A FAST METHOD FOR DETECTING AND MATCHING LINEAR FEATURES IN IMAGES*

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ABSTRACT

A method is proposed for efficiently finding and matching linear features in images. In a first step *markers* of these features must be extracted. Combinations of well-known morphological operators can be used for that purpose. One key point is to find not one, but two sets of markers. The first set should be a strict subset of the desired features, whereas the second can also include markers of undesired features. In a second, independent step, these markers are fitted with ellipses and matched, taking into account their position, orientation, length and width via a score function. We show on a complete example that this approach is simple, reliable and fast.

1. INTRODUCTION

The detection of line segments is a problem present in a number of image analysis applications. Traditional image analysis operators usually function at the local level, whereas line recognition is known to be a non-local process. Indeed, the human vision system is very good at detecting and extrapolating linear features which are not obvious at the pixel level.

In this paper, we outline a fast method that uses both local and non-local information to detect linear features in images.

2. LINEAR SEGMENT DETECTION

The method we propose first relies on local information to find *markers* where linear features might be found. This detection can occur in a number of different ways, depending on the content of the image. We propose a number of methods based on mathematical morphology techniques (MM) [6]. For example in the case of faint bright lines on a noisy background, we propose extracting extended regional maxima [11] from an image filtered by a connected operator such as an area opening [10]. This will extract small bright areas from the image. These maxima are filtered by a thinning by attributes [1], which retain only those bright

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areas that have a high length to width ratio. For images which are not too noisy, other local techniques can be used, such as described in [8].

As a rule, such marker extraction techniques are not robust. To improve robustness, we propose to extract two different sets of markers, using different parameter values. First, a stringent set of parameters is determined that ensures that the markers found using those parameters indeed belong to linear features. We call these markers the minimal markers. A second set of parameters allows more markers to be found, together with a reasonable amount of unwanted noise. We call these markers the maximal markers. This double set of markers is then processed with the following proposed line segment reconnection algorithm.

3. LINE SEGMENT RECONNECTION

We propose to replace each marker in the image by its *best-fitting ellipse* [5, pp. 237-234]. This allows considerable simplification of the semantic content of the image. Each marker is reduced to a set with position, orientation, length and width information. This allows the use of non-local criteria in the matching of the detected markers.

A marker may not be suited for a straightforward ellipse-fitting procedure. For example, a marker may well be too long and too curvy. In this case, the marker may be broken up into several, shorter, straighter segments, and ellipses fitted to these segments, as in Fig. 3. Since these segments are designed to be reconnected later, it helps to remember in the procedure that they once belonged to a larger marker, in order not to try to erroneously connect them to other markers. In practice, only the segments at either extremity of the original marker should be connected to other markers.

Once the set of markers has been replaced by a suitable series of ellipses, the reconnection procedure can take place.

3..1 General line reconnection procedure

The first step is to try and match each major axis extremity of those ellipses with all the other available extremities (see Fig. 1). The score function associated with each possible reconnection is:

$$\text{Score} = \lambda\sqrt{\frac{2\pi - \alpha - \beta}{2\pi}} + (1-\lambda)\frac{d}{diag}, \tag{1}$$

where α and β are the angles between the line constituting the possible reconstruction and the main axis of each of the ellipses. The parameter d is the Euclidean distance between the 2 extremities. The $diag$ parameter is the length of the diagonal of the image and λ is an adjustable parameter.

This function shows that a reconnection will be more probable when the distance between the two extremities decreases, and the angle between the reconnection line and the main axis of both ellipses tends to π, *i.e.*, when the ellipses are well aligned.

The reconnection which has the best score is performed. When no possible reconnection reaches a sufficient score, no reconnection is performed. Also, when two extremities are very close to each other, the reconnection is performed regardless of the angle.

The result of this processing is shown in Fig. 1d.

3..2 Reconnection of a double set of markers

This procedure is further improved when using two sets of markers instead of one:

Let the minimal markers and the maximal markers be those defined in section 2. The procedure is to try and connect together the minimal markers, but if some maximal markers have the right alignment and the right orientation with respect to at least one minimal marker, these maximal markers can become minimal markers and be used in the general reconnection procedure. This increases considerably the reliability and the robustness of the reconnection. Fig. 2 illustrates this point: in this scanning electron microscope image of man-made vitreous fibres, we want to segment the small fibres in order to be able to measure their length for quality control purposes. The double marker approach allows the retrieval of the full length of both fibres, whereas using the minimal marker alone would result in an incorrect length measurement, and using the maximal markers alone would result in an oversegmentation of the image leading to incorrect results.

