A Comparative Study of Machine Learning and Deep Learning Techniques for Sentiment Analysis

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Abstract: **In this day and age an increasing number of people are using online social networks and services to not only connect and communicate but also to voice their opinions. Sentiment Analysis is the identifying and categorizing of these opinions to determine the public's opinion towards a particular topic, problem, product etc. The importance of Sentiment analysis is increasing day by day. Machine learning is a field of computer science that gives computers the ability to learn without being explicitly programmed. Deep Learning is a subfield of machine learning concerned with algorithms that are neural implementations, most commonly seen as neural networks, neural beliefs, etc. It is crucial to employ the most feasible and accurate technique while analyzing sentiments for a given data as this affects both producers as well as consumers. This paper puts forward a study that compares various Machine learning, Deep learning as well as their hybrid techniques. It compares their accuracy for Sentiment Analysis and thus it can be concluded that in most cases Deep learning techniques give better results. However, in some cases the difference in the accuracies of the two techniques is not substantial enough and thus it is better to use Machine Learning methods as they are easier to implement.**

Keywords: **Neural network, sentiment analysis, deep learning, machine learning**

I. INTRODUCTION

Sentiment analysis is the analysis of the emotions or reviews of the consumers or users to determine whether a product, service, news, article, etc. is generating positive, neutral or negative responses. Not just the polarity, but also the depth of the feeling towards the particular service or product is taken into account. Alternatively, sentiment analysis also helps the consumers get a better idea of the pros and cons of the product or service. Nowadays there is a growing availability and popularity of opinion-rich resources like review sites , blogs etc. Sentiment analysis is carried out on these reviews given on various micro blogging sites such as facebook, twitter, etc. The reviews may also belong to a product being sold on an online retail store such as amazon. A lot of jargon and mixed comments can be misleading and this is where sentiment analysis comes into place. It allows the businesses to better understand the general reaction to their products and their standing in the market. Furthermore, they are able to better meet the consumer's needs and wants while simultaneously helping their organization grow.

Sentiment analysis is done at many levels. Depending on the amount of time thatcan be dedicated to sentiment analysis and its importance for a proceeding task, the level of sentiment analysis is chosen. First is sentence level analysis. A sentence has a subject and an object. Subjectivity gives us the subjective views of the object. Thus the subjective part of the sentence is classified into positive negative or neutral.Another level is the feature level. This is the best level as it takes into account words and phrases. It takes a word with an emotion and determines the target of the word. It then classifies the word into positive, negative or neutral. Thus maximum misleading comments are removed. The third level is known as Document Level sentiment analysis. This method takes the complete document as a whole and classifies it as an overall negative or positive document. It does not take into account the finer details of facts and emotions. Thus in most cases feature level is chosen above the rest.

II. SENTIMENT ANALYSIS PROCEDURE

A. Data Collection

The data collection task is the first step in the process of sentiment analysis. Data can be taken from any of the websites or from the many data sets of opinions and reviews available online.

B. Pre-Processing

This is the stage of cleaning the data. Words and symbols that are not required are removed. This is done to simplify further processing. Removing hyperlinks, repetitive words, emoticons and special characters are part of this step. Lemmatization and Stemming is also done. Finally a reduced set of features are taken and given to the classifier.

C. Classification

A classifier is the most important component of a sentiment analysis framework. Classification is done into categories of negative, positive or neutral. Usually one third of the database is used as the training set to create the classifier. The accuracy of the classifier depends on the training set to a large extent. Classification can be done using machine learning classifiers such as SVM, Bayes classifier, maximum entropy classifier, etc. However for the machine learning classifiers, before the classifier is trained and tested, feature extraction is carried out

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where Deep neural networks may also be employed to classify the data.Classification may also be done by simply employing a deep learning method. There are various types deep techniques in the form of neural networks such as convolutional neural network (CNN), probabilistic neural Network(PNN), Recurrent Neural Network, etc. that may be used.

