CONTOUR EXTRACTION AND NOISE REDUCTION ON IMAGES OF NON-ISOTHERMAL JETS

***Adil RACHEK, **Colette PADET**

**Department of Industrial Processes Engineering,*
Ecole Nationale Supérieure des Mines de Rabat
Rabat, Morocco
**Groupe *de Recherche en Sciences Pour l'Ingénieur/ Thermomécanique*
UFR Sciences Exactes et Naturelles
Reims, France

ABSTRACT

In this paper, we propose a contour extraction method where an index of non-linearity is introduced to select the best window size for the analysis. The method is based on one dimension set of data; so, we apply the treatment in four directions: the horizontal one, the vertical one and the two diagonals directions. The intersections of these new set of data with the original image can give the objects contours. But some noisy points can appear in the resulting image; so, there is a necessity to eliminate these points. In order to resolve this problem, an improvement of the previous method is proposed. The resulting image is swept line by line and the neighbor of every pixel is explored to detect the number of surrounding points and their locations to decide if this point can be a part of an object contour or not. In the case of an isolated point, it is considered as an noisy one and must be eliminated. The method is applied to a real photo image of non-isothermal jets, obtained by laser tomography. The good results obtained by this method confirm its effectiveness to eliminate a lot of noisy points and to give a better drawing of the contour. Moreover, we compare our results with many other existing methods, such as the Sobel, Laplacian and Canny detectors. Here again, an improvement of the extraction and the quality of the contours is observed.

Keywords: *contour extraction; noise reduction; image processing; visualization; non-isothermal jet;*

INTRODUCTION

The contours detection is a major problem in image processing especially when the contour isn't clear in foggy images or in those ones obtained from experimental setup. Their detection is needed because they give some interesting information about some physical phenomena, or even they are indispensable for the image segmentation and saving. The contours in an image usually refer to rapid change in some physical properties, such as geometry, illumination, and reflectivity. Mathematically, a discontinuity may be involved in the function representing such physical properties. In the case of digital image, the concept of discontinuity does not apply and a contour may refer to systematic and rapid variation of grey-level values over number of scales. Several methods have been proposed for contour detection, we can classify them in three categories: the differential methods, the methods by optimization based on the modeling of contours and noises and finally the statistical methods.

In the first category, the first-order differential operators [1-4] such as the Robert, Sobel and Prewitt ones are convolved with images to enhance spatial intensity changes, then a threshold is applied to obtain contour points. But the second-order differential operator [5-7], such as the Laplacian one, indicates contour points by its zero-crossing property. In practice, to make contours explicit through differentiation, one looks for extrema of the gradient or zeros of the Laplacian. These operators bring out the contour by detecting sudden variations of grayness.
In the second category, contours detection in noisy environment can be treated as an optimal linear design problem. Canny [8] has constructed a qualitative approach of the contour detection and has determined a criteria that a good operator of contour detection must respect : a good detection (the contour must be detected, it is necessary to minimize the false responses), a good localization (the contour must be localized with precision, it is about minimizing the distance between the detected points and the true contour) and uniqueness of the response (it is about minimizing the number of responses for only one contour). Moreover, he defined an optimal filter to be used in the optimization problem, which can be efficiently approximated by the first derivative of a Gaussian function in the one-dimensional case. But in the same time as Canny works, Shen and Castan [9,10] used, as an optimal filter, the first derivative of Poisson function instead of the Gaussian one.

The last category [11-13] is based on the statistical comparison of two populations: the first one represents the points "contour" while the second one represents the points "non contour". The main inconvenience of this technique is that it is necessary to know the evolution of the grey level in the two regions close the contour to detect. Therefore, it can be applied in those cases where the different contours are known. However, in the general case the contours in an image are often difficult to detect by eyes.

The use of these methods needs the definition of some parameters like the choice of levels or scales to separate the contour from the noise in order to obtain a better extraction of the contour. This can be well done when we have a good perception of the contour.

These remarks lead us to search for a new method based on an objective manner to detect the contour in an image without the need to use some subjective parameters. In the first part of this paper, we propose a self adapting method for the contour extraction. Its principal advantage over the previous cited methods is the reduction of the user arbitrary choice needed to achieve the task. But one of its inconvenient is the apparition of some noisy points which must be eliminated to ameliorate the contour extraction.

