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Comprehensive analysis of natural language processing

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Abstract

Natural Language Processing (NLP) is a fascinating field of study that teaches computers to understand and use human language. This means that computers can read, write, and even translate text just like humans. NLP has many practical uses, such as categorizing text, identifying the tone of language, recognizing names in text, translating languages, and answering questions. NLP has come a long way since it was first developed. In the past, it relied on strict rules to understand language, but now it uses advanced techniques like machine learning and deep learning to understand text. However, there are still some challenges in NLP, such as understanding the meaning of words in context and considering cultural differences. Despite these challenges, NLP is being used in many different areas, from healthcare and finance to education and customer service. NLP is transforming the way humans interact with computers and is making it easier to extract important information from large amounts of text.

Keywords: NLP; Natural Language Processing; NLP APIs; Phases of NLP; Application areas of NLP

1. Introduction

Natural Language Processing (NLP) is a technology that allows computers to understand and analyze human language. It's a complex field that involves many different approaches, but the goal is to make computers better at understanding and using language in a way that's similar to how humans do. This technology can be used for many different things, like helping computers understand and respond to our questions, translating languages, and even analyzing social media data to understand how people are feeling. [1]

Natural Language Processing (NLP) is a computer-based method used to analyze text. It's a very active field of research and development, and it uses both theories and technologies. While there isn't a single definition that everyone agrees on, there are some things that everyone would say are part of NLP. Essentially, NLP is a way to teach computers to understand human language and respond in a way that is similar to how humans would. This can be useful in a variety of applications where language is important. [2]

2. History of NLP

2.1. Early Foundations (1950s-1960s)

The field of Natural Language Processing (NLP) has its roots in the 1950s, when pioneers like Alan Turing proposed ideas about machine intelligence and the possibility of machines understanding human language. The early attempts to automate language translation during this period marked the birth of NLP. Notable among these attempts is the Georgetown-IBM experiment in 1954, where a machine was able to automatically translate over sixty Russian sentences into English. This experiment paved the way for further research in NLP, which has since grown to include a wide range of applications such as sentiment analysis, chatbots, and machine translation.

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2.2. Rule-based Approaches (1960s-1970s)

During the 1960s and 1970s, Natural Language Processing (NLP) researchers focused on using rule-based approaches to develop systems that could parse and comprehend natural language. This involved creating systems with manually crafted rules to process and understand language. Notable systems from this era include the SHRDLU system, developed by Terry Winograd in the late 1960s, which could understand and execute commands in a restricted block world environment. These systems were built using grammatical rules and handcrafted linguistic knowledge to process and understand language. The projects like SHRDLU demonstrated early attempts at natural language understanding by manipulating blocks in a virtual world using English commands.

2.3. Statistical Methods (1980s-1990s)

In the 1980s and 1990s, researchers began using statistical approaches and machine learning techniques for language processing tasks. Hidden Markov Models and n-gram models were popular for speech recognition and language modeling. Notable projects during this time included machine translation and speech recognition systems with limited accuracy. Large-scale annotated corpora facilitated the training of more sophisticated models.

2.4. Rise of Machine Learning (2000s-Present)

Natural Language Processing (NLP) made great strides in the 2000s, thanks to advancements in machine learning. Neural networks like recurrent neural networks (RNNs) and transformer models revolutionized NLP tasks, from translation to sentiment analysis and language generation. Huge datasets like the Penn Treebank and the Common Crawl drove the development of more sophisticated NLP models. Transfer learning techniques like BERT enabled fine-tuning of pre-trained models for specific tasks. TensorFlow and PyTorch accelerated research and development in NLP by providing powerful tools for building and training complex models. The rise of the internet and the availability of vast amounts of text data fuelled NLP growth. Researchers experimented with complex algorithms like Support Vector Machines (SVMs), Conditional Random Fields (CRFs), and neural networks. This period also saw the development of annotated datasets like the Penn Treebank, which were vital for training and evaluating NLP models.