D. Display Results

The result is displayed after the data has been passed through the classifier. The polarity of the sentiments of the entire data is displayed and the level of details provided depends on the type of classifier used.

III. MACHINE LEARNING

Machine Learning is used to provide a computer the ability to learn without being explicitly programmed. It comprises statistical and predictive analysis which is implemented to enable the computer to spot various patterns and used this knowledge to catch hidden insights on the data that has been provided.

All Machine Learning algorithms are classified into Supervised Machine Learning and Unsupervised Machine Learning. Supervised Machine Learning algorithms are those which are used for predictive analysis. These algorithms predict the outcome or dependent variable from a given set of predictors or independent variables, which is done by studying the present pattern and learning how to implement it on a new pattern. Unsupervised Machine Learning algorithms on the other hand are mainly used for grouping of various unique types of data and is implemented in various fields where segregation of the data is required.

Classification plays a crucial role in the field of Sentiment Analysis .In the classification step of sentiment analysis using a Machine Learning technique, a pre-classified database sample, called a training set, is used to train and generate a classifier. This classifier then labels the previously unlabeled data after it has learned the pattern. However any classifier's accuracy is also highly dependent upon the data used to train it. Thus we see that Supervised Machine Learning approaches are the most apt for sentiment analysis. Following are the major Machine Learning classifiers used for Sentiment Analysis

A. Naive Bayes Classifier

Naive Bayes classifier is considered as very straightforward and easy to implement. It is not a single algorithm but is comprised of a collection of various classification algorithms based on the Bayes theorem; a theorem which is used to describe the probability of an event. This probabilistic classifier makes use of all the all the various features present in the feature vector, analyzing them differently, that is considering them independent of each other. It is able to learn the pattern by examining a pre-categorized set of documents. This model states that in the presence of two events say, p1 and p2 , the conditional probability of occurrence of event p1 can be calculated when p2 has already occurred . The input for the training of the Naive Bayes classifier consists of the preprocessed data along with the extracted feature/s. On completion of thetraining, the classification process is carried out on the test data then depending on the results the new data. In this classification method a polarity of the sentiments of the data is provided. For example, the review comment "It was good" would provide Positive polarity as result [11].

B. Support Vector Machine(SVM) Classifier

In SVM there exists an n-dimensional space where n is the number of features present in the feature vector. Each of the data items present in the training set is plotted in this n dimensional space with the value of each feature being the value of the coordinate. The main principle of this method is to find out linear separators in this n-dimensional space which best segregate the various classes.

A discriminative function is used by SVM with parameters defined as follows [10]:
'X' is the feature vector,
'w' is the weights vector and
'b' is the bias vector.
$\varphi()$ is the nonlinear mapping from input space to high dimensional feature space.

The weights and the bias vector are learned automatically on the training set. Thus every data represented as a vector is classified in a particular class. A margin is defined between the two classes such that it is far from any document. This distance defines the classifiers margins and maximizing this margin reduces the indecisive decisions.[11] Although a few features are relevant in this method , they are correlated with one another and thus due to the sparse nature of text , for SVM text classifications are well suited[12].

C. Decision Trees

Decision tree is mainly used for classification problems. The tree is segregated based on the significant attributes or features which are also known as the independent variables. The training data space is represented in a hierarchical form on the basis of these features. Each attribute value has a condition which is the presence or the absence of one or more words. The interior nodes are marked with features while edges leaving the node were named as the trail on the data set weight. Each leaf in the tree was the name of a category or class[14]. In such a manner a Decision Tree classifier maps information of an item to the conclusion of what value is expected of the item.

D. Maximum Entropy

The principle of maximum entropy states that when the probability distribution of a random event is predicted, all the known constraints should be satisfied without any subjective assumption being made about the unknown [12]. Thus classifier makes no assumptions are made regarding the

relationship between the various features [11]. The aim of this classifier is to maximize the entropy of the system defined on the conditional probability distribution. Similar to Naive Bayes is provides a polarity of sentiment for the provided data.

