American International University-Bangladesh (AIUB)

Department of Computer Science

Faculty of Science & Technology (FST)

Research Methodology
Assignment

Submitted By

Semester: Fall_2024-2025 FINAL TERM				Section: E	Group No: 06
SL	SN	Student Name	Student ID	Individual Contribution (100%)	Total Marks: **50** Teamwork (CO1-CO4) + Individual (CO5 + Viva)
A	14	AKTHER, SADIA	21-45427-3	100%	
B	15	NAFISA, MOSAMMAT TASNIN	21-45439-3	100%	
C	18	HASAN, MEHEDI	21-45513-3	100%	
D	19	BANIK, DIPTA	21-45520-3	100%	

Submission Date: 09/01/2025

ASSESSMENT & EVALUATION

ASSIGNMENT: Write a research article following the appropriate research methodology to present noble research findings.

EVALUATION: The assignment will be Evaluated for the following Course Outcomes.

CO1: *Evaluate* all relevant resources for designing a computer science and engineering solution and determine the level of novelty of the research.	Total Marks (9)
Problem Analysis and use of State-of-the-Art Resources: Discuss the research problem background with best use of state-of-art literature, resources, and technologies (e.g., related studies) to produce a significant result that is likely to have a major impact.	[3 Marks]
Critical Reflection and Creativity in Research Objective: Deep insight demonstrated and presented a creative solution to the real-life problem. And Results are critically confronted with various existing literature (e.g., formation of the RQs).	[3 Marks]
Novelty and Contribution of Research: Elaborately discuss and identify the contribution of the research to the development of scientific concepts by recognizing the limitation (e.g., research gaps) of existing research/developments.	[3 Marks]

CO2: *Analyze* the collected data to provide valid solutions to the research problem acknowledging the limitations.	Total Marks (9)
Data Analysis: Elaborately discuss the research method, its appropriateness and details on data collection, analysis, and synthesis for proposing valid solution to the research problem (e.g., research methodology)	[3 Marks]
Solution and Validation: Elaborately discuss and validate the solution of the research problem by establishing a direct connection between proposed solutions with the research objective based on the collected research data (e.g., result & analysis).	[3 Marks]
Limitation of the Study: Elaborately discuss the research summary and conclude remarks of the research by acknowledging the limitations of the studies (e.g., abstract and conclusion)	[3 Marks]

CO3: Determine and demonstrate professional codes of ethics and standard in conducting research considering public safety; the impacts of engineering activity; economic, social, cultural, environmental and sustainability.	Total Marks (9)
Professional codes of ethics and standard, Research Outcomes and Impacts: The research elaborately demonstrates professional codes of ethics and standards in conducting research considering public safety; the impacts of engineering activity; economic, social, cultural, environmental and sustainability of the research outcomes and impacts.	[3 Marks]
Free of Plagiarism, Data Falsification Citations and References: Submit plagiarism free research paper (similarity index is <10%). In-text citations and reference list	[3 Marks]

citations were complete and properly formatted in APA or any other standard style. The Research data is not fabricated or altered intentionally to fit into the predetermined research findings. Materials are properly cited and referenced if they are taken from other sources. And not attributed to a source from which it has not been obtained *(i.e., false citation)*	
Compliance with Report Formatting and Submission Guidelines: Submitted in due time, the report is complete and there are no errors in spelling, format, and grammar. Consistently presents a logical and effective organization.	[3 Marks]

CO4: *Depict* the need for continuing education and participation in professional societies and meetings.	Total Marks (9)
Motivation of the research: Explore extensively the research topics with evidence rich awareness of the research problems (e.g., facts, citations) indicating intense interest in the area.	[3 Marks]
Comprehension and problem solving: Excellent understanding of material and completely demonstrates effective problem- solving skills integrating alternate and divergent ideas or processes to solve the research problem.	[3 Marks]
Future studies: The scope of future studies is stated and discussed elaborately with details of how this study can be extended in future endeavor.	[3 Marks]

