

# Sentiment analysis Using Machine Learning and Deep Learning: A Survey

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**Abstract**—In recent years, internet strengthened itself as an influential platform that has changed the methods of business and communication. Sentiment Analysis (SA) become active research topic in the field of Natural Language Processing (NLP). It is the discipline that analyzes sentiment of people's opinions, attitude and emotions towards different entities such as products, services, organizations, individuals, issues, events, topics, and their attributes. The growth of web and social media such as blogs, business reviews, and social networks have fueled awareness in Sentiment Analysis (SA). There are several methods to analyze sentiments and all methods have numerous challenges, lacks and limitations. Therefore, this area still demands attention of researchers as well as industrialists. The main objective of this survey is to demonstrate an overview of Sentiment Analysis (SA) techniques and highlights limitations from previous studies. Our contribution will provide quick review of latest papers and help the researchers to choose appropriate for their future work. Finally, we attempt to compare the approaches and conclude that which approach can provide high accuracy and highlights more useful algorithms for the SA.

**Keywords** - Machine Learning (ML); Natural Language Processing (NLP); Sentiment Analysis

(SA); Deep Neural Networks, Artificial Neural Networks (ANN)

## 1. INTRODUCTION

Sentiment analysis (SA), also referred as opinion mining, is the area of research that analyzes opinions of people, sentiments, appraisals, attitudes, and emotions towards entities such as products, services, organizations, individuals, issues, events, topics, and their attributes [1].

With increase in use of social media to express people likes or dislikes towards an event greatly increased. With an easy access to internet all over the globe social media has become major source for expressions showing people reaction towards certain things or events. Medium Social median has increasingly become popular way of showing people reactions towards certain things.

The growth of social media such as community platforms, blogs and social networks has fueled awareness in sentiment analysis. With

the large propagation of audience reviews, ratings, recommendations and all other types of online expression and opinions has curved into a type of practical currency for businesses gazing to promote their products, discover new opportunities and handle their reputations. Sentiment analysis is vital for today's businesses because it recognizes ways to enhance business revenue and the product growth. This is implemented by measuring the perception of public against the products, business, services, and even the advertisements. Business possessors and marketing companies will frequently use sentiment analysis to find out exclusive strategies for advertising campaigns, whether it's for online banner ads or direct mail postcards.

The general idea is to construct trustworthiness and loyalty with customers regarding the product, which is important for business growth and expansion. It is much easier to find out how the public experience about certain products with the help of social networking websites and other techniques for measurement. Business possessors use internet as tool to find out public opinions to avoid negativity and persuade the public to acquire their products or services. In recent few decades, there has been a sound increase in attention from organizations, experts, brands, companies as well as researchers in SA and its applications towards business analysis and intelligence. With Sentiment Analysis from a natural languages, we are essentially looking to get an understanding of the emotions of an author and writer against a

topic in a piece given text as well as the polarity; either it's positive, neutral or negative.

Businesses experts are looking to get the hidden meaning of unseen value in the text so that they can be able to identify and understand their customer's emotions, desires, behavior, attitude and desires. This analysis guide them for improvement and let them take fruitful business decisions. Conventionally assessments, workshops, and assessments are important sources to get insight into their consumers feelings, emotions and opinions, but nowadays with up to date technology we are able to use the power of ML and Artificial Intelligence (AI) to extract the meaning of text and jump into sentiments of consumers and see them exterior of the habitually controlled environment of an assessment or survey.

The difficulty is that the majority sentiment analysis algorithms use straight forward conditions to state sentiment about a product or service. Various factors can influence the real meaning of stated text which hinders the interpretation of given opinion. Or can leads to misunderstanding. For example the cultural factors, linguistic shades make it tremendously hard to twist a string of written text into an easy pro or con sentiment.

The fact that humans regularly and frequently astray on the sentiment of content demonstrates that how computers can do this job and compute sentiment effectively and adequately.

