

Fake News Detection Using Data Science: Datasets, Data Modalities, AI Approaches, Their Challenges and Future Perspectives

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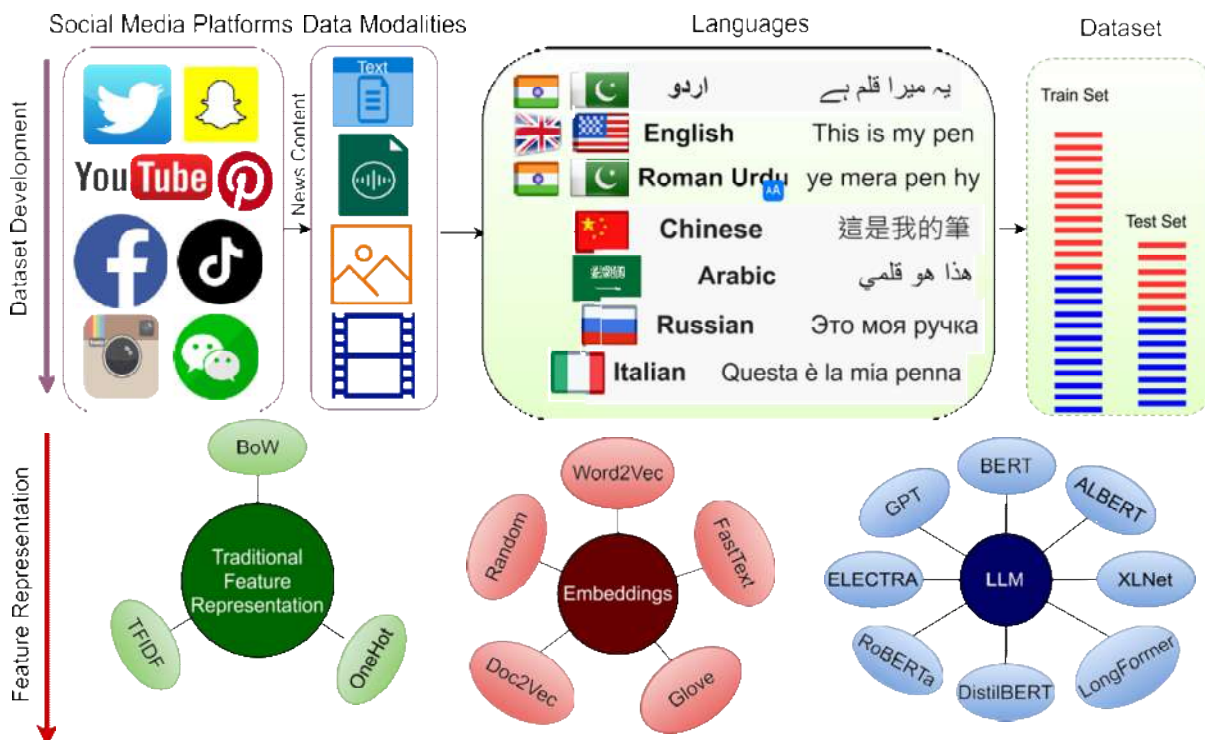
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Abstract: Social media platforms have transformed the world into a global village by providing a unique platform for unrestricted communication and opinion sharing. However, this freedom is used to spread misinformation and disrupt societal harmony. To combat misinformation and fake news on social media platforms, multifarious AI applications have been developed to detect such content in various languages and data modalities, including text, images, and videos. To establish a distinctive platform that fosters the rapid development of AI-driven fake news detectors, researchers have published several review articles in recent years. However, many of these articles are outdated, and lack comprehensiveness, particularly regarding recent trends, public datasets, representation learning methods, and classifiers details. The limited scope of articles hindered their ability to provide in-depth information on predictors' language specificity, data modality focus, and state-of-the-art performance across diverse languages. This paper offers a unique platform with detailed information on these aspects to address this gap. It offers a detailed roadmap for understanding the scope, strengths, and limitations of existing review articles on the subject. To support the development of new benchmark datasets and more accurate predictors, it conducts an in-depth analysis of the definitions and perspectives of fake news within the context of existing literature. This analysis provides a more comprehensive definition and basic concepts of fake news. In addition, 310 fake news detection articles published in the last 8 years have been thoroughly investigated. Within the landscape of these articles, the study presents details of languages, datasets, data modalities, predictor architecture designs, and their performance metrics.

