A systematic survey on deep learning and machine learning approaches of fake news detection in the pre- and post-COVID-19 pandemic

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Abstract

Purpose – The rapid advancement of technology in online communication and fingertip access to the Internet has resulted in the expedited dissemination of fake news to engage a global audience at a low cost by news channels, freelance reporters and websites. Amid the coronavirus disease 2019 (COVID-19) pandemic, individuals are inflicted with these false and potentially harmful claims and stories, which may harm the vaccination process. Psychological studies reveal that the human ability to detect deception is only slightly better than chance; therefore, there is a growing need for serious consideration for developing automated strategies to combat fake news that traverses these platforms at an alarming rate. This paper systematically reviews the existing fake news detection technologies by exploring various machine learning and deep learning techniques pre- and post-pandemic, which has never been done before to the best of the authors' knowledge.

Design/methodology/approach – The detailed literature review on fake news detection is divided into three major parts. The authors searched papers no later than 2017 on fake news detection approaches on deep learning and machine learning. The papers were initially searched through the Google scholar platform, and they have been scrutinized for quality. The authors kept "Scopus" and "Web of Science" as quality indexing parameters. All research gaps and available databases, data pre-processing, feature extraction techniques and evaluation methods for current fake news detection technologies have been explored, illustrating them using tables, charts and trees.

Findings – The paper is dissected into two approaches, namely machine learning and deep learning, to present a better understanding and a clear objective. Next, the authors present a viewpoint on which approach is better and future research trends, issues and challenges for researchers, given the relevance and urgency of a detailed and thorough analysis of existing models. This paper also delves into fake new detection during COVID-19, and it can be inferred that research and modeling are shifting toward the use of ensemble approaches.

Originality/value – The study also identifies several novel automated web-based approaches used by researchers to assess the validity of pandemic news that have proven to be successful, although currently reported accuracy has not yet reached consistent levels in the real world.

Keywords Fake news detection, Machine learning, Deep learning, Artificial intelligence, Natural language processing, COVID-19, Social media, Misinformation

Paper type Literature review

1. Introduction

> Misinformation is not like a plumbing problem; you fix it. It is a social condition, like crime, that you must constantly monitor and adjust to.
>
> – Tom Rosenstiel, director of the American Press Institute and senior fellow at the Brookings Institution

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(Lazer *et al.*, 2018) define fake news as "fabricated information that mimics news media content in form but not in organizational process or intent [. . .] overlaps with other information disorders, such as misinformation (false or misleading information) and disinformation (false information that is purposely spread to deceive people)". The expression "Fake news" became sensationalized during the 2016 US presidential elections. It further acquired legitimacy after being named the "Word of the Year 2017" by the scholarly Collins Dictionary due to the "ubiquitous presence" of the term during that time. (Allcott and Gentzkow, 2017) categorize the reason for the production of fake news as either financial or ideological motivations, i.e. news media or publishers can either draw significant advertising revenue or promote a particular ideology and idea, often by discrediting others. One might argue that journalism (Zhou, 2009; A Brief History of "Lügenpresse," the Nazi-Era Predecessor to Trump's "Fake News" - US News–Haaretz.Com, n.d.) has been the target of such accusations from its very outset; therefore, (The Elements of Journalism What Newspeople Should.Pdf, n.d.) specifically define fake news as "news articles that are intentionally and verifiably false and could mislead readers." Contrarily, the "primary purpose of journalism is to provide citizens with the information they need to be free and self-governing," and above all things, the truth. Fake news consequently undermines the legitimacy of journalism as well (Kang *et al.*, 2011). Given the widespread advancement of the Internet, technology and social media platforms, a vast population (Allcott and Gentzkow, 2017) can effectively like, share and disseminate their opinions, producing positive but, more crucially, negative consequences for the economy and democracy (Online Fake News Costs Us $78 Billion Globally Each Year | ZDNet, n.d.). For example, many fake news websites in the USA, like WashingtonPost.com.co, USAToday.com.co, etc. were identified (Tsfati *et al.*, 2020). Such channels have shown a spike in similar phenomena found throughout the world, ranging from India [8] to France (French Social Media Awash with Fake News Stories from Sources 'Exposed to Russian Influence' Ahead of Presidential Election | The Independent | The Independent, n.d.), Israel (Phone Hacking? Fake Twitter Accounts? You Ain't Seen Nothing yet–Israel Election 2021 - Haaretz.Com, n.d.), Latin America (Fake News Poses a Threat to Democracies across Latin America and Worldwide > Press Releases | World Economic Forum, n.d.) and Indonesia (Fake News Spikes in Indonesia Ahead of Elections | Indonesia | The Guardian, n.d.). Furthermore, factual corrections of content on the Internet and social media are often slow and scarcely made to people who were initially affected by misinformation (Ciampaglia *et al.*, 2018) due to the involvement of human expertise to identify articles or websites as credible or noncredible. Psychological studies reveal that the human ability to detect deception is only slightly better than chance (Pardo *et al.*, 2020). There is, therefore, a growing need for serious consideration for the development of automated strategies to combat fake news that traverses these platforms at an increasingly high rate.

Substantial work has been done to leverage machine learning, artificial intelligence, deep learning and natural language processing (NLP) to automate the process of classifying news as fake or real (Murfi *et al.*, 2019; Ayo *et al.*, 2020; Hossein and Miller, 2018). To categorize a piece of news, we need to know the problem definition first, and then we go for our model and evaluate the result (Umer *et al.*, 2020). Machine learning and deep learning algorithms are two of the most popular approaches for detecting fake news. Machine learning opens up a broad area of possibility for research. Hence, this paper focuses on machine learning and deep learning aspects to classify the most popular fake news detection techniques. The algorithms of machine learning that we explore can be bifurcated as two significant learnings, namely *supervised learning*: Naive Bayes, support vector machine, logistic regression, C4.5, Classification and Regression Trees (CART), etc., and *unsupervised learning*: K-means, K Nearest Neighbour (KNN), Density-based spatial clustering of applications with noise (DBSCAN), etc. Another innovative strategy adopted in recent research under the supervised ML is *ensemble learning*, including voting, bagging and boosting classifier algorithms, like

Decision Tree, Random Forest, Adaptive Boosting (AdaBoost), eXtreme Gradient Boosting (XGBoost), etc. These ensemble learners produce higher accuracy since more than one model is trained using a specific methodology to provide optimum results for the model. Also, according to Rodríguez and Iglesias (2019), deep learning techniques have a significant probability in fake news detection. There are very few studies that propose the significance of neural networks in this area. Some algorithms that have been generally performed for fake news detection are LSTM (Long short-term memory), CNN (Convolution neural network), BERT (Bidirectional encoder representation from transformers, recurrent neural networks and RBM (Restricted Boltzmann machine), which are very common; some of these algorithms can also be classified as discriminative, generative and hybrid models. Furthermore, when discussing learning models for news verification purposes, the preprocessing phase of these models can often be described by implementing NLP, a type of artificial intelligence that involves understanding and deciphering human languages. Based on the existing Machine Learning (ML) and Deep Learning (DL) models built, it is challenging to construct an entirely feature-based NLP model that does not contain any external details. Even apparently efficient NLP models have revealed a significant reduction in accuracy when tested with a novel dataset due to the heavy dependence of the English-language-based NLP features.

In social networks and fast media, the fast rotation of news makes it challenging to calculate its reliability rapidly, such as problems that cannot be reduced to a set number of inputs and outputs and in which the device is needed to keep in store and use background information. It is tough to find the exact and proper definition of the words. There are always new data available that are larger than everything else. How to extract notable features from every modality is difficult too.

Additionally, existing approaches have few challenges for false news detection, e.g. data volume, data quality, domain complexity, interpretability, feature enrichment, model privacy, incorporating expert knowledge, temporal modeling, dynamic, etc. (Randika, 2020). A recurrent neural network (RNN) is valuable because it exhibits similar behavior to how human brains function. However, to strongly build and deploy them proves to be a challenge for data scientists and engineers worldwide (Singhania *et al.*, 2017). For example, in deep learning, despite the immense value of RNN for learning sequential patterns, the gradient descent method is tough to implement because of the famous gradient vanishing/explosion problem (Yang *et al.*, 2018). There are several challenges (data volume, data quality, domain complexity, interpretability, explainability, feature enrichment, federated inference, model privacy, incorporating expert knowledge, temporal modeling, etc.) that need to be improvised in the further research study. Fake news detection techniques are still an active research concern and need to be extended in upcoming research. Also, novel characteristics such as timeliness and oddity1 show that fake news detection does not follow other fake information, e.g. fake statements and fake reviews and thus https://www.axiapr.com/blog/elements-of-news brings about new challenges. The tutorial in Saikh *et al.* (2019) displays the significant open problems that have not been appropriately addressed in recent research. It points out the example of solid resources: fact-checking websites and techniques like deep learning that can address the open challenges. The tutorial they provide also enlightens many tasks as future research direction, increasing the efficiency of fake news detection and increasing our understanding of fake news detection examples: identifying check-worthy content.

