EasyChair Preprint

№ 5156

The Methodological Problem of Machine Translation of Language in the Context of Cognitive Linguistics

Eliana Vladlenova and Natalia Godz

March 16, 2021

The methodological problem of machine translation of language in the context of cognitive linguistics

Eliana Vladlenova[1], Natalia Godz[2]
The National Technical University "Kharkiv Polytechnic Institute", Kharkiv, Ukraine
[1]vladlenova.ntuhpi@gmail.com,
[2]nataliia.hodz@khpi.edu.ua

Abstract. This article discusses the methodological problems that arise during machine translation of the language. The interdisciplinarity of approaches to solving problems is shown. Methods in cognitive linguistics for their solution are considered.
Keywords: methodology, artificial intelligence, machine translation, consciousness, language, cognitive linguistics.

1 Introduction. Development of the problem in a historical perspective

Technology is important in the 21st century. Versatile devices, smartwatches, smartphones, computers are becoming faster, more portable, and more powerful. Internet translators are actively used, which allow you to quickly translate texts, understand the meaning of what is written. This was made possible by technical developments in the field of artificial intelligence. Artificial intelligence is widely used in economic modeling, the study of human motives and emotions in psychology, linguistics, medicine. Natural language processing (NLP) is also evolving rapidly. It is a branch of artificial intelligence that helps computers understand, interpret and translate the human language. These studies combine different scientific disciplines that study, language, thinking, cognition, computer systems, so artificial intelligence is an interdisciplinary field. Artificial intelligence builds intelligent machines capable of performing tasks that usually require human intelligence. Knowledge of philosophy, linguistics, computer science, neurology is necessary for the study of intelligence. One of the main problems in the construction of artificial intelligence is the uncertainty of philosophical concepts: intelligence, consciousness, reason. That is, we do not understand what artificial intelligence is, because we do not fully understand the nature of consciousness. What is artificial intelligence? What is human intelligence? What is consciousness? What makes thinking smart? These are traditional questions of the history of philosophy.

2 Analysis of Recent Research and Publications

In the long run, artificial intelligence will be able to approach human intelligence, and may even surpass man in all cognitive, creative tasks. The question of whether a machine can think has a long history. R. Descartes, D. Diderot, B. Spinoza, D. Locke and D. Hume reflected and discussed this issue. In philosophy, consciousness is seen as the ability to self-reflection, intentionality. Consciousness always manifests itself as a structure of consciousness about something. " What is it like to be a bat?" - this question was asked by T. Nagel in the article [1]. In this article, T. Nagel restored the philosophical discourse in the study of consciousness. Thomas Nagel criticized physicalist reductionism, which at the time was dominant in analytical philosophy. He believed that a being can have consciousness only if the world is perceived from the subjective point of view of this being. Any attempts to identify mental phenomena with physical processes in the brain are wrong because of the subjective nature of consciousness. Therefore, no one can imagine what it means to be a bat. The bat in the process of cognition uses echolocation, which is absent in humans. Therefore, man will not be able to understand this way of knowing the world. H. Dreyfus Hubert Dreyfus, in book «What Computers Can't Do», writes that computers cannot think like humans because humans have an instinctive intelligence that is difficult to understand. and which works not according to the rules [2].

Not all researchers were convinced that a computer could master a language as a human being, but there are researchers who come up with ways to approach it. Linguist N. Chomsky is an iconic figure in linguistics due to his work "Syntactic Structures, which played a major role in the study of language. His works have a great influence on the study of knowledge, mind, and mental processes, becoming an influential work in shaping cognitive science [3;4]. These studies have influenced the study of computers and the brain.

Chomsky began a dialogue between philosophers and linguists, and later computer scientists joined the dialogue. The philosopher of consciousness John Searle called Chomsky's study a remarkable intellectual achievement of his time. He believed that his work revolutionized linguistics, philosophy, and psychology. Chomsky showed that language is subjected to formal, logical analysis. This brought linguistics and the

new field of computer science very close. Chomsky opposed the behaviorist model. He argued that people produce language using separate syntactic and semantic components within the mind.
In 2011, a team of French neurologists led by Christophe Pallier conducted research to see if the real brain mechanisms work the way Chomsky suggested in Syntactic Structures. Chomsky compared the structure of grammar with the laws of the physical sciences. The results of brain research do show that specific parts of the brain process syntactic information in the abstract. They do not depend on other areas of the brain that process semantic information. Moreover, the brain analyzes not just a string of words, but the hierarchical structure of components. These observations confirmed Chomsky's theoretical statements in "Syntactic Structures" [5]. However, although various approaches using brain imaging techniques have sought to characterize the regions involved in syntactic processes, how the human brain computes and encodes syntactic structures, remains largely open questions. But while much remains to be learned about how sentence structure is processed in the brain, these results provide quantitative parametric evidence of how language components are encoded.