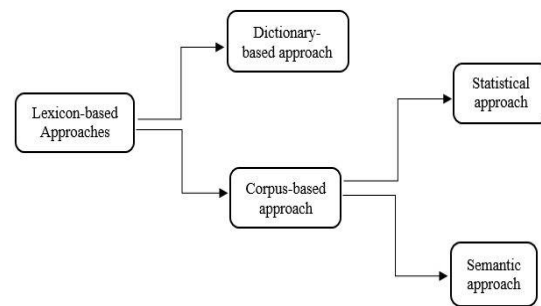
The shorter the filament of text, the harder it turns out to be and it make very challenging to analyze the sentiments due to some reasons: People often articulate opinions in complex and multiple ways, for example; compound sentences, In opinion texts, contents can be deceptive, ambiguous and misleading, Negation changes/effect the polarity of the opinion oriented word, People use sarcastic sentences which is difficult to interpret for machines; e.g. “wow I should go now”! Machine will interpret and categorize this text positively, which is not true. So, Machine capability to analyze the sentiments of people is limited in the form of text. There are many challenges in sentiment analysis such as:

- People often articulate opinions in complex and multiple ways, for example; compound sentences.
- In opinion texts, contents can be deceptive, ambiguous and misleading.
- Negation changes/effect the polarity of the opinion oriented words.

At present, a number of research teams in universities all around the world focus on understanding the dynamism of sentiment in e-communities, social media networks, business, Movies, Restaurants, books, DVD’s through Sentiment Analysis. For example, “The Cyber Emotions project, freshly recognized the role of negative emotions in driving social networks debates”.

Different approaches, techniques, frameworks and tools are currently being employed to analyze the sentiments which helps to develop new frameworks and techniques to overcome the previous challenges and limitations. Three

traditional techniques have been used to analyze the people’s opinion or sentiment over internet are as follow (1) Machine Learning based algorithms, (2) Lexicon based approach and (3) Hybrid approaches [5] [6]. This survey paper discuss latest trends, advancements, limitations and considerable updates regarding different methods that are currently in use in the area of Sentiment Analysis (SA).



The main contribution of this study is following:

- Provide detailed survey and cohesive overview of frequently used techniques from 2010 to 2020 for SA.
- Presented latest trends, advancements and considerable updates, different methods being used and limitations of these methods in the area of SA.
- Help to provide all the possible opportunities for effective future research.

The rest of the paper is structured as follows: Section. 1 provides an introduction of Sentiment Analysis (SA), Section. 2 presents existing SA techniques and limitations along with the tables which contains the author, year

of publication, used technique or methodologies, datasets, language and polarities. Section. 3 provides future work and comparison.

## 2. SENTIMENT ANALYSIS METHODS

Three traditional techniques have been used to analyze the people’s opinion or sentiment over internet are as follow (1) Machine Learning based algorithms, (2) Lexicon based approach and (3) Hybrid Approach.

### 2.1. Lexicon based approach

Lexicon-based approach depends on two methods, first is dictionary-based approach [7] which divide given text (sentences, phrases, or whole text) in to tokens (this process called tokenization). Lexicon-based frameworks contains lexicon module which is responsible to integrates different sentiment lexicons and dictionary resource e.g. Wordnet. Then check the frequency and subjectivity of each token from existing lexicons database of emotional values, pre-recorded words and compute the overall subjectivity of given text.

**Fig-1:** Lexicon based approaches

Text identification module which perform two tasks [8]:

1. Extract sentiment-oriented words from given text.
2. Detect slangs and translate them.

Second is Corpus-based approaches Fig. 1. Depends on domain corpus to find opinion oriented words by using Natural Language Processing (NLP) syntactic, rule-based techniques and features (both sentence and structural level) [9]. This approach might be categorized in to two more approaches which are Statistical and Semantic approaches [6]. Few systems uses automatic classification of both type of reviews either positive or negative. These developed systems use lexicon approach and Natural language processing techniques and achieved average accuracy of above 82% [10]. Complete image of lexicon based approaches shown in Fig. 1.

Lexicon based approach use predictors to predict the intensity of words but when Lingmotif tool was used even with Lingmotif Learn which was specially designed complementary tool for this research, calculates scores for short texts but gives poor results and proves that Lingmotif tool is might be or not be a great predictor. [11]. The major disadvantage of lexicon-based approach is involvement of human being while analyzing text [6].

