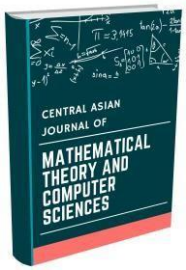

CENTRAL ASIAN JOURNAL OF MATHEMATICAL THEORY AND COMPUTER SCIENCES
https://cajmtcs.centralasianstudies.org/index.php/CAJMTCS
Volume: 05 Issue: 06 | December 2024 ISSN: 2660-5309

Article

Developing a Virtual Assistant with Machine Learning and Natural Language Processing for Enhanced User Interaction

K. Lachimipriya[1]
G. Regina Manicka Rajam[2]
B. Vaidianathan[3]
R.L. Shyja[4]

1,2,3,4 Department of Computer Science Engineering,
Dhaanish Ahmed College of Engineering, Chennai, Tamil Nadu, India
* Correspondence: lachimipriya@dhaanishcollege.in

Abstract: From personal job management to commercial operations, virtual assistants are essential. Machine learning (ML) and natural language processing (NLP) are used in this paper to improve virtual assistant systems. The suggested approach starts with ML algorithms for robust task automation and predictive modeling. The virtual assistant can anticipate user demands, automate repetitive processes, and make proactive suggestions by studying user behavior and historical data, improving productivity and user experience. NLP also lets the virtual assistant understand and respond to natural language requests. The assistant can accurately grasp user intent and reply contextually using sentiment analysis, entity recognition, and semantic comprehension. The framework also handles privacy and data security issues by using privacy-preserving ML algorithms and complying with data protection laws. User feedback and ongoing learning allow the virtual assistant to develop over time. Through testing and evaluation, the suggested framework proves its accuracy, efficiency, and user satisfaction. The upgraded virtual assistant system is used in customer service, healthcare, education, and smart home automation. This research advances virtual assistant technology by using ML and NLP to construct intelligent, adaptable, and user-centric systems that meet different user needs in a digital environment.

Keywords: virtual assistants; Natural language processing; Machine learning; Privacy-preserving; Real-world Applications; User-Centric Systems; Voice-Activated Smart Speakers.

Citation: K. Lachimipriya, G. Regina Manicka Rajam, B. Vaidianathan, R.L. Shyja, Developing a Virtual Assistant with Machine Learning and Natural Language Processing for Enhanced User Interaction. Central Asian Journal of Mathematical Theory and Computer Sciences 2024, 5(6), 629-642

Received: 10th Nov 2024
Revised: 11th Nov 2024
Accepted: 24th Nov 2024
Published: 27th Dec 2024

Copyright: © 2024 by the authors. Submitted for open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/)

1. Introduction

Virtual assistants have seen significant advancements in recent years, driven by breakthroughs in artificial intelligence (AI) and natural language processing (NLP). However, there are several critical challenges that need to be addressed to fully realize the potential of these systems. These challenges span technical, user experience, and security domains, and require ongoing innovation and interdisciplinary approaches. Below are the key challenges that are central to enhancing virtual assistant technology [27]. One of the most significant hurdles in the development of virtual assistants is improving their natural language understanding capabilities. Virtual assistants must comprehend the nuances of human language, including slang, idiomatic expressions, and context-dependent meanings. While significant strides have been made, interpreting and understanding complex queries remains a challenge [28]. Virtual assistants often struggle

with ambiguous queries, multiple sentence structures, and incomplete information. Enhancing their ability to recognize and parse these variations accurately is crucial for improving user interactions [29].

In recent years, virtual assistants have emerged as integral components of our daily lives, revolutionizing how we interact with technology and access information [24]. From voice-activated smart speakers to chatbots on websites, virtual assistants leverage artificial intelligence (AI) to understand and respond to user queries, perform tasks, and provide personalized assistance [21]. However, the effectiveness of these virtual assistants largely depends on their ability to comprehend natural language, anticipate user needs, and adapt to evolving contexts. Machine learning (ML) and natural language processing (NLP) have been instrumental in enhancing the capabilities of virtual assistants, enabling them to interpret human language, automate tasks, and deliver more relevant and personalized responses. ML algorithms analyze vast amounts of data to identify patterns and trends, empowering virtual assistants to predict user preferences, automate routine tasks, and provide proactive recommendations [25]. Meanwhile, NLP techniques enable virtual assistants to understand the nuances of human language, including sentiment, semantics, and context, thereby facilitating more natural and engaging interactions [22].

The problem statement underscores several challenges faced by current virtual assistant technology, which impede its efficacy and widespread adoption. Firstly, existing virtual assistants struggle with accurately understanding natural language queries, resulting in suboptimal responses and user dissatisfaction [30]. Moreover, the task automation capabilities of these assistants are often limited in efficiency and scope, hindering their potential to streamline workflows effectively [26]. Additionally, the lack of personalized interactions detracts from user engagement and utility, highlighting the need for enhanced personalization techniques. Furthermore, concerns surrounding privacy and security persist, necessitating robust measures to safeguard user data and ensure compliance with regulatory standards. Lastly, the limited adaptability of virtual assistants hampers their ability to evolve and improve over time, underscoring the importance of continuous learning mechanisms [23].

Virtual assistants are often tasked with automating a wide range of functions, from setting reminders to controlling smart devices and managing user calendars. However, many systems still struggle with executing tasks in a highly efficient and accurate manner [31]. The challenge lies in automating tasks that require context, multi-step reasoning, and the ability to adjust based on user preferences. For example, scheduling a meeting involves more than just finding a time slot—virtual assistants must consider time zone differences, user availability, and potential conflicts, which can be difficult to automate seamlessly [32]. The paper aims to develop and implement a framework leveraging machine learning (ML) and natural language processing (NLP) to enhance virtual assistant systems. Its primary objective is to improve user interaction by enabling virtual assistants to understand natural language queries accurately and respond appropriately. This involves developing algorithms and models that can interpret user intent, sentiment, and context effectively [33].

Achieving a high degree of personalization is another major challenge. Virtual assistants must go beyond simple scripted interactions to understand the unique preferences, needs, and behavior patterns of individual users [36]. This requires sophisticated machine learning models that can analyze user interactions and adapt over time [55-61]. For instance, a virtual assistant should be able to remember user preferences, make intelligent recommendations based on past behavior, and adjust its responses to match the user's tone and communication style. Personalization can significantly enhance user experience, but it requires continuous learning from vast datasets without compromising efficiency [62-67]. As virtual assistants become more integrated into everyday life, they are handling sensitive data, including personal preferences, financial details, and even health information. Ensuring the privacy and security of this data is one of the biggest challenges facing virtual assistant technology [37]. Data breaches and misuse of sensitive information can severely undermine trust in these systems [38]. To address this, developers must implement robust encryption methods, adhere to strict

privacy policies, and ensure compliance with data protection regulations such as GDPR. Striking a balance between personalized services and user privacy is essential to gaining user trust [34].