Classic works on cognitive linguistics Cognitive linguistics builds research on the border of different scientific disciplines[21;22;23]. Studies of cognitive linguistics aim to help understand cognition in general and are seen as a path to the human mind. Cognitive linguistics is a linguistic paradigm that states that language is closely related to the mental processes of world perception. Cognitive linguistics deals with the assimilation, collection, and use of information, studies the work of the brain and language. The main task of cognitive linguistics is to explain not only linguistic abilities but also the social possibilities of language, the processes of cognition. Some representatives of the industry in the world who founded these technologies: Ronald Langacker, George Lakoff, Mark Johnson, Paul Kay, Mark Turner, Georges Kleiber, John R. Taylor, Vyvyan Evans. People have the ability to learn very quickly on a relatively small amount of data and have a built-in ability to model the world in 3D very effectively. Such operations are difficult for machines. Some opportunities open up with the development of a deep neural network scientific research was based on works Alexey Ivakhnenko, Kunihiko Fukushima, Rina Dechter, Igor Aizenberg, Yann LeCun [29-31].

3 Language is directly related to human thinking, culture, world.

Language and the world are the central concepts of all of Wittgenstein's philosophy. In "Tractatus Logico-Philosophicus" he points to new perspectives in solving some philosophical questions [6]. Language reflects the world because the logical structure of language is identical to the ontological structure of the world. Wittgenstein's views gave impetus to the development of linguistic philosophy, and in Philosophical Investigations he developed the concept of language games. the concept of language-games points at the rule-governed character of the language [6].
R. Rorty abandons the previous philosophical tradition of cognition, according to which knowledge is the correct idea - the "mirror of nature" of human consciousness [9]. Rorty's metaphilosophical critique does not focus on specific techniques, but on the idea that philosophical problems are long-standing intellectual challenges that any thinker must acknowledge and that can be met by advances in methodology regardless of the human mind [8;9]. The philosopher is not able to abstract from the social environment in which he is immersed. Linguistic turn is a phenomenon in the philosophy of the XX century, which is associated with periods thinking about the role of language, is also a book published under the editorship of Richard Rorty in 1967. Further study of language, culture, and consciousness took shape in various philosophical areas, including phenomenology. This is a direction in the philosophy of the XX century, which explores the phenomenon of consciousness, where consciousness is understood as intentionality.
Thanks to intelligent intuition, our consciousness is what Husserl calls a "situation" (Sachlage). He focuses on how the representation of knowledge - the conceptual structure - is organized in the mind. Language is considered a reflection of general aspects of cognition. Different philosophical and linguistic searches have been combined in cognitive linguistics. Cognitive linguistics is an approach to natural language analysis that emerged from G. Lakoff, K. Feyaerts, C. Harrison, G. Lakoff, R. Langacker, L. Talmy [16]. Researchers focused on language as a tool for organizing, processing, and transmitting the information. We can derive three characteristics of cognitive linguistics: the primacy of semantics in linguistic analysis, the encyclopedic nature of linguistic meaning, and the prospects of linguistic meaning.

4 Cognitive linguistics: the study of language and cognition

Cognitive linguistics considers language as embedded in the general cognitive capabilities of man. Thus, it is important to study the relationship between language and thought. In cognitive linguistics, many different approaches partially overlap, forming a single system. This is because thinking, consciousness, language - are very complex phenomena, rather than a single well-defined theory.

Cognitive linguistics is based on the idea that human interaction with the world is mediated through information structures in consciousness. Language is a means of organizing, processing, and transmitting this information. Cognitive linguistics is based on research that uses the latest technology. Computational linguistics is an interdisciplinary field that deals with computational modeling of natural language, as well as the study of appropriate computational approaches to linguistic issues. Computational linguistics is based on many scientific disciplines: linguistics, computer science, artificial intelligence, math, logic, philosophy, cognitive science, cognitive psychology, psycholinguistics, anthropology, and neuroscience, among others. Language is a very complex phenomenon, which develops during the life of the individual.

