Defect Detection and Health Monitoring of Steel Structure based on UAV Integrated with Image Processing System

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Abstract. This paper presents a novel solution for defect detection and health monitoring of steel structure by involving effective use of Unmanned Aerial Vehicle (UAV) and Image Processing System. Lots of the traditional test work depends on manual labor despite that the inspection and testing environment is rather harsh. The conventional inspection method does not meet the requirements of high efficiency comprehensive security. The proposed system integrates six-axis UAV platform, image processing and big data analysis for detection and safety evaluation of steel structure’s surface degradation. The visual sensor, ultrasonic sensor, laser sensor, and other complementary sensors are crossed integration for UAV platform in order to achieve stable and high-definition aerial photography, which can definitely enhance the reliability and stability of the UAV system and intelligent image processing algorithm has been applied to identify the defect and potential diseases of steel structure. Finally, the results show this approach is the cost-effective and time-compressing solution for health monitoring of steel structure.

1. Introduction

Nowadays the defect detection and health monitoring of various types of objects such as steel structures and connecting components are playing more and more importance in daily inspections[1-2].

And the in-person human based inspections can be time consuming, expensive, difficult and often dangerous for an individual to perform. Some examples of the structures pose significant challenges in inspecting including crane, boiler, pipeline, bridges, dams, power plants, power lines and chemical processing plants[3-5].

Recently, with multi-sensors fusion technology and microelectronics, UAV systems are widely applied in several fields such as environmental monitoring, agriculture surveillance, industrial inspection and exploration activities[6-9].

UAV systems have the abilities to fly over the barriers and dangerous areas. If the UAV systems equipped with a high-tech detection unit, the detection efficiency can be improved significantly, and it will be much better than the traditional method. The data obtained by this system can be great useful for the commanders to make decisions and reduce the risk of getting worse[10-11].

Though the employment of UAV with image processing system in structural health monitoring of bridges and other civil structures are convenient with some cases in China that some commercial UAV system has been used in the special equipment accident rescue application to provide video capture, environmental monitoring and other services, there are few research about the combination of the
UAV system with the effective methods to analyzing the acquired data in a reliable ways such as machine vision[12].

In this paper, a novel integrating UAV system with image collection and processing for defect detection and health monitoring of steel structure in an effective way is proposed. The high-tech detection units are mounted on UAVs to transfer inspection data with the ground station. And the real-time information with image processing systems can result in the diagnosis process significantly, which manages the accurate safety evaluation and the potential diseases monitoring of steel structure.

2. Structure Of The Detection System

![Diagram of the detection system](image_url)

**Figure 1. UAV intelligent detection system**

UAV intelligent detection system is shown in Figure 1.

(1) six-axis UAV platform

According to the requirement of special equipment inspection, the UAV intelligent detection system has been improved. The platform is designed with the features of intelligent obstacle avoidance, positioning, stable hover and other flight characteristics when used in the unstructured special equipment detection environment. By carrying a variety of sensor modules such as visual sensing, ultrasonic sensing and laser sensing, the platform is based on the multi-sensor information fusion system. The corresponding rules are designed and the information obtained by sensors is complemented and processed to improve the intelligence of the whole system.

(2) Image processing system

The UAV cradle system is equipped with a suitable high-definition CCD camera. The focal length is adjustable and high-definition image data can be accessed instantly in the stable flight. Also, a machine vision processing unit is embedded in this system. The potential structural failure of steel structure can be suspected and recorded, and this information can be shown on the station system. After the analyzing of image data, it is convenient for the inspectors to locate structural defects and analyze the fatigue and powerful connection parts effectively, making the evaluation and testing more intuitive and clear. Meanwhile, the cradle system can be equipped with a infrared video camera.

(3) Ground station and remote control
A ground monitoring and controlling platform system is designed to enable the UAV platform system communication. During the flight period, the data can be transmitted in a real-time and reliable way. The station can display a variety of flight data, capture the image data and process these data. The data processing system can analyze and process a large number of image point cloud data. The suspicious structural defects can be identified and reported early.

3. Image Detection Working Processing

In some steel structure inspection environment, as shown in Figure 2, there are some interference and uncertainty factors: the wind interference, complex structural limitations, obstacles on the detection path, electromagnetic interference and so on.

The high-definition camera is fixed on the UAV. After shooting the original pictures with the true color quality, the potential structural defects of steel structure can be identified and determined. An example of the image processing is as followed:

1. Image preprocessing

Gaussian filtering is adopted to reduce image noise. The principle is that the weighted average gray value of the pixels in the neighborhood determined by the template replaces the value of the center pixel of the template. Then corrosion is implemented to eliminate noise, and enlarge local low light area. The result can be shown in Figure 3.

![Figure 2. Steel structure inspection environment](image)

(a) crane beam.  (b) boiler tube.  (c) oil pipeline.
(2) color space conversion and matching
HSV thresholding technique is adopted for defect detection, such as crack and corrosion. In the HSV space, threshold screening is carried out according to the color range corresponding to the corroded red. The corresponding range is displayed in the image, and the rectangular box is added to the recognition result. Similarly, the corroded rectangular box is also shown in the original image, which is shown in Figure 4.
Because the absolute depth requires the calibration of the camera and known objects, it is not suitable for the corrosion detection of steel structure. Therefore, the next step is to adopt the relative depth to eliminate the background error. Then the background points with larger relative movement distance can be removed.

Finally, the defective features are marked, extracted and restored. This information also will be used for post-process analysis of the health monitoring of steel structure Conclusion.

4. Conclusion

An effective approach is proposed by applying UAV and image processing algorithm for detection and monitoring of steel structures. Image processing algorithms are developed to determine steel structural defects such as cracks and corrosion. The image of steel structure is captured by a CCD camera, and after processing by the image processing system, the characteristics of the target image can be extracted. Combining color conversion and HSV thresholding method, the structure defect detection is formulated and found to be suitable for inspection in versatile steel structures. The flight and shooting pictures can be operated only by two to three technical staff, and there is no need for other ancillary facilities. This will reduce the workload of inspectors and improve the efficiency and safety., which results in huge economic and social benefits.

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