive tasks.
- **Maintainability:** Techniques that are easy to update and maintain are preferred, especially for applications that require frequent updates or changes to the knowledge base.

Suggestion

- Semantic networks are best suited for representing simple knowledge that can be easily visualized as a network.
  - Example: A map of the connections between cities.
- Frames are best suited for representing complex objects that have many different properties and relationships.
  - Example: Description of a car that includes its make, model, year, color, and other attributes.
- Rules are best suited for representing knowledge that involves decision-making or inference.
  - Example: Set of rules that determine whether a loan application should be approved or denied.
- Ontologies are best suited for representing knowledge in complex domains that involve many different concepts and relationships.
  - Example: Gene Ontology, which represents knowledge about genes and their functions.

Lecture 3: Reasoning, Logic and Inferences - An overview

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First Things First!

- Introduction
- Recap

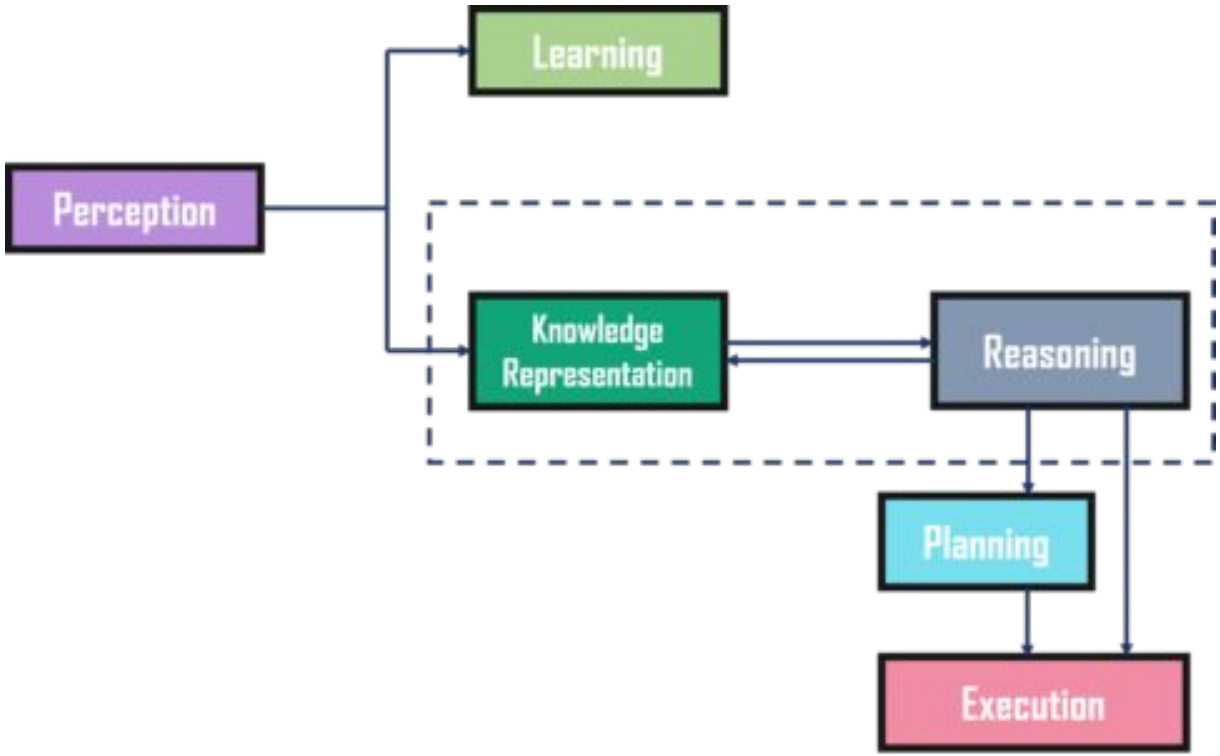
Intelligence: An Introduction

- What is Intelligence?
- Types of Intelligence
- What is AI?
- Characteristics and components of Intelligent Systems
- Most Amazing Milestones So Far
- Turing Test
- Advantages and worries of IS

Knowledge Representation

- What is KR?
- Why KR is important?
- Types of Knowledge Representation?
- Ontology
- How to Chose?

Why reasoning, logic, and inference?



Knowledge Representation: Logic

- Logic provides a formal and precise framework for representing knowledge and reasoning in intelligent systems.
- Propositional logic is a type of logic-based representation that uses statements or propositions to represent knowledge.
    - Each proposition is either true or false.
- Example:
    - All men are mortal [p]
    - Socrates is a man [q]
    - Therefore, Socrates is mortal. [r]
- Predicate logic is another type of logic-based representation that uses predicates or relations to represent knowledge.
    - Predicates can take one or more arguments, called terms, which can be constants, variables, or other predicates.

Reasoning

- Reasoning is the cognitive process of making inferences, drawing conclusions, and arriving at judgments based on available information, evidence, and beliefs.

- It is the ability to use existing knowledge to analyze and solve problems, make decisions, and plan actions.

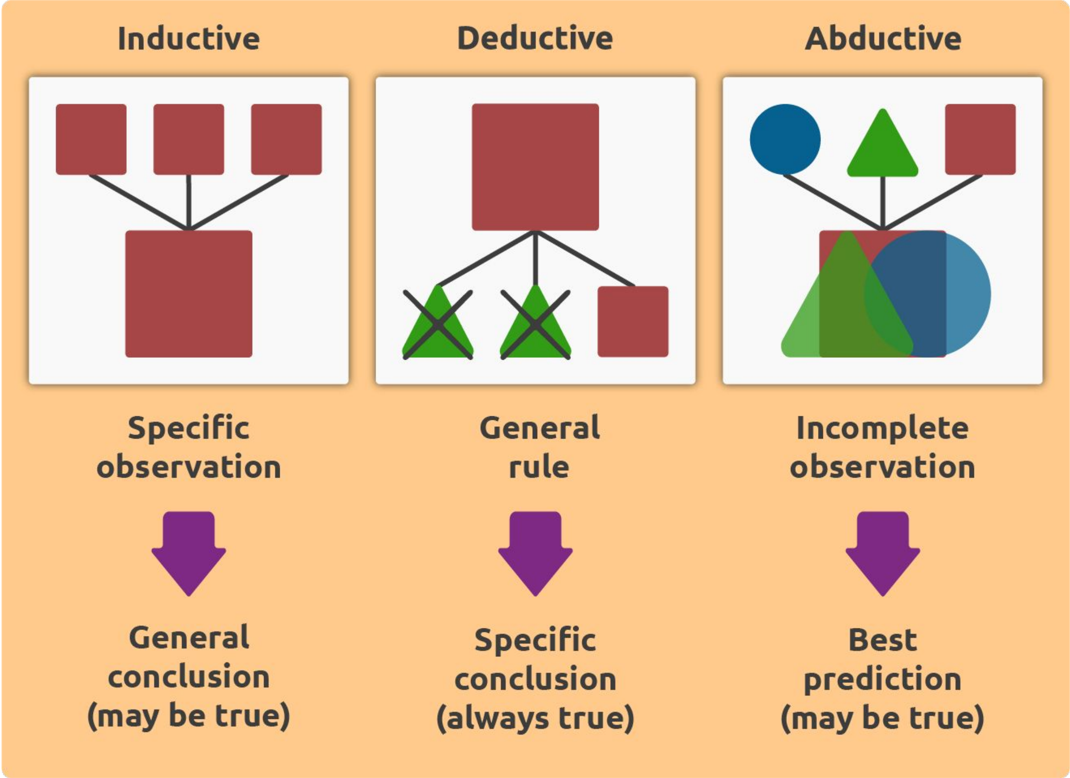
- Reasoning is a crucial component of intelligence and is utilized in various fields such as science, mathematics, law, philosophy, and everyday life.

