DEPRESSION DETECTION USING INTELLIGENT ALGORITHMS FROM SOCIAL MEDIA CONTEXT - STATE OF THE ART, TRENDS AND FUTURE ROADMAP

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ABSTRACT: Depression, responsible for losing 8.5 million of lives per year worldwide, has raised a question mark towards maintaining the mental health of people living in the smart era. Depression is not only the problem of the people belong to the poor economy, but also for the high income and middle-income group. According to WHO, greater than 264 million of people around the world suffers from this mental disorder. Unlike other physical disorders, the symptoms of depression can't be diagnosed so easily. Many times, the person is unaware about his mental condition. Nowadays, with the evolution of Machine Learning and Data Analytics techniques, detection or even prediction of depression maybe possible. Social media can be used as a powerful medium in this regard as very recently its usage has highly increased irrespective of age, gender or profession. But selection of proper machine learning algorithm for accurate detection of depression is still a challenge. This paper performs an analytical study to deliberate the State of the Art, present trend and future roadmap for depression analysis from social media context.

KEYWORDS: Bag of Words; Depression Detection; Random Forest; Support Vector Machine; Topic Modelling; User Generated Content**.**

I. INTRODUCTION

Depression is a major mental disorder nowadays. According to a study done by WHO, nearly 264 million of people are suffering from this devastating mental disorder [1]. Depression, unlike normal mood fluctuation, has become a serious health issue, affecting a large number of populations, irrespective of high. Lower or middle-income group and irrespective of age also. It affects in all walks of life, irrespective of age or gender. Though there are certain physical symptoms like feeling reluctant to do anything, feeling tired all the days, muscle pain or lack of sleep etc., but still one may not be aware about his or her depressive condition and fight with the disease [2].

According to the survey conducted by CDC during 2013-2016, nearly 10.4% women and 5.5% men are affected by depression among world population [3]. The age as well as gender wise report worldwide has been performed by US department of health, shown in fig. 1 and fig. 2 [3], [4].

