Impact of Machine Learning in Natural Language Processing: A Review

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Impact of Machine Learning in Natural Language Processing: A Review

Tatwadarshi P. Nagarhalli
PhD Research Scholar,
Comp. Engg., Shri JJT University
Rajastan, India
tatwadarshipn@gmail.com

Dr. Vinod Vaze
Dept. of Computer Sci & Engg.
Shri JJT University
Rajastan, India
vinod.vaze@gmail.com

Dr. N. K. Rana
Principal
Theem College of Engineering
Mumbai, India
ranank@rediffmail.com

Abstract – **The recent times have seen unprecedented growth in research and development in the field of Artificial Intelligence and its allied fields, subfields, like Machine Learning, Deep Learning and Natural Language Processing. The new found excitement in these fields of research is the availability of high powered computing devices at a cheaper costs and the wide range of applications of these research fields. It can be safely said that in the present times there are hardly any sectors of businesses which have not been positively impacted by artificial intelligence or its subfields.**

Machine learning and deep learning, apart from having a positive impact on different sectors of businesses, machine learning and deep learning have also played a very important role in improving the efficiency of other subfields of artificial intelligence, including computer vision and natural language processing.

Natural Language Processing is the ability of computer systems to understand human languages, which is a difficult task where these learning techniques has played a very important role in proper analysis. The paper proposes to highlight this important role played by the learning techniques in improving the efficiency of natural language processing.

Keywords – Machine Learning, Deep Learning, Natural Language Processing, Artificial Intelligence, and Word Sense Disambiguation.

I. INTRODUCTION

The advancements witnessed in the computer hardware industry in the recent decades have been unprecedented. The advancements in hardware technology and the availability of very high performance computing device has helped the research and the development of advance computer software systems. One of the field which has thrived on this availability of high performance computing systems is Artificial Intelligence. As a matter of fact, now a days even the mobile devices come equipped with dedicated artificial intelligence chips [1].

Defining artificial intelligence is a very tricky task. The reason for this is the word 'intelligence', it has been defined and interpreted differently by different authors. Some define it as the ability of the machines or a computer to work better than the humans [2]. Others define it as a branch of computer science which deals with automation of intelligent behaviour [3]. At the very basic level it can be said that artificial intelligence's endeavour is to enable machines to make smart and informed decisions [4].

Artificial intelligence works through the intelligent agent. Intelligent agent is a largely autonomous entity which performs in such a way that it can maximise its defined goals [4]. Generally, an artificial intelligence system is a collection of many such intelligent agents. These agents perceive or collect information from the environment through sensors. This information is analysed by these intelligent agents and a decision is reached. These informed decisions are then executed on the environment through actuators. Figure 1 shows the general working of an intelligent agent.

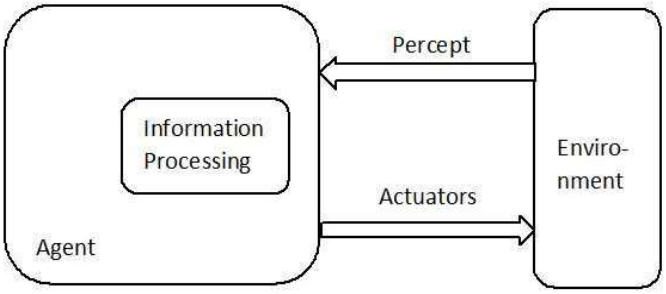

Figure 1: Intelligent Agent

There are three important components in an intelligent agent, perceiving, processing of information and acting on the environment. Many subfields of artificial intelligence have taken birth, or in other words it can said that many subfields of artificial intelligence strive to make these three components of intelligent agent better. Subfields of artificial intelligence like Computer Vision and Natural Language Processing strive to make information collection as intuitive and informational as possible. Whereas, the subfields like Machine Learning and Deep Learning help in making the agent process information in an informed manner, so that the decisions taken are as accurate as possible. Deep learning is a specialisation and subset of machine learning. So, whenever the term machine learning has been used it implies both machine learning and deep learning techniques. On the other hand another subfield of artificial intelligence, Robotics and the allied fields helps the agent act on the environment in an accurate way. It can also be said that the field of natural language processing provides a

communication medium between the users and the intelligent systems. So, studying and understand these two fields of artificial intelligence is important.

