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# Fake News Detection Using Machine Learning

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**A B S T R A C T**

The majority of smartphone users would rather read the news is published on websites, which also offer the verified source. The issue at hand is how to verify the news and articles that shared on social media platform like Facebook pages, Twitter, WhatsApp groups, and other microblogging and social networking sites. It is determined to society for people to accept rumours as fact and pass of them off a news. The detection of it is already the subject of much research. In order to create a model of a product with a supervised machine learning algorithm that can classify fake news as true or false by using this tool like python scikit-learn and natural language processing for textual analyses the research on fake news detection and investigates traditional machine learning models to choose the best. This procedure will yield feature extraction and feature extraction, we suggest utilizing the python scikit-learn module, which includes practical utilities like tiff and count vectorizers. Next, using the confusion matrix results as a guide, we will experiment and select the best-fit features to get the highest level of precision.

## 1. Introduction

The World Wide Web's introduction and the quick uptake of social media sites like Facebook and Twitter opened the door to a level of information sharing never seen in human history.

The purpose of fake news detection is to halt the propagation of rumours via social media messaging apps. This prevent the spread of false information they incite acts of mob lynching, which has been a major driving force behind our work on this project.

The primary goal is to identify false news, which is a well-known text classification issue with an obvious solution. A model that can distinguish between "real" and "fake" news must be developed. The characteristics of the social media platforms themselves provide the following explanation for the change in consumer behaviours: In comparison to traditional journalism, such as newspaper or television, (i) consuming news on social media is frequently First point more affordable and timelier, (ii) sharing and debating the news with friends and fellow readers is facilitated by social media. For example, in 2016 62% of American adults reported getting their news from social media, up to 49% in 2012.

This study prevents an approach to develop a model that uses supervised machine learning algorithms on an annotated (labelled) dataset that is manually classified and guaranteed to determine if an article is legitimate or fraudulent based on its word, phases, sources, and titles. Then, based on the results of the confusion matrix, feature selection techniques are used to experiment and pick the best fit features in order to get the highest precision. We suggest employing various categorization algorithms to build the model. The product will be a model that can be utilized and integrated with any system for future usage, one that can identify and categorize bogus articles. The product model will test the unseen data and plot the findings.

## 2. Related work

### *2.1 Data mining:*

The two primary categories of data mining techniques are supervised and unsupervised. The training data is supervised approach to predict the hidden actions. The goal of un supervised data mining is to identify hidden data models that are supplied without the need for training data, such as input label and categories pairings. Aggregate mines and syndicate bases are prominent instances of unsupervised data mining [2].

### *2.2 Machine Learning (ML) Classification:*

A class of methods known as Machine Learning (ML) enables software systems to produce more accurate result without requiring them to be directly reprogrammed. Data scientists describe attributes or changes that the module must analyse and make use of in order to generate prediction. The algorithm divides the learnt levels into fresh data after training is finished [1]. In this research, six methods are used to categorized false information.

### *2.3 Decision Tree:*

One useful tool that is modify used for classification difficulties is the decision tree, which is built on a structure similar to a flow chart. A condition or "test" on an attribute is specified by each internal node of the decision tree, and branching is carried out based on the test conditions and outcome. When all attribute has been calculated, a class label is finally displayed on the leaf node. The classification rule is represented by the distance between the root and the leaf node. The classification rule is represented by the distance between the root and the leaf. Its ability to function with both categories and dependent variables is astounding. They do a fantastic job of pointing out of the most crucial variables and accurately illustrating how the variables related to one another. They play a major role in generating new variables and characteristics that are helpful for data exploration and accurately predict the target variable [4].

### *2.4 Random Forest:*

The foundation of Random Forest is the idea of creating numerous decision tree algorithms, each of yields a different outcome for the decision tree. The random forest takes up the outcomes that are anticipated by a large number of decision tree. The random forest chooses a subcategory at random from each group in order to guarantee a variety of the decision trees [4].

### *2.5 Support Vector Machine (SVM):*

Each data item is laid down as a point in a range of dimensions n (the number of possible attributes), and the value of a specific property is the number of specified coordinates. This is the foundation of the SVM algorithm.