CO5: *Defend* the research solutions based on complex engineering activities by delivering an effective presentation to the audience.	Total Marks (9)
Presentation delivery (eye contact and body language): Keeps eye contact with audience all the time, use natural gestures and movements, looks confident.	[3 Marks] **A:** **B:** **C:** **D:**
Enthusiasm/Audience Awareness: Demonstrate strong enthusiasm about the topic, significantly increases audience understanding and knowledge of the topic, convinces an audience to recognize the validity and importance of the subject.	[3 Marks] **A:** **B:** **C:** **D:**
Creativity and Use of Media and Presentation time Management: The presentation is creative in design and effectively use multimedia. The presentation is organized with appropriate time management.	[3 Marks] **A:** **B:** **C:** **D:**

Viva/Defense/Q&A	Total Marks (5)
Defend the research on performance in the question/answer session.	**A:** **B:** **C:** **D:**

Flood Rescue Assistance Using UAVs: Enhanced Human and Obstacle Detection with Optimized Path Planning via Bat Algorithm and Improved A*, DWA Integration

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ABSTRACT

Flood disasters pose severe challenges to disaster management, highlighting the urgent need for efficient rescue and relief systems. This research integrates Unmanned Aerial Vehicles (UAVs) with advanced algorithms—Improved A*, Dynamic Window Approach (DWA), and Bat Algorithm (BA)—to address critical gaps in flood response. Insights from a survey revealed key priorities such as clean water (93.33%), medical supplies (73.33%), and temporary shelters (96.67%), alongside barriers like communication failures (90%) and access challenges (60%). Leveraging sensor fusion, UAVs equipped with thermal imaging, radar, and motion detectors enhance victim identification, deliver supplies, and act as mobile communication relays. The proposed system ensures real-time mapping, optimized path planning, and seamless coordination among rescue teams, significantly improving response times and operational efficiency. Future work aims to refine energy efficiency and scalability, positioning UAV-based solutions as a transformative approach to disaster management.

KEYWORDS

UAVs, flood relief, Bat Algorithm, path planning, disaster management, real-time mapping.

INTRODUCTION

Problem Background

Floods are classified as one of the most damaging natural disasters, bringing devastation and destruction in the aftermath. Case in point, the 2024 floods in Bangladesh (Al Jazeera, 2024; CNN, 2024)—afflicted an estimated 5 million people (about twice the population of Mississippi), forcing thousands to be forced from their homes, and many lives lost. These disasters are getting more frequent and intense, making the need for a revolution in disaster response systems more urgent than ever. Although (Unmanned Aerial Vehicles) have proven helpful in times of crisis (e.g., medical deliveries and public area monitoring during the COVID-19 pandemic (Avion Aerospace, 2020; Gavi, 2021)—their potential for saving lives during floods remains underutilized.

FIG-1: A woman and her child wade through floodwaters in Feni, one of the worst-hit areas. [Zakir Hossain Chowdhury/AFP](Al Jazeera, 2024) and They are trying to give relief in this harsh situation. [Dipta Banik]

Dipta Banik from Chauddagram, Bangladesh, is one such person whose story reflects the immediate and tangible hardships experienced during such calamities. In August 2024, Dipta, and a team of specialists found a family stranded on top of a two-story building, isolated for two days without food or a means of communication. All the family could do was watch in despair as floodwaters tore apart their home and isolated them from help. With water depths ranging from 10–12 feet and little mobile connectivity, the situation was grave. These anecdotes of isolation and helplessness in floods are only too commonly heard and underline the urgent need for better disaster management technologies.

While the technologies show great advancement in UAVs overall, disaster scenarios present massive challenges in their application. This covers the ability to plan safe paths in intricate and inundated landscapes, maintain adaptability given varying ecological circumstances, and process current information in decisions (Bai et al., 2021). Existing methods for flood response, such as GIS-based flood mapping, depend on static topographical data that cannot adapt to real-time changes. Though useful, remote sensing technologies like satellite imaging and LIDAR are expensive, resource-intensive, and often too slow to provide immediate help during emergencies (Dhaka Tribune, 2013).

To address these limitations, a comprehensive system that leverages the strengths of UAVs is critical. Such a system must integrate advanced flood detection algorithms, real-time mapping, and efficient resource delivery mechanisms. By combining these capabilities with AI-powered frameworks, disaster management efforts can be transformed to save lives, reach isolated victims, and ensure faster and more effective responses in the face of increasing flood disasters.