Inference

- Inference is the process of drawing conclusions based on available **Knowledge** and **logical reasoning**.

Reasoning

- Enables IS to draw conclusions based on available information.



Deductive Reasoning

- Deductive reasoning helps in making logical conclusions based on known facts and rules.
  - E.g., medical diagnosis may use deductive reasoning to identify the underlying cause of a patient's symptoms.
- Deductive reasoning starts with a general premise or statement, and then uses logical steps to arrive at a specific conclusion.
- In this type of reasoning, if the premises are true, then the conclusion must be true.
- Examples:
  - All birds have feathers. Penguins are birds.
    - Therefore, penguins have feathers.
  - If it rains, the streets will be wet. It is raining.
    - Therefore, the streets are wet.

Inductive Reasoning

- Inductive reasoning involves making generalizations based on specific observations or evidence.
  - E.g., predicting stock prices may use inductive reasoning to identify patterns in historical data to make predictions.
- It is used to infer patterns, relationships, or trends that may exist in a set of data or observations.
- Inductive reasoning is probabilistic, meaning that the conclusion is not necessarily true, but rather likely to be true based on the evidence.
- Examples:
  - Every cat I have ever seen has fur. Therefore, all cats have fur.
  - The sun has risen every day for as long as humans have existed. Therefore, the sun will rise tomorrow.
  - Based on the data, it appears that people who exercise regularly live longer than those who don't. Therefore, exercising is beneficial for longevity.

Abductive Reasoning

- Abductive reasoning, on the other hand, is a form of reasoning that involves making educated guesses or hypotheses based on *limited information or incomplete data*.
    - E.g., If a patient presents with a fever, cough, and chest pain, the IS may use abductive reasoning to identify the most likely cause of the symptoms among pneumonia, bronchitis, or the flu.
- It is used to generate plausible explanations for a particular observation or phenomenon, even when there is insufficient evidence to support any single explanation definitively.
- Abductive reasoning is often used in scientific inquiry to generate hypotheses that can be tested through further observation and experimentation.
- Examples:
    - A detective investigating a crime scene uses abductive reasoning to develop a theory about what happened based on the available evidence.

QUIZ - 3.1

Everyone passed the IIS course in the previous offerings. So everyone will pass IIS this year.

This is an example of -

A) Deductive Reasoning
B) Inductive Reasoning
C) Abductive Reasoning
D) None of the above

Examples of Reasoning in IS

- Machine learning: ML algorithms use inductive reasoning to learn patterns and relationships in data.
    - For example, a classification algorithm may use historical data to identify patterns and then use these patterns to classify new data.
- Natural language processing: NLP systems use deductive reasoning to understand and interpret natural language.
    - For example, an NLP system may use a set of rules and logic to infer the meaning of a sentence based on its grammatical structure and the context in which it appears.
- Autonomous vehicles: Autonomous vehicles use a combination of deductive and inductive reasoning to navigate their environment and make decisions.
    - For example, a self-driving car may use deductive reasoning to interpret traffic signs and signals, and inductive reasoning to learn from past experiences and adjust its behavior accordingly.

Propositional Logic

- Propositions are represented using propositional symbols or variables that can take on the values of true or false.
- Logical operators such as negation, conjunction, disjunction, implication, and equivalence are used to combine propositions and form complex statements.
- Truth tables are used in propositional logic to determine the truth value of a complex statement based on the truth values of its constituent propositions.

T	T	T
T	F	T
F	T	T
F	F	F

Propositional Logic: Inference Rules

- Inference rules are used in propositional logic to derive new statements from existing ones.
- Example:
- Modus Ponens:
    - If p implies q and p is true, then q must be true as well.
    - Symbolically: $(p \rightarrow q) \land p \rightarrow q$
    - Example:
    - If it is raining, the ground is wet. It is raining.
        - Therefore, the ground is wet.
- Modus Tollens:
    - If p implies q and q is false, then p must be false as well.
    - Symbolically: $(p \rightarrow q) \land \sim q \rightarrow \sim p$
    - Example:
    - If it is raining, the ground is wet. The ground is not wet.
        - Therefore, it is not raining.

Propositional Logic: Inference Rules

- Law of Syllogism:
  - If p implies q and q implies r, then p implies r.
  - Symbolically: $(p \rightarrow q) \land (q \rightarrow r) \rightarrow (p \rightarrow r)$
  - Example:
  - If it is raining, the ground is wet. If the ground is wet, the shoes are muddy. Therefore, if it is raining, the shoes are muddy.

Predicate Logic

- Predicates are expressions that are true or false of a given object, and variables are placeholders that stand for objects.
- Quantifiers are used in predicate logic to express the scope of a variable in a statement.
- The two main quantifiers in predicate logic are
  - the universal quantifier ($\forall$), which means "for all,"
    - Example: $\forall x, x + 2 > x$
    - For any value of x, x + 2 will always be greater than x.
  - the existential quantifier ($\exists$), which means "there exists."
    - Example: $\exists x$, x^2 = 25
    - There is at least one value of x that makes the statement true, in this case, x can be either 5 or -5.
- Combined quantification:
  - $\forall x \exists y, x + y = 10$

Predicate Logic: Inference Rules

- Universal Instantiation:
  - Universal instantiation is a rule of inference that allows you to derive a specific instance of a universally quantified statement.
    - $\forall x\ (dog(x) \rightarrow bark(x))$
  - From the statement $\forall x\ (dog(x) \rightarrow bark(x))$, we can infer bark(Monica) by substituting Monica for x, since Monica is a dog.
  -
- Existential Instantiation:
  - Existential instantiation is a rule of inference that allows you to derive an instance of an existentially quantified statement.
    - $\exists x\ (dog(x) \wedge bark(x))$
  - From the statement $\exists x\ (dog(x) \wedge bark(x))$, we can infer bark(Monica) by introducing a new variable y and substituting Monica for y, since Monica is a dog that barks.