4. PERFORMANCE AND EXTENTION

The general line reconnection method can be applied to a number of related line detection and matching problems, such as the management of overlapping objects. For example, Fig. 3a shows an image of man-made vitreous fibres taken in the same conditions as for Fig. 2a. This time the fibres are overlapping. For a correct account of the fibres to be made, these fibres must be logically separated. In Fig. 2b, the compound object made of the two fibres is segmented from the background of the image, using morphological techniques described in [7]. In Fig. 2c, the minimal Euclidean skeleton of the compound object is obtained [9]. The crossing is identified by looking at the multiple points of the skeleton. The area around the intersection is removed to facilitate future reconnection. The markers of the fibre are then too long and curvy, they are therefore broken up into smaller, straighter segments. The proposed method is then applied to these markers, with the result shown on Fig. 2d.

Although this method involves a number of comparisons which grows like the square of the number of objects to be matched, it is usually very fast, even when there are several hundred markers. It usually takes less than a minute to perform marker detection and matching from start to finish, on 512×512 images, on a standard Sun Sparc 10 workstation, as table 1 shows.

We have compared the proposed method with a number of other published methods giving similar results, such as least-square fitting [2], Hough-transform

image	image filtering	marker detection	segmentation and ellipse fitting	marker reconnection
of Fig. 2	24s	31s	15s	1s
of Fig. 3	24s	10s	7s	1s

Table 1: Computing times in second on a Sun Sparc 10 workstation to obtain results shown on given pictures.

based methods [3] or marker propagation [4]. We have found that the proposed method either gives comparable results to those methods but is faster, or can be used in a wider number of cases.

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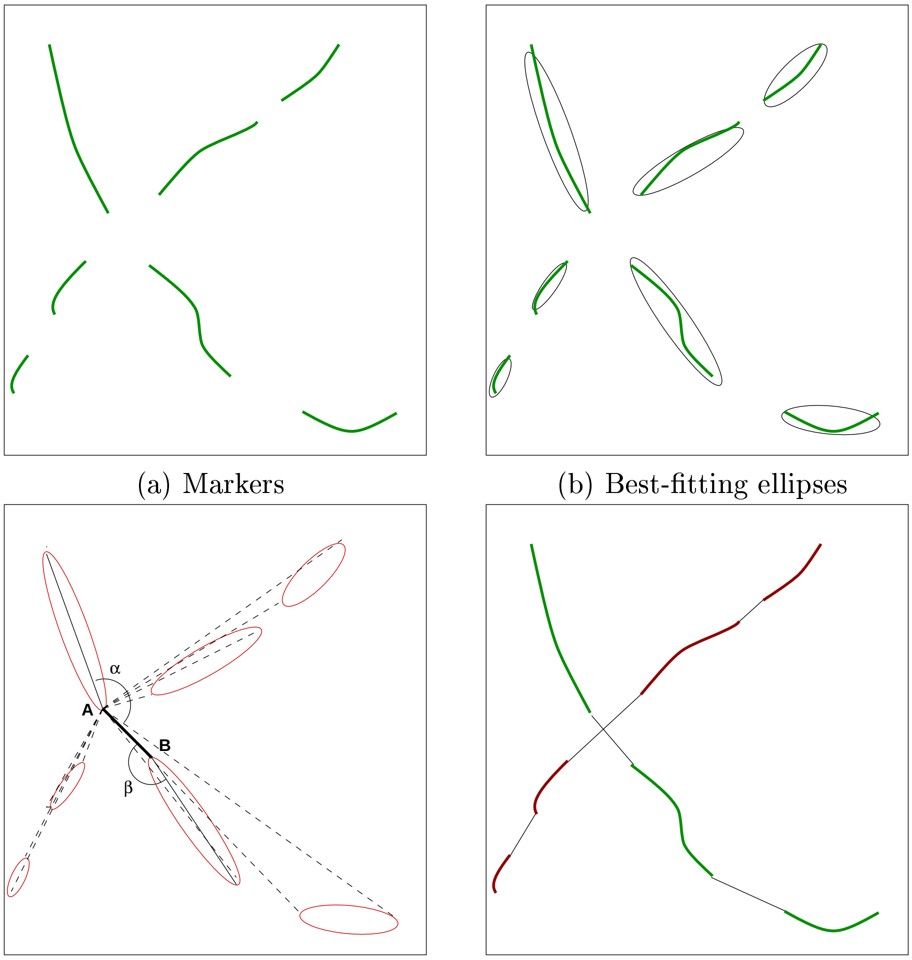


