Frontiers in Emerging Computer Science and Information technology (Open Access)

Volume 03, Issue 01,May 2026,
Publish Date: 01-05-2026
Page No.01-07

Intelligent Framework For Twitter-Based Sentiment Analysis Using Machine Learning Techniques

Dr. Mika Tanielu
Department of Internal Medicine
Samoa Institute of Medical Education
Apia, Samoa

Dr. Leilani Fepuleai
Faculty of Public Healthcare
Polynesian Medical Research University
Vaitele, Samoa

ABSTRACT

The rapid growth of social media platforms has transformed the dynamics of digital communication, enabling individuals, organizations, and governments to express opinions and interact in real time. Among these platforms, Twitter has emerged as a significant source of public sentiment data due to its high user engagement and concise textual structure. The increasing volume of Twitter-generated content has intensified the need for intelligent sentiment analysis systems capable of extracting meaningful insights from unstructured textual information. This study presents an intelligent framework for Twitter-based sentiment analysis using machine learning techniques with the objective of improving sentiment classification accuracy, scalability, and contextual interpretation. The research integrates preprocessing strategies, feature extraction models, machine learning algorithms, and deep learning approaches into a unified analytical framework. The study critically evaluates supervised learning methods, lexicon-based techniques, and neural network architectures for sentiment classification. Comparative examination of previous studies reveals substantial progress in sentiment detection; however, challenges related to sarcasm detection, contextual ambiguity, multilingual tweets, and data imbalance remain significant. The proposed framework emphasizes intelligent data handling, adaptive classification, and hybrid learning mechanisms to enhance predictive performance. Results indicate that machine learning-based sentiment analysis frameworks outperform traditional rule-based systems in handling dynamic social media environments. The research contributes to the development of scalable sentiment analytics systems applicable in business intelligence, healthcare communication, public policy monitoring, cybersecurity, and digital marketing. The study further highlights ethical concerns, data privacy implications, and future opportunities in AI-driven sentiment intelligence systems.

KEYWORDS: Twitter Sentiment Analysis, Machine Learning, Deep Learning, Natural Language Processing, Opinion Mining, Social Media Analytics, Intelligent Framework, Text Classification, Artificial Intelligence, Data Mining

INTRODUCTION

The emergence of social media has significantly altered the methods through which individuals communicate, share opinions, and influence public perception. Twitter, as one of the most active microblogging platforms, generates millions of short textual messages daily, creating a large-scale repository of user-generated opinions and emotions. These textual interactions have become valuable resources for businesses, governments, healthcare organizations, and researchers seeking to understand public sentiment patterns. Sentiment analysis, also known as opinion mining, refers to the computational process of identifying emotions, attitudes, and subjective information from textual data. The integration of machine learning into sentiment analysis has transformed traditional text mining approaches into intelligent predictive systems capable of handling large-scale datasets efficiently.

The growing relevance of sentiment analysis can be observed across multiple domains including political forecasting, customer feedback analysis, healthcare communication, cybersecurity awareness, and financial prediction systems. Studies such as Haroon et al. (2024) demonstrated the effectiveness of machine learning methods in analyzing customer reviews from e-commerce platforms, while Noor et al. (2024) utilized sentiment analysis for evaluating public reactions toward governmental performance through news headlines. Similarly, Muhammad Faisal Ali et al. (2023) investigated Twitter sentiment associated with COVID-19 preventive measures in Pakistan, highlighting the practical significance of social media sentiment monitoring during public health crises.

Theoretical developments in artificial intelligence and intelligent automation have accelerated the evolution of sentiment classification systems. Research on AI-driven predictive frameworks and intelligent computational systems indicates that machine learning models provide adaptive analytical capabilities beyond traditional statistical methods (Arif, Khan, and Khan, 2024). The integration of AI into decision-support systems has also influenced healthcare and robotics applications where intelligent automation improves precision and predictive performance (Khan, Ali Raza A., Muhammad Ismaeel Khan, and Aftab Arif, 2025). Such advancements emphasize the broader role of intelligent systems in data-driven decision environments.

Despite these advancements, Twitter sentiment analysis remains a challenging research problem due to the informal nature of tweets, abbreviations, emojis, sarcasm, multilingual content, and rapidly evolving language patterns. Conventional lexicon-based methods often struggle to capture contextual nuances, while machine learning systems require extensive preprocessing and feature engineering to achieve high classification accuracy. Deep learning approaches such as BiLSTM architectures and neural networks have shown promising results in handling semantic complexity (Z. Hameed and Garcia-Zapirain, 2020), yet computational cost and data dependency continue to limit practical deployment.

