Studying Hueckel Edge Detector Using Binary Step Edge Image

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Abstract

Hueckel edge detector study using binary step edge image is presented. The standard algorithm that Hueckel presented, in his paper without any alteration is adopted. This paper studies a fully analysis for the algorithm efficiency, time consuming and the expected results with slide window size and edge direction. An analysis for its behavior with the changing of the slide window size (disk size) is presented. The best result is acquired when the window size equals to four pixel.

Keywords: Image processing, edge detection, edge fitting, Hueckel edge detection operator.

Introduction

Edge finding is one of the fundamental processes that performs as a pre- or post-process in image processing field. There are two main approaches in finding image's edges, either using gradientedge detection operators like; Sobel, Prewitt, Robert, etc., or using edge fitting to an ideal edge such as Hueckel algorithm, which needed more computation than gradient edge detection methods. The gradient edge detectors had bad reputation to their sensitivity to the image noise, where their performance is effected dramatically in its presence, for those other approaches are looked for to override this malformation [1&2].

Hueckel edge detection algorithm presented as alternative for the gradient edge detectors and to be an edge detector that can detect the edge even with the presence of noise. Its full derivation did not revile by Hueckel but the full algorithm is present in his published papers in 1971 and 1973 [3&4].

The basic principle of Hueckel algorithm is based on opening a slide disk into the image to detect the edge by fitting the image signal to an ideal step edge model, it uses eight bases into Hilbert space to decide whether the image signal is an edge or not by comparing the angular difference between the ideal edge models and the image signal. When the angular difference is(0˚) (i.e. the image signal and the edge model fit) the edge goodness parameter will be (1), on contrary if they are completely mismatched the angular difference will be (90˚) and the edge goodness parameter will be (0).Hueckel derived his algorithm into the contentious signal space to be the optimal edge detector under certain assumptions, but further analysis shows some deficiencies in its optimization process when it is applied into the digital approximation [5]. The inadequacy for analysis for Hueckel algorithm is what drives us to present this paper to find its advantage and disadvantage into the same constrained, as described by Hueckel. This paper is the first applicative work for Hueckel edge detection algorithm that is applied on a full image not on a single edge [6].

Research Procedure

A simple binary step edge image is adopted in this research. The sample image which is used for this algorithm is a tractor image as represented in fig. (1a).The ideal edge of this image had been calculated using a logical approach by comparing the pixel value with its neighbors fig. (1b). The disk radius had been calculated with the same Haeckel's restriction about the area of the slide window outsidethe disk is equal to the void area inside the disk in order to nullify the rounding error of the periphery of the disk, where had been calculated empirically which was (disk radius = 0.533).

Some statistical measurements (maximum, mean, median and the standard deviation) for the goodness criterion, with the execution time and total number of the resultant edge points by applying Hueckel algorithm on the sample image using different window size are calculated in table (1) and fig. (2).The edge goodness criterion considered in this research to be 0.9 as threshold value to find the edge points, as adopted by Hueckel.

A three-dimension representation for the goodness criterion and the edge direction are present in order to give fully understand how Hueckelalgorithm behaves with the changing of the size of the slide window, fig.(3). In this research, the angular difference considered to be a single degree, therefore, the Hueckel algorithm look for the edge points into 360 directions.

Results and Discussion

This research preformed using MATLAB version R2015a on a 64-bitPlatformwith i5 processor series, and 8GB RAM.

The Hueckel algorithm needs at least two-pixel slide window (disk radius = 0.533) in order to detect the edge points, where for one-pixel slide window size no edge points where detected; the best result acquired when the slide window size was four-pixel comparing with the ideal edge image where the perfect number of edge points is 4357 pixels, other than this window size found edge points are either less or greater than it, as noticed in table (1).

An interesting result that the resultant edge points increase with the slide window size until it becomes an exaggerate edge shape beyond the four-pixel slide window size, as the (6 to 13) slide window size in fig. (3), where the resultant edge points increase nonlinearity with the slide window size (disk radius), when they reach to edge saturation points, fig. (2a).

The mismatch between the mean and the median of the edge goodness for the resultant edge image, in fact, it emphases on the reality that the goodness criterion distributed vastly differ in values for resultant image, where some of the image points have edge goodness equal to one which represent the edge points and other pixels have edge goodness equal to zero which represent the foreground or background points, fig. (3).