IV. DEEP LEARNING

It is a more complex and detailed sub-part of Machine Learning. It consists of different types of neural networks and neural beliefs that loosely work on the principle of the neurons in a brain. The data sets that are usually taken for these techniques are enormous in size. Deep learning is used to create deep neural networks that solve complex binary questions, make decisions or return numerical answers with high accuracy.

A. Convolutional Neural Networks

This is one of the most basic types of neural networks. It's specialty is multilayer convolution.. It is an improved form of traditional neural nets that have a neuron in every layer that corresponds to a neuron in the next layer and so on. In a convolutional neural network, a number of convolutional layers are used along with a pool layer and an output layer. The CNN calculates the input layer neurons and the local connections that are made to the output. The CNN applies filters and learns the size of the filters on its own depending on the task that needs to be done, which in this case is the classification of words using the filters. It then summarizes the results with the pooling layer and thus a many layer neural network is created that works on the principles similar to that of the neurons of the brain. Dynamic CNNs are also being used now to enhance the performance of regular CNNs. Fig. 1 shows the diagrammatic representation of a CNN.

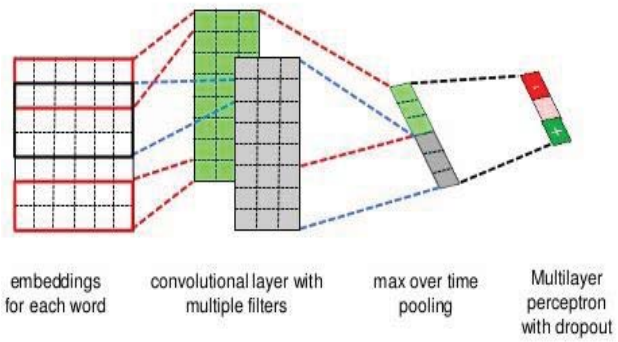

Fig. 1. Diagram representing a convolutional neural network

B. Probabilistic Neural Network

PNN is a type of feed forward [9] neural network that works on Learning Vector Quantization. It uses a training set and a testing set such that if an image is input that is not in the training set then it includes it in the training set and thus this is why a PNN is chosen over other Neural Networks. The PNN consists of 3 main layers, namely input, pattern and output layer. Sometimes there is also a summation layer present between the pattern and output layer. Pattern layer also called the Rule Layer is the actual classifier in the form of a neural implementation. The Probability Density function is calculated with the help of Parzen eliminator and the PDF is such that the chances of incorrectly classifying the training set is reduced. In the first step, the distance of the input sentiment is calculated from that of the training set. The next layer summarizes the contribution of the input sentiments and generates a probability vector. The layers after this continually take maximum probabilities from the previous and finally produce the result. Fig. 2 below shows the layers of a PNN.