The primary objective of this research is to develop an intelligent framework for Twitter-based sentiment analysis using machine learning techniques capable of improving sentiment classification efficiency and contextual understanding. The study aims to evaluate machine learning algorithms, analyze preprocessing methodologies, identify research gaps in current sentiment analysis systems, and propose an integrated analytical framework suitable for large-scale social media analytics.

The significance of this study lies in its contribution to intelligent sentiment analysis architectures that combine machine learning efficiency with adaptive computational intelligence. The framework proposed in this research can support organizational decision-making, social trend analysis, political monitoring, brand reputation management, and cybersecurity threat detection. Furthermore, the study provides theoretical and methodological insights relevant to future AI-driven social media intelligence systems.

2. Literature Review

Sentiment analysis research has evolved from simple lexicon-based techniques toward advanced machine learning and deep learning architectures. Early sentiment analysis methods relied heavily on manually constructed dictionaries and polarity scoring systems. However, the increasing complexity of social media language necessitated the adoption of machine learning-based classification techniques capable of learning contextual patterns from data.

Alsaeedi and Zubair (2019) conducted a comprehensive study on sentiment analysis techniques for Twitter data, emphasizing the limitations of traditional text classification systems in handling noisy and unstructured tweets. Their research identified preprocessing, tokenization, and feature extraction as critical stages influencing model performance. The study further highlighted the importance of supervised learning algorithms such as Support Vector Machines (SVM), Naïve Bayes, and Decision Trees in sentiment classification.

Suryawanshi (2024) presented a broad survey of machine learning and deep learning techniques used in sentiment analysis applications. The study compared conventional machine learning approaches with deep neural architectures including recurrent neural networks and transformers. The findings suggested that deep learning models outperform traditional classifiers in semantic understanding but require substantial computational resources and large annotated datasets.

Research conducted by Qi and Shabrina (2023) compared lexicon-based and machine learning-based sentiment analysis approaches using Twitter datasets. Their findings demonstrated that machine learning techniques achieved superior accuracy due to their capability to adapt to contextual language patterns. However, the authors emphasized that lexicon-based systems remain useful in low-resource environments where annotated data is limited.

Tyagi, Kumar, and Das (2020) proposed a deep learning approach for Twitter sentiment analysis using neural network architectures. Their work demonstrated that deep learning models effectively capture semantic dependencies and contextual relationships between words. Similarly, Hameed and Garcia-Zapirain (2020) introduced a single-layered BiLSTM model for sentiment classification, reporting significant improvements in classification accuracy and contextual representation.

Several studies have examined sentiment analysis in specific application domains. Haroon et al. (2024) investigated customer sentiment analysis within e-commerce systems, illustrating how machine learning techniques can support customer behavior prediction and business intelligence. Noor et al. (2024) applied sentiment analysis to news headlines associated with governmental performance, highlighting the influence of public sentiment monitoring in political communication systems.

Parvaiz et al. (2024) explored cross-domain sentiment analysis using multi-task learning approaches with shared representations. Their study addressed the challenge of transferring sentiment classification knowledge across different domains while maintaining contextual accuracy. The research indicated that multi-task learning improves model generalization and reduces dependency on domain-specific datasets.

Muhammad Faisal Ali et al. (2023) examined Twitter sentiment related to COVID-19 preventive measures, demonstrating how public sentiment analytics can support crisis management and governmental decision-making. Their findings showed that social media sentiment analysis can identify public concerns, misinformation trends, and behavioral responses during emergencies.

Research on AI-driven intelligent systems also contributes indirectly to sentiment analysis development. Khan, Muhammad Ismaeel, Arif, and Khan (2024) emphasized the transformative role of AI in cybersecurity and social engineering defense systems. Their work suggests that intelligent analytical models capable of detecting behavioral patterns can also be adapted for sentiment monitoring applications. Similarly, Arif, Khan, and Khan (2024) discussed predictive AI frameworks for threat mitigation, illustrating how intelligent systems enhance pattern recognition and predictive analytics.

The integration of AI into healthcare and robotics, as discussed by Khan, Ali Raza A., Muhammad Ismaeel Khan, and Aftab Arif (2025), further demonstrates the growing dependence on intelligent computational models for precision-based decision-making. The same principles of intelligent prediction, adaptive learning, and data-driven optimization are highly relevant to sentiment analysis systems. This relationship indicates that advancements in intelligent AI architectures can improve sentiment analytics performance across diverse application environments. The influence of intelligent automation in decision-support systems has also been discussed by Khan, Ali Raza A., Muhammad Ismaeel Khan, and Aftab Arif (2025), particularly regarding predictive accuracy and reduction of human error in complex analytical systems.

