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Application of NLP and Machine Learning for Mental Health Improvement

Trinayan Borah, S. Ganesh Kumar

Abstract: ***Humans' most powerful tool is their mental wellness. Individuals' well-being can be impacted by poor mental health. This paper focuses on a smart technical solution to the problem of mental health issues detection related to the stress, sadness, depression, anxiety etc. which if not handled efficiently may further lead to a severe problem. The paper deals with the designing of an automated smart system using social media posts, that will help mental health experts to successfully identify and understand about the mental health condition of social media users. That can be done based on text analysis of rich social media resources such as Reddit, Twitter posts. The implementation of the system is done using Natural Language Processing (NLP) methods, machine learning and deep learning algorithms. The models are trained using a prepared dataset of social media postings. With this automated system the mental health experts can able to detect the stress or some other emotions of social media uses in a very earlier as well as faster way. The proposed system can predict five emotional categories: 'Happy', 'Angry', 'Surprise', 'Sad', 'Fear' based on machine learning (Logistic Regression, Random Forest, SVM), deep learning Long Short-Term Memory (LSTM) and BERT transfer learning algorithms. All the applied algorithms are evaluated using confusion matrix, the highest accuracy and f1 score achieved is more than 90%, which is better than the existing human emotion detection systems.***

Keywords: ***Natural Language Processing (NLP), Text-Analysis, Machine Learning, Deep Learning, Transfer Learning, Text2emotion, Social Media Posts, LSTM, BERT***

I. INTRODUCTION

Mental Health is a primary matter of concern. Analysis of social media content can lead to a better understanding of mental health concerns such as depression, stress, fear, sadness, and so on, which also can give solutions for early identification of it. Stress, anxiety and depression are all issues that are growing day by day and have an impact on people's physical and mental health. A troubled individual is incapable of doing anything well. Stress may be beneficial or harmful at times. Beneficial stress motivates you to work by keeping you engaged, busy, and motivated. On the other hand, destructive stress, makes you dull, weak, afraid, and unhappy [1]. If we do not know exactly when a person is feeling these kinds of mental issues, we will not be able to give the proper treatment or the essential medicines for him/her. When humans fail to well-being themselves in a high-risk situation, mental health concerns arise. Usually stress occurs when people attempt to act against their emotions or mental state[4]. The traditional approaches that we used for mental health detection are not that much smart enough which can understand the people's behaviour and convey the same to us. They only able to understand based on direct interaction with the people. Identifying these feelings and building an emotionally attentive strategy enables for a strong and long-lasting interaction with users as well as knowledge of their emotional desires[5]. Since, traditional approaches are time consuming and not highly accurate, it is critical that individuals are aware of stressful events so that they can take the appropriate activities to cope with them. However, with the upcoming advanced generation, with advent of social media and digital technology everything is getting smarter day by day. Considering the above, there is a need for an automatic system that can identify stress, depression, anxiety in a timely way and notify the individual so that the problem may be properly treated and make people life better. The Application of NLP and machine learning for mental health improvement. The objectives of this paper are as follows:

[1]. To collect and understand social media user's behaviour of different social media platform.
[2]. To identify mental health issues in people using machine learning and deep learning techniques.
[3]. To automate the detection of mental health problems such as sadness, fear-ness, stress, depression based on social media posts.

II. LITERATURE SURVEY

Face-to-face interviews, self-report questionnaires, or wearable sensors are the mainstays of the traditional psychological mental emotion or stress detection procedure. However, traditional approaches are reactive, which means they are time-taking, and hysterical. People's lives are changing as a result of the advent of social media, in the field of heath care and wellness. With the growth of social networks such as Reddit and Twitter, an increasing number of individuals are interested in sharing their everyday happenings and emotions as well as engage with friends through social media. The author of article [1], Reshma Radheshamjee Baheti, developed a method to detect stress and enjoyment using tweeter datasets. The technique of gathering necessary sentiment-related textual information is known as sentiment analysis.

