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Foreign Object Debris Detection System in the Airplane

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Abstract- **The main purpose of this research is to design and develop a cost-effective system for the detection of Foreign Object Debris (FOD), dedicated to airplanes. FOD detection has been a significant problem for airplanes as it can cause damage to aircraft. This paper describes an image-based foreign object detection system used for FOD detection applications.**

Keywords: Airplane, Computer vision, foreign object debris (FOD); camera; object detection, Machine Learning, System Architecture.

I. INTRODUCTION

The problem with Foreign Object Debris (FOD) in airplanes has increased rapidly in recent years. It is observed that accidents due to FOD occur mainly in airplanes, airport runways, gateways, and taxiways. In unlikely situations, it can cause damage to the aircraft tires or engines excluding them from operating. The resulting situation also gives rise to the substantial delay of multiple aircraft; in extreme cases, it can cause an accident with the possibility of casualties. That is to say, FOD arises as a big problem in the aviation industry that impacts the security of aircraft. For this reason, numerous research projects have been carried out recently to create an appropriate method for FOD detection in aircraft or other objects.

The detection of particles and other debris in airplanes is challenging, due to the necessity of monitoring the parts of the airplanes. In aviation, foreign object debris (FOD) is any particle or substance, alien to an aircraft or system, which could potentially cause damage to the whole airplane or other vehicles. In unlikely situations, it can cause damage to the aircraft wing, flaps, or engines excluding them from operating. Besides the money, there are also invaluable losses, like in the year 2000 when Air France Flight 4590 crashed due to a small metal strip resulting in in-flight fire and loss of control. This project aims are to design and develop a vision-based FOD detection system that can monitor airplanes' carbon flame. Damage to aircraft is mostly caused by small dust present in airplanes. Numerous mammal species also cause damage to aircraft as a result of an inadequate security fence for airplanes, in addition to debris. Unfortunately, during one incident, a deer resulted in the crash of an aircraft at Sitka's runways, and in 2015 a kangaroo caused an aircraft crash. According to the Federal Aviation Administration (FAA), the overall number of strikes raised from about 1,800 in 1990 to over 16,000 in 2018. Further, with the rising frequency of wildlife impacts, more focus has been given to wildlife vulnerability analysis and the maintenance of airfield biodiversity.

In this study, we will introduce a practical application of the FOD detection system which has been installed in an industry. First of all, the layout scheme of our system is explained. Next, the specifications of our system are discussed.

II. MOTIVATION

The potentially disastrous implications of FOD are the fundamental motivation for this research. FOD is one of the main causes of aircraft incidents, in which not only aircraft damage is caused, but also there is a risk of loss of human lives during commercial flights or combat missions. It is imperative to spell out that aircraft have become more sophisticated and complex, and as a consequence, the manufacturing process has become more difficult to adapt for the personnel who work with the aircraft, opening the gap for human error to occur, and therefore more incidents of FOD may occur. There is a necessity to solve the FOD problem in order to completely eliminate the possibility of detecting FOD in any aircraft activity.

The standard airport or airplane FOD detection system uses manual screening methods, but in this project, we employed automatic detection of FOD, which can avoid danger. This will be saving time and less manpower, and it can be more efficient. For a few years, many candidate technologies have been considered and developed for airport or airplane FOD detection applications. Among the existing systems capable of detecting FOD, we find those based on detection and open-cv. These available technologies havethe capability to detect and report the presence of FOD on a carbon flame, greatly enhancing the industry operators' ability to locate and remove debris. Before debris damages an aircraft or causes flight problems, it must be removed.

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III. METHODS

The tools needed in the research include a PC computer, python software, the OpenCV library, Kera's, TensorFlow, SciPy, Sklearn, NumPy, Pandas, and sys libraries. While the equipment used are box, Raspberry Pi, Camera, and Motor for the roller. The whole research on the classification of FOD objects using machine learning consists of three stages: data set design, Convolutional Neural Network (CNN) method model design, and data set validation. We create a GUI where authorized takes to the admin in the industry. Using OpenCV FOD is detected from the image which is captured by the camera.

A. System Design

The foreign object debris detection system can be described in Fig. 1. First of all, the images are obtained by the cameras. Then after the image signals are converted to the digital image by employing the capture card, the digital image is transferred into the computer and processed by the real-time processing subsystem involving the image processing blocks. Finally, the results are to be displayed in the graphical user interface (GUI) and stored in the FOD database for further processing and utilization. In sum, we will devote ourselves to building a fast, efficient, and reliable system for FOD detection.

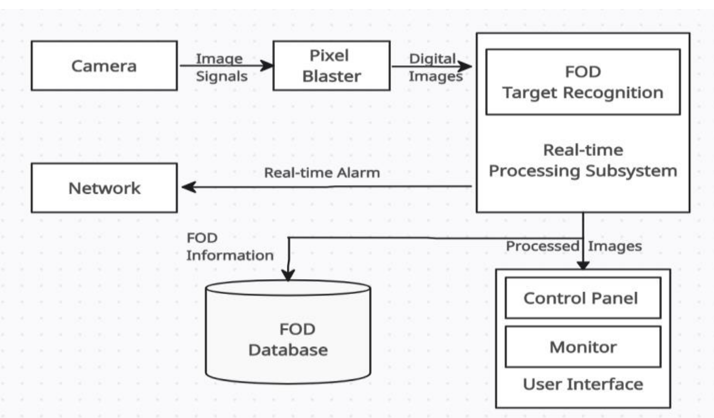

Figure 1. Block diagram of FOD detection system

B. Dataset Design

The dataset design is done by collecting the data used in the study. Data were taken as 1220 data consisting of 305 images of each type of FOD. The data is divided into two parts, namely 1200 data as training data and 20 data as test data. A few FOD datasets were developed and published by previous studies, such as the dataset FOD-A. However, this dataset is designed for the tasks of object detection or classification. All images contain FOD samples with bounding box annotation.

