Thermal Vision for Airfield Safety: A Dynamic FOD Detection Framework

Ravina Gupta, Sarika Jain, Manoj Kumar

Abstract—**Foreign object debris (FOD) poses risks to aircraft engines and airport personnel. Airway inspection teams use traditional and technology-based methods to eliminate FOD from runways. However, these approaches encounter significant limitations in accurately and efficiently detecting diverse types of foreign objects accurately and quickly, particularly under adverse weather conditions, which impeding the timely and effective removal of debris from runways. Reliable FOD detection systems are needed to protect passengers and aircraft. This paper proposes video-based FOD detection from thermal images using image processing and computer vision algorithms. Sequential thermal images were obtained from thermal videos captured at regular intervals of ten seconds. Thermal videos were systematically recorded on tarmac roads resembling runway-like surfaces. Experiments were conducted during the day and night both to include real-world conditions and various weather conditions. Small objects such as bottle caps, coins, bolts, keys, metal nuts and matchboxes which are commonly found on runways are intentionally placed on the pavement to compile a comprehensive dataset. The objects are carefully selected, and the environmental conditions are varied to make the experimental setup robust and adaptable. The proposed algorithm includes average filtering to de-noise the image, threshold operation to enhance image contrast and using a Maximally Stable Extremal Regions (MSER) detector to detect FOD objects. The evaluation results of the proposed algorithm show 99.8% accuracy on thermal imaging which is better than other competing algorithms for object detection. The proposed work can be of great significance for airport authorities to successfully detect and remove objects.**

Index Terms—**FOD, thermal images, object detection, airport, MSER.**

I. Introduction

THE Federal Aviation Administration (FAA) defines Foreign Objects Debris (FOD) as anything in the airport runway area that has the potential to damage an aircraft or adversely affect airport staff. Billion-dollar annual costs are associated with FOD-related damage for the aircraft sector [1]. Manual operators conduct routine airfield inspections to find and remove foreign objects from the airport runway. FODs on the runways can be found in various hues, forms, compositions, and lengths [2]. Magnetic bars are commonly utilized to extract small foreign objects that are difficult to detect through visual inspection. These objects include nuts, bolts, tire debris, tiny tool bits, and small pieces of broken pavement. For instance, one of the busiest airports in the UAE, Dubai International Airport (DXB) has discovered several FODs within its operational area [3]. A selection of sample items that fall into the category of FODs is shown in Fig. 1.

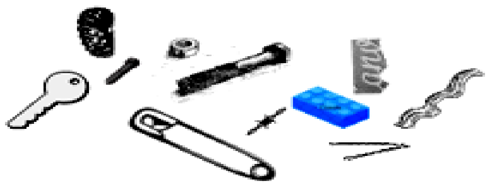

Fig. 1. Sample FOD objects

Along with airport runways, FOD is also present on hangars, gates, cargo aprons, taxiways, and flight decks. The aerospace sector is thought to incur direct expenses associated with the consequent FOD damage of $1.1 to $2 billion annually, which is ten times more expensive than the indirect costs associated with delays, aircraft substitutions, fuel expenditures, and unanticipated repairs. According to [4], runways, taxiways, ramps, and adjoining regions must be cleared of scattered stones and debris, as these can damage aircraft structures or engines and disrupt aircraft systems. The airport service document [1] provides instructions for debris removal using machines and manual methods.

"FOD walks" which are traditionally correlated with military activities, including military forces on the ground searching for a region by going shoulder to shoulder over the pavement and pausing to gather any debris discovered within the aircraft operating area. In contrast, civilian airports prioritize proactive measures to prevent debris that may pose a risk to aircraft. Airport operators conduct regular inspections using a vehicle traveling at an appropriate speed to scan for abnormalities and specifically check for FOD [5]. There is an increased interest in improving the finding and getting rid of FOD at airports, especially under different weather conditions. This is because scheduled inspections are not always reliable due to human error, exhaustion, and complacency. Additionally, adverse weather, darkness, and construction make it more difficult for airport operators to identify and address FOD promptly [6].

In the last few years, several candidate techniques have emerged for the detection of FOD at airport runways. However, these techniques utilize the visual camera for the detection of debris. Techniques for FOD detection that rely

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upon visible spectrum imaging are highly effective, as the visible band of the electromagnetic spectrum exhibits potent, low-noise characteristics such as sharp border lines, hues, and appearance. On the other hand, images taken with visible cameras have poor contrast in high- or low-light conditions. Because of this, existing visible spectrum imaging algorithms struggle to accurately identify objects in difficult illumination conditions, such as fog, rain, evening hours, noise, inadequate vision, poor contrast, background color interference, etc. The images captured tend to have poor contrast and noise [7]. Thermal imaging offers a solution to the issues with visual imaging. The thermal camera uses the infrared part of the electromagnetic spectrum to collect temperature information about the targeted object. The thermal image created by this process is called a "thermo-gram", and its pixel values reflect the temperature of the object. The key advantage of utilizing thermal imaging for object detection is the temperature difference between debris and its surroundings, which remains unaffected by lighting or variations in illumination (as thermal cameras are not influenced by light). Even when the foreground and background colors closely resemble each other, the internal temperatures of the FOD and the surrounding environment typically differ, enabling the use of thermal imaging to detect the debris.