### *2.6 Naïve Bayes:*

This algorithm is utilized in various machine learning issue and operates on the premise that it is free of predictors, as per bayes theory. Naïve Bayes, to put it simply, makes the assumption that each function in the category is independent of the others.

### *2.7 KNN (K- Nearest Neighbors):*

KNN uses the majority from the nearby K in relation to them to classify new places. Based on the role of distance, the allocated place in the class is strongly mutually exclusive with the K Nearest Neighbors [5].

## 3. Methodology

The classification methodology is presented in this section. A technique for identifying phony articles is created using this paradigm. This approach uses supervised collecting phase is the initial stage in solving this classification problem. Preprocessing and feature selection are the next steps, after which the dataset is trained and tested, and classifiers are eventually run. Figure [1] outlines the system methodology that is suggested. The approach is predicted on carrying out a number of experiments on datasets utilizing the majority Voting, SVM, Random Forest, Naïve Bayes, and other classifiers algorithm that were discussed in the preceding section. For optimal accuracy and precision, the trials are carried out separately on each algorithm and in combination with one another.

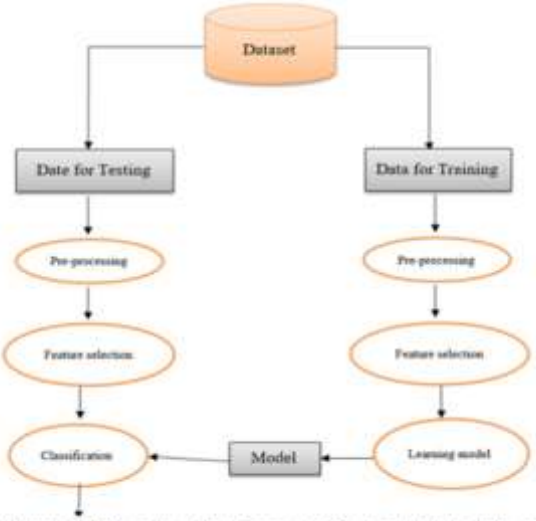


**Figure 1.** Describes the Proposed System Methodology

The major objective is to employ a set of classification methods to create a classification model that can be embedded into a python application to be used as a discovery for false news data, and then use the model as a scanner for fake news by detecting specifies of news detection [33][34]. Additionally, the python code has undergone the necessary refactoring to result in an efficient code [15][16].

K-Nearest neighbors (K-NN), linear regression, XG Boost, Naïve Bayes, Decision tree, Random model, and support Vector Machine (SVM) are the classification techniques used in this model. Each of these algorithms strives for maximum accuracy. When trustworthy based on a comparison between them and their average.

The dataset is run through several algorithm, as depicted in figure [2], to identify bogus news. The ultimate outcome is determined by analysing the correctness of the results collected.

