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EVALUATING YOLOV8 NANO FOR PERSON DETECTION IN SEARCH AND RESCUE OPERATIONS: A REVIEW

Piyush Bagde[*1], Atharv Khonde[*2], Kaiwalyani Gorde[*3], Prof. Anirudh Bhagwat[*4]

[*1,2,3]Student, Department Of AI, G H Raisoni College Of Engineering, Nagpur, Maharashtra, India.

[*4]Professor, Department Of AI, G H Raisoni College Of Engineering, Nagpur, Maharashtra, India.

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ABSTRACT

For search and rescue (SAR) operations, person detection in aerial images is essential, as it impacts the speed and effectiveness of finding people in trouble. This review studies the use of YOLOv8 nano, a deep learning model optimized for resource efficiency and real-time processing, to person detection in SAR, with an emphasis on its implementation. Conventional human being methods of detection suffer in the diverse and uncertain circumstances that most SAR missions encounter. Deep learning techniques—particularly CNNs—have demonstrated significant improvements in accuracy and versatility. For SAR operations where time is of the essence, the most recent version, YOLOv8, provides increased speed and efficiency. Its nano configuration, optimized for resource-constrained devices, makes it especially appropriate for nano drones, which are essential for accessing difficult terrain and disaster zones where larger UAVs may be not feasible. The paper highlights the advantages and disadvantages of different models by analyzing previous research on deep learning for SAR person detection. Although research utilizing YOLOv5 and SlimYOLOv3 shows this model family's potential for aerial picture analysis and quick detection times, issues with accuracy in a variety of situations and the requirement for strong training datasets still need to be addressed. For example, while previous studies utilizing Faster R-CNN showed promise, it struggled to recognize small objects, which is a vital requirement in SAR.

Keywords: SAR, CNN, YOLOv5, YOLOv8, Detection Time, Person Detection, UAVs, Faster R-CNN.

I. INTRODUCTION

The use of unmanned aerial vehicles (UAVs), or drones, has revolutionised search and rescue (SAR) operations, providing a fast and efficient way to search large and potentially dangerous areas [1]. The integration of automated human detection systems into these drones can significantly improve the speed and effectiveness of finding victims, directly impacting survival rates.

Deep learning techniques, particularly those using convolutional neural networks (CNNs), have gained significant traction in object detection tasks, with YOLOv8 emerging as a leading model due to its speed and accuracy [3]. This review paper aims to evaluate the suitability of YOLOv8 nano for person detection in SAR operations, considering its performance on resource-constrained devices like nano drones.

II. BACKGROUND

A. Traditional Person Detection Methods

Earlier techniques of person detection were primarily based on extraction of features and usage of different classifiers. This involved extracting low level visual information such as edges, corners and shapes from the images. This visual information was then used to learn classifiers such as Support Vector Machines or Adaboost to tell human from nonhuman objects. However, while there was a degree of success in these techniques, they were prone to pose and illumination variations as well as background clutters which made them impractical for real usage in SAR applications.

B. Deep Learning and Convolutional Neural Networks (CNNs)

Machine learning where artificial neural networks learn from large data sets, is deep learning based on how the human brain structure and functions [1]. In deep neural networks, they are specialized and built purposefully for the processing of image data. CNNs utilize convolutional layers to allow the system to learn abstract and detailed features from any given picture without any human intervention [14].

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Deep learning architectures like CNNs involve numerous layers, particularly, convolutional layers, pooling layers and fully connected layers. These layers work together to extract features at different levels of abstraction over time, learning to identify more intricate images or patterns.

C. YOLO Family of Object Detection Models

The family of object detection models labelled as YOLO (You Only Look Once) has brought a new paradigm in the ability to perform object detection in a single stage, in real time [5]. In contrast to two-stage detectors that first produce region proposals and then categorize them, YOLO take a step further and do not consider previously defined regions. Instead, they make bounding box and class probabilities predictions directly on the image in one go, and this is much quicker.

D. YOLOv8: Key Features and Suitability for Resource-Constrained Devices

YOLOv8 is the most recent member of the YOLO siblings. It embraces most of the features of the earlier versions while introducing several innovations that increase the speed and accuracy of the algorithm without compromising the efficiency of the core technology.