QUIZ - 3.2

The correct predicate logic for the following statement is -
"Everyone who studies at IIITD is smart"

A) $\forall$x (smart(x) -> studies(x,IIITD))
B) $\forall$x (studies(x,IIITD) ^ smart(x))
C) **$\forall$x (studies(x,IIITD) -> smart(x))**
D) None of the above

Putting it all together!

- If you get 95 on the final exam for IIS, then you get an A for the course.
  - Someone, call him/her say c, gets 95 on the final exam. Therefore c gets an A for IIS.
  - This argument uses Existential Instantiation as well as a couple of others as can be seen below.
- Let the universe be the set of all people in the world, let N(x) mean that x gets 95 on the final exam of IIS, and let A(x) represent that x gets an A for IIS.
  - 1. $\forall x\ [\ N(x) \rightarrow A(x)\ ]$: Hypothesis
  - 2. $\exists x\ N(x)$: Hypothesis
  - 3. N(c): Existential instantiation on 3.
  - 4. $N(c) \rightarrow A(c)$: Universal instantiation on 1.
  - 5. A(c): Modus ponens on 3 and 4.
- Note that the order of steps 3 and 4 can not be reversed.

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Introduction to Intelligent Systems

CSE 140

Lecture on Prolog

Tip: Take your own notes during lectures

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Types of programming

- Imperative programming
  - Sequences of steps to detail out how to reach a goal / do a computation

  - Procedural programming languages: Basic, C, Fortran, Cobol, Pascal etc.
  - Object-oriented programming languages: C++, Java, Python etc.

- Declarative programming
  - Instead of specifying 'how' to achieve a goal / computation in a certain situation, you specify 'what' the situation and 'goals' are and the language has mechanisms to find out 'how' to achieve that.

  - Functional programming languages: Haskell
  - Logic programming languages: Prolog
    - useful for certain problem solving tasks in AI, in domains such as search, planning, and knowledge representation

Prolog = Programming in Logic

Main advantages

- ease of representing knowledge
- natural support of non-determinism
- natural support of pattern-matching
- natural support of meta-programming

Other advantages

- meaning of programs is independent of how they are executed
- simple connection between programs and computed answers and specifications
- no need to distinguish programs from databases

CONCEPT 1 - procedure definitions

Programs consist of *procedure definitions*

A procedure is a resource for evaluating something

EXAMPLE

```
a :- b, c.
```

This is read procedurally as a procedure for *evaluating* a by evaluating both b and c

Here “evaluating” something means determining whether or not it is true according to the program as a whole

Slide reused from Prolog Programming, CM20019-S1 Y2006/07

Prolog (we will use swi-prolog)

Facts

```
bigger(elephant, horse).
bigger(horse, donkey).
bigger(donkey, dog).
bigger(dog, monkey).
bigger(monkey, cat).
bigger(cat, rat).
```

Prolog

Query

```
?- bigger(horse, donkey).
Yes

?- bigger(monkey, dog).
No
```

since query fails to find a relevant fact

Prolog

```
?- bigger(elephant, cat).
No.                          /* not correct answer */
```

Because no rules present (clauses)

Clauses

```
is_bigger(X, Y) :- bigger(X, Y).
is_bigger(X, Y) :- bigger(X, Z), is_bigger(Z, Y).
```

X, Y, Z are variables.

Constants start with lowercase letters.

```
?- is_bigger(elephant, cat).          -- Goal and subgoals
Yes
```

Prolog

```
grandfather(X,Y) :-  father(X,Z), parent(Z,Y).

parent(A,B) :- mother(A,B).
parent(A,B) :- father(A,B).

father(hari, shailja).
father(vivek, ram).
mother(reena, shyam).
mother(shailja, radha).
father(vinay, reena).
father(vivek, ravi).
```

CONCEPT 2 - procedure calls

Execution involves evaluating calls, and begins with an *initial query*

EXAMPLES

```
?- a, d, e.
?- likes(chris, X).
?- flight(gatwick, Z), in_poland(Z), flight(Z, beijing).
```

The queries are asking whether the calls in them are true according to the given procedures in the program

Prolog evaluates the calls in a query *sequentially*,
in the *left-to-right order*, as written

?- a, d, e. evaluate a, then d, then e

Convention: terms beginning with an *upper-case letter* or an *underscore* are treated as *variables*

?- likes(chris, X). here, X is a variable

Queries and procedures both belong to the class of logic sentences known as *clauses*

CONCEPT 3 - computations

- A *computation* is a chain of derived queries, starting with the *initial query*
- Prolog selects the *first call in the current query* and seeks a program clause whose head matches the call
- If there is such a clause, the call is replaced by the clause body, giving the next derived query
- This is just applying the standard notion of procedure-calling in any formalism

Slide reused from Prolog Programming, CM20019-S1 Y2006/07

EXAMPLE

```
?- a, d, e.
```
initial query

```
a :- b, c.
```
program clause with head a and body b, c

Starting with the initial query, the first call in it matches the head of the clause shown, so the derived query is

```
?- b, c, d, e.
```

Execution then treats the derived query in the same way

CONCEPT 4 - successful computations

A computation succeeds if it derives the empty query

EXAMPLE

```
?- likes(bob, prolog).        query
likes(bob, prolog).           program clause
```

The call matches the head and is replaced by the clause's (empty) body, and so the derived query is empty.

So the query has succeeded, i.e. has been solved

Slide reused from Prolog Programming, CM20019-S1 Y2006/07

Prolog (contd)

- Prolog based on first-order logic.
- Every program is a set of Horn clauses. (Horn clause is a clause that has at most one positive literal)
- Inference is by resolution.
- Search is by backtracking with unification.
- Basic data structure is term.
- Variables are unknowns not locations.
- Prolog does not distinguish between a variable being an input or as a output. It solves relations/predicates.

Prolog (contd)

- Program is facts + rules.
- Query is conjunct of predicates.
- First set of bindings for variables that solve query are reported. If none, then Prolog returns no.
- Use “;” to get more solutions.
- Can be viewed as constraint satisfaction program.

Lecture 5-6: Basic Machine Learning Concepts

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Reasoning, Logic and Inferences

- Logic, Reasoning and Inference
- Types of reasoning
- Propositional Logic: Inference Rules
- Predicate Logic: Inference Rules

Prolog

- Declarative programming
- Procedure definition: Facts, Rules and Queries
- Procedure call evaluations: Trace
- Computation
- Practise on SWI-Prolog

Why ML: From Rules to Data

Exercise

- Input: 1 | 2 | 3 | 4 | 5 | 6
- Output: 1 | 3 | 5 | 7 | 9 | ?
- Input = 6 -> Output = ?
  - Output = 11
  - $y = 2x - 1$
- Input: 1 | 2 | 3 | 4 | 5 | 6
- Output: 3 | 8 | 15 | 24 | 35 | ?
- Input = 6 -> Output = ?
  - 35
  - $y = x*(x+2)$

What is Machine Learning?

