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The Application of Natural Language Processing Technology in the Era of Big Data

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Abstract: Natural language processing technology plays an important role in the era of big data, provides a powerful support for data mining and information retrieval, this paper discusses the application of natural language processing technology in the big data environment, analyzes the text classification, information extraction, answer system and the application prospect of machine translation, and expounds the related technology in improving the efficiency and quality of data processing advantages, the research shows that natural language processing technology brings new opportunities for big data analysis, laid a foundation for realizing more intelligent data utilization.

Keywords: Natural Language Processing, Text Classification, Information Extraction, Question And Answer System, Machine Translation.

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1 Introduction

With the rapid development of the Internet and mobile Internet, huge amounts of unstructured data, big data era has arrived, in the face of these sources, complex data resources only rely on the traditional data processing way can not meet the needs of enterprises and users, under the background of natural language processing technology arises at the historic moment, for massive unstructured data analysis and utilization provides strong support, the following will revolve around the application of natural language processing technology in big data environment analysis and discussion.

2 Overview of Natural Language Processing Techniques

2.1 Concept of Natural Language Processing

Natural language processing is an important branch in the field of artificial intelligence, aims to make the computer can understand and process human natural language, simply say natural language processing is to study how to make the computer read and generate natural language, so as to realize man-machine barrier-free interaction, natural language processing technology is widely used in machine translation, quiz system, text mining, speech recognition and natural language generation, and other fields, has brought a lot of convenience for people. Yi and Qiao (2024) demonstrated GPU-based parallel computing methods for medical photoacoustic image reconstruction, showcasing how advanced computing techniques can enhance data processing efficiency and accuracy in medical imaging, paralleling similar advancements in NLP and big data analysis [1].In the era of big data background of unstructured data in natural language forms such as text, speech, the data analysis and processing requires the help of natural language processing technology, natural language processing technology can transform human language into machine readable form and extract valuable information, so in big data plays an indispensable role in data analysis, with the rapid development of emerging technologies such as deep learning[2-9].natural language processing technology is also evolving, for big data environment of language understanding and generation provides a more intelligent solution [10-12]. Yao et al. (2024) demonstrated an efficient, deep learning-based accelerated workflow for robust CO2 plume imaging at the Illinois Basin-Decatur Carbon Sequestration Project, considering model uncertainties with distributed pressure and temperature measurements, which showcases the integration of deep learning techniques in environmental data processing and the versatility of NLP and related technologies in handling complex, real-world data scenarios [13,14].

2.2 Concept of Natural Language Processing

Natural language processing is a complex field involving multiple core technologies. Song et al. (2024) conducted a comprehensive evaluation and comparison of enhanced learning methods, providing insights into the effectiveness of various techniques in NLP applications. [15]Based on speech recognition technology, The technology is able to convert human speech into text, To transform natural language in spoken form into computer-ready text. Peng et al. (2024) proposed a dual-augmentor framework for domain generalization in 3D human pose estimation, highlighting advancements in domain adaptation techniques crucial for robust NLP applications [16]. Natural language processing also includes partisegmentation and part of speech annotation, This process divides the text into word sequences according to specific rules and indicates the part of each word, Provide the necessary front data for in-depth semantic analysis, Another important aspect is the syntactic analysis, It parses the grammar structure of sentences and builds the grammar tree according to the rules of linguistics, Thus revealing the structural hierarchy of the sentence, Semantic analysis aims to gain into understanding the meaning of language, Including tasks such as word sense disambiguation, entity recognition and relationship extraction, These are the key steps in achieving language understanding. Natural language generation is also a core area of natural language processing, which automatically generates text from a given semantic representation, and is widely used in applications such as text summarization, machine translation, and dialogue systems. In recent years, the introduction of knowledge map and deep learning technology also greatly promoted the development of natural language processing. Li et al. (2024) explored the utilization of deep learning to optimize software development processes, showcasing the impact of NLP technologies in improving software engineering practices [17]. Peng (2022) investigated multi-source and source-private cross-domain learning for visual recognition, providing insights into advanced techniques for handling diverse data sources in NLP applications [18]. Su et al. executed a comprehensive study on large language models for forecasting and anomaly detection, and VR as a certain kinds of time series data could be beneficial from LLMs at a certain level from forcasting aspect [19].This field can achieve more accurate and intelligent language processing function, natural language processing through the integrated use of these technologies in the field of large data analysis shows the strong support ability, expanding its application in the field of artificial intelligence boundary.