2.5. Recent Advances and Applications

The incredible advancements in natural language processing have paved the way for a new generation of intelligent applications. With the ability to comprehend, generate, and engage in dialogue, these technologies are making a significant impact in areas such as virtual assistants (e.g. Alexa, Siri), chatbots, sentiment analysis, and machine translation. However, it is crucial that we prioritize ethical and unbiased models to ensure that these powerful tools are used for the greater good. Let us continue to push the boundaries of NLP innovation while always keeping in mind the importance of responsible development. [3]

3. Advantages of NLP

Natural Language Processing (NLP) offers numerous advantages across various domains and industries. Some of the key advantages include:

- NLP facilitates efficient information retrieval by enabling computers to understand and process human language. This helps search engines, recommendation systems, and data analytics retrieve information quickly and accurately from large volumes of text data.
- NLP algorithms analyze unstructured text data for insights, sentiments, and trends. This helps businesses make data-driven decisions efficiently.
- NLP enhances customer interaction by powering chatbots, virtual assistants, and voice recognition systems. This leads to higher satisfaction and retention by instantly responding to inquiries, assisting with tasks, and personalizing user experiences.
- NLP enables multilingual communication through machine translation, sentiment analysis, and language understanding, promoting global collaboration, business expansion, and cultural exchange.
- NLP automates repetitive tasks like document classification, summarization, and sentiment analysis, reducing errors and freeing up resources for more strategic activities, increasing productivity and saving time.
- NLP enables organizations to derive valuable insights from vast amounts of textual data, uncovering hidden patterns and correlations that support data-driven decision-making and innovation.
- NLP technologies, like speech recognition and text-to-speech, improve accessibility for individuals with disabilities, promoting inclusivity and equal access to information and services.

- NLP enables personalization of content recommendations, advertising, and product suggestions based on users' preferences, behaviors, and sentiments. This leads to higher user engagement, conversion rates, and customer loyalty.
- NLP algorithms can detect fraud by analyzing patterns and linguistic cues, protecting against online threats like phishing emails, fake reviews, and malicious content.
- NLP is revolutionizing healthcare delivery by facilitating clinical documentation, medical coding, disease detection, and patient monitoring through analysis of EHRs, medical literature, and patient-generated data. This leads to higher diagnosis accuracy and better treatment outcomes, ultimately improving patient care. [2]

4. Applications areas of NLP

There are many ways that computers can understand and work with human language, and these techniques are used in a lot of different fields. Here are some examples:

- 1. Chatbots and virtual assistants: You might have talked to a computer program that can understand what you're saying and help you with something. These programs use language technology to understand what you're asking for and respond in a way that makes sense.
- 2. Search engines: When you type something into Google or another search engine, it uses language technology to try to find pages that are relevant to what you're looking for. This is why you can type in a question and get an answer or look for a specific kind of product and find it easily.
- 3. Social media and customer feedback: Companies can use language technology to analyze what people are saying about them on social media or in customer reviews. This can help them understand how people feel about their products or services and make changes if necessary.
- 4. Translation: Language technology can help translate text from one language to another. This is useful if you're traveling in a foreign country, or if you need to communicate with someone who speaks a different language.
- 5. Summarizing and understanding documents: Language technology can read through long documents and pull out the most important information. This can be useful for things like reading research papers or trying to find specific information in a large document.
- 6. Identifying important information: Language technology can find important information in text, like the names of people or places. This can be helpful for things like organizing data or finding trends in large amounts of information.
- 7. Answering questions: Language technology can help answer questions, like if you're looking for information about a certain topic. This can be useful if you're doing research or trying to learn something new.
- 8. Sorting and filtering information: Language technology can help sort through large amounts of information and find what's important. This can be helpful for things like sorting through emails or finding the most relevant news articles.
- 9. Speech recognition: Language technology can help computers understand what people are saying, even if they're not typing. This can be helpful for things like hands-free devices or voice-controlled assistants.
- 10. Healthcare: Language technology can help people in the healthcare industry, like doctors and researchers, understand large amounts of medical information. This can help improve patient care and find new treatments for diseases.
- 11. Finance: Language technology can help people in the finance industry understand what's happening in the world and make better decisions. This can be helpful for things like investing or trading in stocks.
- 12. Legal: Language technology can help people in the legal industry analyse and understand complex legal documents. This can be helpful for things like researching laws or finding important information in contracts. [2]

5. Sub-problems in NLP

In Natural Language Processing (NLP), several sub-problems arise due to the complexity and ambiguity inherent in human language. Some of the key sub-problems in NLP include:

- Tokenization breaks down text into smaller units for analysis, but it can be challenging for complex languages or ambiguous text.
- POS (Part-of-Speech) tagging assigns grammatical categories to words in a sentence, but it can be challenging due to ambiguities arising from multiple possible POS tags depending on context.

