A Non-Maxima Suppression Method for Edge Detection with Sub-Pixel Accuracy

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Abstract: In this article we present a two dimensional edge detector which gives the edge position in an image with a sub-pixel accuracy. The method presented here gives an excellent accuracy (the position bias mean is almost zero and the standard deviation is less than one tenth of a pixel) with a low computational cost, and its implementation is very simple since it is derivated from the well-known Non-Maxima Suppression method [2, 4]. We also justify the method by showing that it gives the exact result in a theoretical one dimensional example. We have tested the accuracy and robustness of the edge extractor on several synthetic and real images and both qualitative and quantitative results are reported in this paper.

Key-words: Low-level processing, Edge detection, Sub-Pixel, Differential properties of curves.

(Résumé : tsvp)

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Détection de contours à une précision inférieure au pixel par une méthode dérivée de la NMS

Résumé : Nous présentons un détecteur de contours bidimensionnels qui donne la position du contour dans une image à une précision inférieure au pixel. La méthode présentée ici donne d'excellents résultats (la moyenne de l'erreur en position est presque zéro et son écart type est d'à peine un dixième de pixel) pour un coût en calcul à peine supérieur à une méthode classique, et de plus son implantation est très simple puisqu'elle est dérivée de la méthode classique de suppression des non-maxima locaux (NMS) [2, 4]. Nous justifions également l'utilisation de cette méthode en montrant qu'elle donne le résultat exact dans le cas d'un contour monodimensionnel. Nous avons testé la précision et la robustesse de cet extracteur de contours sur plusieurs types d'images, synthétiques et réelles, et rapportons ici des résultats à la fois qualitatifs et quantitatifs.

Mots-clé : détection de contours, sous-pixel, propriétés différentielles de courbes.

Contents

1 Introduction

Edge detection is now taken for granted by most of the computer vision people, like many other basic tools of computer vision. Since a lot of work has already been done in early vision, people working on higher level features tend to use as input the result of classic low level algorithms and think this is the only information they can get from the image data. In the case of edge detection we used to work on information that was given to within about a pixel, and then had to do some kind of regularization process on it, like polygonal or spline approximation. Both introduce a certain quantity of error, but whereas the approximation error can be chosen, the error on the detected edge position is both fixed and not negligible, especially when one wants to compute differential properties of image curves like orientation, Euclidean curvature or even higher degree properties like affine or projective curvature. Some attempts were made in edge detection at a sub-pixel accuracy a few years ago, for example A. Huertas and G. Medioni [11] used a refinement of the zero-crossing of Laplacian but they did not give any results on the accuracy of the edge detection. A.J. Tababai and O.R. Mitchell [14] did some interesting work in the one-dimensional case which was extended to two-dimensional images and seemed to work properly. An edge relocation mechanism is also given in [15] but the required implementation is rather complex. The best results in terms of accuracy [12] were obtained at a high computational cost, because this involved local surface fitting on the intensity data, and the results are not better than our method. In general, the different methods that have been proposed often end up requiring regularization, excessive computer power, or both of them.

For these reasons we made a very simple enhancement of the classical local non-maxima suppression, that gives a much better estimate of the curve position (up to within a tenth of a pixel) or the curve orientation without regularization, and at a very low computational cost. Using this edge detector, we can also calculate higher order differential properties of curves with much less regularization than when using older methods. Besides, this method can be easily integrated in an existing vision system since it is based on a classical and widely-used method.

We present and interpret a wide variety of results to compare this method with existing edge detection methods. We also calculated in the most simple way the local edge orientation to show that the result of our method can also be used to easily calculate differential properties of the edges.

2 On edge extraction

2.1 The NMS method

This method is based on one of the two methods commonly used for edge detection, the suppression of the local non-maxima of the magnitude of the gradient of image intensity in the direction of this gradient [8] (also called NMS), the other one being to consider edges as the zero-crossings of the Laplacian of image intensity [10, 9]. NMS consists of:

1. Let a point (x, y), where x and y are integers and $I(x, y)$ the intensity of pixel (x, y).

2. Calculate the gradient of image intensity and its magnitude in (x, y).

3. Estimate the magnitude of the gradient along the direction of the gradient in some neighborhood around (x, y).

4. If (x, y) is not a local maximum of the magnitude of the gradient along the direction of the gradient then it is not an edge point.

Usually for step 4 the neighborhood is taken to be 3×3 and the values of the magnitude are linearly interpolated between the closest points in the neighborhood, e.g. in Figure 1 the value at C is interpolated between the values at A_7 and A_8 and the values at B between those at A_3 and A_4. We have also tried to use *quadratic* interpolation to compute these (the value at A would be interpolated between those at A_7, A_8, and A_1 as in Figure 2) and compared the results with the linear interpolation. After this edge detection process one usually does hysteresis thresholding [2] on the gradient norm and linking to get chains of pixels.

2.2 The sub-pixel approximation

Our main improvement of the method is very simple and consists of only adding this single step to the NMS process:

- If (x, y) is a local maximum then estimate the position of the edge point in the direction of the gradient as the maximum of an interpolation on the values of gradient norm at (x, y) and the neighboring points.