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Classification of Amazon Reviews based on Sentiment Analysis using Machine Learning Techniques

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Abstract—*In the growing world, where all the services are conducted online, the validation of such services plays an important role. One such service is online shopping. There are many e-commerce websites, where the products are sold. The companies provide a platform to express the satisfaction of the product in terms of reviews and ratings. The work conducted in this paper is related to the sentimental analysis using this review data. We have conducted the experiments and analysis of various machine learning algorithms. In this paper, we will discuss performance of the naive Bayes, logistic regression, support vector machine, decision trees, k nearest neighbors' classifier algorithm and the respective behavior of the model. For this work, we have used the amazon review dataset. After the implementation of models, we have analyzed and differentiated the model in terms of their performance parameters such as accuracy, F-measure, recall, and precision. By comparing these algorithms, we can see which model gives better performance.*

Keywords—Sentiment Analysis, Machine learning, Hybrid Clustering, TF-IDF, naïve bayes, logistic regression, decision tree, k nearest neighbor, support vector machine.

I. INTRODUCTION

These days, an enormous number of reviews of the users are made on nearly everything that is available on the internet precisely the e-commerce websites, for example, H&M and Amazon and so forth. The reviews may contain an immense number of users experience, so basically a review is that platform wherein the user describes the product based on his or her own experience of having the product and here we can see a mixture of emotions such as sometimes the customer would be extremely happy with the product which shows in the review he passes on the website with some strong positive words and if the customer is in a state of mediocre wherein we can't see any positive emotions of the customer either in liking or disliking the product and customer would give out depressing or angry comments on the reviews if he isn't happy with the product. The main idea of the review is not only to express the satisfaction level of the product but also this will help the organization to make the product better and it will give an insight what customer is thinking. The another major ideology of review is it will help a new customer who is linked by the product, the person can look at the reviews which has been already given by another person and this will provide the new customer about the quality of the product, experience of the product and hence he can make a decision based on his requirements and previous reviews of other customer'ease of Use.

Sentiment Analysis (SA) targets deciding the sentiment of reviewers or customers. With the developing websites, for example, Amazon.com where individuals can state their sentiment on various items and rate them, online business is packed with surveys and appraisals. In a reputation system rating are used to calculate the trust score which is an important technique to measure the trustworthiness of the vendors. At present the e-commerce website for mobile phones, electronics and clothing are at hype. Which is also an added advantage for the traders out there to bring in as many commodities to trade online. The customers and vendors are thereby being benefitted by introducing an immense variety of products. Despite whether Purchasers are searching for shiny new innovations, very particular instruments or some other wanted items, they will discover an appropriate transaction partner on web which may have few drawbacks. As given by (Dellarocas, 2005) [1], the traditional person to person transactions will eventually fail to give a good knowledge about the product to the customer and they will never know if the vendor is trustworthy or not. That is what which is improvised by the e-commerce websites by giving a good detailed description that is given by millions of users so that the person who is interested in buying a product will go through them to know the experience of the customers about various number of products. The reputation system also works well by taking all the reviews and aggregating them and finally giving out the reputation scores as an output. Therefore, the reputation system brings in a reliability factor as well which will gain the trust of the customer and benefit the organization.

This research work focuses on various supervised machine learning algorithms and they are Bernoulli naïve Bayes, multinomial naïve Bayes, logistic regression, support vector machine, k nearest neighbors and decision trees, which are used as the classification algorithms working on amazon product reviews. In this research we have also made use of a clustering technique called hybrid clustering and once clustering is done it will be further utilized to generate several word clouds for different purpose, such as low scored words, high scored words and also average scored words. We also focus on the comparative analysis of how each algorithm works based on performance of each of the model which works on the dataset which is the amazon reviews. The directed tests through the classification algorithms have given out the performance measure of recall, precision, f-measure and accuracy, based on which the comparison can be made. In this paper we have made use of the confusion matrix for the purpose of performance evaluation and confusion matrix

is that platform which allows a better visualization of how well a classifier algorithm perform on a certain dataset and in this research we have adopted the confusion matrix for all the six models and also have the performance measure on each of them which will in turn help us to evaluate on how each algorithm works. Here we are also implementing an AUC ROC curve which is an area under the curve and receiver operating characteristics which shows all the algorithms performance based on the analysis on a single plot. Basically, the roc curve here is used to show the comparison in performance evaluation.