In this paper, we propose video-based approach for FOD detection in thermal videos utilizing image processing algorithms. The aim of this study is to develop a high-performance and efficient system for FOD detection. This paper is organized in the following sections: Section I provides an overview of the topic and outlines the problem. In Section II, a detailed literature review has been done about the existing solutions. Section III is devoted to the methodology of the proposed work and section IV focuses on the experimental results and their analysis. Section V offers a comparative evaluation of the proposed algorithm against the existing algorithms. Lastly, section VI concludes the whole work.

II. Related Work

Detecting foreign object debris quickly and accurately is critical to prevent serious accidents on runways. Various techniques and methods are available for debris detection on runways, including computer vision-based models. This section covers various techniques and methods that improve debris detection under different conditions, with a focus on techniques and methods used specifically in airports.

In their study [8], a novel approach was introduced for detecting debris on airport runways using Synthetic Aperture Radar. They used filtered back projection to simulate two-dimensional imaging. In [9], the author has designed an independent rover equipped with LiDAR technology to efficiently detect and locate foreign object debris (FOD) on the runway. Subsequently, the airfield inspector is duly informed about the exact location of the FOD by the rover, enabling them to take appropriate and timely action. Millimeter-wave radar is proposed in [10] as a solution to reduce the occurrence of missed detections in FOD detection. The system operates in two stages: the first stage differentiates between false alarms and food-borne debris, while the second stage differentiates between the two. The authors in [11] proposed a method using Gabor filters to segment foreign objects in airport runway images. To demonstrate the effectiveness of their approach, they conducted simulated assessment tasks. The objective of this method is to apply computer vision techniques for real-time foreign object detection and surface defect detection under all weather conditions. The authors presented a method in [12] that uses LiDAR technology to detect pavement abnormalities. Their system can identify foreign objects as small as 2 cm with a high level of accuracy. The study in [13] analyzes various techniques for locating debris on airport runways to enhance runway safety and monitoring protocols. The study compares methods such as visual monitoring, continuous inspection, automated and manual approaches, and other modern and classic methods. It also discusses different algorithms and methods for identifying FOD, such as wireless sensor networks, multi-robot systems, and millimeter-wave radar. In their study [14], the authors conducted an in-depth analysis of the causes of FOD generation and ways to minimize its impact. They concluded that creating a FOD awareness plan for all parties concerned is the most efficient way to remove FOD from runways. In [15], a simulator that uses a triangular trihedral corner reflector (TTCR) to identify FOD during rainy weather was explored. The experiment used a reflective aluminum FOD and a radar detection system that operated at a frequency of 93.1 GHz. The experiment was conducted at Kuala Lumpur International Airport.

Computer vision-based models are also designed to detect FOD on airport runways. These models use convolutional neural networks (CNN) and sensor-based technology to accurately analyze visual imagery in real time. Due to the significant advancements in computational power over the past decades, numerous researchers are now utilizing computer vision techniques to detect FOD on airport runways. In their study [16], the authors introduce a real-time algorithm for FOD detection, employing the YOLOv3 model combined with a multi-scale network for detection and feature extraction. The algorithm proposed in [17] enhances object recognition accuracy by utilizing the material distribution features of FOD items. The approach employs transfer learning and is based on AlexNet. An improved version of the YOLOv5 algorithm was presented in [18], which uses a Convolutional Block Attention Module (CBAM) for FOD detection on airport runways. The algorithm achieved an accuracy of 98.2% and a processing rate of 50.2 frames per second, addressing the issues of low positioning accuracy and missed detection. The authors [19] presented a framework to address the issue of precisely and quickly recognizing foreign items on airport runways for removal. Using newly gathered Unmanned Aircraft Systems (UAS) data as well as a publicly accessible dataset of FOD images, they evaluated their architecture using YOLO object detector models. A recent study [20] created a method combining wireless power transfer (WPT) with thermal infrared imaging to identify FOD. STM32 microcontroller and OpenCV toolbox were used to create image processing methods. According to the findings, FOD can be identified by the WPT system at 15 cm. The authors in [21] presented an improved road object detection method using YOLOv8 called YOLOv8-ITA. They evaluated the model on the FLIR infrared dataset and achieved an average accuracy of 78.8%.

III. THERMAL VIDEO BASED FOD DETECTION SYSTEM

The proposed work introduces a thermal video-based FOD detection system. The system uses advanced image processing and computer vision algorithms. The detection of foreign objects has been carried out through a series of steps, namely, data acquisition, data preprocessing for denoising through mean filtering, thresholding and morphological operations, data processing through image subtraction and Maximally Stable Extremal Region algorithm (MSER) and finally the notification of results.

The overall flow of the thermal video-based foreign objects detection system has been described in Fig. 2.