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They used the Tensi Strength framework for sentiment strength identification on online communities to extract sentiment strength from informal English language. 67% of Precision and Recall is achieved using SVM with Ngram. Elsbeth Turcan [2] presents basic supervised learning approaches for recognising stress, both neural and conventional, as well as an analysis of the data's complexity and diversity, and the features of each category. The paper [3] author Deepti Patil is analyzing human speech to detect emotion based on it. Stress is the most significant factor that affects the mental health of a person and urges him to end his life. They focused on the variations of human voice which changes with respect to emotional states. To classify the emotions, machine learning algorithms such as the K-Nearest Neighbor (KNN) and Support Vector Machine classifiers were used. The author Disha Sharma of the research paper [4] tries to lower the risk of stress for understudies students by examine the effectiveness of machine learning algorithms. The data set was collected from university with the help of pss scale and it made up of more than 200 student's data. Naive Bayes, Linear Regression, Multi-layer perceptron, J48 and random forest ML algorithms are applied and also, they calculate their accuracy using a performance parameter.

Mounika Karna [5] explores the efficacy of a deep learning-based Long Short-Term Memory mechanism for textual emotion recognition. The research was undertaken out using the 'Emotion categorization' dataset which had six emotional groupings. The experimental findings demonstrated that LSTM-based text emotion categorization performs well as compared to existing learning approaches in terms of accuracy. The paper [6] the author Umar Rashid explains the Aimens system for detecting emotions in textual discussions. This system uses a deep learning-based Long Short-Term Memory (LSTM) model to recognize emotions such as joyful, sad, and furious in a contextual discussion. The system's primary input is a mix of word2vec and doc2vec embeddings. The results show that f-scores have changed significantly above the model baseline, which has an Aimens system score of 0.7185. According to the paper [7], Dr. S. Vaikole's goal is to distinguish between stressful and non-stressed responses to stimuli (e.g., questions given), with high stress indicating deceit. The suggested approach extracts Melfilter bank coefficients from pre-processed voice input using CNN (Convolutional Neural Network) and dense fully - connected networks, and then predicts stress output using binary decision criteria. Zhentao Xu [8] collected posts from Flickr and used a multimodal strategy that included assessing verbal, visual, and metadata indicators and their relationship to mental health. Their findings show that utilizing many modalities can increase categorization task performance when compared to using only one modality at a time and can give significant indications regarding a user's mental state. Prerna Garg [9] suggested multiple Machine Learning models for detecting stress in individuals using WESAD, a publically accessible multimodal dataset. The dataset is prepared based on various sensors data for predicting three different physiological conditions such as neutral, stress, and amusement. Using machine learning algorithms such as Linear Discriminant Analysis, Random Forest, and Support Vector Machine the F1-score and accuracy were calculated and compared for happy versus normal versus stress three-class and stress vs. non-stress as binary classifications.

Varun Sundaram [10] demonstrates a novel way to finding the emotion on text data based on TFIDF, and this TFIDF basically used to find the important words in word a document. They categorized the emotions into six kinds by applying this strategy. Emotion is retrieved from various utterances, and data is represented using semantic structure. Each sentence is generalized into six basic predetermined emotion groupings. The test demonstrates that this approach is capable of categorizing a text into several emotion groups while maintaining a decent accuracy rate. Zhentao Xu [12] collected posts from Flickr and used a multimodal strategy that included assessing verbal, visual, and metadata indicators and their relationship to mental health. Their findings show that utilizing many modalities can increase categorization task performance when compared to using only one modality at a time and can give significant indications regarding a user's mental state. The research [13] describes a series of classification studies for detecting sadness in social media messages. Their experiment yielded significant findings for detecting depression in social media texts. In this study they only reported results from linear classifiers, using bag-of-n-gram features for simple characters and word. These models perform better than other as they are simple, fast, language independent which are experimented with different number of deep learning architectures. U. Reddy and colleagues [14] Stress is a common problem for those who work in the IT professional field. Individuals working in such industry encounter issues such as changes in their way of personal and professional societies, which have exaggerated the risk of stress. According to their article, they used the OSMI Survey dataset 2017 from the IT industry. Numerous machine learning algorithms were used as well as various types of variables such as sexual orientation, age, family lineage, e-produce medical benefits, and so on. According to the survey, 75% of persons working in IT organisations were moderately at risk of causing pressure.

III. PROPOSED PLAN

A. Dataset Description

There are several datasets available in internet related to the social media posts which can be used for text analysis. In this paper we are taking three different social media platform posts dataset and combine them into one single dataset. ***Text2emotion*** library is used for preparing the output labels for each of the collected text/sentence. Our prepared dataset is having nearly 30K unique social media post of Reddit, Twitter with five different classes: 'Happy', 'Angry', 'Surprise', 'Sad', 'Fear'. The dataset is lengthy multi-class social media data for identifying various emotions of social media users from different categories of Reddit and twitter communities. As we have mentioned our dataset is the combination of three different social media sources. All the datasets are having different number of instances. The dataset-I is having 2414 rows. The dataset-II is having 24440 instances and dataset-III is having 3553 social media posts.