I. INTRODUCTION

Facebook being the main platforms for spreading false information to influence voters' perceptions. Subsequent studies have demonstrated the impact of fake news on the electoral process, public health, and its role in polarizing public opinion. These incidents highlight the use of social media as a channel for spreading fake news and its adverse effects on society by eroding trust in government institutions and influential figures. They also highlight how people exploit social networks to spread fake news for political and economic purposes. Fake news spreads rapidly on social media through posts, comments, and fabricated news articles, often gaining traction through trending topics. The second driver for fake news being a technological threat is the ease of creating automated bot accounts to make fake news viral and trending resulting in various forms of fake news going viral within seconds. Third, generative AI tools such as large language models (LLMs) and deep fakes make it easy for anyone to generate misinformation online. These generative models can produce misinformation in different modalities in a few seconds. Therefore, automated tools to counteract the spread of fake news and detect the veracity of news of varied modalities have become an active research area. Fake news can spread on social networks in different modalities, including text, images, audio, and video.

In addition, news headlines and news articles on social networks play a vital role in spreading fake news. Social media posts usually contain text that can be posted by an individual or an organization. Mostly, people exploit the real post text and manipulate it to misguide the people. Fake image spreaders mostly change the image faces or captions of images. Similarly, audio forgery includes any manipulation of podcasts or speech to affect the person's reputation. Likewise, deep fakes for fake videos have become a serious concern that can damage the reputation of individuals and organizations. A survey conducted from 2012 to 2017 revealed that 40% of the links related to common diseases contained false information. During the COVID-19 pandemic, various fake brands claimed their products as 'immunity boosting'. The purpose of such fake news is to promote products, tarnish reputations, or boost product sales. Similarly, another example of fake news in the health domain is the claim that "fragmented dairy products may protect against heart attack". However, the studies showed that "fragmented dairy products does not protect against heart attack". Such type of fake news can have an enormous public health. It is essential to detect and stop the spread of such fake news among people. The rapid spread of fake news on social media platforms has become a significant concern in recent years, with far-reaching political, economic, and social consequences. Considering the threats associated with fake news in political, social, and health domains, there is a most need to develop AI-driven applications to detect fake news and keep the user informed about the authenticity of the information shared on social media. In recent years, numerous predictors have been developed and the goal behind the development to teach new predictor was to more accurately identify fake news content. The scope and methodologies of these predictors vary widely in terms of different languages and data modalities. Figure 1 provides a high-level overview of distinct phases involved in the development of AI-driven fake news detection applications. As shown in Figure 1, the crucial initial step is to gather news content from various social media platforms, including Facebook, Twitter, and other news sites. Researchers have created numerous datasets for various languages. Among these datasets, many are publicly available and can be used to evaluate the performance of newly developed predictors. After dataset development, the next step is to acquire informative features from distinct data modalities. As shown in Figure 1, researchers at this stage employ several distinct feature extraction strategies. After Feature extraction, the third phase is to use distinct modalities' features to discriminate content in real and fake news by utilizing machine/deep learning classifiers. The final phase involves evaluating the predictor based on its correct and incorrect predictions. The fake news detection landscape has witnessed the development of multifarious AI predictors with contributions either at the dataset level, feature extraction level, or classifier level. To provide a unique platform that facilitates the development of AI-supported fake news detectors, researchers have written around 11 distinct review articles. However, none of the review articles provides comprehensive detail on each phase of predictor development. Comprehensive details of existing review articles like scope and contributions are described.