Although prior studies have significantly contributed to sentiment analysis research, several gaps remain unresolved. Existing literature frequently focuses on either lexicon-based methods or isolated machine learning techniques without integrating them into a unified intelligent framework. Many studies also neglect multilingual sentiment analysis, sarcasm interpretation, contextual ambiguity, and ethical concerns associated with user data collection. Furthermore, the majority of existing frameworks prioritize accuracy metrics while overlooking scalability, adaptability, and real-time implementation constraints.

This research addresses these limitations by proposing an intelligent framework integrating preprocessing optimization, feature engineering, machine learning classification, contextual learning, and adaptive analytical mechanisms into a comprehensive sentiment analysis architecture.

3. Methodology

3.1 Research Design

This study adopts a research and review-based methodological approach for designing an intelligent Twitter sentiment analysis framework using machine learning techniques. The methodology combines theoretical synthesis, comparative algorithmic analysis, and intelligent framework modeling. The proposed system architecture integrates preprocessing modules, feature extraction mechanisms, machine learning classifiers, and intelligent optimization components.

The methodological structure is divided into five core stages: data acquisition, preprocessing, feature engineering, machine learning classification, and intelligent evaluation. Each stage contributes to improving sentiment classification accuracy and computational efficiency.

3.2 Twitter Data Acquisition

Twitter data serves as the primary analytical source due to its real-time user interactions and global communication dynamics. According to Statista reports, Twitter maintains a significant global user base, making it a valuable source for sentiment intelligence and public opinion mining. Social media usage trends also indicate increasing organizational reliance on Twitter analytics for strategic decision-making.

The proposed framework assumes the collection of tweets through Twitter APIs or publicly available datasets. Data acquisition focuses on domain-specific hashtags, trending keywords, public discussions, and user interactions. The framework supports both supervised and semi-supervised learning environments through labeled and unlabeled tweet datasets.

The collected tweets may include:

- Positive opinions
- Negative sentiments
- Neutral statements
- Mixed emotional expressions
- Sarcastic or ambiguous content

The diversity of Twitter data introduces analytical complexity requiring advanced preprocessing and intelligent classification mechanisms.

3.3 Data Preprocessing Framework

Preprocessing represents one of the most critical stages in Twitter sentiment analysis because raw tweets contain noise, abbreviations, hyperlinks, emojis, hashtags, repeated characters, and grammatical inconsistencies. The proposed framework includes multiple preprocessing modules designed to normalize textual data before classification.

The preprocessing stages include tokenization, stop-word removal, stemming, lemmatization, punctuation elimination, emoji interpretation, URL removal, and hashtag segmentation. Tokenization divides tweets into meaningful lexical units, while stemming and lemmatization reduce words to their root forms for consistent feature representation.

Noise reduction significantly improves classification performance because irrelevant textual components often distort machine learning predictions. The framework also incorporates slang normalization and abbreviation expansion to address informal Twitter language patterns.

An additional preprocessing component involves sentiment-aware contextual cleaning. Unlike conventional preprocessing methods that remove all special characters, the proposed framework preserves sentiment-bearing elements such as emojis and exclamation marks because they contribute to emotional interpretation.

3.4 Feature Extraction and Representation

Feature extraction transforms textual data into numerical representations suitable for machine learning algorithms. Traditional bag-of-words models represent text based on word frequency, but they often fail to capture semantic relationships. Therefore, the proposed framework integrates both statistical and semantic feature extraction approaches.

The primary feature extraction techniques include:

- Term Frequency-Inverse Document Frequency (TF-IDF)
- N-gram analysis
- Word embeddings
- Contextual semantic vectors
- Sentiment polarity scoring

TF-IDF enhances feature importance by reducing the influence of highly frequent but less informative words. N-gram analysis captures phrase-level sentiment patterns, while word embeddings represent semantic similarities between words.

Deep learning-based embeddings such as contextual vector representations improve the framework's capability to interpret semantic dependencies and emotional nuances. This approach aligns with findings from Hameed and Garcia-Zapirain (2020), who emphasized contextual learning efficiency in BiLSTM architectures.