- Named Entity Recognition (NER) involves identifying and classifying named entities in text, such as persons, organizations, locations, and dates. Accurately recognizing entities can be challenging due to variations in entity names, ambiguous references, and entity types.
- Syntactic parsing is a powerful tool that helps us better understand the language we use to communicate with each other. Although it faces challenges such as complex structures and ambiguity resolution, this tool allows us to determine the grammatical relationships between words. With syntactic parsing, we can gain a deeper understanding of the meaning behind the words we use. So let's continue to explore the language we use to connect with one another and use these tools to build a better world.
- Semantic analysis is a process that goes beyond the surface structure of text in order to comprehend its intended meaning. One of the primary challenges of this process is resolving ambiguity in word senses. Additionally, it must manage ambiguity in semantics and capture contextual nuances to be effective.
- Word Sense Disambiguation (WSD) is the process of determining the correct meaning of a word based on its context. It is challenging due to polysemy and homonymy in natural language.
- Coreference resolution links expressions referring to the same entity in text, but it can be challenging due to ambiguity.
- Textual entailment recognition involves determining whether one piece of text logically entails another. Challenges include capturing semantic relationships, lexical variations, and handling negation and quantification.
- Sentiment analysis is the process of determining the opinion or sentiment expressed in a text. Challenges include dealing with sarcasm, irony, and figurative language, as well as capturing sentiment intensity and subjectivity.
- Machine translation automatically translates text from one language to another, but it faces challenges like capturing semantic nuances, handling idiomatic expressions, and resolving divergences between languages. These sub-problems in NLP represent fundamental challenges that researchers and practitioners continue to address through the development of advanced algorithms, linguistic resources, and machine-learning techniques. Solutions to these sub-problems contribute to the advancement of NLP and enable the development of more accurate and robust natural language processing systems. [9]

6. Overview of phases of NLP

NLP applications generate a parse tree for sentences. To do this, we rely on language models to identify the class of each word. The process is interdependent and may face ambiguity issues. Rule-based approaches are no longer reliable, so we use data-driven methods which make up the statistical revolution of NLP. The below fig (1) shows five phases of NLP. [4]

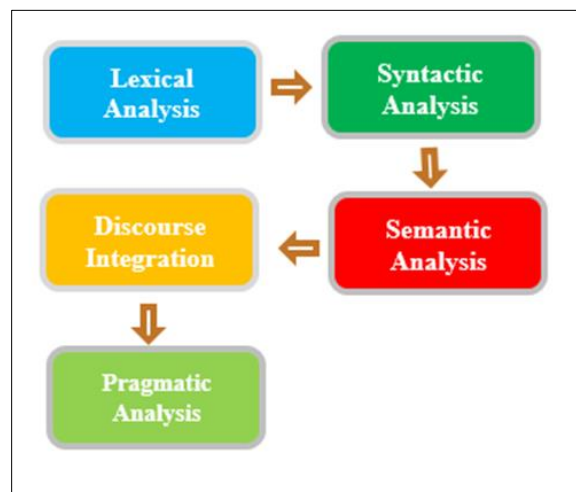


Figure 1 Five Phases of NLP

6.1. Lexical Analysis

The first step in NLP is called Lexical Analysis. It involves scanning the source code as a stream of characters and converting it into meaningful lexemes. The text is then divided into paragraphs, sentences, and words.

6.2. Syntactic Analysis (Parsing)

Syntactic Analysis is a process that helps to verify the correctness of grammar and the relationship between words. It checks the arrangement of words and ensures coherence in the text.

Example: Delhi goes to the Rohit

The sentence " Delhi goes to the Rohit " is not coherent in the real world. This means that the Syntactic analyzer rejects it.

6.3. Semantic Analysis

Semantic analysis is all about understanding the meaning of words, phrases, and sentences. It focuses on the literal meaning of language.

6.4. Discourse Integration

When it comes to Discourse Integration, the sentences that come before and after it play a crucial role in determining its meaning. The context of the preceding sentences and the following ones are both significant in invoking the intended sense of Discourse Integration.

