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Research Article

An Exploration of Sentiment Analysis Techniques Enhancing Customer Purchasing Behavior Prediction of Smartphone using Machine Learning Classifiers for Improved Performance

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ABSTRACT

This research investigates the impact of machine learning classifiers on smart phone product reviews. Every action taken by a living being carries feelings because the world is made of sentiments and emotions. Opinion mining is another name for Sentiment Analysis, and it is a classification process whereby machine-learning techniques are applied to text-driven datasets to analyze the emotion or opinion expressed in a text. The sentiment analysis technique extremely helps many organizations to quantify customer fulfillment with specific products based on reviews of customers in a very faster way. In this study, a sentiment analysis model is proposed for categorizing product reviews into negative, neutral, and positive ones. But in the existing system, the neutral review is not considered which will result in an error in the customer's opinion. In the existing project, various algorithms like Decision Tree, Naive Bayes-NB, Support Vector Machine-SVM, Maximum Entropy and k-Nearest Neighbor-KNN are used to categorize the accuracy of the result. Among these Maximum Entropy and Naive Bayes performs well and produced better accuracy. The proposed research uses the Random Forest methodology for the training stage and the testing stage. A dataset of 50,000 reviews was used for this research concerning Smartphone products. While compared with other machine learning models Random Forest machine learning technique greatly improved the accuracy.

Keywords: Bag of words; Machine learning; Natural language processing; Opinion mining; Random forest; Sentiment analysis.

INTRODUCTION

In the modern world, Smartphone's are playing an essential role in human lives. It is very hard to find a person who does not own a Smartphone and it became one of our most wanted components during the last decade. At present, different mobile phone features are available to customers based on their choice and review. There are a lot of mobile brands in the sale placelike Apple, Samsung, etc. are names associated with brands that are well-known throughout the world. Every brand provides unique features to its products for business growth. There are thousands of companies that offer unique features to their customers. So, finding the right phone for an individual has become a big problem. When a customer wants to buy a product, he will review many similar products and then

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read the reviews that are given by previous customers and finalize which product is good to buy or not based on customer feedback for the product is vital for the company organization's expansion. By grouping reviews from the customer, they will improve the ability and quality of the product merchandise.

Opinion Mining is a Natural Language Processing tool by using this we can able to extract people's emotions from written texts. That includes opinion, attitude, and emotion. Sentiment analysis or opinion mining has recently become the most popular among researchers in social network analysis and text mining. Sentiment analysis is having a significant impact on research-based applications and sentiment analysis is expanding rapidly due to its benefits. Sentiment analysis is a very interesting topic and it is the process of the deriving sentiment of a specific sentence or statement. The reviews for the product are classified using a machine learning method called Random Forest. The RF Classifier is a frequently used methodology that falls below the class of supervised learning technique. It is applied to data classification and prediction. It uses the ensemble learning approach. And it is flexible, and simple to use technique that generates great results most of the time.

The Dataset used in this research work consists of mobile phone reviews of various brands. And the dataset consists of 50,000 reviews. We conducted three experiments on 10,000 reviews, 25,000 reviews and 50,000 reviews to see the performance of the classifier and to find the accuracy with different data sizes.

RELATED WORKS

Kozakijevic,S et al. (2024) [1] in their study improved consumer feedback sentiment classification via a novel approach combining BERT embeddings with an optimized XGBoost model, using a modified metaheuristic algorithm to achieve a peak accuracy of 88.13% on publicly available datasets.

Jambhulkar, P. J. (2024) [2] in his study compares machine learning techniques for sentiment classification, examining algorithms such as Decision Tree, SVM, Random Forest, CNN, Neural Network, LSTM, and BERT, highlighting their advantages and disadvantages through a tabular comparison and prior research analysis.

Bhuiyan, R. J., et al. (2024) [3] in their study applied NLP and machine learning models to analyze customer feedback in the banking sector, finding LSTM outperformed other models with 91% accuracy, and highlighting the potential of advanced techniques for sentiment classification and customer satisfaction insights.