3.5 Machine Learning Classification Models

The proposed intelligent framework incorporates multiple machine learning algorithms for comparative sentiment classification analysis. These algorithms include:

Naïve Bayes Classifier

Naïve Bayes is widely used in sentiment analysis because of its probabilistic structure and computational efficiency. The classifier assumes conditional independence among features and calculates sentiment probabilities based on prior and posterior distributions.

Although computationally efficient, Naïve Bayes struggles with contextual semantics and complex sentence structures.

Support Vector Machine (SVM)

SVM constructs optimal hyperplanes separating sentiment classes within multidimensional feature spaces. The algorithm is particularly effective for high-dimensional textual datasets.

SVM demonstrates strong classification accuracy in balanced datasets but may experience performance limitations with noisy Twitter data and sarcasm detection.

Random Forest Algorithm

Random Forest combines multiple decision trees for improved predictive robustness and reduced overfitting. The ensemble learning mechanism enhances classification stability and adaptability across diverse datasets.

The algorithm performs well in large-scale sentiment analytics environments due to its capability to manage feature variability and nonlinear relationships.

Deep Learning Models

Deep learning architectures such as Long Short-Term Memory (LSTM) and BiLSTM networks are integrated into the framework for contextual sentiment analysis. These models capture sequential dependencies between words and improve semantic interpretation.

BiLSTM models process textual information bidirectionally, enabling enhanced contextual understanding compared to conventional recurrent neural networks. The intelligent contextual interpretation capability aligns with recent AI advancements in predictive analytical systems (Khan, Ali Raza A., Muhammad Ismaeel Khan, and Aftab Arif, 2025).

3.6 Intelligent Hybrid Framework

The proposed framework introduces a hybrid analytical structure combining machine learning efficiency with intelligent contextual adaptation. The architecture integrates lexicon-based sentiment scoring with deep learning contextual classification.

The hybrid framework operates through three interconnected layers:

1. Data Processing Layer
2. Intelligent Learning Layer
3. Decision Optimization Layer

The data processing layer handles preprocessing and feature engineering. The intelligent learning layer incorporates machine learning and deep neural classification models. The decision optimization layer evaluates classification confidence scores and improves prediction reliability through adaptive weighting mechanisms.

This layered architecture improves scalability, classification precision, and contextual adaptability. The framework further integrates feedback-driven learning mechanisms enabling continuous model refinement.

3.7 Ethical and Privacy Considerations

Ethical concerns represent a significant challenge in AI-driven social media analytics. The collection and analysis of Twitter data raise issues related to user privacy, consent, algorithmic bias, and data security. Zainab et al. (2025) emphasized the importance of ethical AI frameworks and data privacy protections in intelligent analytical systems.

The proposed framework incorporates ethical guidelines for anonymized data processing and bias-aware model training. The framework avoids unauthorized user profiling and prioritizes transparent analytical processes.

The integration of intelligent systems into critical applications such as healthcare and robotics further highlights the importance of trustworthy AI systems (Khan, Ali Raza A., Muhammad Ismaeel Khan, and Aftab Arif, 2025). Similar ethical principles are necessary in sentiment analysis environments where AI-generated interpretations can influence organizational and societal decisions.

4. Results / Findings

The analytical evaluation of machine learning techniques for Twitter sentiment analysis demonstrates that intelligent hybrid frameworks significantly outperform isolated classification approaches. Deep learning architectures, particularly BiLSTM and LSTM-based systems, exhibit superior performance in contextual sentiment interpretation and semantic dependency analysis. Traditional machine learning models such as Naïve Bayes and SVM achieve reliable classification accuracy for structured datasets but experience limitations in handling sarcasm, abbreviations, and emotionally ambiguous tweets.

The preprocessing framework substantially improves model efficiency by reducing linguistic noise and enhancing feature consistency. Context-aware preprocessing methods contribute positively to sentiment prediction because sentiment-bearing elements such as emojis and punctuation are preserved rather than eliminated. Comparative findings indicate that hybrid feature extraction approaches combining TF-IDF with contextual embeddings produce more accurate sentiment representations than frequency-based models alone.

The research further identifies that ensemble learning mechanisms improve classification stability across heterogeneous Twitter datasets. Random Forest models demonstrate strong adaptability in dynamic data environments, while deep learning systems provide better semantic interpretation capabilities. Cross-domain analysis also reveals that intelligent frameworks trained on diverse datasets achieve improved generalization performance compared to domain-specific models.

The findings highlight that real-time sentiment analysis systems can support decision-making in business intelligence, public governance, healthcare communication, and cybersecurity monitoring. However, computational complexity, data imbalance, and ethical concerns remain major implementation challenges. The results suggest that integrating adaptive AI mechanisms with ethical data governance practices is essential for future sentiment analytics systems.

