AUTONOMOUS DRONE FOR SEARCH AND RESCUE OPERATIONS

Gokul Ananth R
Department of Robotics and Automation
Rajalakshmi Engineering College
Chennai, India
211601013@rajalakshmi.edu.in

Madheshwaran M
Department of Robotics and Automation
Rajalakshmi Engineering College
Chennai, India
211601027@rajalakshmi.edu.in

Arivudeepanraj N
Department of Robotics and Automation
Rajalakshmi Engineering College
Chennai, India
211601005@rajalakshmi.edu.in

***Abstract*–- This project presents an autonomous drone system that is intended to improve the effectiveness of search and rescue missions in the case of natural and human-made disasters. Utilizing machine learning algorithms and computer vision technology, the drone autonomously detects and locates people in distress based on visual and thermal patterns. Equipped with its high-definition cameras, sensors, and GPS, it makes disaster area assessments, detects people in distress, and sends real-time locations to rescue teams and a command center. apart from its application in detection, the drone assists in rescue activities by carrying critical resources such as emergency medical kits, food supplies, water, and communication tools. Its ability to navigate itself makes it easy to function within difficult terrains and harsh climatic conditions with minimal human oversight, providing constant functionality even within complicated environments. through integrating real-time data processing with communications features, the drone enables quick decision-making and deployment, thus enhancing response time in the event of an emergency. The system's scalability and flexibility enable it to be used in various disaster scenarios, including fires, floods, and earthquakes. Autonomous drone technology is a major leap in disaster response, and it improves the safety, speed, and efficiency of rescue efforts. It eventually plays an important role in saving lives and reducing the effect of crises by connecting the victim and the team.**

Autonomous Human Detection, Machine Learning Algorithms, Computer Vision, Search and Rescue Missions Automated Drone System

I.INTRODUCTION

This project proposes an unmanned drone system that will enhance search and rescue operations during natural disasters and man-made tragedies. The drone is equipped with advanced sensors and automation technology, enabling it to detect people in distress, map their exact location, and forward this data in real-time to command centers and rescue teams. This capability significantly reduces response time and enables quicker identification of the needy and faster deployment of resources. The autonomous navigation system of the drone enables it to move through complex terrain and hostile environments with little human intervention, making it very efficient when operations via manual means turn out to be challenging. Aside from searching for people, the drone can also conduct payload delivery, delivering essential items like medical equipment, food, water, or communication devices to the stranded. Such a feature provides critical assistance in situations where quick assistance is needed but ground access is delayed or restricted. Through the integration of accurate navigation, real-time communication, and autonomous flight, the system offers a reliable and scalable solution to improve disaster response capabilities. Its ability to operate autonomously guarantees dependable performance in high-risk environments, enhancing the effectiveness and safety of search and rescue missions.

During disaster scenarios, timely and efficient search and rescue (SAR) missions play a key role in saving lives. This project introduces an autonomous drone system with the objective of enhancing SAR performance by rapidly surveying vast and inaccessible regions. Equipped with high-definition cameras and thermal detectors, the drone automatically scans the environment to spot and detect individuals at risk. Once detected, it determines their precise GPS coordinates and communicates this information in real time to rescue groups and command posts. Autonomous navigation of the drone allows it to operate with limited human intervention, rendering it highly effective in risky or remote areas. Its ability to move through difficult terrain and harsh weather conditions provides reliable performance on critical missions. Through the provision of real-time data and continuous monitoring, the system significantly reduces search times, increases accuracy, and increases the overall efficiency of SAR operations, in turn, leading to the saving of more lives.Thirdly, it enhances client pleasure by making suggestions that precisely match their requirements and preferences, encouraging enduring engagement and loyalty.From a technical standpoint, this initiative makes use of cutting-edge deep learning and machine learning methods. The foundation of sentiment analysis is made up of neural networks, transformers, and other NLP models, which allow the system to process massive amounts of unstructured textual data

The autonomous drone system for SAR operation has been equipped with complex techniques that facilitate enhanced efficiency and reliability. It makes use of computer vision and image processing algorithms for the detection and identification of humans by exploring the visual and thermal patterns. The drone is equipped with GPS navigation and sensor fusion for autonomous navigation in any terrain to ensure accurate location tracking. Real-time data transmission enables smooth communication with rescue teams, providing immediate GPS coordinates and visual information of identified individuals.

The autonomous search and rescue (SAR) drone system employs YOLO-NAS (You Only Look Once – Neural Architecture Search) for real-time object detection. YOLO-NAS combines YOLO's speed with Neural Architecture Search optimization, ensuring high accuracy and low-latency processing. It enables the drone to detect people in distress by analyzing visual and thermal images, even in complex environments. Its efficient edge deployment positions it ideally for use in drones, providing reliable performance with low computational demands. By embedding YOLO-NAS, the system improves accuracy in human detection, thus enhancing the speed and efficiency of SAR missions, ultimately leading to the saving of more lives.in client mood and preferences. In this project, there are several goals.