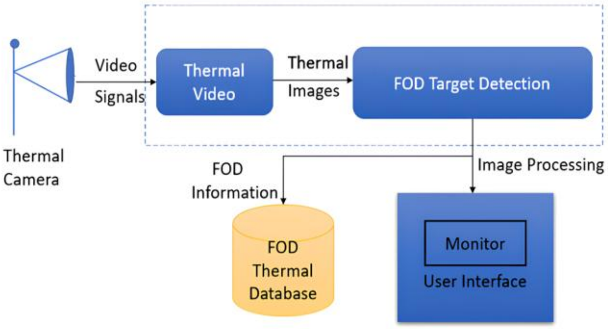

Fig 2. Workflow of FOD detection System

Throughout the experiment, a dedicated thermal imaging camera has been utilized to capture thermal videos. A thermal imaging camera acquires and generates an image of any object based on the infrared radiation emitted by the object. In this study, a shot thermal imaging camera has been utilized for the acquisition of data. The shot camera has an infrared resolution of 206 x 156 pixels and fixed focus lens with a refresh rate of about 9Hz frame rate. The specifications of the thermal imaging camera have been demonstrated in Table I.

TABLE I
SPECIFICATION OF THERMAL IMAGING CAMERA

Sensors	Thermal Imaging Camera
Resolution	206 x 156 (32,000 pixels)
Image/video Format	JPG, MPEG
Field of View	36 Degree
Spectral Range	7.5 – 14 Microns
Frame Rate	< 9Hz

A. *Data acquisition*

Above mentioned camera is used to capture real-time videos in challenging weather, various environmental situations, and problematic lighting conditions including fog, rain, night, noise, etc. Objects such as matchboxes, coins, bolts, metal nuts, and bottle caps are placed on the tarmac road that has similar surfaces like airport runways and record videos to perform foreign object detection. The captured videos are divided into frames and uploaded into the specified folder to make a database of foreign objects. The distance for taking thermal images of an object is approximately 120 - 250 cm. Sample thermal images of foreign objects such as matchboxes, metal bolts, coins and keys taken from the videos are shown in Fig 3.

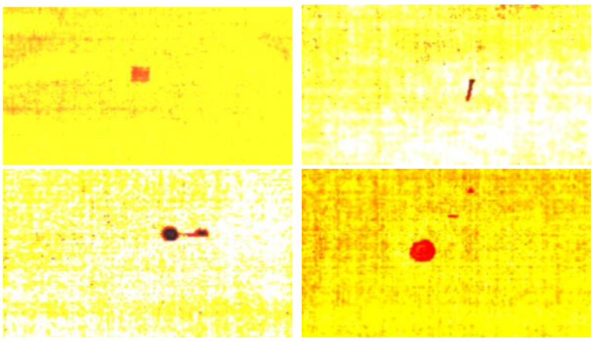

Fig. 3. Thermal images samples extracted from the video

B. *Data Preprocessing*

Image preprocessing algorithms have been used to denoise the thermal video frames/ images. To remove the noisy blobs, mean filtering is employed as an image noise reduction approach followed by thresholding and morphological operations. Details are as follows:

Mean filtering is an image processing technique employed to minimize noise while maintaining the structure and edges of an image. It works by substituting the intensity value of a pixel with the average intensity of its surrounding pixels. To process each pixel in an image, a small area called a "kernel" or "window" is used to calculate the average value of every pixel intensity in that neighborhood. This value is then used to replace the pixel at the center of the kernel. This process is applied to each pixel in the image by moving the kernel across every pixel. The formula for mean filtering at a specific pixel (*x*, *y*) in a grayscale image is defined in Equation.

$$Output(x, y) = N \sum_{i=1}^{n} = \frac{1}{N} Input(xi, yi), \quad (1)$$

where Output (*x*, *y*) is the pixel value obtained after mean filtering at the location (*x*, *y*). the input at position (x_i, y_i) corresponds to the pixel value at a specific point in the original image, where "x_i" and "y_i" are the coordinates at the *i*th position. The variable '*N*' denotes the total count of pixels contained within the neighborhood or kernel. The resultant thermal images of mean filtering are shown in Fig. 4.

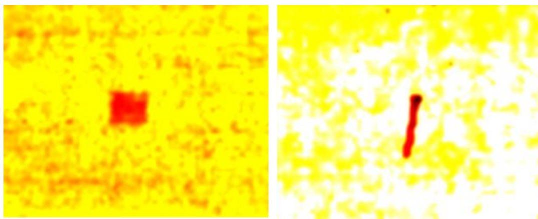

Fig. 4. Thermal images after filtering

Subsequently mean filtering, thresholding and morphological operations have been applied on the thermal images. A binary threshold is applied to the images one by one to remove low density and noise from the images or to emphasize certain regions of interest. The binary thresholding is described in equation (2) [22].

$$dst(x,y) = \begin{cases} \max Val & if\ src(x,y) > thresh \\ 0 & otherwise \end{cases}, \quad (2)$$

Following this phase of noise reduction, the image is further improved by using morphological opening and closing processes. These measures contribute to reducing or fixing minor internal defects and gaps in the images. The morphological operation is defined in equation (3)

$$A \ominus B = \{z | (B)_z \cap A^c \neq \Phi\};$$
$$A \oplus B = \{z | (B)_z \cap A^c \neq \phi\}. \quad (3)$$

The expression $A \ominus B$ represents the operation of erosion, which is applied to set A using the structuring element B. $(B)_z$ refers to the repositioning of the structuring element B to point z, while "A^c" represents the complement of set A. The operation $A \ominus B$ consists of all points z where the repositioning structuring element B is fully contained within the complement of A. The expression $A \oplus B$ represents the operation of dilation, which is applied to set A using the structuring element B. $(B)_z$ refers to the translation of the structuring element B to point z. In the case, $A \oplus B$ includes all points z where the repositioning structuring element B has a non-empty overlap with A. The resultant images after thresholding and morphological operation are shown in Fig. 5.

