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Foreign Object Detection System at Airport Runway based on YOLOv8

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Abstract— With the fast expansion of the global aviation sector, the number and magnitude of airports being built throughout the world is expanding. The job of ensuring aircraft safety has become more difficult in this environment. Any foreign material, trash, or tiny items that occur on the airport runway may represent a major hazard to the aircraft's ground operations safety. As a result, research on FOD detection is crucial. This study presents a detection technique for foreign object debris based on YOLOv8 (You Only Look Once). This technique utilizes a deep residual network to extract features and multi-scale feature fusion to identify small-scale FOD. To validate our proposed technique, sample datasets of foreign object debris are established. Experiments indicate that the YOLOv8-based detection method detects foreign objects and trash with high accuracy and resilience.

Keywords-component; *airports, foreign material, FOD, YOLOv8, multi-scale feature fusion, object detection, small-scale FOD, debris, extract features*

I. INTRODUCTION

FOD comprises any particles, materials, or objects (shown in Fig. 1) that could harm a vehicle or a system. FOD is thus anything that is near, inside, or involved in flight line operations but is not supposed to be there. FOD comes in a variety of sizes and has the potential to endanger personnel or equipment. The damage to airplanes, helicopters, launch vehicles, engines, or other aviation equipment [7] that results from a foreign object smashing the engine, flight controls, airframe, or other operating systems is another description of FOD. FOD is primarily recognized as a hazard element that can seriously affect the airport, workers, and equipment, according to the Federal Aviation Authority (FAA) [8].

During aircraft proximity taxing, when personnel was exposed to the harmful effects of a high-velocity jet blast, the most serious FOD event involved personnel injuries or death. The powerful blast pushed FOD through the airport and frequently injured workers who were nearby. FOD-related catastrophic issues are widespread in the aviation sector. [1] Often, the issue is destruction or damage to the

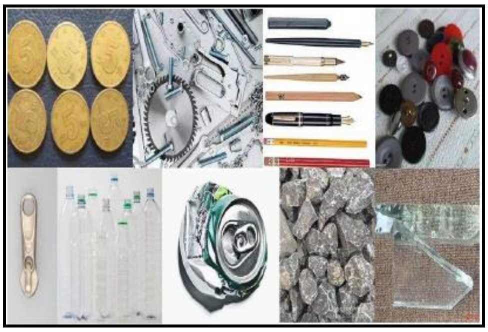

Fig. 1. Common FOD on airport runways.

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aircraft's components. There are two types of damage: minor damage and big damage. Skin dents are an example of minor damage, while control surface malfunction, jammed flying controls, electrical fires, and engine failure are examples of serious damage.

About 11% of FOD incidents, according to ATSB [9], resulted in airframe wheel and engine damage. These losses have a significant financial impact on the company and add to a great deal of direct and indirect expenses. All maintenance costs to fix the damage caused by FOD are considered direct costs. In contrast, indirect expenses come in the form of missed connections, canceled flights, lost revenue, and scheduling disruptions.

II. LITERATURE REVIEW

A. Conventional Detection Method

According to the openness of the runway and the kind of procedure, visual patrolling by vehicle on the runway surface are often utilized to check and remove Foreign Object Debris (FOD) from airport runways. Specialized employees may be hired in some circumstances to keep track for FOD during existing building projects. While specialist elimination equipment is available for use in airport operations, human FOD removal is frequently judged acceptable. The method for detecting and removing FOD may differ depending on the individual situations and needs of the runway operation.

B. Automated Detection Method

i. Radar Detection System

A number of companies, notably Xsight's FODetect [5] (shown in Fig. 2), QinetiQ's Tarsier system (shown in Fig. 3) [4], and Stratech's iFerret [6,] have just created automated Foreign Object Debris (FOD) detection systems that use optical video and radar technology. While radar detection has advantages such as a large identification range and high conclusion, it does not give intuitive video pictures or color characteristics of discovered things, making FOD removal more difficult. However, due to conventional processing of images target identification methodologies, optical video-based FOD detection devices encounter difficulty in precisely defining and extracting features of FOD, and their performance still has space for improvement.

