

## Recognizing Foreign Object Debris (FOD): False Alarm Reduction Implementation

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### Article Info

#### Article history:

Received Jan 31, 2018

Revised Apr 6, 2018

Accepted Apr 20, 2018

#### Keywords:

False alarm

Foreign Object Debris

Infrared images

Morphological image processing

Sensors

### ABSTRACT

Recognition of foreign object debris (FOD) on runways is mandatory to avert the accidents and emergency. The accurate and precise estimation of FOD is very complex because of the intricate shape and their different tiny sizes as well which are not easily visible. For the prompt removal of the FOD from the runways a robust, accurate and precise system is badly needed. Therefore, in our research we have proposed a system comprised of ultrasonic sensor and infrared images capturing device with a combination of false alerts reduction algorithm based on infrared images distribution and morphological edge identification. After the segmentation and morphological processing, the decision unifying divider was designed to identify the actual targets. Several approaches have been done for the detailed and rapid investigation of FOD. Testing and validation have proved that our proposed research performed well compared to the other techniques. In this research ultrasonic sensors results are integrated with the processed infrared images.

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## 1. INTRODUCTION

The Foreign object debris has been a core reason for the aircraft infrastructure and human lives loss [1]. The debris must be detected briskly and addressed to the main station for the abrupt removal of the debris [2]. An annual loss of around 3 to 4 billion US dollar has been observed due to the inadequate foreign object debris identification systems [3]. Due to the tiny enigmatic size and shapes of debris it is very hard to discriminate between real targets and false alerts [3]. Mostly the Foreign object debris are made up of metal like nuts, bolts and strips having very small size [3][4]. Tarsier1100, FO Detect, FOD Finder have been legitimate FOD identification systems that use millimeter radar with the combination of video camera [3][4]. The deadly incident of Concorde on July 25-2000 that was due to the metal strip, FOD analysis on runways and railway traction has been taken under deep examination [3-5]. Practically manual surveillance is not achievable due to the nonstop unending landings and take-offs [3-5]. Birds, mini nut and bolts, tiny falling chunk or scrap have various sizes and shapes therefore it would be more difficult to observe FOD manually as it will have high false alarm rates due to the poor analysis of human being [4-5]. Several sensors based fusion algorithms have been developed to mitigate the false alerts [6].

In large field infrared system needed high data rate bandwidth for the images. Designed Algorithm performed image distribution of particular infrared images by OTSU segmentation procedure and identified the edges by morphological processing [7]. Fusion algorithm of sensors permits the mixture of various data type of sensors to achieve higher accuracy and precision. Various techniques and methods have been applied for the real time investigation of FOD. We have proposed a novel cost effective solution with minimum fake alerts by designing a prototype using primary and secondary transducers with the combination of the camera based on some image processing algorithm.

This research paper is further divided into four sections. Section II is explaining the recent FOD detection trends. Section III describes problem statement and section IV explains the methodology which comprised of problem statement and proposed technique. In section V experimental testing results has been elaborated whereas the conclusion was discussed in the section VI.

## 2. RELATED EARLIER WORK

Efficient visualization of hindrances and debris is required to prevent hazards in advance [8]. Highly authentic imaging technology is esse for the dense vigilance of airport runways and railway traction systems; therefore, carrier frequency was enhanced to a higher frequency like W-band (75-110 GHz) [8]. A sensory network system was connected by optical fiber [6-8]. Radio over fiber distributed frequencies to the radar systems [8]. It has been noticed empirically that an optical fiber linked with millimeter-wave radar system can be beneficial for quick and authentic identification of foreign object debris (FOD) in the larger field of aircraft runways [8][9].

Figure 1 mentions that signal can be transmitted by central office to the millimeter wave radar head utilizing fiber optic link. The transmission loss is less compared to the RF co-axial cable [8].

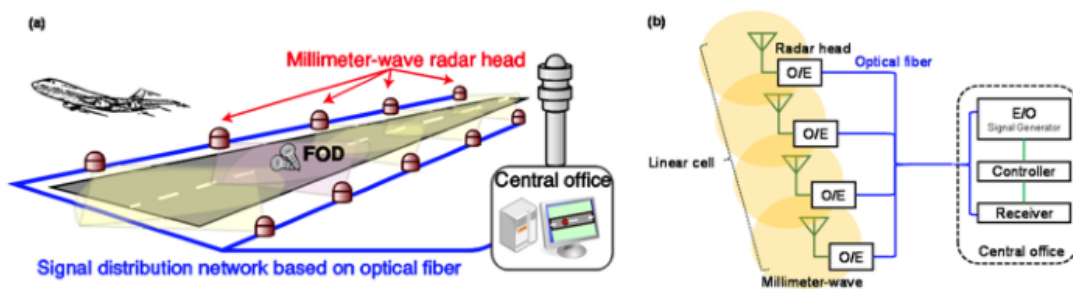


Figure 1. (a) Main Diagram (b) Block Diagram of Radars Linked through Fiber [8]