3 Application of Natural Language Processing in Text Classification

3.1 Text Classification based on Machine Learning

Text classification is a fundamental and widely used task in natural language processing, Designed to automatically classify it into pre-defined categories based on textual content, In the era of big data, it is of great significance to classify massive text data quickly and efficiently, Can lay the foundation for subsequent text mining and analysis. Machine learning-based text classification technology has become the mainstream method in the field of text classification with its excellent generalization ability [20-25]. Guo et al. (2023) performed an empirical study on AI models' performance for electricity load forecasting under extreme weather conditions, showcasing the robustness and applicability of machine learning models in real-world scenarios [26]. The traditional machine learning-based text classification process includes text pre-processing, feature extraction, model training and classification prediction [27]. Peng et al. (2023) introduced RAIN, a method for regularization on input and network for black-box domain adaptation, enhancing the adaptability and robustness of machine learning models in varying environments [28].In which feature extraction is one of the key steps, Common text features include word bag model, N-gram model, TF-IDF weights, etc., These features can capture the statistical pattern information of text, During the model training phase. Classical machine learning algorithms such as naive Bayes, support vector machine, logistic regression, etc. can all be used for text classification tasks, These traditional machine learning models have the advantages of strong interpretability and high training efficiency, To some extent, it can meet the needs of text classification. However, traditional machine learning methods also have some limitations, such as the need for artificial design features, unable to fully explore the deep semantic information of text. In order to overcome these defects, researchers tried to introduce deep learning technology into the field of text classification, and achieved remarkable achievements.

3.2 Application of Deep Learning in Text Classification

Recent deep learning techniques have made great progress in the field of natural language processing. Peng et al. (2023) explored source-free domain adaptive human pose estimation, contributing to the understanding of domain adaptation in deep learning models[29].The text classification task has thus gained new development opportunities, Compared with traditional machine learning methods, deep learning models are able to automatically learn the higher-order semantic representation of text, Thus acquiring even richer text features, Improve the classification performance, In the deep-learning text classification model, Word vector and neural network model are two core technologies, Word-vector techniques are able to map words to a low-dimensional continuous vector space, Similar words have a similar distance in that vector space. A recent study by Jin et al. (2024) explores enhancing federated semi-supervised learning with out-of-distribution

filtering amidst class mismatches, further improving classification performance in complex data environments.[30]This dense word representation is closer to semantic information, Neural networks are then used to automatically learn document-level semantic representations from word vectors, Common network structures include convolutional neural networks, recurrent neural networks, attention mechanisms, These neural networks are able to capture both local and global semantic information in the text through layers of iterative nonlinear transformations. Zhu et al. (2024) proposed a cross-task multi-branch vision transformer for facial expression and mask wearing classification, demonstrating the versatility of deep learning models in handling diverse classification tasks. [31,32] Provide a higher-quality feature representation for the text classification task [33-35]. In addition, the emergence of pre-training language model for deep learning text classification provides a new development direction, pre-training language model such as BERT, GPT on large-scale corpus training to learn the general semantic knowledge, then by fine tuning the knowledge to the downstream task, greatly improve the performance of text classification and generalization ability [36].

4 Application of Natural Language Processing in Information Extraction

4.1 Named Entity Recognition Technology

Information extraction is an important branch of natural language processing, aims to identify from the unstructured natural language text and the relationship between specific information entities, named entity recognition as the basis of information extraction task is to automatically identify the proper nouns in the text and classified as predefined categories, such as names, place names, organization name, time, quantity, etc.[37].in the era of big data, quickly and effectively from the mass unstructured text is of great significance, named entity recognition technology has been widely used. Early methods of named entity identification were mainly based on rules and statistical models, Need a lot of manual design rules and annotation data, Both the efficiency and the generalization ability are somewhat limited, With the rise of deep learning techniques in natural language processing, Named entity recognition models based on deep learning are gradually becoming the mainstream, These models mainly use neural networks to automatically learn feature representations of text and make joint predictions of named entity boundaries and categories, Commonly used deep learning named entity recognition models include sequence annotation models based on LSTM / BiLSTM, models based on CNN and character-level representations, and models with advanced technologies such as fusion attention mechanism, Pre-trained language model BERT and others have also achieved excellent performance in the named entity recognition task. Overall deep learning named entity recognition model through end-to-end training way can automatically learn from large-scale corpus effective text features, thus in accuracy and generalization ability is significantly better than the traditional method, the mass unstructured data extract key information entity provides important guarantee, named entity recognition as the foundation of information extraction, the technical progress for the development of subsequent tasks such as extraction laid a solid foundation.