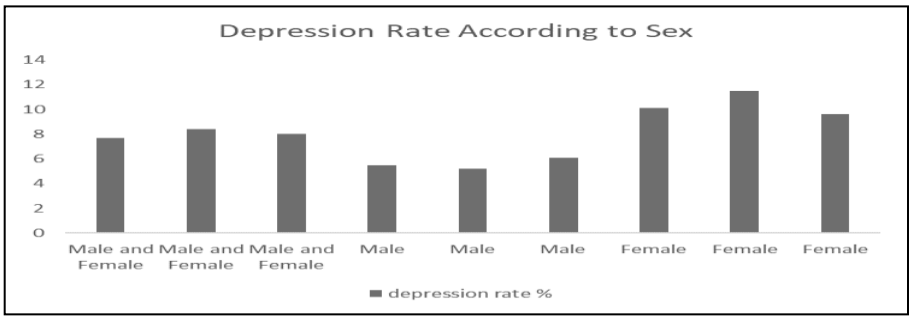

Fig. 1: Depression ratio according to sex

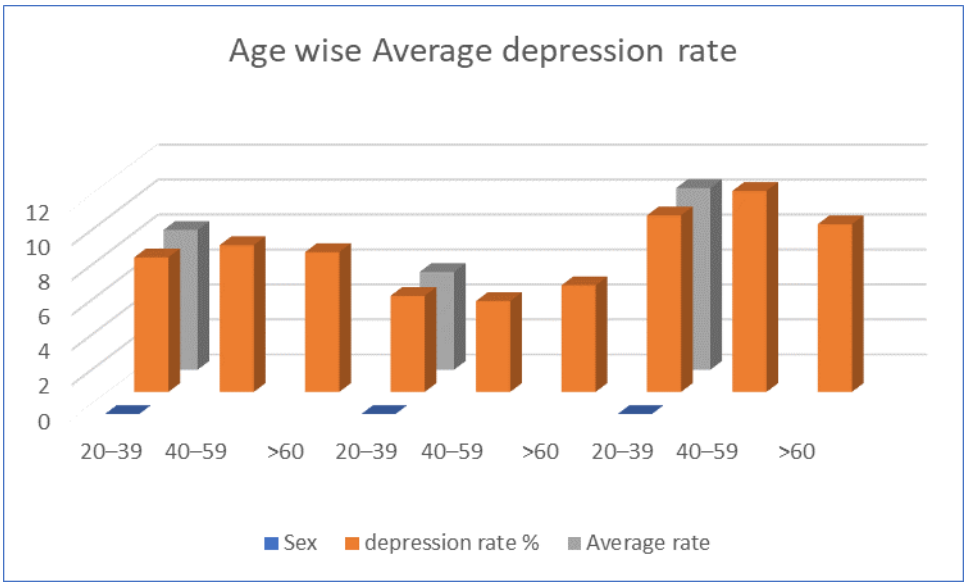

Fig. 2: Age wise average Depression Rate of Male, Female and both

Motivation of the work

Depression, being one of the most familiar reasons of losses many lives around the world. Globally, more than 264 million of people suffer from this mental health problem, according to WHO [1], [5]. According to a survey done by WHO, between 76% to 85% of lower- and middle-income group don't receive any treatment for depression. Depression, being the third highest global alarming disease and second prevalent disease after Alzheimer, is major concerns for the medical practitioners and researchers [6]. Specially, unlike other physical illness, people are generally reluctant to discuss about any mental health problem like depression. Even sometime they are unaware or misinterprets about several physical symptoms for depression.

It has been observed that in present days people are comfortable enough to share their emotion, feelings in social media platform and this trend is increasing as usage of social media has been increased. [7], [8]. So, this powerful media can be used as a tool of detection or prevention of depression to save life. Researchers are already working in this area and after the huge revolution in the world of AI; this research has got a new dimension.

Following are some social media statistics:

Social Media Demographics

Social media is the world's biggest networking platform in today's world, covering more than 45% population of the whole world and it show variations among its usage, in terms of sex, country, and usage time or user habits. One of the core factors of increasing social media users is availability of mobile communication in almost every corner of the world [9], [10]. Among the total Facebook users 43% are female, where as 57% are male. Total numbers of monthly dynamic users in Facebook are 2.5 Billion, among which 2.26 billion are mobile users and 1.4 billion people use Facebook groups [9]. As the worldwide usage of internet has been increased (has shown in fig. 3), the use of social media in the world has also been increased. In the below figure year wise internet usage has also been shown (see fig. 4).

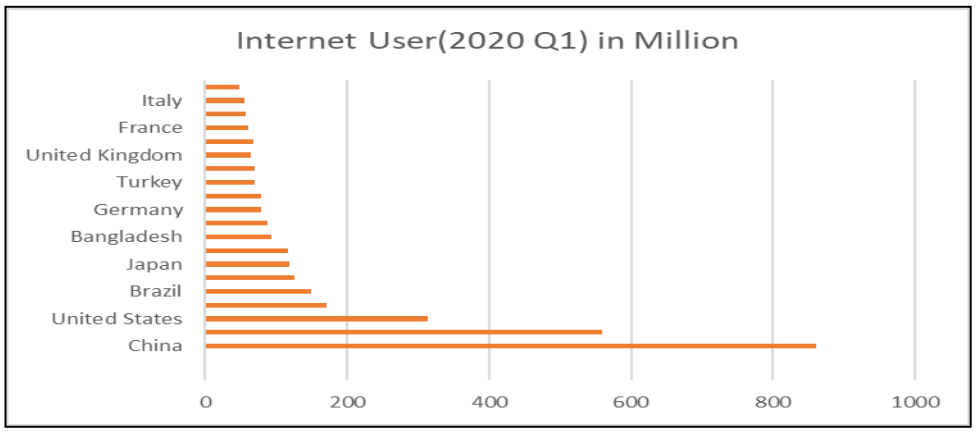

Fig. 3: Worldwide Internet user (Top 20 countries)

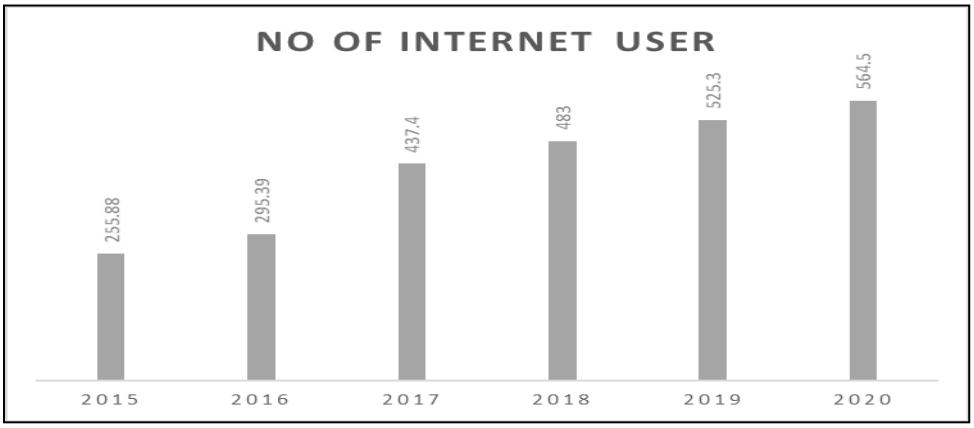

Fig. 4: Year wise Internet usage worldwide (2015-2020)

