



Chapter Six

Communicating, Perceiving, and Acting

Contents

- ▶ Natural Language Processing (NLP)
- ▶ Key components of NLP
- ▶ Key tasks in NLP
- ▶ Types and phases of NLP
- ▶ Natural Language for Communication & Perception
- ▶ Hardware components of a Computer Vision System
- ▶ Tasks of Computer Vision
- ▶ Robotics and its applications

What is Natural Language Processing (NLP)?

- ▶ NLP stands for **Natural Language Processing**, which is a part of Computer Science, Human language, and Artificial Intelligence.
- ▶ Natural Language Processing (NLP) is a branch of artificial intelligence (AI) that focuses on the interaction between computers and humans through natural language.
- ▶ It enables computers to understand, interpret, and generate human language in a way that is both meaningful and useful.
- ▶ NLP combines computational linguistics, computer science, and AI techniques to bridge the gap between human communication and computer understanding.
- ▶ Used by machines to **understand, analyze, manipulate, and interpret human's languages**.

The Connection between CS, AI and Human

- History of NLP(Maybe refer more by yourself)

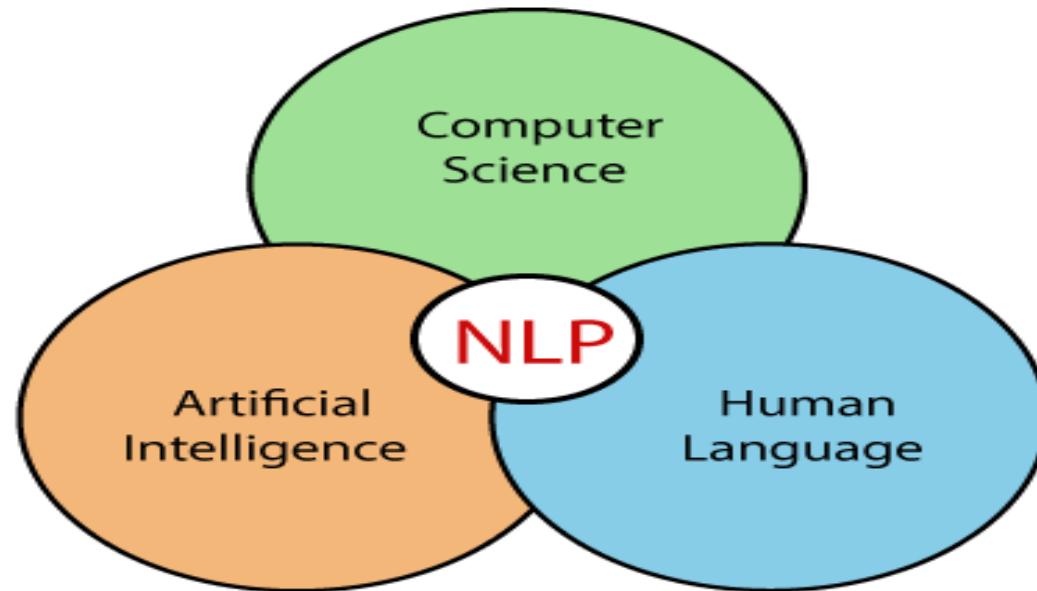


Figure: The connections between NLP, Computer Science, Artificial Intelligence, and Human Interaction

Components of NLP

1. Natural Language Understanding (NLU)

- ▶ NLU helps the machine to **understand** and **analyses** human language by **extracting the metadata from content such as concepts, entities, keywords, emotion, relations, and semantic roles.**
- ▶ Mainly used in **Business applications** to **understand the customer's problem in both spoken and written language.**
- ▶ Tasks:
 - ▶ It is used to **map** the given input into **useful representation**.
 - ▶ It is used to **analyze** different aspects of the language.

2. Natural Language Generation (NLG)

- ▶ NLG acts as a **translator** that converts the **computerized data** into **natural language** representation.
- ▶ It mainly involves **Text planning**, **Sentence planning**, and **Text Realization**.

Key tasks in NLP

► Some of the key tasks in NLP include:

- ✓ **Text Parsing:** involves breaking down text into its constituent parts such as **sentences, words, and phrases** to analyze its structure.
- ✓ **Named Entity Recognition (NER):** identifies and classifies named entities in text such as **people, organizations, locations, dates, etc.**
- ✓ **Part-of-Speech (POS) Tagging:** assigns grammatical categories to words in a sentence, such as **noun, verb, adjective, etc.**
- ✓ **Text Generation:** refers to creating **human-like text** based on given input or prompts.
- ✓ **Text Summarization:** generates **short and meaningful summaries** of long texts while preserving important information.

