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The image adaptive method for solder paste 3D measurement system

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ABSTRACT

The extensive application of Surface Mount Technology (SMT) requires various measurement methods to evaluate the circuit board. The solder paste 3D measurement system utilizing laser light projecting on the printed circuit board (PCB) surface is one of the critical methods. The local oversaturation, arising from the non-consistent reflectivity of the PCB surface, will lead to inaccurate measurement. The paper reports a novel optical image adaptive method of remedying the local oversaturation for solder paste measurement. The liquid crystal on silicon (LCoS) and image sensor (CCD or CMOS) are combined as the high dynamic range image (HDRI) acquisition system. The significant characteristic of the new method is that the image after adjustment is captured by specially designed HDRI acquisition system programmed by the LCoS mask. The formation of the LCoS mask, depending on a HDRI combined with the image fusion algorithm, is based on separating the laser light from the local oversaturated region. Experimental results demonstrate that the method can significantly improve the accuracy for the solder paste 3D measurement system with local oversaturation.

1. Introduction

The development of the Surface Mount Technology requires more precise methods to evaluate the printed circuit board (PCB). The solder paste plays a critical role in the use of PCB. So it is necessary to do research on the solder paste measurement. The structured light vision technology has become one of the main methods due to its low cost and high accuracy. As the laser light projects on PCB surface, local oversaturation emerges from reflection non-consistent in the solder paste 3D measurement system. It affects the feature extraction and leads to inaccurate measurement. To remedy the local oversaturation, a novel image adaptive method for solder paste measurement is proposed in this paper.

At present, most image adaptive methods employ the high dynamic range image (HDRI) and then map the HDRI to the normal image. By HDRI, more details can be obtained than the original image, which can distinguish the local oversaturation. The HDRI is mainly obtained by two methods. To design some fusing algorithms using multiple images fusion technique is one of the methods [1–16]. The other is to improve the measurement system [17–21], such as using HDRI capturing system to widen the dynamic range of system.

The multiple images fusion technique is taking multiple images at varying exposure time or captured by multi-sensors and then fusing a single image by different fusion methods according to the camera curve. One early fused method was proposed by Chavez which extracted the spectral information using selective principle component analysis in the Landsat thematic mapper image data [1]. In [2], Wright proposed a relatively quick method to fuse edge from multi-images using Markov random field approach and iterative conditional modes (ICM). Vogler and Metaxas also used the Markov models to fuse information in sign language recognition [3]. These methods accomplish the feature-level image data fusion.

In 1993, Mann proposed an image compositing method [4], where HDRI was fused by a function. It achieves the pixel-level image fusion. Then many researchers have put forward fused methods about pixel-level image fusion. In the remote sensing field, it is necessary to fuse the multisensory image to the integration. In [5,6], the image is fused by the intensity modulation to improve spatial details of images. Li et al. [7] fused the Landsat thematic mapper images and SPOT panchromatic images using the wavelet frame transform. It could perform well in the situation where the source images cannot register perfectly. There are also many researchers paying attention to image fusion in other fields, such as intelligent robots, defect inspection and so on. In [8], a pixel-by-pixel Kalman filtering was used to fuse the image with different exposure, and the signal-to-noise ratio was improved as much as 9.4 db. The Neural net theory was used in the image fusion in the literatures [9–11]. In [9], the multi-focus images was fused by the neural net, and it performed well in the situation of the moving objects or misregistration of the source images. The

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resolution of the fuse image was enhanced in [10] which proposed two neural data fusion methods. Qin [11] proposed a self-generating neural networks method to fuse the multi-sensor images without knowing the network structures and parameters, and MSE of fused image was lower than such methods as pyramid and wavelet transform approaches. As to the pyramid transform, Liu et al. fused the images by the steerable pyramid for feature extract in [12]. As described in [16], regardless of pyramid transform and wavelet transform, the combining method is needed which is similar to the weight function fused. So the difference in these methods lies in the data before combination. In [7,9–12], the images are decomposed into other formation, and then fused into integration using the different weight functions. Finally, an image is generated by inversed transform according to the integration data. However, using these methods, the gray of the fused laser light image shows discontinuousness. In [13–15], the image was fused by the weight function in which the fused data represent the two-dimension gray value or irradiance information. In [13], it used the weight average method to fuse an image. In [14], the image gray is inversed to irradiance, then fused into one image by a new weight function, which had a less overlap than the traditional weight function. Using this weight function, the ghost artifacts were reduced. In [15], the weight function was not a certain function, it was estimated according to input images and the reference image chosen. It addressed the problems of both temporal consistency and spatial consistency.

