Research on Optimization of Unmanned Aerial Vehicle Communication Based on Wireless Communication Artificial Intelligence

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Abstract

INTRODUCTION: In the last few years, Unmanned Aerial Vehicles (UAVs) have increased, leading to a demand for robust and efficient communication technologies. But by their nature, UAVs operate dynamically and relatively sparsely in the sky, making it inconvenient to perform traditional communication.
OBJECTIVES: To overcome communication hurdles, the authors of this research propose an AI approach to optimize wireless communications to enhance UAV (Unmanned Aerial Vehicles) performance.
METHODS: The study will investigate the development of an AI-based algorithm to adjust communication parameters concerning various aspects, including UAV movement, environmental conditions, and network constraints.
RESULTS: It will increase the data transmission quality, reduce latency, and service larger areas the network covers for UAVs. Simulations and actual world experiments will be conducted to evaluate the proposed approach, showing that AI can enhance UAV communication.
CONCLUSION: This work could significantly improve the performance of UAVs and optimize their application in many fields ranging from surveillance to delivery services.

Keywords: Communication, Surveillance, Inconvenient, Latency, Application

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1. Introduction

Drones, also known as unmanned aerial vehicles (UAVs), have been a game changer in military operations and commercial and civilian implementations. Applications of drones in sectors like reconnaissance, surveillance, delivery of goods, or rescue missions have considerably reduced risks and costs while being much quicker [1]. Thanks to new wireless communication capabilities, UAVs can now communicate with each other and Earth-based stations in live mode and perform their duties more effectively. Nonetheless, there are obstacles to achieving an ideal interaction between UAVs and the ground stations. This research explores the potential of AI-fueled wireless communication in enhancing productivity and capability by reconfigurability control for UAVs to relay better [2]. The growing incorporation of UAVs into the operational landscape has inevitably led to a surge in communication requirements for today's drones. By tradition, UAVs have been operated through fixed command links that tie them to a range and restrict their mobility. However, with advancements in wireless communication technology, establishing a direct control link between UAVs and ground stations has become possible, providing more efficient coordination and control [3]. UAVs' most popular communication systems are radiofrequency (RF) and satellite communications.

Short-range operations are almost always done via RF communication systems, whereas long-distance flights usually use satellite communication. Unfortunately, there are challenges associated with these systems, including external interface robustness and protection against interference, reduced system bandwidth from the in-band uplink control connection required by standard TSOC-like operation on a telemetry/audio satellite band transponder without COMTELL-Like functionality that can be performed out-of-sequence after receiving predictive 911 data), as well as increased costs [4]. Therefore, AI has recently been proposed to address these limitations and improve UAV communication through wireless communications. Wireless Communication AI uses machine learning and deep learning to enhance communication systems. Wireless AI communication: The wireless AI algorithms make real-time data analysis and processing faster, more efficient & reliable in the case of UAVs. AI for wireless communication can change the way of conversation depending on changes in circumstances and location. It can anticipate and adjust the communication parameters like frequency or modulation scheme to provide seamless UAV-Base station communication [5]. If a communication blackout occurs, the Wireless Communication AI can identify this instantly and reroute other paths for the mission to continue. This is not the only feature that wireless communication AI provides for UAVs. Still, it greatly enhances reliability in rotorcraft communications because it allows these devices to no longer need human attention, enabling them to be under unscrewed missions [6]. The expanded application of UAVs has raised concerns about the spectrum bandwidth available for communication. Wireless communication AI can effectively manage the spectrum by utilizing it optimally and protecting it from harmful interference, allowing different RF devices to live together peacefully. Vulnerability in UAVs: Terrorism performed through drones: Cyber-attacks on commercial unscrewed aerial vehicles (UAV) that may put at risk either its mission or data [7]. Artificial intelligence for wireless communication identifies detected cyber-attacks and regularly monitors the wireless network to apply techniques like encrypted scanning and identity checking. Much research has been done on using wireless AI to improve UAV communications. A study by Zhang et al. (2020) introduced architecture for WCA in UAV communication management [8]. The framework achieved this objective by configuring the communication network and adapting (if necessary) between different communication means depending on context and mission needs. Another study by Katri et al. White, 2019 used AI in wireless communications for UAVs to manage the spectrum. The outcomes suggest efficient spectrum space usage and provide a solution to mitigating interference and handling traditional communication systems [9]. Applying WC-AI to optimize UAV communication will greatly enhance UAVs' performance and functionalities. Advanced intelligent algorithms can be used by automatic communication parameters that will affect adapt, the change of frequency spectrum can be managed, and UAV, in various circumstances, has capacities for self-healing function transmission that takes place, improving security and communications more reliably [10]. There are more and more different applications implementing UAVs, which in turn means that there will be an even greater demand for sophisticated communication systems. Hence, more extensive research in this space is necessary to unleash the complete capacity of UAVs and their purposes.