One of the weak point in the Hueckel algorithm is that it consumes a lot of computation with the slide window size(fig. 3) The computation time increases exponentially with window size, therefore, if there is no need for big slide window, slide window equals to four gives a satisfactory result with reasonable computation time.

In order to nullify the rounding error of the periphery of the disk, the Hueckel condition about the area of the slide window outside the disk is equal to the void area inside the disk, which is maintained, the following equation is calculated:

$$\text{Disk Radius} = 0.53305 \times \text{Slide Window Size} \ldots\ldots(1)$$

Conclusion

In this research, the Hueckel edge detection algorithm had been studied on simple binary step edge image.The results show that, this algorithm is capable of finding edges and its direction with a lot of computation time which increases exponentially with the slide window size, beside that not only the computation time increases but the number of the founded edge point also increases nonlinearity with the slide window size until the edge becomes very wide with one angular difference for edge direction. To avoid the rounding error of the periphery of the disk eq.(1) has been adopted.

The best result acquired at window size equals to four as shown in fig. (3), where the number of the detected edge points are closer to the ideal number of the number of the edge points.

The resultant edges from Hueckel edge detection algorithm are connected and strong (binary), which make the exaggerate edge shape not relevant mater; since, the Skeleton transformation can eliminate the extra edge points.

References

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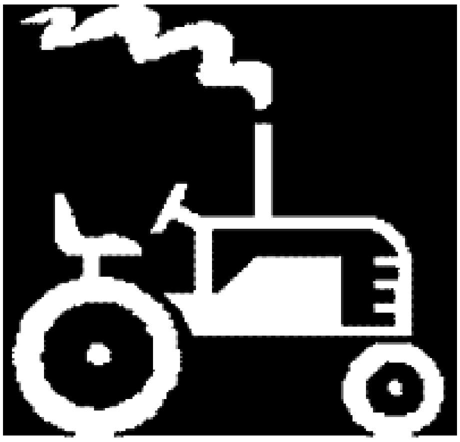
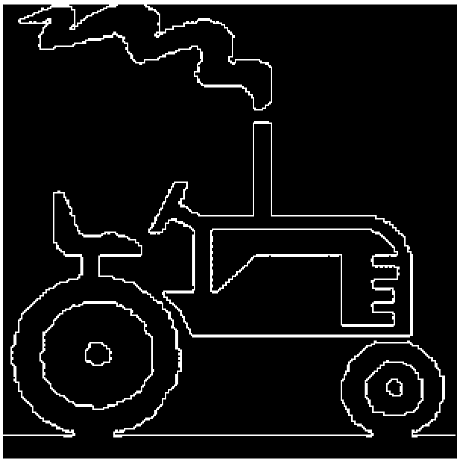
Table (1) The statistical analysis for Hueckel algorithm

Slide Window Size	Disk Radius	Goodness analysis					Execution Time	Edge Points T ≥ 0.9
		max	min	mean	median	std		
1	0.5331	0	0	0	0	0	11.1041	0
2	1.0661	0.9637	0	0.0384	0	0.1782	15.2353	1205
3	1.5992	0.9975	0	0.0684	0	0.2372	21.8365	3833
4	2.1322	1	0	0.2076	0	0.3293	30.875	10508
5	2.6653	0.9992	0	0.2228	0	0.3479	39.6067	12409
6	3.1984	1	0	0.2564	0	0.3771	51.6716	15650
7	3.7314	1	0	0.2113	0	0.4025	66.5469	18361
8	4.2645	1	0	0.2985	0	0.4094	79.3112	20639
9	4.7976	1	0	0.2685	0	0.439	97.3083	23652
10	5.3306	1	0	0.3503	0	0.4428	118.2741	26608
11	5.8637	1	0	0.3719	0	0.4526	137.4827	28632
12	6.3967	1	0	0.3858	0	0.457	158.296	29731
13	6.9298	1	0	0.4002	0	0.4634	184.2037	31363