By making delivery of essential supplies is crucial in disaster response operations. This project uses autonomous drone technology to optimize payload delivery in search and rescue missions. The drone is able to transport medical kits, food, water, and communication devices to the survivors in remote or inaccessible areas. Through independent planning and execution of delivery routes, the system ensures proper and timely delivery of aid without the involvement of people. Its GPS navigation enables pinpoint targeting of delivery sites, and its real-time data transmission allows rescue teams to view supply status.

This project, in summary introduces an independent drone system designed for search and rescue (SAR) operations during crises. Equipped with YOLO-NAS object detection, it accurately locates people in distress by scanning visual and thermal information. GPS navigation, sensor fusion, and real-time communication are used by the drone to transmit the exact position of the victims to rescuers. The payload delivery system transports essential materials, including medical supplies and rations, to remote areas. With autonomous navigation and collision avoidance features, the drone operates well in complex environments, enhancing SAR speed, accuracy, and safety, which ultimately saves lives in emergency situations.

II. LITERATURE SURVEY

In [1], Sharifah Mastura Syed Mohd Daud et.al., (2021) Studied that Drones are increasingly used in agriculture, business, disaster response, and humanitarian relief. There is little evidence of its use in mass disasters. This article aims to review the existing drones. this review synthesizes 52 studies from 2009 to 2020 on the application of drones in disasters, employing the Arksey and O'Malley framework and Joanna Briggs Institute Framework for Scoping Reviews approach.

In [2], The e-commerce decision support methodology presented in this study uses review-based insights to improve item comparison. To overcome the shortcomings of previous models, the model incorporates neutral information and reluctance in textual data and analyzes online reviews using Probability Multivalued Neutrosophic Linguistic Numbers (PMVNLNs). By highlighting both similarities and contrasts, PMVNLNs allow for the nuanced portrayal of both positive and negative review data. In order to account for the restricted rational behaviors of customers, the model also incorporates an outranking approach and regret theory. Empirical comparisons with four other models and PConline.com show better accuracy as determined by the total relative difference metric. A solid strategy for improving e-commerce decision support services that improves customer satisfaction is provided by the suggested model.

In [3], D.C. Sched et.al., (2018) Researched a prototype UAV system for performing autonomous SAR missions in dense forests. It was evaluated in 17 field experiments and detected 38 out of 42 concealed persons with an accuracy of 86% using designated paths. Adaptive path planning enhanced detection confidence by 15%. Real-time on-board image processing, classification, and dynamic flight adjustments enhance efficiency. Deep-learning-based human classification lessens image requirements by 90%, leading to shorter missions. The system operates in remote environments with small bandwidth, sending only detection findings, and is ideal for real-time SAR missions.

In [4], Narek Papyan et.al., (2024) studied drone-based technologies for finding people in the wake of disaster through detecting human screams and cries of distress. Drones can reach remote areas, scan vast areas quickly, and distinguish between human and natural sounds using thermal imaging or artificial intelligence. Techniques such as convolutional neural networks (CNNs) and direction of arrival (DOA) improve the processing and pinpointing of sound. These technologies improve search-and-rescue efficiency by locating people trapped and providing relief to disaster-stricken areas.

In [5], Nooritawati Md Tahir et.al., (2019) Studied Natural disasters are happening more frequently with greater intensity, resulting in unprecedented loss of property and life. Search and rescue missions are unavoidable, particularly in cases of multiple fatalities. Unmanned aerial vehicles (UAVs), or drones, are both cost-effective and efficient means of detecting and identifying victims before they decompose. The benefits of UAVs compared to traditional methods are due to their size and technology.

In [6], Ahmad Hafizam Hasmi et.al., (2023) Researched Drones have been invaluable in search and rescue missions, offering real-time victim detection in hostile environments. YOLOv5 deep learning is employed in this project to automatically detect people in drone video streams. A DJI Matrice 300 drone equipped with a Zen muse H20T camera was employed to gather data on 15,000 m². The yolov5l6 model, at 6x magnification, offered the best precision (0.846), recall (0.543), and mAP50 (0.591) and yet maintained a processing rate of 23fps.

In [7], Jin Q. Cui et.al., (2014) Proposed on International Tiny Aerial Vehicle Competition with a focus on urban search and rescue missions after disasters employing mini aerial vehicles. Key mission areas are real-time map stitching, indoor navigation, and rooftop perching. Solutions proposed were clearly effective in the competition, and they allowed the team to become the champion. This paper identifies innovative approaches and their effective use in overcoming the challenges of the competition.

In [8], Rameesha Tariq et.al., (2018) Studied Natural disasters like bushfires, floods, and earthquakes cause widespread destruction and loss of life, with survivors buried under debris. The application of instant search and rescue efforts is imperative, though. This article introduces "DronAID," a technology that utilizes autonomous drones to scan for individuals under disaster scenarios. DronAID is fitted with a camera module, sensors, and a monitoring system, allowing it to find survivors and provide data for subsequent interventions. Its portability and effectiveness make it an essential tool in urban disaster management, which can save lives in life-threatening conditions.