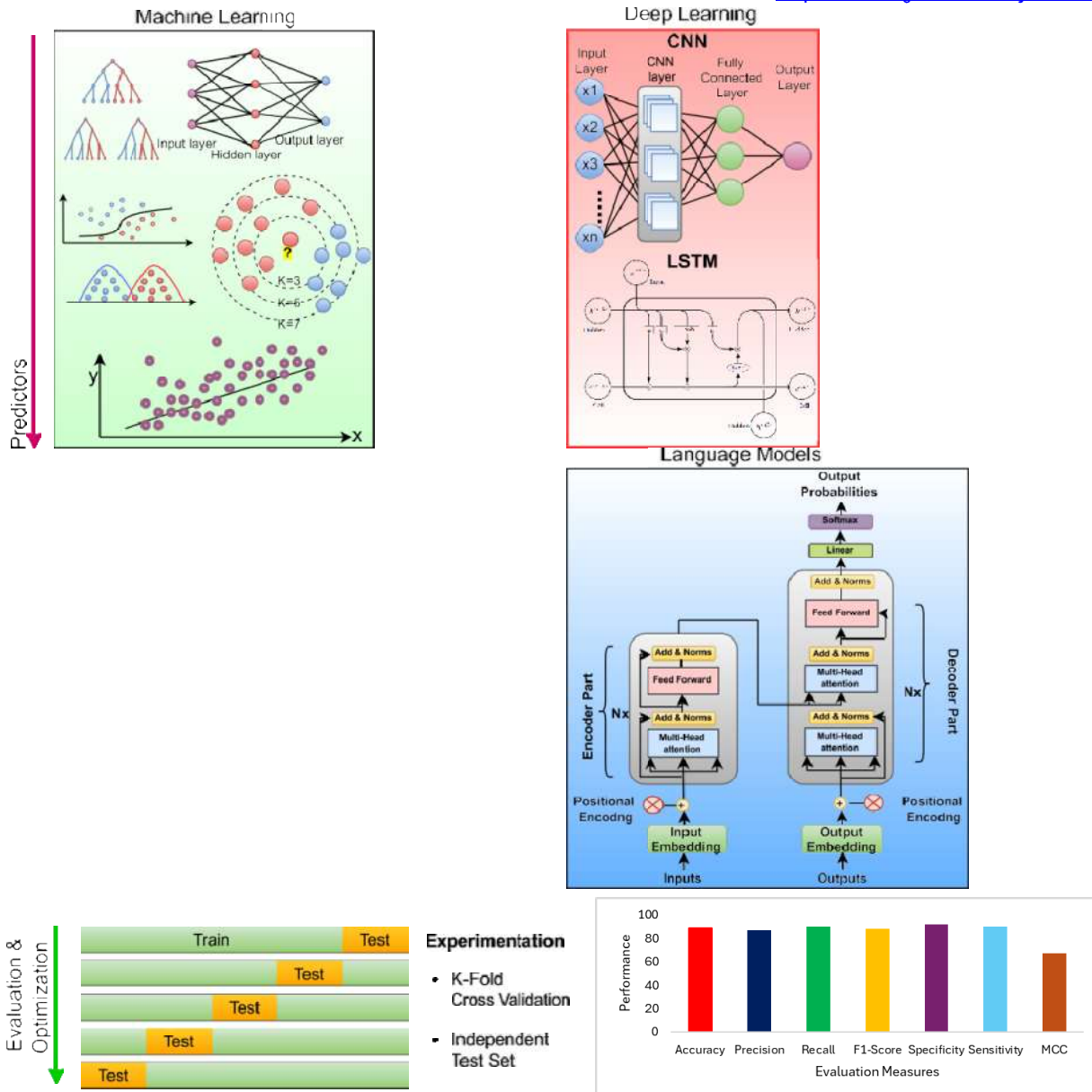


Figure I.A comprehensive overview of fake news detection predictive pipelines:

From dataset development to evaluation data modalities used to develop predictors for each language.

- 1) It provides a detailed analysis of existing predictor architectures, including the representation learning methods and classifiers used for each language.
- 2) Across 271 datasets, it presents predictors' performance values and highlights current state-of-the-art performance values across each public dataset.
- 3) To support large-scale comparative studies, it details existing predictors based on source code availability under different language paradigms and data modalities.

The remainder of this survey paper is structured as follows. Section II covers task formulation, including the background of fake news and fundamental theories. Section III provides a comparative analysis of our survey with the existing surveys. Section IV describes the survey methodology, including a detailed explanation of the PRISMA protocol used to conduct the review. Section V presents the details of fake news datasets and Section VI analyzes fake news studies across different languages and data modalities. The Section VII provides information about predictors source codes. Finally, Section VIII outlines challenges and future directions.

