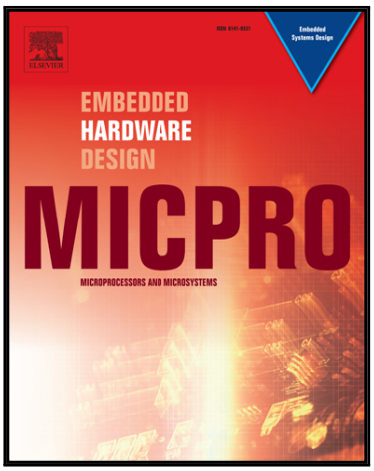

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Miroslav Hagara , Radovan Stojanović , Peter Kubinec , Oldřich Ondráček

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Localization of moving edge with sub-pixel accuracy in 1-D images and its FPGA implementation.

Miroslav Hagara[1*], **Radovan Stojanović**[2], **Peter Kubinec**[1], **Oldřich Ondráček**[1]
[1]Institute of Electronics and Photonics, Slovak University of Technology, Bratislava, Slovakia
[2]Faculty of Electrical Engineering, University of Montenegro, Podgorica, Montenegro

*corresponding author (email: miroslav.hagara@stuba.sk)

ABSTRACT: Contour detection is an algorithm often utilized in picture processing. Sometimes it is useful to localize edges with sub-pixel accuracy. Many methods have been developed for edge detection with sub-pixel accuracy. The question is, how the accuracies of these methods change if the scanned object is moving during the exposure time. In this paper, the impact of object movement on edge detection accuracy is examined. To simulate the moving edge, the accumulative function is defined and then used in three edge detection algorithms with sub-pixel accuracy in 1-D images: algorithm based on approximation of image function with function erf (AEF), method based on statistical moments (GLM) and technique using spatial moments of the 1-D image (SM). Results of simulations with noisy images are presented, the upper and lower 5% quantiles are chosen as accuracy criterion. Gray level moment edge detector (GLM) is used for FPGA implementation, because of its accuracy and simplicity.

Keywords: edge detection, sub-pixel accuracy, moving edge, image processing, FPGA

1. INTRODUCTION

In the many machine vision tasks, such as object recognition or measuring of object dimensions, it is needful to find the contours of the inspected objects. This can be done using an appropriate method for edge detection. A large number of edge detection algorithms have been published in the last two-three decades, Canny edge detector [1] is probably the best known and most widely used. Edge localization accuracy of these methods is at the pixel level. In some applications, such as the contactless measurement of the object dimension [2,3], calibration of the stereoscopic system [4], or the special tasks [5,6], it is desirable to localize edge with higher accuracy (at the sub-pixel level).

Most methods for edge detection with sub-pixel accuracy have been developed for 2-D images [7-11], some methods have been derived for 1-D images and then they have been extended to 2-D pictures [12,13] and a few precise edge detectors have been developed just for 1-D images [14-16]. The algorithms for 1-D images are intended primarily for camera with line sensor but can also be used also in 2-D images, line by line.

In our previous work [16-18] we have dealt with sub-pixel edge detection of static objects. It is clear, that when a subject moves during the capturing time, it will affect the accuracy of edge localization. In this paper, the moving edge is simulated by the accumulative function, which represents the shift of edge by m pixels during capturing time. To test an affect of edge movement on edge localization with sub-pixel accuracy, three best methods for 1-D images are used: algorithm based on approximation of image function with function erf (AEF) [16], gray level moment (GLM) contour detector [12] and method based on spatial moment (SM) [13].

There are many articles about FPGA implementation of edge detection with pixel accuracy [20-24] and two papers about sub-pixel edge detector implemented in FPGA [15,25], but first method [15] is not very precise and second detector [25] actually provides edge detection with pixel accuracy. So we decided to perform FPGA implementation of chosen sub-pixel edge detector for 1-D image. The method based on gray level moments (GLM) was the logical choice because of its accuracy and simplicity.

The rest of the paper is organized as follows. Description of used methods for sub-pixel edge detection in 1-D images is in Section 2. In Section 3, the accumulative function is defined. In Section 4, the simulations are done to show how the movement of the scanned object affects the accuracy of edge localization. FPGA implementation is described in Section 5 and conclusions are in Section 6.

2. SUB-PIXEL STATIC EDGE DETECTION

Tabatabai and Mitchel proposed edge detector (GLM) for 1-D images [12] based on the first three grey level moment m_1, m_2, m_3 of the input data sequence:

$$m_i = \frac{1}{n}\sum_{j=1}^{n} x_i^j \quad .... \; i = 1,2,3 \tag{1}$$

where x_1, x_2, ... x_n are image samples. If they are the samples of ideal step edge and p_h is a number of pixels with gray level h (elements on the left side of the edge), the densities p_1 and p_2 can be calculated as:

$$p_1 = \frac{p_h}{n}, \quad p_2 = \frac{n-p_h}{n} = 1 - p_1. \tag{2}$$