As a result of these large internet users, social media usage has also been increased nowadays. According to a recent survey age and gender wise social media users may vary according to their age and gender worldwide (Has shown in fig. 5):

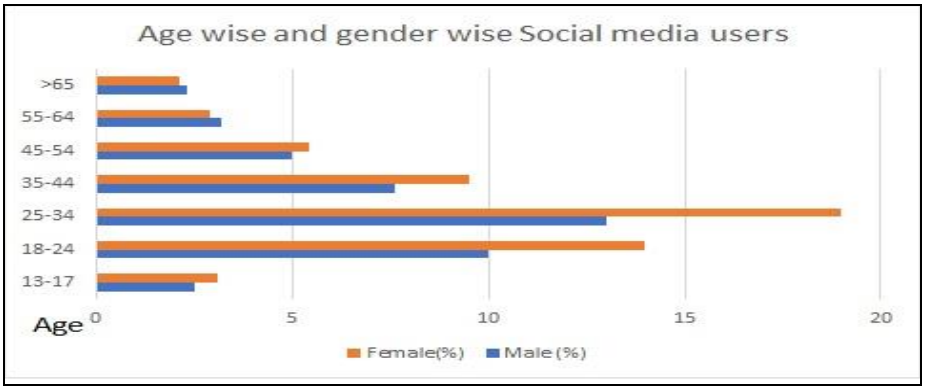

Fig. 5: Age and Gender wise social media usage

Along with large number of Internet users, no of mobile users have also been increased. This statistic not only applied for the developed countries; this is applicable for a third world country like India also. In India, no of Internet users have been increased. Nowadays, many people are able to use internet from their mobile also and along with the decreasing price of mobiles and increasing its facilities in India, the overall number has been increased. Among the overall mobile users, the people over 50 and less than 25 use 100%, whereas people between 25 and 49 uses a little below than 100%. You can view the statistics in the figure below (See fig. 6).

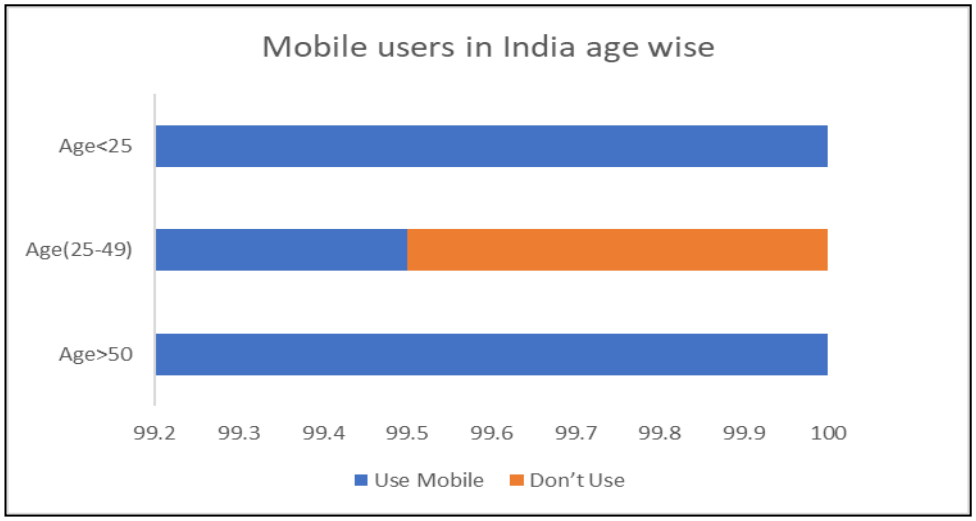

Fig. 6: Mobile users in India Age wise

Year wise social media usage can also be seen in the following figure in India. Among those social media users, most of them uses popular social media platform like Facebook, Twitter, Instagram, and Reddit (has shown in fig. 7). The social media platform has to choose very wisely. It has been observed that among many social media, Twitter, Facebook or Reddit have maximum membership and post like.