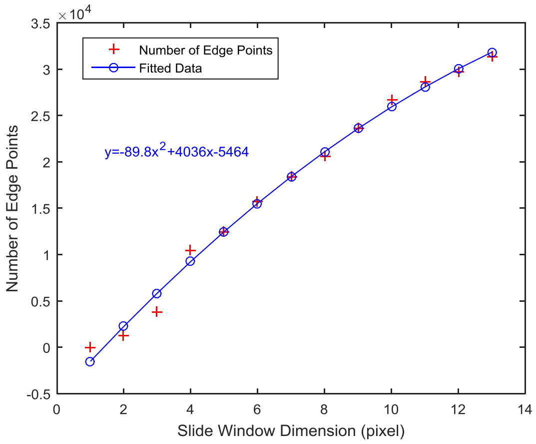


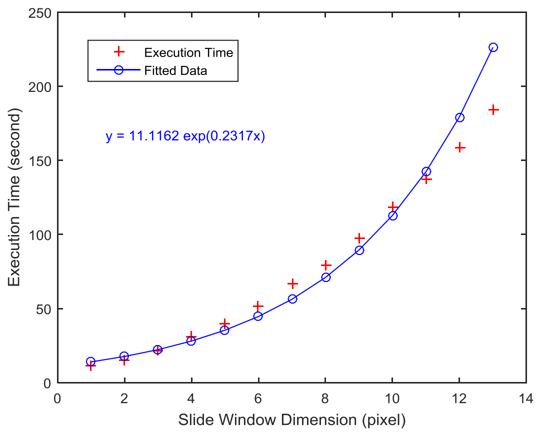
(a)



(b)

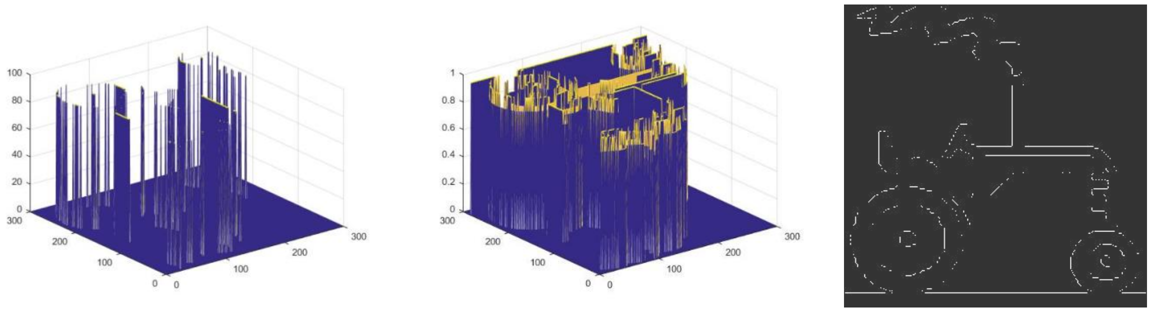
Figure (1) (a) Original sample image, (b) it's ideal edge



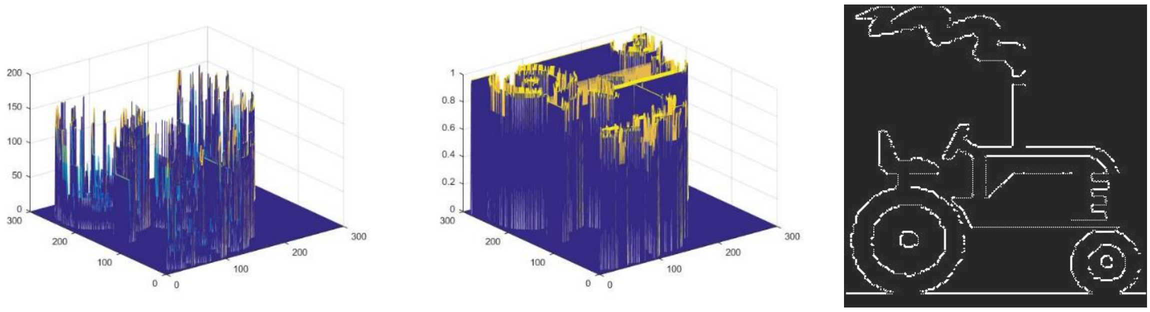


(a) **(b)**

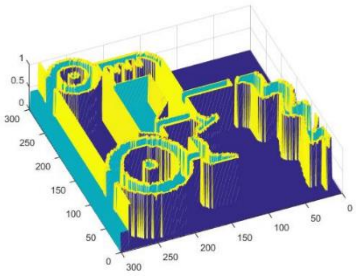
Figure (2) Hueckel algorithm performance with different slide window sizes for: (a) the number of founded edges, (b) the required computation time.