Many Researchers proposed and used different lexicon-based approaches in recent five years. Details about approaches, year, scope and polarities are listed in Table 1:

**TABLE-1:** LEXICON BASED APPROACHES

Approaches	year	Scope/ Data Sets	Languages	Polarity

Lexicon-based sentiment analysis method [12]	2014	Micro Blogs	Cross lingual i.e. English to Dutch Multi-lingual Support	Positive, Negative
Lexicon-Based framework [8]	2014	Tweets	English	Positive, Negative, Neutral
A scalable, Lexicon-Based technique [13]	2014	Social Media (Tweets)	English	Positive, Negative, Neutral
Lexicon-Based Sentiment Analysis Algorithm [14]	2015	Social Media (Twitter and Facebook), Movie Reviews	English, Polish/Portuguese	Positive, Negative, Neutral
Sentiment Based Lexicon-Based Approach [15]	2016	Messages, Short Texts	-----	Positive, Negative, Neutral
Rule Induction Framework [16]	2017	Twitter-based microblogs	English	Positive, negative
Lexicon-Based Method using Sentiment Dictionaries [17]	2017	Amazon, Restaurant and Movie Reviews	-----	Positive, Negative

WKWSC Sentiment Lexicon [18]	2017	Amazon Reviews, News.	English	Positive, Negative
Lexicon-Based Approach [19]	2017	Students feedback and comments	English	positive or negative & levels*
Syntactic and semantic features [20]	2018	Hotel Reviews	Arabic	Positive or negative
Automatic Approach of Sentiment Lexicon Generation [21]	2018	Mobile Shopping Reviews	Chinese and English	Positive, Negative
Lexicon-Based Approach [22]	2018	Movies, Books, Kitchen, DVD's and Electronics	English	Most positive, negative or neutral)
Lexicon-Based Classification Framework [23]	2018	Amazon Reviews	English	Positive, Negative
Lexicon-Based approach [24]	2018	Tweets	English	Positive, Negative
Lexicon based	2019	BBC news	English	Positive,

approach [25]				Negative
Lexicon-based method [26]	2019	Twitter data for movies	English	Positive, Negative

\*Polarity levels can be most positive, most negative, moderate positive, moderate negative, less positive, less negative etc.

A survey recently conducted by Doaa Mohey El-Din Mohamed Hussein and discussed the Lexicon-based approach limitations and challenges in detail: Huge lexicon, Domain dependency and NLP overheads (ambiguity, sarcasm, Multi-lingual and emotions), Bi-polar words, Negation, Spam and fake review detection, feature or keyword extraction and world knowledge [27].

## 2.2. Machine learning approaches

Natural Language Processing (NLP) is an area which make machines, capable to understand natural languages e.g. English, Chinese etc. Sentiment Analysis is subfield of NLP, it studies that how machines process text and perform classification of text. This discipline use Natural Language Processing algorithms to extract features and machine learning algorithms use to train machine for specific datasets and for classification [28] and if increase the number of features, accuracy also increases. [29]. Normally Sentence level sentiment classification need sentence labels used supervised learning which is time consuming and expensive due to manual annotation

Fig. 2. Demonstrating the machine learning approaches, sub categories and techniques. Where Naïve Bayes, SVM, Neural Network are machine learning algorithms.

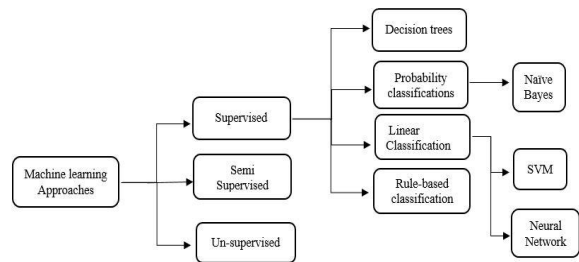


Fig-2: Machine Learning Approaches

### 2.2.1 Supervised learning approaches

The supervised machine learning approach for SA use large number of labeled training and testing datasets. Supervised learning work based on classification which further based on the polarities we already have. Polarities may defined in four types such as Positive, negative, neutral and constructive [30].The polarities assign in different levels as follows: [31].

- a) *Document Level:* Labelling of the complete document as positive, neutral or negative.
- b) *Sentence Level:* Parse whole document into sentences and then assign polarities as positive, negative or neutral.
- c) *Word/Phrase Level:* Analyze the individual feature which might be product attributes or components and



perform sentiment/opinion classification this is simply called word or phrase or feature based sentiment analysis.