Iyer, V. (2024) [4] in his study aims to identify the strengths and weaknesses of different models, conduct a comparative analysis based on accuracy, speed, and efficiency, and evaluate the impact of pre-processing techniques on sentiment analysis performance.

Bari, A., et. al. (2023) [5]in their study introduced novel preprocessing methods and a hybrid model to enhance sentiment analysis of product reviews, leading to improved accuracy and efficiency compared to traditional models.

Rao, C. V., &Bajnaid, W. (2023) [6] in their study employs machine learning algorithms to accurately predict customer sentiment from e-commerce reviews of women's clothing, addressing imbalanced data and negations, and achieving best results with XGB classifier and SMOTE sampling.

Chitra et al. (2022) [7] in their study on review of smart phone the accuracy of the result is classified using the Naive Bayes algorithm based on the reviews obtained from Amazon and the result obtained an accuracy value of 75%. To improve the accuracy of the SVM algorithm, more datasets are employed in the suggested study.

Salem, et al. (2020) [8]applied five classification algorithms to review tweets data about mobile phone products. The results revealed that all classifiers had varying levels of accuracy when it came to the mobile product domain. Like Decision Tree, Naive Bayes-NB, Support Vector Machine-SVM, Maximum Entropy, and K-Nearest Neighbor-KNN performed well in this context. Here, the tweets were marked as positive, negative, or neutral.

Rajeswari, et al. (2020) [9] proposed work would combine a lexical approach with machine-learning methodologies such as Logistic Regression, Decision Tree, SVMand NB for sentiment analysis. This study's objective is to decide which methods are more usefulin resolving customer opinions that fall outside the typical binary review categorization. Additionally, the work compares performance of each method using a test set.

Stephina Rodney, et al. (2019) [10] has used sentiment analysis on multiple reviews to understand the emotional response of customers. The Support Vector Machine classifier achieved 91% accuracy, while the Naive Bayes algorithm attained 66%.

Aljuhani, et al. (2019) [11] compares the efficacy of different feature extraction algorithms by performing stochastic gradient descent, logistic regression, convolution neural networks and naive Bayes.

Abdul lahil Kafi, et al. (2019) [12] compared six different algorithms to understand which one was most appropriate for classifying product ratings in a system. The algorithms used were Stochastic Gradient Descent (SGD), NB, Logistic Regression and SVM. Each algorithm was used multiple times to get an average polarity rating so that the customer could make informed decisions about certain products.

Previous studies have shown that two methods for Opinion Mining are used: lexicon-based and machine-learning. In the two approaches, various classifiers and methodologies were used for detecting and classifying the review's polaritywith acceptable accuracies. In our work, we applied Random Forest machine learning on mobile phone reviews and show the performance comparison with three different dataset sizes to detect how the dataset sizes influence the algorithm performance.

RESEARCH METHODOLOGY

The proposed sentiment analysis model consists of seven main steps: dataset preparation, attribute selection, preliminary processing of data, extracting the feature, dataset splitting, classifying the processed data into either positive, neutral, or negative evaluation. Fig. 1 demonstrates the workflow of the actual model.

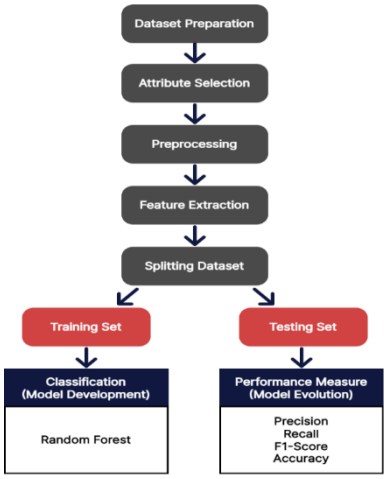

Fig. 1 Research architecture diagram

Dataset preparation: The procedure of collecting data for a study and the accurate measurement and evaluation of data is known as "data collection". The dataset used in this proposal comes from various customer reviews on different mobile phone products. The collected Dataset contains six features namely: unique id, phone name, reviews, rating, star rating, and recommendation. We removed some unnecessary features in the classification process, these features are unique id, phone name, star rating, and recommendation. After removing the feature, two features remain; reviews and ratings. The rating attribute is converted from numeric into three categories; Negative, Neutral, and Positive.

