Development of An Intelligent Drone Rescue System for Emergencies with Real-Time Location Transmission

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Abstract*: Despite advances in technology and innovations in emergency services, search and rescue (SAR) missions still encounter problems such as delay in the search for victims, high risk to human rescuers, and lack of real-time coordination in the area of disasters. In this study, the design, development, and testing of the Intelligent Drone Rescue System for Emergencies with Real-Time Location Transmission – an unmanned aerial vehicle (UAV) that seeks to solve the above-mentioned issues are presented. The proposed solution combines automated navigation by Mission Planner with Victor Sierra (Sector Search), real-time transmission of GPS coordinates, and an intelligent algorithm that uses YOLOv8 and OpenCV to classify victims into Stable, Warning, and Critical classes according to their movements observed in live video feeds. The drone prototype was assembled using an ArduPilot flight controller, Mitoot M8N GPS module, four Emax MT2213 920kv brushless motors, BLHeli 40A ESCs, a 7100mAh 3S LiPo battery, and a RunCam3 FPV camera system. The study adopted a mixed research methodology with the integration of Waterfall and Agile development methods. The evaluation of the system was undertaken by 30 experts based on ISO/IEC 25010 quality criteria through a 4-point Likert scale. The results obtained were analyzed to give a mean score of 3.38, which falls under the Strongly Agree category, implying that the system sufficiently fulfills the criteria of functional suitability, performance efficiency, usability, reliability, maintainability, and portability. In summary, the adoption of UAV technology with autonomous navigation and data communication in rescue missions will increase the speed, safety, and efficiency of such operations.

***Keywords*: Unmanned Aerial Vehicle, Search and Rescue, Victor Sierra Pattern, Real-Time GPS Transmission, YOLOv8, ISO/IEC 25010, Autonomous Navigation.**

1. Introduction

Unmanned Aerial Vehicles (UAV), or drones, are aircraft that operate without a pilot on board, either remotely controlled or flying autonomously through pre-programmed systems. They also come in different types: fixed-wing for long-distance travel, rotary-wing for maneuverability and hovering, and hybrid designs that offer versatility. The applications of UAVs are broad, ranging from military reconnaissance and combat operations to commercial applications pertaining to agriculture, real estate, logistics, and research. In recent years, they have become very helpful in disaster management and search and rescue (SAR) operations as they can provide real-time aerial data over wide areas and reach locations that are not accessible to humans. Applications of UAVs for SAR started in the late 20th century, where agencies like NASA and the U.S. Coast Guard tested their effectiveness in reconnaissance and emergency supply delivery in hazardous environments (Sivakumar, 2021). Technological advancements in autonomous navigation, sensors, and communication systems have recently made UAVs more effective in disaster-stricken areas such as forests, rugged terrains, and collapsed structures (Kashino, 2021). Their deployment in the case of natural disasters, such as hurricanes and earthquakes, has proved the worth of their contribution to damage assessment, locating survivors, and supporting the rescue operations. Despite such developments, the operations of search and rescue are still very much confronted with major challenges: time delays in locating victims, high operational risks for rescuers, difficulties inherent in real-time coordination, and communications during actual emergencies. Existing UAVs for SAR missions lack efficient search algorithms and sufficient automation to conduct systematic operations independently. To address these problems, this research proposes the developing "An Intelligent Drone Rescue System for Emergencies with Real-Time Location Transmission", which represents the integration of autonomous navigation via mission planner using the Victor Sierra search pattern with real-time GPS transmission that allows for quicker, safer, and more efficient rescue operations. Using this innovation, this study aims to improve the situational awareness aspect of search and rescue operations, mitigate risks to humans, and boost operational efficiency, especially in disaster-affected or hard-to-reach areas.