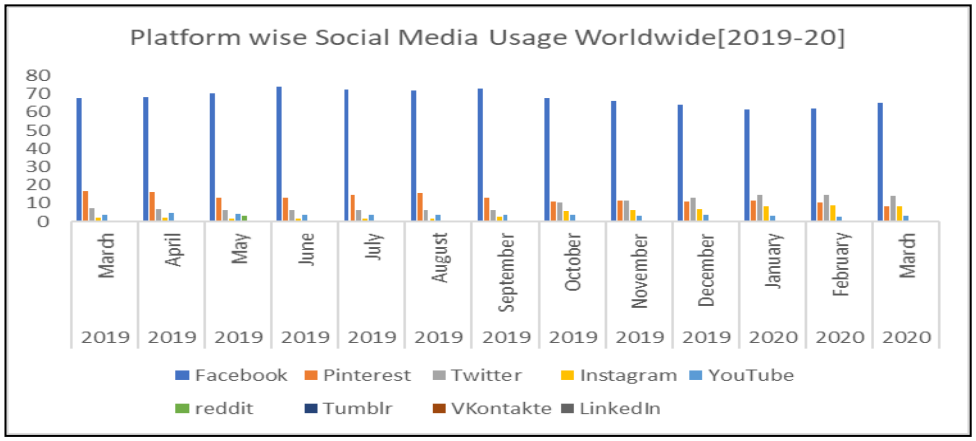

Fig. 7: Social Media usage worldwide on 2019-20 (According to different social media platform share)

In India, the internet use is also increasing per year. Here, may people be using internet as well as social media platforms for sharing their thought, feelings, and emotions. The average social media usage has been increased year wise in India (See in fig. 8).

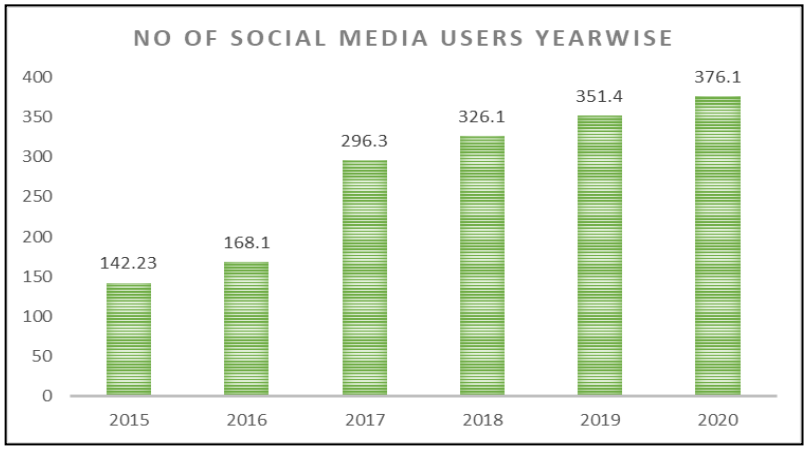

Fig. 8: Social Media usage in India (Year wise)

But very often a depressive person can't differentiate the signals of depression or misunderstood the physical symptoms like fatigue, muscle pain, joint pains, and sleeplessness with other physical diseases. It has been observed that especially in lower -income or middle-income countries, people even after being diagnosed with depression, can't get suitable treatment. So proper diagnosis of depression has become a big challenge area for developed as well as developing countries [1], [2].

Social media and depression

Depression is a mental disorder which may be considered just as other physical disorders. It can be alienated into three categories based on the number and severity of indications. The categories are mild, reasonable or severe. A person having mild depression may experience some struggle in continuing their work and maintaining their social life whereas a person suffering from acute depression might cease to function completely and start abusing drugs or start to show suicidal tendencies. Though depression shows

some physical symptoms like headache, back pain, mussel or joint pain, digestive problems etc., but most of the cases a depressive person may not be identified by those physical disorder only [11], [12].
Though physical symptoms like laziness, headache and joint pains are quite common showing the depression in a person, but depression patient may be undiagnosed as it may be misinterpreted with other somatic illness [12].
Depression may vary with normal mood disorder and it generally persists for a longer period. Depression patients in most of the cases experience severe joint pains, laziness or headache [13].
Many researchers have worked for diagnosis of a relation between the physical symptoms and depression [14], [15]. With the evolving uses of machine learning and data analytics technologies in almost every sector has become a ray of hope in this sector also and researchers have started working on the usage of social media platform to detect a depressive person using machine learning techniques or to predict a person having symbols of depression, or even a person having a suicidal tendency [14], [16], [17], [18].

