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EDGE DETECTION UNCERTAINTY IN FRINGE ANALYSIS

KATIC, M[arko]; MUDRONJA, V[edran] & SIMUNOVIC, V[edran]

Abstract: *Fringe image processing during gauge block measurement is usually performed with some sort of edge detection algorithm, used to find the centers of fringes. This paper addresses potential differences in measurement results that arise due to the use of different edge detection algorithms. Edge detection algorithms compared in this paper include simple image binarization, Prewitt and Sobel filters, Canny algorithm, and an algorithm developed at LFSB.*
Key words: *Fringe analysis, edge detection*

1. INTRODUCTION

Gauge block measurement using interferometry, regardless of the type of interferometer, relies on interpretation of fringes which are superimposed over gauge block image. Fringe separation on the bottom plate provides a metric which is then used to measure the offset of fringes on top of the gauge block relative to the fringes on the bottom plate (Figure 1) (ISO 3650:1998). This offset represents a fraction of light source wavelength which should be added to a previously calculated integer number of wavelengths that span the length of gauge block (Doiron & Beers, 2004).

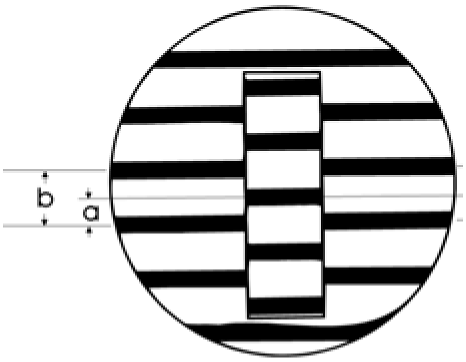

Fig. 1. Model of a fringe pattern

Interferograms are typically images with a lot of noise sources. For instance, camera sensor usually adds Gaussian noise to the image, but there is also random noise coming from dirty optical elements, poor beam spatial filtering, optical fibre imperfections, etc. Also, intensity of reflected light changes upon reflection from base plate and gauge block surface (Figure 2) (Hariharan, 2007).
All these factors make it relatively hard to create an all-purpose, fully automatic fringe analysis algorithm. A few commercial software packages that do exist require a lot of customization and fine tuning to be able to process images from a specific interferometry system. It is a common practice among National Measurement Institutes to develop their own interferogram analysis software packages.

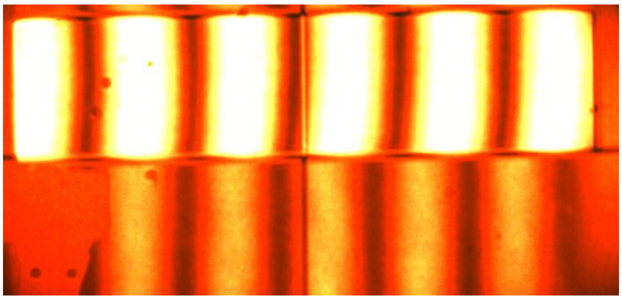

Fig. 2. Interferogram of a 50 mm gauge block

LFSB also decided to write its own software package for interferogram analysis. The software was written using Microsoft Visual Basic 6, and covers the entire measurement process- from environmental conditions sensors to image acquisition and processing. To be able to perform measurements as easily and accurately as possible, LFSB developed a custom adaptive edge detection algorithm that can process images with varying degrees of illumination and noise.

2. FRINGE PATTERN EDGE DETECTION

Edge detection algorithms can be divided into two distinct groups: search-based and zero-crossing based (Figure 3). Search-based filters, like Sobel or Prewitt filters usually use first order derivative expression (i.e. gradient magnitude) to detect local maximum which corresponds to an edge. Zero-crossing filters detect edges on zero-crossings of second order derivative expression, usually of the Laplacian. They include Laplacian of Gaussian and Canny filters (Webb & Jones, 2004).

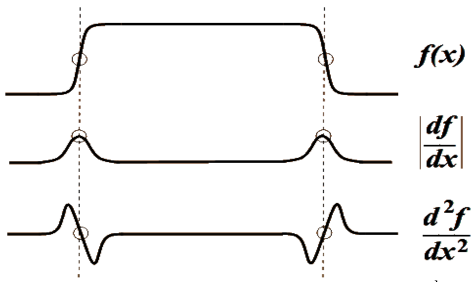

Fig. 3. Histogram of an ideal edge, and its 1st and 2nd derivatives

Each of these filters can be used to detect edges of fringe patterns, with adequate end results. Due to lack of standardization, such application of various filters yields slightly different results when applied on the same image, and this leads to inherent variability of results between different laboratories. It is the goal of this paper to show what these differences amount to in terms of change of length measurement.

3. DIFFERENCES BETWEEN EDGE DETECTION ALGORITHMS

In order to evaluate the performance of an edge detection algorithm, a typical gauge block interferogram was used (Figure 2). After edge detection was applied, interferogram was binarized with a fixed threshold for all edge detection algorithms. After that an edge localization algorithm was applied in order to detect pixels which belong to fringe edges, and afterwards centers of each fringe was calculated. The length of gauge block was calculated from that data using method of excess fractions.