In [9], K. Jayalath et.al., (2021) Researched drone-based approach to identification of persons in search and rescue operations. It employs a TensorFlow neural network to identify persons in real-time airborne video and autonomously heads to suspicious locations for further examination. Image, GPS information, and flight commands are handled by a single-board computer to deliver efficient, real-time identification. Operator override allows flexibility, and the system is thus an efficient tool for enhancing search and rescue operations.

In [10], Matthew C. Fysh et.al., (2018) Studied Despite the increasing use of drones for military, police, and search operations, this analysis takes into account the challenge of identifying people from drone images. Research in cognitive psychology indicates that identification of people is difficult even in optimal conditions, and it is even more difficult with drone surveillance taking into account image quality, body language, and gait identification. Lab experiments are guaranteed to be an underestimate of real-world difficulties, which means that identification of people from drones is still a real challenge in real-world applications.

In [11], Yao-Hua Ho et.al., (2022) Investigated an Open Collaborative Platform for Search and Rescue (SAR) missions in the event of disasters such as wildfires. It employs numerous drones with a Krypto module fitted, which picks up cell phone signals and identifies survivors. Through crowd-sourcing volunteer drones and information, the platform decreases search paths, minimizing the number of drones required as well as the time required for searching, thus enhancing efficiency in disaster response operations in cases of large-scale incidents.

In [12], Felipe N. Martins et.al., (2016) describes a drone-based system that enhances search and rescue operations by detecting individuals and assessing landing sites. Employing a downward-facing camera, the system calculates Histogram of Oriented Gradients (HOG) features and applies a Support Vector Machine (SVM) for discrimination. The findings demonstrate improved performance for people detection (sensitivity >78%, specificity >83%) and discrimination between safe and unsafe landing sites (sensitivity >87%, specificity >98%), enhancing the efficiency of rescue operations.

In [13], Sven Mayer et.al., (2019) Studied occurrence of natural disasters is increasing with global warming, and search and rescue missions are becoming increasingly necessary. Drones provide flexible use in inaccessible areas, help in the search for missing individuals, and provide aid to the injured. Their capacity to shorten rescue time makes them indispensable in saving lives. This study investigates their application in improving rescue efficiency.

In [14], Sergio Caputo et.al., (2022) Researched High-resolution camera-equipped drones and onboard GPUs greatly improve Search and Rescue (SAR) operations, enabling quicker victim identification. Experimental evaluation using YOLOv5 on new SAR-specific datasets demonstrates competitive detection accuracy and lower processing times. These findings demonstrate the potential of drones to improve survival rates by improving detection efficiency and lowering rescue times in remote locations.

In [15], P.J. Baeck et.al., (2019) Investigated that Drone and small cameras improve human detection in search and rescue operations. Aerial photogrammetry delivers accurate localization and 3D terrain modeling. This method detects and maps individuals' coordinates to an Ortho mosaic through nadir drone images, deep learning, and photogrammetric techniques. Full automation of near-real-time processing improves rescue operations in remote regions.

In [16], Y L Lai et.al., (2007) Studied UAVs are promising search and rescue devices that utilize IoT technology to aid geolocation and environmental sensing. This study assesses UAV usability with particulate matter, temperature/humidity, and CO sensors. Findings correlate with EPA data, which is a measure of reliability. Computer-aided simulated flight route planning proves UAV effectiveness in emergency operations, facilitating rapid data acquisition and better decision-making in rescue operations.

In [17], Ali Al-Naji et.al., (2019) Studied that Drones assist in search and rescue during disasters by traversing difficult terrain. This paper investigates a human life detection system with drones using computer vision for the detection of cardiac motion in drone images. Experiments on eight subjects and a mannequin prove the feasibility of remote detection of live signals, offering a non-contact approach for survival evaluation and rescue missions.

In [18], Antonio Albanese et.al., (2022) Researched That SARDO is an infrastructure-independent, autonomous drone-based search and rescue system that locates missing people using phone signals without any dependence on infrastructure assistance or phone upgrade. SARDO uses pseudo-trilateration and machine learning to estimate positions with good accuracy. Field trials are satisfactory with accuracy of tens of meters in less than three minutes per unit and low power consumption (5%), which shows SARDO as a novel and effective disaster relief tool.