II. NATURAL LANGUAGE PROCESSING AND MACHINE LEARNING

Machine Learning and Natural Language Processing are important subfields of artificial intelligence which have gained widespread popularity and adaptation in many sectors in the recent times. Machine learning is a field of study which enables the computers to solve problems for which it wasn't explicitly programmed [5]. There are many real world applications where it is near to impossible to explicitly program or develop an algorithm which can foresee all the possible input types and solve the problems at hand.

Machine Learning and Deep Learning methods help the computer systems learn from the given examples of data and make its own conclusions. This helps the computer systems in solving problems which it might not have encountered earlier or improve its response using its past experiences, over a period of time. This ability of the machine learning techniques coupled with the abundant availability of data has made machine learning and deep learning very popular, and have been adapted many different domains like healthcare, transportation, customer service, etc. This is one of the reasons why in the recent times machine learning has become very popular.

As with artificial intelligence systems in general, even for machine learning another reason for its popularity is the availability of high performance computing devices. Machine learning and especially deep learning techniques are computing resource hungry [6]. The reason for this is, what machine learning does not have in explicit instructions it makes it up by learning from large amount of data.

According to World Economic Forum, at present there is more than 44 zettabytes of data available around the world that is, more than 44 Billion Billion bytes of data. And, not even gigabyte or terabyte but, petabytes of data is being created on a daily basis [7]. Machine learning and deep learning algorithms can learn new insights from this huge amount of available data and apply these insights in solving problems and generating new intelligence.

The availability of cheap high powered computing devices and the availability huge amount of data which can be easily exploited in order to gain new insights have made the field of machine learning and deep learning popular. Another reason for the popularity of machine learning is the wide area of its applications. Machine learning has been adapted in areas like manufacturing, healthcare, transportation, automobile, e-commerce, insurance, customer service, and energy, among many others [8, 9].

While it is absolutely true that machine learning and deep learning have played a major role in making computer systems intelligent, it is also to true that leveraging these intelligent systems is a difficult task. And, even basic usage or communications of these intelligent machine learning systems was restricted to few machine learning engineers. In some ways it can be said that it is Natural Language Processing which has brought these intelligent system to masses, by providing a means to communicate with these intelligent systems in human languages.

Natural Language Processing is an interdisciplinary study of linguistics and computer science. Natural language processing is another important subfield of artificial intelligence which endeavours to provide the computer with the ability to understand human spoken or written language [10].

Processing of natural language in order to understand the meaning of a given sentence is a difficult task. This already difficult task becomes much more difficult considering the fact that languages are inherently ambiguous [11]. By Ambiguity it is meant that same words have different meanings in different contexts [12], for example the word 'Bank' can mean a financial institution or a sloping down a water body. This makes understanding of natural language that much more difficult for the computing systems.

In order to understand the human language, processing and analysis is carried out in multiple stages. These stages include Morphological Analysis, Syntactic Analysis, Semantic Analysis, Discourse Analysis and Pragmatic analysis [10]. The accuracy of these different levels of analysis determines the accuracy with which the natural language has been processed and understood by the machine. These different stages of natural language processing have developed into separate areas of research by themselves as well.

Natural language processing systems like Apple's Siri, Amazon's Alexa and Google's Assistant have made natural language processing very popular. Apart from this it is expected that natural language processing systems are saving millions of dollars for the businesses, apart from making customer services more interactive. These are some of the reasons why billions of dollars are being invested in the research and development of natural language processing systems [13].

Another reason for the popularity of natural language processing is its wide range of important applications. Some of the prominent applications of natural language processing include Sentiment Analysis, Machine Translation, Question Answering System, Chatbot systems or Conversational Agents, Text Classification and Information Retrieval, among others [14, 15].

It is also interesting to note that many subfields of artificial intelligence have helped one another in becoming more efficient and accurate. Like for example, natural language processing has played an important part in the success of robotics and machine learning has helped another subfield of artificial intelligence, computer vision.

In a similar way machine learning has played a very important role in the success of natural language processing. Be it the different stages of analysis in natural language processing or the multiple applications of natural language processing, machine learning and deep learning have played a very

important role in improving their efficiency and accuracy. So, the paper attempts to give a review and highlight this important role played by machine learning and deep learning techniques in improving the efficiency of natural language processing.