II. TASK FORMULATION

This section provides an overview of the concept of fake news drawing upon various definitions and theories from existing studies. It begins by presenting different definitions of fake news from the literature, highlighting the common themes and distinguishing characteristics. Next, it shows a mathematical representation of fake news, formalizing the concept using relevant variables and parameters.

This mathematical framework serves as a foundation for understanding the underlying structure and properties of fake news. To further elucidate the concept, we introduce key related concepts with examples as shown in Table 1. Finally, it explores the fundamental theories proposed to explain the emergence, dissemination, and impact of fake news. These theories draw from disciplines such as psychology, sociology, and communication studies, offering insights into the cognitive biases, social influences, and information-processing mechanisms that contribute to the proliferation of fake news. Establishing a solid conceptual foundation, this section sets the stage for the subsequent analysis of fake news detection techniques and datasets presented in the remainder of the survey paper.

What is Fake News?

There is no universally accepted definition of fake news. Different studies define fake news in different contexts. For the very first time, the term fake news was used in the 1890s when sensational reports in news papers were common. Later on, the word fake news was used in 2017 by the American Dialect Society and Collins Dictionary. In the early 20th century, fake news was defined as the *not only in accurate content but also entertainment-based content like satire and parody* . Later, the term was re-defined as *the fake news exists independently and is misinformation released as the real news*. Different studies also relate fake news with humor, retweeted on social media platforms like Twitter. Another study associates fake news with six different keywords: satire, parody, fabrication, advertising and public relation spresented, photo/video manipulation, and political

Fake New Concept	Examples
Satire	NASA Discovers A New Planet just to rub to other planets Faces
Hoax	In 1938, Orson Wells adoption of HG
Misinformation	People take vaccine will suffer from Covid-19 soon
Disinformation	Russian interference in US Election
Clickbait	Weired AI
Rumor	Share a certain post of bill Gates on Facebook and he will send you money
Fabricated News	A complete False story claiming that a child trafficking ring was being run out of a Washington D.C Pizzeria by high profile politician

We briefly list the different types of related concepts as follows.

- 1) Satire involves an exaggeration of any real-world news It adds humor to the news for public engagement and enjoyment. Satire generally targets current events and stories. The main purpose of satire is entertainment.
- 2) Hoaxes are half-truths about the real news These are for a short period and create sudden unrest among people. For example, the death of a celebrity is a hoax.
- 3) Rumors are ambiguous false stories spread as breaking news . These are for a longer time and confuse people about real news. Rumors propagate on trending real-world topics.
- 4) Click baits are attractive headlines for grabbing the audience's attention. These headlines deceive the public about the real story. Click bait articles and videos are mainly spreading on social media platforms.
- 5) Parody is similar to Satire but it is often non-factual. It also involves humor. The Onion is a well-known Parody website considered a real news site.
- 6) Fabricated news is created from the real news by adopting a similar style. It misguides the people unaware of the source's credibility and considers it true news.
- 7) News-related theories: These theories differentiate fake news from real news based on particular characteristics. Fake news is different in style and quality compared to true news. Another psychological theory presents that when fake news spreads intending to deceive the users, it manipulates the real story in Information manipulation theory was presented by Maccornak et al. , performed reality monitoring of news perceived by external sources and reasoning. The false news is increased in quantity as compared to real news.
- 8) User-related theories: These theories focus on the user characteristics that spread fake news. It also includes fake news followers, social media bots, and fake news commentators. People with incomplete information often add their beliefs as informational cascades. People who intend to be accepted socially spread fake news, and these are called reputational cascades. The prospect theory states that users undervalue the outcomes received by the real news and spread manipulated news. Another theory related to social and group identification suggests that individuals with in a particular group tend to spread fake news that aligns with their group's interests

III. A REVIEW OF EXISTINGS URVEYS AND OUR CONTRIBUTIONS

This section provides a high-level over view of the features that are the primary focus of this review and existing review articles. Following fake news detection predictor development key phases (shown in Figure 1), Table 2presents existing review articles' contributions concerning7 distinct features including details of datasets, languages, data modalities, representation learning methods, classifiers, source codes availability, state-of-the-art performance values across public datasets. This study does not consider the surveys that do not follow the AI paradigm for fake news detection (e.g. block chain fake news citation network analysis and watermarking for fake news detection). A deep analysis of Table 2 reveals that:

- 1) Existing surveys cover fake news detection techniques till the year 2023.
- 2) Existing surveys do not present information about distinct data modalities for fake news detection. Only two survey papers incorporated multiple modalities (text and image).
- 3) The representation learning techniques for different data types are not discussed in existing surveys.
- 4) Majority of the previous surveys focus on English language studies only. Two survey papers cover research in multiple languages.
- 5) The state-of-the-art performance on the fake news datasets is not reported in previous surveys. Two existing survey papers presented predictors' performance on a small selection of datasets.

Table 2. A comparative analysis of our survey and existing surveys.

Review Article	Studied cover till year	Multiple Languages	Multiple Data formalities	Representation of Learning Methods	classifier	Performance Matrics	Number of Datasets
[66]	2019				✓		0
[259]	2020				✓		0
[185]	2021	✓			✓	✓	61
[199]	2021				✓		23
[134]	2021		✓		✓		35
[205]	2021		✓		✓		14
[230]	2022						10
[9]	2022				✓	✓	0
[77]	2024	✓			✓		10
Our Survey	2024	✓		✓	✓		271

Our survey is different from the previous surveys due to the following characteristics:

- This survey is updated according to the time frame covering recent studies from 2016 till February 2024.
- It presents details of fake news detection predictors for different languages including English, Chinese, Arabic, Persian, Korean, Bengali, Urdu, Italian, Portuguese, and Russian.
- It presents a comprehensive review of multiple data modalities.
- It explains the representation learning approaches and predictors of architectural designs.
- It examines adiverse collection of datasets(271) and categorizes them into public, private, and public- forbidden groups.
- It presents the state-of-the-art performance of fake news datasets.

IV. SURVEY METHODOLOGY

This section provides a detailed overview of the research methodology used to identify articles focused on fake news detection. Figure 2 illustrates a two-stage process for article identification and selection.

ARTICLE IDENTIFICATION

The initial stage involves the formulation of quality search queries using different keywords to identify a wide range of relevant scholarly articles. The article identification module contains fake news keywords, analysis, methods, data modality keywords, and languages as illustrated in Figure 4. The keywords used for search include fake news, news misinformation, misinformation, news false information, false information, deceptive news, fabricated news, hoax news, fraudulent news, bogus news, misleading news, news disinformation, disinformation rumor, and fact-checking. To formulate quality search queries, keywords within the same category are combined using the OR operator while keywords of different categories are combined using the AND operator. For example, we combined these terms with logical operators such as "fake news" AND "detection" ,or "disinformation" OR "misinformation" AND "machine learning" to refine our search. Additionally, we applied database specific filters such as title, abstract, and keyword searches to improve precision. To acquire relevant papers, formulated search queries are executed on academic search engines such as Google Scholar,²ACM Digital Library,³Elsevier,⁴Wiley Online Library,⁵SpringerLink,⁶and ScienceDirect.⁷Additionally, data modality keywords i.e. text and images, were employed to explore sources referenced in extracted papers to identify more research articles.

ARTICLE SCREENING AND FILTERING

The second stage selects the most relevant articles in two steps. In the first step, titles and abstracts of 1,902 fake news studies were reviewed. This review analysis identified 429 articles related to fake news detection in different modalities and languages. The second step involves a full-text assessment of articles selected in the first step, resulting in 310 studies for detailed review.

JOURNAL-WISE DISTRIBUTION OF RESEARCH ARTICLES

This section analyzes the journals that published the fake news studies included in this systematic literature review. Figure shows a unique list of these journals, highlighting

- <https://scholar.google.com/>
- <https://www.acm.org/>
- <https://www.elsevier.com/>
- <https://onlinelibrary.wiley.com/>
- <https://link.springer.com/>
- <https://www.sciencedirect.com/>