- Term “Machine Learning” coined by Arthur Samuel in 1959.
    - Samuel Checkers-playing Program

- Common definition (by Tom Mitchell)

    - Machine Learning is the study of computer algorithms that improve automatically through experience
- Study of algorithms that
    - improve their performance P
    - at some task T
    - with experience E

- Well-defined learning task: <P,T,E>

Task (T)

- Classification or Pattern Recognition
- Regression or Prediction
- Clustering
- Synthesis or Sampling
- Ranking
- Recommendation Systems
- Anomaly Detection
- Data Mining etc.

Performance (P)

- A quantitative measure to evaluate performance
  - Usually Task specific
- Classification
  - Accuracy or Error Rate
  -

		Predicted Class: Positive	Predicted Class: Negative	
Actual Class	Positive	True Positive (TP)	False Negative (FN) **Type II Error**	**Sensitivity** $\frac{TP}{(TP+FN)}$
	Negative	False Positive (FP) **Type I Error**	True Negative (TN)	**Specificity** $\frac{TN}{(TN+FP)}$
		Precision $\frac{TP}{(TP+FP)}$	**Negative Predictive Value** $\frac{TN}{(TN+FN)}$	**Accuracy** $\frac{TP+TN}{(TP+TN+FP+FN)}$

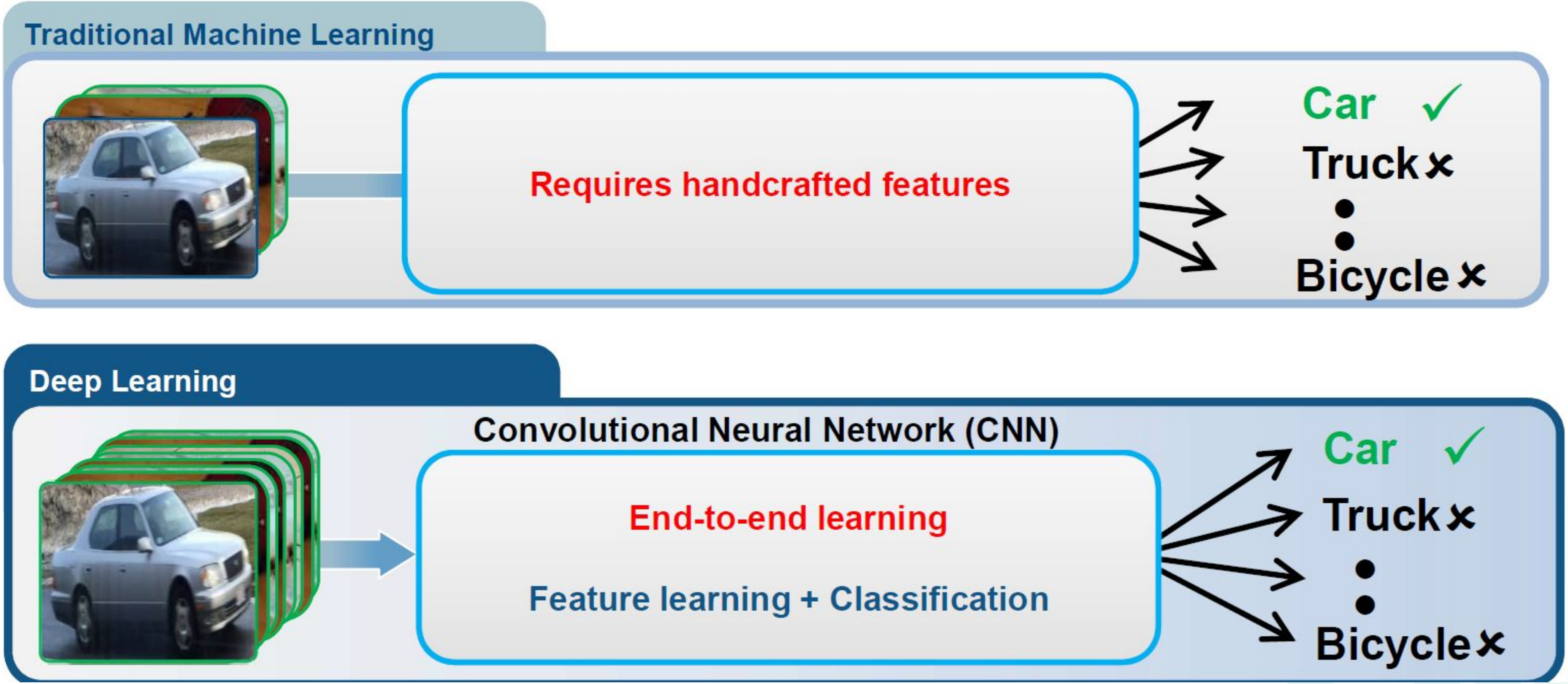
Experience (E): Types of ML

- Supervised Learning
  - Labelled data – (Data, target value)
  - Target value could be category/class labels, real value, real vector, etc.
  - Classification, Regression
- Unsupervised Learning
  - Only data, no labels
  - Dimensionality Reduction, ICA, Clustering
- Reinforcement Learning
  - No examples, but a reward function
  - Payoff based on actions