II. RELATED BACKGROUND STUDY

Researchers are concerned about the serious mental health issue of depression, that are causing a considerable number of lives every year [1], from child to middle Ages and from high income to low income ranges [2]. Depression is not an incurable disease. It can be predicted pretty well. Only it requires our awareness. Many researchers have worked on detection of depression [18], [19], [20], [21], [22], [23], [24], whereas others have worked upon prediction of depression within an individual and thanks to the invention of technologies like machine learning and data analytics, it has become quite easier.
Though depression has some significant physical signs like headache, continuous mussel or joint pains, laziness or tiredness, stomach upset etc. [11], [15], but these symptoms are not enough to make an ordinary person understand that he or she might have a mental disorder like depression. Sometime the unwillingness of the person to consult a psychiatrist or go for a clinical analysis may affect the person's health in a severe manner and the increasing effect may leads a person towards suicide, causing the loss of a life [25].
Stress is a major problem in this highly competitive world. People can be stressed due to social, economic, political or any personal reason like loss of loved one or fear of being ignored by somebody. Stress, if can be handled positive can keep one motivated and inspired for doing good job. But if any person is unable to handle stress properly, this may lead to depression causing long time mood fluctuation and even worse physical condition. Social media has the enough power to detect stress level in a person [26], [27], [28].
With the evolution of artificial intelligence techniques like machine learning algorithms, researchers have applied the new techniques combining with traditional one and resulting surprisingly improvement in the whole process.
Some researchers have applied managed ML algorithms like different classification algorithms, Support Vector Machine or Decision Tree [17], [18], [29], [30], whereas other group of researchers preferred using unsupervised learning algorithms like neural network, deep learning algorithm, LSTM or genetic algorithm [16]. Researchers nowadays prefer use of hybrid algorithms – partial classification or regression along with LSTM or deep learning algorithms [17], [31].
Variations have been noticed in choosing social media platform also, where most of the researchers have targeted Twitter or Facebook data analysis for their experiment [11], [18], [19], [29], [32], then some researchers have worked upon less known social media platform like Reddit or some other micro blogs [16], [20], [30].
Researchers have applied different methodologies for data collection. Where most of the researchers relied upon questioner or interview processes for data collection [12], [20], [30], [33] some of them have

collected their required data through different apps developed or post on different social media like Facebook or Reddit [11], [18], [21], [29], [34].

Choudhury and her coworkers (2013) applied principal component analysis for measuring behavioral attributes from social media post for identifying posts related to depression sign [19].They focused on major depressive disorder, which can be applied to predict the risk of suicidal attempt.

Aldwarish and Hafiz (2017) detected the level of depression from user generated contents on social media website [29]. The authors prepared questioner on social media and using popular Machine Learning algorithms like Naïve Bayes or Support Vector Classification Algo they were successful to categorize the depressed person.

X Liu and his co researchers (2019) they analyze the data posted in micro blogs and then from this data they extract the suicidal prone individual by applying machine learning techniques [33].

Table 1: Survey among Different Papers for Depression Detection through Social Media Post

Reference with year	Methodology used	Platform used	Sample size	Performance and Future Scope
[5],2017	Logistics regression with 10-fold cross validation	Facebook	683 patients, 114 depressed	
[9],2019	Decision Tree algorithm, K Nearest Neighbour, Support Vector Machine	Facebook	7145 comments, comments that shows depression: 4149, Non-depression indicative comments2996	Decision tree recall 98%, precision 58%
[11],2018	probability calculation, using 10- fold cross validation	Facebook post	683, 114 of whom is detected with depression	AUC is 0.69, give same performance as manual survey
[14],2017	Naive Bayes classification, Multiple Social Networking Learning	Twitter	36,993 users, 35 million tweets	85% accuracy they have achieved
[16],2020	Principal Component Analysis, Support Vector Machine 10-fold cross validation	Twitter	set of 476 users	91.7% Accuracy, 92.6% F1-measure, Focused on Major Depressive Disorder or MDD

[17],2017	convolutional neural network, NLP based algorithm.	Reddit	20 epochs with a batch size 64 and 512	
[18],2015	Decision Tree Algorithm, Support Vector Machine, K Nearest Neighbour, Ensembled algorithm	Facebook data	7145 Facebook comments	Evaluated efficiency of algorithm by psycholinguistic feature, Work on Emotional ,Temporal and Linguistic Process and all the above features
[19],2013	crowdsourcing	Twitter feed	554 users	70% accuracy
[20],2013	sentiment analysis, polarity calculation algorithm, Binary logistic regression analysis	Sina micro blog (used in china)	554 users	80% precision, with 10 fold cross validation
[21]	crowdsourcing methodology, probabilistic model	Twitter post	489 users, 251 males, 238 females, and the median age was 25 years	They have achieved high accuracy of 73%.Future target is to develop individual-centric predictive models
[22],2017	Survey based on questioner	Twitter or Facebook or public online sources of dataset		Future target: studies integrating Social Media Analytic Gold standard clinical interview, Data protection and ownership framework is required to avoid ethical issues, no specific clinical criteria has been established