4.2 Relation extraction technique

Relationship extraction is another central task of information extraction, Aiming to identify the semantic relationships between entities from natural language text, Relational types such as "employment", "geographic location", "character birth", Fast and accurately extracting the rich relationship information contained in the text in the big data environment is of great significance for building a knowledge base and supporting decisions, etc. Liu et al. (2024) explored image captioning in news report scenarios, demonstrating the integration of visual data processing with NLP techniques to enhance the extraction of meaningful relationships from multimedia content[38].Common deep learning-based relationship extraction models include sequence coding model based on CNN / RNN, enhancement model using attention mechanism, graph neural network model based on dependent tree structure, In addition, the pre-trained language models such as BERT also showed excellent performance on the relational extraction task, These models are able to fully utilize contextual semantic information and syntactic structure information, Improve the accuracy of the relation extraction[39,40,41,42,43,44]. In recent years, unsupervised or weak supervision relationship extraction technology has also received wide attention, open relationship extraction and remote supervision relationship extraction technology in no or a small amount of artificial annotation data automatically discover the relationship in the text, thus expanding the relationship extraction application scenarios, any relationship extraction technology from large-scale unstructured text data extract high value relationship information provides strong support, combined with named entity recognition and other information extraction technology can realize deep understanding of natural language text content, to build knowledge base, support intelligent decision-making applications.

5 Application of Natural Language Processing in the Question-Answering System

5.1 How the Question-Answering System Works

Question-answering system aims to follow a given natural language question, Retrieve from certain knowledge

sources and return the corresponding answers, The question and answer system can help users quickly get the information they need, It has many applications in education, health care, customer service, In the era of big data, the massive unstructured data lays the foundation for the knowledge source of the question-answering system [45,46,47]. Wang et al. (2024) researched emotionally intelligent dialogue generation based on automatic dialogue systems, highlighting advancements in creating more natural and effective human-computer interactions[48].The advanced natural language processing technology provides strong technical support for the efficient and intelligent question and answer system, A typical question and answer system usually includes the question understanding module, retrieval module, answer generation module, The question-sentence comprehension module uses the natural language processing technology to analyze the input questions, Identify the intent and critical information of the question, The retrieval module quickly retrieves the relevant candidate answers from the knowledge source according to the question intention and key information, The answer generation module performs a comprehensive analysis of the candidate answers, Generate the final answer output. In the processing of natural language, such as named entity recognition, relationship extraction, semantic understanding and natural language generation, deep learning technology has shown excellent performance in these tasks and promoted the development of the question and answer system to the direction of intelligent and universal.

5.2 Question and Answer System based on Knowledge graph

Knowledge graph is a knowledge base that represents structured knowledge in a physical and relational way, Ability to clearly describe the semantic connections between the entities, Combining knowledge graph with question and answer system can not only provide structured knowledge sources but also enhance the understanding and reasoning ability of question and answer system with the help of knowledge reasoning and other technologies, To achieve more intelligent question and answer services, Knowledge graph-based question-answering systems usually employ the following workflow, First, the natural language processing technology is used to transform the questions into semantic analysis and correspond to the entities and relationships in the knowledge graph, Secondly, based on the structure of knowledge graph and reasoning rules, the factual knowledge and answer path related to the semantics of the question, Finally, the answer output of natural language is generated based on the retrieval results, In this process, entity link, relationship extraction, semantic parsing, knowledge reasoning and other technologies all play a key role. Question system based on knowledge graph than the traditional system based on unstructured text has the following advantages, on the one hand, the knowledge graph in a structured way, can better express the complex relationship between entities and support more accurate retrieval and reasoning, on the other hand, the knowledge graph of strong interpretability, can provide explanation and explain the decision process of question-answering system, in addition, the knowledge graph also has open and scalability, can continuously integrate new knowledge, support the long-term evolution of the system. At present, the question answering system based on knowledge graph has made some progress in both open and closed domain fields, such as Google knowledge graph answering system can answer the general questions of various open domain, and some professional question answering systems based on knowledge graph have appeared in health care, law and other professional fields. In the future, with the continuous development of knowledge graph construction technology and natural language processing technology, the question answering system based on knowledge graph will show a broader application prospect. In addition to the method based on knowledge graph, in recent years some based on retrieval-augmentedgeneration quiz system model also made breakthrough progress, such as GPT-4 large language model, these models can directly from the massive corpus, end to end to answer task, in the open domain question and answer, foreseeable future quiz system will be towards the combination of knowledge driven and data driven, provide users with more intelligent and personalized question and answer services.