The papers on fake news detection (ML, DL and during the pandemic era) were searched on the Google Scholar platform from 2017, with the majority of papers between 2019 and 2021. This period was chosen because of the popularization of fake news, especially after the 2016 US elections. Another reason was the vast majority of people globally used the Internet and social media as the only means of communication to voice their opinions during the coronavirus disease 2019 (COVID-19) lockdown. Hence, the authors can draw meaningful inferences into the development of current and future technologies in this domain.

We, therefore, conducted a comprehensive literature survey on fake news detection models using machine learning and deep learning technologies before and after the pandemic. For representing a better understanding, the section on related literature work is subdivided into three separate subsections, namely machine learning approaches, deep learning approaches and fake news detection in the COVID-19 era. The search criteria of the literature are given in Section 2.1. For a more in-depth discussion of the critical AI/ML and DL techniques to build a fake news detection model, see Section 2.

The Director-General of the World Health Organization (WHO), Tedros Adhanom Ghebreyesus, in February 2020 said, "We are not just fighting an epidemic; we are fighting an infodemic. Fake news spreads faster and more easily than this virus and is just as dangerous" (Munich Security Conference, n.d.). This infodemic has proven to increase at dangerous levels throughout this period and even invoked violence, threatening lives due to these fake news articles (Bahja and Safdar, 2020). Furthermore, there is a risk of COVID-19 misinformation rising resistance to the vaccine (Sear *et al.*, 2020). There is already a growing antivaccination movement associated with COVID-19 that, according to others, is better positioned for development than the provaccination community.

This survey focuses on the following research questions, listed below:

RQ1. What are the different machine learning and deep learning approaches used in the prediction of fake news?

RQ2. What are the datasets, preprocessing, feature extraction and supervised/unsupervised methods used in machine learning for fake news detection?

RQ3. Which approach of deep learning method is suitable for fake news detection?

RQ4. What is the current research in fake news detection in pandemic times?

Due to the COVID outbreak, most organizations, institutes, universities and offices were shut down, which resulted in work from home. The usage of the Internet from home has rapidly increased in the past few days. Since most of the population is at home, there is no source apart from online media that can update the current situation. Most people believed the information from online social media such as Facebook, Twitter or any other social media platforms without verifying factual information. Fake or wrongly narrated news, especially about COVID updates, may hamper individual trust. For the scientific community, it is essential to address such issues in fake news using new approaches, like deep learning, machine learning and Artificial Intelligence (AI).

To the best of our knowledge, a detailed literature survey on fake news detection using ML and DL technologies has not been conducted before. The objective of developing this paper is to provide a 360-degree analysis of fake news detection and simultaneously of the various technologies used for this purpose. Provided the relevance and urgency of a detailed and thorough analysis of existing models, we also present a viewpoint on better and future research issues and challenges for researchers. This paper introduces a comprehensive survey on fake new detection in COVID-19, and it can be inferred that research work and modeling are moving toward the use of ensemble approaches. Researchers' novel automated web-based approaches to assess the validity of pandemic news have also shown success, although currently reported accuracy has not yet reached consistent levels in the real world. This research includes SEMiNExt (Rashied Hussein *et al.*, 2020), a search engine extension that generates pop-up alerts in the event of suspicious online health information, and CoVerifi (Kolluri and Murthy, 2021), which verifies pandemic news to show real-time credibility scores of social media posts obtained by the vote of users.

The proposed paper will benefit upcoming researchers with classified and structured detail on existing techniques. Having a systematic overview will act as a repository on

what should be preferred and which open issues to pay attention to. This paper will help build a fake news detection model by considering challenges that have been faced till now and minimizing them with suggested preprocessing, feature extraction and algorithms.

The structure of this paper is organized as follows: Section 2 provides the search criteria followed during our literature survey and the related work using machine learning and deep learning approaches pre- and post-COVID-19 pandemic for our survey study, and the last Section 3 discusses and concludes the study of our paper.

2. Related work

Various myths and misinformation about the recent COVID-19 outbreak, which resulted in severe losses, have been circulating on online platforms. For example, in Iran, rumors about drinking raw alcohol as a remedy for COVID-19 have resulted in numerous deaths (Tanne *et al.*, 2020), and in the United Kingdom, conspiracy theories tying 5G to COVID-19 have resulted in more than 20 mass attacks (Rachel Schraer and Eleanor Lawrie, 2020). Similarly, an incident occurred in the USA due to a tweeted lie (Takashi Imamura, 2017). A man entered the shop with a rifle and began shooting. Fake tweets were shared widely on the Internet, claiming that this pizza restaurant was the center for a child rapist sex ring involving democratic presidential candidate Hillary Clinton, a former Secretary of State, and members of her campaign. The pizza shop's owners began receiving threats from right-wing activists who believed the reports were accurate. There were numerous tweets about newly discovered e-mail related to a pedophile sex ring. These posts were widely disseminated on anonymous bulletin board sites and through social media, and there were numerous abusive videos directed at Ms. Clinton that were widely disseminated on extreme right-wing websites. The Federal Bureau of Investigation (FBI) announced two days before the election that they had reached the decision not to prosecute Ms. Clinton.

2.1 Search strategy and concept map

Our detailed literature review on fake news detection is divided into three major parts. We searched papers no later than 2017 on fake news detection approaches on deep learning and machine learning. The paper was initially searched through the Google scholar platform, and they have been scrutinized for quality [Indexing like Scopus, Science Citation Index (SCI) and PubMed indexed papers]. To make our research topic-oriented, we searched the papers for respective algorithms using specific keywords on Google scholar; for example, for papers on machine learning algorithms, we used the keywords: detect + fake news + social media + covid + machine learning, and for deep learning papers, we searched on detecting + fake news + social media + covid + deep learning. To see the newest articles first, we clicked on "Sort by date" in the sidebar.

These access links cover various ways in which articles may be available – articles that the library subscribes to, open access articles, free-to-read articles from publishers, preprints, articles in repositories, etc. We kept "Scopus" and "Web of Science" as quality indexing parameters. The paper which does not meet the quality criteria has been removed. We have also considered journal papers more than conference papers as the research study carried out in journal papers are more rigorous and in-depth.

Table 1 given gives a clear idea about the papers and further information about the search strategy.

Our extensive research work is based on the following research questions. Figure 1 shows the overall concept map of our detailed 360-degree surveys of various techniques used in fake news detection.

Table 1.
Details of the literature available for fake news detection machine learning, deep learning and pre- and post-pandemic research

Section	Section name	Purpose	Total number of papers	Year
I	Machine learning approaches for fake news detection	Identifying the machine learning techniques for fake news detection, which includes ML models, feature extraction methods, learning methods, framework, the dataset used and parameters used to evaluate the model	29	2017 onwards
II	Deep learning approaches for fake news detection	We are identifying deep learning methods for fake news detection, including models (such as discriminative models, generative models and hybrid models), parameters used for evaluation, etc.	9	2017 onwards
III	Fake news detection research in pre- and post-pandemic	Identifying ML and DL techniques for fake news during COVID 19 pandemic	32	Post-2019–2021 (till date)

2.2 Machine learning approaches for fake news detection

The detection of fake news using machine learning has paved the way for everyone to understand and differentiate between credible and noncredible information (Kar, 2020). Initially, manual fact-checking websites were considered a suitable method to classify fake news, but they provide a lack of generalization over several domains. Therefore, in recent years, several attempts have been made for automated detection via machine learning models to develop a tangible technology. The authors (Traylor *et al.*, 2019) used Glaser and Strauss's grounded theory (Sataloff *et al.*, n.d.) methods to analyze technical linguistic patterns and trends in false documents and observed lack of proper attribution, the most dominant indicator of fake news. This became the critical basis for the feature extraction process in developing a custom ML classifier model using the A-score algorithm to label the documents as real or false. Pretraining of the data involved removing extraneous common words to prevent them from affecting the score. Experimental results provide a low accuracy (69%) due to only one extraction feature and the deceptive nature and complexity of the data collected.