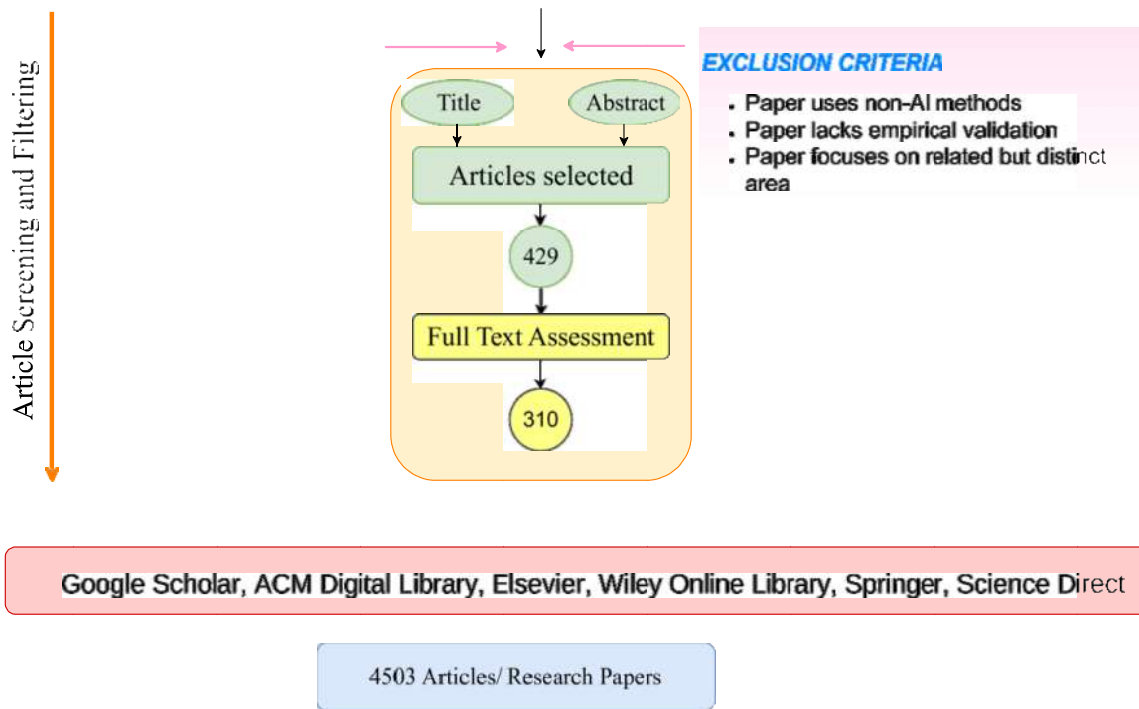
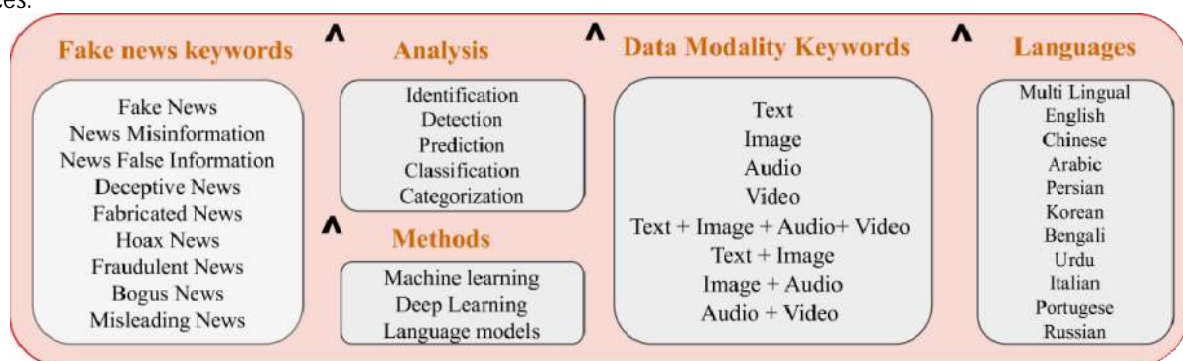


Figure 2.A comprehensive graphical representation of the survey methodology: From article search to final selection across distinct languages and data modalities.