IV. METHODOLOGY

With tremendous improvement in technology, everything is becoming automated, which make people's life faster and easier. With new technologies the systems are getting trained with huge amount of data and they are getting used in our daily life for automatic decision taking applications. The technologies implemented using machine learning and deep learning can play a vital role in the field of healthcare. Which can save people's life as well as help health experts to do faster operations to reduce illness and make our lifestyle healthier in the modern world. The proposed system is basically about multi-class text analysis problem to classify texts into five emotional categories: 'Happy', 'Angry', 'Surprise', 'Sad', 'Fear'. Based on the predicted output of the emotional category the mental health experts can analyze the mental health condition of a person. All the stages of the system implementation are explained below in details.

Stage-I: Dataset collection and Pre-processing

For training the implemented models the text dataset is collected from three different social media platforms. Text2Emotion library is used for preparing output labels of the dataset. The prepared dataset is having total 30k unique instances and contains two attributes **Text** and **Catg**. Fig.1 shows the bar plot of all the five labels counts present in our prepared dataset. Once the dataset collection is done various pre-processing techniques such as tokenization of the sentences, removal of special symbols and removal of stop-words are applied to the social media posts data. All these pre-processing of the text basically helps to clear improve the performance of the applied algorithms.

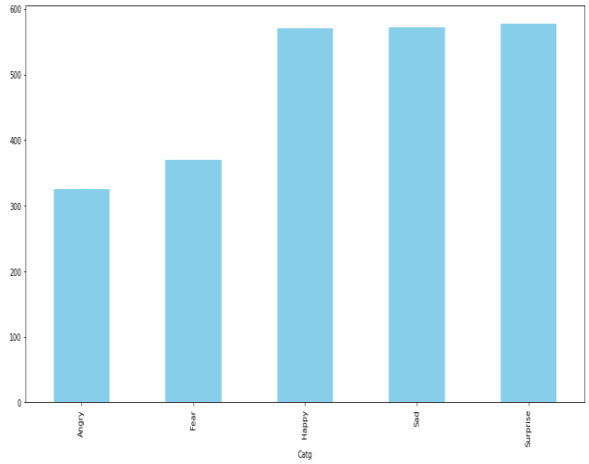


Fig 1. Bar-plot for the output labels count

Remove Non-alphabetic character: Only the letters 'A-Z,' 'a-z,' and a specific symbol can be read by a computer's vision. The numbers '0-9' and symbols that do not have an alphanumeric meaning are eliminated in this phase. This step removes all unreadable format character[1].

Remove Special Symbol: Various inappropriate special symbols appear often in social media posts, causing the algorithmic rule to fail. Symbols such as "!,@,#,$, %,&" are eliminated during this step. Even if the particular symbol provides a lot of information in a matter of seconds, this works very hard to analyse using this developed system.

Remove Stop Words: In English language there are some words called as stopwords which have less importance as compared to other words, but it comes along with sentences. In this step we are removing those stop words based on NLTK library. For example is, if, of, etc. are some stop words.

Stage-II: Output label preparation

The output labels for the dataset are prepared based on the text2emotion library. The Text2emotion is a python package was created with the primary goal of identifying acceptable emotions hidden in text data. It basically returns five human emotions with some confidence values and here we are considering the emotion which is having highest confidence for our label class. Once the output labels are assigned for all the different social media posts, all of them are merged into one single dataset.

Stage-III: Text to Vector conversion

To train the machine learning and deep learning models with text dataset we cannot give the text data as an input to the model directly. Some conversion from the text to vectorize form needs to be done. So, Bag of Words (BoW), TF-IDF and Word2Vec are applied on the data for conversion of the text into vectorized format to give them as input for training of the models.

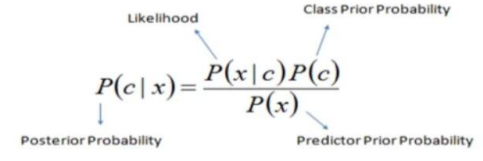
Stage-IV: Application of algorithms

Once the dataset corpus is converted into the vectorized form we have used the corpus for training of the machine learning models (such as Logistic Regression, Naïve Bayes, Random forest, SVM), deep learning Long Short-Term Memory (LSTM) model, transfer learning using BERT and the combination of both LSTM & BERT. All the mentioned models are trained with WSD (Word Sense Disambiguation) and without WSD techniques for predicting the mental health condition of a social media user.