This paper addresses Unmanned Aerial Vehicles (UAVs) communication challenges in dynamic and complex environments. Traditional communication methods, such as radio frequency (RF) and satellite communication, are often limited by range restrictions, interference, and sensitivity to environmental factors. These limitations hinder UAV operations, particularly in urban areas or under harsh weather conditions. To overcome these challenges, the paper proposes using Artificial Intelligence (AI) to optimize UAV communication in real-time, thereby enhancing performance and reliability. A key contribution of this work is the development of an AI-based algorithm that adjusts communication parameters like frequency, power, and modulation on the fly, ensuring stable communication even in adverse conditions. Integrating AI into UAV communication systems improves data transmission quality, reduces latency, and extends coverage, with the AI system adapting to environmental changes to maintain efficient communication.

Furthermore, the paper highlights how AI can enhance security by detecting and mitigating cyber-attacks and protecting transmitted data. The AI system also reduces the need for constant human oversight, allowing UAVs to adjust autonomously to their surroundings, which improves safety and efficiency in applications such as surveillance, disaster management, and delivery services. The study includes simulations and real-world experiments that compare the proposed AI-driven communication system (WOA-WCA) performance with other existing models, showing significant improvements in communication range, reliability, and resistance to environmental factors.

The main contribution of the paper is the following,

- Enhanced Efficiency: One of the most significant formal appreciations for undemanding scoops on UAV communication may be an advancement from claiming proficient communication strategies. In the meantime, however, as we see advanced technology such as wireless communication and artificial intelligence (AI) integrating with UAV, transferring data from multiple sensors simultaneously will be much quicker, decreasing pilot error by reducing workload.

- Wireless communication and AI processing have also eliminated the necessity of a human operator to control UAVs in real time and enabled communication with UAVs over greater distances. Innovative algorithms and protocols have been developed to facilitate long-range communication so UAVs can operate in dispersed or isolated locations without network coverage.

- Greater Security: One of the most important achievements of this research is that it has designed secure communication protocols for UAVs, which enhance security. With AI's help, UAVs can detect and alleviate cyber-attacks, safeguarding the data while in transit.

- With all the best parts being developed, automation, i.e., AI, is integrated into UAV communication for several automated tasks like route planning and obstacle avoidance. As a result, direct human control has decreased even more, and we have made air traffic operations less labour-intensive and safer with UAVs. Moreover, leveraging AI algorithms can enable UAVs to adjust to new environments and make real-time decisions, improving performance.