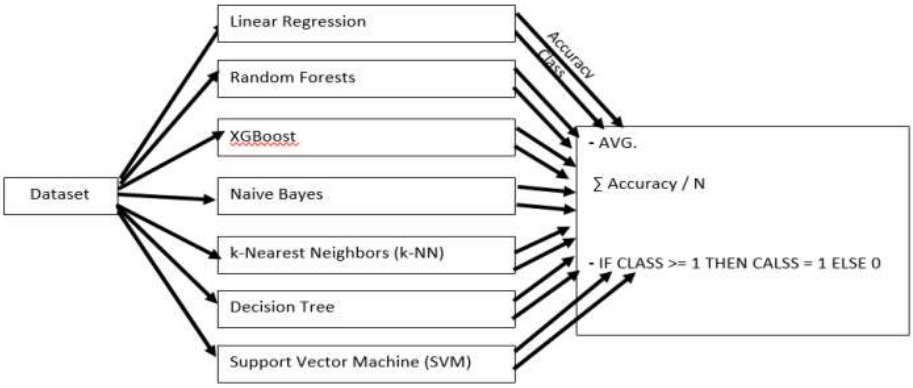


**Figure 2.** The Classification Algorithms

The following is the methodology for identifying political fake news during the model-creation process: Gathering political news datasets (the liar datasets is used for the model) is the first stage. Rough noise reduction is used to do preprocessing. Next, the Natural Language Toolkit (NLTK) is applied to perform POS and feature selection. The suggested classifier model is then created after performing the dataset splitting and applying the ML algorithms (Naïve Bayes and Random Forest). Fig.2 illustrates how the dataset is successfully pre-processed in the system following the application of NLTK, and how a message is generated for the purpose of applying algorithms on the trained selection. After applying N.B. and random forest to the system response, its response message-based model is generated. After testing is completed on a test dataset and the findings are confirmed, the precision must be observed to ensure acceptability. Next, the model is applied to user-selected, unseen data. The models' reset accuracy is 50% since the entire dataset is generated with half of the data consisting of fictitious articles and the other half of the actual ones. From the fake and actual datasets, 80% of the data are chosen at random to be utilize in our full dataset; the remaining 20% are placed aside to be used as a testing set ones our model is finished. In order to apply a classifier to text data, it must first undergo pre-processing. To do this, we will use Stanford Natural Language processing (NLP) for part of speech (POS) processing and tokenization of words. The resulting data resulting data must then be encoded as integers and floating-point values in order for ML algorithms to accept it as an input. This procedure will provide feature extraction and vectorization. To achieve tokenization and feature extraction of text data, the research uses the python scikit-learn library. This package has practical utilities like the Tiff Vectorizer and Count vectorizer. A confusion matrix is displayed graphically with the data. Please see figure 3[35].

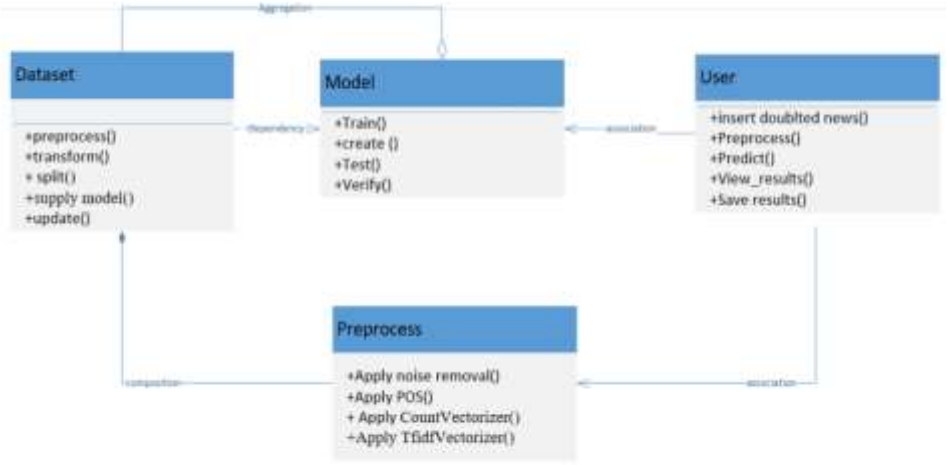


**Figure 3.** Fake Detector Model

The selected dataset, The LIAR-PLUS Master, is covered in this part along with the techniques that were used to clean and extract the data. Proof sentences from the full-text verdict article that journalists published on PolitiFact have been mechanically extracted and added to this dataset. As seen figure 4, we applied part of speech to the statement in addition to using the truth values features to get four more features (noun, verbs, prepositions, and sentences). Each record is labelled with a class label (0, 1, 2, 3) so that the model may be trained using that label. The accuracy of the news has been assessed using the subsequent procedures.

1. The 12.8k pre-processed Liar dataset.

2. The texts in various settings were manually labelled after being retrieved from POLITIFACT.com. Next, python is used to convert it from TSV to CSV format.

3. He next stage is to use the SAFAR v2 library and the NLP NLTK libraries to remove the noise. There are commas, quotation marks, ids, dots, and by stemming the words, the suffix is removed. POS (part of speech) is the next stage that will convert the dataset into tokens and statistical information.

4. Select lexical characteristics to do feature extraction, such as word count, average word length, article length, number count, and number of portions of speech (adjective).

5. Use python sklearn's Tfidf vectorizer method to extract Unigram and Bigram feature extraction that produces TF-IDF n-gram features.