Key tasks in NLP...

- › Sentiment analysis (also called opinion mining) is used to analyze the attitude, behavior, and emotional state of the sender.
- › It classifies text as positive, negative, or neutral and identifies moods such as happy, sad, or angry.

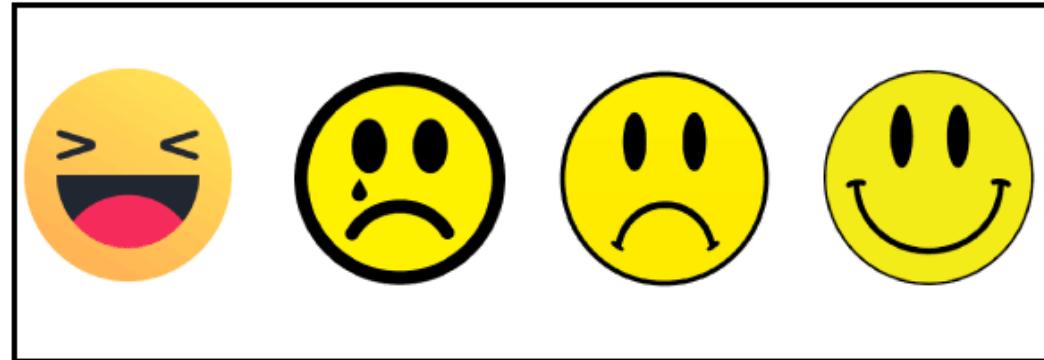


Figure: Mood of the context

- › Natural Language Understanding (NLU) converts natural language text into formal representations that computers can understand and process.

Key tasks in NLP...

- ▶ **Speech recognition** converts **spoken language into text**. It is used in mobile devices, home automation, voice assistants, and dictation software.
- ▶ **Question answering** systems focus on **automatically answering questions** asked by humans in natural language.



Key tasks in NLP...

- ▶ **Machine translation** automatically translates **text or speech** from **one natural language to another.**

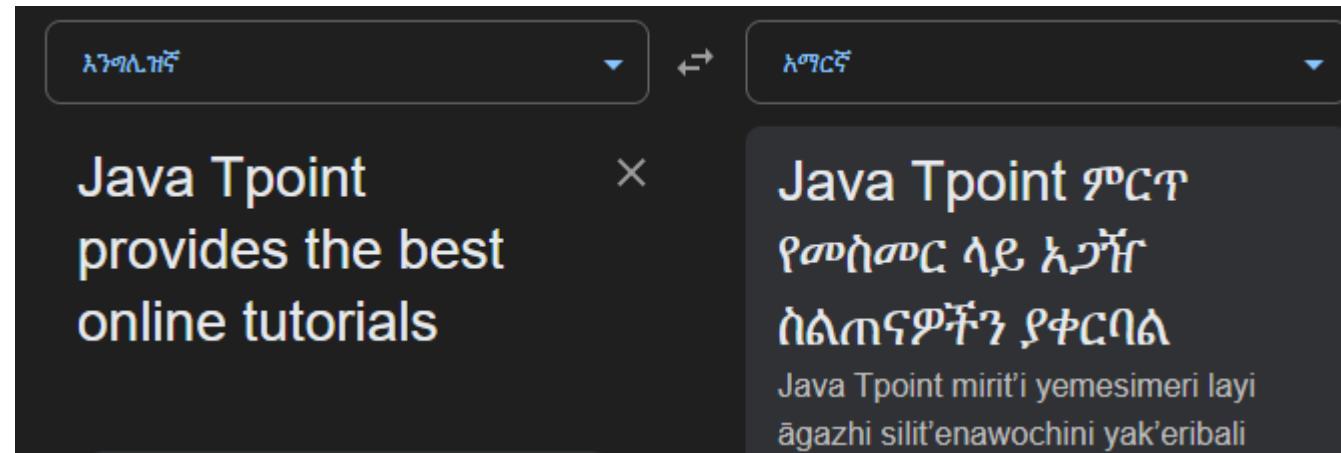


Figure: Machine translation

- ▶ **Information extraction** extracts structured information from unstructured or semi-structured documents.

Key tasks in NLP...

- **Spam detection** identifies unwanted or malicious emails to prevent them from reaching the user's inbox.