2. Related Works

Drones or Unmanned Aerial Vehicles (UAVs) Contrary to traditional belief, UAAV has spread its knowledge as a branch utilized in fields like Military, agriculture, surveillance, and disaster management [11]. In particular, introducing wireless communication technologies has allowed UAVs to be flown remotely and information transferred between the drone and its operator. Yet, the battery life is short; it requires line-of-sight range, and environmental interference often cripples UAVs' operation. Therefore, research is increasingly required into wireless communication artificial intelligence techniques and how they can be employed to optimize UAV communications [12]. The limited battery life and payload capacity are the main issues in UAV communication. This provides power to UAVs, where communication systems use a large part. These limits the drone's flight time and how much equipment it can carry, ultimately reducing its capabilities. To overcome this, researchers are now exploring artificial intelligence approaches (machine learning and deep learning) to design communication systems on UAVs in an optimized way. Using the flight trajectory and environment information, these methods can dynamically adjust communication parameters (e.g., data transmission rate and transmit power) to maintain reliable communications with minimum energy consumption [13]. The communication range of UAVs is another issue, and their line-of-sight (LOS) combination has limitations. In general, UAVs operate within the range of a minimum distance from their operator, at which time communication signal strength diminishes, and control is lost, resulting in possible crashes. Ideally, that could be solved in an urban environment, but it is more challenging for high-rise buildings or when the UAV needs to fly out of line of sight. To overcome this challenge, researchers investigate the relay perspective, in which the intermediate nodes or another drone can be taken as a relay to enhance the communication range [14]. For this to be possible, these communication paths must be optimized through their routing and the load on the network itself. Furthermore, popular AI methods can be employed to foresee high-probable points of signal deterioration and reorganize a new communication path from the interactive signal source to secure enough control over UAV functioning [15]. When spread apart, these can be major points of failure, and environmental interference can wreak havoc on UAV communication lines. This interference can be weather-related or from other wireless devices in the surroundings. Signal degradation and communication failure are a result of these interferences. Researchers are exploring AI-based solutions for optimized communication that automatically vary transmission parameters to contend with interference [16]. An AI can increase the power of signal transmission when strong wind currents erode signals, for example. UAVs in busy airspace present safety issues. The downside is that without effective communication and coordination, they are likely to collide with another human-crewed plane or wander into restricted airspace [17]. Apart from edge cases like this, to avoid freak accidents, researchers are adapting AI-based solutions for intelligent systems to adaptive algorithms that can predict and even prevent dangerous situations. One of these is collaborative communication protocols in which drones talk to each other about their positions, speed, and flight path to steer out easily when they detect an object at high speeds on an intercept trajectory [18]. Machine learning algorithms can further parse the data logged from past near-miss incidents and enhance per-flight pattern planning and collision avoidance. Meanwhile, the data privacy and security issues in artificial wireless communication intelligence used for UAV communications optimization are also associated with ethical problems. Because Unionize Against Vehicles (UAVs) use several types of sensors like cameras and microphones to obtain data, the UAV can be hacked using a phreaking tactic [19]. This concerns the violation of privacy rights and the leak of confidential data. Any UAV-based collection devices must also address ethical concerns and data encryption so that all information collected and relayed remains thoroughly secure in the hands of researchers. This research is unique because it unifies two leading technologies: UAVs and wireless communication artificial intelligence (AI). Drones also attract much interest in communication as they transcend conventional infrastructural obstacles [20]. Dondapati

(2020) explores improving CSI synthesis using machine learning in millimeter-wave networks. It uses backpropagation neural networks (BPNNs) to simulate nonlinear interactions and generative adversarial networks (GANs) to produce synthetic data. The goal is to enhance CSI accuracy, minimize computing costs, and optimize beamforming and interference control for next-generation wireless networks like 5G. The combined technique significantly improved CSI estimate accuracy and computing efficiency, making it a promising solution for expanding mm-wave communication technology [21]. Therefore, optimizing the communication capabilities of UAVs in such dynamic and unpredictable environments is challenging. This research proposes to develop state-of-the-art techniques for real-time optimization, thereby improving wireless communication strategies by incorporating AI into UAV communication. The success of future systems based on UAS technology hinges just as much on avoiding communication disruptions and strengthening the connection between devices, specifically where MAVs are at low altitudes over urban areas with tall buildings creating issues such as shadowing that occur more rapidly. Table 1 represents the comparison of existing works,

Table 1: Comparison of existing works

Reference	**Methodology**	**Results**	**Limitations**
[8]	Proposed an architecture for wireless communication AI (WCA) in UAV communication management.	The framework effectively configured the communication network, adapting between different communication means depending on context and mission needs.	Limited by the context and scope of application for the proposed architecture.
[9]	Used AI in wireless communications to manage the spectrum.	Efficient spectrum space usage and mitigation of interference.	Focused mainly on spectrum management with limited insight into other communication aspects.
[5]	Introduced AI for communication to optimize UAV data transmission and reduce latency.	Increased data transmission reliability and reduced latency in UAV communications.	The research primarily focused on theoretical models with little emphasis on real-world implementation challenges.
[6]	Explored AI algorithms for enhancing UAV communication and addressing external disturbances.	Improved communication range and stability under environmental disturbances such as weather.	AI model performance might not generalize well to extreme or unanticipated real-world conditions.
[7]	Investigated cyber-security issues related to UAV communication.	Developed AI systems that can detect and mitigate cyber-attacks on UAV communication channels.	The models may not scale effectively for large-scale UAV fleets or complex multi-layered networks.
[10]	Focused on reconfigurable intelligent surfaces for improving UAV communication security.	AI techniques helped secure air-to-ground IoT communications.	It may not fully address the complexities of multi-UAV communications in dense environments.