II. Related work

Sentiment analysis is a process which requires the extraction of sentiments from the review given by a customer or a tweet from a twitter user or it can also be any other context. The sentiment words can actually be obtained by various parameters such as uni-grams [2], n-grams [3], pos tagging, tf-idf and adverbs [4] and so on. The classification that has to be applied on these texts are generally done by the machine learning algorithms and some of them are naïve Bayes, logistic regression and support vector machine or it can even be an unsupervised algorithm which can be adopted in order to grab higher accuracy in the classification. The process of summarizing for the basis of analysis of the free text may not always be a simple thing as sometimes it is generated based on the feature sentiment pair the summary is evaluated. Discovering the polarity orientation of the feature [5] and sentiment together and observing the general sense by computing the mined results. It is not always easy to associate the particular context to the extracted sentiment. In this regard, most of the statistical sentiment extraction algorithm doesn't work efficiently. As some of the problems they possess are, concluding that the subject of the document is already known, as it is combining the sentiment to a subject term that coexists in the same sense.

Analysis of sentiment involves finding review feelings b ased on favorable, negative and neutral connotations. Sentiment analysis can be carried out at different levels and they are phase level, sentence level and viz document level. In this sector, a number of previous studies has been perfor med where words and sentences have been categorized with a previous favorable or negative polarity. Although this previous classification is very useful in many occasions, but the sense derived from the negative and positive polarity are totally different when it actually comes to contextual polarity. The confusion was demolished when the contextual polarity came into the act.

This research has been directing on amazon product reviews which is available from a website which is openly available from http://jmcauley.ucsd.edu/data/amazon/ to construct the basis for sentiment analysis to be performed. The analytical research involved here is to mainly study how different machine learning algorithms perform for sentiment analysis of a text and also the comparison of those machine learning algorithms based on various performance measures in which the main thing is accuracy. One of the vital things for a model to function well or perform smoothly is accuracy.

As stated by Mayur [6], et al. in sentiment analysis of food reviews using logistic regression, sentiment analysis on a review text is most vital task because it is really very important to know how the user feels about something after experiencing it and it is practically not possible to go through each and every review and analyze if its good or not. To know how the user feels the product or food in turn will either help many customers sitting at home planning to buy those or it helps an organization that how well they can improve the service. Similarly, they are also doing the analysis by taking into count about the performance measures such as recall, precision, f measure and accuracy which calculated for every model and the different models used are naïve bayes, perceptron and logistic regression whereas in this work we are also considering KNN and Decision trees. In the part of performance evaluation, they are considering unigram, bigram and trigram for each of the classification algorithm and also, they're making use of k cross validation [6] whereas our research is solely based on the performance measure adopted by confusion matrix and roc curve.

III. Design

The block diagram in Fig.1 depicts the process involved in this classification study.

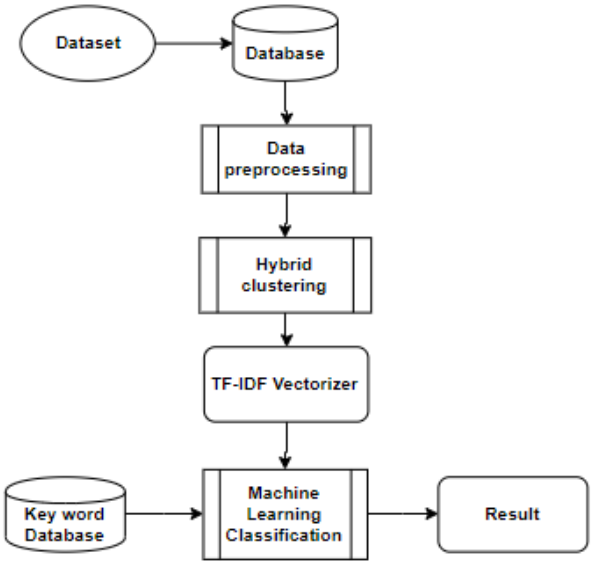

Fig.1: Block Diagram of Sentiment Analysis Classification.

3.1 Dataset:

As we all know Amazon is one of the best online shopping websites which is known for its excellence in delivering a right product and with wide variety of products. There are too many products available on amazon and also there are millions of reviews for those products. Basically analyzing the product reviews of any website is a challenging task and in this paper the amazon review dataset is used for the sentiment analysis and the data was available from the site http://jmcauley.ucsd.edu/data/amazon/ and with prior permission the data has been downloaded. The dataset

consisted about 9 column headers and had a structure as follows,

- reviewerID - ID of the reviewer, e.g. A2SUAM1J3GNN3B
- asin - ID of the product, e.g. 0000013714
- reviewerName - name of the reviewer
- helpful - helpfulness rating of the review, e.g. 2/3
- reviewText - text of the review
- overall - rating of the product
- summary - summary of the review
- unixReviewTime - time of the review (unix time)
- reviewTime - time of the review (raw)

In which we are mainly interested in the reviews and ratings columns. The dataset consists of 1243186 rows × 9 columns.