In the study of Tiwari *et al.* (2020), various machine learning classification algorithms with different feature extraction methods are compared. Results showed that logistic regression proved to be the best algorithm with the highest accuracy (71%) when used with the term frequency -inverse document frequency (TF-IDF) feature extraction method. The authors suggest that prediction accuracy for a particular model on text data depends on its feature extraction method and machine learning algorithm. It varies based on the type of data in which the model has been trained. A drawback observed is that the system's accuracy in classifying the content as fake or genuine is better for USA-based headlines than other countries; hence, it is not generalized to identify fake news articles from multiple regions. Since articles from different countries, regions, domains and sources have a unique textual structure and writing style, it is challenging to train a generic algorithm that works well to classify text from all particular news domains.

The study by Ahmad *et al.* (2020) concluded that the accuracy of ML algorithms drops in such cases compared to the one obtained from data of individual sources. The authors propose a model that overcomes this obstacle by testing it on datasets that include fake and truthful news articles from multiple domains. The paper suggests a hybrid fake news detection approach by training a combination of supervised and unsupervised ML

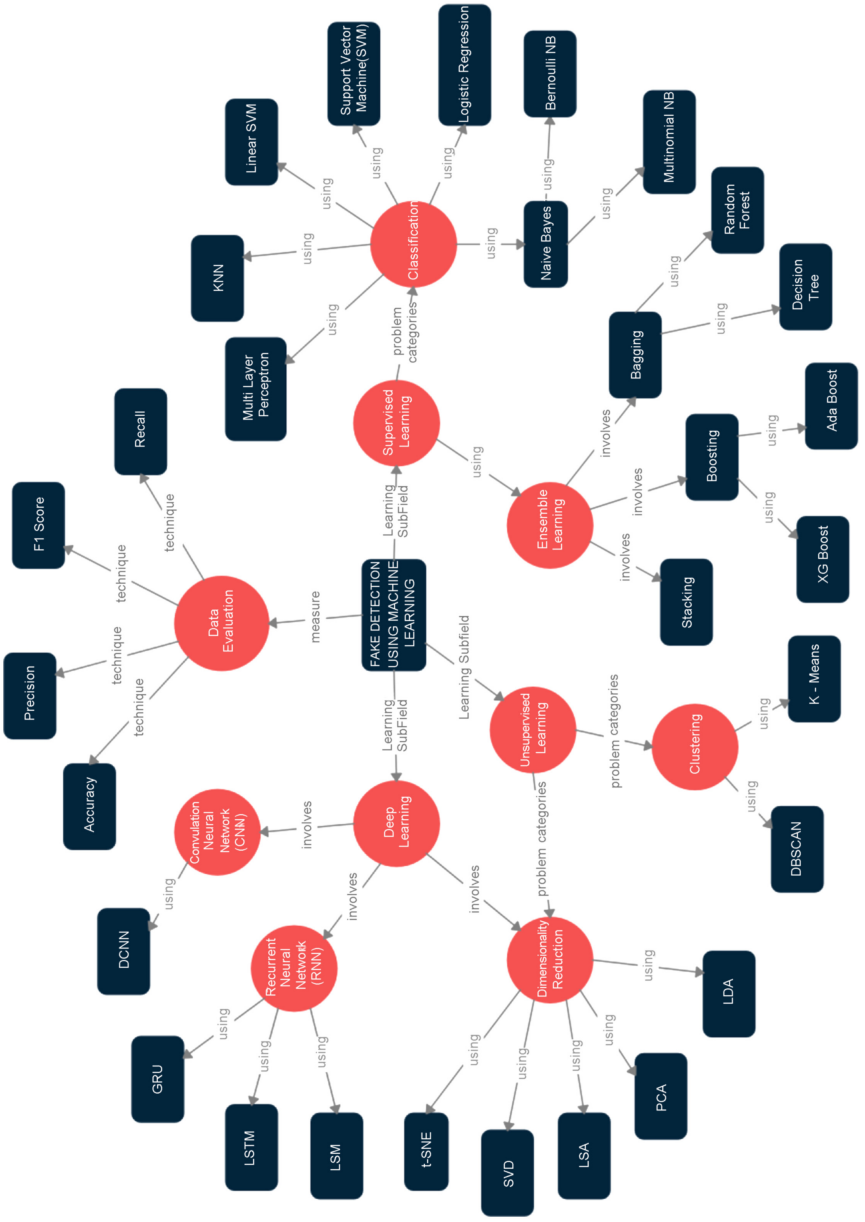

Figure 1.
Concept map of a detailed survey of various techniques used in fake news detection

algorithms using various ensemble methods and linguistic inquiry and word count (LIWC) feature set as an input to the model. The experimental results show that the XG-Boost ensemble boosting classifier provides better evaluation results than the other existing algorithms.

With the advancement of digital technology, native speakers worldwide are producing online content in their languages. Approaches opposed to other existing models, which rely only on resource-rich languages such as English, are also being developed to overcome the obstacles presented by diversified data. The authors (Kareem and Awan, 2019) experimented with fake news detection in Pakistan, showing good accuracy (70%) by implementing the KNN algorithm with Bag of Words (BoW) feature extraction techniques. In the study of Rusli *et al.* (2020), a multi-layer perceptron classifier was implemented to detect fake news articles written in Bahasa, Indonesia. Experimental results achieved the highest F1-score (0.82) by performing the stemming and stop-word removal process along with the BoW model and character bigram. The authors suggest that stemming and stop-word removal preprocessing steps affect the classifier's performance and could cause delays to the results. The authors of Hussain *et al.* (2020) classified news in the Bangla language as real or fake by scraping articles from newspapers and popular websites. Results show the SVM classifier gives higher accuracy (96.64%) than MNB with the linear kernel technique to classify related posts. The common drawbacks of such models are the lack of publicly available large datasets; hence, there is a need to construct local news article corpora for all languages and countries. In the future, alternative feature extraction techniques, like word embeddings, and hybrid and DL classification methods can be used to increase the accuracy of these proposed models.

The researchers Faustini and Covões (2020) trained their models with a customized set of features to overcome the reliance of NLP systems on English features and to evaluate datasets belonging to three language groups (English, Portuguese and Bulgarian). K-fold cross-validation does not guarantee the occurrence of the same topic in different folds, so this paper uses a leave-topic-out approach, achieving an accuracy as high as 94% for SVM and RF models. The authors suggest that not employing DL techniques is the delay caused by manual fact-checking of large datasets. In another work (Vogel and Meghana, 2020), the authors suggest identifying potential fake news propagators on social media, intending to discriminate against authors who have shared false content in the past, from those who always share credible content. Several learning experiments from a multilingual perspective were conducted and evaluated by textual features that are not language-specific. This model took third place in the Project Award Notice (PAN) shared task at CLEF 2020 (Pardo *et al.*, 2020) among 72 competitors, achieving 78 and 87% accuracy on the English and Spanish corpus, using different character n-grams along with SVM and logistic regression. A downfall observed for this model is that it does not consider misspelled words, which results in the loss of many helpful feature prospects. The paper suggests that ensemble-based machine learning techniques can be applied to achieve greater accuracies.

In recent research, authors (Gautam and Jerripothula, 2020) proposed using Grammarly and Spinbot paraphrasing and GloVe tools to extract features like misspelled words and other sentimental features that are essential in detecting whether an article is fake or real. This novel model uses datasets belonging to six news domains and reliable websites, like CNN, FoxNews, etc. Results show that the Random Forest ensemble classifier gives up to 95% accuracy on their datasets.

In the Internet and social media (Zhao *et al.*, 2020), credible news is more likely to be created by official accounts, such as government or mass media agencies. Hence, the authors in [2] gather their data from credible Indian Twitter sources like @CNBCTV18News, @ndtv, @narendramodi and @RajatSharmaLive. The paper proposes a web-based Graphical User Interface (GUI) using supervised naive Bayes and passive-aggressive ML algorithm (*ML algorithms addendum: Passive-aggressive algorithms – Giuseppe* ML Algorithms addendum

Passive Aggressive Algorithms Giuseppe Bonaccorso, n.d.) fake news classification system to categorize the tweets as fake or genuine by comparing tweets with reliable sources. Results showed that the passive-aggressive classifier proved to be a better algorithm giving higher accuracy (78%) with the TF-IDF feature extraction technique. The paper suggests expanding this model in the future to classify data in image format as currently memes have become a new source of propagation of misinformation via social media platforms ("Fake" Memes: A New Subgenre of the Internet Meme, n.d.).