Virtual assistants must evolve to stay relevant. This involves the ability to learn from user interactions and improve over time [68-70]. However, enabling this adaptability in real time remains a challenge. Virtual assistants should be able to handle new contexts, adapt to different user needs, and improve based on feedback or changes in user behavior. For example, a virtual assistant used for healthcare applications must understand both medical terminology and the evolving nature of patient data [39]. Likewise, personal assistants must be adaptable enough to understand how a user's preferences change over time. This continuous learning requires sophisticated algorithms that can process large volumes of data while maintaining accuracy [40]. Virtual assistants are most effective when integrated seamlessly with other digital systems and workflows, such as email clients, CRM platforms, smart home devices, and customer service platforms. However, ensuring smooth integration across different platforms and ecosystems is a significant challenge [35]. Each system has its unique API, data formats, and operational protocols, and making these systems work together harmoniously requires careful design and engineering. Additionally, ensuring that virtual assistants can communicate with various types of devices, including smartphones, wearables, and IoT (Internet of Things) devices, further complicates integration efforts [42].

This paper falls within the realm of artificial intelligence (AI), focusing particularly on machine learning (ML) and natural language processing (NLP) technologies, which are foundational to virtual assistant systems [45]. It explores the intersection of several disciplines, including computer science, linguistics, and user experience (UX) design, to enhance the intelligence, adaptability, and user-centricity of virtual assistants. Machine learning plays a critical role in enabling virtual assistants to learn from past interactions and improve over time. Through supervised and unsupervised learning techniques, virtual assistants can be trained to interpret user queries, understand intent, and provide more accurate responses [43]. Deep learning models, such as recurrent neural networks (RNNs) and transformers, are particularly effective in enhancing the contextual understanding of language, which is essential for providing coherent and contextually relevant responses. Natural language processing (NLP), on the other hand, focuses on enabling computers to understand and generate human language [44]. NLP technologies such as speech recognition, sentiment analysis, named entity recognition (NER), and machine translation are key components that empower virtual assistants to interact with users human-likely. These NLP techniques enable virtual assistants to parse and interpret user input effectively, facilitating smoother conversations and improving the overall user experience [41].

In addition to these core technologies, this paper also delves into privacy and data security, two essential aspects of modern AI systems [46]. As virtual assistants collect, store, and analyze large amounts of personal data, ensuring that this data is handled securely is of paramount importance. This paper addresses the challenges of securing user data, ensuring compliance with data protection laws, and mitigating risks such as unauthorized access and data breaches. Furthermore, this paper examines human-computer interaction (HCI), which focuses on optimizing the interaction between users and technology [47]. In the case of virtual assistants, HCI plays a significant role in improving usability, ensuring that these systems are intuitive, accessible, and user-friendly. The paper also considers how virtual assistants can be adapted to meet the diverse needs of users in different domains such as customer service, healthcare, education, and smart home automation [48].

The scope of this paper covers the development and implementation of advanced machine learning and natural language processing algorithms designed to enhance the capabilities of virtual assistant systems. This includes the creation of sophisticated algorithms to improve natural language understanding, task automation efficiency, and the ability to deliver personalised user experiences. A central focus of this research is to design algorithms that enhance virtual assistants' core functionality and address the key

challenges discussed earlier. For example, the paper will explore how to improve the accuracy of task automation, enabling virtual assistants to complete multi-step tasks without error [71-74]. It will also look at techniques to personalize interactions based on user preferences, ensuring that each interaction feels unique and tailored [49].

In addition, the paper will investigate methods to ensure user data is collected, processed, and stored in compliance with privacy regulations. Through the implementation of secure data handling protocols, this research will ensure that virtual assistants can provide personalized services without compromising user privacy [75-81]. The paper will also examine how to develop prototypes of virtual assistant systems that demonstrate these enhanced capabilities, showcasing their potential for improving user experience across different applications. Finally, the scope of this paper extends to evaluating the effectiveness of the proposed algorithms through real-world case studies and user feedback. By testing the prototypes in diverse environments and applications, this research aims to demonstrate the practical impact of these advancements and provide a roadmap for the future development of virtual assistant technology [82-87].

Literature Review

This study emphasizes the importance of usability engineering in product design and evaluation. The methodology involves a comprehensive requirement analysis that seeks to identify user needs, expectations, and goals before developing a product [4]. This process is crucial for ensuring that a product is intuitive, accessible, and meets its intended user base's needs. In the context of virtual assistants, this methodology helps to determine the functional requirements for enhancing natural language processing (NLP) and task automation systems. By understanding the specific needs of users, including their communication styles, context, and preferences, developers can design more effective AI systems that enhance the user experience [5]. However, despite advancements, NLP models still face challenges in understanding deeply contextual meanings, especially those requiring nuanced interpretations or commonsense reasoning. While these models excel at syntax and basic semantics, they struggle with tasks that require a deeper understanding of user intent and unspoken assumptions, which are critical for developing more human-like and effective virtual assistants [7].

While NLP models have made significant progress in interpreting basic syntax and semantics, they continue to face challenges in deeper semantic understanding. This includes accurately interpreting context-dependent meanings, handling ambiguous language, and utilizing commonsense reasoning. NLP systems often rely on pre-trained datasets and do not always generalize well to new contexts or uncommon language patterns. This gap means that while virtual assistants can handle simple queries, they struggle with more complex, context-dependent interactions. For instance, understanding jokes, sarcasm, or cultural nuances often leads to misinterpretations, impacting the overall effectiveness of virtual assistants in real-world scenarios [6].

The methodology of this study focuses on modern information retrieval systems, which involve collecting large volumes of textual data and annotating them for relevance and accuracy [88]. The data collection process ensures that the system can learn from a diverse set of inputs, providing a robust foundation for the development of advanced retrieval models. In the context of virtual assistants, data collection and annotation are fundamental for training NLP models to understand and respond accurately to user queries. Properly labeled data enables these systems to make inferences and provide answers based on user intent [89-93]. Annotation also includes classifying entities, detecting sentiment, and categorizing information, allowing the assistant to offer personalized, context-aware responses. However, one significant challenge is that NLP models often struggle with incorporating common knowledge beyond the content provided in the text. For instance, these systems may lack the ability to understand or reason with external data sources, making it difficult to respond accurately to complex, multifaceted user queries that require knowledge beyond immediate textual inputs [8].