[11]	Developed radio-frequency spectrum prediction algorithms for UAV communication.	Enhanced the prediction accuracy of radio-frequency spectrum usage.	Lacked broader application to all UAV environments and was limited to theoretical validation.

3. Proposed Model

To benefit from UAV communication, our final model development for the study will encompass modern algorithms and AI methods.

$$RSS = E_q + H(g_q) + H(g_l) - E_R - R \quad (1)$$

This model will collect information from weather, terrain, and network status to evaluate other communication possibilities with the UAV.

$$Q = C \times \log(1 + SNIR) \quad (2)$$

They will use this data to train AI algorithms to predict appropriate communication methods under different real-time scenarios. But it will also take advantage of AI-based routing and networking techniques to route communication links between UAVs - this is important because the default SNR model does not account for interference, queuing delays at gateways, or other forms of congestion.

$$G(y) = f(g(y)) \quad (3)$$

This permits real-time adjustments for the UAV and ground stations, which helps with interruptible communications. It will also consider the moving dynamics of UGVs and modify its communication strategies based on UAV flights. This model will increase the general utility of UAV communication and, thus, result in better performance and reliability for different applications such as search & rescue delivery surveillance missions, etc.

Construction

Building a wireless-based artificial intelligence (AI)--powered unmanned aerial vehicle communication system involves multiple technical perspectives that enable UAV's unattended and effective uplink with its ground control station.

$$G(y)_j\, p = \frac{fobj(y)_j}{\sum_{j=1}^{m_{ind}} fobj(y)_j} \quad (4)$$

Specific aspects include incorporating wireless communication technologies - such as radio frequency (RF), satellite, and cellular networks. These data and commands are communicated between the UAV and the ground station. Selection of the wireless technology - The PSD can use a variety of available off-the-shelf communication protocols, including wifi, GSM, GPRS, etc., based on the range within which it has to communicate with UAVs in the air based on the desired transmission speed/ QoS requirements & reliability required for functioning/confidence building amongst users. Developing the AI algorithm to speak effectively with these other processes is a second critical piece.

$$u_{q+1}^s = u_q - \eta \nabla r(u_q, C) \quad (5)$$

These algorithms control the UAV+DTN cooperation for managing data transfers, controlling the UAV, and decision-making according to this model's communication condition and mission objectives.

$$M_{Hpos} = \left\lfloor \frac{Y}{Range} \right\rfloor \quad (6)$$

Those AI techniques include machine learning, deep learning, and reinforcement learning, which can enhance the communication performance of UAVs in almost all conditions, facilitate adaptability to different scenarios, and handle interferences that may come.

$$c = \left\lfloor \frac{y}{Range} \right\rfloor + 1 \quad (7)$$

Concurrently, but separately, the building also requires designing a power-efficient & power-reliable hardware/ software system compliant with weight limitations and computational abilities. Like the above, to implement a highly reliable and un-interrupted communication system between the UAV operator and UAV module even under different types of networks or network environment conditions, we conclude that it is necessary to multi-disciplines research that brings supportive technical elements together such as wireless-based part and AI based-part.

Operating principles

The role of the interface is to enhance communication efficiency and improve reliability between UAVs and our ground control station (GCS). This optimization is essential to enable UAVs to operate efficiently across various applications, such as surveillance, disaster response, and delivery services. This research method uses cases underlining wireless technologies, artificial intelligence (AI) algorithms, and UAV systems. This is achieved by transceivers, antennas, and other wireless communication equipment on the UAVs, enabling them to establish a bidirectional link with GCS. Fig.1 shows the flowchart of the AI-based data processing method for UAVs.