In order to resolve this problem, in the second part of this paper we present some amelioration to the previous method. The obtained contour image is swept line by line and the neighbor of every pixel is explored to detect the number of the surrounding pixels and their location to decide if theses points may be considered as a part of contour or not.

CONTOUR EXTRACTION METHOD

A. *Description*

The base idea of the method is to apply a one dimensional filter on every set of pixels values $I(i)$ located in every row, column and diagonal in an digitized image to obtain a filtered value of the pixel $\overline{I(i)}$ according to follow :

$$\overline{I(i)} = \sum_{n=-N/2}^{N/2} I(i+n)h_N(n)a(n) \qquad (1)$$

where : $h_{K_N}(n)$ is the impulse response of the filter and *a(n)* is the Hamming window of size *N*, these terms are given by :

$$h_N(n) = \begin{cases} 2/N & n=0 \\ sin(2n\pi/N)/n\pi & n \neq 0 \end{cases} \quad and \quad a(n) = \begin{cases} 0.54 + 0.46\cos(2n\pi/N) & |n| \leq N/2 \\ 0 & |n| > N/2 \end{cases}$$

The use of a filtered will modify the image aspect and moreover some information will be lost. The amount of the lost information depends directly on the window size. The choice of the low-pass filter results from the aim to eliminate some details, from this point of view, the best choice of the window size needs an objective criteria without an arbitrary choice of the user. This criteria can be given by the mean of the index of non-linearity (INL) defined by :

$$INL = \frac{N-1}{(N-1)^{1/2}} \frac{\left(\sum_{i=1}^{N-1}\left(\overline{I_{i+1}} - \overline{I_i} - \overline{I_{N-1}} + \overline{I_1}\right)^2\right)^{1/2}}{\sum_{i=1}^{N-1}\left|\overline{I_{i+1}} - \overline{I_i}\right|} \sum_{i=1}^{N-1}\left(1 + \left(\frac{\overline{I_{i+1}} - \overline{I_i}}{I_{max} - I_{min}}\right)\right)^{1/2} \qquad (2)$$

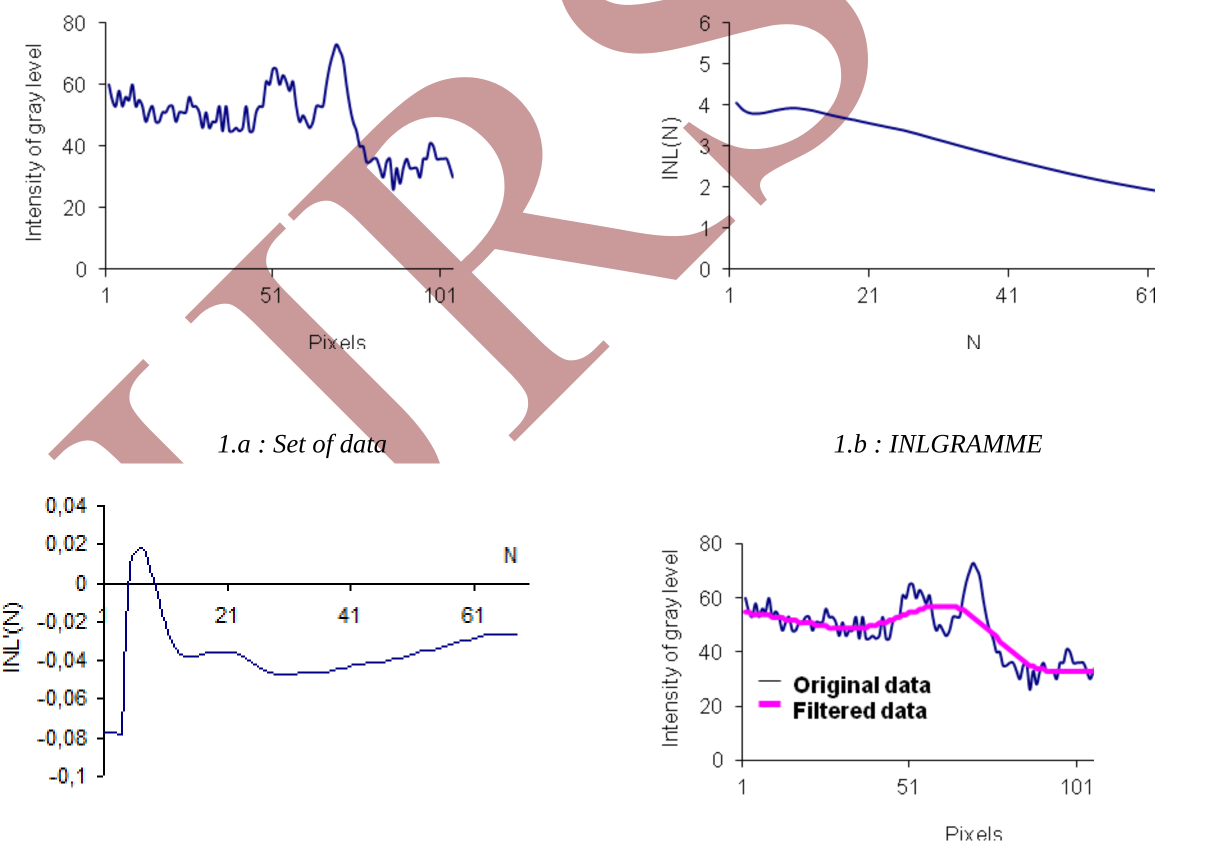
For every window size *N* used in the filter a filtered image $\overline{I_N}$ will be obtained and an associated index of non-linearity can be calculated. So, in this manner we can obtain the INL as a function of the window size.