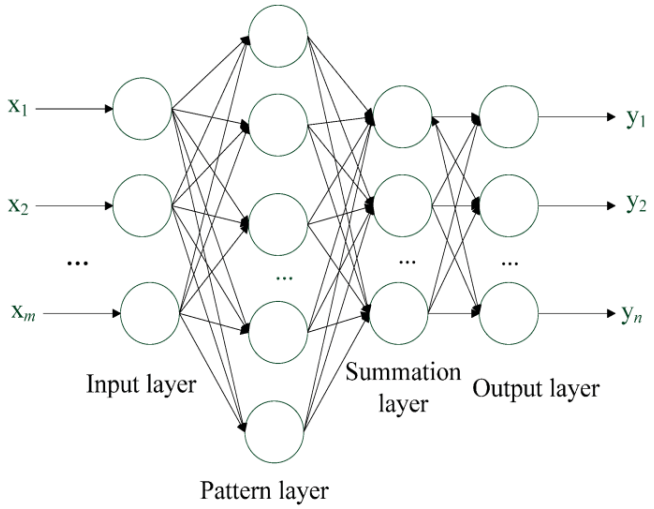

Fig. 2. Diagram representing a probabilistic neural network

C. Recurrent Neural Network

A recurrent neural network is generated by applying similar set of weights within a setting such that the nodes form a directed graph along a sequence. For sentiment analysis, the RNN follows the bottom-top approach such that it computes the parent vectors after using a composition function and classifier that uses features of node vectors at that node. The nodes contain the opinions. The advantage of this neural implementation is that it can use its internal state memory to process the sequence of nodes. Fig. 3 is a diagrammatic representation of a RNN

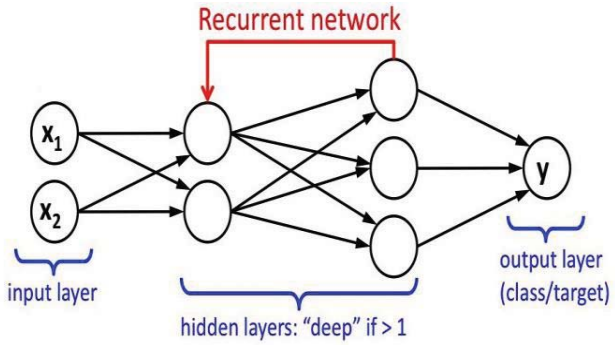

Fig. 3. Diagram representing a recurrent neural network

D. LSTM (Long Short Term Memory)

It is a type of Recurrent Neural Network[8]. Its ability to use its internal state memory to process sequences is superior. It can be used for a diverse set of modeling tasks. It is capable of storing a state over a long period of time. It overcomes the shortcomings of recurrent neural network such as the fact that the gradient vector vanishes or declines after long periods of time. The middle layer in a LSTM is a forgot gate. For effective long term learning, the forgot gate is used to decide the data that needs to be memorized and the data that needs to be forgotten. The middle layer takesdata from the input layer and the output layer displays the result. Fig 4.below shows an LSTM and its gates.

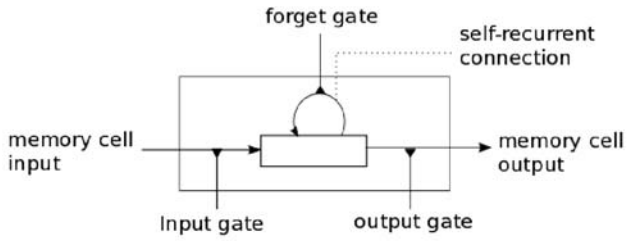

Fig. 4. Architecture of a LSTM

V. LITERATURE REVIEW

Chen and Zhang[1] proposed a model that combines SVM and a Convolutional Neural Network (CNN) for sentiment analysis. The results of their experiment show that their method gives better accuracy than CNN or SVM alone for text sentiment analysis. NLPCC2014 emotional evaluation data set was used by them. This data set was processed such that that it is first filtered and then the filtered set is trained by Word2vec. The CNN learns the features whereas the SVM does the classification.

In [2], the authors propose a model for sentence classification using a joint framework of a CNN and RNN. In the first step the words from sentences are changed to feature vectors. Then a slight alternative of a CNN is used to decrease the number of parameters. The result is then passed to a LSTM recurrent neural network with multiple layers. A 'Black Propagation Through Time' algorithm is used to control the neural net. Finally a classification layer is present which is a logistic regression classifier to give the final result with an accuracy between 89.2% and 93.3%.

In [3] the authors perform sentiment analysis on Google play consumer reviews that are in the Chinese language. 196,651 reviews were collected for the experiment through a web crawler. The data was then pre-processed and integration of dictionaries was performed. LSTM, Naive Bayes and SVM classifiers were used and the results were compared. The results suggest that the LSTM with an accuracy of 94% gave far better results than SVM and Naive Bayes with an accuracy of 76.46% and 74.12% respectively.

