The Impact of Unfocused Vickers Indentation Images on the Segmentation Performance

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Abstract. Whereas common Vickers indentation segmentation algorithms are precise with high quality images, low quality images often cannot be segmented appropriately. We investigate an approach, where unfocused images are segmented. On the one hand, the segmentation accuracy of low quality images can be improved. On the other hand we aim in reducing the overall runtime of the hardness testing method. We introduce one approach based on single unfocused images and one gradual enhancement approach based on image series.

1 Introduction

In Vickers hardness testing, a pyramidal indenter causes a square indentation in a specimen. A major issue is to measure the diagonal lengths of the indentation. Therefore the square object must be segmented from the background to identify the vertices. Especially images of rough surfaces are likely to be highly noisy or have low contrast. The indentation images which should be segmented, approximately fit the following description: The object has a square geometry and is darker than the background. The diagonals are approximately aligned horizontally and vertically. Figure 1 shows example images and the manually determined vertice positions. Whereas the first image is quite perfect, the others suffer from noise and low contrast, respectively. There are several proposals for automated image segmentation of Vickers indentations. The methods proposed in [12] rely on template matching. Others are based on edge detection and Hough transform [3], wavelet analysis [45], thresholding [678] and axis projection [9].

In order to acquire focused images, the Vickers hardness testing facilities rely on autofocus systems. The autofocus system takes pictures, computes the focus metric and moves the camera for one step until the peak of the focus metric
(i.e. the focused image) is reached. We investigate if it is possible to compute approximative segmentation results from unfocused images. This could be advantageous, because an unfocused image is earlier available than the focused image as the autofocus takes a significant amount of time. Moreover, a failure of the autofocus might determine the wrong image to be in focus. Furthermore, we introduce a gradual enhancement approach, which is able to utilize free cpu cycles (caused when moving the camera) to incrementally improve the segmentation results.

This paper is structured in to following way: In Sect. 2 optical effects which occur with focused and unfocused images are explained. In Sect. 3 two different strategies are introduced which are based on unfocused images. In Sect. 4 the results are explained and compared with traditional approaches. Section 5 concludes this paper.

2 Focusing in Vickers Hardness Testing

A modern Vickers hardness testing equipment like the emcoTEST DuraScan hardness tester, used in the experiments, includes an inspection unit which is more or less a camera mounted on a microscope. Hardness indentations are analysed and measured with the inspection unit. The size of the indentations is in the millimetre or sub-millimetre range, so the magnification of the microscope is usually between 10x and 100x, and due to the non-transparency of the specimen, the illumination of the specimen takes place through the optics of the microscope.

In an indentation image a high contrast between the indentation and the surface of the specimen is desired. A high contrast facilitates the perception of the indentation when it is measured manually but also simplifies the segmentation when the image is processed automatically. Usually the indentation appears darker than the surrounding because of the groove that is caused by the pyramidal Vickers indenter.

In certain conditions (due to optical effects in high magnification optics) parts of the indentation do appear brighter than the surrounding or the contrast between the indentation and the surrounding is very small or vanishes completely. Such scenarios are challenging for automatic hardness measurement because algorithms often fail to detect the indentation and thus even do not provide approximate numbers for its position and size.

Figure 2a shows a schema of how an indentation image is taken. In a regular configuration the focus of the optical unit is aligned such that the edges and vertices of the indentation are best focused. This corresponds to a focus level that is roughly at the level of the specimen surface. Because the illumination passes through the optics it has the same focus plane. It can be seen from the figure that especially for high magnification optics (with 60x or 100x magnification) the illumination is considerably spread again when it reaches the bottom of the indentation. Due to the spread it includes a substantial amount of light rays that hit the walls of the indentation pyramid in such an angle that they are reflected back into the lens system. These rays act as an illumination for the