The following pattern is used to determine the category.

i. Positive, if the rating >3

ii. Neutral, if the rating = 3

iii. Negative, if the rating < 3

Preprocessing: The word "pre-processing" delivers that it's a procedure that is used to reconstruct the data that can be understood by a computer. It is an essential step in building an ML model. Pre-processing is an essential path in data mining, which helps increase the accuracy of classification. The reviews may contain some not related words. That affects the quality of the data for that purpose the raw data is pre-processed.

The pre-processing includes the following steps:

i. Remove all special characters: It is irrelevant characters; they are not relevant to analyses. Special characters are a collection of symbols [!”#$%&'()*+,-/:;<=>?@[\]^_`{|}~] will be removed.

ii. Remove the words having length >2: There is some kind of noise is there after completing all the required steps in text processing. So, the words which have a length of less than two will be removed.

iii. Remove the single character from the start: The review message which starts with the single character will be removed.

iv. Remove multiple spaces: It substitutes the multiple spaces in between words into a single space.

v. Return all capitalized letters to lower: All the words are converted into lowercase to avoid data duplication. Because “Mobile” and “mobile” will be considered separate words if this step is not done.

vi. Remove Stop Words: These are the words that are often used in English yet have no clear definition. It contains "a," "the," "is," etc. Because they can obscure a sentence's or document's meaning, stop words are frequently utilized in text mining and natural language processing (NLP). These select phrases sometimes referred to as "noise," can make over much tough for ML algorithms to accurately analyze data. In the implementation, we used a list of English stop words in Python’s NTLK Library.

Feature extraction based on TF-IDF vectorizer: The Term Frequency-Inverse Document Frequency is a tool that helps quantify words in documents. This technique is commonly used for information retrieval and text mining. The machine is unable to understand any data other than numerical values.

$$TF - IDF = Term\ Frequency \times Inverse\ Document\ Frequncy$$

Term frequency, sometimes known as TF, is a tool used to calculate the word frequency in the document. The final value of the normalized TF value will lie within the range [0, 1]. The 0 and 1 both represent possible outcomes.

$$TF = \frac{Frequency\ of\ a\ word\ in\ the\ document}{Total\ word\ in\ the\ documents}$$

The Inverse Document Frequency (IDF) defines is how rare or unique a word is.

$$IDF = Log\left(\frac{Total\ \ number\ of\ documents}{Number\ of\ documents\ containing\ the\ word}\right)$$

Splitting data: In this stage, we will divide the dataset into two separate groups: the training part and the testing part. In the stage of training, data will be used to build a model, while the 20% testing set will be used for the evaluation of performance. This research project uses 80% dataset for training part and 20%dataset for testing part.

Classification: After we have pre-processed and extracted the relevant features, we divide the dataset into a trainingpart and a testing part. Then input these sets into a classifier to make predictions.

RF Classifier: RF is a popularly used classifier algorithmthat falls belowthe class of supervised learning technique. This methodology is used to classifying and predicting data. It classifies different samples using a decision tree and takes the majority vote for classification. Each RF classifier contains several decision trees on different subsets of data. This process helps improve accuracy by averaging predictions from these individual decision trees.

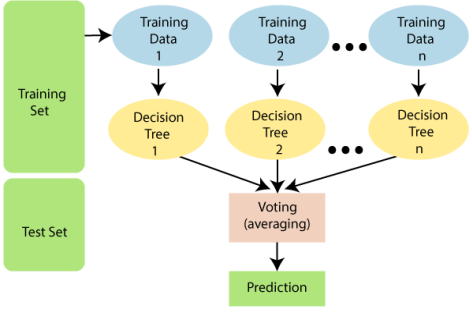

Fig. 2 Working of random forest

Evaluation: Random Forest methodology is accessed through train and test split validation. In order to assess our work, we use F1-value, Accuracy, Precision, and Recall. The confusion matrix serves as a visual representation of the algorithm's accuracy.