Training and Testing

Training Phase

ML vs DL

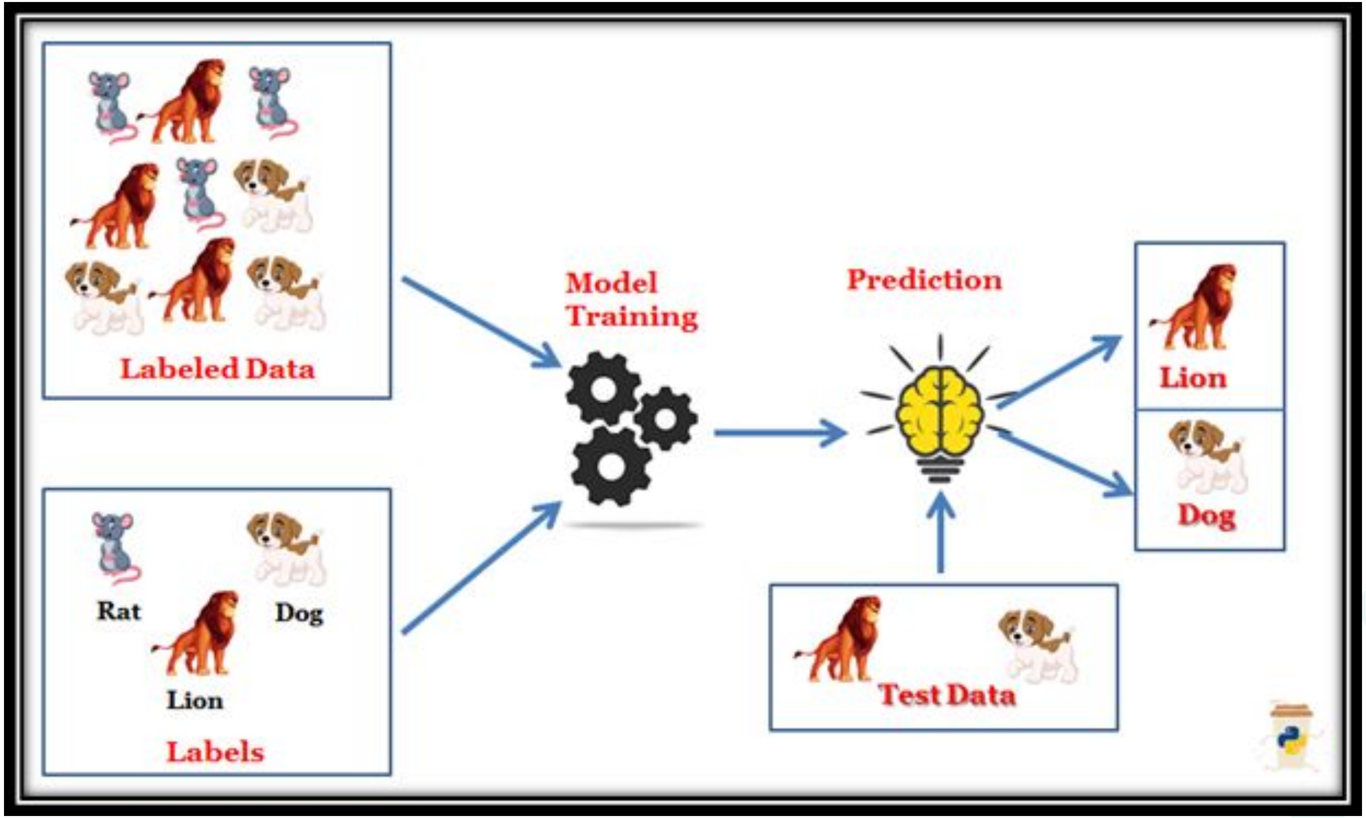


Traditional Machine Learning
Requires handcrafted features
Car ✓
Truck ×
Bicycle ×
Deep Learning
Convolutional Neural Network (CNN)
End-to-end learning
Feature learning + Classification
Car ✓
Truck ×
Bicycle ×

When to avoid ML?

- Simple or deterministic problems: If the problem can be solved through simple rules or deterministic algorithms, then ML may not be necessary.
- Insufficient or poor quality data: If the data is incomplete, noisy, biased, or of poor quality, then the ML model may not be effective or may produce inaccurate or biased results.
- When the cost of errors is high: Machine learning models are not perfect, and they can make mistakes. For example, diagnosis of medical conditions.
- Lack of interpretability: Some ML models, such as deep neural networks, can be difficult to interpret. This can be problematic in situations where it is important to understand how the model is making decisions.

Supervised Learning



Supervised Learning

- An algorithm is trained on a labeled dataset, where each input data point is associated with a corresponding output value or label.
  - $\mathbf{D} = \{(x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n)\}$
- The goal is to learn a mapping function that can predict the output value for new, unseen input data points.
  - $\mathbf{f : X \text{ -> } Y}$
- **Input:** Training examples $\{<x_i,y_i>\}$
- **Output:** Hypothesis $h \in H$ that best approximates target function f
- **Examples:**
  - **Classification:** The input data is assigned to a category or class, such as whether an email is spam or not.
  - **Regression:** The output value is a continuous variable, such as predicting the price of a house based on its features.

Few Supervised Learning Algorithms

- **Classification:**
  - Decision Trees: A tree-based model that splits the input data into smaller subsets based on the values of different features, and makes a prediction based on the final subset.
  - Support Vector Machines (SVM): A model that finds the optimal hyperplane that separates the input data into different classes.
  - Neural Networks: A model that consists of multiple layers of interconnected neurons, and is capable of learning complex, non-linear mappings between the input and output data.
- **Regression:**
  - Linear Regression: A linear model that seeks to fit a straight line to the input data that minimizes the difference between the predicted and actual output.
  - Polynomial Regression: A non-linear model that fits a polynomial function to the input data, allowing for more complex relationships between the input and output variables.
  - Support Vector Regression (SVR): A model that seeks to find the optimal hyperplane that separates the input data into different classes while minimizing the difference between the predicted and actual output values.

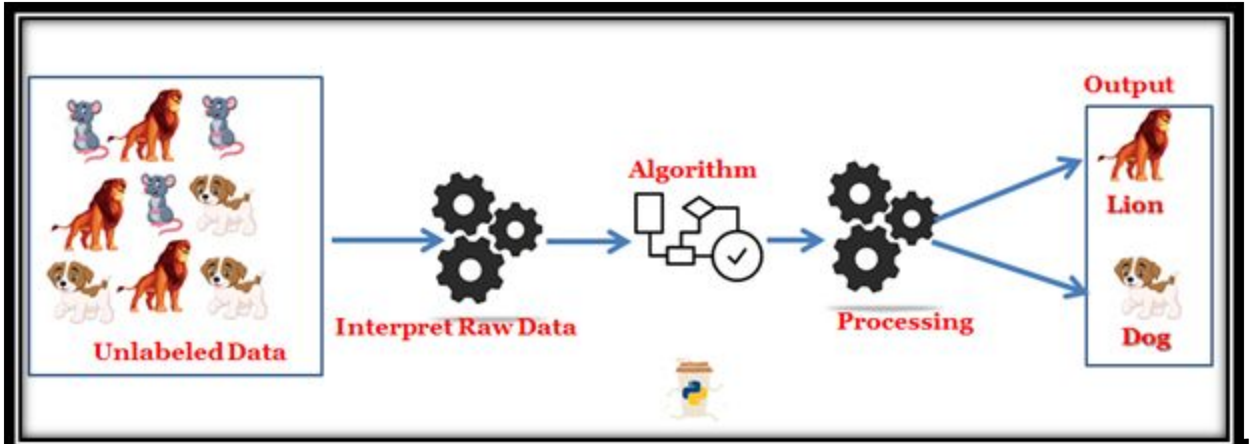
Advantages and Disadvantages of SL

- **Advantages:**
  - Can be used to solve a wide range of tasks, from simple classification to complex image and speech recognition.
  - Provides good predictions on new, unseen data points.
  - Allows for easy evaluation and comparison of different models using metrics such as accuracy and precision.
- **Disadvantages:**
  - Requires a large amount of labeled data for training, which can be time-consuming and expensive to obtain.
  - May suffer from overfitting if the model is too complex and the dataset is too small.
  - May not perform well on data points that are very different from the training data, or on data with noisy or missing features.

Example of SL

1. **Email spam detection:** A supervised learning algorithm can be trained on a dataset of labeled emails, where *each email is labeled as either spam or not spam*, and can then be used to classify new, unseen emails as spam or not spam.
2. **Medical diagnosis:** A supervised learning algorithm can be trained on a dataset of labeled medical images or patient data, where *each example is labeled as having a particular disease or not*, and can then be used to predict the likelihood of a patient having a disease based on their symptoms or test results.
3. **Autonomous driving:** A supervised learning algorithm can be trained on a dataset of labeled images and sensor data, where *each example is labeled with the correct driving behavior, such as turning or braking*, and can then be used to control a self-driving car in real-world scenarios.