Related Studies

Techniques like reinforcement learning and graph-based algorithms have shown promise but often fail in real-time applications due to computational overheads and environmental unpredictability (Zhou et al., 2022). UAVs have been extensively used for real-time flood mapping and monitoring. For instance, research by Smith et al. (2021) demonstrated how UAVs equipped with LiDAR sensors could accurately map flood-affected areas, improving situational awareness for rescue teams. A study by Gupta et al. (2022) highlighted the effectiveness of multi-rotor UAVs in carrying lightweight supplies during emergencies. Thermal imaging and machine learning algorithms have been employed for detecting stranded individuals. Johnson et al. (2020) showed that UAVs using infrared cameras and AI-based image processing could identify victims with high accuracy. The Bat algorithm (BA) is a kind of swarm intelligence optimization algorithm with high efficiency and fast convergence speed (Guo et al., 2015; Yuan et al., 2021). Despite this, it has a gap that UAVs typically have restricted payload capacities, which limits their ability to carry significant amounts of supplies or rescue equipment. Current UAVs often have limited flight durations, making them less effective in covering large flood-affected areas. Efficient coordination among multiple UAVs and rescue teams remains a challenge, particularly in areas where communication infrastructure is damaged. The fusion of Improved A* and DWA algorithms faces issues like static environment assumptions, high re-planning overhead, path discontinuities, and poor adaptation to dynamic obstacles or human detection scenarios. The lack of sensors makes it challenging to identify uncertain obstacles effectively.

Research Objectives

To address the identified gap, the Bat Algorithm (BA) and sensors such as infrared sensors, motion detectors, and radar sensors will be used to provide a solution. The primary objective of this research is to enhance UAV technology for flood relief by accurately detecting individuals, animals, or humans in need of assistance or aid. This study emphasizes the classification of flood zones, humans, animals, and structures using UAV-based object detection methods. Previous studies have explored various obstacles or object detection and path mapping techniques. It seeks to integrate the Bat Algorithm (BA) with Improved A* and DWA algorithms to develop an optimized path planning framework capable of addressing path discontinuities and adapting to dynamic environments. Additionally, the research focuses on improving coordination efficiency among multiple UAVs and rescue teams, even in regions with limited or damaged communication infrastructure, particularly for human or animal detection. Efforts will also be directed at extending UAV operational ranges by proposing methods to increase flight durations and payload capacities.

The research questions are:

- How can UAVs be utilized to identify and deliver essential items like clean water, medical supplies, and shelters to flood victims?
- What role can UAV-based object detection play in identifying severely ill or injured patients during flood relief operations?
- How can UAV technology improve communication and coordination between rescue teams in areas with limited or no network coverage?

Research Contributions

This research addresses the critical challenges of flood disaster management by developing an advanced UAV-based system informed by a survey of flood victims and rescuers. The survey highlighted issues like delays in rescue, difficulties in locating stranded individuals, and communication breakdowns, guiding the design of our system to meet real-world needs. Our contribution lies in integrating the Bat Algorithm (BA) with Improved A* and DWA for efficient path planning, enhanced by advanced sensors for real-time object detection and mapping. This system enables UAVs to deliver essential supplies, locate stranded individuals, and improve coordination among rescue teams, even in areas with damaged communication infrastructure. By extending UAV operational capacities and leveraging AI-powered technologies, our framework reduces response times, increases rescue efficiency, and offers scalable solutions for policymakers and disaster management agencies. This research aims to transform flood relief operations, saving lives and mitigating the impact of these devastating events.

RESEARCH METHODOLOGY

Selection of Data Collection Method

For this research, surveys were selected as the primary data collection method. This quantitative approach is aligned with the goal of obtaining measurable insights into the needs and challenges faced by disaster victims, as well as evaluating the effectiveness of UAV-based technologies in disaster relief operations. The survey method allowed for the collection of diverse perspectives across a wide range of respondents, ensuring comprehensive data to address the research objectives.

Rationale for Selection of Surveys

1. **Quantifiable Insights:** Surveys enable the collection of data that can be statistically analyzed, providing a clear understanding of trends and priorities in disaster management needs.
2. **Broad Reach:** Unlike interviews, surveys can be distributed to a large number of respondents quickly, ensuring data from a variety of demographics and regions.

3. **Direct Relevance to Research Objectives:** The structured nature of surveys ensures that each question addresses specific aspects of the research, such as the identification of relief needs, communication gaps, and the potential role of UAVs in disaster response.