Structural information about languages allows to identify and implement the recognition of similarities between pairs of expressions of the text. For example, based on structural information present in human discourse templates, conceptual recurrence plots can be used to model and visualize trends in data and create reliable measures of similarity between natural textual expressions [12] This technique allows us to study the structure of human discourse. The computational approach helps to explore the extremely complex information contained in discourse data.

Artificial neural networks offer great opportunities for cognitive linguistics. Artificial neural networks (ANN), or connectionist systems which are inspired by the biological neural networks that make up the brain of animals. Such systems learn to solve problems, gradually improve their productivity in solving them [13;14]. The input to each neuron is like the dendrites. Just like in the human nervous system, an artificial neuron collates all the inputs and performs an operation on them. Lastly, it transmits the output to all other neurons (of the next layer) to which it is connected. Neural Network is divided into a layer of 3 types: a) Input Layer: The training observations are fed through these neurons; b) Hidden Layers: These are the intermediate layers between input and output that help the Neural Network learn the complicated relationships involved in data; c). Output Layer: The final output is extracted from the previous two layers. For Example: In the case of a classification problem with 5 classes, the output later will have 5 neurons. A recurrent neural network (RNN) is designed to take sequences of text as inputs or return sequences of text as outputs. They can also do the reverse operation. They're called recurrent because the network's hidden layers have a loop in which the output and cell state from each time step become inputs at the next time step. This process is similar to how a person remembers. It allows contextual information to flow through the network so that relevant outputs from previous time steps can be applied to network operations at the current time step. For language translation, it is important to build a deep neural network that functions as part of a machine translation pipeline. The pipeline accepts, for example, English text as input and returns the Ukrainian translation.

ANN is based on a set of connected nodes called artificial neurons (similar to biological neurons in the brain of animals). Each connection (similar to a synapse) between artificial neurons can transmit a signal from one to another. The artificial neuron that receives the signal can process it and then signal to the artificial neurons attached to it. From the beginning, researchers wanted the machine to solve problems in the same way that the human brain does. ANN is used in a variety of tasks, including computer vision, speech recognition, machine translation, social networking, board, and video gameplay, and medical diagnosis, natural language processing, speech, image classification, segmentation, object detection, video processing, recognition. The greatest interest in neural networks was caused by the possibility of learning. Important opportunities open up in cognitive linguistics with the use of ANN, especially in the translation of texts. A research team led by Ziyue Guo has developed neural machine translation based on an improved method of criticizing actors [17]. There is neural machine translation based on enhanced learning (NMT), but this method is limited to the problem of sparse rewards, which further affects the quality of the model, and the actor-critic method is mainly used to enrich the rewards of source fragments, which significantly improved translation [17, p. 346].

There is also an interesting technology based on Prioritized Experience Replay [18] Reward mechanism of reinforcement learning alleviates the inconsistency between training and evaluation in neural machine translation [18, p. 358]. The authors propose a reinforcement learning method based on prioritized experience replay to deal with the problems. A research team led by Christopher D. Manning is developing Emergent linguistic structure in artificial neural networks trained by self-supervision [19]. They study the knowledge of linguistic structure learned by large artificial neural networks, trained via self-supervision, whereby the model simply tries to predict a masked word in a given context. Human language consists of sequences of words, but the mechanism of constructing different hierarchical structures in a language is a very complex process. Researchers are developing methods to identify a linguistic hierarchical structure, they demonstrate that modern deep contextual language models learn major aspects of this structure, without any explicit supervision.

5 Language translation by means of deep neural network.

For language translation, it is important to build a deep neural network that functions as part of a machine translation pipeline. The pipeline accepts, for example, English text as input and returns the Ukrainian translation.

The goal is to achieve the highest translation accuracy possible. The ability to communicate with each other is an essential part of human existence. Language is the most important means of communication and cognition. There are several thousand different languages in the world. As our world becomes more connected, language translation provides an important cultural and economic bridge between people from different countries and ethnic groups. Today, Google and Microsoft can translate more than 100 different languages, and for many of them, they are close to human accuracy. However, although machine translation has made significant progress, it is still not perfect.