6. Using python Skelearn, divide the dataset into 70% for train and 30% for test.

7. After using all of the algorithm, create an ipynb file for the classification model.

8. Create a confusion matrix and evaluate the model's accuracy on the test subset of the dataset.

9. Compare the f1-score, recall, accuracy, and precision of actual and bogus news.

10. Create the user interface that the user will use to test unseen news.

| | ID | label | statement | barely true counts | false counts | half true counts | mostly true counts | pants on fire counts |
|---|---|---|---|---|---|---|---|---|
| 0 | 2635 | 0 | Says the Annies List political group supports ... | 0 | 1 | 0 | 0 | 0 |
| 1 | 10540 | 3 | When did the decline of coal start? It started... | 0 | 0 | 1 | 1 | 0 |
| 2 | 324 | 3 | Hillary Clinton agrees with John McCain "by vo... | 70 | 71 | 160 | 163 | 9 |
| 3 | 1123 | 0 | Health care reform legislation is likely to ma... | 7 | 19 | 3 | 5 | 44 |
| 4 | 9028 | 3 | The economic turnaround started at the end of ... | 15 | 9 | 20 | 19 | 2 |
| 5 | 12465 | 1 | The Chicago Bears have had more starting quart... | 0 | 3 | 2 | 5 | 1 |
| 6 | 2342 | 3 | Jim Dunnam has not lived in the district he re... | 3 | 1 | 1 | 3 | 1 |
| 7 | 153 | 3 | I'm the only person on this stage who has work... | 70 | 71 | 160 | 163 | 9 |
| 8 | 5602 | 3 | However, it took $19.5 million in Oregon Lotte... | 0 | 0 | 1 | 0 | 1 |
| 9 | 9741 | 3 | Says GOP primary opponents Glenn Grothman and ... | 0 | 0 | 0 | 1 | 0 |

| | ID | label | statement | barely true counts | false counts | half true counts | mostly true counts | pants on fire counts | Nouns | Verbs | Preposition | Sentences |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 12465 | 1 | The Chicago Bears have had more starting quart... | 0 | 3 | 2 | 5 | 1 | 8 | 3 | 4 | 1 |
| 1 | 620 | 1 | McCain opposed a requirement that the governme... | 70 | 71 | 160 | 163 | 9 | 6 | 4 | 1 | 2 |
| 2 | 13237 | 1 | Says Paul Ryan is still endorsing Trump. | 40 | 29 | 69 | 70 | 7 | 3 | 3 | 0 | 1 |
| 3 | 7550 | 1 | We have a federal government that thinks they ... | 36 | 33 | 15 | 19 | 8 | 4 | 4 | 1 | 1 |
| 4 | 9018 | 1 | Austin is a city that has basically doubled in... | 1 | 0 | 4 | 1 | 0 | 4 | 5 | 2 | 1 |
| 5 | 1038 | 1 | The nuclear test conducted in our nation this ... | 0 | 0 | 0 | 0 | 0 | 11 | 4 | 3 | 2 |
| 6 | 8492 | 1 | Under President George W. Bush ... | 2 | 1 | 1 | 4 | 0 | 9 | 2 | 2 | 2 |

**Figure 4.** Dataset LIAR after Preprocessing

The information is split into two sections: seventy-five percent of the data are in the first portion, which is trained data. Here, the algorithm distinguishes between true and false news. The data is then labelled with a binary system, with 0 denoting false news and 1 genuine news. The remaining 25% of the data will then test it to determine if the news is authentic or fake. It will then report the results and determine the algorithm percentage based on the proportion of correct and incorrect answers. See figures 5 & 6[35].

```
In [10]: df = pd.read_csv('output01.csv', encoding="utf_8")
         df
```