The authors (Kar, 2020) suggest that one of the biggest challenges facing their supervised ML model is handling large datasets, language processing, etc., which could be removed in the future using PySpark and Java. Various novel feature extraction techniques, like Hashing and DictVectorizer, are used in the collected dataset, which is split into 45% training and 55% testing set in the postprocessing phase. Experimental results show that SVM and naïve Bayes produce better results than RNN and CNN when a smaller amount of data are used for fast computation. This is because more data availability gives better accuracy in the case of deep learning algorithms.

Recently Whistleblower, the first open and democratic fake news assessment platform, has been developed (Ramachandran *et al.*, 2020). The authors proposed a decentralized and open platform based on blockchain and distributed ledger technology, consisting of a fake news processing engine powered by AI/ML algorithms, a verifiable computation engine and a token-curated registry. This model is trained using the data collected from social media sites in combination with various fact-checking tools. Hence, this system provides an approach to prevent a single stakeholder from controlling and managing the fake news detection process while involving community members to improve the machine learning algorithm's reliability and increasing the accuracy of prediction by the model.

An exciting and obvious fact to highlight is the use of high emotional context in fake news articles. Hence, to detect fake news (Tsfati *et al.*, 2020), emotionalizing the text by emotion lexicon before directly applying machine learning algorithms increases accuracy. As obtained from the results (Salve, 2020b) of two employed settings – supervised and unsupervised, unsupervised seems to have less accuracy since document representation and clustering gives coherent clusters, ignoring different tasks of fake news detection. The only study to analyze unsupervised machine learning for fake news detection, the setting gives the best accuracy for k-means algorithm in unsupervised learning (88.7% at $k = 20$) and Adaboost algorithm of supervised learning (96.5%), proving the reason for the use of supervised learning techniques adopted throughout research field for detecting fake news. Getting hold of authentic and trustworthy information has become difficult due to overwhelming information flowing all over social media (Salve, 2020d). The authors propose a two-step model wherein the first text is mined, processed and extracted features. In total, 23 supervised artificial intelligent algorithms are examined with their accuracies to obtain the best algorithm, which came out to be the Decision Tree algorithm (in terms of accuracy, precision and F-measure) and ZeroR, CVPS and WIHW algorithms (in terms of recall metric).

Precise feature extraction and hyperparameter attribute help in achieving better performance (Salve, 2020a). The ensemble approach has now consistently shown a better result in the ability to deliver. Results have shown that the Random Forest algorithm is a better performer, while the decision tree is a time savior in the data training phase.

An alternate approach suggests (Salve, 2020e) that the involvement of humans in the fact-checking process brings in trust. The authors proposed a framework for fake news detection where artificially intelligent algorithms do the first step in detection, and these results are then verified by crowdsource workers and fact-checking experts. The data to be tagged as fake or real are focused on social media and parliamentary sessions.

Facebook was one of the first social media platforms to witness huge crowds and the overflood of information. Data from Facebook can be collected through web scrapping

software, and a simple naïve Bayes classification model (Salve, 2020c) predicts the truthfulness of these data. This way, a limitation is possible wherein the training set does not have some words; in such scenarios, the author has suggested that the data should be labeled as fake. Hence, in general, the most common way to improve any model is to make use of more data for training the model, use of more significant length datasets as to have extensivity of words in the training set and preprocess the data with methods such as stemming and stop-word removal (Salve, 2020c).

In machine learning, the training data are essential to fit the model and for making predictions. The survey shows that the k-fold (where k is either 5 or 10) cross-validation model is employed for all ensemble classifiers to minimize the risk of overfitting. However, even though each iteration is fitted with a different model, this method does not guarantee that data leakage will not occur in fake news settings. For this reason, innovative techniques such as suggested by the authors of (Faustini and Covões, 2020) can be customized according to the researcher model's dataset requirements. We also observe that novel datasets are created for multilingual ML/DL models. Table 2 summarizes the dataset used to build ML models by various papers of this literature survey.

Table 3 shows that while conducting the survey, it was observed that removal of stop words using NLTK package, irrelevant words with less than three characters (e.g. or, and, the, etc.), and the breakdown of text into features by application of tokenization technique were most popularly performed as part of the preprocessing phase for the proposed ML models to clean the data from the raw format. Although (Kareem and Awan, 2019) argue that these methods could cause a delay in the classification process without significantly affecting the performance of ML classifier models for identifying fake news in some cases, many authors adopt the techniques of noise removal and lowercasing for their database values.

Table 4 shows that TF-IDF vectorizer, countVectorizer and BoW models are the most reliable NLP techniques used by authors to train the model in the relevant extracted features and produce the best data evaluation results.

Table 5 shows that naïve Bayes, support vector machine and logistic regression are the most widely used controlled AI/ML algorithms. Among these, the support vector machine algorithm was found to be very popular in our survey. It can be seen that researchers have

Table 2.
Summary of datasets

Research paper	Data collection source
Nikam and Dalvi (2020)	Twitter API
Kar (2020)	Kaggle
Ahmad *et al.* (2020)	Kaggle, ISOT fake news dataset
Tiwari *et al.* (2020)	Kaggle, GitHub
Vogel and Meghana (2020)	PAN 2020 author profiling corpus
Salve (2020b)	Health and well-being dataset
Salve (2020d)	ISOT fake news dataset, Buzzfeed political news dataset, random political news dataset
Salve (2020a)	ISOT fake news dataset, LIAR dataset
Salve (2020c)	GitHub
Gautam and Jerripothula (2020)	Celebrity, FakeNewsAMT
Faustini and Covões (2020)	FakeBrCorpus; TwitterBR (Faustini and Covões, 2019); Fake_or_real_news; Fakenewsdata1; BTV Lifestyle
Traylor *et al.* (2019)	Novel and customized dataset
Kareem and Awan (2019)	Novel and customized dataset
Rusli *et al.* (2020)	Novel and customized dataset
Hussain *et al.* (2020)	Novel and customized dataset

Method	Nikam and Dalvi (2020)	Kar (2020)	Vogel and Meghana (2020)	Gautam and Jerripothula	Kareem and Awan (2019)	Rusli *et al.* (2020)	Hussain *et al.* (2020)	Traylor *et al.* (2019)	Salve (2020b)	Salve (2020d)	Salve (2020a)
Stop-word removal	✓	✓	✓	✓	✓	✓	✓			✓	✓
Tokenization	✓	✓	✓		✓			✓		✓	✓
Stemming	✓	✓			✓	✓				✓	✓
Blank row removal	✓		✓								
Lowercasing		✓			✓	✓					
Noise removal (emoticons, punctuations, special characters)					✓	✓	✓				
Normalization			✓								
Jurafsky and Martin text normalization					✓						
Replacing by placeholders			✓	✓							
Duplicate removal	✓										
Emotionalizing text			✓	✓					✓		
Convert text into English	✓										
English alphabet and digits removal							✓				

Table 3. Preprocessing methods' summarization

Table 4.
Summarization of feature extraction methods employed

Methods/Paper	Nikam and Dalvi (2020)	Kar (2020)	Ahmad *et al.* (2020)	Tiwari *et al.* (2020)	Vogel and Meghana (2020)	Salve (2020d)	Salve (2020a)	Salve (2020c)	Gautam and Jerripothula	Faustini and Covões (2020)	Traylor *et al.* (2019)	Kareem and Awan (2019)	Rusli *et al.* (2020)	Hussain *et al.* (2020)
TF-IDF vectorizer	✓	✓		✓	✓				✓	✓		✓	✓	✓
Bag of words		✓		✓			✓	✓		✓	✓	✓	✓	
CountVectorizer				✓	✓		✓	✓					✓	✓
Character and word n-gram					✓				✓				✓	
TF distribution					✓	✓								
Word embeddings (Word2Vec)					✓					✓				
GloVe12 (global vectors for word representation)					✓				✓					
Feature hashing/ Hashing vectorizer		✓		✓										
DictVectorizer		✓												
LIWC tool			✓											
ELMo embedding					✓									
Grammarly feature extraction									✓					
Spinbot paraphrasing									✓					
Document-class distance algorithm										✓				
Customized features										✓				
Attribution feature extraction											✓			

Algorithm/ methods	Nikam and Dalvi (2020)	Kar (2020)	Ahmad *et al.* (2020)	Tiwari *et al.* (2020)	Vogel and Meghana (2020)	Salve (2020b)	Salve (2020c)	Gautam and Jerripothula	Faustini and Covões (2020)	Traylor *et al.* (2019)	Kareem and Awan (2019)	Rusli *et al.* (2020)	Hussain *et al.* (2020)
Naïve bayes	✓	✓				✓	✓		✓		✓		
Support vector machine		✓			✓	✓			✓		✓		✓
KNN			✓	✓		✓			✓		✓		
Logistic regression			✓	✓	✓						✓		
Multinomial Naïve Bayes									✓				✓
Linear SVM			✓					✓					
Multi-layer perceptron (MLP)			✓									✓	
Perez SVM			✓										
CART			✓										
Passive aggressive	✓												
A-score										✓			

Table 5. Summary of supervised machine learning algorithms of the literature survey

increasingly adopted the use of ensemble algorithms in recent times over individual classifiers.

