

Natural Language Processing in Finance

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Abstract: Natural language processing (NLP) is a branch of artificial intelligence that focuses on enabling computers to process and analyze large amounts of natural language data. It combines computational linguistics with machine learning, and deep learning models. It bridges the gap between human communication and data processing, allowing AI systems to analyze text, process speech, translate across languages, and grasp nuanced meanings. NLP in the financial sector is revolutionizing various facets, from enhancing operational efficiencies to enabling more informed decision-making. NLP is modifying finance, offering innovative ways to process unstructured data, enhance operational efficiency, and maximize business impact. NLP has become increasingly important in the financial world, where language often reflects strategic intent, risk exposure, or market sentiment. This paper reviews the transformative role of NLP in finance.

Keywords: Natural Language Processing (NLP), Computational Linguistics, Finance, Financial Organizations

I. INTRODUCTION

Technology plays a pivotal role in shaping strategies, optimizing processes, and enhancing decision-making. Among the myriad of technological advancements, natural language processing (NLP) has emerged as a transformative technology across various industries, and finance is no exception. 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 manner that is both meaningful and contextually relevant. It has become a transformative force within the financial sector. By enabling computers to understand, interpret, and generate human language, NLP is revolutionizing various facets of finance, from enhancing operational efficiencies to enabling more sophisticated data-driven decision-making [1].

Financial organizations are tasked with analyzing an overwhelming amount of data, including news reports, earnings calls, financial statements, and regulatory filings. They manage immense textual data. NLP is reshaping how financial institutions process and analyze data, turning previously unmanageable volumes of unstructured information into actionable insights. From identifying emerging market trends to improving the clarity of financial reporting, NLP offers future-proof strategies that empower organizations to meet their goals more effectively [2]. The application of NLP in the financial sector has been transformative across various facets, from enhancing operational efficiencies to enabling more personalized customer engagements and improving strategic decision-making processes.

II. FUNDAMENTALS OF NLP

Natural language processing is a subfield of artificial intelligence that empowers computers to understand, interpret, and generate human language. It is a technique where machine can become more human and thereby making human to

communicate with the machine easily. NLP seeks to make software intelligent enough to process a natural language as humans. For example, imagine a machine that takes instructions by voice.

NLP analysis generally consists of the following three levels [3]:

- *Syntax*, the study of sentence structure. Syntax deals with the formation of a sentence from individual words. Syntax alone suggests the proper interpretation of “Jimmy loves Lucy.”
- *Semantics*, the study of context-independent meaning. This derives the meaning of a sentence based on the meanings of the words/phrases. For example, semantics determines whether the word “bank” refers to a river bank or to a financial institution.
- *Pragmatics*, the study of context-dependent meaning. Pragmatics deals with how meaning changes in the presence of a specific context and how the contexts affect the meaning of the sentences. This level is concerned with the purposeful use of language in situations.

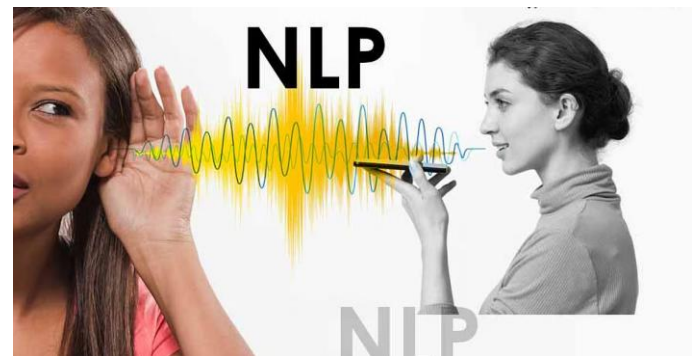


Figure 1: A representation of NLP [4].

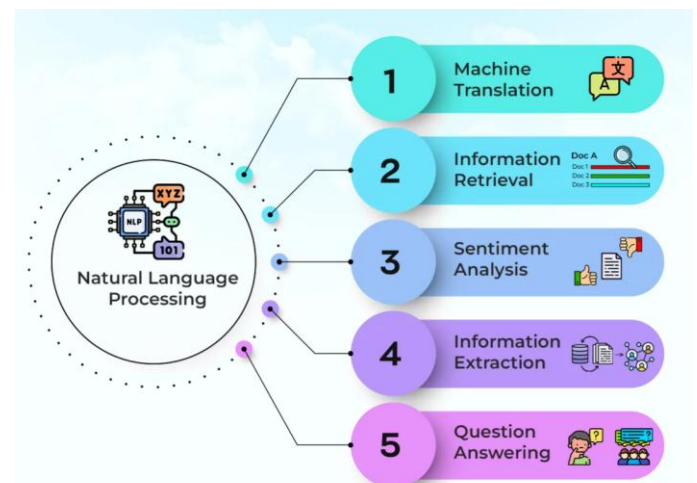


Figure 2: Different components of NLP [5].