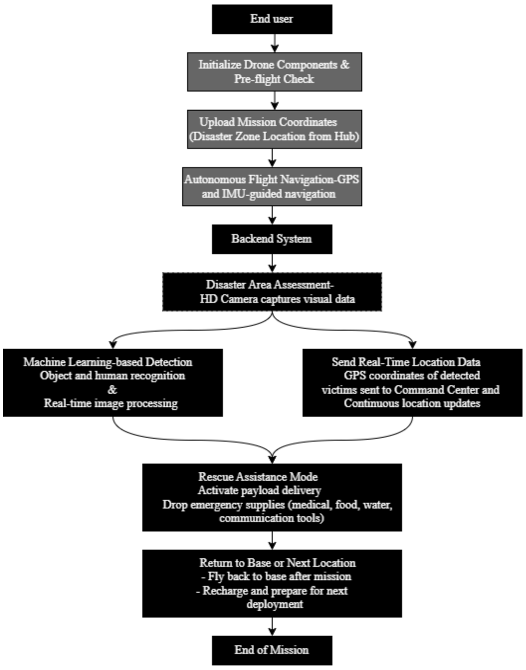
In [19], Donggeun Oh et.al., (2021) Studied that UAVs are widely utilized for disaster relief, but the positioning of survivors becomes challenging in areas where mobile networks or GPS signals are absent. This article presents an autonomous search system of UAVs utilizing a genetic-based localization technique for finding distress signals. The technique has been experimentally validated for practical environments and enables UAVs to identify and navigate towards survivors with no need for ground control, thus providing scope for effective rescue missions.

In [20], Yunus Karaca et.al., (2017) Investigated that Initially developed for military use, drones are used across different sectors such as medicine and search operations. They hold the potential to reduce search duration and enhance response capability, especially in mountainous rescue operations where reaching individuals in a critical phase of 60 minutes is the priority. The research assesses the efficiency of drone-based searching methods against conventional methods, highlighting their ability to detect and assist victims who are found in remote terrain.

In [21], Chunxue Wu et.al., (2019) Studied Deep reinforcement learning (DRL) has revolutionized autonomous drone flight, following the success of AlphaGo. In this paper, DRL is used in the Nokia Snake game to enable autonomous routing. The Snake algorithm holds promise for practical applications like UAV-disaster response, search and rescue, and material delivery, minimizing reliance on manual control in disaster scenarios.

In [22], Tri Nguyen et.al., (2022) Researched that improved Internet-of-Drones (IoD) architecture that combines blockchain and edge artificial intelligence to improve search and rescue (SAR) operations. It overcomes challenges such as the requirement for human intervention, wastage of energy, and security threats. The new architecture uses blockchain to enable real-time communication, automate search protocols, maximize energy efficiency, and provide secure, decentralized communication in the healthcare sector.

III. PROPOSED MODEL



a. INITIALIZE DRONE COMPONENTS MODULE

The Initialize Drone Components Module is a critical stage in the autonomous drone system used in search and rescue missions. This module activates and initializes the critical hardware modules such as GPS, IMU (Inertial Measurement Unit), cameras, sensors, and communication systems. It ensures the drone is sufficiently powered up and forms a steady connection with the command center. The module also performs initial diagnostics to ensure battery levels, sensor operation, and GPS signal accuracy. By ensuring that all systems are in top working order, this module lays the foundation for reliable navigation, real-time transmission of data, and proper evaluation of disaster zones in rescue operations.

b. AUTONOMOUS FLIGHT NAVIGATION MODULE

The Autonomous Flight Navigation Module enables the drone to fly autonomously over disaster zones with minimal human intervention. Through the use of GPS, IMU, and obstacle avoidance algorithms, the module ensures precise path planning and real-time adjustments. It actively detects and avoids obstacles such as debris, buildings, or uneven terrain, allowing it to navigate safely and efficiently. The module also takes control of altitude control, waypoint tracking, and route optimization. Through the use of real-time location data and environmental feedback, it ensures the drone adequately encompasses the search area, enhancing its ability to locate victims and provide vital resources while carrying out rescues.

c. MACHINE LEARNING DETECTION MODULE

The Machine Learning Detection Module is responsible for detecting and locating people in distress using advanced computer vision algorithms. It makes use of the YOLOv5 NAS model, which has remarkable accuracy rates: mAP 96. 8%, Precision 95. 8%, and Recall 96. 4%, using the coco/14 checkpoint. The module processes real-time visual and thermal information collected by the drone cameras, detecting human silhouettes, distress indicators, and objects. Its high precision and recall rates ensure few false alarms and accurate identification, even in complex environments. The module is critical in enhancing the drone's effectiveness in search and rescue operations by providing reliable, real-time victim detection.

d. SEND REAL-TIME LOCATION DATA MODULE

The Send Real-Time Location Data Module is crucial for transmitting accurate coordinates of victims to the rescue team and command center. Through the use of the drone's GPS and communication systems, this module continuously sends the latest latitude and longitude of detected individuals. It also sends live video streams and status reports, providing rescuers with accurate situational awareness. The data is transmitted over a secure and low-latency network to ensure rapid action. This module is essential in boosting rescue efforts through rapid decision-making and guiding teams directly to the victims' points, significantly reducing response time.