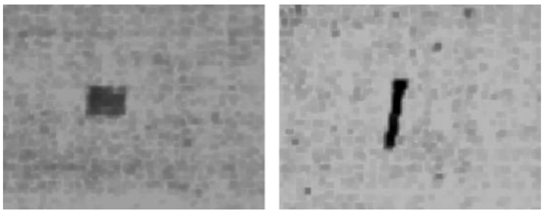

Fig. 5. Resultant images of threshold & morphological operation

C. Data Processing

This step is achieved through background subtraction and MSER algorithms.

- *Background subtraction*: Background subtraction has been a frequently employed approach for detecting objects in images and videos captured/recorded by stationary cameras. The objective of this approach is to detect foreign objects by contrasting the current frame with reference frame, commonly referred to as "background image" or "background model".

Equation (4) calculates the average intensity at a specific pixel location (x, y) across several frames in a video or image sequence. where the average intensity of each pixel across the frames gives a stable background value. write this in formal language. This average value represents the background model for that pixel [23]:

$$B(x,y) = \frac{sum\ of\ intensity\ value\ at\ (x,y)\ in\ total\ f\ frames}{number\ of\ total\ frames}, \quad (4)$$

The widespread formula of background subtraction [9] calculates the total variation between the pixel intensity of the current image and its corresponding reference/ background image.

$$D(x,y) = |C(x,y) - B(x,y)|, \quad (5)$$

where $C(x, y)$ represents the pixel intensity in the current frame at position B (x, y), the foreground mask $M(x)$ is subsequently obtained by the following formula in equation (6):

$$M(x) = \begin{cases} 1 & D(x,y) = |C(x,y) - B(x,y)| > \tau \\ 0 & Otherwise \end{cases}, \quad (6)$$

where τ is the specified threshold and is used to determine whether a pixel should be classified as part of the foreground or not. If $D(x, y) > T$, then the pixel is considered as foreground.

The airport runway is a stationary scene, the original background image can be acquired easily. Over time, it may be necessary to update the background model to reflect gradual changes in the environment. This can be achieved by gradually adjusting the background model through a weighted average of the current model and the intensity values of new frames which are described in equation (7):

$$B(x,y) = (1-a) * B(x,y) + a * C(x,y), \quad (7)$$

where $B(x, y)$ is the pixel value at position (x, y) in the background model and $C(x, y)$ is the pixel value at position (x, y) in the current frame or image. α is a small learning rate. The equation $\alpha * C(x, y)$ represents the contribution of the current frame scaled by "α" which emphasizes the current frame's influence in updating the background model. The updated background model is obtained by combining these two contributions at position (x, y).

After removing the background, a series of sequential steps are applied to the resulting images to accurately display and improve representation of the object: (a) The findings of background subtraction are accumulated in a database for further analysis. (b) After this, frame-by-frame detection of FOD is performed on these saved images using image MSER segmentation techniques [24]. (c) As soon as the object is successfully recognized using these techniques, the central processing system is instantly informed about the detection of the foreign objects.

MSER is a region detector introduced in 2004 that is widely used due to its high repeatability and compatibility with other detectors [25]. It is well-suited for large-scale image retrieval tasks due to its ability to operate with a limited number of regions per image, which makes it preferred option. MSERs have two primary benefits: they are suitable for hardware implementation due to their algorithmic structure, and they have low computational complexity. Additionally, it offers repeatability and accurate identification of important image components, especially for common illustration distortions [26]. The maximally stable extremal region is defined in equation (8).

$$p(R;\triangle) = \frac{|R+\triangle| - |R-\triangle|}{R}, \quad (8)$$

where $\rho(R; \Delta)$ is minimal, the maximally stable extremal region is denoted by R. In level set $S(i)$, the extremal area, often referred to as α-connectivity, is the maximally linked component where the pixel intensity is not greater than i. $R+\Delta$ is the smallest extremal region that contains R and has an intensity greater than R's minimum intensity Δ. $R-\Delta$ is the largest extremal region that R contains, and its intensity is at least Δ higher than R's intensity.

D. Proposed Algorithm

Step 1: Place Foreign objects on the tarmac road.
Step 2: Record a video of the debris present in the area.
Step 3: Convert the recorded video signals into a sequence of digital frames or images.
Step 4: Upload the captured frames to a specific folder.
Step 5: Read the frames from the folder and denoise the

frames by using mean filtering.
Step 6: Apply threshold and morphological operations (opening and dilation) to eliminate noise and improve the visibility of the objects in the binary image.
Step 7: Apply background subtraction using the absolute difference, where the absolute difference refers to the difference between the reference and current images.
Step 8: Perform frame-by-frame detection of FOD by object contouring on the resultant image of absolute difference using the MSER contouring method.
Step 9: Inform the central processing system immediately about the detection of foreign objects.
Step 10: Store the identified detection results in the dedicated database for future reference and analysis.