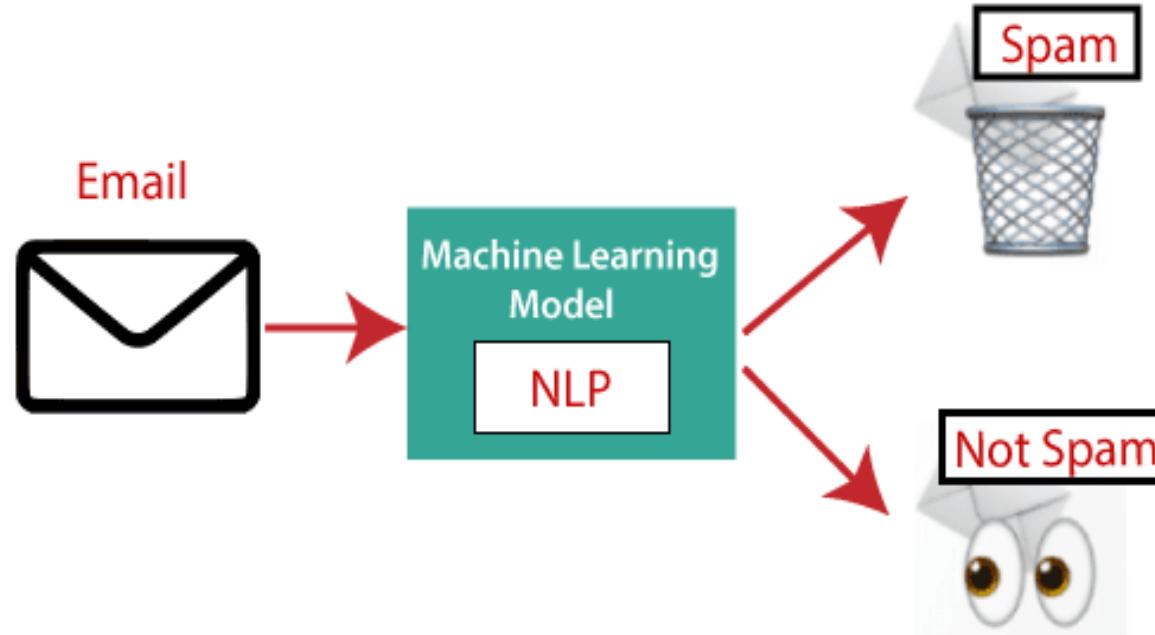


Figure: Spam detection using NLP (e-mails)

Key tasks in NLP...

- ▶ **Spelling correction** detects and corrects spelling errors in text.

Examples include tools like **Microsoft Word**.



Figure: Spelling checker

- ▶ NLP has numerous applications across various domains, including customer service chatbots, virtual assistants, information retrieval systems, and sentiment analysis in social media, language translation services, and much more.
- ▶ As NLP techniques continue to advance, the possibilities for its application are constantly expanding.

Types and phases of NLP

- ▶ Natural Language Processing (NLP) can be classified into different approaches based on how language is analyzed and processed.:
 - ▶ **Rule-based NLP:** In this approach, **linguistic rules** are manually defined by experts to analyze and process text. These rules determine how the system interprets and generates language. Rule-based NLP is effective for **simple and well-defined tasks**, but it is limited in handling **ambiguity, variability, and complex language structures**.
 - ▶ **Statistical NLP:** Statistical NLP uses **large amounts of data** to train models that automatically learn patterns in language.
It employs techniques such as **probabilistic models, machine learning algorithms, and statistical parsing** to analyze and generate text.
This approach performs better than rule-based methods when sufficient data is available.



Types of NLP

- ▶ **Hybrid NLP:** combines **rule-based and statistical approaches** to take advantage of both methods. By integrating linguistic rules with data-driven models, hybrid systems provide **more robust and accurate language processing**.
- ▶ **Deep Learning NLP:** Deep learning has significantly advanced NLP in recent years. This approach uses **neural networks**, such as **Recurrent Neural Networks (RNNs)**, **Convolutional Neural Networks (CNNs)**, and **Transformer models** (e.g., **BERT**, **GPT**). Deep learning models are widely used for tasks such as **text classification**, **language generation**, **sentiment analysis**, and **machine translation**.