e. RESCUE ASSISTANCE MODE MODULE

The Rescue Assistance Mode Module enables the drone to anticipate rescue operations by delivering vital supplies. Equipped with a payload system, the drone carries and autonomously delivers emergency medical kits, foodstuffs, water, and communications equipment to beneficiaries. The module uses precise GPS targeting to dispense supplies at the exact spot of targeted persons. It also promises safe and regulated delivery by paying for wind speed, altitude, and terrain factors. This enhances the efficiency of the drone not only in identifying victims but also in providing necessary resources in real time, thereby significantly increasing the efficiency of the rescue mission.

f. RETURN TO BASE OR NEXT LOCATION MODULE

The Return to Base or Next Location Module is responsible for the navigation of the drone after the completion of its current mission. Once the rescue mission or supply drop has been achieved, the module automatically engages the drone to return to its base station for recharging and maintenance or proceed to the next designated location. It uses GPS waypoints, real-time environmental data, and avoidance of obstacles to ensure a safe and efficient return or transition. This module plays a critical role in maintaining continuous operation of drones, minimizing downtime, and making them ready for potential future assignments.

g. EVALUATION AND FEEDBACK MODULE

The Evaluation and Feedback Module assesses the performance of the drone before and after every rescue mission. It collects and analyzes telemetry information, accuracy of detection, and efficiency of navigation. The module evaluates critical metrics such as precision of flight path, success rate of object detection, and delivery precision. It also receives feedback from the rescue team in terms of response time, reliability of data, and efficiency of supply deployment. This continuous evaluation process helps to identify areas for improvement, optimize the machine learning algorithms of the drone, the navigation system, and communication dependability, such that future rescue operations are conducted with enhanced performance and efficiency.

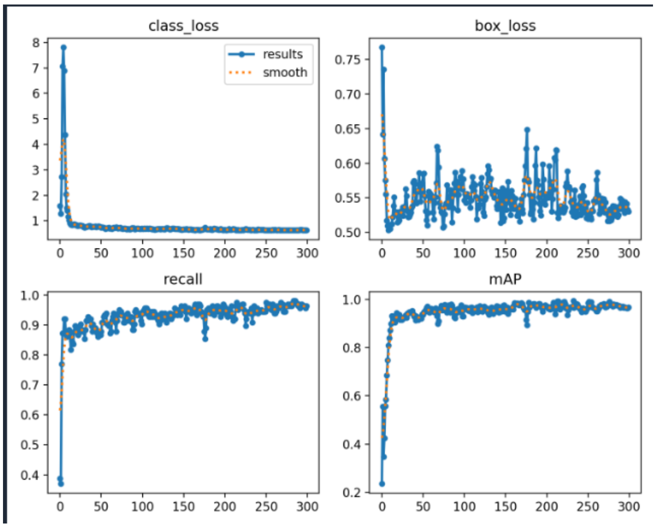
IV. RESULT ANALYSIS

The dataset used in training and evaluating the YOLOv5 NAS model is made up of 527 images with 895 annotations that were specifically prepared for human detection for disaster cases. The dataset has been collected from real-world images of drones, which have been taken during search and rescue activities in various environmental conditions like floods, earthquakes, and fire ground. Also included are openly accessible data such as COCO (Common Objects in Context) or Open Images that have human representations in external environments. Synthetic data is added or included for additional robustness of the model by replicating difficult conditions such as low visibility or presence of debris. The dataset has an average of 1. 7 annotations per image and has one category marked as human. All photos have been reduced to a resolution of 640x640, with an average file size of 0. 41 megapixels. The dataset promotes diversity through the treatment of changing lighting, angles, and terrain, enhancing the ability of the model to generalize. Each photo is labeled with bounding boxes precisely defining human shapes, which assists in accurate training. This diversity makes the model able to effectively identify humans in varying postures and orientations, which makes it ideal for use in real-time disaster scenarios.

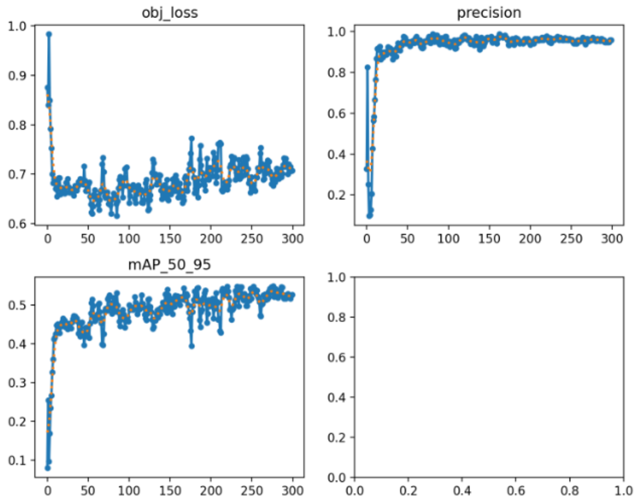
The dataset employs bounding boxes to label each detected human body through (x, y, width, height) coordinates. The format of annotation follows YOLO standards, where each entry denoted as <class_id> <x_center> <y_center> <width> <height> Since the dataset is designed to detect humans, it has only one class label, which is 0. With a mean of 1. 7 annotations

per image, the dataset maintains a well-balanced object density, allowing the model to learn efficiently to detect humans in sparse and dense environments. The accurate bounding boxes significantly enhance the localisation capability of the model, and the consistent annotation format ensures seamless compatibility with the YOLOv5 training process.