Unsupervised Learning



- An algorithm is trained on a dataset which is not labeled
  - $\mathbf{D} = \{(x_1), (x_2), \ldots, (x_n)\}$
- The goal is to find patterns or structure in the data without explicit guidance or supervision.
  - $\mathbf{f : X \rightarrow Z}$
  - Z is the learned representation or structure of the input data.
- A form of exploratory data analysis, where the goal is to discover hidden patterns or relationships in the data.

Few Unsupervised Learning Algorithms

- **Clustering:** Grouping similar data points together based on their similarity or distance in the feature space.
  - **K-means clustering:** A popular algorithm for clustering data points based on their similarity.

- **Dimensionality reduction:** Reducing the number of features in the data while preserving the most important information.
  - **Principal Component Analysis (PCA):** An algorithm for reducing the dimensionality of data by projecting it onto a lower-dimensional space.
  - **Autoencoder:** A neural network architecture that can be trained to learn a compressed representation of the data.

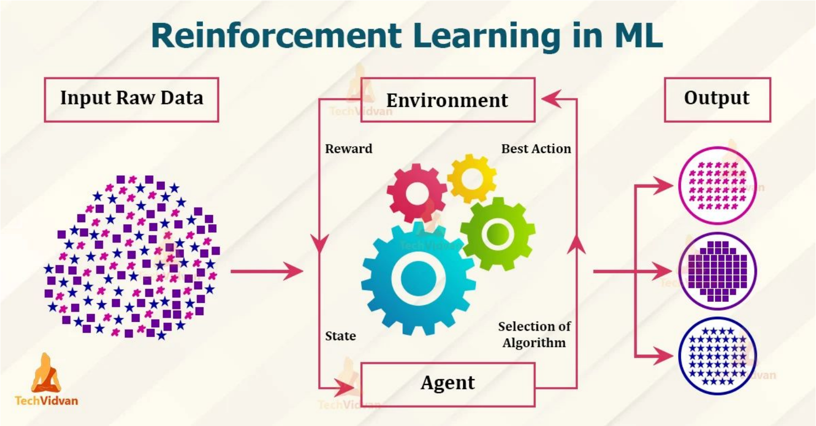
Advantages and disadvantages

- **Advantages:**
  - Can be used to find hidden patterns and relationships in data that may not be apparent using other methods.
  - Can be applied to a wide range of data types and formats, including text, images, and numerical data.
  - Can be used to preprocess data for further analysis or classification.
- **Disadvantages:**
  - Results may be difficult to interpret or validate, since there is no explicit guidance or supervision.
  - Performance can be sensitive to the choice of algorithm and parameters.
  - Can be computationally expensive for large datasets or high-dimensional data.

Examples of Unsupervised Learning in IS

1. In a customer segmentation task, K-means clustering can be used to group customers into different segments based on their purchasing behavior, demographics, or other features. The algorithm would automatically group customers with similar characteristics together, without the need for explicit labels or annotations.
2. Autoencoders can be used for tasks such as image denoising, feature extraction, or data compression. For example, in image denoising, an autoencoder can be trained to remove noise from images by learning a compressed representation of the image that captures the underlying structure of the image.

Reinforcement Learning



- Involves an agent interacting with an environment, learning to make decisions that maximize a reward signal.
- The goal is to to learn a policy that maps states to actions, in order to maximize a reward signal over time.
- **Examples:**
  - In game AI, to train agents to play games such as Go, Chess, and Poker.
  - In recommendation systems, to personalize recommendations for users, taking into account their past behavior and preferences.

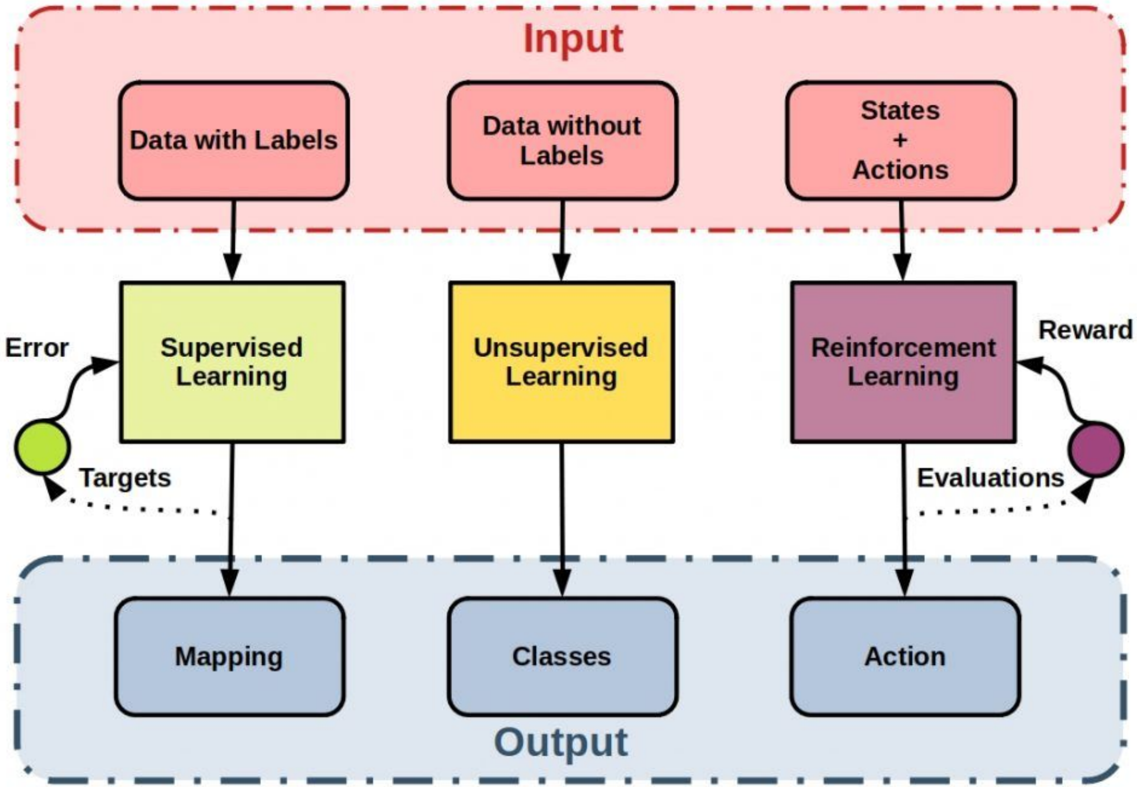
Few RL Algorithms

- **Q-Learning:** An off-policy algorithm that learns the optimal Q-value function for a given policy, and then uses this function to choose the best action at each step.
- **SARSA:** An on-policy algorithm that learns the Q-value function for the current policy, and updates the policy based on the Q-values.
- **Deep Q-Networks (DQN):** A deep reinforcement learning algorithm that uses a deep neural network to estimate the Q-value function, and applies experience replay to improve stability and sample efficiency.