C. Image Processing

The real-time image processing system is the core of our detection system. A variety of strategies are designed to process the images, involving many image-processing steps and core algorithms. Object Debris Detection is to compare images and detect regions of change in images of the same scene taken at different times, getting the information needed of the target according to the difference of the image. It is applied to a large number of applications in diverse disciplines, including image surveillance.

As the airplane body parts are nominally a static scene, regions of change in images taken of the same piece of an airplane at different times can be possibly attributed to newly deposited debris. So, we consider the image processing method based on the object debris detection algorithmto be a very promising approach.

IV. PROPOSED SYSTEM

The FOD detection system in this study is a cost-effective and easy method for FOD detection. The system could be installed in the manufacturing industry. The system is composed of two modules, the FOD-detecting sensors which are in the Raspberry Pi, and the data processing center. In detail, the FOD-detecting sensors are made up of many optical cameras mounted on a pan-tilt that can, the installation costs may be acceptable. The optical pictures taken by the optical cameras are received by the data processing center, and FOD detection is performed in this module using the suggested approach, providing information about the detected FOD (such as image and location). According to the information on FOD, the machine stops rotating and then removes the FOD from a human being.

A. Image Collection

In the FOD system, the camera is set on the rotating machine. When the machine is rotating, the carbon film also rotates from one rotator to another rotator. Above or below the rotator the camera is set. When the carbon film is rotating the camera continues capturing the images of the carbon film. The data is collected as images from body parts of an airplane using UAS to reflect our goal of detecting FOD automatically from the aerial perspective.

B. FOD Localization

The process of the method is the 3840x2160 resolution images, a resolution which is commonly considered to be high, are split into patches to preserve the detail of the images while reducing the computational burden. Using a reconstruction technique, the suggested method achieves FOD localization in patches. The reconstructed patches are used to propose patch-specific segmentation maps that label the background and the anomaly. As needed, the patch-specific segmentation maps can be combined to provide a full image segmentation or to display the FOD localizations on the entire image. Before classification, abnormal areas are removed from the area-specific segmentation map (the actual cropping is done on the original patch, and the segmentation map specifies the position) and accepted as normal.

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C. FOD Classification

To convert the segmentation localization S into the bounding box localization R, which is used for classification and evaluation, we calculate the extreme points on the segmentation map. The extreme points of the segmentation map are the segmented point the furthest left, the segmented point the furthest right, the segmented point closest to the top of the segmentation map, and the segmented point closest to the bottom of the segmentation map. From here, the four coordinates of a bounding box are computed directly from the extreme points to produce the bounding box localization R.

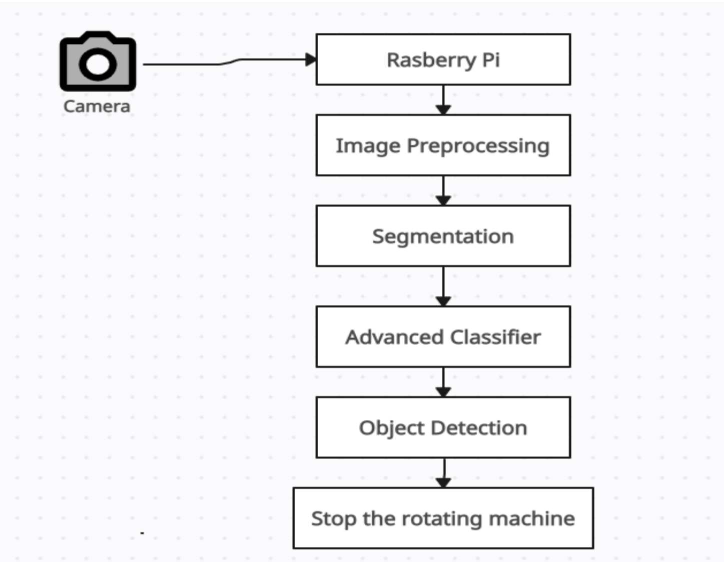

Fig. 2. Proposed System Architecture

V. Conclusion

A foreign object debris detection system and the targetdetection algorithm based on image change detection were designed for FOD detection applications and its detection capabilities were demonstrated by the preliminary experimental results on the industry. The camera sensor and image processing algorithm are the two most significant factors for system improvements. Further work will be carried out taking more experiments under more complicated conditions for our detection algorithms demonstration and system improvement. The detection of FOD is necessary for ensuring the safety of aircraft and the orderly functioning of the airplane. Although there are many detection systems to tackle the problem of FOD, a well-defined solution design is required to achieve a low-cost and efficient device with accurate detection results. To fulfill user criteria, specifications, and limitations using UDD, we have constructed a requirement formulation and objectives for the FOD detection system.

We proposed the design process of a FOD detection system intended for airplane parts use. The presented process approaches the problems at small and medium airplanes from not only our perspective but also considering the shareholder's and future users' requirements, the design procedure considers the various technologies with their functionalities and constraints and even costs. The proposed system design is verified with real-time synopsis to provide an inexpensive device with proper algorithms with good performance for the detection process. The entire system's operation is also explained. The proposed solution for FOD detection can detect and classify the FOD.

V. Future Scope

In this paper, we propose a total solution to implement FOD prevention automatically on carbon film in airplanes. Our future work will focus on Using several camera sensors mounted to another vehicle body parts manufacturing industry to detect the FOD. Further developing our algorithms to have a higher sensitivity, simultaneous object detection capabilities, and low false alarm rate under a full range of operational conditions for demonstration. For better use, we can create a mobile application for giving access to the users so, that they can be notified whenever a FOD is detected.

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