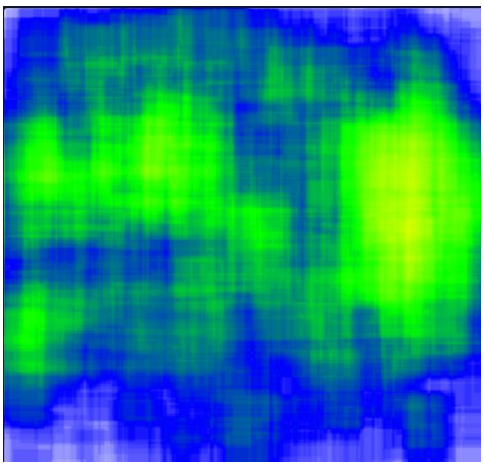
The training plots demonstrate the excellent performance and stability of the YOLOv5 NAS model. The class loss decreases noticeably in the early epochs, indicating rapid learning, and stabilizes at about 50 epochs, showing consistent classification correctness. The box loss, representing the accuracy of bounding box predictions, fluctuates in the beginning but increasingly stabilizes, emphasizing improved localization correctness. The object loss, which measures the model's accuracy in distinguishing objects from backgrounds, greatly reduces during the initial stages before plateauing between 0. 65 to 0. 7, reflecting reliable object detection. The model achieves high precision (~95. 8%) and recall (~96. 4%), with both metrics reflecting rapid improvement and leveling at high values, reflecting the model's effectiveness in detecting human



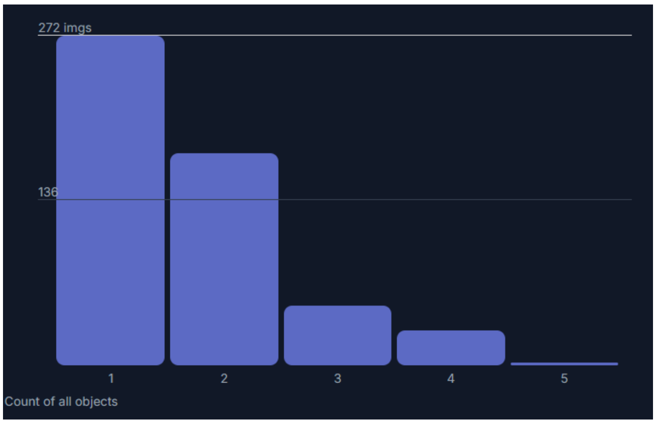
figures with minimal false positives and negatives. The mAP (96. 8%) increases consistently during training, reflecting consistent accuracy at different confidence thresholds, and the mAP_50_95 shows the model's consistent performance at different IoU thresholds, confirming its strong localization capabilities. Overall, the YOLOv5 NAS model shows excellent accuracy, consistent loss values, and excellent generalization, making it extremely effective for detecting humans in disaster scenarios.



These plots indicate that the YOLOv5 NAS model achieves high recall and precision with stable loss values. The minor fluctuations in box loss and object loss suggest that the model generalizes well across different images, and the mAP and mAP_50_95 metrics confirm consistent and reliable detection performance.



The figure shows an Annotation Heatmap of the training data of your YOLOv5 NAS model, highlighting where the bounding box annotations are most concentrated. Green and yellow areas represent areas with high annotations density, where human figures tend to appear frequently. Blue areas correspond to sparse or low-density areas of annotations, where human figures appear rarely. It appears from this heatmap that the human labels are quite evenly distributed across the dataset, covering much of the image space, which is good for improving the model's generalization capacity. The presence of denser locations means that the dataset contains frequent human locations (i. e., middle regions of images), while the less dense areas show isolated human appearances at edges or corners. Such a visualization helps to identify annotation bias or where the model needs to be trained more with data for its accuracy improvement.