Limitations in supervised learning approach are: lack of balanced labeled training data and presence of emoticons and slangs [32]. Jagdale et al, (2019) applied supervised machine learning approaches (Naïve Bayes and Support Vector Machine (SVM)) on the amazon products reviews. They concluded that for product review classification supervised machine learning methods works best and achieved higher accuracy by implementing Naïve Bayes was 98.17% and SVM got accuracy 93.54% [33]. Shirsat et al, (2018) proposed a framework based on sentence-level identification of negations from news content where proposed methodology uses BBC news articles Data. The Results show that supervised machine learning approaches such as SVM and Naïve Bayes are effective regarding sentiment analysis. For proposed methodology, SVM achieves 96.46% accuracy and Naïve Bayes achieves 94.16% [34]. When Machine learning standard approaches detect the polarity of opinions/sentiments, it have drawbacks like domain dependency etc. [30].

Similarly Mohini Chaudhari and Sharvari Govilkar claim that any classifier alone cannot provide complete efficiency towards sentiments analysis since results depend on several factors. [31].

- a) *Naive Bayes*: Naive Bayes is family of algorithms which share a common principle for classification, based on probability and Bayes theorem with assumption of independency as it is considered that specific feature in a class is independent or unrelated to the any other feature presence or absence.

Basic rules used by Naïve Bayes is: Bayes Theorem;

$$p(g|h) = p(h|g) p(g)/p(h) \quad (1)$$

Here g and h are two events or instances and p(.) is the probability of events.

Naïve Bayes simply provide estimation of probability of given text either negative or positive [31]

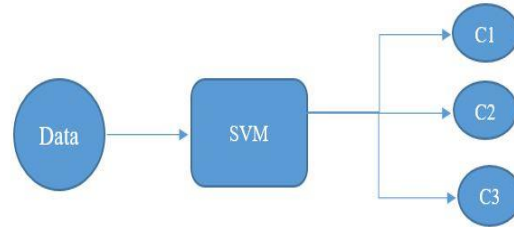
- b) *SVM*: Support Vector Machine (SVM) is a linear model which can be implement on non-linear data and used for both classification and regression purposes. It is in the category of supervised Machine Learning (ML), often use for classification.

Its working simply shown in Fig. 3.

**Fig 3-** SVM simple idea

Here C1, C2 and C3 indicates the 3 classes.

Support Vector Machine often perform better than Naïve Bayes but Naive Bayes is more appropriate when training datasets are small.



Supervised learning approach relies on the machine learning algorithms and Table. 2. Illustrates the recent work in popular Algorithms:

**Table-2: SUPERVISED LEARNING APPROACHES**

Algorithm	Research Fields	Function
Naïve Bayes	Naïve Bayes [35]  Reviews Classification using n-gram [36]  Classification of Amazon reviews using Naive Bayes [33]  Twitter Data-set using Naive Bayes [37]  Machine Learning Techniques [38]  Feature Selection [39]	Classification

	Naïve Bayes and K-NN Classifier [40]  Sentiment analysis in Tweets using Naïve Bayes [29]  Aspect-based sentiment analysis [41]  Toward Optimal Classification of sentence level [42]  Naïve Bayes for BBC news articles sentiment analysis [34]  Twitter Data Sentiment Analysis [43]  Used Naïve Bayes classifier [20],	
Support Vector Machine (SVM)	Machine Learning Techniques [38]	Classification, Regression and anomaly detection



Classification of sentence level [42]
Classification of Amazon reviews using SVM [33].
SVM for BBC news articles sentiment analysis [34]
SVM Classifier [44],
Regression Based Approach [45],

### C. Hybrid approaches

Hybrid approach is combination of different approaches to get effective results. It provides more accurate results and useful to achieve the best of both approaches due to high accuracy from supervised learning algorithms and stability from lexicon approach [46]. Khan et al., (2014) reviewed the issues and limitations of previous methods such as sarcasm, classification accuracy and data sparsity, and proposed a new hybrid

**Table-3: SENTIMENT ANALYSIS CONVOLUTIONAL NEURAL NETWORK (CNN)**

Technique	Related work	Data set	Results
CNN (Convolutional)	[47]	Phrases and messages	Comparison b/w official test sets and proposed

1 Neural Networks)		Official test sets (Semeval-2015)	approach, where proposed approach could rank in first 2 positions.
Word2vec + Convolutional Neural Network (CNN)	[48]	Public data sets e.g. movies reviews	Achieve 46.3% accuracy for movies dataset which is better than other deep learning (RNN) and (MV-RNN).
Convolutional Neural Networks (CNN)	[49]	Twitter images and text SA	Effective performance
2 layer Convolutional Neural Network (CNN)	[50]	Twitter messages (Italian)	Better performance than other traditional methods.
Convolutional Neural Network (CNN) and transfer learning approach	[51]	Twitter images dataset	Proposed model achieved better performance than traditional models.
CNN (Convolutional Neural Networks)	[52]	Twitter sentiment classification	Better performance than Naïve Bayes and SVM.
Convolution Neural Network (CNN)	[53]	Twitter Dataset	Proposed model performs better on the accuracy
Deep Convolutional Neural	[54]	Twitter sentiment classification datasets	Improve the classification accuracy of sentence level SA.