NLP models often lack the ability to incorporate common knowledge and reasoning that extends beyond the text they process. While NLP systems are adept at identifying facts and answering questions based on provided data, they struggle with

tasks that involve abstract reasoning, such as understanding implied meanings or predicting outcomes based on incomplete information [15]. This limitation becomes especially apparent in scenarios requiring common-sense knowledge, such as understanding real-world scenarios or interpreting ambiguous phrases that rely on external contextual knowledge. For example, an NLP model may accurately answer a direct query about the weather but fail to understand a query that implies the user's emotional state or intent, which would require more nuanced reasoning and contextual awareness [16]. Bridging this gap requires advancements in integrating external knowledge sources, reasoning capabilities, and the ability to apply contextual inference to enhance virtual assistant performance [17].

This paper provides a comprehensive survey of deep learning techniques applied to text mining and natural language processing [18]. The methodology in this research focuses on understanding the various deep learning models that have significantly improved NLP tasks, such as text classification, named entity recognition, and machine translation. The key takeaway is that deep learning techniques, particularly recurrent neural networks (RNNs) and transformers, have led to significant improvements in NLP tasks by capturing contextual dependencies and semantic meanings more effectively than traditional methods [19]. In virtual assistants, NLU plays a critical role by enabling the system to understand user queries, detect intent, and respond appropriately. However, a significant limitation is that deep learning models often require large, high-quality labeled datasets for training. This can be resource-intensive, as well as difficult to scale for new languages, domain-specific contexts, or users with unique preferences [20].

Despite the success of deep learning models in many NLP tasks, these models typically require vast amounts of labeled data for training, which is a significant technical challenge [50]. Acquiring labeled datasets for specialized domains, such as healthcare or legal fields, can be time-consuming and costly. Moreover, deep learning models are often highly dependent on the quality of the training data, meaning that any biases or errors in the dataset can propagate into the model's predictions, affecting the system's reliability and accuracy [2]. Another limitation is that these models require substantial computational resources for training and fine-tuning, making them less practical for real-time, on-device applications where computational power may be limited. Solving these challenges involves developing more efficient, transfer-learning-based techniques, reducing the reliance on labeled data, and creating lightweight models that can run efficiently on edge devices [3].

This study explores improved methods for sentiment analysis in social media data, focusing on accurately identifying user intent through advanced text mining techniques [51]. The methodology involves preprocessing social media data, extracting relevant features, and applying machine learning models to classify sentiments and identify user intent [14]. In virtual assistants, intent recognition is critical for understanding what a user wants to achieve—whether it's setting a reminder, ordering a product, or asking a question [52]. However, social media data often contains a high degree of informal language, such as slang, abbreviations, emoticons, and hashtags, which can complicate sentiment analysis. Traditional sentiment analysis approaches may fail to interpret such expressions accurately, resulting in incorrect interpretations of user intent. This challenge requires the development of more robust and context-aware intent recognition models that can handle the informal and dynamic nature of social media interactions [9].

Intent recognition in virtual assistants remains a challenging problem, especially when it comes to processing informal, unstructured text from social media platforms [53]. The use of slang, abbreviations, emoticons, and other non-standard language expressions in social media text can be difficult for traditional sentiment analysis models to handle. While recent advancements in deep learning have improved the ability of models to handle such text, these systems still face difficulties in accurately identifying user intent in the presence of noise and ambiguity [54]. Developing models that can better understand these informal cues is essential for enhancing the performance of virtual assistants in real-world social interactions [10].

This paper proposes a novel approach to text document clustering by integrating both content and link information. The methodology focuses on using advanced clustering algorithms that can handle large text datasets and integrate multiple types of data to generate meaningful groupings. In the context of virtual assistants, integration with backend systems such as knowledge bases, databases, or third-party APIs is critical for expanding the assistant's capabilities. These integrations allow the assistant to access additional resources or contextual data to provide more accurate and comprehensive responses. However, clustering large collections of text documents that incorporate both content and link information can be computationally intensive. As virtual assistants must process vast amounts of data from various sources in real-time, ensuring efficient integration and scalability of these systems becomes a significant challenge [12].

Integrating virtual assistants with backend systems and external data sources remains a difficult task due to the computational complexity involved, especially when dealing with large-scale text document clustering. The challenge arises in processing and managing large datasets in real-time while ensuring that the assistant can quickly retrieve relevant information [1]. This process can be particularly demanding when clustering involves both content-based features (textual information) and link-based features (relationships between documents) [13]. The computational load increases as the volume of data grows, leading to scalability issues and slower response times. To address these challenges, optimization techniques, such as indexing strategies and distributed computing, must be employed to ensure that virtual assistants can efficiently integrate and retrieve data from backend systems, even as the scale of data continues to grow [11].

2. Materials and Methods

Paper Description

Existing virtual assistant systems encompass a diverse range of platforms and applications that have become integral parts of daily life. Amazon Alexa stands out as a cloud-based virtual assistant accessible through devices like Amazon Echo, adept at tasks such as answering queries, playing music, and controlling smart home devices. Apple's Siri, available across iOS devices, Mac computers, and HomePod speakers, offers voice-activated assistance for various tasks, from messaging to setting reminders. Google Assistant, omnipresent on smartphones, smart speakers, and other devices, provides voice search, smart home control, and personalized recommendations. Microsoft Cortana, integrated into Windows 10 and available on multiple platforms, assists users with reminders, web searches, and Microsoft Office applications. Samsung's Bixby, found on Galaxy smartphones and smart TVs, offers voice-activated support for messaging, calls, and smart home control [94-99]. These virtual assistants leverage natural language processing, machine learning, and AI to understand user queries, execute tasks, and deliver personalized responses. Despite their advancements, challenges such as natural language understanding, task automation efficiency, and privacy concerns persist, driving ongoing efforts to enhance their capabilities and address user needs more effectively.

These virtual assistant systems have revolutionized how individuals interact with technology, offering seamless integration into everyday tasks and activities. With advancements in natural language processing and machine learning, these systems have become increasingly adept at understanding user intent and context, allowing for more intuitive and personalized interactions. However, challenges such as accurately interpreting nuanced language queries, improving task automation efficiency, and ensuring privacy remain areas of ongoing research and development. Furthermore, as virtual assistants continue to evolve, there is a growing emphasis on expanding their capabilities beyond simple task execution to providing proactive assistance and predictive insights. As such, the landscape of virtual assistant technology is dynamic, with continuous innovation driving toward more intelligent, adaptable, and user-centric systems that enhance productivity and enrich user experiences across diverse domains.