The algorithmic structure is illustrated in Fig. 6:

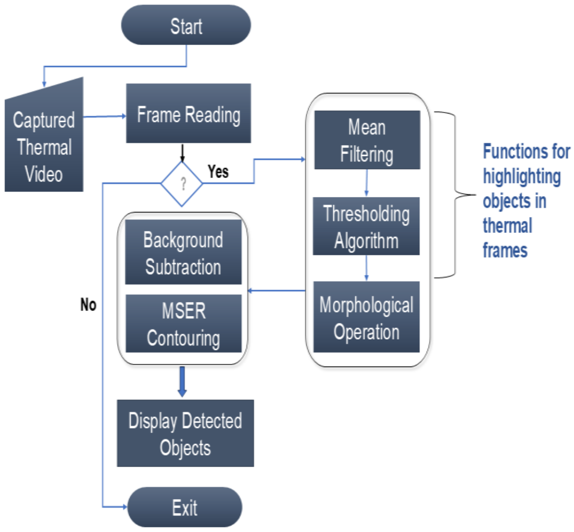

Fig. 6. Algorithm for FOD target detection

IV. Results and Discussions

In the experiment, a streamlined and intuitive platform was used that consisted of a single thermal imaging camera, a conventional personal computer, and readily accessible interface cards. This platform was utilized for conducting FOD measurements on a surface closely resembling that of an airport tarmac road. To validate the monitoring capabilities of the system, various foreign items were intentionally placed at predefined locations on the surface. These items included screws, bottle caps, match boxes, coins and keys. The purpose was to comprehensively evaluate the ability of the system to identify various types of potential debris that could threaten the safety of airport runways.

The images are of objects of various sizes including a matchbox, metal bolt, coin and key, captured at approximately 15 meters from the thermal camera. The size and dimension details of all objects used in this experiment are described in Table II.

TABLE II
DIMENSIONS OF OBJECTS

S. No.	Thermal Frame	Size	Distance From Camera
1.	Match Box	40x25x10 mm	15m
2.	Metal Bolt	4.5mm	15m
3.	Coin	1.45mm	15m
4.	Key	25mm	15m

Some sample frames from the thermal imaging dataset utilized in the proposed algorithm are displayed in Fig. 7 and provide insights into the nature of objects and scenes captured in this study.

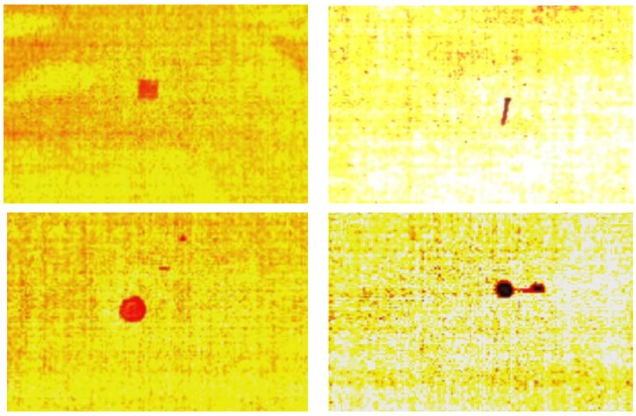

Fig. 7. Thermal frames used in this experiment

A reference background image is shown in Fig. 8 and is used as the background for all captured videos in the experiment, allowing the same reference background image to be used for all images during the background subtraction method.

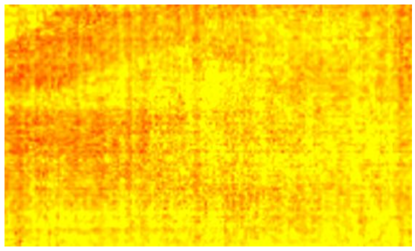

Fig. 8. Reference thermal image

The results after the pre-processing steps like mean filtering, thresholding algorithm, and morphological operations are shown in Fig. 9.

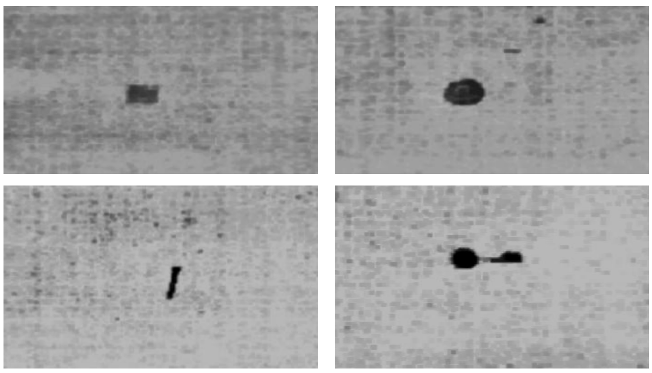

Fig. 9 Result of threshold & morphological operations

Finally, the results of the detected objects are displayed in Fig. 10. Image subtraction and MSER algorithm were used to get the final objects.