Another unique approach was designing model of foreign object debris (FOD) on 2D algorithms in the W-band (75-110 GHz) [9]. Synthetic Aperture Radar (SAR), having robust competency of weather monitoring and capturing high resolution images is playing a crucial role in National Economy, Military and other fields [3]. SAR imaging theory states that to calculate the two dimensions of actual target, the respective position between radar and target must be varied [3]. Basically, SAR covered all mini antennas together and modulated them to a large antenna [3]. SAR produced two dimensional images of the target and was delivered to the controller for the further processing [3]. Two various curled reflect array antennas with a combo of cosec-formed design have been utilized to enhance the system processing and area [10]. CFAR (constant false alarm rate) algorithm with the combined processing of moving target implication would be a better achievement [10]. Linear filtering approach is performed by mathematical operations but produce blur images but non-linear filtering methods can improve the edge of the image [11]. Usually edges are linked with the outer countour of the image therefore edge analysis can also be performed for the segmentation and features may also be extracted [12]. The main motive of the fuzzy based morphological component was to achieve huge conjoining edge characteristics of the image [12].

## 3. PROBLEM STATEMENT

Foreign object debris can be in any shape and size and may cause dreadful accidents if they are not detected on early basis. Debris may harm pilots, passenger as well as aircraft and infrastructure loss. FOD

can be tool, wire, strip, hardware metallic part, connectors, nuts, bolts and nozzles. There are so many earlier research works available in which several methodologies and techniques have been designed and developed to recognize Foreign object debris exactly and flawlessly. For the security of aircraft and to avoid further losses, an intelligent and smart system is strongly needed that must be enough competent to detect the Foreign object debris (FOD) accurately and precisely. To eliminate the issue, we have proposed a cost-effective solution based on transducers and image processing algorithm based on infrared images for the rigor FOD investigation. The main problem was the existence of missed information, high false alarm rate and errors in compressed images. To mitigate the issue, a transmission protocol was needed in the application layer so that the compressed images must be received properly and accurately in a right order.

#### 4. METHODOLOGY

In large field infrared system needed high data rate bandwidth for the images. Our proposed algorithm segmented the images by OTSU segmentation (image distribution) procedure and detected the edges by morphological technique. The question arises mostly is that how can we achieve the accuracy and precision in detecting the real targeted objects to minimize the false alarm.

##### 4.1. OTSU and Edge Processing

Setting of threshold level was quite complex due to the ambiguous surroundings and dissimilarities in greyscale of infrared images. We have two types of filtering approaches; linear filtering approach was performed by mathematical operations but produced blur images but non-linear filtering approaches can improve the image esdges as the edges are correlated with image boundaries.

We have used iterative OTSU segmentation method that can be considered as real image processing algorithm. Edge detection was done by morphology. Morphological gradient can be elaborated as the change in maximum and minimum greyscale. It has the capability to improve the image. IRST (Infrared search and track) captured the real images in complicated long black coloured runways that has been tested and validated. OTSU segmentation and morphological processing has been done on original infrared images. Debris false alarm has been minimized by fusion decision criterion algorithm.

##### 4.2. Feature Extraction

After performing the OTSU distribution and morphological processing it would be harder to discriminate the acutal targets from other fake alert elements as they have same grey scale features. Several characteristics were obtained which can help us to distinguish between actual debris targets and other similar jamming elements. Length width ratio waz analyzed.

##### 4.3. SNR and Constrat ratio

SNR was calculated to investigate the intensity level compared to the surroundings using the following expression.

$$SNR = \frac{fT - fB}{\sigma} \quad (1)$$

In the equation no. 1  $fT$  and  $fB$  can be considered as a greyscale value of actual target and runway surroundings and  $\sigma$  is the variance of the size.

The local contrast ratio can be estimated as

$$LC = \frac{fT - fB}{fB} \quad (2)$$

Where  $fT$  represents the average value of segmentation and  $fB$  represents the average value of the background.

##### 4.4. Classifier

Moving debris or debris commonly exhibit legitimate frames in sequence of the image. While jamming elements pattern are haphazard and irregular. On the basis of these the motion is extracted. Figure 2 displays the infrared image processing results after the segmentation and morphological image processing. The feaure extraction technique was also performed to minimize the false alarm rate and to enhance the identification ratio high.