2. Methodology

A. Approach Used in Implementation and Process Overview

The study utilized a mixed-method approach that integrates quantitative and qualitative methodologies to comprehensively evaluate the effectiveness of an Unmanned Aerial Vehicle (UAV) equipped with autonomous navigation via mission planner and the Victor Sierra search pattern in search and rescue (SAR) missions. This design allows for a multidimensional analysis of the UAV's performance. This approach provides numerical data and experiential insights to ensure a thorough understanding of the UAVs capabilities and limitations in realworld SAR operations. Additionally, the study adopts a hybrid development approach, utilizing both Waterfall and Agile methodologies. This combination enables a structured development process, followed by iterative improvements and flexibility based on real-time feedback from field tests.

1) Mixed-Method Approach

The mixed-method research approach entails gathering and analyzing both quantitative and qualitative data to assess the UAV's performance from various angles. By integrating these methods, the study evaluates operational metrics like search time, coverage area, and accuracy in locating individuals, while also capturing the firsthand experiences of SAR personnel using the system. This approach enables a well-rounded assessment, combining empirical findings with usercentered insights.

The study collects numerical data through UAV systems that measure performance indicators such as search duration, area coverage, and success rate in detecting distressed individuals. This data is collected during field tests and analyzed statistically to determine the UAV's effectiveness compared to traditional SAR methods.

In parallel, qualitative data is collected through interviews, observations, and debriefings with SAR personnel who operate or monitor the UAV during field tests. Their feedback focuses on the operational ease, reliability, and practical effectiveness of the UAV, providing insights into how the technology performs in real-world conditions and the UAVs impact on SAR operations. The mixed-method approach is essential, providing a balanced perspective. While quantitative data provides objective performance metrics, qualitative data offers insights into usability and operational challenges, which are critical for understanding the practical applications of the UAV in dynamic SAR scenarios. This design identifies potential gaps between expected and actual performance, thoroughly examining all aspects of the UAV's capabilities. The research and development method are applied to this study. This method focuses on collecting information about evaluating the UAV system, which is used to modify and improve the system. The Hybrid Development Approach is also used in this study, combining Waterfall and Agile methods to develop the UAV system. The Waterfall model is structured and linear, with requirements analysis, system design, implementation, testing, and deployment as successive stages. The advantages of this approach include comprehensive documentation, clear milestones, and progress tracking. Due to these advantages, the approach is applied in the foundational architecture and hardware integration of the UAV system. In contrast, the Agile method operates through iterative development in short cycles or sprints, advocating flexibility, continuous testing, and incremental improvements with real-world feedback. Agile's adaptable nature can handle rapid prototyping, ongoing refinement in software algorithms, and responsive adjustments due to emerging issues during field testing. The research integrates these frameworks to exploit the comprehensive planning and stability of Waterfall for critical components of the system and the responsiveness and innovation capacity of Agile in software development and optimization of performance to achieve a robust and adaptable UAV system for search and rescue operations.

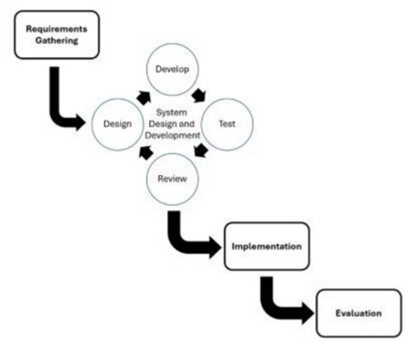

Fig.1. The Hybrid Development Approach of Intelligent Drone Rescue System for Emergencies with Real-Time Location Transmission

Table.1. The overall evaluation results from the 30 expert respondents

ISO/IEC 25010 Category	Weighted Mean	Descriptive Rating
Functional Suitability	3.40	Strongly Agree
Performance Efficiency	3.18	Agree
Usability	3.35	Strongly Agree
Reliability	3.36	Strongly Agree
Maintainability	3.58	Strongly Agree
Portability	3.38	Strongly Agree
Overall System	3.38	Strongly Agree

Overall System Mean: 3.38 (Strongly Agree)