V. FAKENEWS DETECTION DATASETS

The effectiveness of artificial intelligence-driven fake news detection systems fundamentally relies on the quality and diversity of training datasets. Our comprehensive analysis examined 271 distinct fake news detection datasets identified through a thorough review of 310 research articles. These datasets were developed using four primary strategies: manual news verification[12],[41], open web source tools, crowd-based evaluation [241], and fact-checking site assessments [240],[241]. To offer a structured understanding of the current landscape, we have categorized these datasets by language specificity, data modality, and availability status. Table 3 presents a detailed distribution of datasets across languages and modalities, categorizing them into public, private, and forbidden accessibility (where only a part of the dataset, such as Tweet IDs, are publicly available). The English language demonstrates the most extensive dataset coverage, particularly in textual content with 41 public and 58 private datasets. The integration of text and image modalities in English datasets shows moderate availability with 14 public and 7 private datasets. However, other modalities in English exhibit limited resources, with only one public dataset each for pure image and audio content, whereas video content maintains 4 public datasets. The Chinese language presents the second largest dataset collection, though significantly smaller than English resources.



VI. FAKE NEWS DETECTION ACROSS DISTINCT LANGUAGES AND DATA MODALITIES

This section presents a comprehensive analysis of fake news studies based on two fundamental parameters: language diversity and data modality. Figure 4 illustrates the distribution of the studies in ten languages and five distinct modalities, including text, text/image, image, audio, and video content. The analysis reveals significant trends in research focus and critical gaps in current detection capabilities. English language studies demonstrate substantial research attention, with 96 studies focusing on textual content. The integration of text and image modalities in English studies is explored in 23 research works. However, other modalities in English show limited investigation, with only two studies examining pure image-based detection. One study investigates audio content, while six studies examine video-based detection methods. This distribution highlights that textual content remains the primary focus of fake news detection research in English. The Chinese language represents these cond most studied domain, with five studies investigating text-based approaches and one examining text and image combinations. Multilingual detection methods show a relatively balanced distribution, with 11 studies exploring text-based detection. Five studies analyze text and image combinations, whereas only one focuses on image-based detection. The remaining languages, including Urdu, Russian, Korean, Italian, Persian, Bengali, and Portuguese, each have only one study dedicated solely to textual content analysis. A comparative analysis with existing surveys, as shown in Table 2, reinforces our comprehensive coverage. While previous surveys from 2019 to 2023 focused on specific aspects such as classifiers or performance metrics, our analysis examines 271 datasets spanning multiple languages and modalities. This broader scope enables us to identify critical research gaps, including limited exploration of non-textual modalities in non-English languages and minimal investigation of cross-modal approaches. The evident research concentration in English language content and text-based approaches indicates substantial limitations in current fake news detection capabilities. This imbalance necessitates increased research attention toward developing detection methods for diverse languages and modalities. Such expansion would strengthen our ability to combat misinformation across various cultural and linguistic contexts.

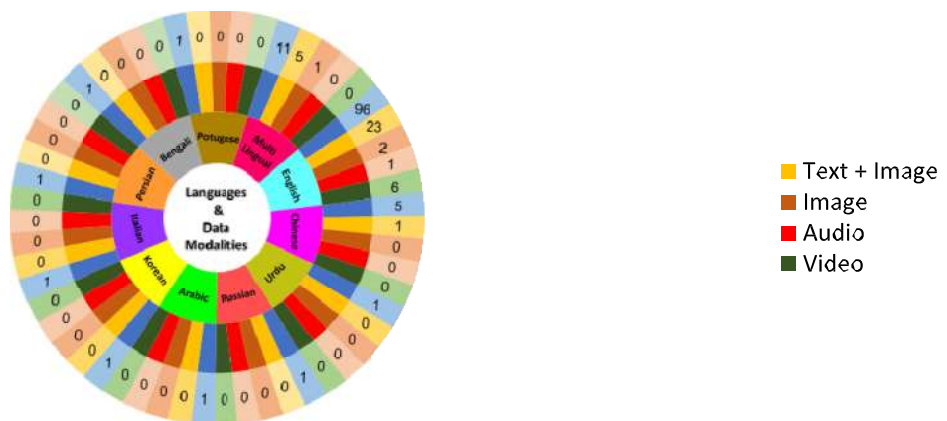


Figure 4. Distribution of fake news detection public datasets across distinct data modalities and languages

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