Optics and Lasers in Engineering 51 (2013) 148–158

Contents lists available at SciVerse ScienceDirect

Optics and Lasers in Engineering

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

An image acquisition method for raised characters based on laser vision technology

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ARTICLE INFO

Article history:
Received 5 April 2012
Received in revised form
31 July 2012
Accepted 25 August 2012
Available online 17 September 2012

Keywords:
Raised characters
Image acquisition
Laser vision technology

ABSTRACT

In this paper, based on laser three-dimensional (3D) vision technology, a fast gray-scale image acquisition method for no-color raised characters is presented. The image acquisition system is mainly composed of a CCD camera, a laser projector and a scanning galvanometer. The single-line laser stripe emitted by the laser projector is reflected to cross-sections of raised characters surface by the mirror rotated by a galvanometer. The CCD camera captures images of laser stripes distorted by heights of raised characters. Then, distortions of laser stripes are directly converted to gray values by the designed height-grayscale conversion function. The 3D vision model of the image acquisition system is established. System parameters are also determined. To get uniform image in the full field of view, distortions of laser stripes in various positions are analyzed and the distortion compensating method is proposed. To lessen the impact of surface reflection on image quality, and to extract the exact outline of the laser stripe, a laser stripe extracting method based on second-order gradient image is developed. Experiments on raised characters with different reflection properties and different structures show that the proposed method can get uniform and well-separated images of raised characters under various conditions. Experiments on image acquisition speed show that the time to scan a row of raised characters is 0.34 s.

1. Introduction

Recently, with the drastic expansion of digital cameras with reasonable prices, a particular domain of pattern recognition offers promising applications in industry, one of which is raised characters (also called embossed characters) in industrial areas. Since they are more changeless for spot and durable than color characters, they are more widely used.

Compared with color characters, raised characters have got obvious characteristics [1]:

Firstly, raised characters are higher than the background, and it is a reflectorized character on the difference of reflectance by vision.

Secondly, the image quality of raised character is far lower than that of color character, due to the foreground and background having the same color.

Thirdly, most of raised characters are manufactured on metallic materials which are reflective, and its surroundings contain strong noise.

These characteristics lead to a poor character image quality when capturing images by common camera-based method. So, as stated in Refs. [2,3], optical character recognition (OCR) methods based on color information are not effective for raised characters.

2. Related works

Literatures on detection or recognition of raised characters can be summarized as three categories: recognition of the Braille, recognition of raised character in credit card and recognition of raised character in industrial areas.

The task of Braille recognition is to translate Braille to English [4]. Most of research works [5–8] have similar strategies: First, the shadow image of protruding points is captured using the scanner or the camera; then, a variety of algorithms are designed to recognize Braille characters through the relative position between protruding points. However, the structures of the Braille are far simpler than those of raised characters because they are composed by many independent dots. Therefore, it has very little reference to raised character recognition although the Braille is a kind of protruding characters.

Another category is raised characters in credit card. Detailed research reports were mainly published many years ago. For example, Candace [9] studied the re- and post- processing algorithms for raised numbers of credit card. And the neural network is used for character classification. In his studies, the

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http://dx.doi.org/10.1016/j.optlaseng.2012.08.011

character image is captured by a common camera. To improve the image quality, a specialized lighting scheme is designed. However, the main limitation is that the method lacks versatility and is no longer effective for the background with serious reflection.

In recent years, many research works are done on raised characters recognition for industrial uses. Shah [10] designed an artificial neural network (ANN) to recognize the vehicle identification number (VIN), whose VIN image was captured by a CCD camera. Chatterjee [11] also studied the recognition of VIN numbers. To improve the image quality, the shadow Moiré method was introduced to capture the image of VIN. Young [12] developed an image processing method based on slope of arc and hough transform for raised characters on a tire. The image they used was also captured by a common camera. Bovisio [13] studied the recognition of raised characters on a nuclear container. The first step was to get the 3D model of the entire container using structured light, and then, characters were recognized using the 3D features. Taweepol [14] developed a similar method with Bovisio [13] to recognize embossed characters on a steel product surface. The two papers provide us with some reference because the 3D features of raised character are used. Unfortunately, in these two papers, raised characters together with the carrier surface were reconstructed, which resulted in mass computation and inefficiency. Follow-up studies focused on recognition or inspection of raised characters on industrial tags. Cao [1] adopted vector-sum and ring projection to inspect the image quality of raised characters on an industrial tag. LI [15] proposed a gabor feature extracting method for raised characters. Lu [16] developed a novel PCA method for the recognition of raised characters. The common feature of these studies is that images they used are all camera-based images and the recognition methods have no fundamental difference with traditional OCR methods.