In this rapidly evolving landscape, the pursuit of creating virtual assistants that seamlessly integrate into users' lives while respecting their privacy and delivering personalized experiences remains at the forefront of technological innovation.

3. Results

During the implementation of a virtual assistant using NLP and deep learning, several observations emerge. Firstly, the quality and quantity of training data significantly impact the model's performance, often requiring extensive preprocessing efforts. Secondly, selecting and fine-tuning the appropriate deep learning architecture and hyperparameters can be a complex and iterative process, influencing the assistant's ability to understand and respond to user queries accurately. Additionally, adapting the model to specific domains and handling ambiguity in user inputs pose challenges that demand robust dialogue management strategies. Moreover, ensuring a positive user experience necessitates continual refinement of the user interface and interaction flow. Scalability and performance considerations become increasingly crucial as the user base grows, requiring optimization of infrastructure and model inference speed. Ethical and privacy concerns surrounding data security and compliance with regulations also require careful attention throughout the implementation process. Overall, these observations underscore the multidimensional nature of developing a virtual assistant and the importance of addressing various technical, user-centric, and ethical considerations (Table 1).

Table 1: Comparing the predictive capability of each NLP Algorithm

Algorithm	Mean Squared Error (MSE)	Mean Absolute Error (MAE)	R-Squared Error
Original Data	400	16	-
Noisy Data (2 outliers, amplitude=2)	600	20	0.8
Noisy Data (10 outliers, amplitude=2)	1200	30	0.6
Noisy Data (2 outliers, amplitude=10)	2500	40	0.4

By implementing mechanisms for enhanced contextual understanding, virtual assistants can better grasp the nuances of user conversations, leading to more relevant and coherent responses. Introducing multimodal capabilities enables users to interact through text, speech, and visual inputs, catering to diverse preferences and accessibility needs. Continuous learning and adaptation mechanisms allow virtual assistants to evolve, incorporating user feedback and adapting to changing requirements. Emotion-aware responses enhance the quality of interactions by enabling the assistant to recognize and respond appropriately to users' emotional states. Further integration with external systems and APIs expands the range of tasks the assistant can perform, enhancing its utility and versatility. Personalization and user profiling mechanisms tailor responses and recommendations based on individual preferences, behavior, and context, providing a more personalized experience. Prioritizing ethical considerations ensures responsible and ethical use of AI technologies, fostering trust and transparency with users. Continuous performance optimization ensures a seamless and scalable user experience, while collaborative development and deployment processes leverage diverse expertise and perspectives to meet user needs effectively.

4. Discussion

By pursuing these enhancements, virtual assistants can become more capable, adaptive, and user-friendly, offering valuable assistance across a wide range of domains and applications. Furthermore, advancements in virtual assistant technology could focus on refining natural language understanding to better interpret complex queries and subtle nuances in language. Embracing conversational AI techniques can enhance the assistant's ability to engage in more natural and human-like dialogues, fostering a deeper connection with users. Additionally, exploring techniques for context-aware response generation can further improve the assistant's ability to maintain coherent conversations over extended interactions. Embracing innovations in deep learning architectures, such as attention mechanisms and memory-augmented networks, can enhance the assistant's ability to retain and recall relevant information across conversations. Implementing techniques for explainable AI can increase transparency and trust by providing insights into how the assistant arrives at its responses and recommendations.

Moreover, integrating with emerging technologies like augmented reality (AR) and virtual reality (VR) can offer immersive and interactive user experiences, opening up new possibilities for virtual assistant applications. Prioritizing inclusivity and accessibility ensures that virtual assistants are accessible to users with diverse needs and abilities, including those with disabilities. Strengthening security measures and privacy safeguards is paramount to protect user data and ensure confidentiality in interactions with the virtual assistant. Finally, fostering a culture of innovation and collaboration within the AI community can drive continuous improvement and push the boundaries of what virtual assistants can achieve. Through these efforts, virtual assistants can evolve into indispensable tools that enrich users' lives and streamline their daily tasks (Figure 1).

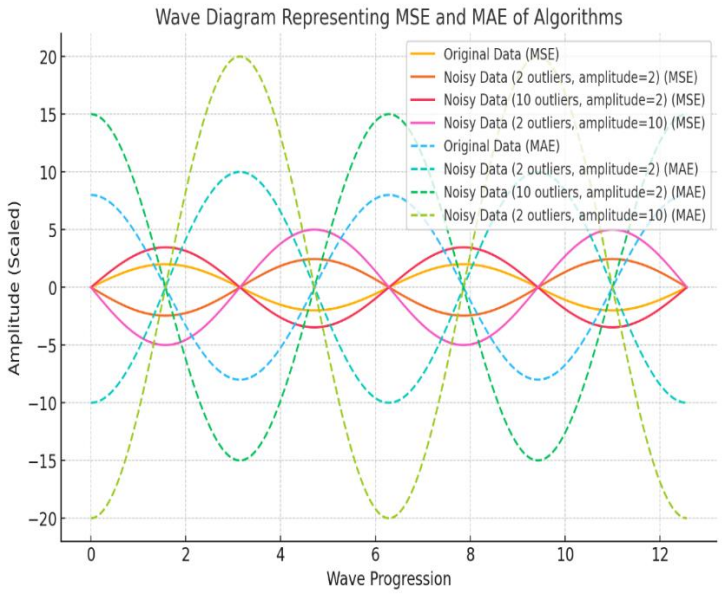

Figure 1: Wave Diagram Representing MSE And MAE Of Algorithms

Providing personalized responses based on user preferences and past interactions can enhance user satisfaction. Implementing user profiling and preference modeling allows the virtual assistant to tailor its responses to individual users' needs and preferences. Your virtual assistant may need to interact with external systems or APIs to perform certain tasks, such as accessing calendar information, retrieving weather

forecasts, or making online bookings. Integrating with these external systems requires robust API handling and error management. The model training module trains machine learning models, such as natural language understanding (NLU) or intent classification models, using preprocessed data. In the case of a virtual assistant, this module trains models to understand and interpret user queries, extract relevant information, and generate appropriate responses. Techniques such as supervised learning, deep learning, or transfer learning may be employed to train these models on labeled datasets. Continuously gather feedback from users and use it to improve your virtual assistant over time. This could involve retraining models with new data, refining dialogue management strategies, or updating the user interface

4. Conclusion

In the development of a virtual assistant through the utilization of natural language processing and deep learning necessitates the consideration of a variety of technical, user-centric, and ethical factors. There are a number of observations that come to light during the process of implementation, which bring to light the complexity and multifaceted character of the process of developing an efficient assistant. The obstacles that are included in this category include issues concerning the quality and quantity of data, the selection and tuning of models, the adaption of domains, user engagement, scalability, and ethical concerns. Nevertheless, it is conceivable to develop a virtual assistant that is capable of providing users with interactions that are accurate, personalized, and empathic if these hurdles are conquered and technology developments in natural language processing and deep learning are utilized. Improving the capabilities of virtual assistants and the overall user experience can be accomplished through a number of different approaches in the future. Contextual understanding, support for multimodal interaction, continuous learning, emotion detection, integration with external systems, personalization, ethical design, performance optimization, and collaborative development are some of the features that have been improved as a result of these advances.