Network (DeepCNN)			
Convolutional Neural Network (CNN)	[55]	Twitter Emoji's	CNN is better for this data set and achieved remarkable performance.
Convolutional Neural Network (CNN)	[56]	Hindi Movie reviews dataset	Achieved better performance than ML methods and get an accuracy of 95%.

classification scheme to achieve high accuracy and overcome previous problems [57].

Ribeiro et al., (2015) proposed hybrid approach by using SentiWordNet and domain-specific classifier which perform four steps: extract techniques, exclude noisy tweets, lexicon creation and analysis of sentiments and it achieves 82% accuracy [58].

A unified hybrid approach framework proposed by [59] which uses domain-specific classifier and SentiWordNet framework, to classify text more accurately which was suggested to improve the performance of SA on twitter data.

Sentiment analysis of Korean text through the use hybrid approach proposed by Yoo and Nam (2018), this model used and observed the success rate as based on Support Vector Machine (SVM), Artificial Neural Networks (ANNs) as classification algorithms and Genetic Algorithm (GA) for optimization [60]. A hybrid model proposed for classification of positive and negative Turkish tweets using SVM and GA. Yelmen, 2018 achieved the

accuracy of 96.8% SVM and GA both used in hybrid model for positive and negative classification of Turkish tweets [61].

Based on Naïve Bayes Classification and DECO dictionary and PSDs outperforming the baselines.

Hybrid model was developed which identify the positive and negative text, this model provides better accuracy and complexity than Naïve Bayes, SVM and KNN etc [62].

Analysis of amazon products reviews were carried by hybrid approach and show that hybrid approach outperforms the state-of-the-art individual classifiers.

Mrabti et al., (2018) evaluates the performance of feature selection methods such as MI, CHI, ANOVA and combined with Naïve Bayes (NB), SVM and KNN and proved that feature selection is important task for SA [63]. Yadev et al., (2020) compared different sentiment analysis methods and shown that to use the hybrid approach with sentiment features provide satisfactory result as compared to traditional SA methods. [64]

#### D. Sentiment Analysis using Deep Learning techniques

Deep Learning is sub category of ML, basically inspired by neural networks and mimic human brain. To analyze sentiments/opinions deep learning has become hot research area as initially it was started for image analysis and for this purpose various deep learning models are being use and provide effective results [67]. Deep learning models has shown best results regarding the Sentiment Analysis and

text classification such as Convolutional Neural Networks (CNN), Recursive Neural Network (RecNN), Deep Neural Networks (DNN), Recurrent Neural Network (RNN), and Hybrid Neural Network.

**a) Convolutional Neural Networks (CNN)**

The CNN contains pooling layers and considered as a conventional model to get fixed size sentences from variable length and scattered vectors. CNN can extract feature of images and text from global information so, CNN use for image and text and image analysis. Table 3 shows the related work done in previous five years with datasets and results.

**b) Recursive Neural Networks (RecNN)**

RNN is directed acyclic graph structure to learn from data such as tree structure. It is independent from window size to perform NLP tasks but considered inappropriate for NLP tasks due to limitations [68]. Table 4. Demonstrates the related work.

**Table-4:** SENTIMENT ANALYSIS USING RECURSIVE NEURAL NETWORK (RECNN)

Technique	Related work	Dataset	Results
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Recursive Neural Deep Model (RNDM)	[69]	Chinese sentiment analysis of social media	Outperforms (higher (90.8%)) than traditional used baselines methods
Recursive Neural Network (RecNN)	[70]	Russian carding forum, top malware or carding sellers	Deep learning technique shows superior outcomes than shallow classifiers.

**c) Recurrent Neural Network (RNN)**

Recurrent Neural Network (RNN) is an area of neural networks which has connections between neurons form a directed cycle. If compare with the feedforward neural networks, Recurrent Neural Network (RNN) can use its internal memory to process the sequence of given inputs [71].

