Measurement 49 (2014) 275–282

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Reparability measurement of vision sensor in active stereo visual system

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ARTICLE INFO

Article history:
Received 7 June 2013
Received in revised form 29 November 2013
Accepted 3 December 2013
Available online 13 December 2013

Keywords:
Reparability
Model
Vision sensor
Active inspection

ABSTRACT

The active visual inspection has made giant strides in development. Due to the complexity of field conditions, the binocular stereo vision sensor in active stereo visual inspection system is difficult to acquire the ideal image pair under the poor illumination environment, or cannot work normally because one of two cameras is damaged. To solve the practical problem, a reparability method of the vision sensor in active stereo visual inspection system is proposed. Based on the traditional measurement platform with a structured stripe projector and two industrial cameras, a reparability mathematical model is established, which merges the measurement mode of the stereo vision and the structured light vision to inspect feature points based on the reparability measurement model. Meanwhile, a mathematical model and calibration method of the structured light vision are developed based on the homography between the image and light plane. The method greatly improved the stability and reliability of measurement data. It is proven by experiment that the method is valid, which can accomplish reparability tasks commendably and achieve uninterrupted inspection of feature points in the actual industrial applications.

1. Introduction

With the development of photo-electronics, image processing and computer vision, visual inspection [1–3] has made giant strides in development due to the advantages of non-contact, fast measuring speed, well flexibility and low cost. The active visual inspection [4,5] has been used more in the industrial production, especially in the Multi-Sensor Visual Inspection System (MSVIS), such as the car body-in-white on-line inspection system.

In general, most of the inspected characteristic of the car body-in-white are feature points lying on the ridges, and others are positioning holes, so the active stereo vision is often used for consideration of structural unity of the vision sensor and measurement stability of the inspection station. The vision sensor is commonly configured as dual cameras and a structured light stripe projector or the light emitting diode (LED) array, which project the laser beam or LED on the ridges and holes actively. To inspect the key feature points on the ridges, the laser projects a laser beam intersecting with the measured edges, and the left and right cameras with narrowband filter capture two images sequentially. The feature of the intersection point lying on the light plane is extracted, and then the spatial coordinate of the break point can be reconstructed based on the mathematical model of the stereo vision. The structure-uniform stereo visual inspection system developed by Xue et al. [6] has been used in many automobile manufactories in China. For the above stereo visual inspection system, measured feature must be observed by two cameras in the stereo vision simultaneously. Traditionally, in order to obtain the measurement data of feature points with high precision and stability, both the left and right cameras must be able to provide high-quality images of measured feature. However, it is difficult to get an ideal stereo image

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http://dx.doi.org/10.1016/j.measurement.2013.12.008

pair in some cases due to the complexity of field conditions, such as the following

(1) One of two cameras in the active stereo vision system is damaged, and cannot obtain the necessary image as pairs. In order to make the inspection system work normally, the entire vision sensor need be replaced, and the whole inspection system must be globally re-calibrated, resulting in a very long maintenance cycle.
(2) Due to the spatial limitation of the inspection station, the binocular stereo vision sensor cannot be installed in the accurate location or adjusted to the proper position. It makes the left and right cameras unavailable to acquire the ideal images simultaneously.
(3) Changes in the external environment, such as the different light reflection characteristics for the various measured surface, or changes in the external illumination condition have relatively large influence. In particular, the images of measurement feature are seriously impacted by the latter, and sometimes the measured feature is even flooded in the noise completely. So it cannot achieve the stable and reliable reconstruction data based on the mathematical model of the traditional binocular stereo vision.

Currently, for the active binocular stereo vision inspection system of the car body-in-white, solutions to the impact of external illumination are mainly as follows: ① According to the center wavelength of semiconductor laser, appropriate narrowband filter is mounted on the lens to eliminate the interference of background light to the greatest extent. ② If the inspection space and condition permit, the shading shed is generally installed around the inspection system. The two methods mentioned above are effective under certain conditions, but they cannot solve the problem completely due to the complexities of field conditions.

In order to solve the practical problems fundamentally, a reparability method of the vision sensor in active stereo visual inspection system is proposed. Xu et al. [7] used structured light stereovision for seam tracking to simplify laser calibration and improve the reliability of the visual system, and set up the hand-eye modal in real-time arc welding robot visual control system. In the paper, we establish a mathematical model of reparability in active stereo visual inspection system. On the basis of the mathematical model of the stereo vision, although we still utilize a laser projector and two industrial cameras to make up the measurement platform, the measurement mode of the stereo vision and the structured light vision are merged to inspect the feature points using the reparability measurement model. What's more, we develop a calibration method of structured light vision for reparability in the active stereo visual inspection. Zhou and Zhang [8] constructed features in the structured light plane based on the cross-ratio invariance, and implemented the calibration of the structured light vision sensor with planar target. Wu et al. [9] established the mathematical model of multi-line structured light vision sensor to measure the straightness and diameter of seamless steel pipe. In above researches, structured light plane equation is used to set up the mathematical model. Considering the image plane of the camera and the light plane are ideal plane, and those follow the homography mapping relationship, we establish a simple mathematical model of structured light vision sensor by homography between the image plane and the light stripe plane, which is more conceptually intuitionistic and will make calibration easier. The reparability approach greatly improves the stability and reliability of measurement data. It is proven by experiment that the method is valid and can implement the repair tasks successfully, and the system can achieve the uninterrupted measurement for feature points.

The paper is organized as follows. Section 2 describes the typical application for the active stereo visual inspection system of car body-in-white, and the reparability principle of the vision sensor. Section 3 introduces the reparability mathematical model, which includes the perspective projection model of the camera and the measurement model of the reparable vision sensor. Section 4 provides the experimental results. Real measurement data are used to validate the proposed method. Last, we give concluding remarks in Section 5.

2. Application and measurement principle of reparability

2.1. Application of reparability

Fig. 1 shows the typical application of the active binocular stereo visual inspection system, the car body-in-white visual inspection system. The inspection system is a typical Multi-Sensor Visual Inspection System (MSVIS), which mainly composed of a number of active binocular vision sensors, transport mechanism, positioning mechanism, electrical control device and the computer. The transport and positioning mechanism send the inspected car body to the predetermined position, and each active binocular vision sensor monitors an area of measurement feature. All the vision sensors are connected through the field

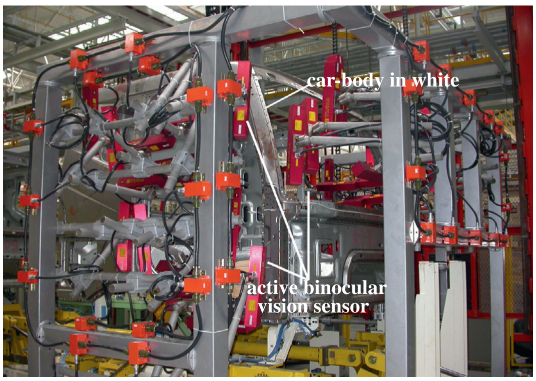

Fig. 1. Application of the car body-in-white visual inspecting station.