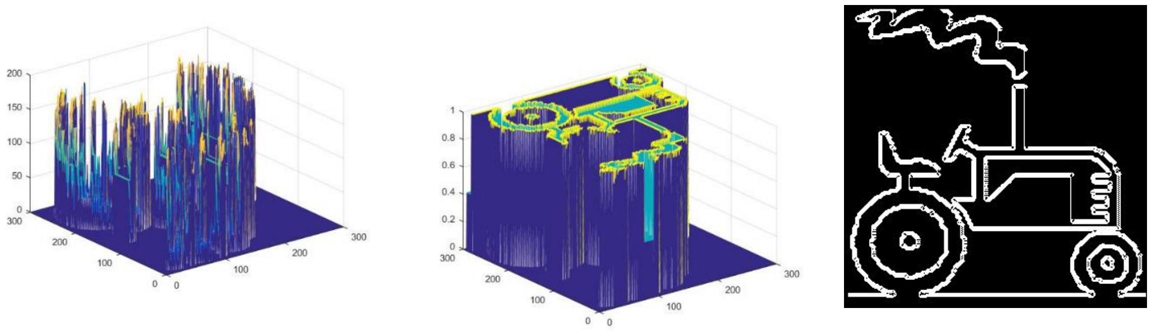
2x2 Slide Window



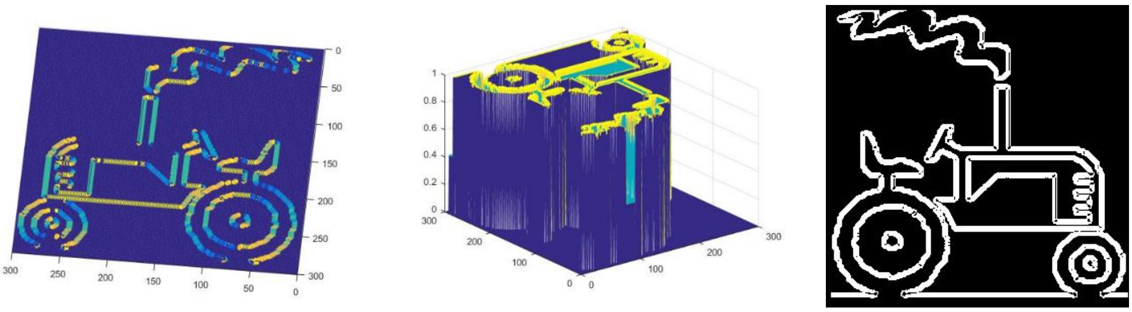
3x3 Slide Window



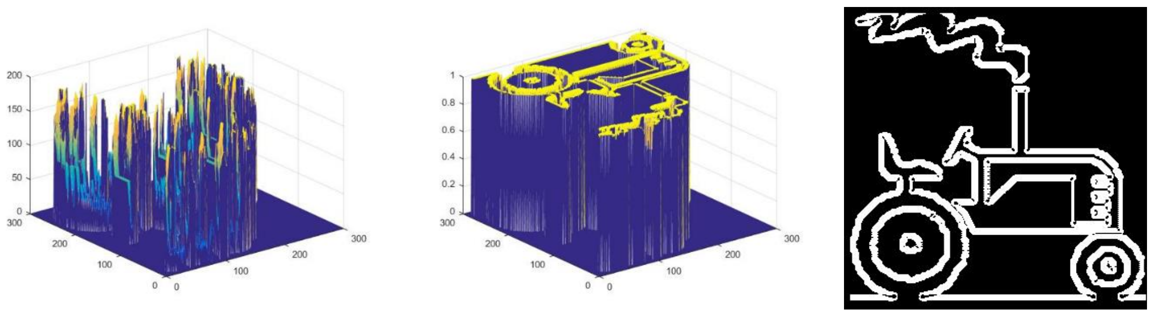
4x4 Slide Window



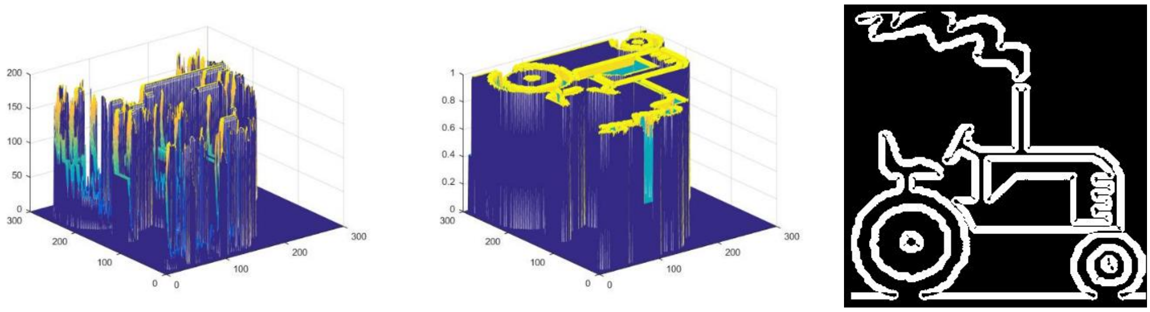
5x5 Slide Window



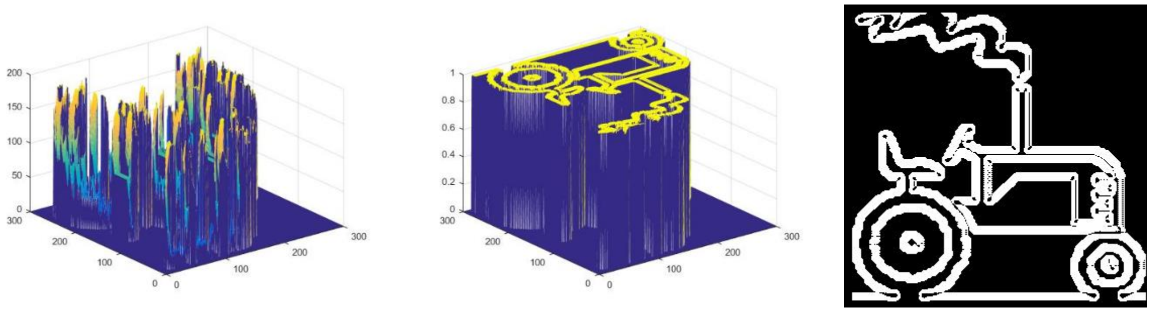
6x6 Slide Window



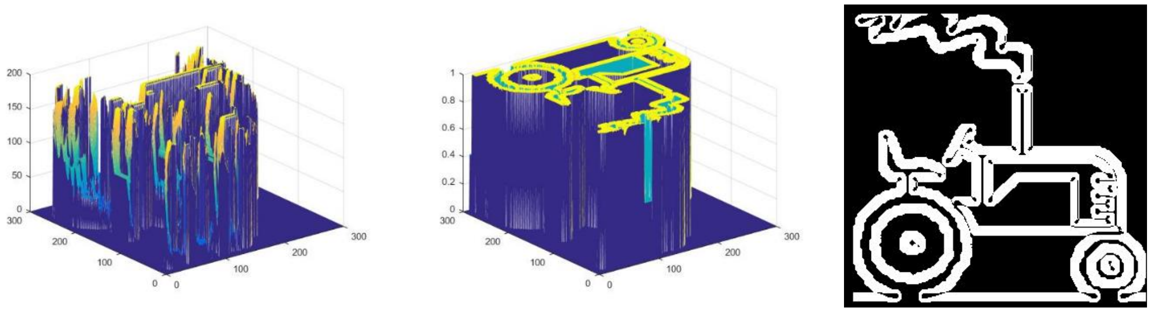
7x7 Slide Window



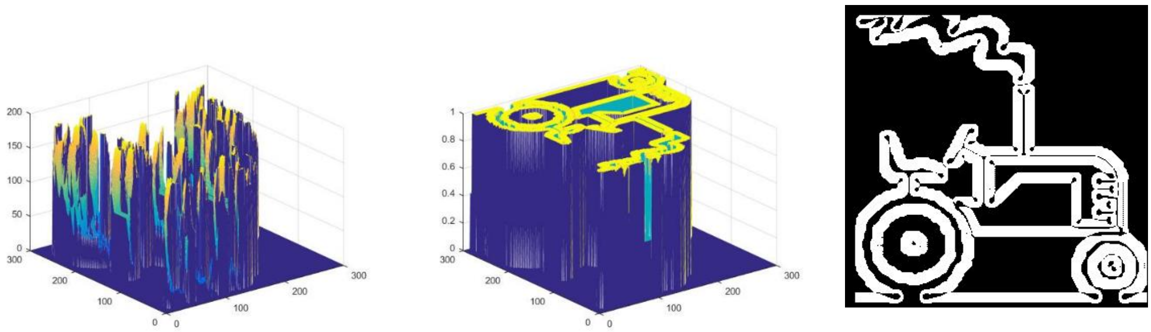
8x8 Slide Window