It is evident from recent research that most models are based on supervised learning algorithms that bestow their ability to provide better accuracy. As a result, there is a scarcity of unsupervised models for false news detection.

We can observe from Table 6 that *K* means and D.B. Scan algorithms are the two unsupervised learning algorithms used to categorize unlabeled data from a computer than manually labeled data to train the AI/ML model.

From our literature survey, we observe that ensemble learners tend to have higher accuracy, as more than one model is trained using a specific technique to reduce the overall error rate and improve the model's performance. They provide an almost optimal outcome in the majority of cases. Table 7 shows that the random forest algorithm approach is the most adopted ensemble method in our survey.

From the literature survey, we conclude that the performance of any given ML model is heavily based on the dataset used to train the classifier. Accuracy measures the closeness of prediction to the actual value for a given model (Kar, 2020). Figure 2 shows that it is a critical metric for authors to evaluate their model's results, followed by precision and F1-score.

2.3 Deep learning approaches for fake news detection

Deep learning is part of a broad family of machine learning methods based on artificial neural networks with representation learning. It is a subcategory of machine learning in artificial intelligence that has networks capable of learning unsupervised from unstructured or unlabeled data. It is a subcategory of machine learning that uses a hierarchical level of artificial neural networks to carry out machine learning. It has attracted a great deal of attention primarily because it is particularly good at a type of learning that can be very useful for real-life situations.

Table 6.
Summary of unsupervised machine learning algorithms of the literature survey

Algorithms/methods	Salve (2020b)
K-means	✓
DB-scan	✓

Table 7.
Summary of supervised ensemble machine learning algorithms of the literature survey

Algorithms/methods	Ahmad *et al.* (2020)	Tiwari *et al.* (2020)	Salve (2020b)	Salve (2020d)	Salve (2020a)	Gautam and Jerripothula	Faustini and Covões (2020)	Kareem and Awan (2019)
Decision tree	✓	✓	✓		✓			✓
Random forest	✓	✓	✓		✓	✓	✓	✓
Bagging classifier (DT)	✓			✓	✓			
Boosting classifier (AdaBoost)	✓		✓					
Boosting classifier (XGBoost)	✓				✓			

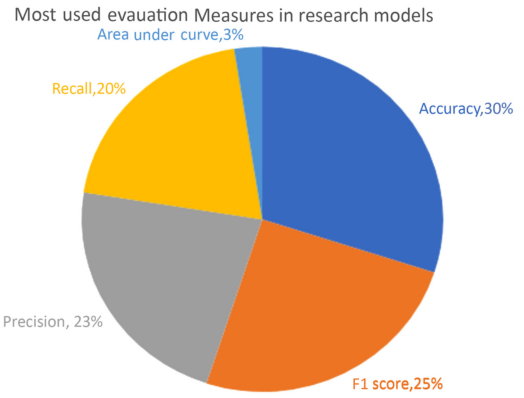

Figure 2.
Analysis of data evaluation parameters used in related work for ML models

The main objective of all the research that is ever done on this topic is to obtain several models based on deep neural networks aimed at detecting and categorizing fake news so that people can have some trust degree indicator of the information they consume and thus avoid bias and misconceptions. In general, there are various deep learning algorithms utilized for fake news detection. Our paper gives an overview of all the algorithms as seen in the tree (Figure 3), such as their accuracies achieved, their procedures and systematic comparative

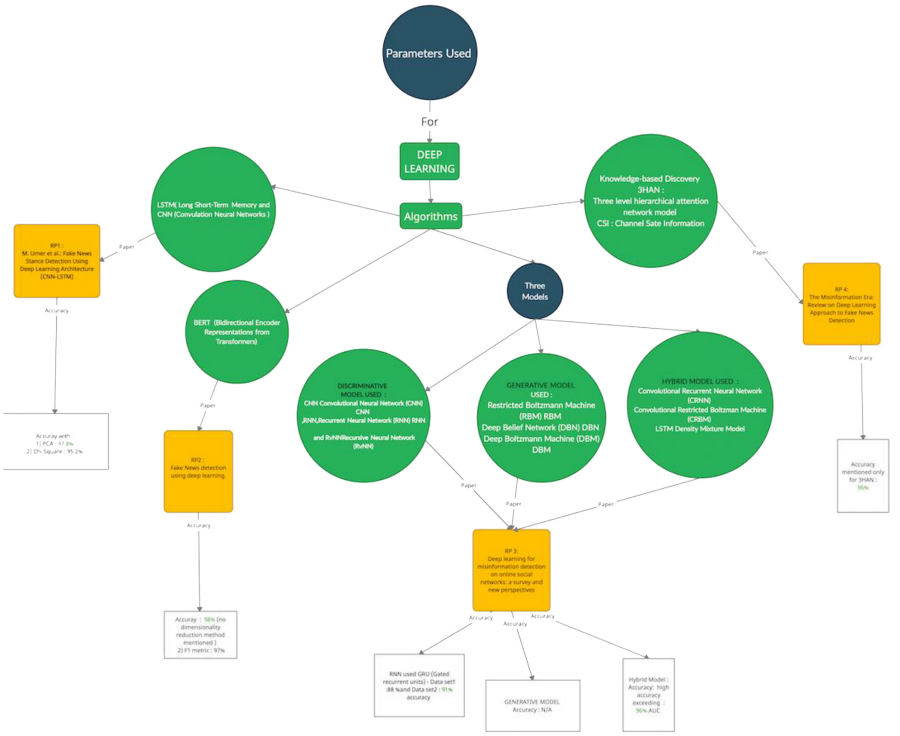

Figure 3.
Summarizing existing research work using deep learning approach models

study of which algorithm could be suitable for fake news detection. Other than already existing approaches, we will also summarize a novel method found for the same.

(Islam *et al.*, 2020) present a state-of-the-art systematic review of the existing problem solutions and validation of Minimal Infectious Dose (MID) (Fake news detection) in online social networks based on various deep learning techniques. To identify the latest and future trends of MID research, they analyze the key strengths and limitations of the various existing techniques and describe state-of-the-art deep learning as an emerging technique on massive social network data. It categorizes misinformation into five parts (false info, rumor, spam, fake news and disinformation). For example, you have been given a hotel review of E among N users to analyze user feedback, which contains real feedback and fake reviews created by hotel owners. It is not easy to differentiate the false review from the true ones. Hence, the researcher's role is to detect real and fake reviews. F(a) = {1, if a is false; 0 otherwise. It divided the DL techniques into three main categories based on the model: Discriminative models, generative models and hybrid models. All three categories have a great number of architectural models that are normally used for MID. However, due to differences in performance, they only discussed 12 models, namely under the three basic models: 1. The discriminative model includes (a) CNNs (b) Recurrent neural networks (RNNs) with different RNN architectures, namely tanh-RNN, LSTM and gated recurrent unit (GRU) and (c) Recursive neural networks (RVNNs). Among the proposed architectures, GRU has obtained the highest results, with 0.88 and 0.91 accuracies, respectively, for two datasets. 2. The generative model includes (a) RBMs (b) Deep Boltzmann machines (DBMs) (c) Deep belief networks (DBNs) and (d) Variational autoencoders (VAEs). 3. Hybrid model includes (a) Convolutional restricted Boltzmann machines (CRBMs) (b) Convolutional recurrent neural networks (CRNNs) (c) Ensemble-based fusion (EBF) and (d) LSTM which claims that their model can achieve high accuracy exceeding 0.96 as shown in the tree (reference).

Umer *et al.* (2020) in their study proposed a fake news stance detection model based on the headline and the body of the news irrespective of the previous studies, which only considered the individual sentences or phrases. The model incorporates principal component analysis (PCA) and chi-square with CNN and LSTM, in which PCA and chi-square extract the quality features passed to the CNN-LSTM model. First, it passes the nonreduced feature set with and without preprocessing to the neural network. Then the dimensionality reduction techniques are applied, and the results are compared. PCA elevates the classifier's performance for fake news detection as it removes the irrelevant, noisy and redundant features from the feature vector. This process produces promising results by scoring up to 97.8% accuracy whereas CNN-LSTM without preprocessing, with preprocessing and with chi-square gave lower accuracy ~78.4, 93, 95.2% respectively, which is considerably less efficient than the model with PCA. It is also appropriate to say that dimensionality reduction approaches can reduce the number of features while preserving the high performance of classifiers.