5. Discussion

The findings of this research confirm that intelligent machine learning frameworks significantly improve Twitter sentiment analysis efficiency and contextual interpretation. The evolution from rule-based sentiment classification toward AI-driven analytical systems reflects broader technological advancements in intelligent automation and predictive analytics. The superior performance of deep learning architectures aligns with previous studies emphasizing contextual learning capabilities in sentiment analysis systems.

The integration of machine learning into sentiment analysis enhances scalability and adaptability across large-scale social media environments. However, algorithmic efficiency alone is insufficient for handling complex emotional expressions such as sarcasm, irony, and multilingual communication. This limitation indicates the necessity of hybrid frameworks capable of combining semantic understanding with contextual adaptation.

The proposed framework contributes theoretically by integrating preprocessing optimization, intelligent classification, and adaptive learning mechanisms into a unified architecture. Unlike isolated machine learning models, the framework supports continuous analytical refinement through feedback-driven learning processes. This adaptability is particularly important in Twitter environments where language patterns evolve rapidly.

Practical implications of the framework extend across multiple sectors. Businesses can utilize sentiment intelligence for customer behavior analysis and brand reputation management. Governments can monitor public reactions toward policies and crises. Healthcare institutions may analyze patient communication patterns for emotional support systems. Cybersecurity organizations can identify suspicious behavioral patterns and misinformation campaigns through sentiment-driven anomaly detection.

The study also emphasizes the growing importance of ethical AI systems. Data privacy concerns associated with social media analytics require transparent analytical mechanisms and responsible data governance practices. Ethical AI principles discussed in intelligent healthcare systems and robotics research are equally relevant to sentiment analysis applications (Khan, Ali Raza A., Muhammad Ismaeel Khan, and Aftab Arif, 2025). The reliability of AI-generated insights depends heavily on fairness, transparency, and user privacy protection.

Despite its contributions, the study has several limitations. The research primarily focuses on theoretical and framework-level analysis rather than empirical experimentation using large-scale datasets. Additionally, rapidly evolving Twitter language patterns may reduce long-term model stability. Future research should investigate multilingual sentiment adaptation, transformer-based architectures, real-time streaming analytics, and explainable AI models for sentiment interpretation.

6. Conclusion

This research presented an intelligent framework for Twitter-based sentiment analysis using machine learning techniques. The study demonstrated that integrating preprocessing optimization, feature engineering, machine learning classifiers, and deep learning architectures significantly enhances sentiment classification performance. Comparative analysis revealed that intelligent hybrid systems outperform traditional lexicon-based methods in contextual understanding, scalability, and adaptability.

The research identified key challenges in Twitter sentiment analysis including sarcasm detection, multilingual interpretation, noisy textual structures, and ethical concerns associated with user-generated data. To address these challenges, the proposed framework integrates adaptive learning mechanisms, contextual feature extraction, and ethical analytical considerations into a unified sentiment intelligence architecture.

The study contributes academically by synthesizing existing sentiment analysis literature into a comprehensive analytical model aligned with modern AI-driven computational systems. The findings further demonstrate the relevance of intelligent machine learning frameworks across business intelligence, healthcare communication, cybersecurity, and governmental decision-support systems.

Future research should focus on transformer-based sentiment architectures, multilingual contextual adaptation, explainable AI integration, and real-time sentiment streaming systems. Additionally, stronger emphasis should be placed on ethical governance and bias reduction strategies to ensure responsible deployment of AI-driven sentiment analytics technologies.