Human language consists of a large number of words. In translation programs, vectors are created and indexes are assigned to each unique word in the input language, and then this process is repeated for the output language. By assigning a unique index to each unique word, we will create what is called a vocabulary for each language. Ideally, the vocabulary for each language would simply contain each unique word in that language. But any single language can have hundreds of thousands of words, so typically the vocabulary is often truncated to the N most common words in a data set (where N is chosen arbitrarily, but often ranges from 1,000 to 100,000 depending on the size of the data set). At the basic level, technology mechanically replaces words in one language with words in another, but only this rarely gives a good translation, because it requires recognition of whole phrases, there are idioms, a stable indivisible inversion of language that conveys a single concept, the meaning of which is not determined by its constituent elements. There are many figurative words in languages, metaphors that make machine translation much more difficult. Language - is part of the mental process of man. In the process of communication, a person can use sophisms, sarcasm, humor, which are difficult to translate into "machine language". Not all words in one language have equivalent words in another language, and many words have more than one meaning. There are different styles of sentences, for example, there are features of legal texts, scientific, artistic. Solving this problem with corpus statistical and neural techniques is a rapidly-growing field that is leading to better translations, handling differences in linguistic typology, translation of idioms, and the isolation of anomalies [20]. A method for automatically estimating a translation time comprises receiving translation data, determining one or more translation parameters based on the translation data, retrieving one or more pre-determined translation coefficients associated with the one or more translation parameters, and calculating an estimated translation time based on the one more or more translation parameters and the one or more pre-determined translation coefficients. This method allows you to adjust to the domain associated with professional activities, which allows you to determine the style of the sentence, choose a more appropriate word, limit the scope of choice of the meaning of the word. But in this approach, it is necessary to constantly update dictionaries of translations. This human intervention leads to improved translation quality through automation with repetitive processes and reduction of manual errors [20, p.].

6 Conclusions

The process of translating the text is quite complex. For example, the work of a translator-synchronizer requires great attention, the concentration of all mental abilities. language translation is associated with cognitive thinking. To fully decipher the meaning of the source text, the translator must interpret and analyze all the features of the text. This process requires a deep knowledge of grammar, semantics, syntax, idioms, stylistic devices, artistic means, culture, which affects the thinking of different languages. Therefore, the success of machine translation requires solving the problem of understanding natural language. This understanding can be achieved in an interdisciplinary search, which should also involve philosophers, anthropologists, which will help to better understand the language and thought processes of man.

Ideally, machine translation should not be different from human translation. Modern technology is approaching this process, but there are still many drawbacks. However, the obstacles to computer translation are primarily linguistic. To overcome them, it is necessary to solve the ambiguity that permeates natural language, its essence, its connection with human cognitive abilities.

References

1. Nagel, Thomas What Is it Like to Be a Bat?// Philosophical Review, 1974, pp. 435–50.

2. Hubert, Lederer Dreyfus What Computers Can't Do: The Limits of Artificial Intelligence. Creative Media Partners, LLC, 2015.

3. Avram Noam, Chomsky Syntactic Structures, Mouton & Co, 1957.

4. Avram Noam, Chomsky Reflections on Language, Pantheon Books, 1975.

5. Pallier, Christophe; Devauchelle, Anne-Dominique; Dehaene, Stanislas (2011), "Cortical representation of the constituent structure of sentences", Proceedings of the National Academy of Sciences, 108 (6): 2522–2527, doi:10.1073/pnas.1018711108)

6. Wittgenstein, Ludwig Tractatus Logico-Philosophicus translated by C.K. Ogden ,1922.

7. Wittgenstein Philosophical Investigations Pearson, 1973.

8. Richard, Rorty Introduction: Metaphilosophical difficulties of linguistic philosophy. The University of Chicago Press, Chicago and London, 1967.

9. Richard, Rorty Philosophy and the Mirror of Nature. Princeton, NJ: Princeton University Press, 1979.

10. Richard, Rorty Linguistic turn: Recent Essays in Philosophical Method, University of Chicago Press, 1992.

11. Edmund, Husserl Logical Investigations, London: Routledge, 1973.

12. Angus, D.; Smith, A. & Wiles, J. Conceptual recurrence plots: revealing patterns in human discourse // IEEE Transactions on Visualization and Computer Graphics. 18 (6): 988–97, 2012. doi:10.1109/TVCG.2011.100/

13. Ciresan, Dan; Meier, U.; Schmidhuber, J. Multi-column deep neural networks for image classification. // IEEE Conference on Computer Vision and Pattern Recognition. pp. 3642–3649, 2012. arXiv:1202.2745

14. Kruse, Rudolf; Borgelt, Christian; Klawonn, F.; Moewes, Christian; Steinbrecher, Matthias; Held, Pascal Computational intelligence : a methodological introduction. Springer, 2013. ISBN 978-1-4471-5012-1. OCLC 837524179.