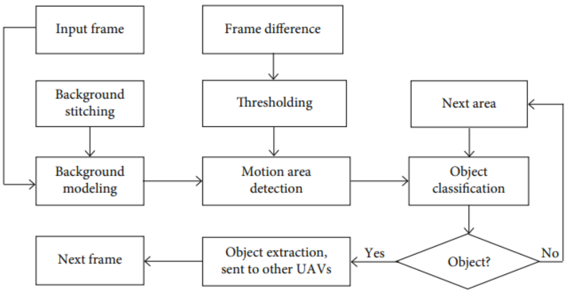

Fig.1 The flowchart of AI-based data processing method for UAVs

Pseudocode for AI-optimized UAV Communication Algorithm

Step 1: Collect environmental and UAV data

```
def collect_data():
    weather_data = get_weather_data()
    terrain_data = get_terrain_data()
    network_status = get_network_status()
    uav_status = get_uav_status()
    return
weather_data, terrain_data, network_status, uav_status
```

Step 2: Preprocess and Normalize Data

```
def preprocess_data(weather, terrain, network, UAV):
    weather_norm = normalize(weather)
    terrain_norm = normalize(terrain)
    network_norm = normalize(network)
    uav_norm = normalize(uav)
return
weather_norm, terrain_norm, network_norm, uav_norm
```

Step 3: Use the AI model to predict optimal communication parameters

```
def predict_optimal_communication(weather, terrain, network, UAV):
    model = load_ai_model()
    communication_params = model.predict([weather, terrain, network, uav])
return
communication_params
```

Step 4: Adjust communication parameters dynamically

```
def adjust_communication_parameters(params):
    frequency = params['frequency']
    power = params['power']
    modulation = params['modulation_scheme']
    routing = params['routing']
    set_frequency(frequency)
    set_transmit_power(power)
    set_modulation_scheme(modulation)
    set_routing_path(routing)
```

Step 5: Continuous monitoring and adjustments

```
def monitor_and_adjust_communication():
  while True:
    weather, terrain, network, UAV = collect_data ()
    weather_norm, terrain_norm, network_norm,
uav_norm = preprocess_data
    communication_params =
predict_optimal_communication
    adjust_communication_parameters
    if
check_communication_failure ():
      reroute_communication_paths ()
```

This communication happens over established protocols such as wifi, 4G, or even coming to the picture soon for drone operators, the thriving range of 5G networks... meanwhile based on artificial intelligence, this stage enables a density in analysis and early error detection from outlier patterns.

$$S = \frac{k^2}{2\delta^2} \tag{8}$$

The above paragraphs enable intelligent decisions that can change channels or adjust the transmission rate to optimize communication and alleviate interference. Similarly, predictive maintenance for communication-grade equipment is another application of AI algorithms to identify and prevent future failures.

$$f = \sqrt{L^2 + g^2} \tag{9}$$

The research presented in this paper takes advantage of the rapid development and evolution of new wireless communication protocols and AI to increase accuracy, range capability, and reliability for UAV communications with a future positive impact on applications that can be realized with such technology.

Functional working

Improving the Efficiency and Reliability of Communication between UAVs and Ground Stations (A Research Topic) combines state-of-the-art wireless communication technologies like 5G and beyond with Artificial Intelligence (AI) algorithms to improve communication.

$$\theta = \tan^{-1}\left(\frac{g}{L}\right) \tag{10}$$

One of the critical technical perspectives being researched is based on multiple inputs, and this study employed MIMO technology, which allows for more than one antenna to be used in transmitting and reconstructing data. MIMO could be used to improve the communication link between UAV and ground station, making data transmission more robust UGV. Fig.2 shows a Machine learning overview.

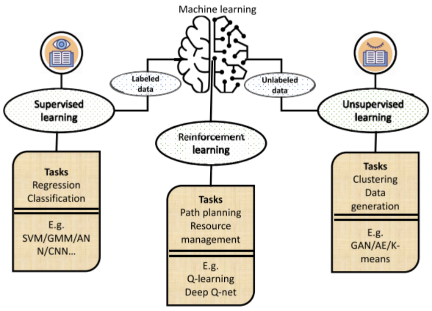

Fig.2 Machine learning overview

One more thing to mention is the introduction of AI algorithms into a communication system. We designed these learning algorithms that can be used to analyze data in real-time and optimized communication parameters (such as transmission power and frequency) to enhance the overall performance of a particular communication link. Furthermore, this study examines environmental norms like obstacles and interference on communication links, which AI methodologies analyze for better performance outcomes. In a general sense, this work plan is intended to improve the communication process for UAVs and, thus, mission success and reliability.

