

XI - Chapter 2.2

Natural Language Processing (NLP)

Learning Objectives

After studying this chapter, students will be able to:

- Understand Natural Language Processing
- Learn more about Text Generation as an application of NLP
- Learn more about Language Translation as an application of NLP
- Learn more about Question Answering (Chatbots)
- Know more about the various types of Internet Searches

1 Human Language vs Computer Language

Humans naturally communicate through speech and writing, which our brain constantly interprets. For example, in a classroom, even if you are listening to the teacher, your attention might suddenly shift when your friend starts speaking. Your brain then processes both inputs but prioritizes the one that interests you more.

Speech is received through the ears, converted into signals, and interpreted by the brain, allowing us to understand meaning. If the meaning is unclear, we ask for clarification.

Computers, on the other hand, communicate through numbers and codes. Any input must be in their language, and even a small error can cause rejection of the command. Unlike humans, machines rely on structured, error-free input.

2 What is Natural Language Processing?

Natural Language Processing (NLP) is one of the most important branches of Artificial Intelligence (AI). It focuses on enabling computers and machines to understand, interpret, process, and generate human language in a way that feels natural and meaningful. In simple words, NLP is about teaching machines how to "read, listen, and talk" like humans.

Every day, enormous amounts of text are generated — conversations in chats, social media posts, tweets, blogs, articles, reviews, and much more. All of this is known as unstructured data, because unlike numbers in a spreadsheet, it doesn't follow a neat or uniform structure. Hidden inside this unstructured data is a wealth of information about opinions, emotions, facts, and knowledge.

NLP uses linguistics, computer science, and machine learning algorithms to extract this hidden information. For example, it can identify whether a product review is positive or negative, recognize the main topics in a long document, or even detect the emotion behind a social media post.

The ultimate goal of NLP is to allow computers to interact with humans using natural language. This includes tasks such as:

- Text summarization – condensing large documents into concise summaries.
- Language translation – converting text from one language to another (e.g., Google Translate).
- Chatbots and virtual assistants – answering questions and assisting users in real time.
- Speech recognition – converting spoken words into written text (e.g., voice typing, Siri, Alexa).
- Sentiment analysis – identifying emotions and opinions expressed in text.

2.1 Why is NLP difficult?

Computers are used to structured, rule-based communication. Human language, however, is ambiguous, context-driven, and full of variations like slang, sarcasm, and cultural references.

- Some rules are abstract (e.g., sarcasm).
- Others are simple (e.g., adding “s” for plurals).

For NLP to succeed, machines must not only recognize words but also understand how they combine to express meaning.

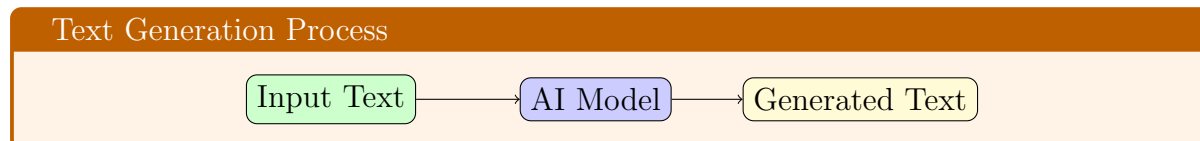
3 Text Generation as an Application of NLP

Text generation refers to AI creating human-like text—whether it’s a story, poem, article, or even code. This is achieved using language models like GPT or Google’s PaLM, which are trained on large datasets.

3.1 How it Works

At the heart of text generation lies language modelling. NLP models are trained on vast amounts of text data, learning the patterns, grammar, and style of human language. These models can then predict the next word in a sequence, allowing them to generate coherent and contextually relevant text.

At the core of text generation are language models, such as GPT (Generative Pre-trained Transformer) and Google’s PaLM, which have been trained on vast amounts of text data from the internet. These models employ deep learning techniques, specifically neural networks, to understand the structure of sentences and generate coherent and contextually relevant text.



3.2 Applications of Text Generation

Text generation has a wide range of applications, including:

- **Content creation:** Articles, blogs, product descriptions.
- **Chatbots and virtual assistants:** Conversational responses.
- **Language translation:** Generating real-time language conversions.
- **Summarization:** Condensing long texts into concise versions.

3.3 Limitations of Text Generation

Text generation also has certain limitations:

- May lack deep context understanding.
- Rely heavily on training data.
- Struggle with rare/unseen scenarios.
- Raise ethical issues such as bias or misinformation.

3.4 Examples

- **GPT-3 (OpenAI):** versatile text generation.
- **LaMDA (Google):** dialogue-focused model.
- **AI Dungeon:** an interactive story game.