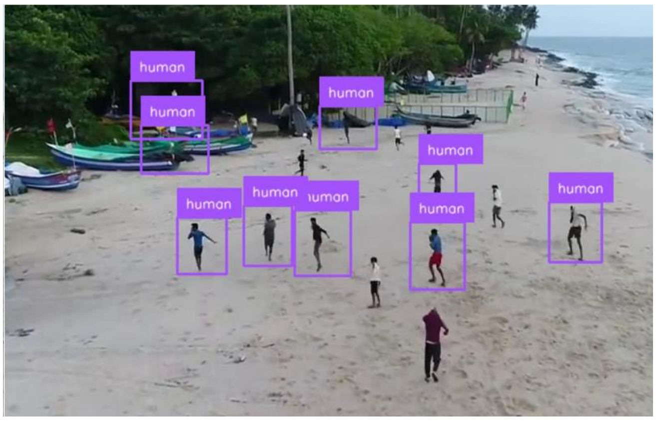


The picture shows a Histogram of Object Count by Image for your training data for your YOLOv5 NAS model, providing an overview of the number of human annotations per image. The x-axis represents the number of objects (humans) annotated in each image, while the y-axis shows the number of images containing that specific object count. Key observations from the histogram show that 272 images contain exactly 1 human, which is the most common situation in your data set. 136 images contain 2 humans, and few images contain 3, 4, or 5 humans, showing that multi-human occurrences are relatively infrequent. This split means your dataset is heavily skewed toward single-human images, and this may lead to a potential model prediction bias. Thus, the model will be very good at recognizing a single person but not so good when dealing with multi-human cases. If your use case requires the recognition of multiple humans (e. g., disaster rescue with crowds), you would want to enrich the dataset with more multi-human images for better generalization and stability.

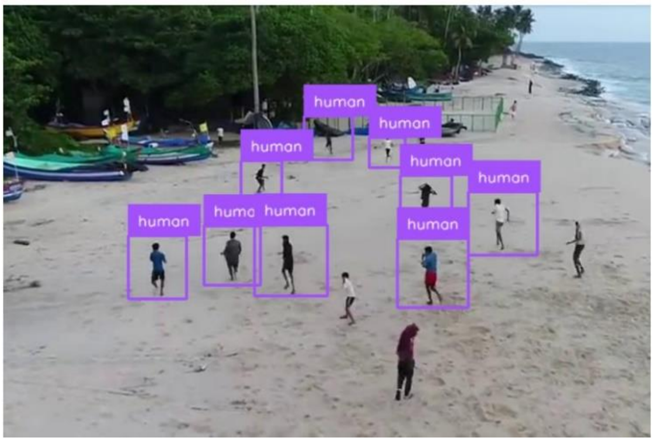
Class Balance: The dataset contains a full total of 895 human annotations over all images. The class distribution shows that your dataset solely has the "human" class, but no other object categories. This would imply a model dedicated to single-class detection, which is specifically good at detecting humans. The balance appears to be roughly consistent across the training, validation, and test sets, for even representation during the model's learning period.

In the Dimension Insights, the size distribution indicates that all images in the dataset are of the same size, 640×640 pixels. Uniform image size helps the model to attain consistent feature extraction and reduces the need for additional resizing operations at inference time, enhancing detection speed and accuracy.

Aspect ratio distribution confirms that the images in the dataset maintain a 1:1 aspect ratio (square) to ensure equal coverage in both width and height directions. This uniformity minimizes the chances of distortion or scaling issues during training and inference, improving stable detection performance.
In conclusion, the data is properly organized and balanced and is specifically designed for human detection applications and therefore suited for drone-based search and rescue operations.



The pictures shows the result of your YOLOv5 NAS model identifying a few humans on a beach. The model has been able to detect and label the people with bounding boxes and class label "human" in purple. The detection comprises individuals at various distances, from those close to the camera to those at the far end near the shore. The capability of the model to identify humans uniformly at different scales and locations demonstrates its strong generalization. The image includes a mix of static and moving people, highlighting the model's ability to identify dynamic subjects. The background indicates boats, trees, and sea, implying that the model can effectively separate humans from other objects around them. This efficient multi-human detection is promising for autonomous drone-based rescue missions, as it indicates the model's ability to identify scattered people in areas of disaster, improving efficiency in finding survivors. Generally, the detection appears reliable and accurate in an actual outdoor environment.



V.CONCLUSION

The YOLOv5 NAS model's performance assessment for detecting people in drone-augmented search and rescue operations showcases superior precision and robustness, making it extremely practical for deployment. The model achieves a staggering mean Average Precision (mAP) of 96. 8%, Precision of 95. 8%, and Recall of 96. 4%, demonstrating its ability to precisely detect and localize human bodies with low false positive and low false negative rates. These figures confirm that the model is able to effectively detect people in complex situations, as required for life-saving operations. The analysis of the dataset shows 895 human annotations, which point to a single-class detection model focused exclusively on humans. The histogram of object counts shows that the dataset is heavily skewed towards single-human images, with fewer instances of multiple humans, which could affect the accuracy of the model in detecting crowds. To mitigate this, augmenting the dataset with more multi-human images would improve the model's generalizability in crowded environments. The heatmap of annotation shows how human bodies are always spread throughout the image field, allowing the model to be able to recognize people placed at both central and peripheral locations, which is very important for searching for victims within dynamic and complex environments. Images have consistent size of 640×640 pixels, allowing constant processing and quality feature extraction. The detection result obtained from the drone video shows the model's excellent real-world performance, correctly detecting multiple people with accurately defined bounding boxes, indicating good localization abilities. The model demonstrates strong detection under diverse conditions, such as different distances and angles, making it highly reliable for aerial search and rescue missions. In order to increase its efficiency further, you could fine-tune the model with real-world aerial video and utilize post-processing methods for better tracking and localization. Additionally, the inclusion of temporal tracking and trajectory forecasting might further increase the model's ability to monitor human movement from frame to frame, making it more reliable in active rescue missions. In total, your YOLOv5 NAS model is a very capable and accurate detection system, making it well-suited for autonomous drone-based disaster response. By expanding the dataset diversity and incorporating advanced post-processing techniques, you can further enhance the model for challenging real-world applications, making it reliable and effective for human detection in rescue missions.