The authors of Rodríguez and Iglesias (2019) expressed the same problem to solve in a more formal way given as a news article defined by a set of own characteristics (i.e. title, text, photos, newspaper, author, etc.) a function f is sought such as f(a) = {0; if a is fake; 1 if a is true; it proposed three architectures relating to textual analysis for fake news detection. Two of those were created, optimized and trained from scratch, and the last one was fine-tuned from BERT, a pretrained language model which achieved state-of-the-art results in a significant number of NLP tasks. Even though there is not any benchmark available aimed at evaluating the task of fake news detection, the models presented here surpass the results in the original work which compiled the dataset used in the 2018 study (Yang *et al.*, 2018) (93% of accuracy; highest till now). This study permits us to state that the usage of deep learning models for fake news detection can be potentially efficient for a wide range of actors, from social network companies to the final user, to reduce the increasing fraud on the Internet.

In June 2019, (Saikh *et al.*, 2019) introduced a novel approach toward fake news detection; it briefs deep learning augmented with textual entailment features. They introduced two work methods that (1) Relates the problem to TE and proposes various ML-based models. It exploited the TE-based features and showed the effect of TE for stance classification and further for fake news detection. (2) It merged the ML feature values and extracted features from the DL network and fed them into a feed-forward neural network. In this way, they provide external knowledge to neural network-based models. This system defeats the state of the-art reported in the literature for the problem on this particular dataset. It inculcated both traditional supervised machine learning and deep learning approaches.

Randika (2020) gives a systematic outline of research done to identify fake news manually and automatically using deep learning techniques based on knowledge-based discovery, such as the 3HAN proposed to identify fake news using only text-based inputs. This mode has three levels of architecture, for each word, sentence and headline with a news article vector to represent an article in a hierarchical bottom-up manner. The model was trained on a dataset of fake articles from 2016 to 2017, with 65% of them being US presidential news, 15% for both regional news and world news and 5% for entertainment news. They arrived at 96% of the accuracy of fake news detection. A unique approach to the problem is given by this paper (Singhania *et al.*, 2017) by a simple model, which will output whether a claim is genuine or not. Another deep learning-based model is proposed as the CSI (channel state information) model. It is the potential to be used as a censoring tool by spiteful users or entities.

Moreover, the challenges incurred with these techniques for fake news detection (Singhania *et al.*, 2017) also involve the fact that no level of news can be identified as false or not. However, there are specific categories of false stories. If there is a rating available for any newsreader reader, they can use those standards to test it. However, most people do not check the validity of the information presented or receive other resources to verify the original story. These types of standards can be helpful for adoption models and will enhance research so that the standard can serve as a model for the models. This can also help create unbiased social media platforms that do not target political parties, positions or ideologies. That, too, could be part of a solution to the global political divide. It can also help make social media platforms like Facebook; Twitter has free conversations on their platform without making biased decisions regarding fake news. Resource protection is significant in matters affecting national security or any other important issue in dispute. These stories can be labeled as false stories by the government or another organization accused or convicted of any wrongdoing. These discovery algorithms should also protect the publisher, the author and the natural story sources. This will not be done using the printer's publishers, authors and sources. This could raise privacy concerns about the authors' details that would eventually expose the natural sources of the news. This is a significant concern for media freedom, as some governments have tried to crack down on journalists. Investigators should be more concerned about data protection, such as data collection that is not well-researched regarding false information detection models. We have tried to cover all the ways of overcoming these challenges via various algorithms used in the machine and deep learning approach in every reference we could.

There is also a lack of good data to conduct experimental research mentioned in a few papers. So, if research wants to improve at a faster rate, public databases need to be expanded. Some researchers have presented large datasets for false data acquisitions, although the number of databases should be increased and the data size should be more significant. Another research gap is that there is no place for comedy, parodies and satire. Investigators did not pay much attention to it as their primary goal was to identify false information. Those that imitate people with humor should be considered in terms of their artistic standards. Human intervention is needed to determine whether the news stories are

parody or satire, which is a method of further research. Models should be smart enough to identify these subtle differences, and further research is needed to achieve that.

2.4 Fake news detection research in post-COVID-19 pandemic era

It all started in 2019 in Wuhan, China due to the emergence of a highly contagious novel coronavirus, i.e. COVID-19. We are in 2021, and many parts of the world are still fighting the disease; we accept all of this as usual. The disease was initially treated as a common cold or virus now shows no signs of infection. The WHO and the world's governments have been taking steps to address the global problem. The controversial topic of COVID-19 starting point has seen conflicting opinions around the world. To date, we keep on seeing troughs and crests in the "affected" chart. A global health emergency announced continued outbreaks by the WHO on January 30, 2020 [1]. As of May 10, 2020, more than 4,145,000 people were infected with the disease, resulting in more than 281,900 deaths. Outbreaks appear to be exacerbated during the crisis, leading to an increase in infected people and deaths worldwide.

In recent years, social media has played a vital role in disseminating information on public health. During the COVID-19 epidemic, false news and false stories exposed a major issue that led to confusion and insecurity. At the beginning of the epidemic, the medical community also played a role in making the situation even more confusing by providing, in some cases, inaccurate and sometimes contradictory clues to COVID-19. There have been many media debates about who promoted the various conflicting positions. Two conflicting positions can be seen in many conversations between members of the medical community: on the one hand, those who were inclined to spread shocking news, and on the other hand, who had optimistic views in support of COVID-19. A few weeks after the onset of the epidemic, the views of nonexperts on respiratory infections can be seen in the mainstream media. It appeared that the entire scientific community (gastroenterologists, nephrologists, surgeons and neurologists), as per (Tagliabue *et al.*, 2020), were making statements and writing articles as if they were the leading experts of COVID-19. Some people have reportedly committed suicide after being detected with COVID-19 due to the dissembling of COVID-19 in social and mainstream media (Coronavirus: Indian Man "died by Suicide" after Becoming Convinced He Was Infected, n.d.).

The WHO expressed concern about a global misinformation "infodemic" in February 2020, recognizing that the COVID-19 pandemic would be fought on the ground and social media. That is because an effective vaccine rollout will rely on high vaccine confidence, and viral misinformation can adversely affect that confidence, leading to vaccine hesitancy; as per the WHO, as of February 18, 2021, a minimum of seven completely different vaccines across three platforms are unrolled in countries. Over 200 further immunogen candidates are in development at a constant time; over 60 are in clinical development. COVAX is a component of the ACT Accelerator (Access to COVID-19 Tools Accelerator), which the WHO launched with partners in 2020. COVAX, the vaccine pillar of ACT Accelerator, convened by Coalition for Epidemic Preparedness Innovations (CEPI), Global Alliance for Vaccines and Immunizations (Gavi) and WHO, aims to finish the critical part of the COVID-19 pandemic by dashing up the event of safe and effective vaccines against COVID-19 supporting the building of producing capabilities and dealing with governments and makers to confirm the fair and equitable allocation of the vaccines for all countries.

Following the outbreak of COVID-19, a rich literature study has surfaced on the amount of fake news and approaches to combat fake news. Past research concluded that ensemble and hybrid machine learning approaches provide a generalized model with higher accuracy, which outperforms the conventional single classifiers (Zhou, 2009), mainly when applied to new datasets. To overcome the drawback of overfitting, an ensemble stacking model (Al-Rakhami and Al-Amri, 2020) was proposed using SVM + RF (97.8% accuracy) for levels

0 and C4.5 (96% accuracy) as a level 1 meta-model, which was trained by the use of ten-fold cross-validation. The annotated dataset achieved reliable results (0.74 scores) using Bayesian generalized linear mixed model (GLMM) to ensure there was no bias in the manual labeling of 400k tweets as credible or noncredible. The authors suggest extracting 26 hand-crafted features related to COVID-19 to improve the automated detection of fake news. Kappa statistics are also suggested to be a better evaluation matrix for classifiers than simple accuracy. The results show that combining multiple learners is unnecessary when creating an ensemble model, as performance can degrade due to few weak classifiers. In the future, the use of complex content from other social networking websites can enhance the dataset with the implementation of an updated set of ensemble techniques.