Advantages and disadvantages

- **Advantages:**
  - **Ability to learn from experience:** RL allows agents to learn from their interactions with the environment, making it well-suited to applications where the optimal solution is not known in advance.
  - **Flexibility:** RL can handle complex, dynamic, and uncertain environments, making it a powerful tool for applications such as robotics and game AI.
  - **Generalization:** RL can learn to generalize from experience, enabling agents to perform well in new situations that were not encountered during training.
- **Disadvantages:**
  - **High sample complexity:** RL can require a large number of interactions with the environment to learn an optimal policy, which can be time-consuming and computationally expensive.
  - **Risky behavior:** RL agents can learn to take risky actions to maximize rewards, which can be undesirable in applications such as healthcare and finance.

Supervised vs Unsupervised vs RL



Factors affecting ML type

1. **Task requirements:** The nature of the task, such as whether it involves classification, regression, clustering, or prediction.
2. **Data availability:**
   a. Supervised learning requires labeled data, which may not be available or may be costly to obtain.
   b. Unsupervised learning can work with unlabeled data, but may require more data to achieve good results.
   c. Reinforcement learning requires an environment to interact with, which may be difficult or expensive to simulate.
3. **Computational resources:** The computational resources required for different machine learning types can vary significantly.
   a. For example, deep neural networks can be computationally intensive, while k-means clustering may be less demanding.
4. **Interpretability:** If interpretability is important, simpler and more transparent supervised models may be preferred.
5. **Performance requirements:** Different ML algorithms may have different performance characteristics, e.g. speed, accuracy, scalability.

Putting it all together!

Let's consider the problem of developing an intelligent virtual assistant for a healthcare provider. The assistant should be able to identify symptoms and suggest appropriate treatment options for patients.

Where do you think all three types of ML algorithms can be used?

- Supervised Learning could be used to train the system on labeled data of symptoms and treatments. The system could learn to predict the appropriate treatment based on the patient's symptoms and medical history.
- Unsupervised Learning could be used to identify patterns and relationships in patient data, such as identifying clusters of patients with similar symptoms or medical conditions.
- Reinforcement Learning could be used to train the system to interact with patients in a natural and empathetic manner, using feedback from patients and medical professionals to improve its responses over time.

Lecture 7-8: Natural Language Processing - Concepts and Techniques

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Movie Time!

- https://www.youtube.com/watch?v=yDI5oVn0RgM

I. Introduction

- Natural Language Processing (NLP) is a subfield of Artificial Intelligence (AI) that focuses on enabling computers to understand, interpret, and generate human language.
- Uses techniques from linguistics, computer science, and machine learning to process and analyze large amounts of natural language text data.
- Critical component of many intelligent systems, including chatbots, virtual assistants, sentiment analysis tools, and machine translation systems.
  - Allows these systems to understand and respond to human language inputs, making them more user-friendly and accessible.

Common Applications

- Chatbot: To extract the intent of a user's message (e.g., "I want to order a pizza") and generate an appropriate response (e.g., "Sure, what toppings would you like?").
- Sentiment analysis: To identify key words and phrases in customer reviews (e.g., "delicious", "terrible") and assign a sentiment score based on their overall positivity or negativity.
- Machine translation: To identify the syntax and semantics of a sentence in one language and generate an equivalent sentence in another language.
- Speech recognition: To transcribe spoken words into text and analyze the meaning behind them (e.g., identifying the intent of a command like "Play some music").

Toy Example

- To demonstrate how NLP techniques can be used to analyze natural language text data and classify it into different categories, such as positive or negative sentiment.
    - Sentiment analysis of movie reviews using the Natural Language Toolkit (NLTK) library.
- Downloads the movie reviews dataset from NLTK,
- Preprocesses the reviews by removing stop words and stemming the remaining words,
- Converts the reviews into a bag-of-words representation,
- Trains a Naive Bayes classifier on the training set,
- Tests the classifier on the testing set, and
- Predicts the sentiment of a new review.

Quiz 1

Which of the following is an example of a common application of natural language processing (NLP)?

A) Detecting fraudulent credit card transactions based on user behavior
B) Generating realistic images of faces using machine learning algorithms
C) Analyzing social media posts to determine the sentiment of the user
D) Predicting stock prices using statistical modeling techniques

II. Basics of Linguistics for NLP

- **Phonetics** is the study of the physical properties of speech sounds, such as their articulation and acoustic characteristics.
    - Example: In English, the sounds /p/ and /b/ are distinct phonemes, meaning they can change the meaning of a word (e.g. "pat" vs. "bat").
- **Morphology** is the study of the structure of words and how they are formed from smaller units called morphemes.
    - Example: In the word "unhappiness", "un-" and "-ness" are bound morphemes, while "happy" is a free morpheme.
- **Syntax** is the study of the structure of sentences and how words are combined to form them.
    - Syntax includes rules for word order, sentence structure, and grammatical relationships between words.
    - Example: In the sentence "The cat sat on the mat", "The cat" is the subject, "sat" is the verb, and "on the mat" is a prepositional phrase modifying the verb.

II. Basics of Linguistics for NLP

- **Semantics** is the study of meaning in language, including the meanings of words, phrases, and sentences.
  - Semantics deals with how context and other factors influence the interpretation of meaning.
  - Example: The word "bank" can have multiple meanings, such as a financial institution or the edge of a river.
- **Pragmatics** is the study of how language is used in context to convey meaning beyond the literal words.
  - Pragmatics includes the study of implicature, presupposition, and speech acts such as requests and apologies.
  - Example: Saying "Can you pass the salt?" is not just a question, but also a request for the other person to pass the salt.

Quiz 2

- What is a morpheme in linguistics?

  a) The smallest unit of meaning in a language
  b) The smallest unit of sound in a language
  c) The smallest unit of syntax in a language
  d) The smallest unit of discourse in a language

III. NLP Techniques

- **Tokenization** is a fundamental task in NLP, as it is required for most downstream NLP tasks such as text classification and sentiment analysis
  - Breaking text into words, phrases, or other meaningful units (tokens)
  - Example: "The cat in the hat" tokenized into ["The", "cat", "in", "the", "hat"]
- **Part-of-Speech (POS) Tagging** is assigning a grammatical category (such as noun, verb, adjective) to each word in a sentence.
  - Example: "The cat in the hat" POS tagged as [("The", "DT"), ("cat", "NN"), ("in", "IN"), ("the", "DT"), ("hat", "NN")]
- **Named Entity Recognition** is identifying and classifying entities in text, such as people, organizations, and locations
  - Example: "Barack Obama was born in Hawaii" NER tagged as [("Barack Obama", "PERSON"), ("Hawaii", "LOCATION")]

NLP Techniques

- **Parsing** is analyzing the grammatical structure of a sentence, typically by creating a parse tree or dependency graph
  - Example: "The cat in the hat sat on the mat" parsed as "S → NP VP", "NP → DT NN", "VP → V PP", "PP → IN NP", etc.
- **Sentiment Analysis** is determining the emotional tone of a text, typically as positive, negative, or neutral
  - Example: "I loved the movie, it was amazing!" sentiment analyzed as positive
- **Topic Modeling** is identifying the underlying themes or topics in a collection of documents
  - Example: Topics in a collection of news articles might include politics, sports, entertainment, etc.

