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Extraction of the zero-crossing of the curvature derivative in volumic 3D medical images : a multi-scale approach

Olivier MONGA, Richard LENGAGNE
INRIA, Domaine de Voluceau - Rocquencourt
BP 105, 78153 Le Chesnay Cedex, France
Rachid DERICHE
INRIA Sophia Antipolis
2004 Route des Lucioles 06565 Valbonne Cedex

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1 Summary

Volumic 3D images are now widely distributed in the medical field [HL79, TPRS80, GHJ75, Aya93]. They are produced from various modalities such as Magnetic Resonance Imagery (MRI), Computed Tomography Imagery (CT), Nuclear Medicine Imagery (NMI) or Ultrasound Imagery (USI). Such data are represented by a discrete 3D grey level function $I(i,j,k)$ where the high-contrast points (3D edge points) correspond to the discrete trace of the surfaces of the geometrical structures [MDR91, MDM91, ZH81]. A motivating issue is then to extract typical features of these surfaces. The most natural way is to look for differential Euclidean surface invariants such as : curvatures, crest lines, parabolic lines, umbilic points... [MAS92, SZ, San89], [SZ90, Koe90, MBF92, BR91, TA92, PB85]. Recently, we have shown that the differential properties of a surface defined by an iso-contour in a 3D image can be recovered from the partial derivatives of the corresponding grey level function [MBF92]. In [MBF92] crest lines are extracted using first, second and third order partial derivatives provided by 3D Deriche filters [MDM91, MDR91]. The critical point of this approach also studied in [TA92] is the stability of expressions including second and third order

partial derivatives such as the "extremality criterion" defined in [MBF92, TA92].

In this work we propose recursive 3D filters to improve the computation of partial derivatives and also a multi-scale approach to extract the zero-crossings of the extremality criterion.

First, we show that derivative filters coming from isotropic (rotation invariant) smoothing filters should be used to ensure the Euclidean invariance of the curvatures. Then we derive an algorithm to compute first, second and third order partial derivatives of a 3D volumic image. These derivatives are used to obtain curvatures invariant by rigid motion (Euclidean invariant).

Then we deal with the computation of the curvatures of the surfaces traced by the iso-contours (3D edge points) from the partial derivatives of the image (for instance provided by the previous method). We use the main results of the reference [MBF92] and show the problems induced by a single scale filtering.

Finally, we propose to use different widths of filters to compute the curvatures. This leads to a multi-scale curvature computation scheme where the scale is the width of the filters. We apply this principle to track the zero-crossings of the derivative of the maximum curvature points along the maximum curvature direction (extremality criterion) which correspond to the crest points. The zero-crossings coming from the different scales are merged using a valuated adjacency graph. We propose some simple and efficient strategies to extract stable zero-crossings from this graph.

We present experimental results obtained on synthetic and real data (CT and MR 3D images). We show that our approach combining a multi-scale scheme and also the use of better filters provides reliable crest lines even for noisy data.

This work is more precisely described in the reference [MLD94].

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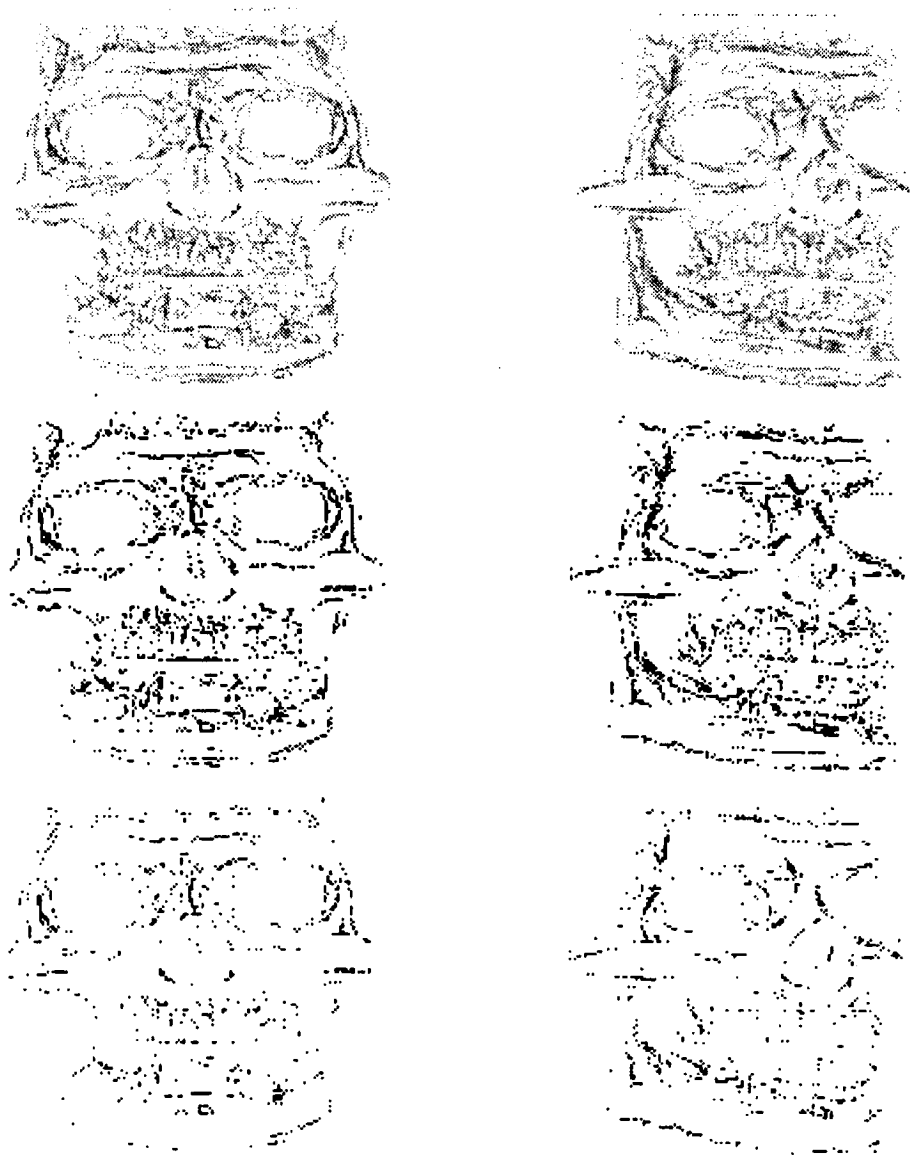

Figure 1: Up : perspective views corresponding to the positions A (left) and B (right) where the grey level is set to the number of scales such that the point is a crest point ; middle : perspective views corresponding to the positions A (left) and B (right) where only the points which are crest points for at least 4 scales are marked; bottom :perspective views corresponding to the positions A (left) and B (right) where only the points which are crest points for at least 5 scales are marked.

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