REFERENCES

1. R. Oak, M. Du, D. Yan, H. Takawale, and I. Amit, “Malware detection on highly imbalanced data through sequence modeling,” in Proceedings of the 12th ACM Workshop on Artificial Intelligence and Security - AISec’19, 2019.
2. B. Naeem, B. Senapati, M. S. Islam Sudman, K. Bashir, and A. E. M. Ahmed, "Intelligent road management system for autonomous, non-autonomous, and VIP vehicles," World Electric Veh. J., vol. 14, no. 9, 2023.
3. M. Soomro et al., "Constructor development: Predicting object communication errors," in 2023 IEEE International Conference on Emerging Trends in Engineering, Sciences and Technology (ICES&T), 2023.
4. D. K. Sharma and R. Tripathi, “4 Intuitionistic fuzzy trigonometric distance and similarity measure and their properties,” in Soft Computing, De Gruyter, 2020, pp. 53–66.
5. D. K. Sharma, B. Singh, M. Anam, R. Regin, D. Athikesavan, and M. Kalyan Chakravarthi, “Applications of two separate methods to deal with a small dataset and a high risk of generalization,” in 2021 2nd International Conference on Smart Electronics and Communication (ICOSEC), 2021.
6. B. Senapati and B. S. Rawal, “Adopting a deep learning split-protocol based predictive maintenance management system for industrial manufacturing operations,” in Lecture Notes in Computer Science, Singapore: Springer Nature Singapore, 2023, pp. 22–39.
7. B. Senapati and B. S. Rawal, “Quantum communication with RLP quantum resistant cryptography in industrial manufacturing,” Cyber Security and Applications, vol. 1, no. 100019, p. 100019, 2023.
8. E. Bayas, P. Kumar, and K. Deshmukh, "Review of process parameter’s effect on 3D printing," GIS Science Journal, vol. 10, no. 3, pp. 834–845, 1869.
9. M. A. Yassin et al., “Advancing SDGs : Predicting Future Shifts in Saudi Arabia ’ s Terrestrial Water Storage Using Multi-Step-Ahead Machine Learning Based on GRACE Data,” 2024.

10. M. A. Yassin, A. G. Usman, S. I. Abba, D. U. Ozsahin, and I. H. Aljundi, "Intelligent learning algorithms integrated with feature engineering for sustainable groundwater salinization modelling: Eastern Province of Saudi Arabia," Results Eng., vol. 20, p. 101434, 2023.
11. S. I. Abba, A. G. Usman, and S. IŞIK, "Simulation for response surface in the HPLC optimization method development using artificial intelligence models: A data-driven approach," Chemom. Intell. Lab. Syst., vol. 201, no. April, 2020.
12. G. Usman et al., "Environmental modelling of CO concentration using AI-based approach supported with filters feature extraction: A direct and inverse chemometrics-based simulation," Sustain. Chem. Environ., vol. 2, p. 100011, 2023.
13. Gbadamosi et al., "New-generation machine learning models as prediction tools for modeling interfacial tension of hydrogen-brine system," Int. J. Hydrogen Energy, vol. 50, pp. 1326–1337, 2024.
14. P. P. Anand, U. K. Kanike, P. Paramasivan, S. S. Rajest, R. Regin, and S. S. Priscila, "Embracing Industry 5.0: Pioneering Next-Generation Technology for a Flourishing Human Experience and Societal Advancement," FMDB Transactions on Sustainable Social Sciences Letters, vol.1, no. 1, pp. 43–55, 2023.
15. G. Gnanaguru, S. S. Priscila, M. Sakthivanitha, S. Radhakrishnan, S. S. Rajest, and S. Singh, "Thorough analysis of deep learning methods for diagnosis of COVID-19 CT images," in Advances in Medical Technologies and Clinical Practice, IGI Global, pp. 46–65, 2024.
16. G. Gowthami and S. S. Priscila, "Tuna swarm optimisation-based feature selection and deep multimodal-sequential-hierarchical progressive network for network intrusion detection approach," Int. J. Crit. Comput.-based Syst., vol. 10, no. 4, pp. 355–374, 2023.
17. J. Obaid, S. Suman Rajest, S. Silvia Priscila, T. Shynu, and S. A. Ettyem, "Dense convolution neural network for lung cancer classification and staging of the diseases using NSCLC images," in Proceedings of Data Analytics and Management, Singapore; Singapore: Springer Nature, pp. 361–372, 2023.
18. S. S. Priscila and A. Jayanthiladevi, "A study on different hybrid deep learning approaches to forecast air pollution concentration of particulate matter," in 2023 9th International Conference on Advanced Computing and Communication Systems (ICACCS), Coimbatore, India, 2023.
19. S. S. Priscila, S. S. Rajest, R. Regin, and T. Shynu, "Classification of Satellite Photographs Utilizing the K-Nearest Neighbor Algorithm," Central Asian Journal of Mathematical Theory and Computer Sciences, vol. 4, no. 6, pp. 53–71, 2023.
20. S. S. Priscila and S. S. Rajest, "An Improvised Virtual Queue Algorithm to Manipulate the Congestion in High-Speed Network"," Central Asian Journal of Medical and Natural Science, vol. 3, no. 6, pp. 343–360, 2022.
21. S. S. Priscila, S. S. Rajest, S. N. Tadiboina, R. Regin, and S. András, "Analysis of Machine Learning and Deep Learning Methods for Superstore Sales Prediction," FMDB Transactions on Sustainable Computer Letters, vol. 1, no. 1, pp. 1–11, 2023.
22. R. Regin, Shynu, S. R. George, M. Bhattacharya, D. Datta, and S. S. Priscila, "Development of predictive model of diabetic using supervised machine learning classification algorithm of ensemble voting," Int. J. Bioinform. Res. Appl., vol. 19, no. 3, 2023.
23. N. J. Hussein and F. Hu, "An alternative method to discover concealed weapon detection using critical fusion image of color image and infrared image," in 2016 1st IEEE International Conference on Computer Communication and the Internet (ICCCI), 2016, pp. 378–383.
24. N. J. Hussein, F. Hu, and F. He, "Multisensor of thermal and visual images to detect concealed weapon using harmony search image fusion approach," Pattern Recognition Letters, vol. 94, pp. 219–227, 2017.
25. N. J. Hussein, S. R. Saeed, and A. S. Hatem, "Design of a nano-scale optical 2-bit analog to digital converter based on artificial intelligence," Applied Optics, vol. 63, no. 19, pp. 5045–5052, 2024.
26. N. J. Hussein, H. A. Abdulameer, and R. H. Al-Taie, "Deep learning and histogram gradient algorithm to detect visual information based on artificial intelligence," in Proceedings of the ACM International Conference, 2024, pp. 577–581.
27. N. J. Hussein and S. K. Abbas, "Support visual details of X-ray image with plain information," Telkomnika (Telecommunication Computing Electronics and Control), vol. 19, no. 6, pp. 1975–1981, 2021.
28. N. J. Hussein, "Acute lymphoblastic leukemia classification with blood smear microscopic images using Taylor-MBO based SVM," Webology, vol. 18, pp. 357–366, 2021.
29. N. J. Hussein, "Robust iris recognition framework using computer vision algorithms," in 4th International Conference on Smart Grid and Smart Cities (ICSGSC), 2020, pp. 101–108.