In another work (Elhadad *et al.*, 2020), the authors proposed voting ensemble learning of ten machine learning classifiers to detect pandemic news in the English language. Upon completing the exploratory data analysis (EDA), the relevant textual features related to the user, location, time and publisher have been extracted from the data collected based on the BoW model and TF, and TF-IDF and word embeddings technique convert them to machine-readable numerical form. These data were randomly split into 80% training and 20% testing for performing a five-fold cross-validation technique to build a detection model by deploying the scikit-learn python library. This paper uses 12 metrics derived from the confusion matrix for performance evaluation from different perspectives, allowing the user to decide which classifier to choose for specific purposes, but overall, the NN, DT and LR classifiers offer the best results. In the future, the authors aim to extend this model in the detection of multilingual, shared and retweeted information in real time.

The researchers Khanday *et al.* (2020) and Maakoul *et al.* (2020) proposed a hybrid feature engineering technique to build a supervised machine learning model for the binary classification of a novel dataset of 5k tweets into propaganda and nonpropaganda classes. A total of 100 valuable features were extracted from the collected dataset, which is then split into 70% training and 30% testing set for performing ten-fold cross-validation. The paper suggests that fine-tuning machine learning algorithms by giving them different parameters give improved results. Results show that Decision Tree outperforms all other individual machine learning algorithms (98.5% accuracy, 0.99 precision, 0.99 recall and 0.99 F1-score), reflecting neither underfitting nor overfitting during the training and testing phase.

Maakoul *et al.* (2020) proposed a novel algorithm based on logistic regression to detect and analyze fake Facebook posts and comments related to the pandemic in the Moroccan context. The authors suggest using the LR algorithm because it executes based on the data provided and does not require previous theoretical rules to link the input and output of the model. Results also show that LR provides better accuracy compared to other algorithms. Due to the lack of availability of fake news datasets related to Morocco and restrictions on collecting data from Facebook, several open-source tools were used during the data-extraction phase, limiting the performance of the model. The paper suggests using special software or devoting more time to the data collection and cleaning phase to build a successful ML model. Verifying fake news in the image and video format (or DeepFake) is an important area for future research in text extraction and image recognition techniques.

Before the outbreak of COVID-19, researchers have concluded that social media plays a crucial role in the spread of health-related fake news in miseducating society (Waszak *et al.*, 2018). Thus in recent research, the authors Rashied Hussein *et al.* (2020) have developed a novel real-time machine learning model integrated with a search engine notification extension named SEMiNExt to prevent the spread of online fake news related to online health or COVID-related inquiries. In case of suspicion on the credibility of the news article, the notification pop-up in the browser suggests the user links to visit the WHO website and verify the information. In this paper, six ML classifiers are trained, and their performance parameters are compared, and the results show that Decision Tree provides the most

fantastic accuracy (84.3%) and F1-score (84.1%) when 80% of the data collected are used as the training set. The authors suggest that DM and DL techniques can be incorporated in the future to improve the outcomes of the proposed model.

Another novel pandemic news verification system named CoVerifi (Kolluri and Murthy, 2021) was developed using ML models to display credibility ratings obtained by the votes from other social media (Bing, Reddit and Twitter) users. This model was trained on bidirectional LSTM on news content from the COVID-19 dataset, CoAID (Cui and Lee, 2020), by performing 75% train and 25% test split, resulting in 0.93 F1-score, precision, recall and accuracy. The authors tested this trained model on a novel pandemic-related fake news dataset obtaining the result of 0.75 F1-score, precision, recall and accuracy, performing better than most models on random datasets. This proposed model uses an IP-based vote limitation (one vote per piece of content per IP address) approach to promote fair play and provide more incentives for the users to vote.

It is seen that specific topics have higher rates of producing fake news, and certain writers or spreaders have more probability and intention of producing fake news. The study by Liao *et al.* (2021) integrates representation learning and multitask learning, and this model produces better results as to the existing models. This line of research shows that while a fully automated real-world application based on a machine learning approach to evaluate the validity of a piece of news may indeed be possible, it appears to be a complicated, computationally intensive process with potentially marginal gains.

Deep learning is also a productive methodology for detecting COVID-19 fake news in matters of text classification (Koirala, 2020). However, the choice of definitive models is also fundamental, which can be visualized via the four different types of techniques performed (Koirala, 2020). It used (1) Logical regression accuracy, which gave an accuracy of 75.07% on the validation dataset. Application of stop-word removal, normalization measures (stemming, lemmatization) and n-grams applied before logistic regression resulted in a model with an accuracy of 75.65%. (2) Embedding with a dense layer provides training accuracy of 86.93% and validation accuracy of 68.74%. (3) Embedding layer with LSTM: The training accuracy and validation accuracy is 86.9 and 68.7%. (4) Bi-directional LSTM: The accuracy of 72.31% on the training set and 70.64% on the validation set was stated.

Also, deviation in the dataset might lead to a change in the model. The dataset used also has such inconsistencies. There are various kinds of fake news articles. Some news articles contain utterly false information, while some contain partially false statements. Some news articles are not complete, and some contain only advertisement texts. So, trying to learn such inconsistent data could be why the accuracy bar achieved is not so high. One way to deal with this could be subclassification among news articles and building hybrid models for the final classification. This would allow the initial models to only learn necessary parameters from subclasses. These parameters can be combined to build the final model, which would contain essential parameters included in every subclass, thus contributing to remodeling the accuracy of the overall classifier.

In the postpandemic era, it is observed that researchers focus more on the originating sources of content while validating data for the training of their fake news detection models. This shows a growing trend to define the legitimacy of any piece of information to be the intent and credibility of the publisher while delivering a news story. Hence, Table 8 shows that the focus is shifting more toward defining the validity of data based on facts collected from affiliated, reliable and unbiased institutions, such as an official health agency, WHO, UNICEF, United Nations, IFCN or a fact-checking platform. It was also noted that major international organizations were targeted for these purposes, not health ministries, to avoid inaccuracies and bias in the statements and information related to their country's COVID situation.

From Table 9, it should be noted that postpandemic research still focuses on the elimination of stop words and the breakdown of text into features through the use of

Source of information	Al-Rakhami and Al-Amri (2020)	Elhadad *et al.* (2020)	Khanday *et al.* (2020)	Maakoul *et al.* (2020)	Kolluri and Murthy (2021)	Koirala (2020)	AbdElminaam *et al.* (2021)
Twitter Application Programming Interface (API)	✓		✓				✓
Facebook				✓	✓		✓
Google fact check tools API		✓				✓	
World Health Organization (WHO) website		✓					✓
United Nations Children's Fund (UNICEF) website		✓					
United Nations (UN) website		✓					
Instant data scraper				✓			
Comments extractor				✓			
Bing news search API					✓		
Reddit news API					✓		
CoAID (Cui and Lee, 2020)					✓		✓
Novel dataset		✓			✓		✓
Webhose.io						✓	
The disaster dataset							✓
The gossip cop dataset							✓
The PolitiFact dataset							✓

Table 8.
Summary of datasets used in the postpandemic fake news detection

tokenization techniques as part of the preprocessing step for the proposed ML models to clean raw data. We also note that the lowering of dataset value technique has gained interest in producing a better model, even though few researchers (Elhadad *et al.*, 2020) argue that retaining capital letters is an effective heuristic in deciding the importance of the word used.

From Table 10, we observe that logistic regression, support vector machine and naïve Bayes are still the most popularly used supervised AI/ML algorithms, with increased use of the K nearest neighbor approach for fake news classification. Ensemble techniques are used more as they have ensured higher precision in prepandemic research in this area. More than one model is trained using a particular approach to provide optimal performance for the model.

In the postpandemic era, researchers have not investigated fake news detection algorithms for unsupervised machine learning approaches. We also observe that neural network and bidirectional LSTM are preferred DL algorithms for fake news verification.

