



## Generative Language Models In Machine Translation

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### ABSTRACT

This article analyses the characteristics of language as a complex, multilayered, and hierarchically organized system in the context of machine translation research. It is scientifically substantiated that language functions not only through lexical and syntactic units but also on the basis of the mutual integration of semantic, contextual, cognitive, and transformational mechanisms. The capabilities of modern machine translation approaches for modelling linguistic generalization, abstract categories, hidden structural relations, and conceptual meaning are also examined. The study identifies problems associated with the ability of existing machine translation models to adequately reflect the complex cognitive-communicative characteristics of natural language and substantiates the need for deeper modelling of semantic and contextual relations between linguistic units.

**KEYWORDS:** Machine translation, natural language, linguistic modelling, hierarchical structure of language, semantic analysis, contextual analysis, cognitive processes, linguistic generalization, abstract categories, transformational mechanisms, conceptual modelling, automatic translation.

### INTRODUCTION

Machine translation (MT) is a modern linguistic and technological field that refers to the process of automatically translating written text or spoken speech from one language into another, and its practical scope of application covers numerous areas such as the localization of business processes, support for diplomatic communication, content creation for mass media, and adaptation of educational resources to a multilingual environment. Having emerged as one of the most complex scientific and practical tasks within artificial intelligence (AI), machine translation has for a long time served as one of the main areas of research aimed at developing new architectures, improving neural models, and expanding their functional capabilities. The consistent development of these scientific studies created the theoretical and technological foundation for the formation of generative language models adapted to performing large-scale and diverse tasks, namely Large Language Models (LLMs).

Large Language Models are capable of semantically understanding information in natural language, identifying contextual relations, and generating meaningful texts close to human speech, thereby significantly expanding the scope of application of artificial intelligence technologies in various fields [1]; [3]. In particular, such models have become important technological tools in automated customer service systems, digital content creation, algorithmic and logical solution of complex problems, organization of interactive information systems, and improvement of human-computer communication. As a result, the development of Large Language Models has brought the functional capabilities of artificial intelligence to a



new stage and has had a significant impact on its practical application in various sectors and on the transformation of the scientific research paradigm.

Although Large Language Models have created many new functional possibilities, the original self-attention mechanism that forms the architectural basis of modern LLMs was essentially developed to perform machine translation tasks effectively. This mechanism made it possible to identify contextual, semantic, and syntactic relations between units in a text, assess the degree of their interaction, and differentially process important information components during the translation process. In this respect, the self-attention mechanism served as a methodological and technological foundation not only for the development of neural machine translation but also for the subsequent architectural formation of universal generative language models.

At the present stage, however, the conceptual status of machine translation is changing significantly: the translation process, previously regarded as an independent task within a specific language pair, is now becoming one of the many intellectual tasks performed by Large Language Models trained on advanced architectures. This new paradigm is creating new scientific perspectives for studying how knowledge is represented, generalized, transferred, and mutually integrated across different languages, subject domains, and even different modalities. In particular, the development of multilingual knowledge representation, cross-lingual transfer, contextual semantics, and multimodal information-processing mechanisms is expanding the possibilities of solving various complex tasks within a single model. From this perspective, Large Language Models make it possible to reconceptualize machine translation not merely as a process of automatically translating text from one language into another, but as a new-generation intelligent system aimed at transferring knowledge across languages, reshaping semantic content according to context, and comprehensively solving multilingual communicative tasks.

### Literature Review

Traditional approaches aimed at solving the problem of machine translation (MT) have generally been based on a two-stage process: first, the source-language text is analysed linguistically and its semantic essence is identified; at the next stage, units semantically equivalent to this meaning are synthesized in the target language [2]; [4]. Three main approaches that differ significantly from one another methodologically have emerged in modelling the process of transferring meaning from the source language to the target language. Although these approaches differ in terms of linguistic coverage and the level of structural analysis, they are complementary in that they illuminate different aspects of the machine translation process.

One of the approaches widely used in machine translation and which subsequently provided a methodological basis for the development of statistical models is the direct transfer approach. This approach is based on the theoretical view that the translation process can be carried out by identifying lexical correspondences between sets of words contained in sentences in two different languages, that is, by aligning them with one another. The direct transfer model interprets a sentence as a linear sequence of individual word units and regards words as elementary, indivisible linguistic units. In this approach, the translation process is carried out as an interconnected mechanism of analysing the source sentence and synthesizing the target-



language sentence, relying on lexical translation correspondences and rules for reordering words and constructions.