Description of Data Collection Process

The data collection process involved the preparation of a structured questionnaire designed to capture a wide range of information relevant to disaster management. This included six key sections: demographics, relief needs, emergency responses, communication challenges, access to specific needs, and suggestions for improvement.

1. Preparation Phase

In the preparation phase, a semi-structured questionnaire was developed with a mix of closed-ended and open-ended questions. The questionnaire focused on obtaining both quantitative data and in-depth insights into participants' experiences during disasters. Pilot testing of the questionnaire was conducted with a small sample to refine question clarity and relevance, ensuring that the final version effectively addressed research objectives.

2. Survey Distribution

Surveys were distributed to a diverse sample of 30 participants, including flood victims, first responders, and local community leaders. To ensure broad representation, efforts were made to include varied demographics such as age groups (14–18, 19–25, and above 25 years) and gender (male and female). Participants were selected from regions directly affected by floods to gather firsthand experiences and challenges faced during relief operations.

3. Questionnaire Highlights

The questionnaire included targeted questions to explore specific aspects of disaster relief. For example:

- What essential items (e.g., food, water, medical supplies) were most needed during the disaster?
- How was communication affected, and which methods were most effective in maintaining connectivity?
- What challenges did participants face in accessing aid or relief?

Data Analysis and Integration

The collected survey data was analyzed through statistical methods to uncover key insights and trends. Percentages were calculated for each survey section, offering a clear understanding of priorities and challenges, such as the overwhelming need for water (93.33%) and medical supplies (73.33%). Communication issues were also prominent, with 90% of respondents experiencing network failures. The data was then integrated with the UAV-based disaster management methodology to evaluate its effectiveness. UAV technology was found to address gaps in relief efforts, such as delivering essential supplies to remote areas, using object detection for injured victims, and establishing temporary communication networks. The analysis reinforced the practicality of UAVs in supporting disaster operations, aligning well with survey findings and methodological insights. Ethical considerations were maintained throughout, ensuring anonymity, unbiased data collection, and transparency in data handling.

Ethical Considerations

1. **Bias in Data Collection**:
    - Participants were randomly selected to ensure diversity in responses.
    - Efforts were made to include varied demographics: age groups (14-18, 19-25, above 25 years), gender representation (male and female), and individuals with different roles in disaster situations.

2. **Privacy and Confidentiality**:

    - All participants were informed about the purpose of the survey, and consent was obtained prior to their participation.

    - Data was anonymized to ensure the confidentiality of respondents' identities and opinions.

3. **Transparency**:

    - A detailed record of the survey distribution, data collection, and analysis processes was maintained.

    - Raw survey data and methodology documentation were archived to ensure reproducibility and allow further scrutiny by researchers.

Professional Codes of Ethics and Standards

Adhering to professional research ethics, every precaution was taken to ensure that the study maintained credibility and reliability:

- Respondents were treated respectfully, and their participation was voluntary.

- Data collection and storage complied with ethical guidelines to protect participant privacy.

RESULTS AND ANALYSIS

Research Data

The survey provided crucial insights into the needs and challenges faced by disaster-affected communities and their suggestions for improvement in flood relief efforts. The results are discussed below, emphasizing the critical aspects related to relief needs, emergency responses, access challenges, and suggestions for enhanced disaster management.

Relief Needs

The data highlighted an urgent demand for essential items, with food being the most needed (43.33%), followed by mobile chargers and power banks (23.33%) and access to mobile networks and the internet (20%). Electricity connections and other miscellaneous needs each accounted for 6.67%. A staggering 93.33% of respondents indicated the necessity for clean drinking water, while 73.33% emphasized the need for medical supplies.

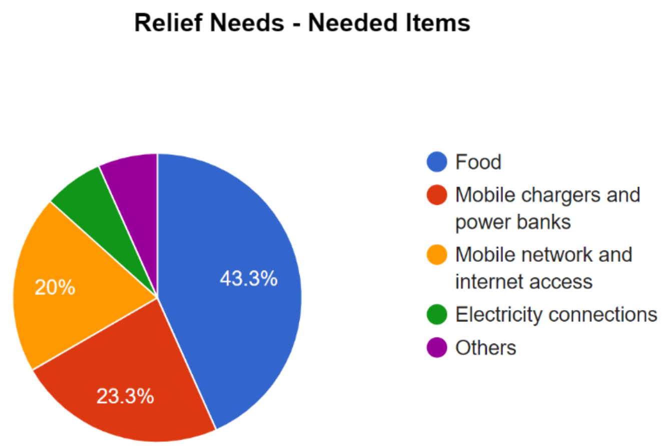

Fig-2: The corresponding pie chart illustrates the proportional demand for these items, underscoring the importance of prioritizing water, food, and medical aid in relief efforts.