Generally, the INL will decrease with increasing values of the window size. So, the graph of the INL (INLgramme) is a decreasing one. But an examination of the INLgramme shows that according to the case, the curve slop can decrease, presents some top or bottom or some constant values. The corresponding values of the windows size *N* can be determined by the mean of the first derivative of the INLgramme. These values give us the criteria to choose the best window size.

When the optimal filter window size is determined by the mean of the INL for every set of one-dimensional data, the filtered data will be calculated. As the image have two dimensions, the use of one-dimensional process will lead to some losses of information in the other directions. In order to keep all the information within an image we used the filter in four directions: horizontal, vertical and two diagonals. In this manner, we obtain four filtered images corresponding to the four sweep directions, then we search the intersection between the original image and each of the filtered one. The contours will be obtained by superimposition of the resulting intersection images.

Mathematically, an image I(k,l) can be viewed as a surface in the space domain, where the pixel intensity is a function of the spatial coordinates (k,l). The original image as well as the filtered ones represent different surfaces, the projection of the intersection between the original image surface and the filtered one give the searched contours. We call these intersections as passing through zero of the difference between the original image and filtered one. In the projected surface we can assign a labeling of contours by giving a 0 value for the contour points and 255 value otherwise. The mathematical condition to find the intersection between two set of data for a specified row k is :

$$\left[I(k,l-1)-\overline{I(k,l-1)}\right]\times\left[I(k,l+1)-\overline{I(k,l+1)}\right]<0 \qquad (3)$$



1.a : Set of data *1.b : INLGRAMME*

1.c : First derivative of the INLGRAMME *1.d : Intersection of the original and filtered data*

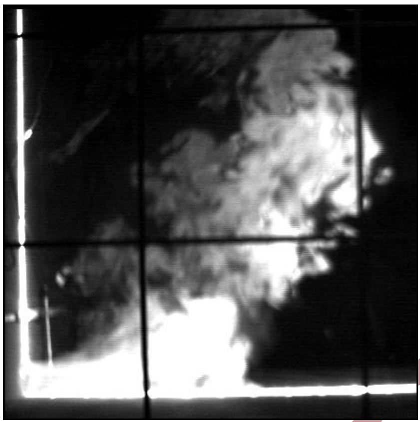
Fig. 1 : Different steps to find the contour points.