3.2 Database:

The data was in json file format, in python we have separate modules to read the json (JavaScript Object Notation) file data. Using json module to read inside the data. Then the reading data was arranging as a tabular form to separate rows and columns, after reading data we arrange it as the data frame, this data frame was rewritten as a (.CSV) file for separate reviews column and rating column using CSV module. Once the data is stored in the CSV file format named as (reviews.csv), All the data was imported to SQLITE for creating tables to separate all the columns for better understanding. Here the data will be stored in the amazonReviews.db file. From this file, we need to read all queries and product review summary to rearrange data. This data will be used to manipulate and extract features from key words of review summary analysis the review of the product, all the algorithms are used to perform on this database. The purpose of using a database is, as the data is huge it would be better to use a database so that the data can be extracted whenever needed in a faster manner and with high data protectivity.

3.3 Data Pre-Processing:

The review column and the summary column data from the overall dataset is subjected to data pre-processing initially. The work basically starts with text normalization. Text normalization includes the following:

1. converting all the letters to lower or upper case: converting the text to a standard form that is in this case converting all the letters in a text to lowercase for convenience.
2. converting numbers into words or removing numbers: Remove numbers if they are not relevant to your analyses. Usually, regular expressions are used to remove numbers.
3. removing punctuations, accent marks, and other diacritics: Remove punctuation this set of symbols [!”#$%&’()*+,-./:;<=>?@[\]^_`{|}~]
4. removing white spaces: To remove leading and ending spaces, the strip() function is used on white spaces.
5. Tokenization: Tokenization is the process of splitting the given text into smaller pieces called tokens. Words, numbers, punctuation marks, and others can be considered as tokens.
6. removing stop words: “Stop words” are the most common words in a language like “the”, “a”, “on”, “is”, “all”. These words do not carry important meaning and are usually removed from texts. It is possible to remove stop words using Natural Language Toolkit NLTK.

3.4 Hybrid Clustering:

After pre-processing, hybrid clustering technique can be used to produce cluster for high scored, low scored and average scored words, these words will be stored in a csv file called cluster.csv. The clustered data is used to generate word clouds for different criteria’s such as each for high scored words, low scored words and average words.

3.5 TF-IDF Vectorizer:

Term frequency is a weight representing how often a word occurs in a document, if we have several occurrences of a same word in a document then the tf-idf value increases. Inverse document frequency is a weight representing how common a word occurs across a set of all documents, if there are more occurrences of a same word across all documents then the tf-idf decreases.

By using TF-IDF one advantage is that we will be able to ignore the unimportant words like across many numbers of documents’ if the same word is appearing then it’s not important and tf-idf goes down representing that word as a stopwords or something. The TF-IDF vectorizer is very important mechanism involved in prior to fit and run the model.

3.6 Machine Learning Based Approach:

The different machine learning algorithms that are being used in this study are as follows:

3.6.1 Bernoulli Naïve Bayes:

The Naïve Bayes is probabilistic classifier method is usually preferred and said to give a good performance for relatively small dataset. So basically, naïve bayes is adopted for a small training data. This method is based on the mathematical bayes theorem, usually there are two types of naïve bayes classifiers used in predictive analysis and they are multinomial naïve bayes used for discrete or variants of text and Bernoulli naïve bayes for a word appears in the text

or not. multinomial naïve bayes method data follows a multinomial distribution and each feature value is count. In a nutshell, a multivariate Bernoulli naïve bayes is very useful only for feature vectors which are binary. The scope would be text classification with bag of words model where in a 0 represents the word doesn't occur and 1 represents the occurrence of the word.

3.6.2 Multinomial Naïve Bayes:

The naïve bayes classifier is one of the simplest machine learning algorithms which works on the basis of probabilistic statistics like bayes rule. The probability of a class is determined by the probability of each features, each one has their own distribution. In reality, the independence is not that consistent, and we may rarely find the independence. To avoid this, the multinomial naïve bayes is preferred when the data has discrete features. For an instance this can be related in the product reviews as if a product review has mixed number of emotions then there will be more than two features influencing the emotion of the review and in cases like these the multinomial naïve bayes works better than the Bernoulli naïve bayes and there has a better performance. But still we consider both the naïve bayes methodology to show how they both work individually, and which one is better based on the accuracy.

