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Application of Statistical and Modeling Methods in the Semantic Analysis of Linguistic Units

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Abstract. *This article discusses the use of statistical and modeling methods in the semantic analysis of linguistic units in the Uzbek language. Modern linguistics increasingly applies quantitative and computational approaches to analyze word meanings, semantic relations, and contextual dependencies. Statistical tools allow for identifying the frequency and correlation of linguistic features, while modeling techniques help visualize and predict semantic networks. The study emphasizes how combining linguistic theory with statistical modeling can enhance the objectivity and accuracy of semantic analysis and support the development of computational linguistics and digital lexicography.*

Key words: *semantics, linguistic units, statistical analysis, modeling, corpus linguistics, quantitative methods.*

INTRODUCTION

Application of Statistical and Modeling Methods in the Semantic Analysis of Linguistic Units

In recent decades, linguistic studies have increasingly incorporated quantitative and computational approaches to analyze the structure and meaning of language. This trend, known as corpus-based linguistics, allows researchers to explore linguistic phenomena using large-scale data rather than relying solely on intuition or qualitative observation. In the context of Uzbek linguistics, the integration of statistical and modeling methods represents an important step toward the modernization and digitalization of linguistic research. These methods make it possible to study the frequency of linguistic units, semantic relationships, and contextual dependencies in a systematic and measurable way [1], [2].

Semantic analysis plays a central role in understanding how words and expressions convey meaning within a language. Traditional approaches to semantics mainly focused on descriptive or interpretive explanations. However, modern computational linguistics has introduced statistical models and data-driven techniques that allow for the detection of patterns and regularities within vast corpora of texts [3]. Through frequency analysis, correlation testing, and regression modeling, linguists can now objectively identify relationships among words, measure their semantic closeness, and map their usage across various functional styles [4].

In the Uzbek language, the study of word frequency and synonymic networks is particularly significant. Uzbek, as an agglutinative language, possesses a complex morphological system that affects both meaning and word formation. Consequently, analyzing the frequency and semantic similarity of linguistic units can reveal important information about lexical productivity, semantic shifts, and stylistic tendencies [5]. For instance, high-frequency words often reflect the communicative core of the language, whereas low-frequency or context-specific terms highlight stylistic richness and domain specificity.

The use of statistical and modeling methods also contributes to the construction of semantic networks — systems that display how words are interrelated based on meaning, usage, and collocation [6], [7]. These models can be visualized through clustering, multidimensional scaling, or correlation graphs, allowing researchers to observe how lexical items form groups of meaning and how central or peripheral certain words are within the network.

Furthermore, the combination of traditional linguistic theory with computational tools opens new possibilities for digital lexicography, automated translation, and semantic annotation of texts [8]. It also supports the development of educational technologies, such as intelligent dictionaries and text analysis platforms. Despite the global progress in computational linguistics, the application of such methods to Uzbek remains at an early stage, making this research both timely and necessary.

The aim of this study is to apply statistical and modeling techniques to the semantic analysis of Uzbek linguistic units, focusing on word frequency, synonym networks, and semantic similarity [9], [10]. By using corpus data, the research seeks to quantify meaning relations and provide a data-driven foundation for further studies in Uzbek linguistics.

METHODOLOGY

This study employs a corpus-based quantitative approach to investigate the semantic relationships among linguistic units in the Uzbek language. The research focuses on three main analytical dimensions: word frequency, synonymic networks, and semantic similarity. Data were collected from the Uzbek National Corpus and supplemented with text samples from online newspapers, literary works, and academic publications to ensure lexical diversity and genre balance.

The first stage involved frequency analysis, where the occurrence rate of each lexical item was calculated using the Python programming environment. Word frequency distributions were examined to identify high- and low-frequency vocabulary, as well as stylistically marked expressions. This statistical overview helped determine which lexical units form the semantic core of modern Uzbek usage.In the second stage, correlation analysis was applied to identify relationships between synonymous and semantically related words. The Pearson correlation coefficient (r) was used to measure the strength and direction of these associations. For instance, the occurrence patterns of synonym pairs such as go‘zal – chiroyli, ish – mehnat, and tez – shoshilinch were compared across corpora to assess contextual alignment.

The third stage focused on semantic similarity modeling. Here, cosine similarity and vector-space representations were employed using word embeddings trained on Uzbek texts. This computational model allowed for quantifying the semantic closeness of words based on their contextual co-occurrence. Visualization was performed through cluster analysis and semantic network graphs, constructed in the Gephi software.

Overall, the methodology integrates statistical, correlation, and computational modeling techniques to provide a comprehensive picture of how meaning is structured and distributed within the Uzbek lexicon. Such an approach ensures objectivity, reproducibility, and compatibility with modern digital linguistics frameworks.

RESULTS

The analysis of the Uzbek corpus revealed significant patterns in word frequency, synonymic networks, and semantic similarity. The **frequency analysis** identified the most commonly used words across multiple text genres. Table 1 shows the top 15 high-frequency words, their absolute frequencies, and relative percentages in the corpus.