Logistic Regression. This is a form of machine learning approach. This algorithm is a popular statistics model. Regression analysis is a statistical learning methodology in supervised machine learning that is specifically related to the objective of 'classification.'

$$\phi(z) = \frac{1}{1+e^{-z}}$$

Naïve Bayes. Naive Baye's classifier is a statistical classifier formula. It is founded on Baye's Theorem. Considering its simple architecture and naïve conception, it may be used to exceedingly complicated issues. This classifier is predicated on the premise that each attribute is not dependent of the others.



$$P(c|X) = P(x_1|c) \times P(x_2|c) \times \cdots \times P(x_n|c) \times P(c)$$

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Support Vector Machine. Both regression and classification can be done with SVM. It is a supervised ML algorithm. We cause SVM for any categorical issues without any interpretations. The SVM algorithm basically works identifying a hyper - plane in an N-dimensional environment that properly distinguish the data points.

Long-Short Term Memory. LSTMs, or long short-term memory networks, are a kind of Deep Learning network. It is a multilayer perceptron (RNN) that can able to train themselves with the dependencies of some long-term memory and is beneficial for timeline prediction problems.

Bidirectional Encoder Representations from Transformers. BERT is an open access artificial intelligence platform for language processing (NLP). By building context with surrounding text, BERT is meant to aid computers in comprehending the meaning of emotional language in text. The purpose of Google BERT is very simple. BERT basically use to produce two distinct vectors for the list of terms when it is used in two distinct contexts. The name itself says that it use to process the text in both the directions so that it can perform more accuratly.

Stage VI: Final Output

This is the architecture's ending stage. It closes by predicting the outcome of the social media post as 'Happy,' 'Angry,' 'Surprise,' 'Sad,' and 'Fear.'.

True Positive Rate (TPR). It counts the number of items that are accurately identified as true, i.e. correspond to a class.

False Positive Rate (FPR). It counts the number of items that are mistakenly classed as true, i.e. pertaining to a class.

Precision. It processes the percentage of records that the classifier categorized as helpful are actually positive.

$$\text{Precision} = TP/\ TP+FP$$

Recall. In general, we may utilise recall to estimate how many positive tuples the classifier labelled as positive. Simply put, there is an inverse connection among precision and recall.

$$\text{Recall} = TP/TP+FN$$

F–Score. It is computed by determining the natural logarithm of accuracy and recall.

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F1-score = 2 x Precision x Recall / Precision + Recall
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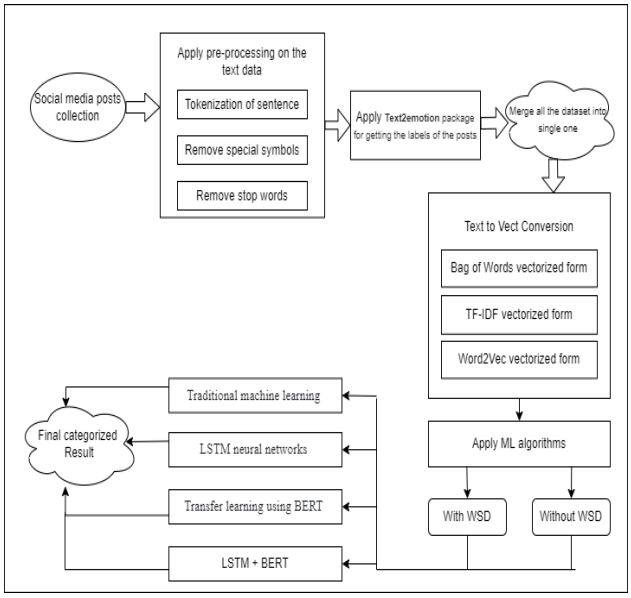
Word2Vec. Word2vec is essentially a neural network structure that can be trained on a supervised classification problem to create word embedding. Mikolov et al.,2013 has present it for the first time, and it has been shown to be highly successful in creating word embedding that can be used to quantify grammatical and semantic similarities between words.

WSD (Word Sense Disambiguation). WSD is a technique for addressing ambiguity caused by word meanings in different circumstances. Word sense disambiguation (WSD) is the major challenge in NLP of determining which intended meaning of a word is influenced by its use in a certain scenario.