[23],2019	NLP, Support Vector Machine, Random Forest Multilayer Perceptron Classifier	Reddit	1293 depressive and 548 standard post	80% accuracy (With SVM) and 91% with MLP Future target relationship between personality and depressive behaviour from social media data
[29],2017	SVM and Naïve Bayes Classifier).	Twitter, Facebook	2073 post indicating depression and 2073 posts indicating non-depression	The authors have calculated accuracy, precision and recall.
[30],2018	Support Vector Machine	Reddit	531,453 submissions from 892 unique users	it is a reimplementation model, model has been selected undue maximum risk window
[33],2019	machine learning methods	Micro blog post, Questioner	27,007 comments	First it proactively identifies risk, then inform the crisis management system and act as a mediator
[34],2015	They provided a questioner-based approach	Twitter post	500–1000 tweets	deep learning algorithm may be used for more efficiency
[35],2017	Random forest, Hidden Markov Model	Twitter	204 persons (105 having depression, 99 healthy), 74,990 daily observations	85% accuracy they have achieved
[36],2018	Deep learning neural network	Twitter	580 depressed, 580 non depressed	They have achieved 95% accuracy
[37]	Perform survey among different ML techniques	Twitter, Facebook	Compare among different models	This paper compare the result among

	to identify depression			different recent works
[38],2014	Three level stress detection frameworks	Twitter	600 million tweets	
[39],2018	Deep Learning models Recurrent Neural Network	Facebook or Twitter		High Accuracy
[40],2018	Random Forest, Logistics Regression, Support Vector Machine	Reddit	150 users	35% of users refused to share data here, data trends change
[41],2019	Random forest Classifier	Reddit	500,000 posts, 887 different subjects	
[42],2017	Integrated review	Facebook and Twitter	Compare among dataset	Review

III. RECENT TRENDS

Studies have been performed upon several supervised and unsupervised machine learning techniques. Among the first category many researchers have used classification techniques like Support Vector Machine [11], [14], [16], [18], [20] Random Forest [11], [43], Hidden Markov Model [22], Naïve Bayes [20], [32], [35] or regression algorithm namely logistics regression[2], [11], [44]. Whereas some researchers have applied advanced algorithms like Artificial Neural network or deep learning approach like Artificial Neural Network (ANN) or Convolutional Neural Network (CNN) [16], [36] or data analytics technique like Principal component analysis [1].

Researchers are using several machine learning algorithms for detecting or predicting depression and stress detection from social media context [11], [12], [18], [21], [26], [27], [28], [29], [30], [33], [34], [37], [44], [45], [46]:

Machine Learning algorithms used:

Researchers are using several supervised and unsupervised machine learning algorithms for depression detection from social media context. Machine learning algorithms may be categorized as follows:

Supervised Learning

Most of the ML researchers have applied supervised Classification as well as Regression methods like Support Vector Machine (SVM), Logistic Regression (LR), Random Forest (RF), Radial Basis Function Classifier, Hidden Markov Model (HMM) to predict depression are some popular algorithms.

Support Vector Machine

It is the one of the very familiar supervised Machine Learning algorithms used for depression detection, can be implemented in classification as well as in regression. In this algorithm the training dataset builds a non probabilistic linear binary classification model. SVM uses the kernel trick for better efficiency [47].

Equation of Support Vector Machine classification algorithm is (See in Equation 1):

$$\frac{1}{n}\sum_{i=1}^{n}\max\left(0,1-y_i(w.x_i-b)\right)+\lambda|\omega| \qquad (1)$$

Support Vector Machine divides the samples of the dataset with the help of a hyperplane. (See in fig. 9).

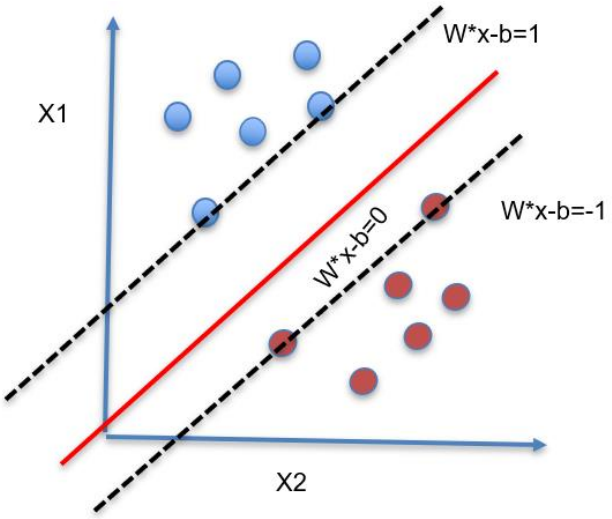

Fig. 9: Support Vector Machine(SVM)