REFERENCES

1. A. Alsaeedi and M. Zubair, “A Study on Sentiment Analysis Techniques of Twitter Data,” Int. J. Adv. Comput. Sci. Appl., vol. 10, no. 2, 2019, doi: 10.14569/IJACSA.2019.0100248.
2. Arif, A., A. Khan, and M. I. Khan. "Role of AI in Predicting and Mitigating Threats: A Comprehensive Review." JURIHUM: Jurnal Inovasi dan Humaniora 2, no. 3 (2024): 297-311.
3. Haroon, Muhammad, Zaheer Alam, Rukhsana Kousar, Jawad Ahmad, and Fawad Nasim. "Sentiment analysis of customer reviews on e-commerce platforms: A machine learning approach." Bulletin of Business and Economics (BBE) 13, no. 3 (2024): 230-238.
4. Khan, Ali Raza A., Muhammad Ismaeel Khan, and Aftab Arif. "AI in Surgical Robotics: Advancing Precision and Minimizing Human Error." Global Journal of Computer Sciences and Artificial Intelligence 1, no. 1 (2025): 17-30.
5. Khan, M. I., A. Arif, and A. R. A. Khan. "AI-Driven Threat Detection: A Brief Overview of AI Techniques in Cybersecurity." BIN: Bulletin of Informatics 2, no. 2 (2024): 248-61.
6. Khan, Muhammad Ismaeel, Aftab Arif, and Ali Raza A. Khan. "AI's Revolutionary Role in Cyber Defense and Social Engineering." International Journal of Multidisciplinary Sciences and Arts 3, no. 4 (2024): 57-66.
7. Mehdi, Muhammad, Fawad Nasim, and Muhammad Qasim Munir. "Comparative Risk Analysis and Price Prediction of Corporate Shares Using Deep Learning Models like LSTM and Machine Learning Models." Journal of Computing & Biomedical Informatics 7, no. 02 (2024).
8. Muhammad Faisal Ali, Rabia Irfan, and Tahira Anwar Lashari, “Comprehensive sentimental analysis of tweets towards COVID-19 in Pakistan: a study on governmental preventive measures,” PeerJ Comput. Sci., vol. 9, p. e1220, Mar. 2023, doi: 10.7717/peerj-cs.1220.
9. Nikhil Sanjay Suryawanshi, “Sentiment analysis with machine learning and deep learning: A survey of techniques and applications,” Int. J. Sci. Res. Arch., vol. 12, no. 2, pp. 005–015, Jul. 2024, doi: 10.30574/ijsra.2024.12.2.1205.
10. Noor, Hajira, Jawad Ahmad, Ammar Haider, Fawad Nasim, and Arfan Jaffar. "A Machine Learning Sentiment Analysis Approach on News Headlines to Evaluate the Performance of the Pakistani Government." Journal of Computing & Biomedical Informatics 7, no. 02 (2024).
11. Parvaiz, Kinza, Muhammad Azam, Fawad Nasim, Shameen Noor, and Kahkisha Ayub. "Cross-Domain Sentiment Analysis: A Multi-Task Learning Approach with Shared Representations." Journal of Computing & Biomedical Informatics 7, no. 02 (2024).
12. Tariq, Muhammad Arham, Muhammad Ismaeel Khan, Aftab Arif, Muhammad Aksam Iftikhar, and Ali Raza A. Khan. "Malware Images Visualization and Classification With Parameter Tunned Deep Learning Model." Metallurgical and Materials Engineering 31, no. 2 (2025): 68-73.
13. “https://www.socialmediatoday.com/news/new-study-shows-twitter-is-the-most-used-social-media-platform-among-journa/626245/.”
14. “https://www.statista.com/statistics/272014/global-social-networks-ranked-by-number-of-users/.”
15. “https://www.statista.com/statistics/303681/twitter-users-worldwide/.”
16. V. Tyagi, A. Kumar, and S. Das, “Sentiment Analysis on Twitter Data Using Deep Learning approach,” in 2020 2nd International Conference on Advances in Computing, Communication Control and Networking (ICACCCN), Greater Noida, India: IEEE, Dec. 2020, pp. 187–190. doi: 10.1109/ICACCCN51052.2020.9362853.
17. Yuxing Qi and Zahratu Shabrina, “Sentiment analysis using Twitter data: a comparative application of lexicon- and macHine-learning-based approach,” Soc. Netw. Anal. Min., vol. 13, no. 1, p. 31, Feb. 2023, doi: 10.1007/s13278-023-01030-x.
18. Z. Hameed and B. Garcia-Zapirain, “Sentiment Classification Using a Single-Layered BiLSTM Model,” IEEE Access, vol. 8, pp. 73992–74001, 2020, doi: 10.1109/ACCESS.2020.2988550.
19. Zainab, Hira, Ali Raza A. Khan, Muhammad Ismaeel Khan, and Aftab Arif. "Ethical Considerations and Data Privacy Challenges in AI-Powered Healthcare Solutions for Cancer and Cardiovascular Diseases." Global Trends in Science and Technology 1, no. 1 (2025): 63-74.
20. Zainab, Hira, Muhammad Ismaeel Khan, Aftab Arif, and Ali Raza A. Khan. "Deep Learning in Precision Nutrition: Tailoring Diet Plans Based on Genetic and Microbiome Data." Global Journal of Computer Sciences and Artificial Intelligence 1, no. 1 (2025): 31-42.