Response to Emergencies

The availability of medical assistance during disasters revealed significant gaps. While 43.33% of injured individuals were treated by mobile medical teams and 33.33% were taken to hospitals, 23.33% reported receiving no medical assistance. This disparity highlights the urgency for more efficient emergency healthcare systems. Emergency sanitation efforts also faced challenges, with 46.67% receiving hygiene kits, but 26.67% reporting no support. Temporary toilets were provided to 20%, and other measures accounted for 6.67%.

The process of identifying needs varies across communities. Local community efforts were responsible for 43.33% of reported cases, while 23.33% of victims signaled for help themselves. Technology, such as drones, played a role in 20% of cases, and 13.34% relied on other methods.

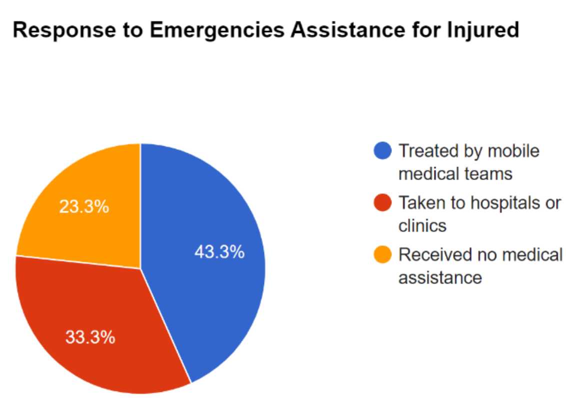

Fig-3: Pie charts provide a clear visual summary of the emergency responses and the methods of identifying victims' needs.

Challenges and Communication

The survey revealed that communication breakdowns were a major issue during disasters, affecting 90% of respondents. Informal communication methods, such as community networks and word-of-mouth, were the most effective, used by 66.67%, while patrols and on-ground surveys accounted for 33.33%. The failure of communication networks underscores the critical need for alternative solutions to ensure reliable connectivity during relief operations.

Access and Specific Needs

Access to relief services was a significant barrier, with 60% of respondents indicating challenges. Specialized aid was deemed necessary by 40%, with another 40% citing varied specific needs such as medical assistance, nutrition, or rescue. Only 20% reported no need for specialized aid.

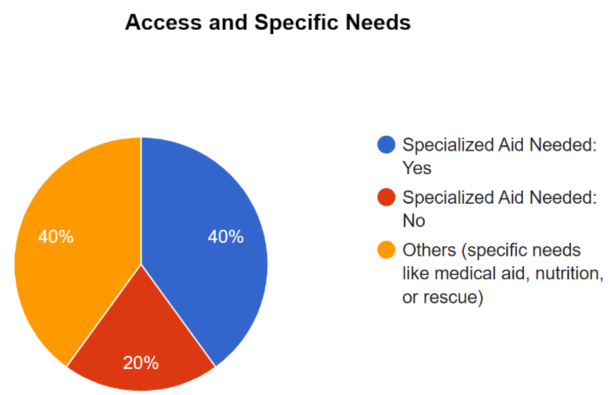

Fig-4: The pie chart on access challenges and specific needs vividly illustrates these barriers and priorities.

Suggestions for Improvement

Respondents provided valuable recommendations for improving disaster relief systems. Temporary shelters were overwhelmingly identified as essential, with 96.67% prioritizing their availability. Coordination gaps were noted by 63.33% of respondents, emphasizing the need for improved planning and execution.

Communication improvements emerged as a central theme, with 36.67% suggesting emergency mobile towers, 26.67% advocating for wider use of radios, and 23.33% emphasizing real-time community alerts. For supply delivery, pre-positioning supplies (33.33%) and real-time tracking (26.67%) were the most favored approaches, while 16.67% called for better infrastructure. The remaining 23.33% recommended a combination of these strategies.