A sample image which illustrates the process of edge detection is shown in Figure 4, and the results obtained by applying several algorithms on the same interferogram image are given in Table 1.

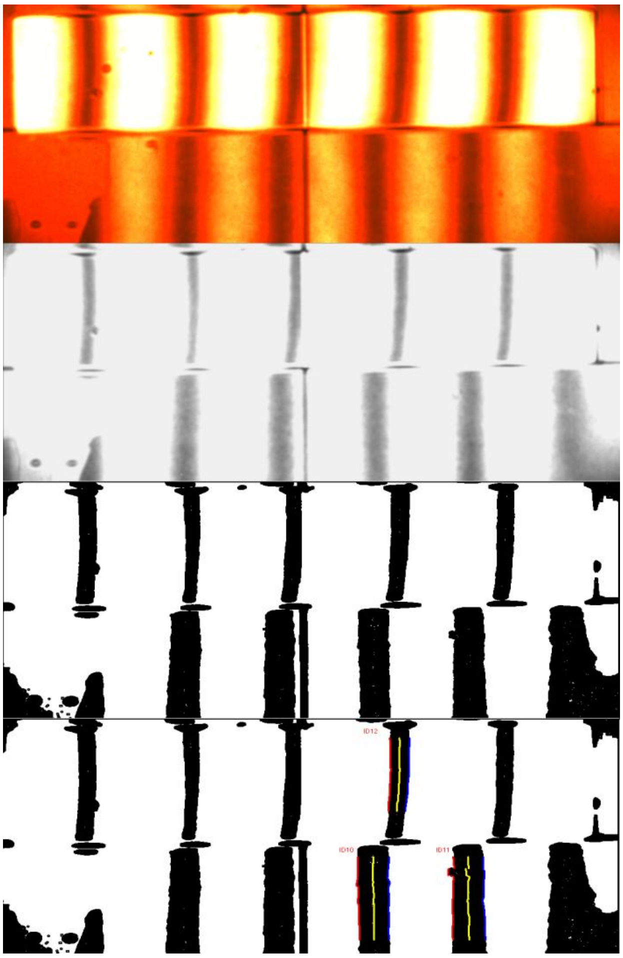

Fig. 4. Determination of fringe center position

The data from Table 1 shows that differences between different edge detection algorithms can amount to 3 nm for a 50 mm gauge block. This is a significant variation, which can lead to discrepancies when intercomparisons between different National Measurement Institutes (NMIs) are carried out.

Algorithm	Measured fraction	Deviation from central length (nm)
Canny	0,2710	286
Isotropic	0,2677	285
Prewitt	0,2620	283
Sobel	0,2678	285
LFSB	0,2669	285

Tab. 1 Comparison of various edge detection algorithms

4. SENSITIVITY OF EDGE DETECTION ALGORITHMS

To assess the sensitivity of an edge detection algorithm different threshold levels are applied to the same algorithm. Ideally, no change in fringe center should be made, and subsequently no change in deviation of length should be detected. However, it can be expected that small changes will occur. These changes contribute to the uncertainty budget of a measurement, since they introduce a variation in determination of fringe centers. Figure 5 shows the influence of threshold variation, and Table 2 gives the results of this variation when applied to Sobel and LFSB algorithms.

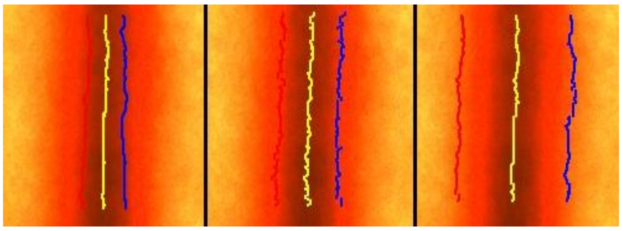

Fig. 5. Influence of threshold variation to edge position

Threshold value	Fraction		Length deviation (nm)	
	Sobel	LFSB	Sobel	LFSB
200	0,2611	0,2672	283	285
210	0,2646	0,2654	284	284
220	0,2654	0,2669	284	285
230	0,2655	0,2675	284	285
240	0,2667	0,2655	285	284
250	0,2678	0,2662	285	284

Tab. 2. Influence of threshold variation

It can be seen from data in Table 2 that 2-3 nm of variation in determination of fringe centers can be expected due to threshold variation. These influences would amount to ~6 nm difference in reported length even if every other influence would be fixed. It can also be seen that LFSB algorithm minimizes this variation to just 1 nm.

5. CONCLUSION

Influence of edge detection of typical fringe patterns obtained in gauge block metrology was investigated. It was shown that differences between various edge detection algorithms can introduce significant variation in measured length deviation. Furthermore, threshold variation which is necessary to localize edges can introduce additional variation of 2-3 nm. The existence of this variation makes comparison of interferometric measurements (interferograms) between different laboratories difficult, so and it was shown that it can be successfully reduced, using a custom edge detection algorithm, to a 1 nm variation.

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