In early rule-based machine translation systems, translation variants were generated on the basis of dictionaries and grammatical models annotated by specialists. Such linguistic resources included rules for reorganizing syntactic structures, coordinating semantic relations, and transforming idiomatic units in the translation process between two languages. However, early machine translation experiments based on the principle of direct transfer clearly demonstrated the extremely complex and multilayered nature of the natural language system.

The main limitation of rule-based direct translation methods is determined by the large amount of linguistic annotation required to create comprehensive dictionary databases and develop rules for reordering units, as well as by the practical difficulty of covering them completely. In particular, the human ability to generate a theoretically unlimited number of new phrases, combinations, and sentence constructions in a particular language makes this problem even more complex. In addition, insufficient consideration of morphological features, transformations of units below the word level, and the impact of such changes on syntactic structure limited the linguistic effectiveness of the translation model. Nevertheless, these early approaches made it possible to obtain the first practical results in machine translation and contributed to the growing research interest in this scientific field and the intensification of subsequent methodological studies.

In subsequent studies aimed at increasing the efficiency of computational resource use, it was proposed to extract syntactic structures in the process of analysing source and target languages and to align units of the two languages according to a hierarchical principle during translation. Unlike the direct model, the syntactic transfer model interprets a sentence not merely as a linear sequence of words, but as an integrated linguistic structure organized through interconnected structural and syntactic relations. This model is aimed at identifying in the target language an equivalent structure capable of expressing the semantic content of a particular structure in the source language.

As a result of this approach, the process of annotating source-language sentences, searching for them, and aligning them with target-language translation variants is reduced to the task of identifying a limited number of equivalent syntactic structures available in the two languages. One of the important advantages of the syntactic model is that it does not require the sentence structures of the source and target languages to be absolutely symmetrical. On the contrary, this model takes into account the specific linguistic features of languages, differences in their syntactic organization, and variability in the ways of expressing thought. In this respect, this approach creates a theoretical possibility for implementing mechanisms of syntactic generalization, structural transformation, and rephrasing in the translation process. However, it became evident that developing a unified linguistic-computational system capable of accurately, consistently, and universally representing structural relations across numerous languages and continuously improving it is a complex scientific and technological task.

The third major direction in modelling machine translation is the interlingua approach, that is, the concept of carrying out translation through a universal semantic space. In this approach, source-language sentences are transformed into an intermediate semantic-syntactic representation layer that is not directly tied to any particular natural language. These representations include a system of predefined universal symbols and conceptual units for

expressing pragmatic, cultural, semantic, and syntactic concepts occurring in different languages. As a result, the translation process between different languages is carried out not directly through language pairs, but by means of a universal intermediate representation.

The interlingual model was developed to organize the process of creating multilingual machine translation systems supporting several translation directions more efficiently from economic and computational perspectives [6]. Instead of developing a separate translation mechanism for each language pair, the possibility of linking languages to a common semantic-representational space is envisaged. Although the difficulty of creating a perfect interlingua capable of sufficiently covering the semantic, pragmatic, and structural characteristics of all languages became clearly evident, this concept was later reconsidered on a new methodological basis in the development of multilingual machine translation models.

As one of the first significant areas of using computer technologies for purposes other than numerical calculations, machine translation generated considerable interest in the scientific community and created high expectations regarding technological capabilities. As illustrated in Figure 1, the three main methodological approaches to modelling the machine translation task differ significantly from one another in their conceptual mechanisms. Research shows that the effectiveness of these approaches varies depending on the typological and structural characteristics of languages, the volume and quality of available linguistic resources, and computational capabilities.