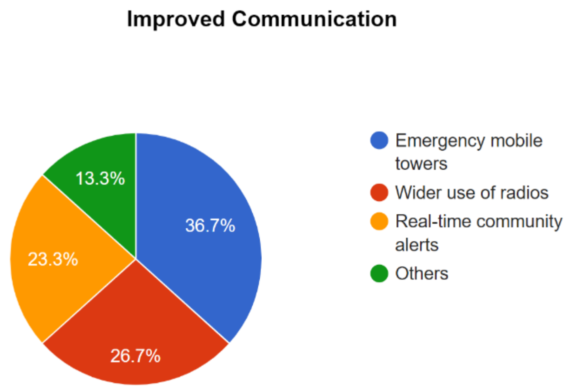

Fig-5: Pie charts accompanying these results highlight the distribution of suggestions, offering a comprehensive view of respondents' priorities.

ANALYSIS AND DISCUSSION:

1. How can UAVs be utilized to identify and deliver essential items like clean water, medical supplies, and shelters to flood victims?

The methodology outlines the use of UAVs integrated with advanced sensors, GPS systems, and delivery mechanisms to conduct aerial surveys and distribute essential resources. Survey data indicates that water (93.33%), medical supplies (73.33%), and temporary shelters (96.67%) are top priorities during flood relief.

Identification: UAVs can perform real-time aerial surveys of flood-affected areas, identifying regions with concentrated populations or visible signs of distress. The survey revealed that technology like drones was used in 20% of cases to identify needs, demonstrating the practicality of UAVs for this purpose.

Efficient Delivery: Given the barriers to access reported by 60% of respondents, UAVs can overcome terrain challenges to deliver water, food, medical kits, and shelter materials directly to isolated areas. Pre-positioning supplies, as suggested by 33.33% of respondents, combined with UAV real-time tracking (favored by 26.67%), enhances delivery efficiency.

This approach aligns the survey's identified relief needs with the methodology's UAV-based delivery mechanisms, ensuring timely and precise resource distribution.

2. What role can UAV-based object detection play in identifying severely ill or injured patients during flood relief operations?

The methodology involves leveraging UAVs equipped with object detection algorithms and thermal imaging sensors to locate and prioritize injured victims. Survey data highlights that 23.33% of respondents received no medical assistance, and 43.33% were treated by mobile medical teams, showing a clear need for improved identification of injured individuals.

Locating Injured Individuals: UAVs equipped with object detection can scan flood zones to identify individuals showing signs of distress or immobility. This technological approach directly supports the survey findings where 20% of need identification involves technology like drones.

Prioritizing Medical Assistance: By analyzing thermal signatures and visual cues, UAVs can identify severely injured individuals and relay their locations to rescue teams. This ensures that limited medical resources are directed to those most in need, addressing the gap where 23.33% of respondents reported no medical aid.

The integration of UAV-based object detection with mobile medical teams (already assisting 43.33%) enhances their operational efficiency and aligns with both the survey data and the methodology.

3. How can UAV technology improve communication and coordination between rescue teams in areas with limited or no network coverage?

The methodology emphasizes the deployment of UAVs as temporary communication relays and tools for real-time data sharing. Survey data reveals that 90% of respondents experienced communication network failures, making this a critical area for improvement.

Temporary Network Solutions: UAVs can establish mobile communication networks in areas where infrastructure is damaged. The survey’s finding that community networks and word-of-mouth (66.67%) were the primary methods of communication highlights the need for technology-based solutions.

Real-Time Data Sharing: UAVs equipped with live-streaming capabilities can provide real-time visuals to command centers, facilitating better coordination among rescue teams. This complements the 33.33% reliance on patrols and on-ground surveys, enhancing their effectiveness.

Localized Alerts: By broadcasting emergency messages, UAVs can reach isolated communities directly, addressing the survey's suggestion of real-time community alerts (23.33%).

Solution Validation

1. **Identifying and Delivering Essential Items**

Solution:
UAVs equipped with optimized path-planning algorithms (Bat Algorithm, Improved A*, and DWA) should be deployed to deliver essential items such as clean water, medical supplies, and temporary shelters to flood victims. These UAVs can efficiently navigate through flood-affected regions and bypass debris or other obstacles, ensuring timely delivery to inaccessible areas.