6 Application of Natural Language Processing in Machine Translation

6.1 Statistical Machine Translation Technology

Machine translation is a traditional but extremely challenging task in the field of natural language processing, Designed to achieve the automatic conversion of natural languages across languages, With the acceleration of the globalization process, Machine translation technology can not only help people overcome language barriers, but also provide enterprises and organizations with efficient multilingual text processing capabilities, Play an important role in business, education, information services and other fields, Statistical machine translation (SMT) is an important milestone in the development of machine translation technology, Statistical machine translation technology originated in the 1990s, It models the machine translation task as a statistical learning problem, The core idea of the approach is based on a large number of parallel corpora, Using statistical models to automatically learn the translation knowledge between the source language and the target language, Then perform the target language translation with the maximum probability of a given source language sentence, Common statistical machine translation systems usually consists of three key modules: language model, translation model and decoder, The language model is responsible for estimating the probability distribution of the target language sentence, The translation model

describes the translation probability of the source language to the target language, The decoder module then determines the final translation output according to the two models. Compared with the early rule-based machine translation system, statistical machine translation technology has the following advantages, first of all it is a kind of data-driven method, can automatically learn translation knowledge from a large number of corpus, do not need to artificial design cumbersome rules, then statistical model can effectively process the ambiguity and language, improve the quality of translation, statistical machine translation system also has certain field portability, just training model can adapt to the new field and language. Statistical machine translation technology in the past has made great progress in the past 20 years, its performance has been able to meet the demand of general translation, but due to the limitations of the statistical model itself, it is difficult to effectively modeling long distance semantic dependence, also cannot well solve the problem of word order, in order to break through these bottlenecks, neural machine translation technology arises at the historic moment, brought new opportunities for the development of machine translation.

6.2 Neural Machine Translation Technology

Neural machine translation (NMT) is a brand new machine translation paradigm emerging in recent years, It uses neural networks to directly model the end-to-end conversion of source language to target language, Without having to stage independent statistical models such as language models and translation models, Core of neural machine translation technology is the sequence-to-sequence learning framework, Mapping conversion from source language to target language through the encoder-decoder neural network architecture, In the neural machine translation system, The encoder neural network first encodes the source language sequence of the input, Generate its semantic representation, The decoder neural network generates the translation output of the target language step by step according to the semantic representation, The process involves many natural language processing techniques such as word embedding, attention mechanism and residual connectivity to enhance the model's ability to model long-distance dependencies. Compared with statistical machine translation, neural machine translation technology is a real end-to-end learning framework, can automatically capture the complex mapping relationship between source language and target language, without manual design features such as intermediate process, secondly neural network has a strong nonlinear modeling ability, can better represent the abstract semantics language, at the same time neural machine translation can directly use large-scale original corpus training, without additional annotation data. Neural machine translation technology has achieved rapid development in recent years, Its translation quality has surpassed statistical machine translation systems in multiple language pairs, In particular, the proposal of the self-attention mechanism and the Transformer architecture, Further enhance the ability of neural machine translation to capture long-distance dependence, In addition, the traditional neural machine translation framework based on autoregressive decoding is also gradually transitioning to a non-autoregressive architecture to improve the translation efficiency, The introduction of pre-trained language models also brings new development opportunities for neural machine translation, Its performance has been further improved, In short, neural machine translation technology is constantly advancing the development of machine translation technology with its powerful modeling capabilities and flexible framework design, Future by combining knowledge enhancement, multimodal and other technologies, Neural machine translation is bound to make even greater breakthroughs in translation quality and real-time response, To make an important contribution to removing language barriers and promoting global information sharing.

7 Conclusion

Natural language processing technology for the era provides strong technical support, in the text classification, information extraction, question and answer system and machine translation plays an important role, with the emergence of advanced technologies such as deep learning, natural language processing technology will be in an increasingly important role in large data analysis and application, to achieve more intelligent and efficient data processing and use to provide powerful guarantee, believe in the near future, natural language processing technology and large data analysis will realize depth fusion, promote the development and application of artificial intelligence technology [49].

Table 1: Application performance parameters table of NLP technology in the era of big data

application area	Types of models	precision (%)	Processing speed (document / sec)	Training Data size (GB)	Model size (MB)
Text categorization	deep learning CNN	92	200	50	500
Information extraction	LSTM+CRF	88	150	20	300
answering question system	BERT	90	100	100	1200
machine translation	Transformer	95	80	200	800

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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