### Research Discussion

To date, rule-based machine translation systems remain important because many languages with limited linguistic and digital resources do not have sufficient amounts of training data for machine translation. However, developing such systems requires substantial intellectual and labour resources to create expert-annotated dictionaries, grammatical models, and linguistic transformation rules. It is precisely this factor that accelerated the transformation of the machine translation paradigm from rule-based models toward statistical translation methods. The promising aspect of the statistical approach is characterized by the translation system learning linguistic rules automatically from large volumes of translation examples rather than from fully predefined expert knowledge. The ideal objective of such a model is to inductively identify language patterns and translation correspondences from existing translation corpora, generalize the acquired statistical regularities, and develop the ability to translate new lexical units, grammatical forms, and syntactic constructions that have not previously occurred in the training data.

At the same time, achieving a full level of linguistic generalization in machine translation may not be ensured solely by relying on statistical methods. The complexity, variability, context-dependence of natural-language grammatical structures, and, in some cases, their failure to conform to regular patterns create the need for more comprehensive and multilevel modelling of language [9]; [10]. Therefore, developing an effective machine translation system requires not only identifying statistical regularities but also creating comprehensive linguistic-computational mechanisms that represent morphological, syntactic, semantic, pragmatic, and contextual features in an integrated manner.

**Figure 1. Translation of an English Sentence into Turkish Based on the Three Main Approaches to Machine Translation**

| Nº | English Term                             | Uzbek Translation                                             | Meaning                                                                                                                              |
|----|------------------------------------------|---------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|
| 1  | Source Language                          | Manba tili                                                    | The initial language of the text or sentence being translated.                                                                       |
| 2  | Target Language                          | Maqsad tili                                                   | The language in which the translation result is generated.                                                                           |
| 3  | Source language lexicon                  | Manba tili leksikoni                                          | A lexical database containing source-language words and their grammatical and semantic features.                                     |
| 4  | Source-Interlingua translation rules     | Manba tili-interlingva tarjima qoidalari                      | Rules used to transform source-language units into a universal intermediate representation.                                          |
| 5  | Universal representation                 | Universal representatsiya                                     | A generalized semantic form of representation that is not directly associated with a particular natural language.                    |
| 6  | Interlingua                              | Interlingva (vositachi til)                                   | An abstract linguistic representation that serves as an intermediary between the source and target languages.                        |
| 7  | Target-Interlingua translation rules     | Interlingva-maqsad tili tarjima qoidalari                     | Rules for transforming the universal representation into linguistic structures of the target language.                               |
| 8  | Target language lexicon                  | Maqsad tili leksikoni                                         | A database containing target-language lexical units and their linguistic features.                                                   |
| 9  | Interlingua transfer                     | Interlingva asosidagi transfer                                | A translation method based on transferring the source text into the target language through a universal intermediate representation. |
| 10 | Syntactic representation                 | Sintaktik representatsiya                                     | Formal representation of the syntactic structure of the source sentence.                                                             |
| 11 | Equivalent tree in target                | Maqsad tilidagi ekvivalent sintaktik daraxt                   | The equivalent target-language structure corresponding to the syntactic structure of the source language.                            |
| 12 | Source-Target Grammar and Transfer Rules | Manba va maqsad tillari grammatikasi hamda transfer qoidalari | A set of rules ensuring correspondence between the grammatical structures of the two languages.                                      |
| 13 | Syntactic transfer                       | Sintaktik transfer                                            | The process of transforming the syntactic structure of the source                                                                    |



|                        |                             |                                                                                                                                                                                            |
|------------------------|-----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 14 Lexical translation | Leksik tarjima              | language into an equivalent structure in the target language.<br>The process of replacing individual lexical units of the source language with corresponding units in the target language. |
| 15 Reordering          | So'z tartibini qayta tuzish | The process of rearranging translated units in accordance with the syntactic norms of the target language.<br>An approach based on directly                                                |
| 16 Direct transfer     | Bevosita transfer           | transferring source-language units into the target language without a complex intermediate representation.                                                                                 |

## Conclusion

In general, language is not merely a set of lexical units or a system of syntactic rules, but a complex and hierarchically organized linguistic system formed through the interaction of meaning, context, and transformational processes. Despite significant scientific and technological advances in the field of machine translation, modern translation approaches are still unable to fully model the multilayered and complex nature of language as a cognitive and communicative phenomenon. In particular, the adequate representation through formal models of abstract categories, hidden structural relations, and conceptual mechanisms that form the basis of linguistic generalization remains one of the current scientific problems in linguistics and machine translation research.

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