3.6.3 Logistic Regression:

Logistic regression is the machine learning algorithm also known as the logistic function which performs observations on discrete set of classes. Logistic regression actually belongs to the family of classifiers which is known as the exponential log-linear or exponential classifiers [6]. The classifier performs by mining some weighted features from input data, taking logs and combining them in linear form. The logistic regression classifiers tend to classify an observation into one or two classes and there is also multinomial logistic regression which is used while classifying more than two classes. The essential difference between a logistic regression and a naïve bayes classifier is that the logistic regression is a discriminative classifier and a naïve bayes classifier is a generative classifier.

3.6.4 Decision Tree:

The Decision tree algorithm is a non-parametric supervised machine learning technique used for the process of classification and regression. The decision trees understand from the data to roughly establish a sine curve with a set of rules. The more profound the tree, the decision trees would be even more complex, and the model would end up being fitter. The decision tree is basically used for both classification and regression, here it is used for the purpose of classification. The decision tree splits a data into further smaller subsets but actually in the meantime generally an associated tree would be additionally evolved. The tree usually ends with a leaf node once it's completely done and the leaf node is the one which represents the classification can also be seen as a result. The root node is the one from which the split initiated which also means that the root node might have the best attribute features. The good thing to use a decision tree is that it is easy to interpret and also, they don't require feature scaling. One of the drawbacks of the decision tree is that it is prune to overfitting.

3.6.5 K Nearest Neighbors:

The k nearest neighbors is one of the simplest and easiest machine learning algorithms which stores all the cases and classifies a random new case based on the distance function which is termed as similarity measures. Since 1970's that is the beginning of KNN, the KNN has been used for pattern recognition and statistical estimation. K nearest neighbor is non-parametric in nature and that is why it doesn't make any pre-assumptions on the data. The way a KNN algorithm work is pretty amusing when it performed in the training phase there is nothing happening initially. But as the test data is fed to the KNN model it becomes ready and starts finding the neighbors for the analysis. Here in a KNN model, the distance can be calculated by various techniques in which one of the main techniques is minkowski distance which is the generalization technique of Euclidean and Manhattan distance. These distance measures are generally used to compute dissimilarity of objects described by numeric attributes. The KNN algorithm is best suited and works well with a low dimensional data and is computationally expensive for a high dimensional data.

3.6.6 Support Vector Machine:

The support vector machine is a machine learning technique which uses each set of features classify a position within a hyperspace then the Support vector machine works well by dividing them with the help of a hyperplane, which helps to maximize the distance among this hyperplane and each vector, minimizing objective function. The space division is difficult to achieve and sometimes it is nearly impossible, due to this the support vector machine can adapt a margin that lets to misclassify some instances, but the overall performance gradually goes up.

IV. PERFORMANCE EVALUATION

4.1 Confusion Matrix:

In the field of statistical computation and machine learning classification, a confusion matrix is also known as a measure for error matrix. The confusion matrix is one which allows the visualization of the performance of the algorithm. It generally constructs a table which will define the performance of a classifier by the help of some test data whose true values are known. Here we have used confusion matrix to generate the analytical results on various performance measures such as accuracy, recall, precision and F measure which are important to make comparative performance analysis of various machine learning algorithms, as in this paper we will be showing the evaluation for six machine learning models such as Bernoulli naïve

bayes, multinomial naïve bayes, logistic regression, K nearest neighbors, decision tree and support vector machine. The confusion matrix is used for the purpose of evaluation of the output of the classifier on the dataset. The main property of a confusion matrix is that the diagonal element present shows the points for which the predicted label is a true label, whereas the off-diagonal elements shows the points which are mislabeled by classifier. In short, the greater number of correct predictions can be observed among the diagonal elements of the matrix. The different performance measures are explained below.

4.1.1 Accuracy:

The accuracy predicted shows how well it predicts for a positive label to the true positive label and same with negative. There are certain strange things about accuracy that It assumes equal weightage for both types of errors. A 99% accuracy can be excellent, good, mediocre, poor or terrible depending about the problem. Accuracy is given by the relation,