Deep learning-based target detection techniques offer a new concept for autonomous detection of FOD with the rapid growth of deep learning techniques represented by convolutional neural networks. One of the key features of computer vision technology is target recognition. Common target detection algorithms are often built for large targets such as faces, cars, and pedestrians. On the other hand, FOD targets have many types of damage and often have no fixed geometry, so the properties available for detection are very different from conventional targets. Additionally, detection methods tend to be more sensitive to target substances and hazard levels. Targets made from different materials present very different hazards, and the subsequent treatment processes for these targets also differ greatly.

Fig. 2. Xsight's FODetect.

Fig. 3. QinetiQ's Tarsier system.

ii. Camera Detection System

It is critical to effectively see interference and debris in order to avoid future hazards. In [11], electro-

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optical color pictures and an infrared sensor on board the aircraft were proposed for detecting runway incursion, cracks, and obstructions. Image processing techniques were used for identifying FOD and characterizing it.

For example, [12]proposed a video based FOD detection system using a single camera sensor located on the runway at Nanyang International Airport, where an image change algorithm is employed to successfully identify FOD up to 4cm in size [13]. Another method for identifying runways is machine vision. However, camera detection systems suffer vision challenges owing to weather, fog, and darkness.

C. FOD Detection Algorithm

The FOD identification technique, as illustrated in Figure 4, is at the heart of our experimental system, which also includes preprocessing, background removal, post-processing, and FOD localization. The backdrop image is automatically refreshed by the background extraction module. When compared to the prior approach, certain new strategies for background removal and post-processing are incorporated. Postprocessing completely solves the difficulties of noise suppression and color camouflage eradication. The system identifies, locates, and warns operators of potentially hazardous FOD using this upgraded algorithm.

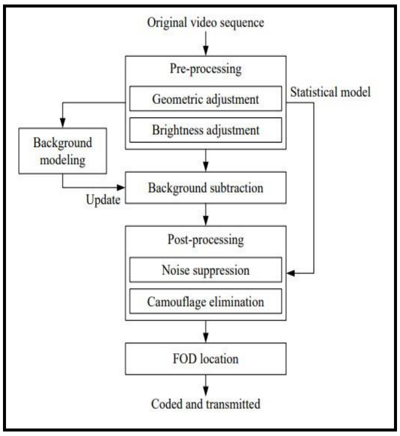

Fig. 4. Flowchart of FOD Detection System

i. Pre-processing

Preparatory to change detection, pre-processing methods are utilized to remove tiny changes in the image produced by modest camera motion or oscillations in light source intensity. At this step, geometric and brightness modifications are performed to reduce these interferences. Geometric rectification reduces camera-induced alterations, especially when the examined region is reasonably stiff and the camera's movement is modest. In such instances, spatial transformations such as projective transformation are typically utilized for registration. There are several techniques of dealing with this problem. A traditional approach, as described by Zitov and Flusser (2003), includes matching raw pictures from the same video sequence into a shared coordinate system.

ii. Background Subtraction

Backdrop subtraction is a popular method to detect foreign objects in a sequence of photos acquired by a camera that stays still that detects changes in the backdrop but does not update it quickly. Image noise, on the other hand, might induce irregularities in the values of pixels of the backdrop model. To overcome this, more robust and flexible strategies for thresholding the subtracted result, such as Gaussian combinations and non-parametric in models, can be used (Elgammal et al., 2002). Because the backdrop might change over time owing to modifications in the surrounding environment, the background model in engineering applications is frequently updated on a regular basis. To calculate an average picture of the scene without any incursion components is one of the simplest ways for background modeling.

iii. Post-processing

Regardless of how accurate background modeling is, there may still be false positives and partly recognized objects in the picture after background elimination. As a consequence, using a statistical model obtained from the original picture, post-processing techniques such as noise reduction and camouflage eradication are applied to the initial change masks. Noise reduction techniques that are often utilized include median filtering and

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morphological processing. However, these strategies only work on the initial modification mask and ignore the original picture statistics. A Markov random field (MRF) model may also be used to examine the nearby labels of positive detections in the first change mask. This enables the use of probabilities based on surrounding labels to calculate the label of each pixel, yielding a more nuanced and accurate output.

iv. FOD location

Following the preceding three steps, the image's related areas are classified as FOD targets. Using region labeling, the pixels in each unconnected target region of the binary PPI picture are labeled with the same number. The measurements, including the center coordinates and the size of each target indicated by pixel number n, are obtained on this basis.