6.5. Pragmatic Analysis

The NLP process has five phases, and Pragmatic is the final one. Pragmatic helps you understand the intended effect by using a set of rules that define cooperative dialogues.

For Example: When someone says "Close the door", it should be understood as a request rather than an order. [6]

7. Difficulties in NLP

Natural Language Processing (NLP) is a complex field of study that deals with the interpretation and manipulation of human language by computers. One of the major challenges of NLP is language ambiguity, which refers to the fact that many words and phrases can have multiple meanings depending on the context in which they are used. This can make it difficult for NLP algorithms to accurately understand and interpret the meaning of text, speech, or other forms of human language.

Three types of ambiguities exist which are as follows: -

7.1. Lexical Ambiguity

Lexical ambiguity is a phenomenon that occurs when a word in a sentence has multiple possible meanings, each of which can significantly alter the interpretation of the sentence. This ambiguity may arise due to the structure of the sentence, the context in which it is used, or the multiple definitions or connotations associated with the word in question.

Example: Ram is looking for a **match**.

In the above example, the word match refers to that either Ram is looking for a partner or Ram is looking for a match. (Cricket or another match)

7.2. Syntactic Ambiguity

Syntactic ambiguity refers to a situation where a sentence can have two or more possible meanings due to the presence of structural or grammatical ambiguity. In other words, when a sentence can be interpreted in more than one way, it is said to be syntactically ambiguous.

Example: I saw the kid with the binoculars.

In the above example, did I have the binoculars? Or did the kid have the binoculars?

7.3. Referential Ambiguity

Referential ambiguity is a linguistic phenomenon that occurs when a pronoun used in a sentence can refer to multiple possible antecedents, making it unclear which one is being referred to.

Example: Rakesh went to Mahesh. He said, "I am hungry."

In the above sentence, you do not know that who is hungry, either Rakesh or Mahesh. [5]

8. NLP APIs

Below there is a comprehensive list of Natural Language Processing (NLP) APIs that are available for use:

8.1. IBM Watson API

IBM Watson API uses machine-learning to classify text into custom categories, supporting multiple languages. It extracts insights, automates workflows, enhances search, and analyzes sentiment. The API is also known for its ease of use.

Pricing: Firstly, it offers a free 30-day trial IBM cloud account. You can also opt for its paid plans.

8.2. Chatbot API

Chatbot API creates intelligent chatbots for web applications with support for Unicode characters, text classification, and multiple languages.

Pricing: Chatbot API is free for 150 requests per month. You can also opt for its paid version, which starts from \$100 to \$5,000 per month.

8.3. Speech-to-text API

The Speech to Text API is a useful tool that enables the conversion of spoken words into written text. It works by analyzing the audio input and transcribing it into text format, which can then be easily read and processed by a computer. This technology is commonly used in various applications, such as virtual assistants, transcription software, audio-to-text converters, and speech recognition systems. The API can recognize multiple languages and dialects, and it can be integrated into different platforms, including mobile devices, web browsers, and desktop applications.

Pricing: Speech-to-text API is free for converting 60 minutes per month. Its paid version starts from \$500 to \$1,500 per month.

8.4. Sentiment Analysis API

Sentiment Analysis API, also known as 'opinion mining', is a powerful tool that enables the identification and analysis of the prevailing tone or sentiment of a user's opinion. It can accurately classify the sentiment of a given text as either positive, negative, or neutral, and provide insightful information about how people feel towards a particular topic or product. This technology uses natural language processing and machine learning algorithms to help businesses and organizations understand the opinions and emotions of their customers, which can aid in making informed decisions and improving customer experience.

Pricing: Sentiment Analysis API is free for less than 500 requests per month. Its paid version starts from \$19 to \$99 per month.

8.5. Translation API by SYSTRAN

The Translation API by SYSTRAN is a powerful tool that enables users to translate text from one language to another. In addition to translation, the API also provides a range of natural language processing (NLP) capabilities such as language detection, text segmentation, named entity recognition, and tokenization. These features allow users to analyze and manipulate text in a variety of ways, making the API a versatile and valuable resource for anyone working with multilingual content. Whether you are a language learner, a content creator, or a business looking to expand globally, the Translation API by SYSTRAN is a great choice for all your language-related needs.