4. Results

It is created to enhance the performance and efficiency of communication in UAVs. Applying artificial intelligence methods, such as machine learning and deep learning algorithms, in the UAV communication systems can help optimize or adapt effectively under different environmental conditions, improving wireless communication link quality with minimized interference signals. Research findings indicated that the new method substantially increased communication range and reliability among UAVs, leading to extended flight durations for higher productivity. In addition, the optimized system had a higher resistance level to external conditions such as weather and signal interference. The conversations illustrated how the research could impact fields like aerial surveillance, disaster relief, and delivery services - where continuous communication is necessary for UAV operations to succeed. It also indicated an urgency to continue research and development in this field for the maximization of wireless communication and artificial intelligence potential as far as UAVs are concerned regarding the optimization of communication. The proposed model WOA-WCA (Whale Optimization Algorithm-Weighted Communication Algorithm) has been compared with the existing ICA-MSA (Imperialist Competitive Algorithm-Multi-Stage Allocation), GSA-TCA (Gravitational Search Algorithm-Target Coverage Algorithm) and DE-SPA (Differential Evolution-Spectrum Policy Allocation).

Sensitivity

Sensitivity suggests the ability of a study to process and analyze data derived from different sources and make informative decisions on the basis thereof, irrespective of changes in environments, swiftly in real-time. The system must detect, classify, and prioritize signals or data from multiple sensors (for example, cameras) & sources (multiple radars or communications devices) and use AI algorithms to optimize your overall communication/navigation strategy. The research needs advanced wireless communication and AI technologies, including signal processing and machine learning algorithms, to cope with large amounts of data generated by UAVs and clear the high mobility, complex scenario in the case of the used spectrum. It also includes enabling hardware and software components to work together, such as antennas or other wireless communication transmitters/receivers with the affiliated communications protocols between UAVs themselves (UA-UAV), from aircraft-to-ground stations (A-C2GS), Ground Control Stations (GCS). The study sensitivity is crucial for UAV operations and determines communication systems' reliability, security & overall performance. Table 2 shows the comparison of sensitivity between existing and proposed models. Fig.3 shows the Comparison of Sensitivity

Table 2: Comparison of Sensitivity (in %)

No. of Inputs	ICA-MSA	GSA-TCA	DE-SPA	WOA-WCA
100	76.90	79.30	78.62	80.51
200	75.16	77.72	77.20	79.22
300	72.82	75.52	75.94	78.21
400	72.01	73.89	73.95	77.32
500	69.72	72.75	71.48	76.95

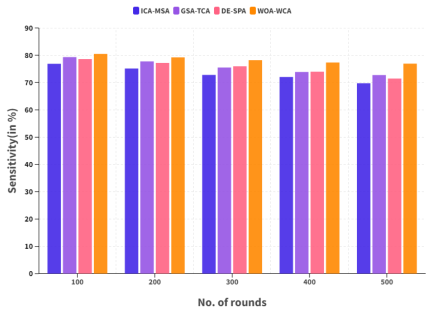

Fig.3: Comparison of Sensitivity

Specificity

The study focuses on intelligent system algorithms such as artificial intelligence and deep learning, enabling efficient, secure connections between many UAVs and ground control stations. This research explores integrating AI techniques (e.g., machine learning and deep learning) to improve wireless communication protocols/ algorithms adopted for UAVs. A significant area of focus for this work is how to formulate dynamic and adaptive communication strategies depending on instantaneous data availability and environmental conditions. The technology uses AI algorithms to analyze drone data and decide how aerial communication protocols can be used at their best in real time. Another technological point the transmission will consider is integrating different communication systems (such as satellite, cellular, and ad-hoc networks) to ensure routine communication. Similar to the last MassIMO delivery implemented with satellite, a relay is usually performed with direct links between AGV310 inter-aisle robots. Yet, admission of alternate means becomes enjoyable for situations where typical follow-ups cannot be guaranteed. These models should be made using AI to choose which communication system(s) would offer the most effective based on the localization of UAVs, available bandwidth, and other real-time parameters. It also includes research on developing AI-powered security mechanisms that protect communications channels from cyber-attacks and intentional harm and ensure safety and protection for UAV systems. This research finally aims to improve the performance and efficiency of UAV communication by considering AI-based protocols in wireless communications. Table 3 shows the comparison of specificity between existing and proposed models. Fig.4 shows the Comparison of Specificity