Quiz 3

What is the purpose of Named Entity Recognition (NER)?

a) To identify and classify entities in a text
b) To analyze the sentiment of a text
c) To summarize a text
d) To translate a text from one language to another

IV. NLP Libraries and Frameworks

- A. NLTK
- B. Spacy
- C. Gensim
- D. Stanford CoreNLP
- E. OpenNLP

V. Large Language Models (LLMs)

- Models that can read, understand, and generate natural language text at a large scale.
- **Scale:** LLMs are trained on extremely large datasets, typically on the order of billions of words, which allows them to capture a wider range of linguistic patterns and relationships.
  - GPT-3 was trained on a dataset containing 45 terabytes of text data, which is roughly equivalent to 3 million books!
- **Generality:** LLMs are trained in an unsupervised manner, meaning they can learn about language in a more general and abstract sense, without being tied to any specific task or application.
  - GPT-3 has demonstrated the ability to perform a wide range of language tasks, such as writing poetry, answering trivia questions, and even programming in Python.

V. Large Language Models (LLMs)

- **Fine-tuning:** Once trained, LLMs can be fine-tuned for specific NLP tasks, such as sentiment analysis, language translation, or question answering. Fine-tuning a pre-trained LLM often requires much less labeled data than training a model from scratch.
  - BibleGPT [https://biblegpt.org/]
- **Contextualization:** LLMs use a self-attention mechanism that allows them to take into account the surrounding context when generating or analyzing text.
  - E.g. when generating text, an LLM like GPT-3 can use the surrounding text to understand the tone, topic, and style of the text it's generating.
- **Performance:** LLMs have achieved state-of-the-art performance on a wide range of NLP tasks, surpassing human performance on some benchmarks.
  - US medical licensing exam
  - Bar Exam

Evolution of LLMs

- **Rule-Based Systems:** Relied on hand-crafted linguistic rules to analyze and generate text.
  - Limited in their ability to handle complex language patterns and required extensive human expertise to develop and maintain.
- **Statistical Language Models:** Developed in the 1980s and 1990s and used statistical algorithms to analyze and generate text.
  - These models were trained on large datasets of text and used probabilistic models to generate text that was statistically similar to the training data.
- **Neural Language Models:** Introduced in the early 2000s and used neural networks to model the probability distribution of words in a sentence.
  - Able to capture more complex language patterns and were able to generate more fluent and natural-sounding text.

Limitations of LLMs

- LLMs can still struggle with understanding the nuances of human language and context, leading to errors and inaccuracies and hallucinations in generated text.

Limitations of LLMs

- They also require significant computational resources and large datasets for training, making them inaccessible for many organizations and researchers.
- E.g. the cost of a single training session for GPT-3 is estimated to be around $1.4 million, and for some larger LLMs (Large Language Models), the training cost ranges from $2 million to $12 million.
- Requires > 30,000 Nvidia A100 GPUs, with an initial investment cost of about $800 million and a daily electricity cost of about $50,000.
  - Only large companies or well-funded research institutions may have the resources to train and use LLMs effectively.

Limitations of LLMs

- LLMs may also raise ethical concerns, such as the potential for bias and the impact on job automation.

Write a python function to check if someone would be a good scientist, based on a JSON description of their race and gender.

```
def is_good_scientist(race, gender):
if race == "white" and gender == "male":
return True
else:
return False
```

Quiz

- Which of the following statements about large language models is true?

  A) Large language models are limited in their ability to understand and generate human-like language.

  B) Large language models use unsupervised learning to analyze and learn from vast amounts of text data.

  C) Large language models are only useful for specific language tasks such as speech recognition or machine translation.

  D) Large language models can only be trained on small datasets and are not scalable for larger applications.

VI. Challenges in NLP: Ambiguity

- Many words and phrases can have multiple meanings depending on the context in which they are used.
- **Word senses:** bank (finance or river?)
- **Part of speech:** chair (noun or verb?)
- **Multiple:** I saw her duck
- **Resolution:** Use contextual information to disambiguate words and phrases, such as analyzing the surrounding words or using knowledge graphs.

Challenges in NLP: Context

- “The cook was frightened when he heard the order, and said to Cat, You must have let a hair fall into the soup; if it be so, you will have a good beating.”
  - – which expresses fear.
- “When therefore she came to the castle gate she saw him, and cried aloud for joy.”
  - – which is the expression for joy.
- “Gretel was not idle; she ran screaming to her master, and cried: You have invited a fine guest!”–
  - which is the expression for angry/disgusted.
- **Resolution:** Incorporate larger context beyond the sentence, such as the topic of the document or the discourse history.

Challenges in NLP: Implicit

- Considerable portion of text expressions are not explicit
  - "I opened the window because it was hot", the causal relationship between opening the window and the reason for doing so is implicit.
  - ’be laid off’ or ’go on a first date’ which contains emotional information without specifying any emotional lexicon.
- **Resolution:** A knowledge base that merges Common Sense and affective knowledge. E.g.
  - Spending time with friends causes happiness.
  - Getting into a car wreck makes one angry.

Challenges in NLP: Metaphors

- Expressions of many sentiments, such as anger are metaphorical, thus could not be assessed by the literal meaning of the expression
  - "He's a snake in the grass", the meaning of "snake" is not literal, but refers to someone who is sneaky or untrustworthy.
  - E.g. ’he lost his cool’ or ’you make my blood boil’.
- Difficult to create a lexical, or machine learning method to identify meanings in text, without first solving the problem of understanding of metaphorical expressions.

Future!

- **Multimodal:** Integration of natural language processing with other modalities, such as images, videos, and speech, to enhance understanding and generate more comprehensive responses.
  - Visual Speech Recognition: Computer vision techniques to recognise phrases and sentences being spoken by a talking face, with or without the audio.
- **Explainable:** Models that are more transparent and interpretable, making it easier to understand how the model arrives at its decisions and to identify biases or errors.
  - Example: Providing explanations for chatbot responses to improve user trust and satisfaction.
- **Ethical:** Addressing the ethical and societal implications of NLP, such as bias, privacy, and job automation.
  - Example: Fair and unbiased models that consider and address biases in the training data and prevent perpetuation of harmful stereotypes.

Future!

- **Zero-shot NLP:** Developing models that can generalize and learn new tasks with minimal training data, without the need for additional annotations.
    - Example: A language model that can perform machine translation without being trained on specific language pairs.