As a foundational pillar of modern artificial intelligence, NLP encompasses a wide array of tasks, including speech

recognition, text classification, natural language understanding (NLU), and natural language generation (NLG). NLP encompasses a wide range of tasks, such as information retrieval (IR), named entity recognition (NER), relation extraction, text classification, topic modeling, semantic textual similarity, machine translation, and question answering (QA). Figure 1 shows how NLP transforms raw acoustic data into meaningful interactions [4], while Figure 2 shows different components of NLP [5].

Recently, large language models (LLMs) have shown their ability in learning universal language representations, text understanding and generation. LLMs refer to a model with a large number of parameters, vast training data, and substantial compute, enabling it to capture complex language patterns. In LLM-based NLP, pre-processing is followed by prompt engineering, which guides LLMs to produce outputs that align with extraction requirements during inference without altering the model's parameters. Models like GPT are pushing the boundaries of language understanding, enabling nuanced and context-aware applications. The GPT (Generative Pretrained Transformer) is a large-scale language model developed by OpenAI that consists of multiple layers of transformer blocks, each with a self-attention mechanism and a forward neural network [6]. GPT-based systems can summarize complex reports or generate creative content like essays, making them versatile in both academic and professional environments. ChatGPT uses NLP techniques to understand prompts. When you enter a prompt, the chatbot comprehends it and provides relevant replies. Figure 3 shows how NLP works [7], where Figure 4 depicts some applications of NLP [8].

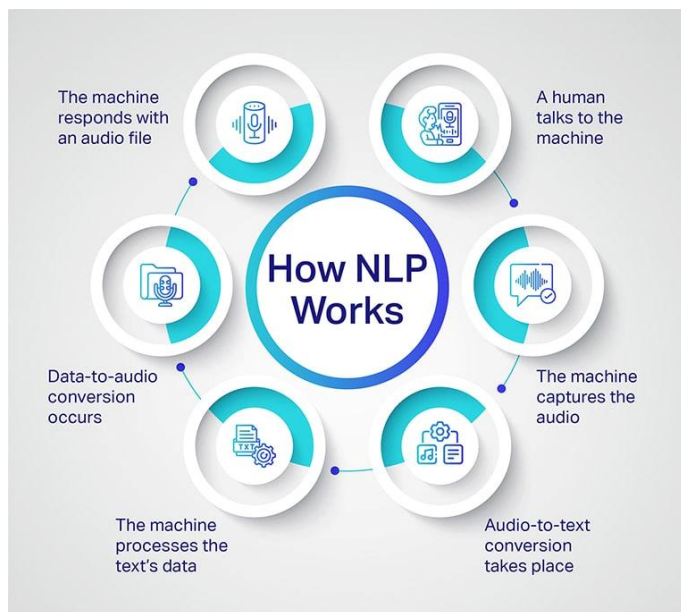


Figure 3: How NLP works [7].



Figure 4: Some applications of NLP [8].

III. NLP IN FINANCE

Finance used to be all about numbers: spreadsheets, budgets, forecasts. But today, there is a new expectation: explain what the numbers mean. The financial industry, characterized by its vast and complex datasets, is undergoing a significant transformation driven by advancements in artificial intelligence, particularly natural language processing (NLP). NLP enables computers to understand, interpret, and generate human language, unlocking unprecedented insights from the vast ocean of unstructured textual data that permeates the financial world. It has emerged as a critical technology for extracting valuable insights from unstructured textual data [9]. By combining linguistics with machine learning, NLP makes it possible to analyze large volumes of unstructured text, such as financial disclosures, earnings call transcripts, and research reports, with speed and consistency. NLP encompasses a wide array of tasks aimed at understanding, interpreting, and extracting information from textual data in the financial domain. This includes processing corporate data, public news and announcement, social media data, and any other form of textual data that can impact financial markets and decision-making. Figure 5 shows a representation of NLP in finance [8].



Figure 5: A representation of NLP in finance [8].