Pricing: This API is available for free. But for commercial users, you need to use its paid version.

8.6. Text Analysis API by AYLIEN

The Text Analysis API developed by AYLIEN is an incredibly useful tool that enables users to derive meaningful insights from textual content. Whether you're looking to analyze customer feedback or gain a better understanding of social media trends, this API can help you make sense of large volumes of text. The best part is that it's available in both free and paid versions, with the paid version starting at just \$119 per month. And the best part is that it's incredibly easy to use, even if you don't have any prior experience with text analysis tools. With its intuitive interface and robust features, the Text Analysis API by AYLIEN is an excellent choice for anyone looking to gain valuable insights from textual data.

Pricing: This API is available free for 1,000 hits per day. You can also use its paid version, which starts from \$199 to \$1,399 per month.

8.7. Cloud NLP API

The Cloud NLP API is a powerful tool that can significantly enhance the natural language processing capabilities of any application. This technology enables you to perform a range of natural language processing functions, including but not limited to sentiment analysis and language detection. By leveraging the Cloud NLP API, you can quickly and easily extract valuable insights from unstructured text data, which can help you make more informed business decisions. The API is designed to be intuitive and user-friendly, so you don't need to be an expert in natural language processing to take full advantage of its capabilities. Whether you're working on a small-scale project or a large enterprise application, the Cloud NLP API is a reliable and efficient solution for improving your natural language processing workflows.

Pricing: Cloud NLP API is available for free.

8.8. Google Cloud Natural Language API

The Google Cloud Natural Language API is a powerful tool that enables you to extract valuable insights from unstructured text. With this API, you can perform a range of sophisticated analyses, including entity recognition, sentiment analysis, content classification, and syntax analysis. The API features over 700 predefined categories, allowing you to categorize your text data with a high degree of accuracy. Additionally, the Google Cloud Natural Language API supports text analysis in multiple languages, including English, French, Chinese, and German. This makes it an ideal solution for businesses operating across multiple countries and regions, or for any project requiring multilingual text analysis capabilities.

Pricing: After performing entity analysis for 5,000 to 10,000,000 units, you need to pay \$1.00 per 1000 units per month. [7, 8]

9. Comparison of NLP with structured programming Languages

NLP is a powerful subfield of artificial intelligence that focuses on the interaction between human language and computers. It allows machines to understand, interpret, and respond to natural language input from users. On the other hand, structured programming languages are computer programming languages that are designed to be easy to read and understand, often used to create software applications, web services, and other computer programs.

The comparison also involves exploring the various techniques used in NLP, such as syntactic and semantic analysis, and how they differ from the algorithms used in structured programming languages.

Ultimately, understanding the differences between NLP and structured programming languages is crucial for building effective and efficient computer systems that can interact with users in a natural way. It enables developers to create software that can understand and respond to human language input, making it easier for people to interact with technology and access the information they need. [6]

10. Scope of NLP in practical life

Natural Language Processing (NLP) is becoming increasingly important in our daily lives. It has revolutionized the way we interact with technology and the applications of NLP are vast and varied. Some practical applications of NLP include speech recognition, sentiment analysis, language translation, chatbots, and voice assistants. These technologies have made our lives easier by providing us with personalized experiences and quick access to information. As NLP continues to advance, we can expect to see even more innovative uses in a wide range of industries, from healthcare to finance to education.

In healthcare, NLP helps in analyzing medical reports, detecting diseases, and assisting in medical research. In education, NLP assists in improving language learning, providing personalized feedback, and evaluating academic writing. In finance, NLP helps in analyzing financial documents, detecting fraud, and predicting market trends. In customer service, NLP assists in providing quick and efficient responses to customers' queries, automating support services, and improving customer satisfaction. Overall, the scope of NLP in practical life is immense, and it has become an integral part of our daily lives without us even realizing it.

11. Conclusion

NLP has the potential to revolutionize software development and human-computer interaction, making programming more accessible to a broader audience and empowering individuals without coding expertise to engage in software development tasks. Additionally, NLP can reshape the future of computing by driving advancements in automation, artificial intelligence, and human-computer collaboration, ultimately paving the way for a new era of human-machine interaction.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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