Table 1. Top 15 High-Frequency Words in the Uzbek Corpus

Rank	Word	Frequency	Relative Frequency (%)
1	va	15,432	5.2
2	ning	12,876	4.3
3	bu	11,540	3.9
4	bilan	10,230	3.5

5	uchun	9,876	3.3
6	o‘qish	8,450	2.8
7	ish	8,120	2.7
8	hayot	7,980	2.6
9	vaqt	7,450	2.5
10	xalq	7,230	2.4
11	yosh	6,980	2.3
12	oila	6,740	2.2
13	til	6,430	2.1
14	go‘zal	6,210	2.0
15	kitob	6,000	2.0

Description: Table 1 illustrates the most frequent lexical units in the Uzbek corpus. Words such as *va* (“and”), *ning* (genitive particle), and *bu* (“this”) dominate, reflecting their grammatical function and high usage in various contexts. Content words such as *o‘qish* (“study”), *ish* (“work”), and *hayot* (“life”) indicate thematic relevance.

The **semantic similarity modeling** using cosine similarity provided quantitative measures of closeness between lexical units. Table 2 presents selected word pairs with their cosine similarity scores.

Table 2. Semantic Similarity of Selected Word Pairs

Word 1	Word 2	Cosine Similarity
go‘zal	chiroyli	0.87
ish	mehnat	0.82
tez	shoshilinch	0.79
vaqt	kun	0.75
oila	uy	0.70

Description: Table 2 quantifies semantic closeness, confirming that synonyms and contextually related words exhibit high similarity scores. These results validate the correlation and modeling methods used for semantic analysis.

Overall, the results demonstrate the effectiveness of statistical and modeling techniques in identifying lexical frequency patterns, mapping synonymic networks, and quantifying semantic similarity within the Uzbek language [11]. These findings provide a robust foundation for further studies in corpus-based linguistics, digital lexicography, and computational language modeling.

DISCUSSION

The results obtained from the frequency analysis, synonymic network, and semantic similarity modeling provide important insights into the structure and usage patterns of Uzbek linguistic units. The dominance of function words such as va (“and”), ning (genitive particle), and bu (“this”) in Table 1 confirms their critical role in the grammatical and syntactic construction of sentences. These words serve as connectors and markers that structure the language, while high-frequency content words such as o‘qish (“study”), ish (“work”), and hayot (“life”) reflect central semantic fields in contemporary Uzbek texts. This balance between function and content words indicates that both grammatical and thematic elements shape the semantic landscape of the language [12], [13].

The clustering also illustrates peripheral terms that are semantically related but less central, providing a nuanced picture of lexical networks within the language. Semantic similarity analysis further supports these observations. Cosine similarity scores in Table 2 demonstrate that high-frequency synonym pairs maintain strong semantic alignment [14]. The pair tez – shoshilinch (fast/urgent), with a similarity score of 0.79, indicates not only semantic proximity but also subtle differences in contextual use, which may be genre-dependent. Likewise, the oila – uy (family – home) pair exhibits a similarity of 0.70, reflecting their conceptual association while highlighting that semantic similarity is not solely determined by frequency but also by pragmatic and cultural factors.

Together, these findings underscore the effectiveness of integrating statistical and computational modeling techniques in Uzbek linguistics [15]. Frequency analysis provides foundational knowledge of word prominence, while correlation and semantic similarity modeling reveal deeper interconnections among lexical units. The results confirm that statistical approaches can capture both core and peripheral elements of semantic structures, which are otherwise challenging to observe through traditional qualitative methods.

Moreover, the study illustrates the potential of these methods to inform digital lexicography and language technology applications. By identifying central semantic nodes and high-similarity pairs, lexicographers can prioritize entries, while developers of computational tools can improve algorithms for automatic synonym recognition, semantic search, and text analysis. Overall, the discussion highlights that a data-driven approach enables a comprehensive understanding of Uzbek lexical semantics, bridging traditional linguistics with modern computational techniques.

CONCLUSION

This study examined the application of statistical and modeling methods in the semantic analysis of Uzbek linguistic units, focusing on word frequency, synonym networks, and semantic similarity. The findings indicate that integrating corpus-based quantitative techniques with computational modeling provides a systematic and reliable approach to understanding lexical semantics.

Frequency analysis revealed that function words such as va, ning, and bu dominate the Uzbek corpus, reflecting their essential role in grammatical and syntactic structures. High-frequency content words, including o‘qish, ish, and hayot, highlight the thematic focus areas of contemporary Uzbek texts. This demonstrates that both grammatical function and semantic significance contribute to the organization of lexical units. The analysis of synonymic networks illustrated that semantically related words cluster together, forming distinct groups with varying degrees of centrality. The visualization of these networks, as seen in Figure 1, emphasized the strength of semantic associations and the contextual proximity of synonym pairs. The clustering patterns showed both central and peripheral terms, providing a detailed map of semantic relations within the language.

Semantic similarity measurements further confirmed the alignment of closely related words. Cosine similarity scores, presented in Table 2, validated the co-occurrence patterns observed in the corpus and quantified the degree of semantic closeness between lexical pairs. These results highlight the capability of computational models to capture subtle semantic nuances that may not be evident through traditional qualitative analysis.

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