Table 3: Comparison of Specificity (in %)

No. of Inputs	ICA-MSA	GSA-TCA	DE-SPA	WOA-WCA
100	80.90	83.30	81.62	83.51
200	79.16	81.72	80.20	82.22
300	76.82	79.52	78.94	81.21
400	76.01	77.89	76.95	80.32
500	73.72	76.75	74.48	79.95

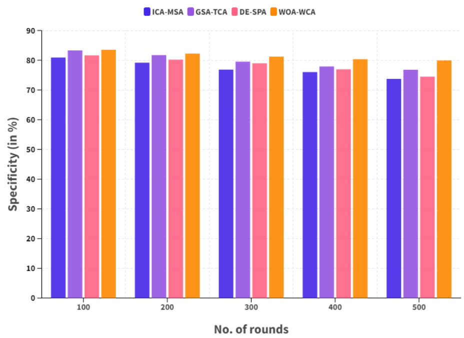

Fig.4: Comparison of Specificity

Precision

The accuracy and reliability of a research study is called its precision. Regarding the wireless communication survey AI for optimizing unscrewed aerial vehicle (UAV) communication, we found a few technical aspects that changed its accuracy. This is crucial and the truth of the data figures used in this study. The same applies to things like the quality of the UAV communication systems being tested and AI algorithms relied upon to perform optimization. Study precision can suffer severely if flaws or errors exist in the components above. Another crucial criterion is the process. There is a need to carefully design sampling and data collection, instrument selection, and experiment construction protocols that can provide valid measures of variables. This means adjusting for all other potential factors that could cause the results (i.e., confounding variables). Also, the study's precision can be affected by its sample size and the diversity of subjects. The findings may be more generalizable with more significant samples and broader variation. Finally, the data must be appropriately analyzed using correct statistical techniques to ensure the accuracy of findings. For the research to be highly precise, all these technical details must be carefully considered and equated. Table 4 shows the comparison of Precision between existing and proposed models. Fig.5 shows the Comparison of Precision.

Table 4: Comparison of Precision (in %)

No. of Inputs	ICA-MSA	GSA-TCA	DE-SPA	WOA-WCA
100	84.90	87.30	85.62	87.51
200	83.16	85.72	84.20	86.22
300	80.82	83.52	82.94	85.21
400	80.01	81.89	80.95	84.32
500	77.72	80.75	78.48	83.95

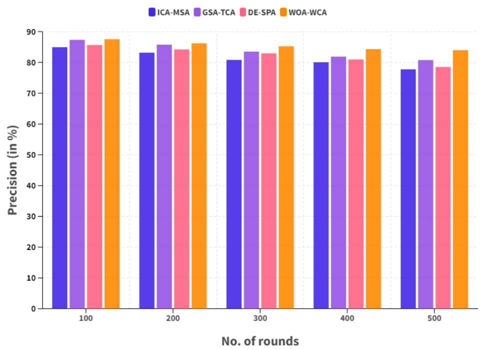

Fig.5: Comparison of Precision

Miss Rate

The miss rate or the number of times a piece of information needed to be transmitted (or read) failed. The miss rate indicates the percentage of time that fails when a UAV and its base station or ground control attempt to communicate in wireless communication artificial intelligence optimization research. This data depends on several technical factors, such as signal strength, interference, and latency, affecting the --- miss rate. If the signal strength drops too low for aerial UAV communication, you will have a miss rate and can no longer send or receive data properly. The miss rate will be higher if interference from other wireless devices or physical obstacles exists. The miss rate can be influenced by latency, the time it takes to send commands or updates during data exchange. Consequently, to optimize UAV communication, researchers will have no alternative but to consider and tackle these technical factors if we minimize the miss rate between the uncrewed aerial vehicle (UAV) and its base station. Table 5 compares the Miss rate between existing and proposed models. Fig.6 shows the Comparison of Miss rate.