In summary, the paper presents a video-based system for detecting FOD in Video frames under diverse weather conditions. The objective is to enhance the quality of thermal frames and detect the target FOD. All the results are again displayed on Fig. 11 obtained at each stage of processing accompanied by their corresponding histograms. The histograms illustrate varying pixel intensity distributions, highlighting the brightness and contrast differences across the images. A sharply skewed high peak in a histogram reflects a concentration of high-intensity pixels, which often represents a bright background. The lower-intensity pixels in such a distribution typically correspond to the detected object, creating a strong contrast between the object and its surroundings. This visualization clearly explains the performance and the transformations applied at each step.

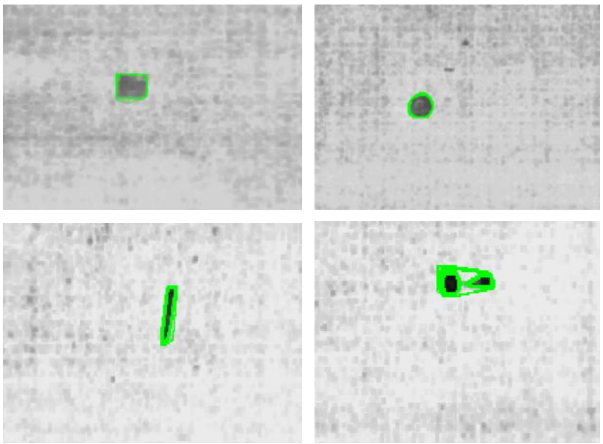

Fig. 10. Subtracted image with MSER object contouring

The proposed algorithm can detect multiple objects within a single frame and simultaneously segment multiple high-contrast regions. The robustness of the algorithm in multi-object detection and feature extraction is highlighted by quantitative analysis, which validates the detection results. Consequently, the algorithm is highly efficient for complex thermal imagery scenarios. The results of multi-object detection, along with their corresponding histograms, have been obtained at each processing stage and are displayed in Fig.12.

V. COMPARATIVE ANALYSIS

A comparative study has been conducted to demonstrate the performance of the proposed algorithm against other contouring algorithms. All algorithms, including the proposed, were implemented on the same data with the same parameters to improve comparisons. The results demonstrated that the proposed approach performs better target detection than other popular algorithms. It has uses in several fields of study, such as security, surveillance, and driverless automobiles. The comparative results with Scale-Invariant Feature Transform (SIFT), Haar Cascades and Speeded Up Robust Features (SURF) are listed in Table III.

TABLE III
COMPARISON TABLE WITH OTHER TECHNIQUES

	Precision	Recall	F1-Score
SIFT	76.5	78.3	77.6
Haar Cascades	83	84.5	83.7
SURF	79	79.2	79.5
Proposed	98	99.8	98.8