In the financial sector, where accuracy, timeliness, and informed analysis are critical, NLP bridges the gap between unstructured language data and actionable insights. Its ability to interpret and process human language allows financial institutions to stay ahead in an industry where decisions are based on nuanced and complex information. NLP in finance refers to the broader application of NLP techniques to the financial sector, which generally includes corporate data, public financial news and announcements, and social media data. NLP in the finance market is segmented into banking, insurance, financial services, and others. It encompasses a wide array of tasks aimed at understanding, interpreting, and extracting information from textual data in the financial domain.

IV. APPLICATIONS OF NLP FINANCE

The application of NLP in finance spans a wide array of critical functions, significantly impacting how financial institutions operate and interact with market data. Applications of NLP techniques within the financial sector include financial sentiment analysis, financial forecasting, portfolio management, virtual assistant and chatbot, risk management, regulatory compliance, and market research. Common applications of NLP in finance are explained as follows [2,9-11]:

- *Sentiment Analysis:* One of the most prominent applications of NLP is financial sentiment analysis, which involves determining the emotional tone behind textual data. Financial markets are heavily influenced by

sentiment, which is often expressed in textual data such as news articles, social media posts, analyst reports, and earnings call transcripts. NLP algorithms are adept at extracting market sentiment from a vast ocean of unstructured text data, including e-mails, social media posts, news articles, financial reports, customer reviews, and other text-heavy formats that do not fit neatly into traditional databases. This capability provides invaluable insights into market psychology, influencing algorithmic trading strategies and offering a predictive edge in understanding market volatility. Financial institutions leverage NLP to analyze news articles and analyst reports to gauge market sentiment towards specific companies, sectors, or the overall economy.

- **Regulatory Compliance:** Regulatory compliance is a paramount concern for financial institutions, with ever-evolving rules and stringent reporting requirements. The financial industry is heavily regulated, with a constant need to interpret and comply with complex regulatory texts. NLP plays a crucial role in automating compliance checks by analyzing regulatory texts, identifying potential breaches, and ensuring adherence to guidelines. NLP automates the laborious process of understanding these regulations, enabling financial institutions to monitor communications for potential fraud, insider trading, or other non-compliant behaviors. This proactive approach helps in flagging questionable activities before they escalate into regulatory issues, thereby streamlining compliance processes and reducing operational risks.
- **Risk Management:** Risk management is a crucial aspect of financial operations, requiring detailed analysis of contracts, market data, and regulatory updates. In risk management, NLP helps identify emerging risks by analyzing financial reports, news feeds, and economic indicators. It can also enhance credit scoring models by incorporating non-traditional textual data, providing a more holistic view of a borrower's financial health and potential risks. NLP-powered tools improve risk management by identifying vulnerabilities in contracts and regulatory filings, reducing exposure to financial risks. For example, a bank reviewing loan agreements can use NLP to flag terms that suggest higher risk profiles or identify inconsistencies in regulatory compliance. These insights allow institutions to proactively address vulnerabilities, reduce financial exposure, and ensure operational stability.
- **Portfolio Management:** Portfolio management requires continuous monitoring of market conditions, news sentiment, and investment performance. NLP tools analyze these data sources to provide actionable insights, helping portfolio managers optimize allocations and identify profitable opportunities. The ability to process various data streams in real time helps organizations improve portfolio outcomes, maximize returns, and mitigate potential losses.
- **Market research:** Market research relies heavily on data collection and analysis, and NLP streamlines this process by automating the extraction of trends and patterns from large volumes of text. Organizations use this information to identify untapped business opportunities and guide investment or product strategies. NLP automates the analysis of financial reports, earnings calls, and news articles, enhancing investment research. By processing and analyzing vast amounts of textual

data, NLP tools extract key insights and trends that influence investment strategies.