For Precision,

$$Precision = \frac{True\ Positive}{True\ Positive + False\ Positive} \times 100\%$$

For Recall,

$$Recall = \frac{True\ Positive}{True\ Positive + False\ Positive} \times 100\%$$

For F1 – measure,

$$F1 - measure = 2 \times \frac{Precision \times Recall}{Precision + Recall} \times 100\%$$

For Accuracy,

$$Accuracy = \frac{True\ Positive + True\ Negative}{True\ Positive + False\ Positive + True\ Negative + False\ Negative}$$

Accuracy is important for statistical measures like the Confusion Matrix, which looks at how many cases were examined.

EXPERIMENTAL RESULT AND DISCUSSION

Google co-laboratory is used for implementation. The dataset has gone through the pre-processing phase, Feature Extraction and then dividing dataset into a training part and a testing part. The feature contains three categories, each with corresponding review content. The Random Forest methodology is used to determine the outcome in terms of precision (value), recall (no. of correct responses) and F1-measure score (a measure of how well a machine can generalize from one example).

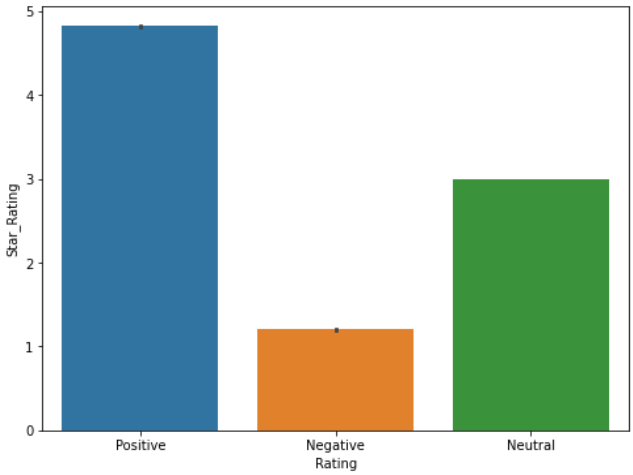

Fig. 3 Smartphone review dataset

The above fig. 3 reveals the No. of negative, neutral, and positive reviews of the product dataset.

First experiment: 10000 reviews

In this experiment, 10000 reviews from the dataset are selected for training and testing. The F1-value, Precision, and Recall results for the negative, neutral and positive reviews are in table 4.1.1. The outcome of this experiment is shown in the table 4.2.2. It determines the F1-value, accuracy, precision, and recall of the classifier.

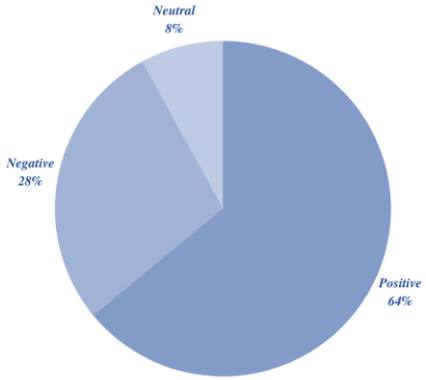

Fig. 4 Pie chart for first experiment

Table 1. Sentiment analysis score of experiment 1

Class	Precision	Recall	F1-Score
Negative	88%	88%	88%
Neutral	92%	40%	55%
Positive	91%	97%	94%

Table 2. Result of experiment 1

Classifier	Precision	Recall	F1-Score	Accuracy
Random Forest	90%	75%	79%	89.8%

Second experiment: 25000 reviews

The results of the random forest classifier were applied to 25,000 reviews from the data set. A training portion and a testing portion made up the 25000 reviews. Like the first experiment, the result of F1-value, Precision, and Recallfor negative, neutral and positive reviews are shown in table 4.2.1 and table 4.2.2 demonstrate the result of the F1-value, accuracy, precision, and recall of the classifier.