Phases of NLP

- ▶ Natural Language Processing (NLP) helps computers **understand, analyze, and interact with human language.**
- ▶ It involves a series of **processing phases**, where each phase contributes to understanding the **structure and meaning** of language.
- ▶ Although the exact phases may vary depending on the task, the following are **fundamental phases commonly used in NLP pipelines.**

Phases of NLP...

- ▶ Five phases of NLP

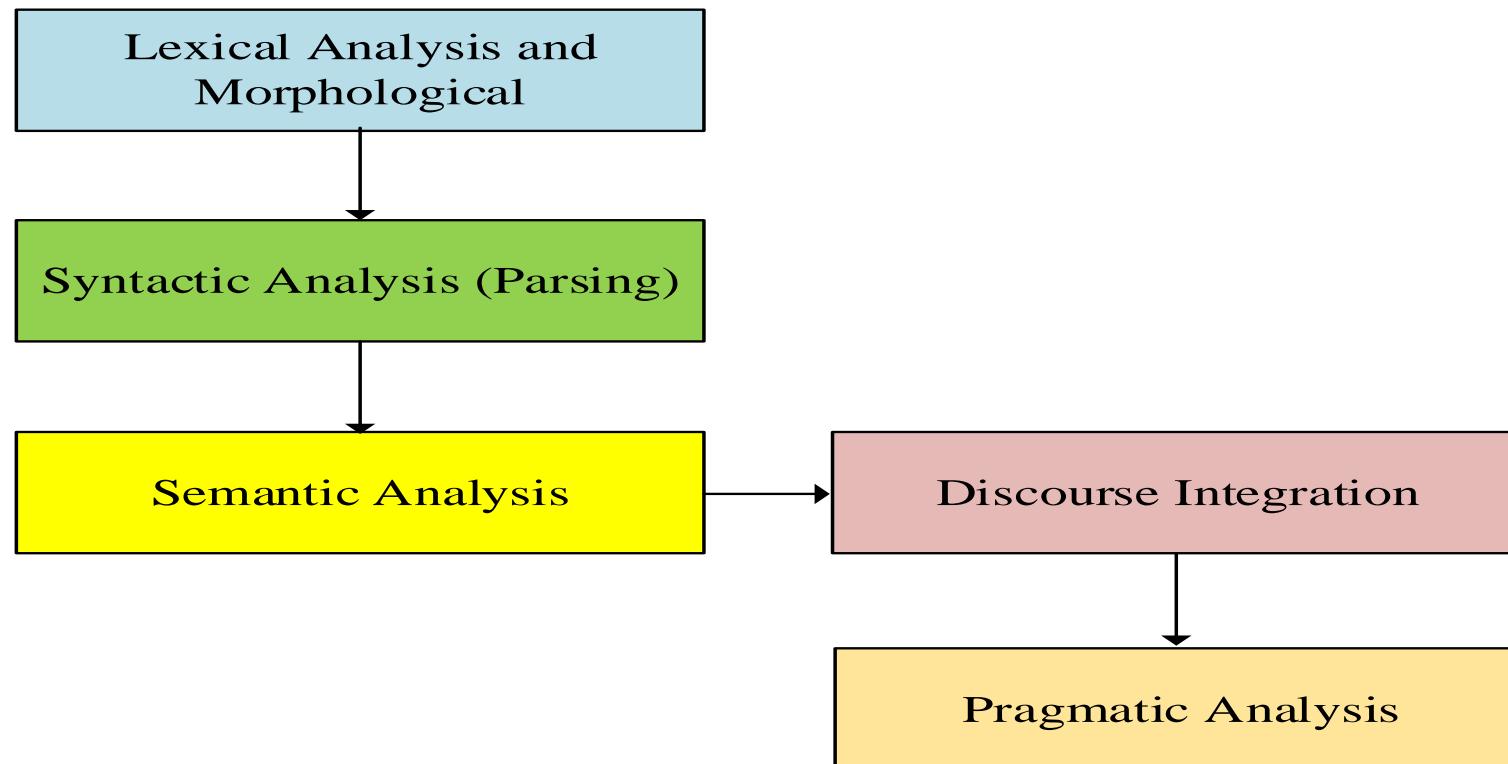


Figure: Five phases of NLP

Lexical Analysis and Morphological

1. Lexical Analysis and Morphological

- › The first phase of NLP is the **Lexical (relating to the words) Analysis**.
- › This phase scans the source code as **a stream (group) of characters and converts it into meaningful lexemes**.
- › It divides the whole text into **paragraphs, sentences, and words**.
- › It breaks down the input text into individual tokens that are meaningful units of language such as words or phrases.