III. NATURAL LANGUAGE PROCESSING AND LEARNING TECHNIQUES

A machine cannot understand the language of humans. It can only understand the language of 0's and 1's. In order to make a machine or computer understand the human language many processing tasks are required to be done. These tasks include identifying the words and the sentences for a stream of characters, checking if the sentence identify confirm with the rules of the language, extracting or understanding the meaning of the given sentence, trying to make sense of the sentence when the given sentence is referring to something which is outside of the given sentence and finally trying to identify the intended meaning of the sentence. These five tasks have been names as morphological analysis, syntactic analysis, semantic analysis, discourse analysis and pragmatic analysis, respectively.

It has been observed that machine learning techniques like the Naïve Bayes, Support Vector Machines, Decision Trees, Random Forest and deep learning techniques like Recurrent Neural Network and Convolution Neural Network have made a very positive contribution in almost of all these stages of natural language processing. Figure 2 shows the stages in natural language processing. It is important to note that these analysis stages have to be performed sequentially one after the other for better processing of the natural language.

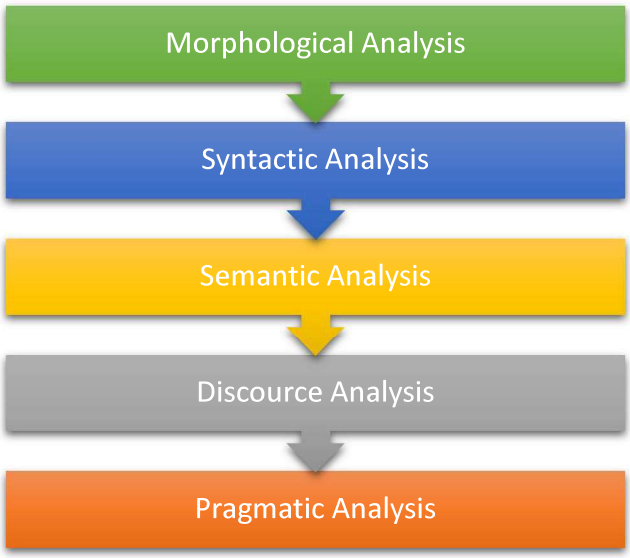

Figure 2: Stages in Natural Language Processing

It is also important to note that all these five stages of natural language processing have been research areas by themselves. Detailed research has been carried out of these stages independently. As a matter of fact some of the topics within each of these processing stages have been independently researched. For example, the topics within the five stages of natural language processing which have been extensively researched include Word Sense Disambiguation, Sarcasm Detection, Syntactic Parsers, Stemming, Part of Speech Tagging, Named Entity Recognition and Reference Resolution, among others.

These multitude of research work which has been carried out have included traditional approaches as well of learning technique based approaches. Here, only the contribution of the learning techniques have been identified and mentioned.

1. Morphological Analysis

For a machine the words and sentences that it receives is a bunch of characters. So, the first step in natural language processing is to identify the words and the sentences, this process is called as the tokenisation. Many a times these words contain affixes which might confuse the machine. So, a process called as stemming is carried out in order to remove these affixes. Tokenisation and Stemming is carried out at the morphological stage in natural language processing.

One of the important task at morphological level is the tokenisation. It has been observed that research has been carried out to identify how machine learning approaches can improve the efficiency of tokenisation.

Anand Kumar M., et. al. [16] propose to make use of the sequence labelling classification methods for performing efficient morphological tokenisation of Tamil texts. Whereas, M. Nisha, et. al. [17] make use of machine learning techniques for improving the efficiency of morphological analysis for the Malayalam language. Both the paper claims that the use of learning techniques improved the performance and accuracy of the system in carrying out morphological analysis.

2. Syntactic Analysis

Once the words and sentences have been identified and the affixes removed, the next step in natural language processing is to check if the given sentences follow the rules of a language. All human languages have certain rules. For example, in the English language there are 4 basic rules [31]:

1. A complete sentence requires a subject and a verb and expresses a complete thought.
2. Separate ideas generally require separate sentences.
3. English word order follows the subject-verb-object sequence (Ram(S) plays(V) Cricket(O)).
4. A dependent clause contains a subject and a verb.

Similar to these there are many such rules in the language which the sentences should follow in order to qualify and pass the syntactic analysis stage. This checking and analysis of syntax of the sentence is very important in order to make the 'right' meaning of the given sentence.