(IJRST) 2015, Vol. No. 5, Issue No. III, Jul-Sep **e-ISSN: 2249-0604; p-ISSN:2454-180X**

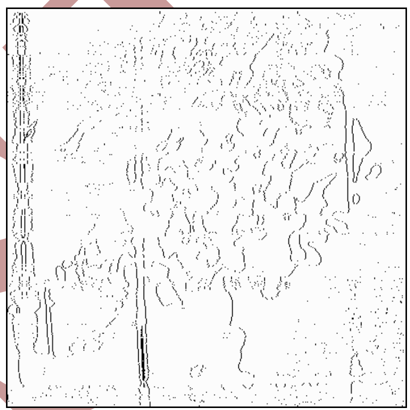
The intersection of the original image and filtered one based on the best window size will occur in the region of rapid change of the gray level. So, in this manner we can obtain the image contour.

B. ***Results***

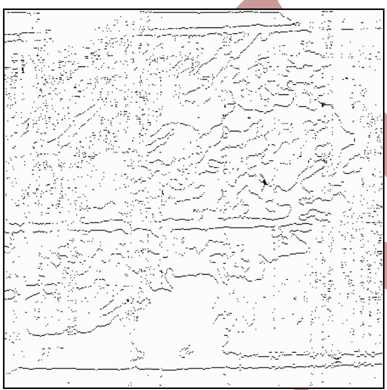
The image presented in (Fig. 2.a) is obtained from an experimental setup by visualization technique using laser tomography. The aim of the experimental study is to determine the detachment points of a horizontal non-isothermal air jet in order to determine the detachment distances. To achieve this task, we must previously find the boundary of the jet, so a contour detection is needed. By using the previously described method, we obtain these results:



2.a : Original image



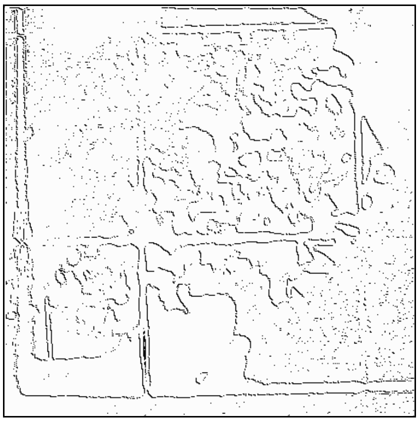
2.b : Vertical sweep



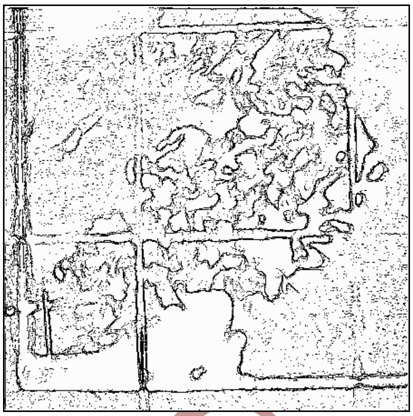
2.c : Horizontal sweep

2.d : Right diagonal sweep

(IJRST) 2015, Vol. No. 5, Issue No. III, Jul-Sep e-ISSN: 2249-0604; p-ISSN:2454-180X



2.e : Left diagonal sweep



2.f : Superimposition

Fig.2: The contours obtained by the different sweeps and their superimposition.

In figure 2, we can see the results of the intersection of the original image and the filtered one obtained in each sweep direction: Fig. 2.b for the vertical sweep, Fig. 2.c for the horizontal one, Fig. 2.d for the right diagonal one and Fig. 2.e for the left diagonal one.

As we can see, the use of the horizontal sweep gives clearly the vertical lines of contours but it lakes to detect the horizontal ones which will be found easily by the vertical sweep. Similarly, the left diagonal sweep finds out the right diagonal lines where the right diagonal sweep does for the left diagonal lines. So, if we use only one direction sweep some details will be lost, but inversely, when we superimpose these four figures we can obtain a good detection of the whole contours (Fig 2.f) even those corresponding to slow spatial variation of the intensity. Moreover, the detected contours delimit, in a very acceptable manner, the outline of objects contained in the original image. But one of the inconvenient is the apparition of some noisy points which must be eliminated to ameliorate the contour extraction.