Lexical Analysis and Morphological...

► Key tasks in Lexical analysis:

1) **Tokenization**: Process of dividing a text into smaller chunks called tokens. For example the sentence "I love programming" would be tokenized into ["I", "love", "programming"].

2) **Part-of-Speech Tagging**: Assigning parts of speech such as noun, verb, adjective to each token in the sentence. This helps us to understand grammatical roles of words in the context.

► **Example:** Consider the sentence: "I am reading a book."

► **Tokenization:** Sentence is broken down into individual tokens or words: ["I", "am", "reading", "a", "book"]

► **Part-of-Speech Tagging:** Each token is assigned a part of speech: ["I" → Pronoun (PRP), "am" → Verb (VBP), "reading" → Verb (VBG), "a" → Article (DT), "book" → Noun (NN)]

Lexical Analysis and Morphological...

► Importance of Lexical Analysis

- ✓ **Word Identification:** It breaks text into tokens which helps the system to understand individual words for further processing.
- ✓ **Text Simplification:** It simplifies text through tokenization and stemming which improves accuracy in NLP tasks.

► Morphological Analysis:

- ✓ It deals with **morphemes** which are the smallest units of meaning in a word.
- ✓ It is important for understanding structure of words and their parts by identifying free morphemes (independent words like "cat") and bound morphemes (like prefixes or suffixes e.g. "un-" or "-ing").

Lexical Analysis and Morphological...

► Key tasks in morphological analysis:

1. **Stemming**: Reducing words to their root form like "running" to "run".
2. **Lemmatization**: Converting words to their base or dictionary form considering the context like "better" becomes "good".

► Importance of Morphological Analysis

1. **Understanding Word Structure**: It helps in breaking the composition of complex words.
 2. **Improving Accuracy**: It enhances accuracy of tasks such as part-of-speech tagging, syntactic parsing and machine translation.
- By identifying and analyzing morphemes system can identify text correctly at the most basic level which helps in more advanced NLP applications.

Syntactic Analysis (Parsing)

- ▶ **Syntactic Analysis** is used to **check grammar** and **word arrangements**, and shows the **relationship among the words**.
- ▶ **Syntactic Analysis** helps in understanding how words in a sentence are arranged according to grammar rules.
- ▶ It ensures that the sentence follows correct grammar which makes the meaning clearer.
- ▶ It breaks the sentence into parts like the subject, verb and object and shows how these parts are connected. This helps machines understand the relationships between words in the sentence.

Syntactic Analysis (Parsing)...

- ▶ **Key components of syntactic analysis include:**
 - **POS Tagging:** Assigning parts of speech (noun, verb, adjective) to words in a sentence as discussed earlier.
 - **Ambiguity Resolution:** Handling words that have multiple meanings (e.g "book" can be a noun or a verb).
- ▶ **Examples:-**Consider the following sentences:

Correct Syntax: "John eats an apple."

Incorrect Syntax: "Apple eats John an."

- ▶ Despite using same words only the first sentence is grammatically correct and makes sense.
- ▶ The correct arrangement of words according to grammatical rules is what makes the sentence meaningful.
- ▶ By analyzing sentence structure ,NLP systems can better understand and generate human language.

Semantic Analysis

- ▶ **Semantic analysis** is concerned with **the meaning representation**.
- ▶ It mainly focuses on the **literal meaning of words, phrases, and sentences**.
- ▶ It ensures that the text is not only grammatically correct but also logically coherent and contextually relevant.
- ▶ It aims to understand dictionary definitions of words and their usage in context and also find whether the arrangement of words in a sentence makes logical sense.

Semantic Analysis...

► Key Tasks in Semantic Analysis

- 1) **Named Entity Recognition (NER)**: It identifies and classifies entities such as names of people, locations, organizations, dates and more. These entities provide important meaning in the text and help in understanding the context. For example in the sentence "Tesla announced its new electric vehicle in California.
- 2) **Word Sense Disambiguation (WSD)**: Many words have multiple meanings depending on the context in which they are used. It identifies the correct meaning of a word based on its surrounding text. For example word "bank" can refer to a financial institution or the side of a river. It uses context to identify which meaning applies in a given sentence which ensures that interpretation is accurate.

Semantic Analysis...

▶ Example of Semantic Analysis

- ✓ "Apple eats a John." while grammatically correct this sentence doesn't make sense semantically because an apple cannot "eat" a person.
- ✓ Semantic analysis ensures that the meaning is logically sound and contextually appropriate.
- ✓ It is important for various NLP applications including machine translation, information retrieval and question answering.