**Table-5:** SENTIMENT ANALYSIS USING RECURRENT NEURAL NETWORK (RNN)

Technique	Related work	Data set	Results
Conv-GRNN + LSTM-GRNN	[72]	Review datasets (Semantics of sentences)	Boosted performance than traditional algorithms

Recurrent neural network (RNN)	[73]	Large scale review datasets	Improved performance at document level and state of the art results on given datasets
Recurrent neural network vs. support vector machine	[74]	Arabic Hotels reviews	RNN time was faster than SVM but SVM perform better in research investigated 3 tasks

### c) Hybrid Neural Network

Hybrid Neural Network combine two or more deep learning models e.g. RNN with CNN for effective model building to correctly classify the sentiments. Minaee et al., (2019) presented an ensemble model based on CNN and long-short-term-memory (LSTM). Experimental result has shown that ensemble model may have capability to can outperform both models and achieved higher accuracy as compared to individual models [75]. Wang et al., (2020) proposed hybrid model based on deep neural network for effective classification of emotions. The model consist on the combination of Multilevel Interactive Bidirectional Gated Recurrent Unit (MI-biGRU) with Attention Mechanisms (AM), and extract position features through MI-biGRU. Experiments show that effective classification

accuracy can achieve by using MI-biGRU with AT [76]. Aslam et al., (2020) proposed a hybrid model based on Recurrent Neural Network (RNN), Long Short Term Memory (LSTM), and Bidirectional LSTM to get the actual context of text. They performed experiments on movie reviews dataset and get high performance by implementing the proposed model [77].

Techniques	Author and year	Dataset	Results
Recursive Neural Networks + Recurrent Neural Network	[78]	Bag-of-words features	Test-set with accuracy of 83.88%
(Long Short Term Memory) LSTM + DCNN (Dynamic Convolutional Neural Network)	[79]	Thai tweets	Better performance than classical sentiment analysis techniques
CNN + RNN + Machine learning classifier	[73]	Large scale review datasets	Improved performance at document level and state of the art results on given datasets
CNN Architecture + SVM	[80]	Hindi and English language datasets	Proposed method provides consistently better accuracy reports than

			the other several baselines methods
Bi-LSTM-CRF + CNN	[81]	Sentences	State-of-the-art results on datasets.
Recursive Neural Network (RNN) + Convolutional Neural Networks (CNN):	[82]	Movie Review datasets and Stanford Sentiment dataset	Fewer parameters and a high level of Performance as 93.4% accuracy Movie review data set and Stanford Sentiment dataset with 48.8% fine-grained and 89.2% binary accuracy
Recurrent Neural Network (RNN) + Long Short-Term Memory (LSTM)	[67]	English Tweets, SemEval-2017	Provides significantly better results.
Ensemble of LSTM and CNN	[75]	IMDB (movie reviews) dataset	Achieved 90% accuracy
LSTM-CNN Deep Learning Model	[83]	Dialectal Arabic	For binary classification, proposed model achieved between 81% and 93% and

			for three way, got 66% to 76% accuracy.
CNN- and LSTM-DNN (Deep neural network)	[84]	SNAP dataset, 100 K dataset, T4SA dataset, Sentiment 140 dataset and CKAN dataset	91.52% Recall, 88.20% F-measure, 91.82% accuracy and 86.21 precision for proposed model

**Table-6:** SENTIMENT ANALYSIS USING RECURRENT NEURAL NETWORK (RNN)

### 3. CONCLUSION AND FUTURE WORK

The main objective is to demonstrate the cohesive overviews of Sentiment Analysis (SA) approaches, comparative analysis and limitations. The contribution will provide quick review of SA methodologies and help the researchers to choose appropriate one for future research. Finally, we attempt to compare the approaches and conclude that which approach give high accuracy and highlights more useful algorithms as well for this purpose.

If we compare the Deep Learning, Machine Learning and Lexicon-based approaches for Sentiment Analysis, it is noted that hybrid approaches either Lexicon-based with Machine Learning techniques or combination of Neural Networks techniques perform better

than use these techniques separately. Only few methods reached high level of accuracy but to get satisfactory results in terms of conceptual and aspect level Sentiment Analysis still required a lot of work yet to be done. Likewise BERT (Bidirectional Encoder Representations from Transformers) is Natural language processing algorithm, presented by Google in 2018. BERT can explore useful insights in the NLP tasks including Sentiment Analysis.

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