REFERENCES

[1]. Sharifah Mastura Syed Mohd Daud et.al., (2021) "Applications of drone in disaster management: A scoping review" *The Chartered Society of Forensic Sciences*.

[2]. Daniel Câmara (2014) "Cavalry to the Rescue: Drones Fleet to Help Rescuers Operations over Disasters Scenarios"

[3]. Muhammad Shahir Hakimy Salem et.al., (2021) "Human Detection Implementation on UAVs in Search and Rescue Operation" *journal of electrical and electronic systems research*

[4]. Fadhlan Hafizhelmi Kamaru Zaman et.al., (2023) "Human Detection from Drone using You Only Look Once (YOLOv5) for Search and Rescue Operation". *Journal of Advanced Research in Applied Sciences and Engineering Technology 30, Issue 3.*

[5]. Rameesha Tariq et.al., (2018) "DronAID: A Smart Human Detection Drone for Rescue" *15th International Conference on Smart Cities.*

[6]. K. Jayalath et.al., (2021) "Drone-based Autonomous Human Identification for Search and Rescue Missions in Real-time" *International Conference on Information and Automation for Sustainability (ICAFS)*.

[7]. N. Martins, F et.al., (2016) "Human Detection and Classification of Landing Sites for Search and Rescue Drones" *European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning*.

[8]. Sven Mayer et.al., (2019) "Drones for Search and Rescue. 1st International Workshop on Human-Drone Interaction," *Ecole Nationale de Aviation Civile [ENAC]*.

[9]. P.J. Baeck et.al., (2019) "DRONE BASED NEAR REAL-TIME HUMAN DETECTION WITH GEOGRAPHIC LOCALIZATION" *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLII-3/W8.*

[10]. Antonio Albanese et.al., (2022) "SARDO: An Automated Search-and-Rescue Drone-Based Solution for Victims Localization", *Institute of Electrical and Electronics Engineers.*

[11]. K. Boudjit et.al., (2015) "Detection and Implementation Autonomous Target Tracking with a Quadrotor AR Drone" *International Conference on Informatics in Control, Automation and Robotics.*

[12]. Dante Teeza et.al., (2019) "The State-of-the-Art of Human Drone Interaction: A Survey" *Institute of Electrical and Electronics Engineers VOLUME 7.*

[13]. Maria Tzelepi et.al., (2017) "Human Crowd Detection for Drone Flight Safety Using Convolutional Neural Networks" *European Signal Processing Conference (EIJSIPCO).*

[14]. Abdulla Al-Kaff et.al., (2017) "An Appearance-Based Tracking Algorithm for Aerial Search and Rescue Purposes*" IEEE International Symposium on Safety, Security and Rescue Robotics (SSRR).*

[15]. Shahid Karim et.al., (2017) "Image Processing Based Proposed Drone for Detecting and Controlling Street Crimes" *17th IEEE International Conference on Communication Technology*.

[16]. Giao N. Pham et.al., (2020) "Drone Detection Experiment Based on Image Processing and Machine Learning" international journal of scientific & technology research volume 9, issue 02.

[17]. Sruthi M S et.al., (2021) "YOLOv5 based Open-Source UAV for Human Detection during Search and Rescue (SAR)" *International Conference on Advances in Computing and Communications (ICACC).*

[18]. TOBIAS N¨ AGELI et.al., (2017) "Real-time Planning for Automated Multi-View Drone Cinematography", *ACM Transactions on Graphics, Vol. 36, No. 4, Article 132.*

[19]. *Zahra A. Elashaal et.al., "Autonomous Search and Rescue Drone", Libyan Journal of Informatics, Vol. 01, Issue 01, June 2024.*

[20]. López, L. B., Van Manen, N., Van der Zee, E., & Bos, S. (2017). "Drone Alert: Autonomous drones for emergency response". *In J. Nurmi, E.-S. Lohan, H. Wymeersch, G. Seco-Granados, & O. Nykänen (Eds.), Multi-Technology Positioning (pp. 303-321). Springer International Publishing Switzerland.*