Discourse Integration

- ▶ **Discourse Integration** depends upon the sentences that proceed it and also invoke the meaning of the sentences that follow it.
- ▶ It is the process of **understanding how individual sentences or segments of text connect and relate to each other** within a broader context.
- ▶ This phase ensures that the meaning of a text is consistent and coherent across multiple sentences or paragraphs.
- ▶ It is important for understanding long or complex texts where meaning focuses on previous statements.

Discourse Integration...

► Key aspects of discourse integration

- 1) **Anaphora Resolution:** Anaphora refers to the use of pronouns or other references that depend on earlier parts of the text. For example in the sentence "Taylor went to the store. She bought groceries" pronoun "She" refers back to "Taylor." It ensures that references like these are correctly understood by linking them to their antecedents.
- 2) **Contextual References:** Many words or phrases can only be fully understood when considered in the context of following sentences. It helps in interpreting how certain words or phrases focus on context. For example "It was a great day" is clearer when you know what event or situation is being discussed.

Discourse Integration...

► Example of Discourse Integration

- ✓ Taylor went to the store to buy some groceries. She realized she forgot her wallet." Understanding that "Taylor" is the antecedent of "she" is important for understanding sentence's meaning.
- ✓ "This is unfair!" helps in understand what "this" refers to we need to identify following sentences.

Without context statement's meaning remains unclear.

- ✓ It is important for NLP applications like machine translation, chatbots and text summarization. It ensures that meaning remains same across sentences which helps machines to understand context. This enables accurate and natural responses in applications like conversational AI and document translation

Pragmatic Analysis

- ▶ **Pragmatic analysis** helps in understanding the **deeper meaning behind words and sentences** by looking beyond their literal meanings.
- ▶ It helps you to discover the **intended effect by applying a set of rules that characterize cooperative dialogues**.
- ▶ For Example: "Open the door" is interpreted as a request instead of an order.
- ▶ **Key tasks in pragmatic analysis:**
 - 1) **Understanding Intentions:** Sometimes language doesn't mean what it says literally. For example when someone asks "Can you pass the salt?" it's not about ability but a polite request. It helps to understand true intention behind such expressions.
 - 2) **Figurative Meaning:** Language often uses idioms or metaphors that can't be taken literally.

Pragmatic Analysis

► Examples of Pragmatic Analysis

- ✓ "Hello! What time is it?" here it might be a straightforward request for the current time but it could also imply concern about being late.
- ✓ For example "I'm falling for you" means "I love you" not literally falling. It helps to interpret these non-literal meanings.
- ✓ It is important for NLP tasks like sentiment analysis, chatbots and conversation-based AI. It helps machines to understand the speaker's intentions, tone and context which go beyond the literal meaning of words.

Natural Language for Communication & Perception

- ▶ “Natural Language for Communication & Perception” refers to the ability of humans and machines to **understand, process, and generate natural language** in order to **communicate effectively** and **perceive, interpret, and make sense of information from their environment**.
- ▶ It involves using language both as a medium of communication and as a means of understanding meaning, intent, and context.

Communication

- ▶ **Interpersonal Communication:** Humans use **natural language** to convey thoughts, ideas, emotions, and intentions to others. This includes: **Spoken communication** in face-to-face conversations, **Written communication** through letters and emails, **Digital communication** via chat messages and social media platforms
- ▶ Natural language enables effective understanding and interaction between individuals.

Communication

- ▶ **Human–Computer Interaction (HCI):** involves communication between humans and computers. **Natural language interfaces** allow users to interact with computers by typing or speaking normal human language, rather than using programming commands or complex menu-based inputs.
- ▶ Examples include: **Virtual assistants, Chatbots, Voice-controlled systems**
- ▶ These systems rely on **Natural Language Processing (NLP)** technologies to understand user input and generate appropriate responses.

Perception

- ▶ **Multilingual Communication:** Natural language acts as a **bridge between people who speak different languages**, enabling communication across cultural and linguistic boundaries. Translation and interpretation systems support multilingual interaction, Language learning tools help users understand and produce new languages. **Examples:** Machine translation systems, Multilingual chat applications
- ▶ **Text Understanding:** allows machines to **analyze and interpret written text** by: Extracting meaning, Identifying entities and relationships, Making inferences
- ▶ Text understanding is used in: Information retrieval, Sentiment analysis, Content categorization.