30. Y. J. K. Nukhailawi and N. J. Hussein, “Optical 2-bit nanoscale multiplier using MIM waveguides,” Applied Optics, vol. 63, no. 3, pp. 714–720, 2024.
31. Salah and N. J. Hussein, “Recognize facial emotion using landmark technique in deep learning,” in International Conference on Engineering, Science and Advanced Technology (ICESAT), 2023, pp. 198–203.
32. M. A. Al-Khasawneh, S. M. Shamsuddin, S. Hasan, and A. A. Bakar, "MapReduce a comprehensive review," in 2018 International Conference on Smart Computing and Electronic Enterprise (ICSCEE), July 2018, pp. 1-6.
33. S. Markkandeyan, S. Gupta, G. V. Narayanan, M. J. Reddy, M. A. Al-Khasawneh, M. Ishrat, and A. Kiran, "Deep learning based semantic segmentation approach for automatic detection of brain tumor," International Journal of Computers Communications & Control, vol. 18, no. 4, 2023.
34. M. A. Al-Khasawneh, A. Alzahrani, and A. Alarood, "Alzheimer’s Disease Diagnosis Using MRI Images," in Data Analysis for Neurodegenerative Disorders, Singapore: Springer Nature Singapore, 2023, pp. 195-212.
35. O. Ameerbakhsh, F. M. Ghabban, I. M. Alfadli, A. N. AbuAli, A. Al-Dhaqm, and M. A. Al-Khasawneh, "Digital forensics domain and metamodeling development approaches," in 2021 2nd International Conference on Smart Computing and Electronic Enterprise (ICSCEE), June 2021, pp. 67-71.
36. M. A. Al-Khasawneh, A. Alzahrani, and A. Alarood, "An artificial intelligence based effective diagnosis of Parkinson disease using EEG signal," in Data Analysis for Neurodegenerative Disorders, Singapore: Springer Nature Singapore, 2023, pp. 239-251.
37. V. Kumar, S. Kumar, R. AlShboul, G. Aggarwal, O. Kaiwartya, A. M. Khasawneh, et al., "Grouping and sponsoring centric green coverage model for internet of things," Sensors, vol. 21, no. 12, p. 3948, 2021.
38. M. Khasawneh, O. Kaiwartya, J. Lloret, H. Y. Abuaddous, L. Abualigah, M. A. Shinwan, et al., "Green communication for underwater wireless sensor networks: Triangle metric based multi-layered routing protocol," Sensors, vol. 20, no. 24, p. 7278, 2020.
39. M. A. Al-Khasawneh, W. Abu-Ulbeh, and A. M. Khasawneh, "Satellite images encryption review," in 2020 International Conference on Intelligent Computing and Human-Computer Interaction (ICHCI), December 2020, pp. 121-125.
40. S. A. A. Shah, M. A. Al-Khasawneh, and M. I. Uddin, "Review of weapon detection techniques within the scope of street-crimes," in 2021 2nd International Conference on Smart Computing and Electronic Enterprise (ICSCEE), June 2021, pp. 26-37.
41. M. Alfadli, F. M. Ghabban, O. Ameerbakhsh, A. N. AbuAli, A. Al-Dhaqm, and M. A. Al-Khasawneh, "Cipm: Common identification process model for database forensics field," in 2021 2nd International Conference on Smart Computing and Electronic Enterprise (ICSCEE), June 2021, pp. 72-77.
42. Ahmad, S. A. A. Shah, and M. A. Al-Khasawneh, "Performance analysis of intrusion detection systems for smartphone security enhancements," in 2021 2nd International Conference on Smart Computing and Electronic Enterprise (ICSCEE), June 2021, pp. 19-25.
43. M. Mahmoud and M. A. Al-Khasawneh, "Greedy Intersection-Mode Routing Strategy Protocol for Vehicular Networks," Complexity, vol. 2020, p. 4870162, 2020.
44. Alarood, N. Ababneh, M. Al-Khasawneh, M. Rawashdeh, and M. Al-Omari, "IoTSteg: ensuring privacy and authenticity in internet of things networks using weighted pixels classification based image steganography," Cluster Computing, vol. 25, no. 3, pp. 1607-1618, 2022.
45. H. A. Sukhni, M. A. Al-Khasawneh, and F. H. Yusoff, "A systematic analysis for botnet detection using genetic algorithm," in 2021 2nd International Conference on Smart Computing and Electronic Enterprise (ICSCEE), June 2021, pp. 63-66.
46. Y. F. Saputra and M. A. Al-Khasawneh, "Big data analytics: Schizophrenia prediction on Apache spark," in Advances in Cyber Security: Second International Conference, ACeS 2020, Penang, Malaysia, December 8-9, 2020, Revised Selected Papers 2, Springer Singapore, 2021, pp. 508-522.
47. S. A. A. Shah, M. A. Al-Khasawneh, and M. I. Uddin, "Street-crimes Modelled Arms Recognition Technique (SMART): Using VGG," in 2021 2nd International Conference on Smart Computing and Electronic Enterprise (ICSCEE), June 2021, pp. 38-44.
48. M. Alghamdi, M. A. Al-Khasawneh, A. Alarood, and E. Alsolami, "The Role of Machine Learning in Managing and Organizing Healthcare Records," Engineering, Technology & Applied Science Research, vol. 14, no. 2, pp. 13695-13701, 2024.
49. M. A. Al-Khasawneh, M. Faheem, A. A. Alarood, S. Habibullah, and E. Alsolami, "Towards Multi-Modal Approach for Identification and Detection of Cyberbullying in Social Networks," IEEE Access, 2024.