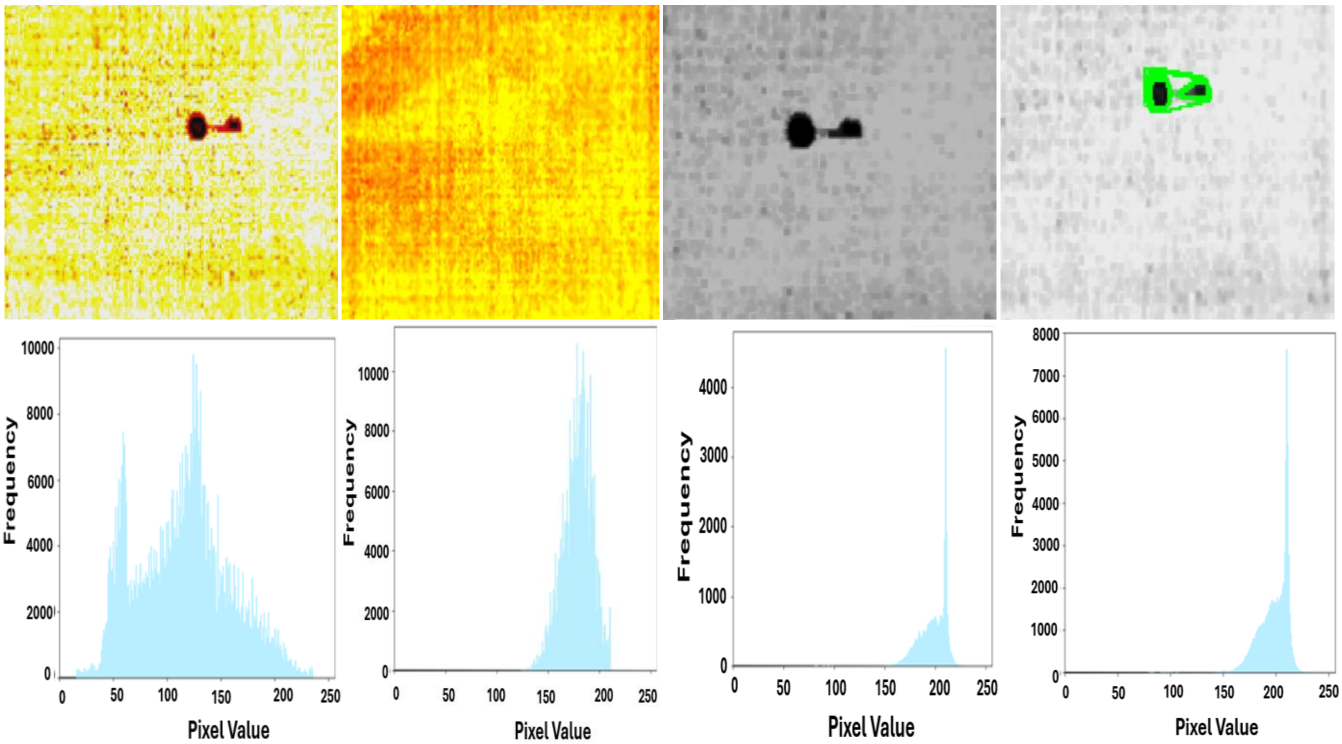

Fig. 11. Performance evaluation results of the proposed algorithms at every step along with their histogram

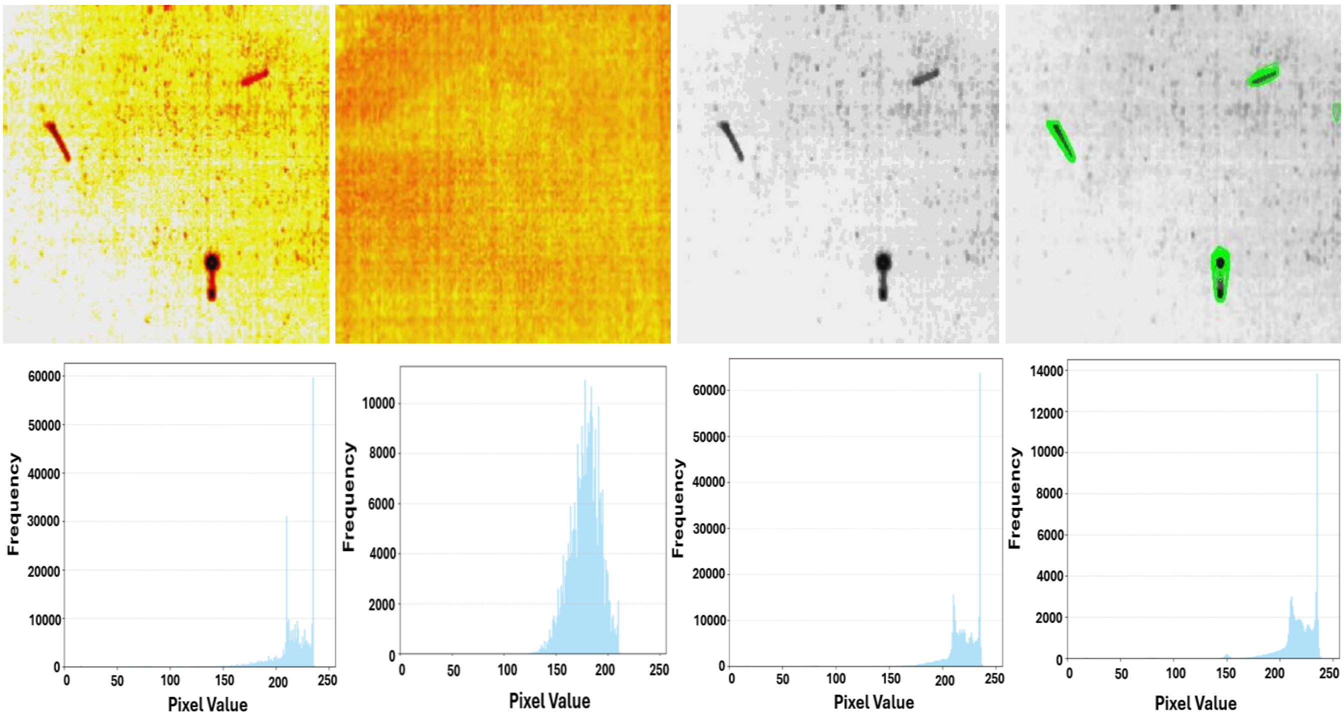

Fig 12. Performance evaluation results of the proposed algorithm multi-object detection in a single frame at every step along with their histogram

The graphical representation of the comparative study with other contour detection algorithms is shown in Fig. 13. The comparison of the proposed FOD detection algorithm has also been done with other existing techniques present in the literature based on accuracy as presented in Fig. 14.

Our method achieves a significantly higher accuracy of 99.8%, outperforming other object detection methods in thermal imaging. This demonstrates the superior accuracy and effectiveness of the proposed approach compared to other methods. This research aims to fill a gap in the study of analyzing ground-based thermal images, especially in detecting small objects with dimensions of around 5-15 mm. The study presents a new method specifically designed for detecting small objects in ground-based thermal images, which has not been explored much in current literature. The comparative study related to the diverse range of detection is shown in Table IV. This study addresses the inherent difficulties in detecting small objects in thermal imaging by presenting an innovative approach that enhances accuracy without depending on extensive datasets. The implications of this research are significant for applications such as autonomous driving, security systems, and wildlife monitoring, where the precise detection of small objects is of utmost importance. Furthermore, this research sets a benchmark for future studies in the analysis of ground-based thermal images.

