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Significant effect of image contrast enhancement on weld defect detection

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Abstract

Weld defect inspection is an essential aspect of testing in industries field. From a human viewpoint, a manual inspection can make appropriate justification more difficult and lead to incorrect identification during weld defect detection. Weld defect inspection uses X-radiography testing, which is now mostly outdated. Recently, numerous researchers have utilized X-radiography digital images to inspect the defect. As a result, for error-free inspection, an autonomous weld detection and classification system are required. One of the most difficult issues in the field of image processing, particularly for enhancing image quality, is the issue of contrast variation and luminosity. Enhancement is carried out by adjusting the brightness of the dark or bright intensity to boost segmentation performance and image quality. To equalize contrast variation and luminosity, many different approaches have recently been put forth. In this research, a novel approach called Hybrid Statistical Enhancement (HSE), which is based on a direct strategy using statistical data, is proposed. The HSE method divided each pixel into three groups, the foreground, border, and problematic region, using the mean and standard deviation of a global and local neighborhood (luminosity and contrast). To illustrate the impact of the HSE method on the segmentation or detection stage, the datasets, specifically the weld defect image, were used. Bernsen and Otsu's methods are the two segmentation techniques utilized. The findings from the objective and visual elements demonstrated that the HSE approach might automatically improve segmentation output while effectively enhancing contrast variation and normalizing luminosity. In comparison to the Homomorphic Filter (HF) and Difference of Gaussian (DoG) approaches, the segmentation results for HSE images had the lowest result according to Misclassification Error (ME). After being applied to the HSE images during the segmentation stage, every quantitative result showed an increase. For example, accuracy increased from 64.171 to 84.964. In summary, the application of the HSE method has resulted in an effective and efficient outcome for background correction as well as improving the quality of images.

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Introduction

Many researchers agreed that pre-processing is an essential stage in regard to image analysis [1, 2]. Contrast variation and luminosity problems are commonly affected by occlusion, pose, and lighting, causing difficulties in the segmentation process [3–6]. Contrast and luminosity enhancement are important, where it cannot build a perfect mathematical model, in particular with respect to extreme illumination [7]. Usually, the researcher proposes various approaches to eliminate uneven illumination in an image. However, the proposed methods are unsuccessful if the images have both luminosity and contrast problems [7, 8]. Many enhancement methods were established in the past few decades for specific types of images and applications based on the literature. Still, there is no single method applicable to solve the contrast variation and luminosity simultaneously. This served as the driving force behind the current investigation. As per earlier studies, the key challenge is identifying a dividing line to distinguish between the bright and the dark area prior to using the contrast enhancement method. Secondly, the cut-off value is the primary issue when thinking about filtering methods (for instance, homomorphic filtering). The literature states that the researchers manually tested the cut-off and other factors to acquire them [9, 10]. For all varieties of non-uniform images, the parameter value is inefficient and inaccurate. To the greatest of the author's knowledge, several instances in the literature systematically detail the influence of contrast variation prior to the segmentation process, even though many review analyses focused on contrast enhancement [11–13]. In the segmentation process, the contrast and illumination effect are important since the non-uniform contrast images will reduce the effectiveness of the segmentation result. According to the study by [14], the image with uneven illumination and contrast variability significantly affect the vertebral bone segmentation process. This paper presented a comprehensive review of three contrast enhancement techniques, namely histogram equalisation (HE), gamma correction (GC), contrast limited adaptive histogram equalisation (CLAHE), as well as the effect on the segmentation performance. A research finding by [13] also points to non-uniform skin image's impact on the segmentation accuracy. Similarly, low contrast is important to be solved before applying the segmentation process. The enhancement methods were proposed to normalise the low contrast effect and automatically improve the image quality [15–17].

Literature review

Weld defect inspection from radiography films is essential for ensuring weld joint's serviceability and safety. Due to the human interpretation's limitations, the establishment of novel computer-aided algorithms with respect to automated detection coming from radiography images has become a focus of current research. Pre-processing, defect classification, and defect segmentation is three parts of automated defect inspection. First, the classic defect classification approach based on feature selection, extraction, as well as the classifier is presented in terms of its accomplishments and limits. The applications of innovative learning-based models (particularly deep learning) were then discussed [18].

In 2018, Kalaiselvi and John Aravindhar [19] developed a computer-aided detection (CAD) system depending on image processing techniques to identify weld defects. Here, X-ray images are used in non-destructive testing. Gradient image creation, filtration using the Gaussian pyramidal filters technique, and segmentation employing the Expectation and Maximization (EM) algorithm are the three phases of the suggested system. The suggested system's performance is evaluated by comparing the segmented image's sensitivity, specificity, as well as accuracy to its associated ground truth images. With the same goal in mind, Wang et al. [20] released a study outlining an integrative strategy based on magneto-optical imaging (MOI) that joints novel image capture, filtering, as well as enhancement algorithms for orthogonal