A NEW DEFINITION OF CONTOURS IN IMAGES APPLICATIONS IN HEAT AND MASS TRANSFER

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We propose a new definition of contours of the objects resulting from the experimental visualization and we use it for edge detection and image smoothing in heat and mass transfer. This work is a contribution to image analysis, in the area of search for outlines of the features and their structures towards the discovery of trends they represent.

INTRODUCTION

For the phenomena of thermodynamics, fluid mechanics, heat and mass transfer, and others, visualization through hierarchical development allows access to a vast amount of information otherwise obscured, an example being the discovery of structures in the flow of liquids. For the latter, it is necessary to obtain a plausible identification of extracted contours of the analysed image. So, the discovery of outlines of the objects in a noisy environment is a major element in determination of the boundaries of the object for which we are searching and in various techniques of segmentation, transmission and storage of the complete image. Unique storage and transmission of the outlines permits optimization, with respect to time and space complexity, of these aspects, when it is applied to the entire objects.

We commence by summarizing the main methods for outlines detection, published in open literature, and by discussing the main difficulties they encountered. The definitions of the outlines usually correspond, either to the areas of rapid change in the level of grayness of the image (lines of maximum contrast), or to the lines of constant values. In a great majority of existing methods, invariably, the extracted parameters are optimized only following the completion of a process subject to visualization. They lead to fairly arbitrary choices, by permitting their user to choose one or more parameter values to fit his idea about the results he may wish to obtain. For these reasons, we endeavor to search for an objective self-adapting method, which would not lead to exceptional cases or some arbitrary decisions. Then, we can use the original aspects of our method to propose a new definition of the outlines in an image.

METHODOLOGY

We concentrate on detecting contours of numerical images. Here, an image consists of a matrix of K rows and L columns of the pixels. The intensity of luminosity at points (k,l) gives a spatial representation of an object. For establishing a criterion for determining the trends of this data set, we need to introduce two new definitions.

First, a parameter, the Index of Nonlinearity (INL), permits to calculate the degree of fluctuations of a trend obtained by application of a low-pass filter with a cut-off period Kn, around a straight line.

Secondly, we propose a criterion for determining the structural trends of a data set. For each window Kn, we calculate the INL of the smoothed data set. A graph (the INL-GRAMME) can be associated with the index of nonlinearity and demonstrates the global decrease of INL when Kn increases. The values of Kn, corresponding to the minima of the INL can provide criteria for choosing a length of the window of Hamming of the low-pass filter which would produce the structural trends of the image. We define partial trends of order j as the trend resulting from the filter associated with the j'th value Kn. The trend corresponding to the largest of the values Kn (the last one) is called the ultimate trend.

These trends, determined by the INL and thus specific to each data set, represent the aspects of phenomena, considered at different levels (scales) of observation. The ultimate trend corresponds to the highest level, beyond which the loss of information would distort the analyzed signal. This formes a generalization of the notion of a mean, and follows the suggestion of the mathematician Jean BASS to define an average dependent on time or another independent variable.

RESULTS

The definition of the trends implies existence of the intersections between them and the initial curve. These intersections represent the points, which remain invariant under the change of the level of observation. Within the image, these intersections could be isolated points, insignificant elements, or entire lines.
We postulate that these lines form a separate class of contours called Structural Contours and represent structural properties of the image. In particular, structural contours defined in this manner could be adjacent to the lines of maximum contrast or the lines of constant values, which are typically used themselves to define a contour. However, the structural contours have much more general significance.
In the last part of this study, we apply our method to an image resulting from mixed convection (obtained using laser tomography) at the Laboratoire d'Etudes Thermiques (LET) in Poitiers (France). It represents a cold downwards isothermal plane jet. The Reynolds number is equal to 3760. The size of the image is 566x362 pixels (Fig.1). We proceeded by processing separately each row, column, and diagonal to find first the trends and then the intersections with the original image (Fig.2 to Fig.5). Comparing the results of such separate one-dimensional analyses, we observe that some points appear only in one of the directions horizontal, vertical or diagonal. To maximize the information, we decided to superimpose the intersections obtained from these three directional treatments (Fig.6).

CONCLUSION

It is shown that the contours can be superimposed and completed almost perfectly. Moreover, we compared our results with those obtained using a computer program based on Laplacian operator method. An improvement of detection and quality of contours is evident.

Fig. 1 : Original image

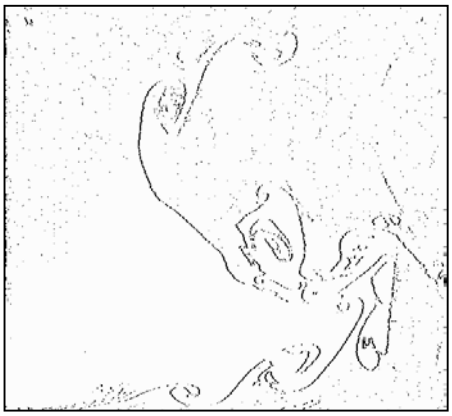

Fig. 2 : Horizontal intersection

Fig. 3 : Vertical intersection

Fig. 4 : Left diagonal intersection

Fig. 5 : Right diagonal intersection

Fig. 6 : Superimposition