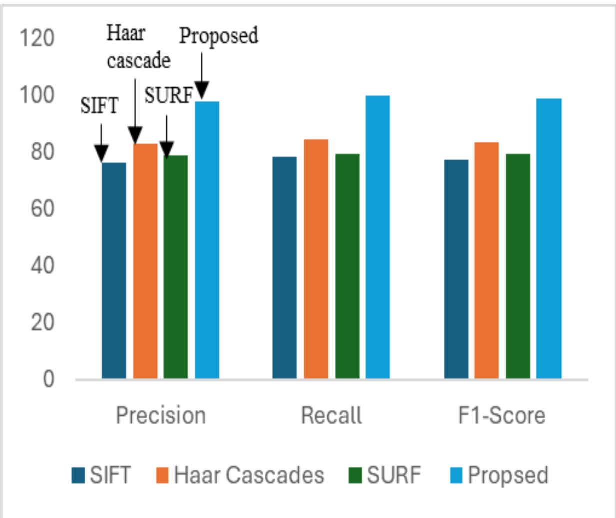

Fig. 13. Analysis of the Proposed Algorithm's Effectiveness Compared to Other Target Detection Approaches

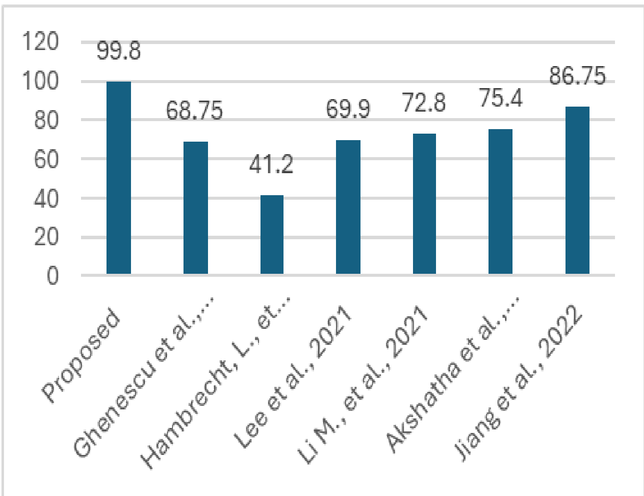

Fig. 14. Performance Comparison of the Proposed Algorithm with Alternative Methods

Table IV
PERFORMANCE EVALUATION OF THE PROPOSED ALGORITHM AND STATE-OF-THE-ART METHODS

		Proposed Method	Ghenescu et al., 2018	Jiang et al., 2022	Akshatha et al., 2022	Lee et al., 2021	Li M., et al., 2021	Hambrecht, L., et al., 2019
Used Dataset		Ground-Based Thermal Imaging Dataset	UAV Thermal Dataset	FLIR Thermal Imaging Dataset	Arial Thermal Images	UAV Derived RGB and Thermal Images	UAV-Borne Thermal Images	UAV Derived RGB and Thermal Images
Site	Location	Tarmac India	coastline on Jeju Island, Korea	metropolitan areas, US	Oklahoma State University	Animal Farm, Hongcheon, Republic of Korea	Sports Ground, Expressway, with dense pedestrians at noon China	Issa study site, Tanzania
Data Acquisition	Date	12 2023	-	07 2018	02 2015	11 2020	2020	03 2017
	Time	11:00~20:00	-	-	-	11:00~13:00	-	-
	Altitude(m)	1.45~ 5	-	11582.4	40-200 (approx.)	25~275	60 (approx.)	70-100
Target	Name	FOD Objects (Small)	Human, Vehicle, Boat	Car, Person, Bicycle	Human,	Alpaca	Human, Car	Human
	Body length (m)	5-25mm	0.0132	33mm	7-12	0.8~1.0	-	0.3~0.5
Accuracy (%)		**99.8**	68.75	86.75	75.4	69.9	72.8	41.2

VI. CONCLUSION

FOD refers to unintentionally present objects, such as metal strips, screws, nuts, studs, and debris, found near an aircraft that can cause damage to the aircraft or its passenger. This study presents a thermal video-based detection experimental system. A target detection algorithm focused on image change detection has been meticulously designed for FOD detection applications, aiming to enhance safety and operational efficiency in aviation environments. Initial experiments were conducted on a tarmac road to validate the system's detection capabilities. The proposed algorithm showcases the critical functioning of the system by effectively addressing the limitations of traditional visual object detection methods, particularly under low-lighting conditions and during nighttime operations. The results obtained show that the proposed algorithm achieved an accuracy of 99.8%, which is better than other detection methods. The evaluated method detects FOD objects in thermal videos accurately. This robust system significantly improves the detection of small objects even in challenging conditions such as foggy weather. The novelty of this approach lies in its integration of thermal imaging and advanced detection algorithms, ensuring high detection accuracy and reliability.

The practical applications of this system are significant. It can effectively detect FOD, thereby improving the safety of aircraft and passengers and optimizing airport maintenance operations. The innovative use of thermal imaging and advanced detection technologies has the potential to revolutionize FOD detection, setting a new standard in aviation safety protocol

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