In order to resolve this problem, in the following, we present the improvement of the previous method to eliminate these points.

IMPROVEMENT METHOD

A. *Description*

The amelioration of the previous method is based on the study of every contour pixel neighbor. We use the discrete convolution product to have some information on the surrounding pixels, specially the number and the position of the black points (zero value) in the neighborhood of the pixel

The discrete convolution product is a mathematical transformation that allows us to replace the actual value of the pixel by a linear combination of the surrounding pixel neighbors. The resulting value contain all the information about the neighbors.

Let IC(x,y) be the contour image and M(g,h) the convolution mask, the convolution product will give an image ICc(x,y) defined by :

$$ICc(x,y)=\int_{-a}^{+a}\int_{-a}^{+a} IC(x+u,y+v)M(u,v)dudv \qquad (4)$$

In discrete case, the convolution product can be written as :

$$ICc(i,j)=\sum_{g=-m}^{m}\sum_{h=-m}^{m} IC(i+g,j+h)M(m+g,m+h) \qquad (5)$$

where (i+g,j+h) are the neighbors of the pixel (i,j) located in inside a circle of radius of m points.

The neighborhood of a pixel can be defined by the mean of a convolution mask matrix centered on the pixel. Every term in the matrix represents the associated weight to the corresponding neighbor. In our case we have chosen m=1 and the following matrix :

$$M(k,l)=\begin{bmatrix} M(0,0) & M(0,1) & M(0,2) \\ M(1,0) & M(1,1) & M(1,2) \\ M(2,0) & M(2,1) & M(2,2) \end{bmatrix}=\begin{bmatrix} 128 & 64 & 32 \\ 16 & 0 & 8 \\ 4 & 2 & 1 \end{bmatrix} \qquad (6)$$

In some cases, the product result may be out of the allowed range values for the image codification, so in the case, there is a need to normalize the result by using a normalized coefficient like :

$$NC=\sum_{k=0}^{2}\sum_{l=0}^{2} M(k,l)$$

and the normalized convolution product can be written as :

$$ICc(i,j)=\frac{\sum_{g=-1}^{1}\sum_{h=-1}^{1} IC(i+g,j+h)M(g+1,h+1)}{NC} \qquad (7)$$

Every pixel is treated sequentially by visiting the contour image line by line, from the left top side of the image to the right bottom one. The treatment looks like a slip of the mask from top to bottom and from left to right on the contour image.

The result of the convolution product will give a new image of the same size of the original image named the convoluted image. By analyzing the values of that image we can get the needed information about the neighbor of every pixel. For instance, if the value of a pixel is 255 in the convoluted image, then the corresponding pixel in the contour image is a isolated one and can be eliminated. Similarly, we test if we have two adjacent isolated pixels, in this case we eliminate then too. In this manner, we keep the pixels that likely seem to form the contour of the image.

B. ***Results***

To verify this technique, we have used this ameliorated algorithm on the image in Fig. 2.f. the result is showed in the Fig. 3. We can see that, effectively, the improvement method ameliorate the quality of the resulting image by eliminating many noisy points.

Moreover, we compare the result with another existing operators presented in the literature, like the Sobel operator (Fig. 4), the Laplacian operator (Fig. 5) and the Canny one (Fig. 6). We can observe that the different operators give a part of the contours, and some of them like the Sobel operator and the Laplacian one fail to detect contours when there is a slow spatial variation of the intensity. But, the Canny operator and our method give a better detection of the contour with an advantage of the ours on the first one in the detection of some details.