TensorFlow Text Classifier. TensorFlow is created by Google Brain for deep learning framework. To train the deep learning classifier, we are using the TensorFlow for text classification. A text classifier is trained so that it can detect social media posts and then classify the post into different classes or categories.

A. Flow Chart/Block Diagram



The dataset is collected from three different social media platforms. Pre-processing techniques are applied on the collected social media posts for tokenization, removal of special symbols and stop-words based on nltk library. The output labels for the dataset are prepared using text2emotion library. The labels are assigned for all the pre-processed sentence and merged all the sentences into a single dataframe. Once the final dataset is prepared various vectorization techniques such as Bag of Words (BoW), TF-IDF and Word2Vec are applied for conversion of the text data into vectorized format. Different machine learning (Logistic Regression, Naïve Bayes, Random forest, SVM), LSTM neural networks and transfer learning using BERT are applied on the vectorized dataset with WSD (Word Sense Disambiguation) and without WSD techniques for predicting the mental health condition of a social media user. For the implementation of LSTM neural network we are using tensorflow for training of the model. As mentioned earlier same pre-processing steps are followed to clear the dataset from special symbol, characters and stopwords. For the conversion of the text instances to vector form we have used Word2Vect technique. Word2vec is essentially a neural network structure that can be trained on a supervised classification problem to create word embedding. Mikolov et al.,2013 has present it for the first time, and it has been shown to be highly successful in creating word embedding that can be used to quantify grammatical and semantic similarities between words. Same steps are followed for BERT and combination of LSTM and BERT implementation.

V. CONCLUSION

The final output of the proposed system will be detecting the mental health condition of a person based on five categories of human emotions: 'Happy', 'Angry', 'Surprise', 'Sad', 'Fear'.

The trained machine learning and deep learning algorithms try to predict whether a person is having any mental health issues such as stress, fear-ness, depression, sadness, etc based on social media post analysis.

VI. RESULTS AND DISCUSSION

For the proposed system, multiple classifiers were implemented for detecting stress and other mental emotions, on the given set of inputs. As a result of the proposed system we are predicting five emotion categories which are 'Happy', 'Angry', 'Surprise', 'Sad', 'Fear'. Based on the automatic prediction of the categories mental health experts can able to identify whether a person mental condition is Stress or Relaxed. The performance of different classifiers are shown in Table 1.

Table- I: Summary of Mental Health Detection Algorithm Results

Algorithm	F1-Score	Accuracy	Error rate
Logistic Regression	81.74	81.74	0.19
Support Vector Machine	86.44	86.44	0.14
Random Forest classifier	72.89	72.89	0.27
LSTM	78.63	78.63	0.21
BERT	90.68	90.68	0.10
LSTM+BERT	93.28	93.28	0.07