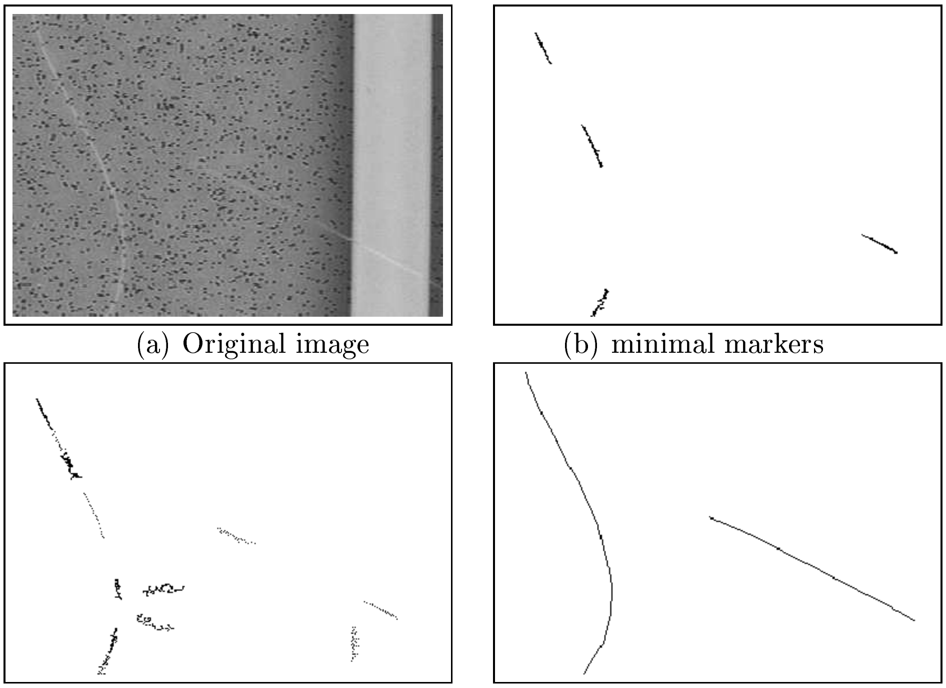
(a) Markers

(b) Best-fitting ellipses

(c) Reconnection on point A

(d) Final reconnection

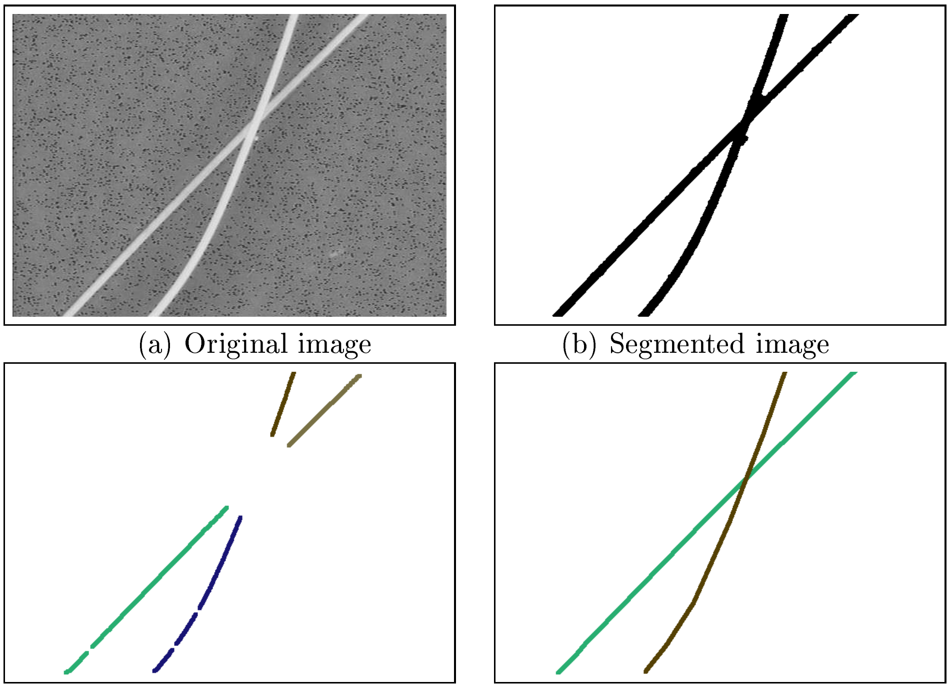
Figure 1: General reconnection procedure.



(a) Original image (b) minimal markers

(c) maximal markers (d) Final reconnection

Figure 2: Reconnection using a double set of markers.



(a) Original image (b) Segmented image

(c) Best-fitted ellipses (d) Final reconnection

Figure 3: Reconnection of crossing objects.