Validation:
Survey data indicates that clean water (93.33%), medical supplies (73.33%), and temporary shelters (96.67%) were identified as the most critical relief needs. Participants reported significant challenges in accessing these items due to damaged infrastructure. By integrating UAVs with advanced navigation systems, timely and efficient delivery becomes feasible, addressing the exact needs highlighted in the survey.

2. **Enhancing Victim Detection and Medical Assistance**

Solution:
Implement UAV-based object detection systems capable of identifying stranded or severely injured individuals. These systems should include thermal imaging and machine learning models to detect victims under challenging conditions like poor visibility or dense vegetation.

Validation:
Survey results showed that 23.33% of injured victims received no medical assistance, highlighting a significant gap in emergency response. UAVs with enhanced object detection can identify victims who are otherwise overlooked. This technology ensures that rescue teams can prioritize medical aid for those in critical condition, validating its alignment with the challenges reported by respondents.

3. **Improving Communication and Coordination**

Solution:
Deploy UAVs as mobile communication hubs to restore connectivity in areas where networks are disrupted. These UAVs can establish temporary communication links, enabling coordination between rescue teams and real-time information dissemination to affected communities.

Validation:
The survey revealed that 90% of respondents experienced network disruptions during disasters, making communication a critical challenge. Participants relied heavily on alternative methods such as community networks (66.67%) and patrols (33.33%) to share information. UAV-based communication hubs address this gap by providing reliable and immediate connectivity, enhancing coordination and response efficiency during rescue operations.

4. **Efficient Obstacle Navigation in Disaster Zones**

Solution:
Integrate advanced path-planning algorithms such as the Bat Algorithm, Improved A*, and DWA to enable UAVs to navigate dynamically around obstacles like debris, waterlogging, or collapsed infrastructure.

Validation:
Access to aid was a significant issue, with 60% of respondents citing difficulties due to environmental barriers. UAVs equipped with real-time path optimization can adapt to changing environments and avoid obstacles, ensuring uninterrupted relief efforts. This solution aligns with the reported challenges, validating its relevance and practicality in disaster scenarios.

5. **Enhancing Real-Time Relief Operations**

Solution:
Incorporate real-time tracking and monitoring features into UAV operations to improve the delivery of supplies and coordination of rescue teams.

Validation:
Survey participants emphasized the need for real-time tracking (26.67%) and better infrastructure (16.67%) for more efficient relief efforts. UAVs equipped with tracking capabilities can provide live updates on the location of victims, hazards, and relief supplies, ensuring that resources are allocated effectively and efficiently, as suggested by the survey.

CONCLUSION

This paper employs improved A*, improved DWA, and the Bat Algorithm (BA) to enhance UAV path planning and human or animal detection. The Improved A* algorithm is used for global path planning, providing an initial feasible path, while the Improved DWA handles local path adjustments, ensuring obstacle avoidance and real-time adaptability. The BA algorithm is employed to detect humans, animals, and uncertain obstacles, contributing to dynamic adaptability and precise obstacle identification. Sensors are integrated to further enhance the system's effectiveness. Infrared sensors detect heat sources in the environment (e.g., humans and animals), motion detectors highlight regions of irregular movement (e.g., running animals or moving vehicles), and radar sensors map the size and shape of obstacles, distinguishing between smaller objects (e.g., debris) and larger ones (e.g., humans). However, A* struggles with dynamic environments and UAV kinematic constraints, while DWA’s short planning horizon often results in local minima and reactive, suboptimal behavior. These algorithms also lack robust integration of real-time sensor data, limiting their suitability for environments where dynamic obstacle tracking or human detection is essential. The BA algorithm, in contrast, naturally balances exploration and exploitation, making it more effective in dynamic environments and better at avoiding local minima compared to the A*-DWA fusion. By integrating sensors such as infrared, motion detectors, and radar, BA dynamically updates its optimization process in real time. The limitation of this paper, the energy efficiency of the system decreases due to the computational demands of these algorithms, and the BA algorithm suffers from lower convergence accuracy. In the future, energy efficiency could be improved by implementing the Dinkelbach approach and the BA algorithm's performance can be enhanced using the Inertia Weight Decreasing Strategy, which dynamically adjusts the balance between exploration and exploitation, thereby improving convergence speed.

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