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | 3054 | 1 | Whether you like to admit it or not, half our ... | 0 | 3 | 1 | 1 | 0 | 2 | 3 | 1 | 1 |
| 27 | 9554 | 1 | There are already more American jobs in the so... | 2 | 3 | 2 | 7 | 0 | 5 | 1 | 3 | 1 |
| 28 | 2537 | 1 | Webster sponsored a bill to create a form of m... | 6 | 5 | 4 | 11 | 1 | 6 | 3 | 2 | 1 |
| 29 | 4681 | 1 | Says judges get better benefits at a lower cos... | 10 | 17 | 27 | 19 | 8 | 5 | 2 | 3 | 1 |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 3048 | 5647 | 0 | Says new estimates from the Congressional Budg... | 0 | 1 | 0 | 0 | 0 | 8 | 5 | 3 | 1 |
| 3049 | 5123 | 0 | Mitt Romney has 15 homes. | 2 | 2 | 3 | 1 | 0 | 3 | 1 | 0 | 1 |
| 3050 | 2960 | 0 | [State Rep. Doug McKillips] donors deserve a r... | 0 | 1 | 0 | 1 | 0 | 7 | 1 | 0 | 1 |
| 3051 | 8591 | 0 | On changing the rules for filibusters | 7 | 6 | 5 | 7 | 0 | 3 | 1 | 3 | 1 |

**Figure 5.** Dataset LIAR after Preprocessing

```
In [13]: from sklearn.model_selection import train_test_split
         X = df[['barely true counts','false counts', 'half true counts','mostly true counts','pants on fire counts','Nouns','Ve
         y = df['label']
         X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.25, random_state=1)

In [75]: # X_train

In [76]: # X_test

In [13]: # y_train

In [14]: # y_test
```

**Figure 6.** Dataset LIAR after Preprocessing

## 4. Results

This project's scope includes covering political news data from the Liar-dataset, a new benchmark dataset for false news detection that is categorized as either trust or fake news. We have examined the "Liar" dataset via analysis. The confusion matrix has been used to illustrate the findings of the dataset analysis conducted using six algorithms. The following six algorithm were employed in the detection:

• XGboost

• Random Forests

• Naïve Bayes

• K-Nearest Neighbours (KNN)

• Decision Tree

• SVM

When the algorithm code is executed on the Anaconda platform, python code that makes use of the cognitive learning library automatically generates the confusion matrix.

The following figure 7 shows the confusion matrix for each algorithm [35]:

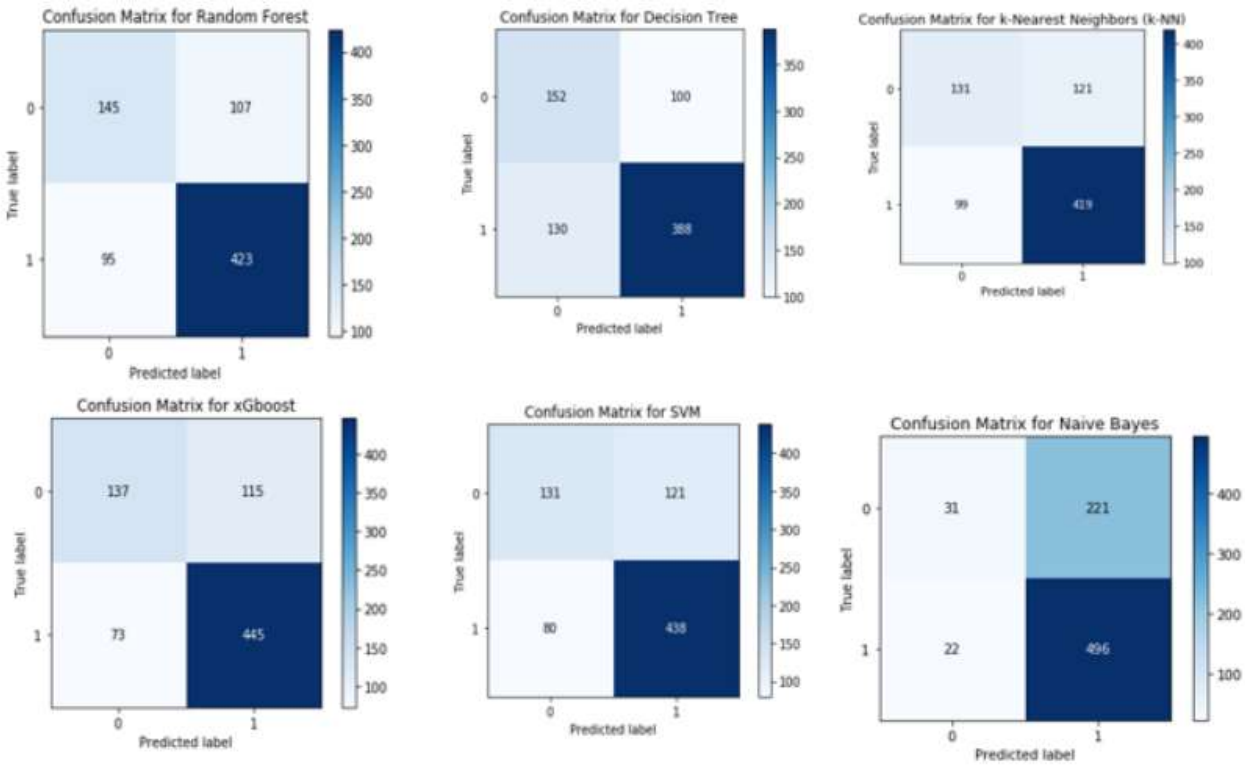


**Figure 7.** Confusion Matrix Results for the Algorithms

These algorithm's accuracy is expressed in figure 8[35]. As can be seen, XGBoost has the highest accuracy, showing over 75%; SVM and Random Forest follow with about 73% accuracy each.

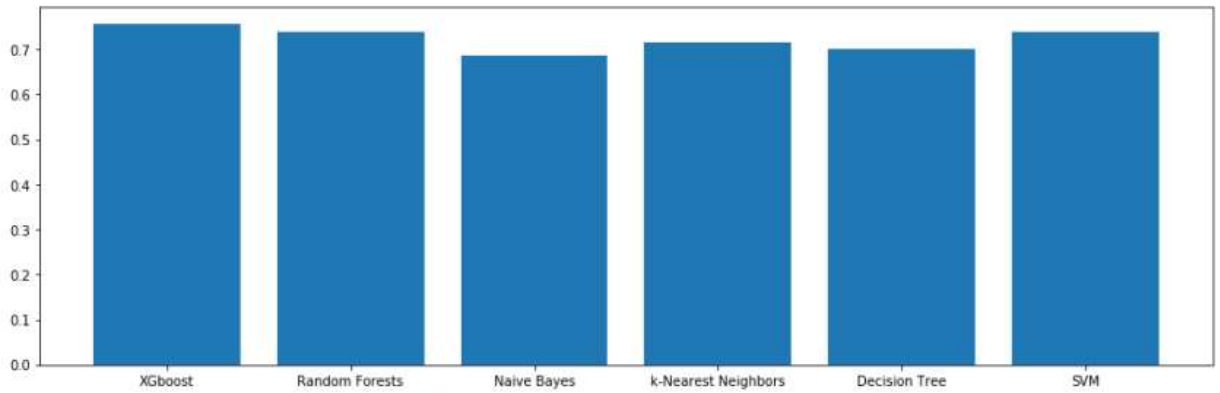


**Figure 8.** Accuracy Results of all the Algorithms

## 5. Conclusion

This paper's research focuses on identifying bogus news through two levels of review: characterization and disclosure. The fundamental ideas and precepts of false news are emphasized on social media during the first phase. Using several supervised learning algorithms, the existing approaches for the identification of false news are examined during the discovery stage.

Regarding the [10] methods for detecting false news that are presented in the research, they rely on text analysis and employ predictive models and models based on voice features that don't align with existing models. They achieve 74% [12] accuracy rate in identifying false news from various sources by using the Naïve Bayes classifier. Integrated machine learning methods are employed, yet their 85-91% accuracy [17] depends on an unstable probability threshold. Use Navies Bayes to identify false information from various social media platforms; nevertheless, the findings for the shady sources