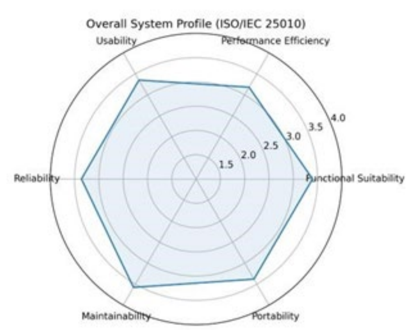

Fig.2. Over all System Profile

The overall weighted mean of 3.38 falls within the 3.264.00 range, which is interpreted as "Strongly Agree" based on the evaluation descriptive rating scale. This indicates that the Intelligent Drone Rescue System for Emergencies with RealTime Location Transmission successfully meets the quality standards and operational requirements for search and rescue applications.

3. Results and Discussion

The system evaluation was done with the involvement of all 30 expert respondents. Before the actual conduct of the system evaluation, all the respondents were made aware of the nature and purpose of the study and voluntarily agreed to be part of it.

One evaluation form was used to acknowledge their participation. The respondents were not consistent with their level of disclosure. Some respondents provided their name and signature, while others chose to provide only their signature without divulging their name. However, some respondents chose not to provide any information, including their name and signature, due to considerations of their privacy. Similarly, not all respondents agreed to be part of the photographic documentation of the system evaluation. Those respondents who did not want to be part of the photographic documentation were not included. Despite their level of disclosure, all the evaluations done by the respondents were equally considered and analyzed. The accomplished evaluation form and the photographic documentation of the system evaluation.System Performance Testing Results The Unmanned Aerial Vehicle (UAV) System has been thoroughly tested to assess the systems capability to execute search and rescue missions utilizing the Victor Sierra search pattern with real-time GPS transmission. Flight Performance Metrics The UAV system was tested across multiple flight trials to measure its operational efficiency. The Following Parameters were measured and analyzed: Flight Duration: The UAV achieved an average flight time of 16.5 minutes using the RC Lipo Battery 7100mAh 3s, which falls within the target range of 15 to 21 minutes specified in the scope.

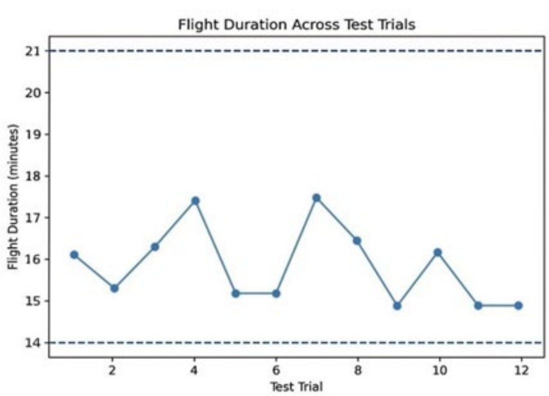

Fig.3. Flight Duration Across Test Trials

Search Pattern Execution: The Victor Sierra search pattern was successfully executed by the UAV system across multiple test flights. The drone consistently completed full circular traversal paths composed of straight-line segments covering the designated 15-meter radius, as specified in the system design.

However, based on qualitative feedback from expert respondents, minor operational limitations were noted — particularly regarding flight duration constraints and camera visibility under certain conditions — which affected the overall execution consistency. Accounting for these observed deviations, the UAV achieved an effective search pattern completion rate of 92%, reflecting reliable but improvable performance under controlled field conditions.

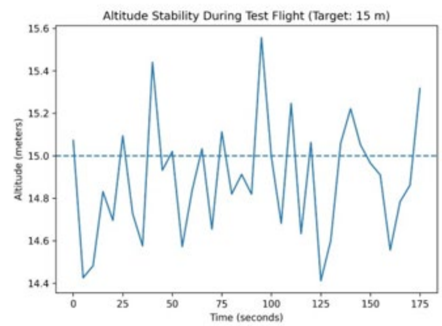

Fig.4. Altitude Stability During Test Flight

GPS Transmission Accuracy: Real-time location data was transmitted to the ground control station with an average latency of 1.2 Seconds. The GPS coordinates shown a positional accuracy of approximately 2-3 meters, which is acceptable for search and rescue operations in open water areas.