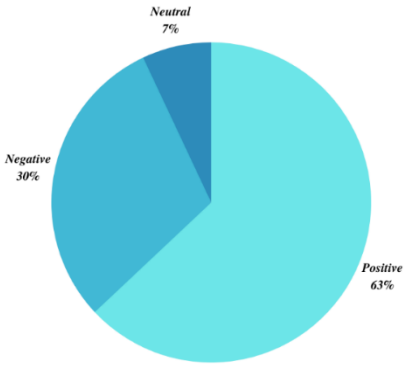

Fig. 5 Pie chart for second experiment

Table 3. Sentiment analysis score of experiment 2

Class	**Precision**	**Recall**	**F1-Score**
Negative	90%	92%	91%
Neutral	97%	56%	71%
Positive	94%	97%	95%

Table 4. Result of experiment 2

Classifier	Precision	Recall	F1-Score	Accuracy
Random Forest	92%	80%	87%	93.6%

4.3 Third experiment: 50000 reviews

In this experiment, the random forest classifier was applied to 50000 reviews that are selected from the data set. Training and testing portions of the 50,000 reviews were separated. Similar to first and second experiments the results of F1-value, Precision, and Recall for negative, neutral and positive reviews are shown in table 4.3.1. The results of F1-value, accuracy, precision, and recall of the classifier are shown in the table 4.3.2 and the result of the final experiment provides better performance and high accuracy.

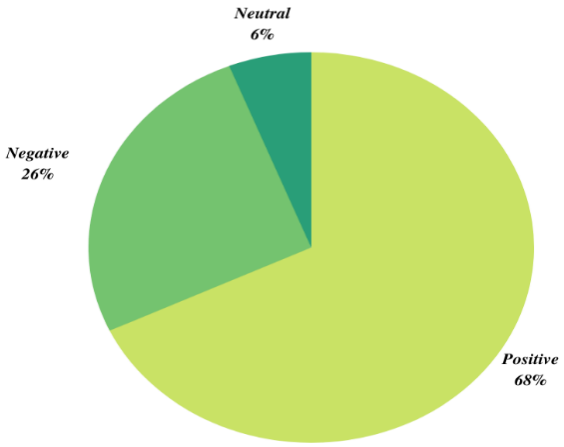

Fig. 6 Pie chart for third experiment

Table 5. Sentiment analysis score of experiment 3

Class	Precision	Recall	F1-Score
Negative	94%	94%	94%
Neutral	98%	72%	83%
Positive	96%	99%	98%

Table 6. Result of experiment 3

Classifier	Precision	Recall	F1-Score	Accuracy
Random Forest	96%	88%	92%	96%

Discussion

We analysed the results of the three previous experiments and noticed that Random Forest Classifier performs well. While comparing the various techniques like K-Nearest Neighbor-KNN, Decision Tree, Support Vector Machine-SVM, Maximum Entropy, and Naive Bayes-NB algorithm performs well and provides better accuracy. In the first experiment, 10000 reviews were used for the training phase and the testing phase. It comes up with an accuracy of 89.9%. In the second experiment, 25000 reviews were used for both the training and testing stages. It produces an accuracy of 92.5%. While comparing experiment 2 with experiment 1, the second experiment provides higher accuracy. In the final experiment, 500000 reviews were used for training and testing. The third experiment provides an accuracy of at most 96%. When we compare all three experiments, the third experiment provides higher accuracy. From this, we can notice that in the RF classifier if we increase the size of the dataset means it gradually increases the accuracy. So here the increase in the dataset is not affecting the classifier performance.

CONCLUSION

In this research, we used three datasets with distinct sizes for experimentation and proposed asentiment analysis model used to identify negative, neutral, and positive reviews for a mobile product. In this research paper, we used the popular machine-learning RF classifier with the aim to provide better accuracy. This method is applied to problems involving classification and regression. We described every aspect of the system model in detail, giving the evaluation matrices. The dataset used in this technique consists of 50,000 mobile phone product reviews. The features of the review comments were extracted using a word bag and TF-IDF. The data was split in half, with 80% used for training and 20% used for testing. We measured the outcomes of the algorithm by using F1-value, accuracy, precision, and recall. From this, we can conclude that the Random Forest technique provides better performance and produces better accuracy than other machine learning algorithms. Further, this work can be improved in various ways. Various deep-learning techniques and different pre-processing techniques will be used for acquiring a more accurate system. And we also suggest using more data to practice to get better results.

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