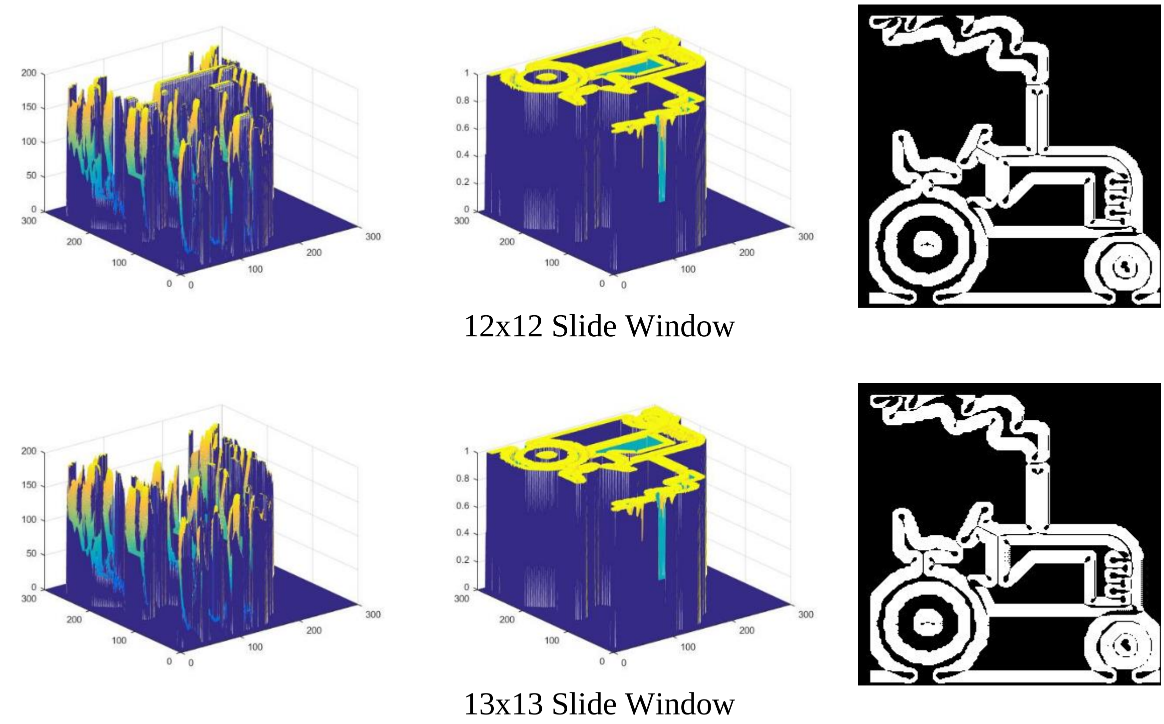
9x9 Slide Window



10x10 Slide Window



11x11 Slide Window



(a) **(b)** **(c)**

Figure (3) The results of different slide window sizes (a) edge direction, (b) edge goodness criterion, (c) final product.

دراسة كاشف الحافة هيوكل باستعمال صورة حافة ثنائية الخطوة

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الخلاصة

تم في هذا البحث تقديم دراسة كاشف الحافة هيوكل باستعمال صورة حافة ثنائية الخطوة. واعتمدت الخوارزمية القياسية التي قدمها هيوكل في أبحاثة دون أي تغيير.درس هذا البحث تحليلا كاملا لكفاءة الخوارزمية، الوقت المستغرق والنتائج المتوقعة مع حجم النافذة المنزلقة واتجاه الحافة. وقدم تحليلا لسلوكها بتغييرحجم النافذة المنزلقة (حجم القرص). كانت أفضل نتيجة تم الحصول عليها عند حجم النافذة أربعة بكسل.

الكلمات المفتاحية: معالجة الصور الرقمية، كشف الحافة، الحافة المناسبة، مؤثركشفِ حافةِ هيوكل.