- **Chatbots:** NLP powers intelligent chatbots and virtual assistants that provide 24/7 customer support in the financial industry. These NLP-driven systems can understand customer queries, provide instant answers to frequently asked questions, assist with routine transactions, and guide customers through complex financial processes. This not only improves customer satisfaction but also reduces the workload on human customer service representatives, allowing them to focus on more complex issues. Figure 6 shows the use of a chatbot [2].
- **Fraud Detection:** NLP can identify unusual patterns or anomalies in textual data, aiding in the detection of fraudulent activities. It can be used to analyze text data to identify patterns that might indicate fraudulent activity. For example, it can be used to analyze customer emails or social media posts to identify potential money laundering attempts. NLP can analyze transaction descriptions and detect suspicious or unauthorized activities. It enhances fraud detection systems by analyzing unstructured data from emails, chat logs, and transaction descriptions to identify suspicious activities. By detecting patterns and keywords associated with fraudulent activities, NLP improves the ability to identify sophisticated fraud schemes. NLP can aid with the identification of significant potential risks and possible fraud, like money laundering. This helps to increase value-generating activities in order to disseminate them across the organization.
- **Auditing:** Companies now realize NLP's importance in gaining a significant advantage in the audit process, especially after dealing with endless daily transactions and invoice-like papers for decades. NLP enables financial professionals to directly identify, focus, and visualize anomalies in day-to-day transactions.
- **Stock Predictions:** Predicting time series for financial analysis is a complicated task because of the fluctuating and irregular data as well as the long-term and seasonal variations that can cause large errors in the analysis. However, deep learning combined with NLP outmatches previous methodologies working with financial time series to a great extent. These two technologies combined effectively deal with large amounts of information. These methods are viable alternatives to existing conventional techniques of stock indices prediction because of the high-level of precision they offer. NLP and deep learning techniques are useful to predict the volatility of stock prices and trends and also are a valuable tool for making stock trading decisions.



Figure 6: Use of a chatbot [2].

V. BENEFITS

Natural language processing is undeniably reshaping the financial landscape, offering unprecedented opportunities for automation, enhanced decision-making, and improved efficiency across various domains. It drives more intelligent, faster, and more effective financial operations by delivering automation, insights, and scalability. Other benefits of NLP in finance include the following [1,9]:

- *Automation:* There is a notable surge in demand within the finance industry for automation and efficiency, especially in leveraging NLP. Financial institutions deal with an immense amount of unstructured data daily, from contracts and legal documents to customer emails and internal reports. This sheer volume makes manual processing time-intensive, error-prone, and inefficient. Automating the processing of text-heavy resources like earnings reports, contracts, and market analyses significantly reduces manual intervention. NLP can automate the manual processes involved in converting this unstructured data into a usable format, leading to significant time and cost savings. It allows financial institutions to automate labor-intensive tasks, saving time and reducing operational costs. Using machine learning in finance helps firms analyze sentiment, assess risk, and improve accuracy, far beyond what manual processes can achieve. Automation accelerates the speed at which financial data is processed and analyzed, thereby enabling quicker decision-making.
- *Enhanced Accuracy:* NLP algorithms excel at identifying trends, detecting risks, and analyzing vast datasets with precision. Unlike traditional methods prone to human error, NLP offers consistently accurate insights, granting firms to minimize costly risk management, portfolio management, and compliance mistakes.
- *Improved Decision-making:* By providing faster, more accurate, and more comprehensive insights from textual data, NLP enables financial professionals to make better-informed decisions.
- *Improved Customer Service:* NLP can be used to power chatbots that can answer customer questions, resolve issues, and provide personalized financial advice. This can improve customer satisfaction and reduce costs for financial institutions.
- *Scalability:* The finance industry is significantly adopting cloud-based services which provide scalability. Financial services generate terabytes of data daily, requiring scalable methods to process this information quickly. NLP systems can process these datasets in real time, making managing tasks like analyzing regulatory updates or summarizing financial statements at scale easier. Their scalability and efficiency allow organizations to achieve faster results, future-proof their strategies, and unlock previously untapped potential. Scaling NLP models to handle enterprise-level data while maintaining high performance and low latency requires robust infrastructure and optimization strategies. Scalability is crucial for NLP tasks such as sentiment analysis, trend detection, and risk assessment, which require processing large datasets in real-time.

VI. CHALLENGES

Despite its transformative potential, NLP in finance faces challenges, particularly in grasping the nuances of human language, understanding financial jargon, and adapting to

rapidly evolving market environments. Challenges related to explainability, bias, data quality, privacy concerns, complexity, model reliability, numerical reasoning, multimodal integration, and regulatory compliance persist. Other challenges of NLP in finance include the following [9]:

