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ARTIFICIAL NEURAL NETWORKS IN MACHINE LINGUISTICS

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Abstract. *Artificial neural networks (ANN) have revolutionized natural language processing (NLP) and have fundamentally changed the approach to solving linguistic problems. Due to their ability to learn from large amounts of data, ANN demonstrate high performance in tasks such as machine translation, emotion analysis, speech recognition, text generation, etc. In addition, ANNs have become a key tool in solving complex linguistic problems due to their ability to learn from large amounts of data, generalize information, and deep understanding of context.*

The purpose of this article is to analyze the current state of ANN use in linguistics, review the main architectures and technologies, and discuss the challenges and prospects for further development.

Key words: *machine linguistics, machine learning, artificial neural networks, deep ANN*

Introduction.

Machine linguistics is actively developing due to the introduction of cognitive and intelligent information technologies, because it is these technologies that allow creating systems capable of automated processing and analysis (both texts and natural language), contextual understanding of language, prediction and generation of text (and even natural speech). Cognitive information systems model the processes of perception, thinking and decision-making [1, 2], while intelligent technologies use machine learning and artificial intelligence algorithms for analysis and analytics of accumulated data [3] and automation of linguistic tasks.

However, the above-mentioned cognitive and intelligent technologies in machine linguistics are implemented by two different approaches: first symbolic, and then connectionist, respectively, first within the framework of classical machine linguistics, and then within the framework of modern neural machine linguistics (based on deep artificial neural network technologies).

Natural Language Processing (NLP) emerged in the 1950s (and was widely used until the early 2000s) as a branch of artificial intelligence that deals with the development of algorithms for automated processing and analysis of natural language. It is based on formal rules [4], linguistic regularities, classical machine learning [5] and statistical methods. The classical approach involves the use of regular expressions, context-free grammars, Markov models and other statistical algorithms. These methods allow solving standard, basic NLP tasks, such as: tokenization, morphological analysis, parsing, machine translation, sentiment analysis and text classification.

Thanks to the rapid development of special architectures of computing power (in particular NVidia neurochips), Big Data technologies, architectures and algorithms for training artificial neural networks [6], in particular deep neural networks [7] - a revolution in machine linguistics has begun - the rapid development and spread of neurolinguistics. Thanks to neurolinguistics - NLP has achieved revolutionary successes (providing high accuracy and adaptability) in solving large-scale, complex and complex, contextual and personalized, large and long-term - complex tasks of machine linguistics.

So, taking into account the above, currently the scientific and practical tasks of improving modern technologies and approaches, improving specialized architectures and algorithms for training DEEP artificial neural networks in machine linguistics, as well as researching challenges and future directions of their development have become particularly relevant.

Main text.

The following taxonomy of promising areas for effective use of ANNs in machine linguistics is proposed:

1). Contextual language understanding: Traditional statistical methods have limited ability to understand context and word polysemy. ANNs are able to learn complex semantic and syntactic relationships, providing a deeper understanding of context.

2). Text generation: Creating coherent and grammatically correct text is a complex task that requires modeling long-term dependencies and context.

3). Scalability and adaptability: ANNs are easily scaled to large amounts of data and can adapt to new domains and languages.

4). Versatility of applications: ANNs are effectively used in a wide range of linguistic tasks, such as machine translation, speech recognition, sentiment analysis, question-answering, text generation, and chatbots.

Taxonomy of ANN architectures and learning algorithms in machine linguistics:

1). Convolutional Neural Networks (CNN). Used to capture local dependencies and spatial relationships in text. Effective in text classification, sentiment analysis, and keyword detection.

2). Recurrent Neural Networks (RNN) and Long Short-Term Memory (LSTM). Model sequences of words, taking into account temporal dependencies. LSTMs use a mechanism for forgetting and storing information, which allows them to effectively model long-term dependencies. Used in machine translation, speech recognition, and text generation.

3). Attention Mechanisms. Provide a flexible mechanism for focusing on different parts of the input sequence. Increase the efficiency of processing long texts and complex syntactic structures.

4). Transformers. Use full attention (self-attention), which allows sequences to be processed in parallel. Transformer-based models, such as BERT and GPT, have become the basis of modern language models. BERT (Bidirectional Encoder Representations from Transformers) provides bidirectional context encoding. GPT (Generative Pre-trained Transformer) uses autoregressive encoding for text generation.

The main areas of application of ANN in machine linguistics are highlighted:

a). Sentiment Analysis and Text Classification. Using CNN and BERT for contextual analysis of sentiment in texts (examples: BERT, RoBERTa, DistilBERT).

b). Text Generation and Chatbots. The GPT architecture is used to generate coherent text and create intelligent chatbots (examples: ChatGPT, Bard, Claude).

c). Machine Translation. Transformers have achieved revolutionary successes in machine translation due to powerful attention and contextualization mechanisms (examples: Seq2Seq, Transformer, GPT, T5).

d). Speech Recognition. Using CNN for spectrogram processing and RNN/LSTM for modeling temporal dependencies (examples: Tacotron, Wav2Vec, Whisper).

e). Multi-modal applications (examples: CLIP, DALL-E, Gemini).

The main challenges/difficulties and prospects for the application of ANN in machine linguistics are highlighted:

A). Explainability: difficulty in interpreting model solutions.

B). Scalability and Computational Cost: high computational and power requirements.

C). Bias and Ethics: problems with generating biased or offensive responses.

D). Data Constraints: insufficient annotated data for less common languages.

The main prospects for the application of ANNs in machine linguistics are formulated:

A). Knowledge Generalization: Zero-Shot and Few-Shot Learning.

B). Model Optimization: Sparse Transformers, LoRA.

C). Logical Thinking Integration: Neural-Symbolic AI.

Summary and conclusions.

Cognitive and intelligent information technologies significantly expand the capabilities of machine linguistics, providing contextual language understanding, adaptive learning and interactivity.

Classical machine linguistics (which does NOT involve the use of deep ANN) - laid the foundations of natural language processing, forming formal grammars, statistical models and transformation rules. It contributed to the development of syntactic analysis, machine translation and text classification. However, classical machine linguistics methods are limited in understanding context, ambiguity and complex syntactic structures.

Modern machine linguistics (neurolinguistics) – based on new generations/paradigms of deep artificial neural networks – provides high-precision processing and adaptive personalized learning for contextual understanding of natural language and effective generation of not only formalized and structured text, but also streaming semi-structured and unstructured speech in audio format, or in multimedia format (for example: audio+video, audio+generated slides, etc.).

The author especially notes that it is the emergence (since 2017) and active development of the 3rd generation of deep ANNs - transformers - that has significantly improved the contextualization and generative capabilities of machine linguistics. However, there are still significant difficulties and challenges - which is why future research should focus on developing more personalized and ethical models, effective scaling and reducing relative computational costs, improving context processing and adaptation to new language domains.

Discussion.

As a promising direction of his future research, the author puts forward the following debatable thesis: classical approaches and methods of machine linguistics remain important in modern hybrid linguistic systems (which combine rules, statistical models and deep learning). That is why scientific and practical research on the integration of classical symbolic and modern connectionist methods of machine linguistics is relevant - not only for further improving the efficiency, accuracy, adaptability of NLP systems, but also for the interpretability/explainability, openness of the results of modern NLP systems (deep neural networks of the 3rd and 4th generation trained on Big semi-structured & unstructured Data). It is this promising direction of the author's future scientific research that will be reflected in future publications.

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