Random Forest

Random Forest method is a type of supervised learning method used for classification of data [48]. A forest average prediction of *m* trees and individual weight function w_j *have* the following formula (See in Equation 2):

$$y=\frac{i}{m}\sum_{j=1}^{m}\sum_{i-1}^{n}W_j\,(x_i,x')y_i$$

$$=\sum_{i=1}^{n}(\sum_{j=1}^{m}W_j(x_i,x'))y_i \qquad (2)$$

In Random Forest Algorithm, the dataset is divided into several individual trees and forms a class with similar functionalities. Then from the different classes, the final class is selected by voting the majority (See picture in fig. 10).

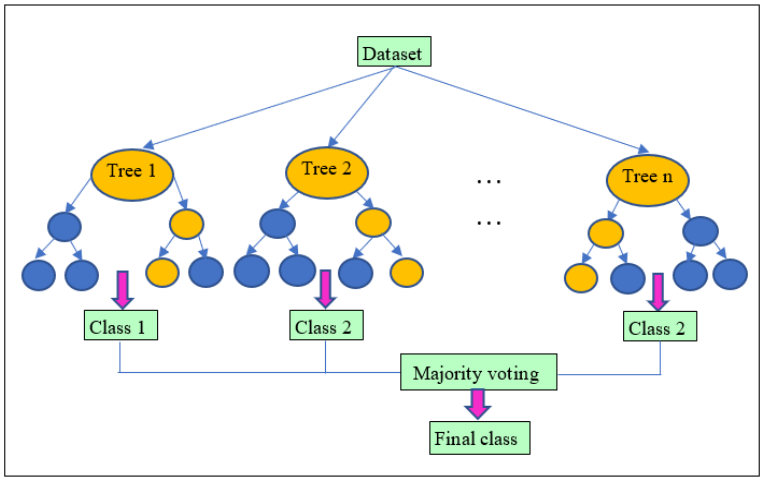

Fig. 10: Support Vector Machine(SVM)

The main advantage of any decision tree-based algorithm like Random Forest is the clear and understandable prediction rules that may be generated from training dataset.
The variance or mean square error of a regression process may be expressed as (See in Equation 3):

$$\frac{1}{N}\sum_{i=1}^{N}(y_i - \mu)^2 \qquad (3)$$

Here, y is an instance, N = Total number of instances and μ is the mean value.

Logistics Regression

It is a linear regression model which may be of different type like ordinal logistic regression, multinomial logistic regression or binary logistics regression. Here, data can be classified by setting a decision boundary [49]. It is very often used to predict a binary outcome.

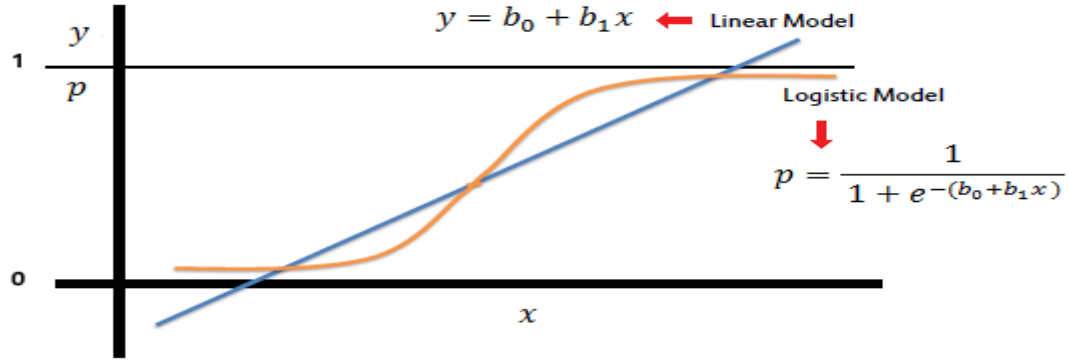

Fig. 11: Logistics Regression

The equation for logistics regression is (See Equation 4):

$$p = \frac{e^{a+bx}}{1 + e^{a+bx}} \qquad (4)$$

Here, p=probability of a, e =base of natural logarithm

a and b are the parameters or arguments of the model. A loss function is also to be measured with the following equation (See Equation 5):

$$b = (x'x)^{-1}.xy \qquad (5)$$

With many of the logistics curve where mathematical solution is not easy to find out, the loss function may be treated as maximum likelihood. In Logistics Regression model the dependent variable is logit and we find

$$logit(p) = \ln\left(\frac{p}{1-p}\right) = a + bx \qquad (6)$$

From the above equation it is clear that the logit is linearly related to x, hence the relation between x and p is nonlinear.