Fig. 3 ameliorated contour

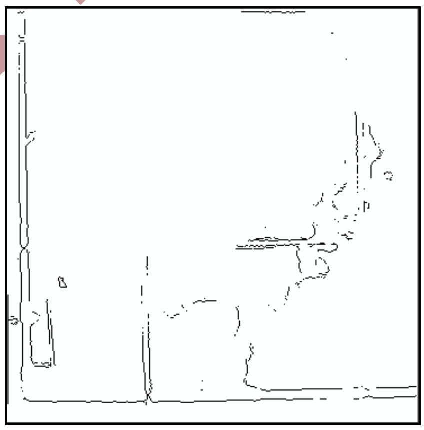


Fig. 4 Sobel operator

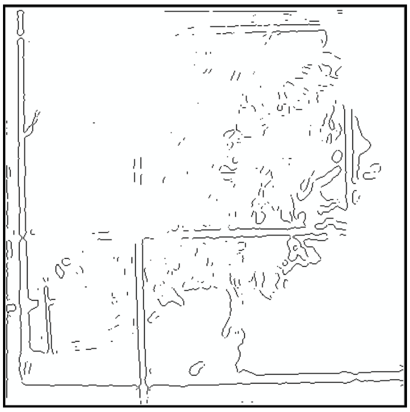


Fig. 5 Laplacian operator

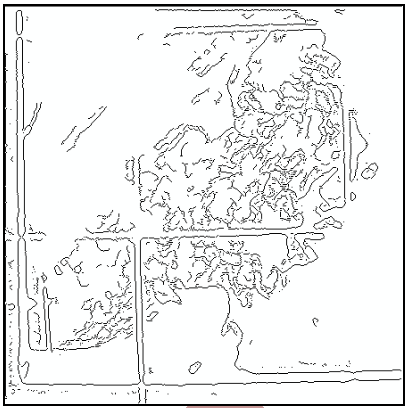


Fig. 6 Canny operator

CONCLUSION

The performance of the proposed method is compared with many other existing ones, such as the Sobel, Prewitt, Laplacian, and Canny detectors. An improvement of detection and quality of contours is evident and the effectiveness of our method and its superior efficiency is confirmed. The intersections of the original image with the filtered one can give the object contours. But some noisy points can appear in the resulting image. In order to resolve this problem, in the second part of this work, we proposed an algorithm to eliminate these noisy points. The new algorithm presented in this paper presents a good improvement on the original method, and we have seen that it can eliminate a lot of noisy points. But, in the case of highly discontinuous contours some points can be considered as an isolated ones, and so they can be eliminated. In future work, we will develop a better algorithm to resolve these apparent problems.

REFERENCES

[1] Roberts, L. G. Machine perception of three-dimensional solids. In Optical and Electrooptical Infomation Processing, J.T.Trippett et al. Eds. Cambridge, MA : MIT Press, (1965) 159-197.

[2] Prewitt J. M. S., *Object enhancement and extraction*, in:B.S. Lipkin, A. Rosenfeld (Eds.), Picture Processing and Psychopictorics, Academic Press, New York (1970).

[3] Kirsch R., *Computer determination of the constituent structure of biological images*, Comput. Biomed. Res. 4, (1971) 314-328.

[4] Duda, R. O. & Hart, P. E. (1973) Pattern classification and scene analysis, *Wiley*, *New York*, 271-272.

[5] Haralick, R. M. (1984) Digital step edges from zero crossing of second directional derivatives. *IEEE Transactions on Pattern Analysis and Machine Intelligence* 6(1), 58-68.

[6] Marr D., Hidreth E., *Theory of edge detection*, Proc. Roy. Soc. London PAMI-6 58, (1984).

[7] Cocquerez, J. P. & Philipp, S. (1995) Analyse d'images : filtrage et segmentation, *Masson*.

[8] Canny J., *Computational approach to edge detectio*n, IEEE Trans. Pattern Anal. Mach. Intell. PAMI-8, (1986).

[9] Deriche, R. & Giraudon, G. (1993) A computational approach for corner and vertex detection. *International Journal of Computer Visio* 10(2), 101-124.

[10] Shen J., Castan S., *An Optimal Linear Operator for Step Edge Detection*, CVGIP, vol. 54, (1992) 112-133.

[11] Souza, P. D. (1983) Edge detection using sliding statistical tests. *Computer vision, graphics, and image processing* (23), 1-14.

[12] Huang J.S., Tseng D.H.: Statistical theory of edge detection. Comput. Vision Graphics Image Process. 43, pp 337-346, 1988.

[13] Haberstroh J., Kurz L.: Line detection in noisy and structured background using Graco-Latin squares. CVGIP: Graphical Models Image Process, 55, pp 161-179, 1993.