Figure 2. Image Processing Outcomes

Figure 3 illustrates the main flow of the proposed research for the foreign object debris identification. Ultrasonic sensors detect the presence of the obstacles, objects and debris and infrared images are transmitted through communication protocol that was used in the conference paper related to this enhanced research work [13].

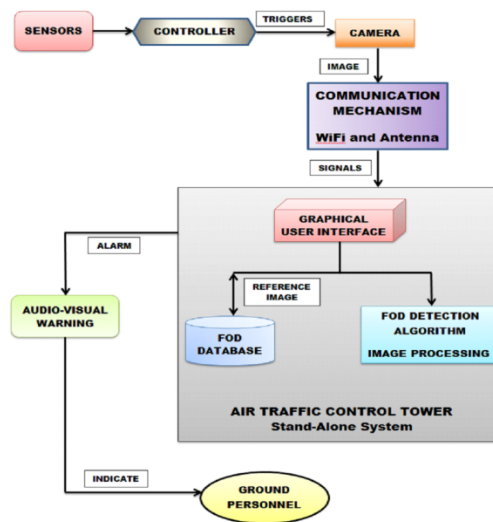


Figure 3. Main Flow Diagram [13]

Figure 4 demonstrates the transmission and the delivery of the images through Wi-Fi. The transmission protocol has been discussed in detail in the previous paper [13].

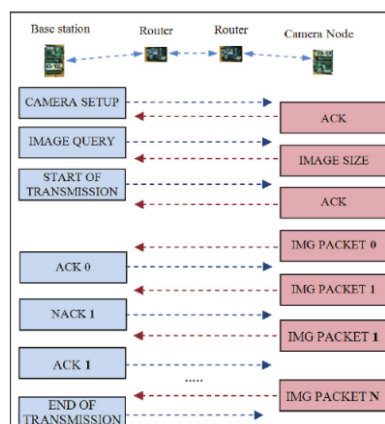


Figure 4. Demonstration of Transmission Protocol [13]

**5. RESULTS ANALYSIS**

Figure 5 shows the sensor status in the presence of the foreign object debris as it would be detected by the ultrasonic sensors.

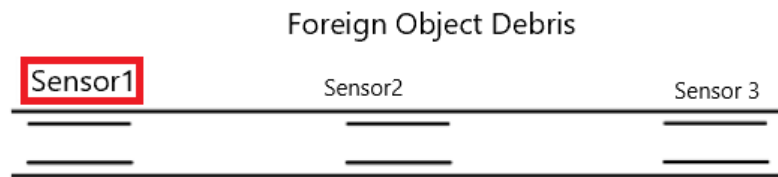


Figure 5. GUI in the Existence of Debris [13]

Figure 6 portrays the various vigilant observations (Low=0, Moderate=0.5, Severe=1) in the presence of the foreign object debris. The sensor output depicts the exact investigation of the debris.

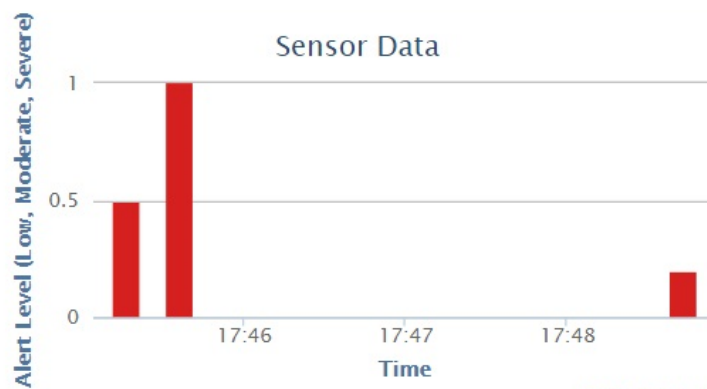


Figure 6. Sensor Alert Levels

**6. CONCLUSION**

Experimental outcomes confirmed that our proposed research worker well or equivalent to the earlier related work. Our suggested approach consisted of transducers and image processing algorithm with less fake alerts is a cost-effective resolution in contrast to all other recent approaches. Current procedurs like Radar based, transucers based and drone based approaches cannot be thought-out as a cost-effective solution. We have tried our best to mitigate the fake alert rate by using MSER up to 10% in our previous paper [13] and now we have performed infrared images processings based on the OTSU segmentaion, morphological image or edge processing and feature extraction. As a future work this research work can be expanded more by applying MLP (multi-layer perceptron) as a classifier to eliminate the false alarm more accurately and precisely.

**ACKNOWLEDGEMENTS**

Financial assistance for this research by the IIUM Research Management Center (RMC) via RIGS Grant No RIGS 15-147-0147 is highly acknowledged.

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