Generally, the rules of a languages are defined elaborately and there are no updates in these rules hence, there are well established rule based parsers which can parse the sentence and check the syntax of a sentence. For this reason, there has

been no major contribution by learning techniques with regards to syntactic analysis.

3. Semantic Analysis

After the syntax has been confirmed and verified in the syntactic analysis stage, the next step is to understand the meaning of the sentence, from the sentences itself. Using word and word-meaning dictionaries this task of understanding the meaning of the sentence is achieved. This step is the semantic analysis step in the processing of natural language.

A language by nature is ambiguous, and this is especially true for word meanings. In any language there will be many words which will have different meanings or will give different sense. There are many words which exhibit different meanings under different circumstances. Generally, these meaning are determined by the context.

For example, the word 'Bank' can mean a financial institution or a storage of some kind or a river side. Identifying which meaning to take becomes difficult for a machine. So, even while using a word and word-meaning dictionaries it becomes difficult to identify the actual sense of a particular word in a given context, this is called Word Sense Ambiguity. Hence, disambiguation this word sense is a very important task which needs to be performed while performing semantic analysis.

Word Sense Disambiguation is an important research problem which is being researched even now because of the different factors which needs to be considered while performing the task.

Word sense disambiguation has been considered as a classification problem and machine learning and deep learning techniques have been employed in order to solve this ambiguity in the word meanings. Understanding the importance of word sense disambiguation many research works have tried to tackle this issue for many different languages.

Pranjal Protim Borah, et. al. [18] propose to make use of supervised machine leaning algorithms for performing word sense disambiguation on the Assamese language. Whereas, Himdweep Walia, et. al. [19] propose to perform word sense disambiguation on the Punjabi language, also called as the Gurmukhi language. The paper makes use of K-Nearest Neighbour classification and claim to produce good accuracy. Considering K-Nearest Neighbour as one of the simplest classification algorithm, it can be said that more sophisticated classification techniques would perform even better.

Mohamadreza Mahmoodvand and Maryam Hourali [20] decided to take the semi supervised route for performing word sense disambiguation on the Persian language. The reason for going with semi supervised approach was the lack of annotated data in the Persian language.

Oliveira, et. al. [21] experiment with unsupervised learning approach for tagging the disambiguated words for the bilingual corpus of Portuguese and Chinese language. The paper makes use of the bilingual corpus because the main aim of the paper is to perform translation with special focus on word sense disambiguation.

M. Rajani Shree and Shambhavi B.R [22] perform a detail evaluation of different word sense disambiguation techniques proposed by different papers for the Indian languages. In the paper it can be observed that the machine learning techniques perform better in most cases compared to other methods and techniques.

These are some of the examples which highlight how a crucial role has been played by the learning techniques in performing word sense disambiguation in different languages.

4. Discourse Analysis

There are cases where sentences can start with pronouns or the sentences may refer to a subject or an object which is not present in the present sentence. For example, consider the two sentences "Ram is a good by. He likes to play Cricket." If the second sentence is analysed independently it would make no sense at all because of the presence of the pronoun 'He'. The second sentence will only make sense when it is analysed together with the first sentence. Here, he refers to the person 'Ram'. This is discourse analysis.

There some tougher examples and cases which have to be handled by the system while performing discourse analysis. For example, consider the given two sentences "Ram went to Shyam's shop to check out new Cricket bats. He looked at it for hours." In the second sentence of the given example the words 'He' and 'it' can refer to multiple things even if the first sentence is taken into consideration. 'He', can refer to either 'Ram' or 'Shyam' and 'it' can refer to either the 'shop' or the 'Cricket Bat'.

In such cases it becomes difficult to analyse the sentence and extract the actual meaning of the sentence. For such cases, it is not enough to have only the knowledge of the previous sentences some like of methodology is required in order to resolve such reference problems. Resolving such cases which is carried out in discourse analysis is called as Reference Resolution. As mentioned earlier, reference resolution is a very active area of research by itself.

Reference resolution is a very important task when making sense of a large text. Machine learning techniques has also been used for perform resolution of coreference. G. Veena, et. al. [23] are of the opinion that the Support Vector Machine perform better than other learning algorithms for the dataset under consideration. Whereas, Zoran Dzunic, et. al. [24] propose to make use of decision tree algorithm for word sense disambiguation, and produces good results as well.

