3D Measurement and Stereo Reconstruction for Aeroengine Interior Damage

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Abstract: The borescopy inspection problem of aeroengine interior important part damages such as firebox's burn and corruption, vane's crack, bump, abrade and concave pit, is aimed at. A new system is developed to carry out 3D measurement and stereo reconstruction of engine interior damage, in which the borescope of Japanese OLYMPUS Corporation is used as hardware. In the system, functions are implemented, such as image collection, camera calibration, image preprocessing, stereo matching, 3D measurement and stereo reconstruction. It can provide more detailed inspection and more accurate estimation of engine interior damages. Finally, an example is used to verify the effectivity of the new method.

Key words: aeroengine; nondestructive testing (NDT); interior damage inspection; 3D measurement; stereo reconstruction

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摘　要:针对航空发动机内部重要部件结构损伤,如燃烧室烧伤和腐蚀、叶片裂纹、碰磨及凹坑等的孔探检测问题,开发了发动机内部损伤的三维测量与重建系统。该系统利用日本OLYMPUS孔探仪作为系统硬件,实现了图像采集、摄像机标定、图像预处理、立体匹配、三维计算及重建等功能模块,该系统能够为详细观察和评价发动机内部损伤提供了更为准确和直观的依据。应用实例验证了方法的有效性。

关键词:航空发动机;无损检测;内部损伤检查;3D测量;立体重建

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Endoscopy technique has been widely applied in medicine, metallurgy, traffic and transportation, aeronautics and astronautics fields, in which inner status need be inspected to control product quantity. Currently endoscopy has already become an important method of NDT (Nondestructive Testing) technique in inspecting aeroengine inner damage (burn, corrosion, bump and wear, sunken pit, and so on) of important parts (firebox, vane, and so on). Traditional borescopy inspection method has following shortcomings: ①its automatization level is very low, ②it is very difficult to realize quantity measurement for damage, ③it can not realize 3-D measurement and stereo reconstruction. Thus, these problems of traditional borescopy need be solved by introducing new technique.

In this paper, the problems of inspection and evaluation for aeroengine inner damage based on borescopy are aimed at. Based on the developement trend of world endoscopy technique, the IV6c6 borescopy of Japanese OLYMPUS Corporation is used as hardware, and a new image analysis system based on stereo-vision is developed, and it can realize 3-D measurement and reconstruction for aeroengine inner damage through combining computer technique, stereo vision technique and traditional borescopy technique. In this paper, the basic principles and key techniques for the new system are presented in brief because of a limited space, and an example is given to verify its effectivity at the same time.

1 System Constitution

The hardware for this system is mainly com-

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prised of borescope imaging system, CCD camera and monitor, CPU controller and computer. In this system, the technical indexes for sensor of borescope are as follows: optical visual angle is 60°× 60°, depth range is 7-60mm, port outer diameter is Ø6.1mm and the length for end rigid segment is 38mm. Sensor is composed of twin lens and twin CCDs, focuses of twin lens are equal and fixed, and light axes of twin CCDs are parallel. According to the principle of stereo vision, a integrated stereo vision system include usually six parts such as image acquirement, camera calibration, feature abstraction, stereo matching, depth computation and inside interpolation.

2 Camera Calibrations

In computer vision, The aim for camera calibration[1-4] is to establish the relation between the point in 3D scene and the corresponding point in 2D scene. In this system, camera model is perspective projection model, which is applied most widely.

Through verification, the calibration precision of the system is fairly high, and calibration error is less 2 %.

3 Stereo Matching

Stereo matching[5] is the most difficult problem in stereovision and it is usually classified into matching based on area and matching based on feature.

Because images in this system come from engine inner cavity, image quality is very well, and matching method based on area is very fit for the system. At the same time, a quick matching algorithm based on image merging is put forward, and the computation quantity can be decreased greatly.

4 3D Measurement

In engine endoscopy technique, the damage status of engine importance components (such as vane and firebox) usually need be known, such as crack length and depth, concave area and depth, and burn area. These data can be obtained through the computation of point-point distance, point-line distance, and point-plane distance for 3D data of object surface[6].

5 Example

In order to verify the method put forward in this paper, an example is given. Fig. 1 shows a left image and a right image, which are provided by IV6C6 borescope of Olympus Corporation, and it shows a concave, which exists on engine vane, whose depth is 0.07mm, and whose width is 14mm.

