

# The interpretation of closed curves as noisy, symmetric polygons through shape analysis based on a hierarchical structure

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This paper describes the implementation and use of an effective method for the interpretation of closed, usually irregular, shapes as symmetric polygons distorted by noise. Results from the analyses of real data are presented, the motivation for the method is explained, and its relevance to generalisation is discussed.

The closed curves to be analysed were the boundaries ('contours') of crystal cross-sections extracted from photomicrograph images. The crystal faces must be identified to support the description of the crystal symmetry and form, which in turn supports identification of the mineral and/or description of the crystal development.

The task of finding crystal faces on the region contour is a *perceptual* problem: it can be viewed as the selection or extraction of the overall 'best shape' for the crystal – combining local contour straightness and non-local shape and symmetry. The problem possesses what Dreyfus [1994, p.244] identified as the crucial feature of gestalt interpretation: what counts as a part is defined in terms of the whole. Here, what is seen as a face is defined by the overall pattern of faces in which it is seen.

With perfect crystal growth and ideal image preparation, crystal faces would be realised on crystal cross-sections as perfectly straight segments of the region boundary. However, since the crystal grown may not be ideal, and the image processing that isolates (*i.e.* segments) the regions is likely to introduce error, the faces may be expected to depart from the ideal and be irregular or 'noisy'.

The problem of identifying faces on a contour does not reduce to finding a simple polygonal approximation of the contour. Variations in noise mean that the appropriate resolution for the linear approximation of a boundary segment may vary around the contour. Further, as remarked, the overall crystal shape does not depend on local contour straightness alone: True crystal faces are expected to show some symmetric arrangement. To interpret the possibly irregular crystal contour as a set of faces therefore requires consideration of contour straightness *and* non-local information such as parallelism, collinearity or other signs of symmetry.

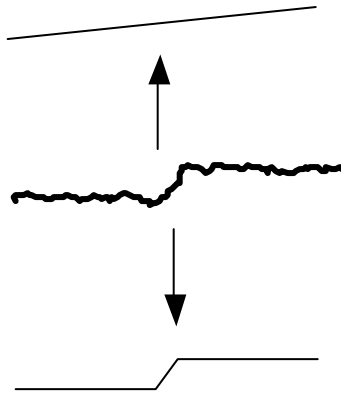


Figure 1. Two possible approximations to a noisy contour segment

Figure 1, for example, shows a noisy contour segment which, on the basis of local straightness information alone, could plausibly be interpreted as three straight line segments, using one resolution, or by a single segment, using a coarser resolution.

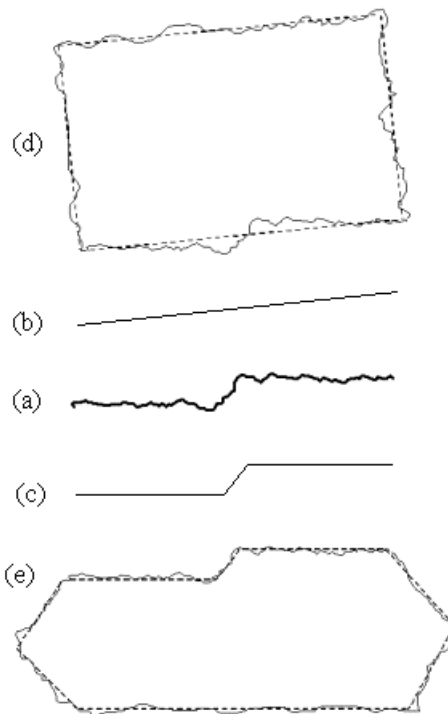


Figure 2. The noisy contour segment in two different contexts

Figure 2 shows that the appropriate approximation can only be decided by taking into account the wider context of the resultant crystal shape. Figures 2a, 2b and 2c represent the irregular curve segment of figure 1 and its two possible interpretations as polylines. Figures 2d and 2e place the irregular curve segment in different contexts as part of crystal section shapes showing, respectively, orthorhombic (rectangular) and hexagonal symmetry. It is clear that in context (d) the approximation (b) should be favoured, and approximation (c) should be favoured in context (e).

Because of the possibly wide variation in the level of 'noise' present around a crystal contour a multi-scale analysis was required to derive the appropriate contour

interpretations. The solution that was devised and implemented used a two-stage analysis procedure. First, a hierarchical, multi-resolution representation of the potentially significant linear and near-linear structure on the contour was constructed: this was called a 'face-tree'. The face-tree implicitly contains all plausible interpretations of the contour as a set of faces. In order to avoid the needless and inefficient representation of the structure at all possible scales, the analysis included a filtering stage to identify and retain only the significantly different interpretations. The face tree therefore provides a succinct description of the likely significant linear and near-linear structure found on the contour.