From Table 11, we infer that researchers are using more data evaluation measures to test their models, derived from the confusion matrix (Elhadad *et al.*, 2020) for performance

Table 9.
Preprocessing method summarization

Pre-processing method	Al-Rakhami and Al-Amri (2020)	Elhadad *et al.* (2020)	Khanday *et al.* (2020)	Maakoul *et al.* (2020)	Salve (2020b)	Kolluri and Murth (2021)	Koirala (2020)	AbdElminaam *et al.* (2021)
Stop-word removal		✓	✓	✓	✓			✓
Tokenization		✓	✓	✓			✓	✓
Stemming		✓			✓			✓
Lowercasing				✓	✓			✓
Duplicate removal	✓	✓						
Standardization (after data fusion)		✓						
Numeric to text data conversion		✓					✓	
Irrelevant tweet removal	✓							✓
Dimensionality reduction		✓					✓	
Retweets removal						✓		
Removing unnecessary columns				✓				✓
PoS (part of speech) tagging		✓						
Capital letters heuristics		✓						
No short heuristics		✓						
Lemmatization			✓					
Transliteration				✓				
Punctuation mark removal					✓			
CountVectorizer							✓	
Baseline classifiers							✓	

Method	Al-Rakhami and Al-Amri (2020)	Elhadad *et al.* (2020)	Khanday *et al.* (2020)	Maakoul *et al.* (2020)	Salve (2020b)	Kolluri and Murth (2021)	Koirala (2020)	AbdElminaam *et al.* (2021)
Supervised machine learning								
Logistic regression		✓	✓	✓	✓		✓	✓
SVM	✓		✓		✓			✓
K nearest neighbor	✓	✓			✓			✓
NB	✓				✓			✓
Linear SVM		✓						
Multinomial NB		✓	✓					
Bernoulli NB		✓						
Bayes net	✓						✓	
C4.5	✓							
Ensemble (supervised) learning								
DT		✓	✓		✓			✓
RF	✓	✓			✓			✓
Boosting classifier (XGBoost)		✓						
Deep learning								
Neural network (DL)		✓					✓	✓
Perceptron neural network		✓						
Bidirectional LSTM						✓	✓	✓
LSTM								✓
GRU								✓
RNN								✓
CNN								✓

Table 10. Summary of ML and DL methodologies in COVID-19 fake news detection

Table 11.
Data evaluation methods' summarization

Method	Al-Rakhami and Al-Amri (2020)	Elhadad *et al.* (2020)	Khanday *et al.* (2020)	Maakoul *et al.* (2020)	Kolluri and Murth (2021)	Koirala (2020)	AbdElminaam *et al.* (2021)
Accuracy	✓	✓	✓	✓	✓	✓	✓
F1-score	✓	✓	✓		✓	✓	✓
Precision	✓	✓	✓		✓	✓	✓
Recall	✓		✓		✓	✓	✓
The area under the ROC curve	✓	✓					
Root relative squared error	✓						
Kappa statistics	✓						
Geometric Mean		✓					
Sensitivity		✓					
Specificity		✓					
Error rate		✓					
Miss rate		✓					
False discovery rate		✓					
Fall out rate		✓					
Omission rate		✓					
Loss curve						✓	
Neurons							✓
Dropout							✓
Regression rate							✓

evaluation from different perspectives, allowing the user to decide which classifier to choose for specific purposes.

3. Conclusion and discussion

False or misleading information that is sometimes purposefully disseminated in legitimate news media content to deceive people is referred to as fake news. It is written to infringe on the rights of a person, group or agency to profit financially by using false headlines or clickbait to increase online sharing and readership of the content. With the widespread advancement of the Internet, technology and social media platforms, a vast population can effectively like, share and disseminate their opinions, resulting in positive and, more importantly, negative societal consequences. Also, in COVID-19 pandemic, incorrect knowledge exacerbates the pandemic condition, especially during the vaccination stage. Hence, there is an increasing need to develop automated strategies to combat fake news, which is spreading at an unprecedented pace across these platforms.

This paper reviewed various efficient machine learning and deep learning algorithms to detect fake news for various datasets and COVID-19. In particular, we took a comprehensive view of all aspects related to machine learning and deep learning and how they aid in the detection of fake news. We compared several research papers and technologies from the pre- and post-pandemic era, illustrating them using tables, charts and trees. Others who decide to investigate ML and DL models for fake news detection may find our helpful paper. Machine learning and artificial intelligence play a legitimate role in fake news detection. There have been various possibilities in phony news detection models, and our extensive review of numerous algorithms will help build a robust model. It is hard to ascertain whether there is a single algorithm that produces the best results because the outcomes are heavily dependent on several factors such as the dataset used, the optimal degree to which the data are cleaned and pre-processed, the relevance of features extracted from it to train the classification model and the hyperparameter configurations.

The above analysis led us to the most reasonable conclusion: Naive Bayes, support vector machine and logistic regression are the most widely used supervised ML algorithms for developing fake news detection models. There has been a hike in the use of supervised ensemble learning classifiers in recent times, over individual classifiers, with the random forest algorithm approach becoming the most widely used ensemble method in our review. Researchers prefer supervised machine learning algorithms over unsupervised algorithms because they train on labeled datasets and provide results based on prior experience. In terms of accuracy, it outperforms unsupervised algorithms because document representation and clustering produce coherent clusters while ignoring different tasks of fake news detection.

Several novels take been taken while preprocessing the data to train fake news detection models. Stop-word removal, stemming and tokenization technique is most popularly performed to clean the data from the raw format. The ML models are increasingly being trained with a customized set of features to overcome the reliance of NLP systems on English features. Some research considers the use of emotionalizing the material due to highly emotional content in fake news posts. Overall, our analysis demonstrates that using feature-extraction techniques like bag of words and TF-IDF vectorizers when constructing models improves accuracy.

Deep learning algorithms are one of the best and the future of fake news detection. It is an effective technique for measuring the misinformation problem today, and it perfectly identifies false facts. The results and effectiveness are excellent, and they are comparable to human performance. DL algorithms can also be used to improve unlabeled and imbalanced data.

With the above-detailed analysis, we could conclude that PCA elevates the classifier's performance for fake news detection as it extracts the unrelated, noisy and redundant

features from the feature vector. This process produces good results by scoring up to 97.8% accuracy, which is significantly progressing than the early studies done. Also, one of the CNN-based models includes different metadata (text, author and title) to perform fake news detection. As a result, it has reached its highest accuracy with the text and author input. The most excellent accuracy score is 96%. This helps us to venture that it is possible to train neural networks concentrated on detecting fake news solely using textual-based characteristics and that results at the current level can be gained through the approaches proposed. However, the detection algorithm can be improved to detect edge case situations, parody and mockery.

Following the COVID-19 pandemic, researchers focus on building more hybrid ensemble models, with the Decision Tree algorithm now outperforming all other individual machine learning algorithms in terms of accuracy, precision and recall while exhibiting neither underfitting nor overfitting. There has been a surge in classification research using the K nearest neighbor supervised ML approach. Furthermore, no research into fake news identification for unsupervised ML approaches has been conducted. Neural network and bidirectional LSTM remain the preferred DL algorithms for fake news verification purposes.

A growing trend in defining the legitimacy of any piece of information is the publisher's intent and credibility when delivering a news story. To avoid inaccuracies and bias in statements and information related to their countries' COVID-19 situation, researchers have shifted their research focus to defining data validity based on facts collected from internationally affiliated, reliable and unbiased institutions, such as WHO, UNICEF, United Nations, IFCN, etc.

Individuals look to social media for reliable information on how to protect themselves and their family members. During the COVID-19 epidemic, false information spread by the medical community, scientific community and mainstream news media debates exposed a major issue that led to confusion and insecurity among the people. These events have fuelled interest in fully automated real-time applications based on machine learning and deep learning approaches. Despite the computationally intensive process with potentially marginal gains, there are clear considerations and opportunities for further research and advancement in this area.

We reviewed enhanced deep learning techniques to recognize fake news after the COVID-19 pandemic. Regarding the COVID-19 dataset, the best results are achieved by LSTM (two layers). The metric performance results are as follows: the accuracy is 98.6%, the precision is 98.55%, the recall is 98.6% and the F1-score is 98.5%. However, some criticism leveled at the use of DL techniques for causing delays due to manual fact-checking of large datasets. Therefore, deep learning-based algorithms are still an active research topic and need to be expanded in future research.

Many open issues in fake news detection necessitate the attention of researchers. The textual structure and writing style of new material and papers from various countries, territories, domains and sources are distinct. The findings presented in the study have limitations primarily due to the homogeneous data used in the analysis. Due to this, applying deep learning-based advanced approaches may not produce reliable results. However, sentiment analysis can provide crucial information about the overarching emotion and common trends associated with the topics across the available dataset used by researchers. Though there is clarity that a generalized model that can identify text from all news domains must be trained across multiple domains, due to the scarcity of publicly available large datasets, it is challenging to advance research beyond current models that depend solely on resource-rich languages such as English. Among the significant future research, the creation of local news article corpora for all languages and countries, preservation of data sources in news stories and the global standard of fake news detection. Another limitation of the study is the relatively lower volume and quality of data available for analysis. The smaller corpus is

due to the restriction in diverse and unbiased data covering various topics. A larger corpus can provide a more robust and insightful analysis to develop more advanced fake news detection technologies. Incorporating more tricky topics into the dataset can help improve the variety and veracity of the dataset, making it easier to use deep learning-based NLP methods. Few other challenges in our study include model privacy and feature enrichment, which need to be refined in future research work. Due to these constraints, the study could not establish a universal methodology for successful fake news detection.

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