The methods to widen the dynamic range of image fall into two categories with regards to the measurement system. One is to extend the sampling circuit of the CCD/CMOS sensor according to the image acquisition principle, such as [17]. The other is to change the light intensity under the CCD/CMOS sensor dynamic range [18–21]. In the [18], S.K. Nayar, V. Branzoi, T.E. Boult proposed using a digital micromirror array(DMA) to accomplish programmable imaging. Although DMA only can be controlled in two states, it introduces a notion of image programmable system. In [19,20], the HDR camera is designed by the LCoS using the notion in [18]. For application in the machine vision, a HDRI capture method using LCoS is introduced in [21].

However, the traditional image fusion methods call for strict registration of source images and the camera respond curve, and the fused images carry some ghost artifacts. The image captured by the traditional HDRI capture systems is an equalization image with details. In the solder paste 3D measurement system, the aim of the image adaptation is to get real laser light and remedy the local oversaturation. So a new image adaptive method is proposed in this paper which combines the HDRI acquisition system with the weight image fusion method. In this paper, HDRI is captured by the HDRI system which is controlled by the LCoS mask, and the LCoS mask is generated by the image fusion technology. Comparing to the traditional methods, the proposed method is less strict in registration of source images, and the fused image for mask computing have less ghost artifacts than other methods for its weight function without overlap. According to the mapping function of LCoS mask, the position of local oversaturation is modulated to the lowest gray possible, and the image local oversaturation is reduced.

In this paper, a novel image adaptive method to reduce the local oversaturation is proposed. The HDRI acquisition system, as described in Section 2, is built by the LCoS optical system and the CCD camera. A calibration procedure, as presented in Section 3, is needed to accomplish the image adaptation. The LCoS *Y–G* curve should be acquired to reconstruct HDRI, and the camera characteristic curve is calibrated to compute LCoS *Y–G* by the theory of Debevec Section 3.1. Then the LCoS *Y–G* curve is achieved in Section 3.2 based on the least square method through the statistical analysis. The LCoS pixel grid and CCD pixel grid mapping are also described in Section 3.3 to accomplish the image brightness adjustment pixel to pixel. According to the LCoS *Y–G* curve, the HDRI image could be reconstructed using the image captured, but the HDRI image shows much noise in the low gray. To avoid the noise, image fusion is mentioned in Section 4.1. The weight function in this paper is different from the traditional function as stated in Section 4.2. The LCoS mask generation method is also expressed in Section 4.3. Some experimental results in Section 5 confirm the validity of this method before a conclusion in Section 6.

2. Princple of the system

Reflective liquid crystal on silicon (LCoS) can change the reflectance of reflected light by rotating its liquid crystal, which is controlled by the voltage at each pixel. So, this paper comes up with a HDRI acquisition system using LCoS optical system in front of the camera. The system controls the reflectance of incident light into the camera sensor, it can adjust the image gray pixel to pixel. The proposed schematic diagram of HDRI acquisition system for the solder paste 3D measurement is shown in Fig. 1. The system consists of (1) LCoS optical system, (2) LCoS driven circuit, (3) a laser, and (4) a camera.

The system works in the following way: the reflected light of the measured object reaches the LCoS chip through the objective lens and the Polarizing Beam Splitter (PBS). The driving circuit controls the reflectance of every LCoS pixel depending on the computer given modulation signal-LCoS mask. Then, the adjusted light reaches the CCD camera sensor plane through the PBS and the relay lens. At last, the real image forms on the CCD sensor after adjustment.

The image brightness can be adjusted by a closed loop, constructed by the LCoS modulation control signal, LCoS optical system and the image captured by camera. As LCoS modulation control signal – the LCoS mask is generated by the original image, the local oversaturation will be remedied using a suitable method.

3. Calibration

The camera characteristic curve is the mapping from the exposure X to the gray value Z. The relation between the image gray and the real radiance is very complex in the image acquisition procedure, and hard to obtain. As shown in Fig. 1, the main device in the system is LCoS, a discrete device. The input of LCoS driven circuit is a 1024×768 image with the value of 0–255, and the output of LCoS chip is the light intensity after modulation. As the adaptive method is to be declared in Section 4, the system calibration is described by the following three aspects.

3.1. Calibration of the camera characteristic curve

As mentioned above, the relation between the image gray and the exposure is very complex, so the camera characteristic curve needs to be calibrated to calculate the *Y–G* curve of LCoS. The camera characteristic curve has the features of monotonicity, continuity and inherence.

The response from the gray $Z_{i,j}$ at (i,j) to the variations in exposure $X_{i,j}$ at (i,j) is called camera characteristic curve, and the exposure $X_{i,j}$ at (i,j) is the product of the irradiance $E_{i,j}$ at (i,j) and the exposure time t. The image reciprocity equation can be expressed as

$$Z_{i,j} = f(E_{i,j}t) \tag{1}$$