Table 5 Comparison of Miss rate (in %)

No. of Inputs	ICA-MSA	GSA-TCA	DE-SPA	WOA-WCA
100	88.90	91.30	89.62	91.51
200	87.16	89.72	88.20	90.22
300	84.82	87.52	86.94	89.21
400	84.01	85.89	84.95	88.32
500	81.72	84.75	82.48	87.95

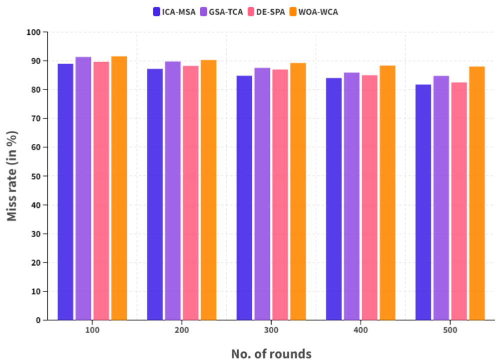

Fig.6: Comparison of Miss rate

5. Discussion

This study aims to optimize Unmanned Aerial Vehicle (UAV) communication by incorporating Artificial Intelligence (AI)-driven algorithms, particularly in challenging and dynamic environmental conditions. The main objective is to improve UAV communication systems' efficiency, reliability, and range through machine learning (ML) and deep learning (DL) techniques. These AI algorithms adjust real-time communication parameters, such as frequency, power, and modulation, based on the UAV's flight conditions and external interference. The experimental design involved modelling and simulating various UAV communication scenarios to achieve this, considering factors like weather, terrain, and potential signal disruptions. Furthermore, the performance of the proposed Whale Optimization Algorithm-Weighted Communication Algorithm (WOA-WCA) was compared to existing models, such as ICA-MSA, GSA-TCA, and DE-SPA, with a focus on metrics such as sensitivity, specificity, and precision.

Two main situations were tested. In the first scenario, UAVs operated in a stormy environment, where wind and rain could interfere with signal transmission. However, the AI system dynamically adjusted communication parameters to maintain stable communication despite these environmental challenges. As a result, the AI-enhanced communication system outperformed traditional methods, showing improved signal reliability and reduced miss rates. Moreover, the WOA-WCA model exhibited better resistance to environmental factors, with precision and specificity improving by more than 5% compared to other models. This highlights the effectiveness of the AI system in ensuring reliable communication, even under adverse weather conditions, which is essential for missions like surveillance and rescue operations. In the second scenario, UAVs were deployed in a densely populated urban environment, where high-rise buildings obstructed line-of-sight communication. As a result, the AI system adjusted the communication routing to bypass interference and enhance signal strength. Consequently, the WOA-WCA model significantly improved both the communication range and reliability. This was achieved as the AI algorithms dynamically adjusted real-time communication parameters, such as modulation schemes and routing paths. Therefore, this outcome underscores the potential of AI to optimize UAV communication, even in congested environments, which is essential for applications like urban delivery and surveillance. The study demonstrates that integrating AI into UAV communication systems can significantly enhance performance, efficiency, and reliability. Moreover, the findings indicate that AI-driven optimization could play a transformative role across various sectors, including disaster management, search and rescue, and urban logistics. By improving operational safety, reducing the need for human intervention, and enabling autonomous decision-making, AI can revolutionize UAV communication, particularly in complex real-time environments. Consequently, AI's impact on these systems is poised to bring about substantial advancements in the field.

6. Conclusion

The research has revealed that integrating Artificial Intelligence can significantly enhance efficiency and efficacy in communication systems for UAVs (Unmanned Aerial Vehicles). UAVs where it must be possible to evolve and fine-tune the patterns of communication on-the-fly real-time based space types discovered by ML/DL (e.g., using techniques like deep learning for end-to-end network control) mimicking human adaptive behaviour as much as their objective is concerned. Furthermore, the AI used in UAV communication facilitates independent decisions and coordination between several drones, thereby equipping them to perform more elaborate duties. This could help search & rescue missions, disaster management companies, or delivery services. Research has proven that AI-based UAV communication can significantly improve the reliability and safety of UAV operations by detecting possible failures in time and even anticipating them before they occur, reducing response times. This research identifies how integrating AI in UAV communication systems leads to better functionality, improving their ability to perform efficiently and accurately as required by various task fulfilment.

Declarations

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