15. Dirk, Geeraerts and Hubert Cuyckens Introducing Cognitive Linguistics Linguistics, Morphology and Syntax Online Publication Date: Sep 2012. DOI: 10.1093/oxfordhb/9780199738632.013.0001. URL: https://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780199738632.001.0001/oxfordhb-9780199738632-e-1.

16. Tummers, Jose´, Kris Heylen, and Dirk Geeraerts. 2005. Usage-based approaches in Cognitive Linguistics: A technical state of the art // Corpus Linguistics and Linguistic Theory 1:225-26, 2005. DOI: https://doi.org/10.1515/cllt.2005.1.2.225.

17. Ziyue Guo, Hongxu Hou, Nier Wu, Shuo Sun, Neural Machine Translation Based on Improved Actor-Critic Method // Artificial Neural Networks and Machine Learning – ICANN 2020 29th International Conference on Artificial Neural Networks, Bratislava, Slovakia, September 15–18, 2020, Proceedings, Part II.- Pages 346-357.

18. Shuo Sun, Hongxu Hou, Nier Wu, Ziyue Guo , Neural Machine Translation Based on Prioritized Experience Replay// Artificial Neural Networks and Machine Learning – ICANN 2020 29th International Conference on Artificial Neural Networks, Bratislava, Slovakia, September 15–18, 2020, Proceedings, Part II.- Pages 358-368.

19. Christopher D. Manning, Kevin Clark, John Hewitt, Urvashi Khandelwal, and Omer Levy Emergent linguistic structure in artificial neural networks trained by self-supervision //PNAS December 1, 2020 117 (48) 30046-30054; first published June 3, 2020; https://doi.org/10.1073/pnas.1907367117.

20. Albat, Thomas Frit Systems and Methods for Automatically Estimating a Translation Time. US Patent 0185235, 19 July 2012.

21. Geeraerts, Dirk Cognitive Linguistics: Basic Readings. Berlin: Mouton, 2006.

22. Vyvyan Evans, Ben Bergen, and Jørg Zinken The Cognitive Linguistics Reader. London: Equinox, 2007.

23. Littlemore, Jeanette and John R. Taylor The Bloomsbury Companion to Cognitive Linguistics. London: Bloomsbury, 2014.

24. Dancygier, Barbara The Cambridge Handbook of Cognitive Linguistics, Cambridge University Press, 2017.

25. Geeraerts, Dirk and Hubert Cuyckens Handbook of Cognitive Linguistics. Oxford University Press, 2010.

26. Vyvyan, Evans A Glossary of Cognitive Linguistics, by Edinburgh University Press, 2007.

27. Schmidhuber, J. Deep Learning in Neural Networks: An Overview // Neural Networks. 61: 85–117. arXiv:1404.7828, 2015. doi:10.1016/j.neunet.2014.09.003. PMID 25462637. S2CID 11715509.

28. Bengio, Yoshua; LeCun, Yann; Hinton, Geoffrey Deep Learning // Nature. 521 (7553): 436–444,2015. doi:10.1038/nature14539. PMID 26017442. S2CID 3074096.

29. Marblestone, Adam H.; Wayne, Greg; Kording, Konrad P. (2016). "Toward an Integration of Deep Learning and Neuroscience". Frontiers in Computational Neuroscience. 10: 94, 2016. doi:10.3389/fncom.2016.00094.

30. LeCun, Yann; Bengio, Yoshua; Hinton, Geoffrey Deep learning // Nature. 521 (7553): 436–444, 2015. doi: 10.1038/nature14539.

31. Sonoda, Sho, Murata, Noboru Neural network with unbounded activation functions is universal approximator // Applied and Computational Harmonic Analysis. 43 (2): 233–268, 2017. arXiv:1505.03654. doi:10.1016/j.acha.2015.12.005. S2CID 12149203.