were not reliable. There data was obtained with an accuracy of 74.5% on average from Kaggle. Employed Naïve Bayes algorithms with accuracy ratings ranging from 70% to 71.2% to identify Twitter spammers. They experimented with several methods, achieving 76% accuracy [19]. Through their study, three popular methodologies are used: Support Vector Machine (SVM), Neural Network, and Naïve Bayes. The accuracy of Naïve Bayes in identifying fraudulent communications is 96.08%. The accuracy achieved by both the neural network and the machine vector (SVM) was 99.9 0%. [20ss] By combining KNN and random forests, they were able to enhance the end results utilizing a mixed false message detection model by as much as 8%. They examined the performance of eight supervised machine learning classifiers in the twitter dataset while working false news related to the 2012 Dutch elections. Additionally, they make the assumption that the data set with a F score of 88% [32] is optimal for the decision tree method. Presented a model for detecting counterfeit goods using N-gram analysis, which produced the best results when used with a unigram and a linear SVM algorithm. 92% is the greatest accuracy. According to the system analysis and study summary described above, the majority of research articles employed the Naïve Bayes algorithm, with prediction precision ranging from 70 to 76%. The majority of these studies relied mostly on qualitative analysis, with sentiment analysis, word frequency repetition, and titles playing a major role. We suggest incorporating POS textual analysis, a quantitative approach that relies on the addition of utile random forest and augmenting these features will yield even better precession result. Total words (tokens), Total Unique Words (types), Type/Token Ratio (TTR), Number of sentences, Average Sentence Length (ASL), Number Of Characters, Average Word Length (AWL), nouns, preposition, and adjectives are the feature we propose to add to our dataset.

## 6. References

[1]. Sumeet Dua, Xian Du. “Data Mining and Machine Learning in Cybersecurity”. New York: Auerbach Publications.19 April 2016.

[2]. RAY, S. https://www.analyticsvidhya.com/blog/2017/09/common-machine-learning-algorithms/ 2017, September

[3]. Huang, T.-Q. (n.d.) https://www.researchgate.net/figure/Pseudo-code-of-information-gain-basedrecursive-feature-elimination-procedure-with-SVM_fig2_228366941 2018

[4]. Researchgate.net. Available at: Available at: https://www.researchgate.net/figure/Pseudocode-ofnaive-bayes-algorithm_fig2_325937073. 2018.

[5]. Researchgate.net. Available at: https://www.researchgate.net/figure/Pseudocode-for-KNNclassification_fig7_260397165, 2014.

[6]. Rampersad G, Althiyabi T 2020 “Fake news: Acceptance by demographics and culture on social media” J. Inf. Technol. Politics 2020, 17, 1–11.

[7]. NaphapornSirikulviriya; SukreeSinthupinyo. “Integration of Rules from a Random Forest.” International Conference on Information and Electronics Engineering (p. 194 : 198). Singapore: semanticscholar.org. 2011.

[8]. Jasmin Kevric et el. “An effective combining classifier approach using tree algorithms for network intrusion detection.” Neural Computing and Applications , 1051–1058. 2017.

[9]. ShivamB.Parikh and PradeepK.Atrey. “Media-RichFake News Detection: A Survey.” IEEE Conference on Multimedia Information. Miami, FL: IEEE. 2018.

[10]. MykhailoGranik and VolodymyrMesyura. “Fake news detection using naive Bayes classifier.” First Ukraine Conference on Electrical and Computer Engineering (UKRCON). Ukraine : IEEE. 2017.

[11]. Gilda, S. “Evaluating machine learning algorithms for fake news detection.” 15th Student Conference on Research and Development (SCOReD) (pp. 110-115). IEEE. 2017.

[12]. Akshay Jain and AmeyKasbe. “Fake News Detection.” 2018 IEEE International Students' Conference on Electrical, Electronics and Computer Science (SCEECS). Bhopal, India: IEEE. 2018.

[13]. Yumeng Qin et al. “Predicting Future Rumours.” Chinese Journal of Electronics ( Volume: 27 , Issue: 3 , 5 2018, 514 - 520.

[14]. ArushiGupta and RishabhKaushal. “Improving spam detection in Online Social Networks.” International Conference on Cognitive Computing and Information Processing (CCIP). semanticscholar.org.2015

[15]. Khanam, Z., Ahsan, M.N.”Evaluating the effectiveness of test driven development: advantages and pitfalls.”International. J. Appl. Eng. Res. 12, 7705–7716, 2017

[16]. Khanam, Z. “Analyzing refactoring trends and practices in the software industry.” Int. J. Adv. Res. Comput. Sci. 10, 0976–5697, 2018.

