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Original research article

A three-dimensional inspection system for high temperature steel product surface sample height using stereo vision and blue encoded patterns

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ABSTRACT

Vision-based surface inspection system is extremely important research hotspot in the field of steel surface defect inspection. However, most of the vision-based surface inspection systems focus on the two-dimensional image processing, three-dimensional height information acquisition is still a major challenge, especially for high temperature steel product. To achieve the surface sample height information of high temperature steel product sample, a three dimensional inspection system for static object is designed in this paper. In this system, physical filter and digital filter methods are combined to obtain the images of steel product. The stereo rectification and column encoded patterns are employed to achieve the surface sample height information. Furthermore, the graphics processing unit (GPU) is used to improve the computation speed. Seven steel product surface samples are picked to verify the effectiveness of the proposed method. The actual experimental results of the proposed method are very close to the true height, that is, the smallest error is less than 1 mm and the average error is less than 2 mm.

1. Introduction

Because of the limitations of using the raw materials and technological process, the surface of the steel plate inevitably exist different types of defects. These defects not only affect the appearance of the product, but also reduce the properties of the product such as corrosion resistance, abrasion resistance and fatigue strength, which can cause huge economic losses to the enterprise. Therefore, many steel production enterprises cost a huge sum of money on the steel surface quality inspection for the purpose of improving the quality of products.

In recent years, the vision-based surface inspection system (SIS), as a kind of non-contact inspection method, has become a research hotspot in the field of surface defect inspection [1]. Moreover, a consortium of manufacturers organized an annual international surface inspection summit (ISIS) to carry out academic exchanges about the theoretical methods and practical technologies. A typical surface defect inspection system mainly includes two components: hardware configuration and software processing.

In the hardware configuration, a suitable layout of the light source and camera is very important to the whole performance of the surface defect inspection system. For different types of steel, there are different corresponding layout. Yun et al. [2] applied five annular combined cameras to detect the surface defects for steel wire rods. Zhao et al. [3] combined a line

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0030-4026/

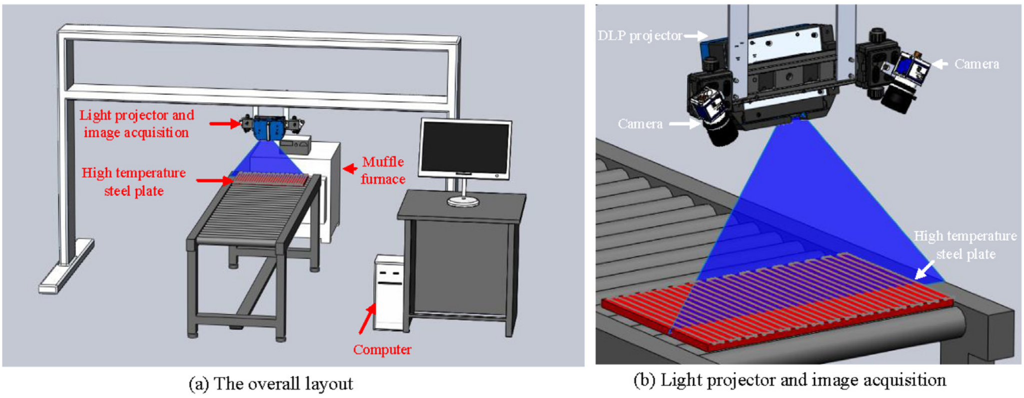

Fig. 1. Three-dimensional inspection system design.

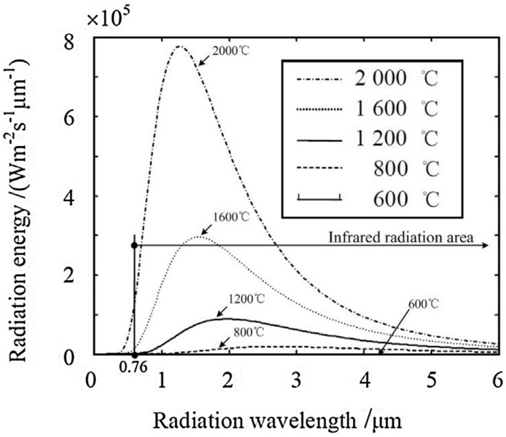

Fig. 2. Relationship between radiation wavelength and radiation energy according to different temperature.

array camera and an area array camera to suppress the respective limitations. Zhang et al. [4] integrated a light projector and a camera for 3D surface crack contour measurement. Kang et al. [5] developed multi-channel camera system using multispectral photometric stereo technique. Recently, Jeon et al. [6] used a dual-light switching-lighting (DLSL) method to decrease the effect of non-uniformity of surface brightness. In addition, Luo et al. [7] used the FPGA in parallel to improve the inspection speed.

In the software processing, the core algorithm includes defect detection and recognition. The detection algorithms are mainly for the purpose of locating the position of the defects, such as engineering-driven rule-based detection (ERD) [8], univariate dynamic encoding algorithm for searches (uDEAS) [9], morphology [10], local annular contrast [11], saliency map [12], lower envelope weber contrast [13], region [14], and Otsu [15]. In addition, some researchers focus on a single type of defect such as residual oxide scale [16], periodical defects [17,18], micro defects [19], crack defects [20,21], edges [22], and oil pollution interference [23].

Defect recognition mainly includes the defect feature extraction and feature classification. In the first component, the defect features are extracted by varied method such as gabor filters [24], wavelet filters [25], curvelet transform [26], shearlet transform [27], local binary pattern (LBP) [28,29], scattering convolution network (SCN) [30], multi-scale geometric analysis (MGA) [31], and variance of variance (VOV) [32]. Then the extracted features are classified by diversified classifiers, e.g., Bayesian network [33], support vector machine (SVM) [34], process knowledge based support vector machine (PKSVM) [35], enhanced twin support vector machine (TWSVM) [36,37], and hybrid chromosome genetic algorithm [38].

However, most of the algorithms focus on the two-dimensional image processing, three-dimensional height information acquisition is still a major challenge, especially for high temperature steel product. The height information is an important parameter in the quality of steel product. The error between the inspection height information and the theoretical height information can be used to judge the quality of the steel product. In the vision-based inspection technology, stereo vision system with structured light is often employed to obtain the surface height information. This system usually contains the stereo matching [39] and the encoded pattern technology [40,41]. Moreover, the encoded pattern technology is the key element. According to different coding strategy, the encoded pattern technology mainly includes four categories: random encoded patterns [42], binary encoded patterns [40], color encoded patterns [43], and phase-shifting encoded patterns [44].