Hidden Markov Model:

It is a statistical Markov Process model where it follows Markov's rule. It is reinforcement learning. In Markov model a sequence can be drawn from null distribution and it is a significant process for prediction of depression from the text value [41].

Naive Bayes Theorem:

The following is the equation for Naïve Bayes, where P(c|x) is subsequent or posterior probability, P(x|c) is likelihood, P(x) is predictor probability and P(c) is class probability. The following is the equation for Naïve Bayes (See Equation 7).

$$P(c|x) = \frac{P(x|c).P(c)}{P(x)} \qquad (7)$$

It is a supervised classifier algorithm very popularly used in machine learning. It is a probabilistic classifier model. It is a highly scalable algorithm and very popular method for text categorization [13]. Some researchers have followed this model as it can generate better efficiency in comparatively less training data.
The above equation for Naïve Bayes, where P(c|x) is Subsequent probability, P(x|c) is likelihood, P(x) is interpreter probability and P(c) is class probability. See the following equation for calculating.

In following section, a summary has been represented showing recent works using the above-mentioned algorithms (See Table 2).

Table 2: Recent Survey among several machine learning algorithms for depression detection [recent works]

Algorithm Used	References	Sample Size	Performance
Support Vector Machine	i) Aldarwish and et. al[29] ii) Islam and et. al[18] iii)Sadeque, Xu and Bethard [30] iv)Tadesse, Lin and Yang [50]	i) 2073 depressed post ii)7145 Facebook comment iii) 2000 post per user and from 892 Reddit users iv)1293 depressive and 548 non depressive Reddit Post	i) Accuracy-63%, Precision 100% ii)Accuracy:50-60% iii) 77.1 precision iv)80% accuracy
Random Forest	i)Kosinski and Behrend [7] ii) Cheda and et. al. [41]	i)150 Reddit Users ii) 500,000 Reddit posts from 887 different subjects	i) precision 0.86(Using BOW) ii) Dual model has 10% better performance than singleton model
Logistics Regression	Wang and et. al. [20]	122 depressed users	High accuracy
Naive Bayes	Shen and et. al. [17]	Twitter data analysis of 1402 depressed	85% with F1-measure

		users, 292,564 tweets	
Artificial Neural Network	Tadesse M. M., Lin H,Xu B. and Yang L[16]	Twitter data analysis,476 sample dataset	91.7% Accuracy 92.6% F1 measure
Deep Learning Models	i)Jia Jia[36] ii) Chatout A. Chatterjee J. M. and Rouniyar R. S [39]	Twitter Analysis,1160 sample size(580-Depressed), Twitter Data Analysis	i)95% Accuracy ii) High Accuracy

IV. DATA ACQUISITION

To perform the study, around 70 papers have been selected at the initial phase of study covering year 2013 to 2020. Among them around 12 papers have been rejected upon further screening, for not directly involving with the relevant area. After eliminating papers indicating clinical diagnosis or other factors, the final study have been performed with approximately 50 journals or white papers which are related with depression or stress analysis from social media platforms [8], [48], [50], [51], [52], [53], [54], [55].
Selected papers have been categorized according to different machine learning algorithm applied and the work summary has been represented in tabular format. Most of the dataset have been collected from Twitter [16], [17], [19], [21], [22], [29], [36], [38], [40], [56], [57], Facebook [9], [11], [18], [22], or Reddit [17], [23], [50], and some other from unpopular micro blogs similar to Facebook or Twitter [20], [58], [59]. The users range from 122 to 1293.

V. CONCLUSION AND FUTURE SCOPE

This work deliberates about several ML models used to detect or predict depression symbols within an individual, which can be diagnosed through different posts, activities or online forum membership. Popular social media platforms like Facebook, Twitter, Reddit or Instagram are being used mostly for data collection. Most of the existing works emphasizes on conventional machine learning algorithm such as Support Vector machine, Random Forest, Logistics Regression or Naive Bayes. Some of the researchers have used neural network also. The study shows that researchers nowadays are keen to use new machine learning techniques such as deep learning algorithms or topic modelling to diagnose a depressive person from his social media activities. The further study will be focused on proposing a deep learning-based model for diagnosing a depressive person from his social media activities beforehand.

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