Apart from machine learning techniques like Convolution Neural Network have also been experimented with for perform discourse analysis. Both the papers [25] and [26] make use of convolution neural network with different architectures and claim to have produced very good results. This shows that both machine learning and deep learning techniques have not only been effectively used for reference resolution, more often than not they have outperformed other techniques while performing reference resolution.

5. Pragmatic analysis

Finally, there are many cases where the written meaning and the actual intended meaning may be completely different. In such cases the meaning of the sentences understood by semantic analysis is not sufficient. So, pragmatic analysis is carried out in order to identify the intended meaning of a given sentence.

For example, consider the sentence "The soldier fought like a lion." The literal meaning does not make any real sense at all. The actual meaning of the sentence is that the soldier fought very ferociously, which is the intended meaning. The given examples showcases the necessity of perform pragmatic analysis.

One of the most integrating task of natural language processing which has baffled and has kept engaged many researchers has been the automatic detection of sarcasm by the machine. Sarcasm is a satirical remark which generally intend to give the opposite meaning to what has been said. Automatic sarcasm detection is one of the most classic examples of pragmatic analysis.

Consider the example, "I slipped and fell in my bathroom today morning. What a perfect start to a morning." The semantic meaning of the second sentence is a positive sentiment. Whereas, the intended meaning is exactly the opposite. It is actually an expression of aghast. Pragmatic analysis tries to find out intended meaning from such sentences.

Pragmatic analysis in general and automatic sarcasm detection has been one of the very widely researched topic in natural language processing.

Multitudes of research work has been carried out by many different researchers for accurate sarcasm detection. Many different machine learning and deep learning approaches have been experimented with in order accurately identify sarcasm.

Machine Learning algorithms like K-Nearest Neighbour, Support Vector Machines, and Random Forest algorithm [27] has been employed for sarcasm detection on twitter data. In addition to these machine learning algorithm being used independently, machine learning techniques have also been used in conjunction with rule based systems for getting better detection accuracy.

Apart from machine learning techniques deep learning techniques like Deep Neural Network [28], Recurrent Neural Network [29] and Long Short Term Memory based Recurrent Neural Network [30] have been experimented with. And, by and large it can be said that in most of the cases these the learning techniques produce far better results than tradition techniques.

Even though these learning techniques have given better results than other methods for performing different natural language processing tasks, many a times it has been observed that these results are scalable enough for it to be implemented in a real world scenario or robust enough in adapting to different situations and datasets. So, there is ample opportunities for performing research on either the different stages of natural language processing or the specific tasks like the Word Sense Disambiguation, Sarcasm Detection, Syntactic Parsers, Stemming, Part of Speech Tagging, Named Entity Recognition and Reference Resolution, etc.

IV. CONCLUSIONS

Machine Learning and Natural Language Processing are very important subfields of Artificial Intelligence which have again gained prominence in the last couple of decades. Machine learning and its specialisation, Deep Learning techniques have revolutionised many sectors of business. As a matter fact these learning techniques have positively contributed in many different technologies as well, including Natural Language Processing.

There are five important tasks in Natural Language Processing, performing which enables the machine or a computing device to understand the human language. The accuracy with which these tasks are performed determine the level of natural language understanding by the machine. The paper showcases how the machine learning and deep learning techniques have been successfully employed in performing most of these tasks and they have produced very good results as well.

Word Sense Disambiguation, Sarcasm Detection, Syntactic Parsers, Stemming, Part of Speech Tagging, Named Entity Recognition and Reference Resolution are some of the most crucial and important tasks in natural language processing. The paper showcases that researchers has not only successfully used different machine learning and deep learning techniques in performing such tasks but also, these techniques have performed the tasks far better than any of the traditional techniques.

So, it can be concluded that the employment of machine learning and deep learning techniques in the different tasks of natural language processing have had a very positive impact. These leaning techniques have in most of the cases increased the efficiency and accuracy in the processing of natural languages.

Having said that, there is still ample scope of research in increasing the efficiency with which these tasks of natural language processing can be performed. This also warrants further study and research in natural language processing. Having highlighted the important role played by the learning techniques in natural language processing it is expected that by further experimenting with different learning techniques the efficiency and accuracy of natural language processing can be improved.

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