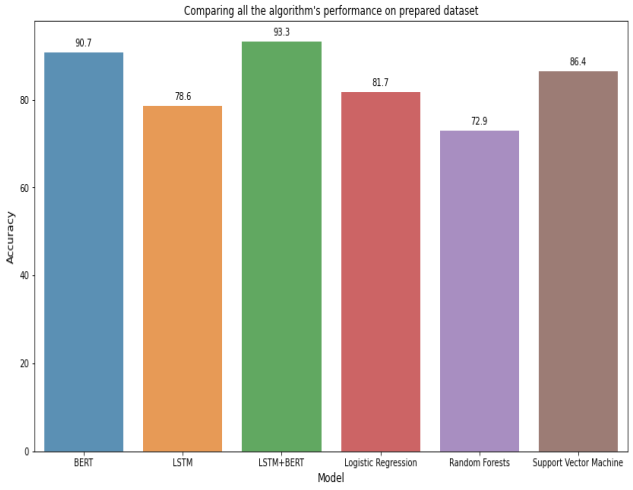


Fig 2. Bar-plot for the implemented models with accuracy value

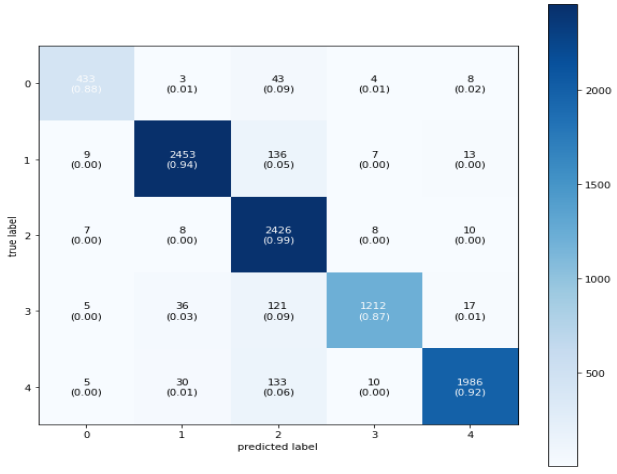


Fig 3. Confusion metrix using LSTM + BERT

The figure 2, shows the comparative analysis of accuracy value for all the algorithms. With accuracy and F1-scores of 93.28, the LSTM and BERT combination outscored the all other five methods. The Random Forest classifier and BERT also showed equivalent results to the LSTM + BERT combination classifier. In Figure 3, we plotted the confusion matrix of all the five emotional classes for LSTM + BERT.

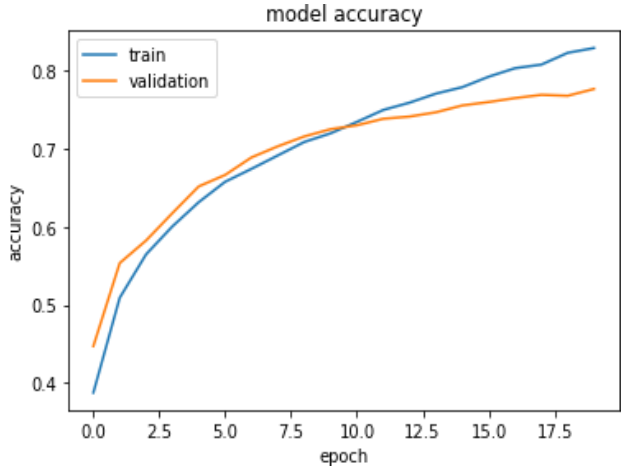


Fig 4. Training Validation with respect to accuracy

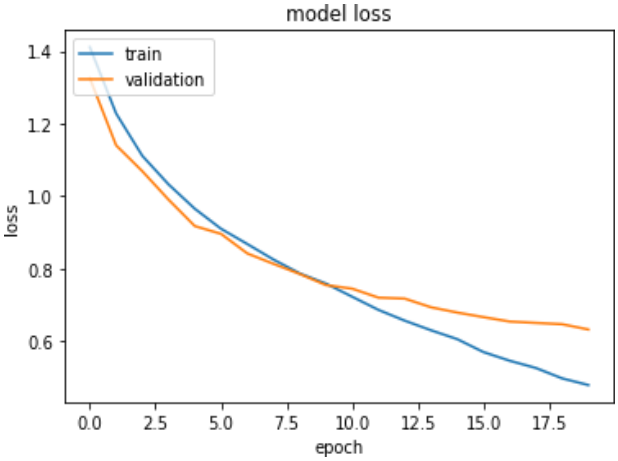


Fig 5. Training Validation with respect to Loss

The fig 4 shows the graph for the training and validation graph for the LSTM model accuracy. As we can observe from the graph the model is not overfitted.

The validation dataset is near to the training data of the model which means that the model is fitted properly. The fig 5 shows the graph for the training and validation graph for the LSTM model loss.

This graph also indicate that the model is getting fitted properly. As we see the validation dataset is near to the training data of the model so the model is not overfitted.

The goal of the proposed system is to mitigate the problem of mental health issues related to fear-ness, sadness and stress and provide a smart solution for early identification of it. It will allow mental health experts to identify problems related to depression, sadness, stress in a preliminary stage so that it won't go to a severe problem.

The proposed system will result in an automated detection of mental health problems (such as sadness, fear-ness, stress, depression) based on social media posts using Natural Language Processing (NLP) with machine learning and deep learning methodologies. The system also learns the pattern how the internet users post and share their thoughts in social media platforms.

VII. CONCLUSION AND FUTURE SCOPE

Stress, sadness, and fear-ness have all become major issues in today's society. The primary goal of this paper is to identify these mental health issues in people using machine learning and deep learning classification techniques, with the final goal of enhancing people's quality of life. In this paper we have deployed several machine learning and deep learning classification models on a freely accessible dataset in order to achieve faster and accurate detection of human emotions. The traditional stress and emotion detection process is an extremely tedious, time consuming, and inaccurate process. Automatic analysis will allow mental health experts to perform faster and more accurate results for earlier identification of mental health condition. In near future, more accurate results can be achieved by applying more pre-processing on the text and with the combination of various optimization techniques to reduce information loss. A GUI can also be implemented to take user inputs and show them the predicted output on the UI.

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