The face-tree representation was then input to specially designed symmetry analyses in order to extract the optimal interpretation. These symmetry analyses carried across ideas of 'angular symmetry' from crystallographic analysis to the study of 2D shape, and so introduce novel analysis tools that can be applied to what would normally be considered asymmetric figures [Thomson & Claridge 1992].

This two-stage analysis strategy successfully combined the 'local' contour linearity information with 'global' information about the overall shape of the contour. This process, therefore, effectively solved one manifestation of the perceptual problem of extracting the 'best shape' – basically, finding the 'simplest' interpretation.

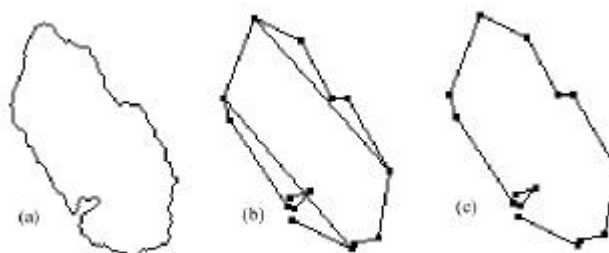


Figure 3. A topaz crystal contour extracted from a micrograph, the tree of faces found by multiscale analysis, and the set of faces selected by symmetry analysis

Figure 3(a) shows the outline of a topaz crystal in cross-section taken from a micrograph image. Figure 3(b) shows the face-tree of possible faces identified by the multiscale analysis of local contour straightness information: only two levels of significant structure have been found in this case. Figure 3(c) shows the subset of faces selected by the symmetry analysis of the face-tree.

Figure 4 shows corresponding displays for a lamprophyllite crystal section (in this case the face-tree shows three levels of significant structure).

The multiscale analysis of local linearity can be seen to have produced a useful and reasonable description of the possible faces; the final selection of faces by the symmetry analysis does appear to provide a good interpretation of the crystal shape, and indeed was found in tests to be closely comparable with human interpretations.

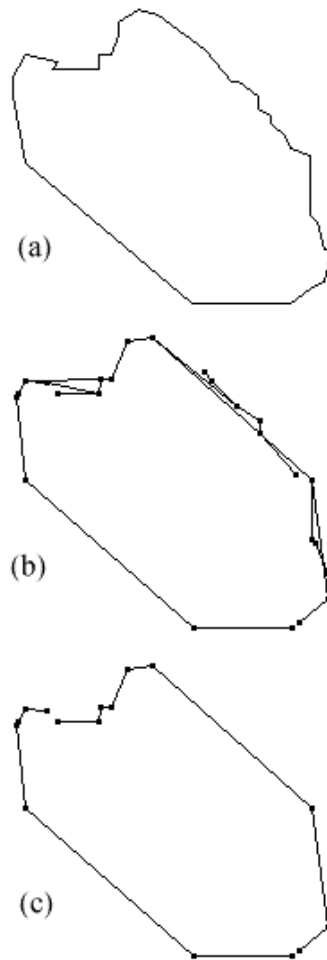


Figure 4. A lamprophyllite crystal contour extracted from a micrograph, the tree of faces found, and the final set of faces selected by symmetry analysis

This analysis can be viewed as a special instance of perceptual pattern recognition which has served to identify the important shape features in the presence of ‘noise’, in a manner that allows the noise to be quantified. The need for multiscale analysis in such analyses has been recognised, and a practical implementation method was presented.

The emphasis on the recognition of perceptually significant image features gives this work a relevance to spatial data generalisation. The importance of perceptual organisation to generalisation has long been recognised [DeLucia & Black 1987]. Perceptual organisation provides a basic level of image understanding that is domain independent yet sufficiently powerful to gauge the relative importance of features and support generalisation, and other analyses.

It is also suggested that the ‘character’ of an image is a function of the perceptual groups it contains, and so the preservation of salient perceptual groups – perhaps in some attenuated form, perhaps even in exaggerated form – should help retain that character during generalisation. This principle has been exploited, for example, in

network generalisation [Thomson & Brooks 2002] . Since perceptual organisation principles identify forms of spatial patterns that are important *irrespective* of context or semantics such analyses have the potential for very wide application – if they can be effectively implemented.

### *References*

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