4 Text Understanding

Text Understanding or Natural Language Understanding (NLU) goes beyond words to grasp meaning and context. It involves:

4.1 Components of NLU

- **Semantic analysis:** Understanding the meaning of words and phrases.
- **Syntactic analysis:** Analyzing the grammatical structure of sentences.
- **Contextual understanding:** Interpreting the meaning of text based on its surrounding context.
- **Sentiment analysis:** Determining the emotional tone of text.
- **Entity recognition:** Identifying and classifying named entities (e.g., people, places, organizations).

4.2 Applications

- **Search engines:** Understanding search queries to provide relevant results.
- **Chatbots:** Comprehending user input to provide accurate responses.
- **Sentiment analysis tools:** Analyzing customer reviews and social media posts.
- **Information extraction:** Automatically extracting key information from documents.

5 Language Translation

Machine translation refers to the use of **Artificial Intelligence (AI)** and **Machine Learning algorithms** to automatically translate text or speech from one language into another. It is a key application of **Natural Language Processing (NLP)** that enables cross-linguistic communication.

5.1 Steps

- **Input Processing:** Breaking down the source language into words, grammar, and context.
- **Model Application:** Using AI models such as neural networks (e.g., Google's Transformer models) to understand meaning and context.
- **Output Generation:** Producing text or speech in the target language while preserving meaning, tone, and context.

5.2 Techniques

- **Statistical Machine Translation (SMT):** Uses statistical models to learn the probabilities of word and phrase correspondences between languages.
- **Neural Machine Translation (NMT):** Employs deep learning models, particularly sequence-to-sequence models, to learn complex mappings between languages and generate more fluent and natural-sounding translations.

5.3 Examples

- Google Translate, Microsoft Translator, and DeepL for text translation.
- Real-time speech translators in applications like Zoom and Skype.

5.4 Applications of Machine Translation

Machine Translation has a wide range of applications in daily life, education, and global industries. It plays a vital role in reducing language barriers and enabling seamless communication. Some important applications include:

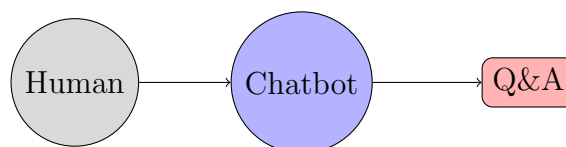
- **Machine Translation Tools:** Online services such as *Google Translate*, *Bing Translator*, and *DeepL* provide instant translation of text, documents, and even entire web pages across multiple languages.
- **Cross-Border Communication:** Facilitates communication between people from different countries, enhancing international cooperation, diplomacy, and travel experiences.
- **Localization:** Used to translate websites, mobile applications, and software interfaces into multiple languages, making digital content more accessible to users around the globe.
- **Business and Commerce:** Helps businesses translate documents, contracts, emails, and marketing materials, enabling them to expand internationally and collaborate effectively with global partners.
- **Education and Learning:** Supports language learning by offering translations that aid students in understanding new languages. It also provides multilingual learning resources for learners across the world.

5.5 Challenges

- Ambiguity in meanings.
- Idioms and cultural nuances.
- Limited resources for less common languages.

6 Chatbots

They focus on building systems that automatically answer questions posted by human beings in their natural language.



6.1 How They Work

Question answering chatbots utilize NLP techniques in these ways:

- They analyze the user's question to identify the key information and intent behind it.
- They search through a knowledge base or a collection of documents to find relevant information that can answer the question.
- They generate a human-like response that provides the answer in a clear and concise way.

6.2 Applications

- **Customer service:** Providing instant support and answering customer queries.
- **Education:** Answering student questions and providing learning resources.
- **Information retrieval:** Helping users find information quickly and easily.
- **Virtual assistants:** Assisting users with various tasks and answering their questions.

6.3 Examples

- **Chatbots on websites:** Many websites use chatbots to answer frequently asked questions.

7 Smart Assistants (Dialogue Systems)

Smart assistants are computer programs that use artificial intelligence to understand and respond to human language. They are designed to help users with various tasks and services.

- **They “understand” you:** Smart assistants use AI, specifically Natural Language Processing (NLP), to interpret your voice commands or text requests.
- **They perform actions:** Based on your instructions, they can do things like:
 - Answer your questions (like “What’s the weather?”)
 - Set reminders and alarms
 - Play music
 - Control smart home devices (like lights and thermostats)
 - Make calls and send messages
 - Provide information (like news or sports scores)

Some popular examples of smart assistants include **Siri (Apple)**, **Google Assistant**, **Amazon Alexa** and **Microsoft Cortana**.