[17]. Veronica Perez-Rosas et al. Available at: https://www.researchgate.net/publication/319255985_Automatic_Detection_of_Fake_News August, 2017.

[18]. Supanya Aphiwongsophon et al. “ Detecting Fake News with Machine Learning Method.” 2018 15th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON). Chiang Rai, Thailand, Thailand: IEEE . 2018.

[19]. Prabhjot Kaur et al. “ Hybrid Text Classification Method for Fake News Detection.” International Journal of Engineering and Advanced Technology (IJEAT) , 2388-2392. 2019.

[20]. Looijenga, M. S. “The Detection of Fake Messages using Machine Learning.” 29 Twente Student Conference on IT, Jun. 6th, 2018, Enschede, The Netherlands. Netherlands: essay.utwente.nl. 2018.

[21]. I. Traore et al. “Detection of Online Fake News Using N-Gram Analysis and Machine Learning Techniques.” International Conference on Intelligent, Secure, and Dependable Systems in Distributed and Cloud Environments (pp. 127–138). Springer International Publishing . 2017.

[22]. Khanam Z., Alkhaldi S. “An Intelligent Recommendation Engine for Selecting the University for Graduate Courses in KSA: SARS Student Admission Recommender System.” In: Smys S., Bestak R., Rocha Á. (eds) Inventive Computation Technologies. ICICIT 2019. Lecture Notes in Networks and Systems, vol 98. Springer, Cham. 2019.

[23]. Khanam Z. and Ahsan M.N. “ Implementation of the pHash algorithm for face recognition in secured remote online examination system.” International Journal of Advances in Scientific Research and Engineering (ijasre) Volume 4, Issue 11 November. 2018.

[24]. Sharma, K., Qian, F., Jiang, H., Ruchansky, N., Zhang, M., & Liu, Y. (2019). Combating fake news: A survey on identification and mitigation techniques. ACM Transactions on Intelligent Systems and Technology (TIST), 10(3), 1-42.

[25]. Sharma, Karishma, et al. "Combating fake news: A survey on identification and mitigation techniques." ACM Transactions on Intelligent Systems and Technology (TIST) 10.3 (2019): 1-42.

[26]. Shu, K., Sliva, A., Wang, S., Tang, J., & Liu, H. (2017). Fake news detection on social media: A data mining perspective. ACM SIGKDD explorations newsletter, 19(1), 22-36.

[27]. Shu, Kai, et al. "Fake news detection on social media: A data mining perspective." ACM SIGKDD explorations newsletter 19.1 (2017): 22-36.

[28]. Khanam Z. and Agarwal S. Map-reduce implementations: Survey and Performance comparison, International Journal of Computer Science & Information Technology (IJCSIT) Vol 7, No 4, August 2015.

[29]. Zhang, Jiawei, Bowen Dong, and S. Yu Philip. "Fakedetector: Effective fake news detection with deep diffusive neural network." 2020 IEEE 36th International Conference on Data Engineering (ICDE). IEEE, 2020.

[30]. K Ludwig, M Creation 2020 “Dissemination and uptake of fake-quotes in lay political discourse on Facebook and Twitter” J. Pragmat, 157, 101–118.

[31]. Can Machines Learn to Detect Fake News? A Survey Focused on Social Media. Available at: https://scholarspace.manoa.hawaii.edu/handle/10125/59713

[32]. Cardoso Durier da Silva, F., Vieira, R., & Garcia, A. C. (2019, January). Can machines learn to detect fake news? a survey focused on social media. In Proceedings of the 52nd Hawaii International Conference on System Sciences.

[33]. Bovet, Alexandre, and Hernán A. Makse. "Influence of fake news in Twitter during the 2016 US presidential election." Nature communications 10.1 (2019): 1-14. The science of fake news.

[34]. https://science.sciencemag.org/content/359/6380/1094.summary Science 09 Mar 2018:Vol. 359, Issue 6380, pp. 1094-1096 DOI: 10.1126/science.aao2998.

[35]. Khanam, Z., et al. "Fake news detection using machine learning approaches." *IOP conference series: materials science and engineering*. Vol. 1099. No. 1. IOP Publishing, 2021.