- *High Cost:* Minor and small-scale organizations cannot afford advanced NLP-based systems as they are quite expensive. Apart from the software and additional hardware costs, regular updates need to be scheduled and implemented. Systems can be unavailable for an extended period of time if there is a problem with the update.
- *Data Quality:* The quality and complexity of financial data present ongoing challenges. Financial text is often dense, highly technical, and replete with specialized jargon, requiring sophisticated NLP models capable of accurately interpreting this nuanced language. Financial data is often highly sensitive, regulated, and proprietary, making its collection, annotation, and sharing a complex undertaking. Ensuring data quality, consistency, and privacy while adhering to stringent regulatory frameworks like GDPR or CCPA is paramount.
- *Bias:* Bias is another critical concern. NLP models trained on historical data may inadvertently perpetuate or amplify existing biases present in that data, leading to unfair or discriminatory outcomes in areas such as credit scoring, loan approvals, or even hiring processes. Ensuring fairness and mitigating bias in NLP applications is paramount for ethical deployment. NLP models must be meticulously designed to mitigate bias and ensure fairness, avoiding discriminatory outcomes based on protected characteristics present in the training data. Achieving this requires careful data curation and robust bias detection and mitigation strategies.
- *Complexity:* The financial sector presents a unique set of complexities that pose significant challenges to the effective implementation and scaling of NLP solutions. One of the primary challenges stems from the context and ambiguity inherent in financial language. Unlike general English, financial texts often employ specialized terminology where common words can carry distinct meanings. The highly regulated nature of the financial industry adds another layer of complexity.
- *Low Signal-to-Noise Ratio:* Financial markets are characterized by a vast amount of information, much of which is irrelevant or redundant. Identifying genuine market-moving signals amidst this low signal-to-noise ratio is a significant challenge for NLP models.
- *Hallucinations:* LLMs, while capable of generating fluent and coherent text, are prone to hallucinations, producing factually incorrect or nonsensical outputs. In a domain where accuracy is paramount, such errors can have severe consequences, potentially propagating through critical financial workflows if not meticulously checked.
- *Integration:* Integrating NLP solutions with legacy systems in the finance market presents several complexities. Financial information is rarely confined to text alone. Financial institutions rely on legacy systems, making integration a challenging process. Annual reports, earnings call transcripts, and market analyses often include tables, charts, and even audio. The ability of NLP models to perform multimodal integration, processing and understanding information across these diverse formats, is crucial and technically challenging.

- *Collaboration:* As the field evolves, collaborative efforts between NLP researchers, financial experts, and regulators will be essential to overcome these hurdles and pave the way for a more intelligent and efficient financial future.

VII. FUTURE OF NLP FINANCE

The NLP in finance market is experiencing robust growth. A notable trend is the shift towards large language models (LLMs). The industry is moving beyond traditional NLP techniques to more sophisticated transformer-based architectures and specialized LLMs. As NLP technologies, particularly LLMs, become more sophisticated, their impact on financial operations, strategic decision-making, and overall market dynamics is expected to grow even further, ushering in an era of more intelligent, efficient, and resilient financial systems [9].

The future of NLP in finance looks promising, with advancements in AI and machine learning paving the way for more sophisticated applications. The future points towards real-time, tailored insights that will further democratize financial analytics, making sophisticated tools accessible to a broader range of users and continuing to drive innovation across the industry. As NLP models become more advanced, they will offer more accurate predictions of market trends and stock movements [1]. In the future, NLP will help the banks identify new revenue streams, make lending decisions, and provide personalized financial advice.

CONCLUSION

Natural language processing is no longer a nascent technology in finance but a mature and indispensable tool that is reshaping the industry. From automating tedious tasks and enhancing risk management to providing deeper market insights and improving customer engagement, NLP's applications are vast and continue to expand. NLP is becoming indispensable for financial companies seeking measurable business impact through better resource management, accurate analytics, and improved customer experiences. It holds immense potential for transforming the finance industry, revolutionizing how financial institutions analyze data, interact with customers, and manage risks. NLP is used across the financial industry, from retail banking to hedge fund investing.

Natural language processing (NLP) is rapidly transforming the financial sector by unlocking the value hidden in vast amounts of unstructured text data. NLP techniques are used to transform the unstructured text information into insightful analytics. It enables machines to understand, interpret, and generate human language, offering financial institutions powerful tools to automate routine tasks, enhance decision-making, and gain deeper market insights. There has never been a better time to build NLP solutions for finance. Traders, portfolio managers, analysts, banks and other financial organizations strive to improve their financial analysis, and NLP and ML have become the technologies of choice [11]. More information about the integration of NLP in finance can be found in [12-15] and the following related journals:

- *Natural Language Processing Journal*
- *Journal of Emerging Technologies and Innovative Research*

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