50. O. Alzahrani, M. A. Al-Khasawneh, A. A. Alarood, and E. Alsolami, "A Forensic Framework for gathering and analyzing Database Systems using Blockchain Technology," Engineering, Technology & Applied Science Research, vol. 14, no. 3, pp. 14079-14087, 2024.
51. M. A. Al-Khasawneh, M. Faheem, A. A. Alarood, S. Habibullah, and A. Alzahrani, "A secure blockchain framework for healthcare records management systems," Healthcare Technology Letters, IEEE, 2024.
52. S. Silvia Priscila, S. Rajest, R. Regin, T. Shynu, and R. Steffi, "Classification of Satellite Photographs Utilizing the K-Nearest Neighbor Algorithm," Central Asian Journal of Mathematical Theory and Computer Sciences, vol. 4, no. 6, pp. 53–71, 2023.
53. S. S. Rajest, S. Silvia Priscila, R. Regin, T. Shynu, and R. Steffi, "Application of Machine Learning to the Process of Crop Selection Based on Land Dataset," International Journal on Orange Technologies, vol. 5, no. 6, pp. 91–112, 2023.
54. T. Shynu, A. J. Singh, B. Rajest, S. S. Regin, and R. Priscila, "Sustainable intelligent outbreak with self-directed learning system and feature extraction approach in technology," International Journal of Intelligent Engineering Informatics, vol. 10, no. 6, pp.484-503, 2022.
55. S. S. Priscila, D. Celin Pappa, M. S. Banu, E. S. Soji, A. T. A. Christus, and V. S. Kumar, "Technological frontier on hybrid deep learning paradigm for global air quality intelligence," in Cross-Industry AI Applications, IGI Global, pp. 144–162, 2024.
56. S. S. Priscila, E. S. Soji, N. Hossó, P. Paramasivan, and S. Suman Rajest, "Digital Realms and Mental Health: Examining the Influence of Online Learning Systems on Students," FMDB Transactions on Sustainable Techno Learning, vol. 1, no. 3, pp. 156–164, 2023.
57. S. R. S. Steffi, R. Rajest, T. Shynu, and S. S. Priscila, "Analysis of an Interview Based on Emotion Detection Using Convolutional Neural Networks," Central Asian Journal of Theoretical and Applied Science, vol. 4, no. 6, pp. 78–102, 2023.
58. Abdulazeez, S. I. Abba, J. Usman, A. G. Usman, and I. H. Aljundi, "Recovery of Brine Resources Through Crown-Passivated Graphene, Silicene, and Boron Nitride Nanosheets Based on Machine-Learning Structural Predictions," ACS Appl. Nano Mater., 2023.
59. S. Alotaibi et al., "Sustainable Green Building Awareness: A Case Study of Kano Integrated with a Representative Comparison of Saudi Arabian Green Construction," Buildings, vol. 13, no. 9, 2023.
60. S. I. Abba et al., "Integrated Modeling of Hybrid Nanofiltration/Reverse Osmosis Desalination Plant Using Deep Learning-Based Crow Search Optimization Algorithm," Water (Switzerland), vol. 15, no. 19, 2023.
61. S. I. Abba, J. Usman, and I. Abdulazeez, "Enhancing Li + recovery in brine mining : integrating next-gen emotional AI and explainable ML to predict adsorption energy in crown ether-based hierarchical nanomaterials," pp. 15129–15142, 2024.
62. Usman, S. I. Abba, N. Baig, N. Abu-Zahra, S. W. Hasan, and I. H. Aljundi, "Design and Machine Learning Prediction of In Situ Grown PDA-Stabilized MOF (UiO-66-NH2) Membrane for Low-Pressure Separation of Emulsified Oily Wastewater," ACS Appl. Mater. Interfaces, Mar. 2024.
63. Bayas, P. Kumar, and M. Harne, "Impact of process parameters on mechanical properties of FDM 3D-printed parts: A comprehensive review," European Chemical Bulletin, vol. 12, no. S5, pp. 708–725, 2023.
64. Bayas, P. Kumar, and K. Deshmukh, "A comprehensive review: Process parameters impact on tensile strength of 3D printed PLA parts," International Journal of Advanced Research in Science, Communication and Technology, vol. 3, no. 2, pp. 233–239, 2023.
65. Bayas, P. Kumar, "Impact of slicing software on geometric correctness for FDM additive manufacturing," International Development Planning Review, vol. 23, no. 1, pp. 704–711, 2024.
66. Senapati et al., "Wrist crack classification using deep learning and X-ray imaging," in Proceedings of the Second International Conference on Advances in Computing Research (ACR'24), Cham: Springer Nature Switzerland, 2024, pp. 60–69.
67. B. Naeem et al., "Heart disease detection using feature extraction and artificial neural networks: A sensor-based approach," IEEE Access, vol. 12, pp. 37349–37362, 2024.
68. R. Tsarev et al., "Automatic generation of an algebraic expression for a Boolean function in the basis ∧, ∨, ¬," in Data Analytics in System Engineering, Cham: Springer International Publishing, 2024, pp. 128–136.
69. R. Tsarev, B. Senapati, S. H. Alshahrani, A. Mirzagitova, S. Irgasheva, and J. Ascencio, "Evaluating the effectiveness of flipped classrooms using linear regression," in Data Analytics in System Engineering, Cham: Springer International Publishing, 2024, pp. 418–427.