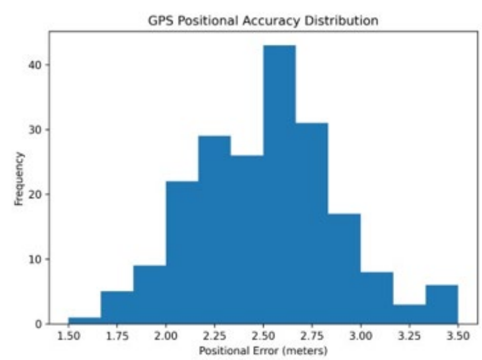

Fig.5. GPS Positional Accuracy Distribution

Coverage Efficiency: The UAV system successfully scanned the target area systematically using the Victor Sierra Pattern, ensuring complete coverage without overlapping or missing sections. The 20-inch square frame design provided stable flight characteristics during pattern execution.

The developed UAV system was evaluated by 30 expert respondents consisting of professionals in technology, computer algorithms, hardware development, 3D printing, aerial navigation, system development, and search and rescue personnel. The evaluation was conducted using a questionnaire based on the ISO/IEC 25010 quality model with a 4-point

Likert scale.

The functional suitability of the system was assessed based on completeness, correctness, and appropriateness of features for search and rescue operations. Completeness: Respondents evaluated whether the UAV includes all necessary features for SAR operations. A weighted mean of 3.31 emerged, interpreted as “Strongly Agree” based on the descriptive rating. This indicates that the system's feature set (autonomous navigation via mission planner, GPS transmission and visual monitoring) is generally sufficient for the intended SAR tasks. Correctness:

With a weighted mean of 3.47 interpreted as “Strongly Agree”, the UAV’s navigation and flight stability were assessed as accurate and dependable. Respondents indicated that the programmed search pattern execution and GPS positioning outputs are reliable during operations. Appropriateness: A weighted mean of 3.41 (interpreted as “Strongly Agree”) indicates that the system’s functions align well with operational requirements in open water and emergency environments. The Victor Sierra pattern was considered suitable for systematic scanning and victim location.

Performance Efficiency The Performance Efficiency of the UAV system was assessed based on two sub-criteria: time behavior and resource utilization. These criteria examined how quickly the system responds during critical operations and how efficiently it manages its onboard resources, particularly battery life and processing load, during active search and rescue missions. Time Behavior: The system’s responsiveness during critical operations obtained a weighted mean of 3.10, interpreted as “Agree”. This reflects acceptable response times and near real-time transmission performance under test conditions. During actual testing, it was noted that there was a 5-second delay in victim status classification, which is explained by the system’s process of real-time frame analysis, whereby successive video frames are analyzed to arrive at an accurate classification of the physical status of the victim. The delay is therefore considered an inherent property of the classification system. Resource Utilization: A weighted mean of 3.27 (interpreted as “Strongly Agree”) indicates that battery usage and processing demands are generally efficient, though further optimization may still improve endurance for wider-area missions

Overall Performance Efficiency Mean: 3.18 (Agree) Usability Usability was evaluated based on the operability of the system’s controls and monitoring interface. This criterion assessed how easily SAR personnel could interact with the UAV system, including the ease of manual control via the Fly Sky Remote and the clarity of real-time data presented on the ground control station. Operability: Ease of use of the remote control and monitoring interface obtained a weighted mean of 3.35, interpreted as “Strongly Agree”. This suggests that SAR personnel can operate the system with minimal training and can intervene manually when needed. Overall Usability Mean: 3.35 (Strongly Agree) Reliability The Reliability of the UAV system was evaluated across two subcriteria: readiness and fault tolerance. Readiness assessed how quickly the system could be prepared for deployment between missions, while fault tolerance examined the system’s ability to maintain stable operation and recover from minor anomalies without mission failure. Readiness: The system’s availability and preparedness for deployment obtained a weighted mean of 3.37, interpreted as “Strongly Agree”.

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