In this paper, MATLAB software is adopted to 3D display for 3D data. Through eliminating error-matching points, interpolating and smoothing, smoothing surface can be obtained. Fig. 2 is the results of 3D reconstruction for rectangle field of Fig. 1.

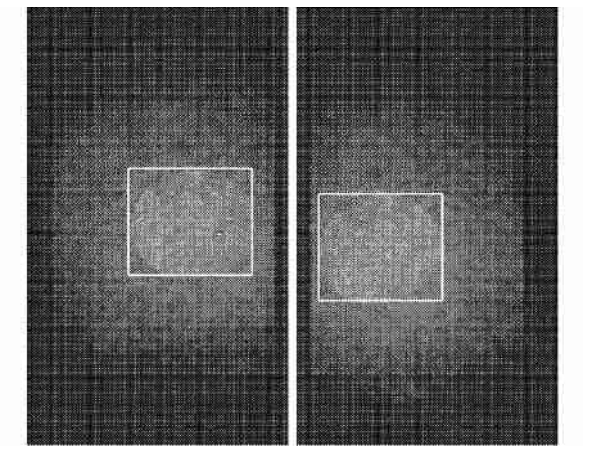

Fig. 1 Twin-eye borescope images

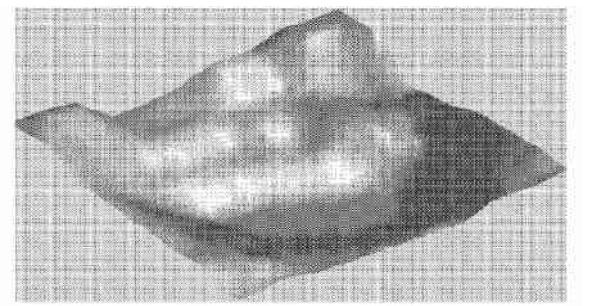

Fig. 2 3D reconstruction surface

Fig. 3 is an example of 3D computation for surface concave. The results are: point-point distance is 13.8221mm; point-line distance is 8.5712mm; point-plane distance is - 0.0731mm. Because point-plane distance is negative, it shows

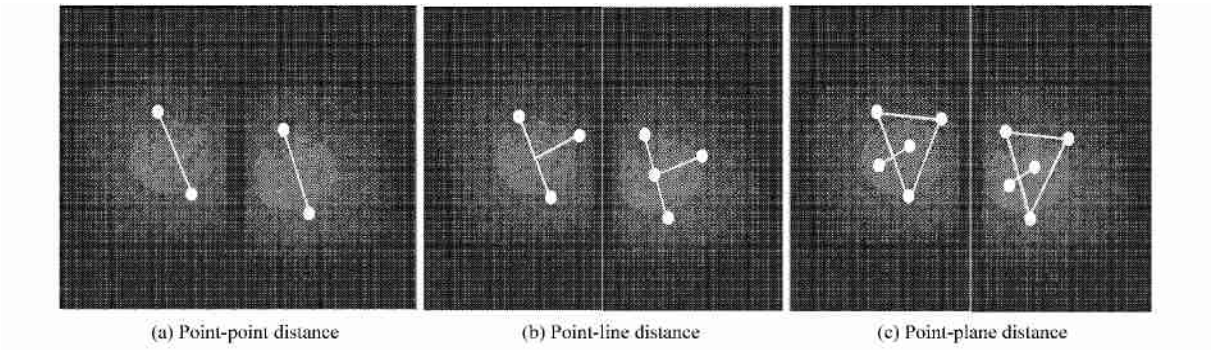

Fig. 3 3D computation example

that the point is below the plane, and it verifies that the damage is a concave. Obviously, computation results verify the effectivity and correctness of the new developed system.

6 Conclusions

In brief, main conclusions of this paper are:

(1) 3D measurement and reconstruction system frame based on borescope image analysis for engine inner damage is put forward;

(2) The camera calibration and quick stereo matching algorithm are carried out;

(3) 3D computation and reconstruction for engine inner damage are implemented by using parallel twin-eye vision theory.

In addition, further work, such as verification, correction and system integration, need be done to improve this system.

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