III. IMPLEMENTATION

Foreign object detection is a common problem in computer vision, and PyTorch is a popular deep-learning framework that can be used to build object recognition models. Here are some steps to implement the foreign object detection model in PyTorch: Data preparation: Collect and label a dataset of foreign body images. This dataset should be divided into a training set and a validation set. Choose a pre-trained object detection model: PyTorch provides several pre-trained models that can be used for object detection, such as Faster R-CNN, Mask R-CNN and YOLO. Choose the model that suits your needs and download its preset scales. Modify your dataset model: The pre-trained model is trained on a different dataset, so you need to modify it for your dataset. This requires changing the number of categories and possibly the size of the input images. Refine the dataset model: Train the modified model on your dataset. This involves loading pre-trained weights and fine-tuning the model by updating its weights using the dataset. You can use a pre-trained optimizer like Adam or SGD to train the model. Model evaluation: After training the model, evaluate its performance on the validation set. You can use metrics like precision, recall and F1 score to evaluate its performance. Deploying the model: When you are satisfied with the performance of the model, you can deploy it to detect foreign bodies in new images.

Using our improved training dataset, we create a variety of object recognition models. We investigate the You Only Look Once (YOLO) family of object detection device prototypes (Bochkovskiy, Wang, & Liao, 2020) as a possible candidate in the put forward FOD detection structure due to their lightweight architecture speeds up the processing time, which is critical for real-world detection and global implementation of this framework. Our suggested FOD detection system with multiple YOLOv8 models works quite well on both datasets, according to experimental findings. In the assessment phase, data augmentation strategies trained on gathered data using the YOLOv8 object classification model surpass every other strategy in terms of average recognition value, recall rate, and precision rate. [10]

IV. CONCLUSION

Using this paper and the experimental findings, we can detect objects more accurately and identify individual objects present on the runway with their exact location (on the x-axis and y-axis). Since this project uses real-time object detection, a fast and accurate algorithm is a must. This project can use multiple IP cameras installed along the entire runway with proper configuration to accurately detect objects. The system alerts the air traffic control center to prevent serious dangers that cost not only the capital but also several lives. The model used here is trained to recognize object features and classify and identify objects for further processing. This model also uses a few pre-trained models and transfer learning. If the object's position and visibility relative to the camera position are well-defined, the model can give accurate results with an accuracy of about 70%.

V. FUTURE SCOPE

Foreign body detection is an important research field with various applications such as food processing, medical imaging, and safety research.

Improved accuracy with machine learning: machine learning algorithms such as neural networks and support vector machines have shown promising

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results in detecting foreign objects. However, there is still room for improvement in accuracy. A possible future area could be to explore different machine learning models and techniques to improve the accuracy of foreign body detection.

Computer vision for using Real-time detection: Real-time detection of foreign objects is crucial in many industries such as manufacturing and food processing. Computer vision techniques such as object detection and segmentation can be used to detect foreign bodies in real-time. A possible future area could be the development of more efficient and accurate computer vision techniques for real-time detection of foreign bodies.

Improved detection using Multimodal imaging: Multimodal imaging involves combining different imaging modalities, such as X-ray and ultrasound, to improve detection accuracy. A possible future area could be to explore the use of multimodal imaging for foreign body detection, especially in medical imaging. Detection of non-metallic objects: Most current foreign object detection techniques focus on metallic objects. However, non-metallic items such as plastic and glass can be hazardous in certain industries. A possible future area may be the development of non-metallic foreign body detection techniques.

Automation on the removal of foreign objects: When a foreign object is detected, it must be removed. Manual removal can be time-consuming and expensive. The future potential may be the development of automated foreign body removal techniques using robotics and artificial intelligence. These are just a few of the possible future possibilities for alien object detection that you can explore in your research. The field is constantly evolving and there are many exciting opportunities for further research and development.

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