Text Understanding

- ▶ **Speech Recognition:** enables machines to **perceive spoken language and convert it into text** using Automatic Speech Recognition (ASR) systems.
- ▶ Applications include: Voice-controlled interfaces, Dictation software, Real-time transcription services.
- ▶ **Language Generation:** Natural Language Generation (NLG) allows machines to **produce human-like text** based on input data or predefined rules.
- ▶ Applications include: Report generation, Text summarization, Personalized message creation

Text Understanding

- ▶ **Contextual Understanding:** Effective communication and perception require understanding language in context, considering factors such as tone, intent, and cultural nuances. Contextual understanding is essential for tasks like sentiment analysis, conversational agents, and personalized recommendations.
- ▶ **Visual and Multimodal Perception:** Natural language can be integrated with other modalities, such as images, videos, and sensor data, to enhance perception and understanding.
- ▶ Multimodal technologies enable applications like image captioning, visual question answering, and augmented reality interfaces.

Advantages of NLP

- ▶ Helps users to **ask questions** about any subject and **get a direct response within seconds**.
- ▶ Helps computers to **communicate with humans in their languages**.
- ▶ It is very **time efficient**.
- ▶ Most of the **companies use NLP** to improve the efficiency of documentation processes, accuracy of documentation, and identify the information from large databases (**think about big data**).

Disadvantages of NLP

- ▶ May not show **context**.
- ▶ Is **unpredictable** (Ambiguity)
- ▶ May require more **keystrokes**
- ▶ Is unable to **adapt** to the **new domain**, and **it has a limited function that's why NLP is built for a single and specific task only.**

What is computer vision?

What is computer vision?

- ▶ Computer Vision is a branch of **Artificial Intelligence (AI)** that enables machines and robots to **perceive, analyze, and understand visual data** such as images and videos.
- ▶ It plays an important role in many domains including **safety, security, healthcare, accessibility, transportation, and entertainment**.
- ▶ Computer Vision systems automatically **extract, analyze, and interpret meaningful information** from single or multiple images or video streams by using **algorithms and models for automated visual understanding**.

Hardware components of a Computer Vision System

- ▶ Hardware of **Computer Vision System** - This involves –
 - Power supply
 - Image acquisition device such as camera
 - A processor
 - A display device for monitoring the system
 - Accessories such as camera stands, cables, and connectors

Tasks of Computer Vision

- ▶ **Optical Character Recognition (OCR):** is a Computer Vision task that converts **scanned documents or images containing text into editable and searchable digital text.**
- ▶ It is commonly used in document digitization, form processing, and text recognition systems.
- ▶ **Face Detection:** identifies and locates **human faces in images or videos.** It is used in modern cameras for auto-focus and in security systems.
- ▶ When combined with **Face Recognition,** it allows user authentication by matching detected faces with stored identities.
- ▶ **Object Recognition:** enables systems to **identify and classify objects within images or video streams.** It is widely used in **supermarkets, surveillance systems, and autonomous vehicles,** including advanced systems in cars by companies such as BMW, GM, and Volvo.

Tasks of Computer Vision...

- ▶ **Estimating Position:** It is estimating the position of an object concerning the camera as in the position of the tumor in the human body.
- ▶ **Image Classification:** Assigning a label or category to an entire image based on its content.
- ▶ **Semantic Segmentation:** Assigning a class label to each pixel in an image, allowing for detailed analysis of scenes and objects.
- ▶ **Image Super-Resolution:** Enhancing the resolution of low-resolution images.
- ▶ **Image Restoration:** Improving the quality of degraded or damaged images.
- ▶ **Image Captioning:** Generating text descriptions of images.

What is Robotics?

- ▶ Robotics is a branch of **Artificial Intelligence (AI)** that focuses on the **design, development, and operation of intelligent robots**.
- ▶ These robots act as **artificial agents** that interact with **real-world environments**.
- ▶ The primary objective of robotics is to enable robots to **perceive their environment and manipulate objects** by selecting, moving, and altering their physical properties.
- ▶ This allows robots to perform **repetitive, dangerous, or physically demanding tasks**, reducing human effort while ensuring **accuracy, consistency, and reliability** in operations.

Aspects of Robotics

- ▶ The robots have mechanical construction, form, or shape designed to accomplish a particular task.
- ▶ They have electrical components that power and control the machinery.
- ▶ They contain some level of a computer program that determines what, when, and how a robot does something.