By accessing our data, they can help us in keeping notes of our tasks, make calls for us, send messages and a lot more. With the help of speech recognition, these assistants can not only detect our speech but can also make sense out of it.

8 Internet Search

Every day, billions of queries are entered into search engines to find information. Approximately **2.2 trillion search queries** are processed by all search engines each year. As of April 2023, Google dominates the market with **92.82%** share, and around **68% of all online experiences** begin with a search. Google alone processes over **8.5 billion searches daily**.

Internet search is the process of using a search engine to locate information on the internet. It involves entering a query (a word or phrase) into a search engine, which then returns a ranked list of relevant web pages and other online content.

Whether it’s a simple question like “*What’s the weather today?*” or a complex inquiry like product comparisons, search queries are the gateway to information. Essentially, they help search engines understand **user intent**, enabling them to present the most relevant content, products, or services.

8.1 Main Types of Searches

8.1.1 Navigational Searches

Navigational queries are like the GPS of the online world—they guide users directly to a specific website or page. These searches are performed when the user already knows where they want to go, using the search engine as a shortcut.

Examples:

- Facebook
- YouTube login
- Amazon Prime

Case: “YouTube login” is a navigational query because it directly leads users to YouTube’s login page.

8.1.2 Informational Searches

These are learning-oriented queries, where the goal is to gain knowledge, explore a new topic, or answer a question. Such searches reflect curiosity and the need for information.

Examples:

- How to bake a cake
- Symptoms of the common cold
- Best places to visit in Italy

8.1.3 Transactional Searches

Transactional searches are action-oriented queries where the intent is to perform a specific task, such as buying, subscribing, or downloading.

Examples:

- Buy iPhone 16
- Order pizza online
- Book a flight to London

Case: “Subscribe to Netflix” is a transactional search as it initiates a subscription process.

8.1.4 Investigative Searches

Investigative queries focus on comparison, reviews, or exploration before making a decision. They often occur during the research phase of a purchase.

Examples:

- Top rated laptops for students
- Compare Samsung Galaxy vs. Google Pixel
- Best credit cards for travel rewards
- Reviews of electric cars

8.1.5 Voice Searches

Voice searches represent a growing trend, where users speak naturally to search engines via voice assistants. These queries often resemble human conversation.

Examples:

- “OK Google, what’s the weather today?”
- “Hey Siri, find me directions to the nearest coffee shop.”
- “Alexa, play music by Taylor Swift.”

Case: Asking, “What movies are playing tonight?” is a voice search query, imitating natural human interaction with technology.

Note:

Some searches may fall into multiple categories. For example, “best laptops” can be both *informational* (learning about laptops) and *investigative* (comparing options).

9 Key Terms

- **Natural Language Processing (NLP):** A subfield of AI focused on enabling computers to understand and process human languages. NLP attempts to extract information from spoken and written words using algorithms.
- **Text Generation:** A process where an AI system produces written content, imitating human language patterns and styles. Language models like GPT (Generative Pre-trained Transformer) and Google’s PaLM are at the core of text generation.
- **Machine Translation:** The use of AI and machine learning algorithms to automatically translate text or speech from one language to another.
- **Question Answering Chatbots:** Computer systems that understand natural language and can translate sentences written by humans into an internal representation to generate valid answers.
- **Internet Search:** The process of using a search engine to find information on the internet.
- **Navigational Searches:** Queries that guide users to a specific website or page.
- **Informational Searches:** Queries where users are looking for information on a topic, to learn something new, or to answer a question.
- **Transactional Searches:** Searches driven by a clear intent to perform a specific action, such as making a purchase or signing up for a service.
- **Investigative Searches:** Queries where users are researching and comparing options before making a decision, often a purchase.
- **Voice Searches:** Using voice to speak a search query instead of typing it.

Exercise Questions

Short Answer Questions

1. Define Natural Language Processing in one sentence.
2. Name two real-world tools or platforms that use machine translation.
3. List any two popular smart assistants.
4. What is the main purpose of sentiment analysis?
5. Explain why NLP is considered difficult for computers.
6. Differentiate between **Statistical Machine Translation (SMT)** and **Neural Machine Translation (NMT)**.
7. Mention three applications of **text generation**.
8. What are the key components of Natural Language Understanding (NLU)?

Long Answer Questions

1. With the help of examples, explain how text generation models like GPT work and what their limitations are.
2. “Human language is ambiguous, while computer language is structured.” — Discuss this statement with reference to NLP.
3. Explain the working process of a chatbot using NLP. Mention its advantages and challenges.
4. Describe the types of internet searches (navigational, informational, transactional, investigative, and voice search) with suitable examples.
5. Explain in your own words what Natural Language Processing (NLP) is and why it is useful.