- **CSPDarknet53 Backbone**: this backbone architecture improves the process of feature extraction through its effectiveness in the information flow between layers.
- **C2f Module**: This module effectively integrates features at different levels, which improves performance in small object detection – a critical aspect of realistic SAR images where the victims can be very small in size.
- **Spatial Attention Mechanisms**: these mechanisms allow the model to concentrate on only the necessary portions of the input image which directly improves object localization performance.
- **Data Augmentation Techniques:** The YOLOv8 architectures have been designed to incorporate intricate data augmentation techniques that enhance the generalizability of the model by expanding the training dataset almost artificially, making the approach useful to several scenarios of SAR.

The performance and applicability of YOLOv8 on lightweight platforms such as nano drones is significant from the perspective of real time applications in SAR systems. [6] The architecture of the model makes it deployable even on computing power restricted devices so as to allow processing of aerial images on the device without any server [13]. This is very important especially in SAR operations where data needs to be verified and analysed as soon as it is received.

III. RELATED WORK

Researchers have researched---- the use of deep learning models such as Faster R-CNN, YOLOv4, RetinaNet, and Cascade R-CNN for the purpose of detecting humans in aerial images. These studies have shown the advantages of deep learning algorithms over traditional approaches to image processing in terms of both performance and robustness, highlighting its applicability in SAR [7].

- **Use of YOLOv5 for Human Detection Operability in Hypothetical Rescue Operations:** In the area Dr. Zaman and his team published a paper where they used a DJI Matrice 300 Drone to evaluate the performance of YOLO-5 algorithms in detecting mannequins within a mannequin-based SAR scenario [1],[4],[11]. Besides, the researchers noted that the yolov5l6 model yielded the best results, showcasing the advances in Aerial Human Detection focused on human detection using YOLO models in extreme climates.
- **Deep Learning for the Detection of Individuals from Aerial Imagery**: Concerning above facial recognition from an aerial perspective, several studies made by the researchers around the world show that deep learning frameworks such as Faster R-CNN, YOLOv4, RetinaNet, and Cascade R-CNN can be effective for person detection from aerial images. Real-world studies have demonstrated that deep learning-based approaches are significantly superior to conventional imaging techniques in discipline performance which is very important for SAR [7],[11],[17].
- **Tackling the Challenges Faced in Recognizing People in Aerial Pictures:** Although the detection of people in aerial images using deep learning in SAR has been presented, researchers have noted certain concerns [4],[15]. They include:
  - **Detection of Small Objects**: In some aerial photographs, survivors may be a very small dot; hence, the chances of their detection become extremely limited. The problem becomes worse with the imaging resolution as the drones take off and fly at higher levels.

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- **Environmental Factors:** The degree of lighting, shadows, and obstruction caused by foliage and rubbish can all hinder the accuracy of detection.
- **Real-Time Performance:** SAR missions require that the processing of the drone images must be near real time or real time to allow an effective SAR response. This calls for both the models and the hardware to be able to process the images quickly [16].

IV. YOLOV8 FOR PERSON DETECTION IN SEACRH AND RESCUE

Advantages of YOLOv8

YOLOv8 is a good option for nano drone deployment because it offers a number of benefits for human detection in SAR operations.

- **Real-Time Processing Capabilities:** The architecture of YOLOv8 is speed-centric and more effective in its lightweight nano version. This allows for real-time stream processing of video captured from drones to facilitate instant detection of Potential victims [8]. The faster the processing the faster the response time which may lead to rescue of lives in mission operations like SAR that are prone to time limitation [13].
- **Resource Efficiency:** YOLOv8 Nano has been adapted to work on resource limited devices such as nano drones. Its smaller model size and computation efficiency allow installation on less powerful and less memory retentive platforms [9]. Such portability is crucial in SAR as it allows for the use of smaller more flexible unmanned vehicles that are capable of manoeuvring in harsher terrains more effectively.