Other AI program vs Robotics system

Table: Comparison between Other AI Programs and Robotics Systems

AI Programs	Robots
<ul style="list-style-type: none">• They usually operate in computer-stimulated words	<ul style="list-style-type: none">• They operate in the real physical world
<ul style="list-style-type: none">• The input to an AI program is in symbols and rules	<ul style="list-style-type: none">• Inputs to robots is analog signals in the form of speech waveforms or images
<ul style="list-style-type: none">• Need general-purpose computers to operate on	<ul style="list-style-type: none">• They need special hardware with sensors and effectors

Reinforcement Learning in Robotics

- ▶ Reinforcement Learning (RL) in robotics is a **subfield of AI** that focuses on training robots to perform tasks **autonomously through trial and error**.
- ▶ In RL, robots learn by interacting with their environment and receiving feedback in the form of rewards or penalties.
- ▶ **Key Components of Reinforcement Learning**
 - ▶ **Agent:** The robot or autonomous system that interacts with the environment.
 - ▶ **Environment:** The physical or virtual world in which the agent operates.
 - ▶ **Actions:** The set of possible actions that the agent can take in the environment.
 - ▶ **State:** The current configuration or observation of the environment.
 - ▶ **Rewards:** Feedback signals provided by the environment to indicate the desirability of actions taken by the agent.



Types of robotics

- ▶ Robotics is a **multidisciplinary field** that involves the **design, construction, operation, and application of robots**.
- ▶ Robots are **programmable machines** capable of performing tasks **autonomously or semi-autonomously**.
- ▶ There are various types of robotics, including the following common categories:
- ▶ **Industrial Robotics:** are used in **manufacturing environments** for tasks such as **assembly, welding, painting, and material handling**. They improve efficiency, precision, and safety.
- ▶ **Mobile Robotics:** are designed to **move through different environments**. Examples include **autonomous vehicles, delivery robots, and mobile service robots**.



Types of robotics...

- ▶ **Medical Robotics:** are used in **healthcare applications**, including **robot-assisted surgeries, rehabilitation therapy, and patient care systems**.
- ▶ **Humanoid Robotics:** resemble the **human body structure**. They are used in **research, education, entertainment, and assistance roles**.
- ▶ **Aerial Robotics (Drones):** commonly known as **drones**, are unmanned aerial vehicles used for **aerial photography, surveillance, mapping, disaster monitoring, and delivery services**.
- ▶ **Consumer Robotics:** are designed for **personal or household use**, such as **robot vacuum cleaners, lawn mowers, and personal assistant robots**.
- ▶ **Space Robotics:** are used in **space exploration missions**, including **satellite servicing, planetary exploration, and space station maintenance**.



Application areas, pros and cons

▶ Robotics is applied in various fields to improve efficiency, accuracy, and safety. Below are some major application areas of robotics along with their advantages and disadvantages.

▶ **1. Manufacturing and Industrial Automation**

- ✓ **Pros:** Increase efficiency, productivity, and precision in manufacturing processes. Robots can work continuously without fatigue, handle hazardous materials, and perform repetitive tasks with high accuracy.
- ✓ **Cons:** High initial investment costs for setup and maintenance. Requires specialized programming and may lead to job displacement for certain manual labor roles.



Application areas, pros and cons...

2. Healthcare and Medical Robotics

- ✓ **Pros:** Assist in surgeries, rehabilitation, and patient care, improving precision and reducing the risk of human error.
- ✓ **Cons:** Complex regulatory approval processes and concerns about safety, reliability, and ethical considerations. Limited accessibility due to high costs and technological dependencies.

3. Service and Hospitality Robots

- ✓ **Pros:** Assist in tasks such as cleaning, delivery, customer service, and entertainment, enhancing efficiency and customer satisfaction. Can operate 24/7, reducing labor costs and improving service quality.
- ✓ **Cons:** Limited adaptability and social interaction capabilities compared to human counterparts. Concerns about privacy, security, and potential job displacement in service industries.



Application areas, pros and cons...

4. Agricultural Robotics

- ✓ **Pros:** Automate tasks like planting, harvesting, and monitoring crops, increasing yield, reducing labor costs, and minimizing environmental impact. Precision agriculture techniques enabled by robotics improve resource utilization and crop management.
- ✓ **Cons:** Challenges in adapting to diverse terrains, crops, and weather conditions. Initial investment costs and the need for integration with existing agricultural practices.





End of Chapter Six



Any doubt?