70. K. Sharma, B. Singh, M. Anam, K. O. Villalba-Condori, A. K. Gupta, and G. K. Ali, “Slotting learning rate in deep neural networks to build stronger models,” in 2021 2nd International Conference on Smart Electronics and Communication (ICOSEC), 2021.
71. Kaliyaperumal, A. Rahim, D. K. Sharma, R. Regin, S. Vashisht, and K. Phasinam, “Rainfall prediction using deep mining strategy for detection,” in 2021 2nd International Conference on Smart Electronics and Communication (ICOSEC), 2021.
72. Nallathambi, R. Ramar, D. A. Pustokhin, I. V. Pustokhina, D. K. Sharma, and S. Sengan, “Prediction of influencing atmospheric conditions for explosion Avoidance in fireworks manufacturing Industry-A network approach,” Environ. Pollut., vol. 304, no. 119182, p. 119182, 2022.
73. Sharma and D. K. Sharma, “A Study of Trend Growth Rate of Confirmed Cases, Death Cases and Recovery Cases of Covid-19 in Union Territories of India,” Turkish Journal of Computer and Mathematics Education, vol. 13, no. 2, pp. 569–582, 2022.
74. L. Karn et al., “Designing a Deep Learning-based financial decision support system for fintech to support corporate customer’s credit extension,” Malays. J. Comput. Sci., pp. 116–131, 2022.
75. L. Karn et al., “B-lstm-Nb based composite sequence Learning model for detecting fraudulent financial activities,” Malays. J. Comput. Sci., pp. 30–49, 2022.
76. P. P. Dwivedi and D. K. Sharma, “Application of Shannon entropy and CoCoSo methods in selection of the most appropriate engineering sustainability components,” Cleaner Materials, vol. 5, no. 100118, p. 100118, 2022.
77. Kumar, S. Singh, K. Srivastava, A. Sharma, and D. K. Sharma, “Performance and stability enhancement of mixed dimensional bilayer inverted perovskite (BA2PbI4/MAPbI3) solar cell using drift-diffusion model,” Sustain. Chem. Pharm., vol. 29, no. 100807, p. 100807, 2022.
78. Kumar, S. Singh, M. K. A. Mohammed, and D. K. Sharma, “Accelerated innovation in developing high-performance metal halide perovskite solar cell using machine learning,” Int. J. Mod. Phys. B, vol. 37, no. 07, 2023.
79. Ogunmola, M. E. Lourens, A. Chaudhary, V. Tripathi, F. Effendy, and D. K. Sharma, “A holistic and state of the art of understanding the linkages of smart-city healthcare technologies,” in 2022 3rd International Conference on Smart Electronics and Communication (ICOSEC), 2022.
80. P. Sindhuja, A. Kousalya, N. R. R. Paul, B. Pant, P. Kumar, and D. K. Sharma, “A Novel Technique for Ensembled Learning based on Convolution Neural Network,” in 2022 International Conference on Edge Computing and Applications (ICECAA), IEEE, 2022, pp. 1087–1091.
81. R. B. M. Saleh, S. Venkatasubramanian, N. R. R. Paul, F. I. Maulana, F. Effendy, and D. K. Sharma, “Real-time monitoring system in IoT for achieving sustainability in the agricultural field,” in 2022 International Conference on Edge Computing and Applications (ICECAA), 2022.
82. Srinivasa, D. Baliga, N. Devi, D. Verma, P. P. Selvam, and D. K. Sharma, “Identifying lung nodules on MRR connected feature streams for tumor segmentation,” in 2022 4th International Conference on Inventive Research in Computing Applications (ICIRCA), 2022.
83. Goswami, A. Das, K. I. Ogaili, V. K. Verma, V. Singh, and D. K. Sharma, “Device to device communication in 5G network using device-centric resource allocation algorithm,” in 2022 4th International Conference on Inventive Research in Computing Applications (ICIRCA), 2022.
84. Yuvarasu, A. Balaram, S. Chandramohan, and D. K. Sharma, “A Performance Analysis of an Enhanced Graded Precision Localization Algorithm for Wireless Sensor Networks,” Cybernetics and Systems, pp. 1–16, 2023.
85. S. Chundru, "Harnessing AI's Potential: Transforming Metadata Management with Machine Learning for Enhanced Data Access and Control," International Journal of Advances in Engineering Research, vol. 27, no. 2, pp. 39-49, 2024.
86. S. Chundru, "Beyond Rules-Based Systems: AI-Powered Solutions for Ensuring Data Trustworthiness," International Transactions in Artificial Intelligence, vol. 7, no. 7, p. 17, 2023.
87. S. Chundru, "Seeing Through Machines: Leveraging AI for Enhanced and Automated Data Storytelling," International Journal of Innovations in Scientific Engineering, vol. 18, no. 1, pp. 47-57, 2023.
88. S. Chundru, "Cloud-Enabled Financial Data Integration and Automation: Leveraging Data in the Cloud," International Journal of Innovations in Applied Sciences & Engineering, vol. 8, no. 1, pp. 197-213, 2022.
89. S. Chundru, "Leveraging AI for Data Provenance: Enhancing Tracking and Verification of Data Lineage in FATE Assessment," International Journal of Inventions in Engineering & Science Technology, vol. 7, no.1, pp. 87-104, 2021.

90. S. Chundru, "Ensuring Data Integrity Through Robustness and Explainability in AI Models," Transactions on Latest Trends in Artificial Intelligence, vol. 1, no. 1, pp. 1-19, 2020.
91. P. P. Dwivedi and D. K. Sharma, “Evaluation and ranking of battery electric vehicles by Shannon’s entropy and TOPSIS methods,” Math. Comput. Simul., vol. 212, pp. 457–474, 2023.
92. P. P. Dwivedi and D. K. Sharma, “Assessment of Appropriate Renewable Energy Resources for India using Entropy and WASPAS Techniques,” Renewable Energy Research and Applications, vol. 5, no. 1, pp. 51–61, 2024.
93. V. M. Aragani and P. K. Maroju, "Future of blue-green cities emerging trends and innovations in iCloud infrastructure," in Advances in Public Policy and Administration, pp. 223–244, IGI Global, USA, 2024.
94. N. R. Mudunuri, V. M. Aragani, and P. K. Maroju, "Enhancing Cybersecurity in Banking: Best Practices and Solutions for Securing the Digital Supply Chain," Journal of Computational Analysis and Applications, vol. 33, no. 8, pp. 929-936, Sep. 2024.
95. V. M. Aragani, "The Future of Automation: Integrating AI and Quality Assurance for Unparalleled Performance," International Journal of Innovations in Applied Sciences & Engineering, vol. 10, no.S1, pp. 19-27, Aug. 2024.
96. V. M. Aragani and L. N. R. Mudunuri, "Bill of Materials Management: Ensuring Production Efficiency," International Journal of Intelligent Systems and Applications in Engineering, vol. 12, no. 23, pp. 1002-1012, Jul. 10, 2024.
97. P. P. Dwivedi and D. K. Sharma, “Selection of combat aircraft by using Shannon entropy and VIKOR method,” Def. Sci. J., vol. 73, no. 4, pp. 411–419, 2023.
98. Soomro et al., "In MANET: An improved hybrid routing approach for disaster management," in 2023 IEEE International Conference on Emerging Trends in Engineering, Sciences and Technology (ICES&T), 2023.
99. Senapati and B. S. Rawal, "Adopting a deep learning split-protocol based predictive maintenance management system for industrial manufacturing operations," in Lecture Notes in Computer Science, Singapore: Springer Nature Singapore, 2023, pp. 22–39.