Case Study

Although the literature does not mention a particular case or trial involving the use of YOLOv8 nano for person identification in SAR, it does provide examples of previously conducted studies where the different versions of YOLO were used in such cases. For example, a YOLOv5 variant, yolov5l, was utilized to identify humans (represented by dummies) in overhead images similar to those in response operations using SAR [4]. The conditions varied with respect to the patterns of drone flights and the extent of zoom used on the camera, indicating the versatility of the model in different search terrains. In another case, a few deep learning-based object detection algorithms were evaluated, including a scaled down version of YOLOv3 and it was observed that the sub-optimized model provided similar detection performance but with improved speed of inference time which demonstrates the viability of dome shaped optimizations of the YOLO undertakings for SAR systems with limited resources [9].

Although these cases do not focus on assessing the performance of YOLOv8 nano in an explicit manner, they, however, suggest that person detection in SAR can be achieved by the YOLOv8 nano with the appropriate amount of training data and tuning. Still its merits and demerits in real time SAR applications needs more research and development to be clearly established.

V. RESULTS AND DISCUSSION

Limitations of YOLOv8 for Person Detection in SAR

Despite its strengths, YOLOv8, even in its nano version, has limitations that need consideration for SAR applications:

- **Accuracy in Challenging Conditions:** Even though YOLOv8 is quite reliable in several situations, its performance is bound to suffer under very harsh environmental factors such as those experienced in SAR, where there may be extreme visual obstruction, downpours, or blizzards [10]. Such situations can result in deteriorated images, which hinder the ability of the model to separate humans from the video footage background. This warrants further study on ways to enhance the capability of YOLOv8 against such challenges [17],[12]
- **Generalization to Diverse SAR Environments:** The performance of YOLOv8 is strictly proportional to the amount and variety of the training dataset employed. For instance, training a model using a dataset that is insufficiently representative of the conditions present during SAR operations, will generally lead to poor performance in terms of generalization and a higher false-negative / false-positive rate [4]. Therefore, it is imperative that more extensive and more representative SAR very large area change detection training and evaluation datasets for YOLOv8 are prepared.

- **Ethical Considerations and Potential Bias:** Ethical considerations and potential bias: Like any AI system, the ethical aspects and possible bias of training data need to be tackled seriously. The model in training may become problematic biased trained on unbalanced datasets not representing more than one ethnicity, gender, or even age groups which could compromise detection accuracy on other groups. It is essential to promote fairness and reduce bias during data collection and while developing the model for the ethical use of AI in SAR.

VI. CONCLUSION

The YOLOv8 nano model illustrates a way forward in enhancing the detection of humans within Search and Rescue modes of operation. With its ability to process images in real time and its low requirement of processing power, it can be employed on nano drones allowing for reduced reaction times and possibly saving more lives. However, this calls for more extensive studies to test the strength and weaknesses of the tool in different SAR scenarios and to improve on predictive accuracy and generalization as well. It is of great necessity to build more complex and strong training data sets and investigate ways to optimally use the YOLOv8 nano during SAR operations in extreme conditions.

VII. FUTURE RESEARCH DIRECTIONS

- **Domain-Specific Training Data:** Create expansive databases which overall comprise of a greater latitude of conditions, environments and appearances as experienced in actual SAR missions in order to enhance the generalizability and performance of the model.
- **Robustness to Environmental Conditions:** Investigate and provide solutions that will enhance the performance of YOLOv8 nano even in extreme environmental conditions such as darkness, fog, heavy rainfall, and snow. Also, consider data augmentations, synthetic data, and multi-spectral images in performing well in these conditions.
- **Integration with Other Sensors:** Explore the combination of the YOLOv8 nano with other sensor systems, such as thermal and LiDAR imaging, to enhance the detection performance even in situations where the visibility is poor and the level of dependence on visual data is highly minimized.
- **Explainability and Trustworthiness:** Propose solutions for improving the interpretability of the YOLOv8 nano detection in order to increase confidence among SAR operators.
- **Ethical Considerations and Bias Mitigation:** Perform comprehensive analyses and corrective actions aimed at ensuring the absence of bias in training information, as well as model outputs to guarantee the just and balanced use in SAR missions.

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