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}$$

4.1.2 Recall:

The Recall is derived as the ratio of total number of correctly classified positive examples divide to the total number of positive examples. The class is generally properly recognized if there is a high recall indication. Recall usually provides an ideology about when it is yes and how often does it predict yes. Recall is given by the relation,

$$\textit{Recall} = \frac{TP}{TP + FN}$$

4.1.3 Precision:

To find the value of precision we divide the total number of correctly classified positive examples by total number of predicted positive examples. An example is labelled as positive is indeed positive when there is a high indication of precision. Precision gives an idea about when it predicts yes and how often is it correct. Precision is given by the relation,

$$\textit{Precision} = \frac{TP}{TP + FP}$$

4.1.4 F-Measure:

As we will have the two measures (precision and recall) being calculated in prior it will help in order to have a measurement that represents both. For this we make use of the F-measure which makes use of the harmonic mean instead of arithmetic mean as it pushes the extreme values more. In general, the value of the F-measure is said to be closer to small value of either recall or precision.

$$\textit{F - measure} = \frac{2*Recall*Precision}{Recall + Precision}$$

The below table will show the analytical results and comparison of various machine learning algorithms based on confusion matrix performance measures. It basically shows what accuracy have been achieved by the 6 machine learning algorithms and it also shows other performance measures for the 6 models such as recall, precision and F-measure.

ALG	Accuracy	Recall		Precision		F-Measure	
		+ve	-ve	+ve	-ve	+ve	-ve
BNB	0.83	0.22	1.00	0.93	0.84	0.36	0.91
MNB	0.88	0.46	1.00	0.97	0.88	0.62	0.93
LR	0.93	0.79	0.97	0.86	0.95	0.82	0.96
DT	0.90	0.78	0.94	0.77	0.94	0.78	0.94
KNN	0.87	0.46	0.98	0.85	0.88	0.60	0.93
SVM	0.93	0.80	0.97	0.87	0.95	0.84	0.96

Table1: Performance Analysis of Machine Learning Algorithms.

From the table 1, {BNB stands for Bernoulli naïve bayes, MNB stands for Multinomial naïve bayes, LR stands for Logistic Regression, DT stands for Decision trees, KNN stands for K Nearest neighbors and SVM stands for support vector machine}

4.2 AUC ROC Curve:

When it comes to machine learning, the performance measurement becomes real important task. As here we are going to implement different classification algorithms for the analysis, an AUC-ROC (area under the curve – receiver operating curve) curve is one of the best mechanisms to perform classification tasks. To visualize the model or classification algorithms to check how they perform, AUC-ROC curve works well. It is sometimes also written as AUROC (area under the receiver operating characteristics). Basically, the ROC is also the probabilistic curve and AUC is used to represent the measure of separability. It also informs about how well a model is capable of distinguishing between classes. Generally, when AUC is high then the model is more accurate as high value in AUS assures that a model is successful in predicting 0's as 0's and 1's as 1's. It is also known that AUC-ROC is said to be one of the best ways to evaluate the performance when it comes to the classification algorithm. Here in this paper, we have made use of the AUC-ROC curve to evaluate the performance of various machine learning algorithms. We can also state the comparison among various classifier algorithms by visualizing the AUC-ROC curve as shown in fig.

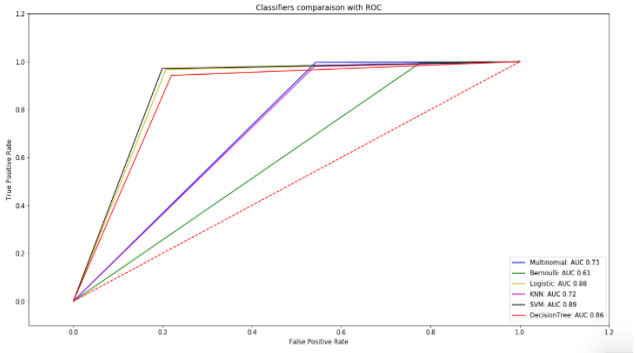

Fig.2: AUC- ROC curve.

The Roc curve is plotted by true positive rate v/s false positive rate, true positive rate on y-axis and false positive rate on x-axis. Where true positive rate is also known as recall or sensitivity and false positive rate is also known as 1-specificity. Through this plot we can speculate the performance of the model by looking at what is the value of AUC, if AUC nears 1 also means that the model performs perfectly and if AUC nears 0 means that the model performance has let down.

V. Conclusion

This analysis here considers six machine learning algorithms for sentiment analysis on product reviews and we are able to figure out the performance measure of each of them. In the six machine learning algorithms it can be seen that Bernoulli naïve bayes has achieved the least accuracy score of 83%. Logistic regression and Support Vector machine have achieved relatively the highest accuracy score of 93%. As it can be seen that the naïve bayes performs not so good as it is subjected to a huge dataset and algorithms like support vector machine and logistic regression performs very well with a huge dataset. The analysis solely based on how well the classification algorithms work when it comes to sentiment analysis of product reviews data.

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