To sum up, a great amount of studies on raised character recognition has been reported. However, most of them are color information based methods, which are exactly the same with the traditional OCR methods. As mentioned in Section 1, the image of raised characters captured by common camera-based methods is poor, in which the identification information is very much limited. Therefore, the recognition effect is not ideal even with many measures taken in subsequent image preprocessing, feature extraction and feature classification steps. Many researchers have introduced various methods to improve the image quality, such as, using a special light source, and rationally designing the optical path. However, these methods lack versatility and are not suitable for industrial applications. Therefore, more than studying further on image preprocessing and feature extraction, getting high-contrast character image is important for raised character recognition. As discussed in Section 1, the unique feature, which separates raised characters from background, is the character's height. Therefore, acquiring the 3D data of the characters and converting it into the image intensity is vital to getting high-quality character images.

Raised character is a typical small object. Related research works about inspection and 3D reconstruction of small objects are as follows. Quan [17] and Tsai [18] adopted similar methods to reconstruct raised characters in coins using sinusoidal structured-light. To enlarge small targets, long-focus microscopes were placed in both the projection path and the camera path. Complicated calibration and computation for 3D reconstruction are necessary in their methods. Since the sinusoidal structured-light is rather sensitive to the reflection of inspected surface, it is not suitable for raised characters in industrial areas. Chatterjee [11] developed a shadow moiré method to capture images of raised characters on a credit card. However, according to the principle of shadow moiré, light source and camera must be placed far away from each other, which would result in a large system. Another typical small object is the solder joint in PCB board. A large number of 3D inspection methods are used to inspect the quality of solder joints. X-ray digital tomosynthesis (DT) [19,20], scanning acoustic microscopy (SAM) [21,22], laser ultrasound [23], pulsed phase thermography (PPT) [24], phase-shifting projection moiré [25], and structured-light [26] all have been introduced to solder paste inspection. However, the morphology structure of solder paste is far simpler than that of raised characters. These methods cannot be directly applied to raised characters.

Therefore, unlike previous research works, this paper mainly aims at the high-quality image acquisition of raised characters. Height features of raised characters are fully considered. A fast method based on 3D vision technology is proposed to convert the height of characters into the intensity of image.

The remainder of the paper is organized as follows. Section 3 explains the 3D data acquisition system in detail. Section 4 presents the image processing and center extraction method. In Section 5, height-grayscale conversion method is discussed. Experiment results and analysis are presented in Section 6. Finally, conclusions are drawn in Section 7.

3. 3D data acquisition of raised character

3.1. System principle and configuration

Fig. 1 shows the image acquisition system. The single-line laser stripe generated by laser projector (Part.2) is firstly projected on the mirror (Part.5) rotated by galvanometer (Part.4). Then, it is reflected to cross-sections of raised characters (Part.8) with the rotation of the galvanometer. According to the laser triangulation principle, light stripes are distorted by the height of raised characters since they are higher than the top surface of character carrier (Part.9). Character images with distorted stripes at different cross-sections are captured by camera (Part.1). Fig. 1(b) is the schematic diagram which shows one of character images with distorted stripe. Fig. 1(c) shows the distorted stripe image separated from Fig. 1(b) using image processing algorithm. After centerline extracting of the laser stripe, distortions of centerline are directly converted into gray values of image using a skillfully designed height-grayscale conversion function. And the uniform grayscale image of raised characters whose gray values are proportional to the character height is got. Because all raised characters have different height with the character carrier, it is certain that the high-contrast and well-separated character image with the background can be obtained.

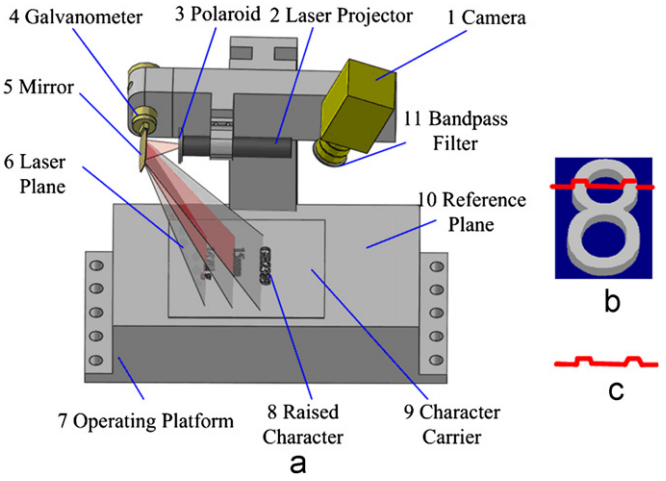

Fig. 1. Data acquisition system and configuration.