Zharmagambetov and Pak present a deep learning approach for sentiment analysis with the help of Google's Word2Vec. The first step is preprocessing to extract features. Word2Vec is used such that a Continuous Bag of Words(CBOW) predicts the current word whereas a skip-gram predicts the surrounding words. An Elman type RNN[4] is used to train the data and later clustering is done. The results showed that deep learning was better than a traditional CBOW method, but the difference in accuracy was not much.

In[5] the authors propose a hybrid method for sentiment classification using a Restricted Boltzman Machine(RBM) and a Probabilistic Neural Network(PNN) that fared better than traditional deep architectures in 5 data sets. First, the RBM was used to reduce the dimensionality. Next, the learning method is applied and a Contrastive Divergence Algorithm is used. Finally sentiment classification is done with the PNN.

In [6] an unsupervised Hierarchical Deep neural network is implemented for document level sentiment analysis and the results are compared with that of an SVM and it is concluded that as the dataset size grows the neural network gives more accurate results.

One of the many applications of Sentiment Analysis is its application in a recommender system on cloud. The authors of [7] have used a recurrent neural network to recommend places depending on the positive polarity of the reviews to users that are nearby.

For different problem statements, different feature vectors are to be created for a more efficiently trained classifier. In [10] various different supervised classifiers are trained with the similar feature vector and the variance in the accuracies has been recorded.

Sentiment analysis was carried out in [11] on a pre labelled twitter dataset and the accuracy of each method was compared. It was observed that Naive Bayes returned better results, that is , had a higher accuracy rate as compared to SVM and Maximum Entropy.

In [12] the authors compared between SVM, Naive Bayes , Maximum Entropy on the basis of theoretical accuracy as well as theoretical training speed. [13] compares and contrasts between the various supervised machine learning approaches taking the measures of Accuracy , Precision , Recall and F-Score into account. On the other hand [14] has observed both the advantages and disadvantages of the various approaches , thus better putting across which classifier works best under which prevalent condition.

VI. COMPARATIVE STUDY

This section presents a comparative study of different algorithms that are proposed by various researchers for

sentiment classification. The comparative study is done on the basis of accuracy with which each algorithm calculates the polarity and thus categorizes the data into positive, negative or neutral.

TABLE I: Comparision of Major Sentiment classifiers and their accuracy

Sentiment Classifier Technique	Accuracy (%)
Machine Learning classifiers	
Naive Bayes Classifier[11][13]	83-88 %
Support Vector Machine (SVM)Classifier[11]	82.5-85%
Decision Tree Classifier[13]	85-90%
Maximum Entropy (ME) Classifier[11]	79-83%
SVM for Chinese text[3]	76.46%
Naive Bayes for Chinese text[3]	74.12%
Deep and Combination Classifiers	
LSTM for Chinese text[3]	94%
CNN-SVM combination[1]	88.9%
Joint CNN-RNN framework[2]	93.2%
PNN (with single smoothing parameter for whole network)[9]	92%
PNN(with different smoothing parameters for different classes)[9]	95%
RBM+PNN[5]	93.1-94.9%
Word2Vec+Decision Tree[4]	89.8%
RNN (for recommender system)[7]	90.47%

VII. CONCLUSION

Sentiment analysis is a growing field with many applications. Based on the result of the sentiment analysis, not only are customer needs met, but also manufacturers, producers etc. get an idea about the response of the user or customer, thus ensuring that they can make the required changes. We have reviewed techniques of both machine and deep learning. Machine learning methods are more basic in nature and easier to implement. They give substantial results. Deep learning methods as well as the combination of deep learning and machine learning methods are superior and complex in nature. In most cases they give better results than traditional machine learning algorithms. In some rare cases however, the difference in the accuracy of the two techniques are not very high and in such cases the deep learning method only increases the complexity of solving.

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