Perceptual Grouping and Active contour functions for the extraction of roads in satellite pictures

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Crest lines detection after low level processing

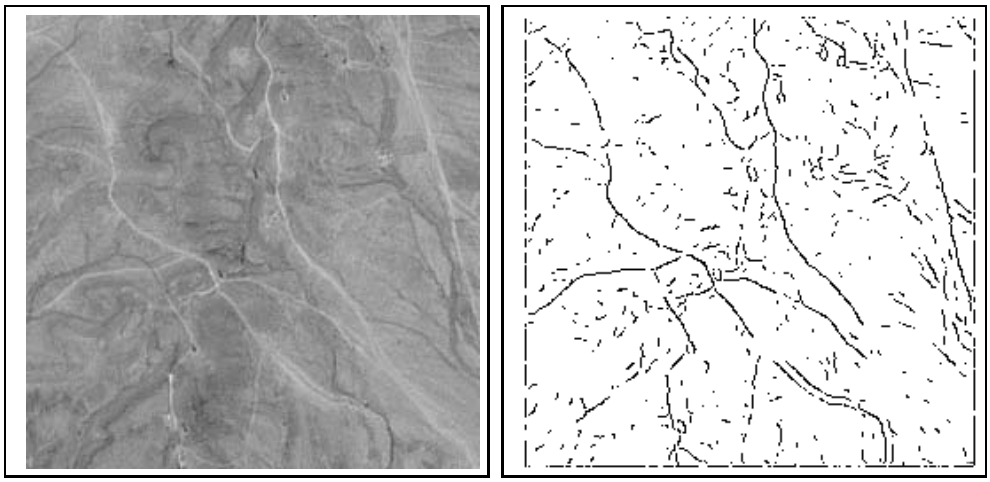

FIG. 1 - *Lines detection after low level processings*

Extraction of the salient network ?

Proposed method : Perceptual organisation with active contour functions

In order to

- **extract the salient network**
- **fill gaps**
- **ignore the noise**

we propose a method in three steps :

- **Definition of a quality function**
  After the choice of visual properties.

- **Local to global optimization**
  Creation of a network of locally connected pixels with global contributions.

- **Following and Selection of the optimized solutions**

Choice of the visual properties

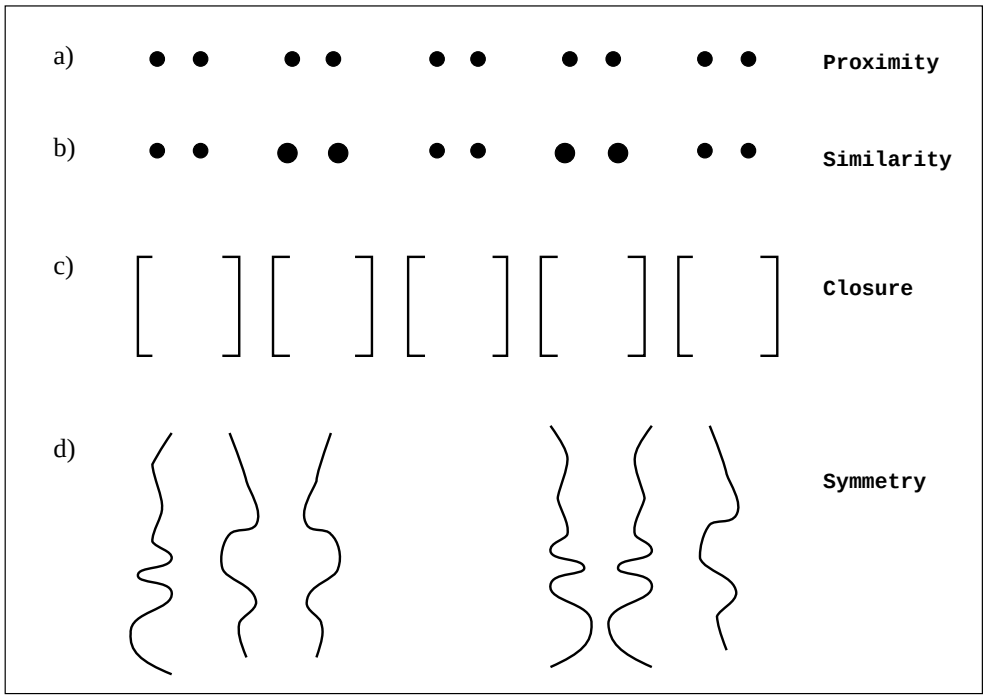

FIG. 2 - *Example of Visual properties*

Long, continuous and smooth curves

– **Length**

Extracted curves should match pixels of the image after Crest Lines detection.

– **Smoothed Continuity**

To keep extracted curves consistent and control the changes in orientations.

Quality function

A quality function composed of opposed terms :

- **External terms imposed by the image**
  Grey levels and Orientations of tangents.
- **Internal terms imposed by the geometry of the curves**
  Curvature and Co-circularity.

The resulting function is similar to active contour functions : opposition of internal and external terms

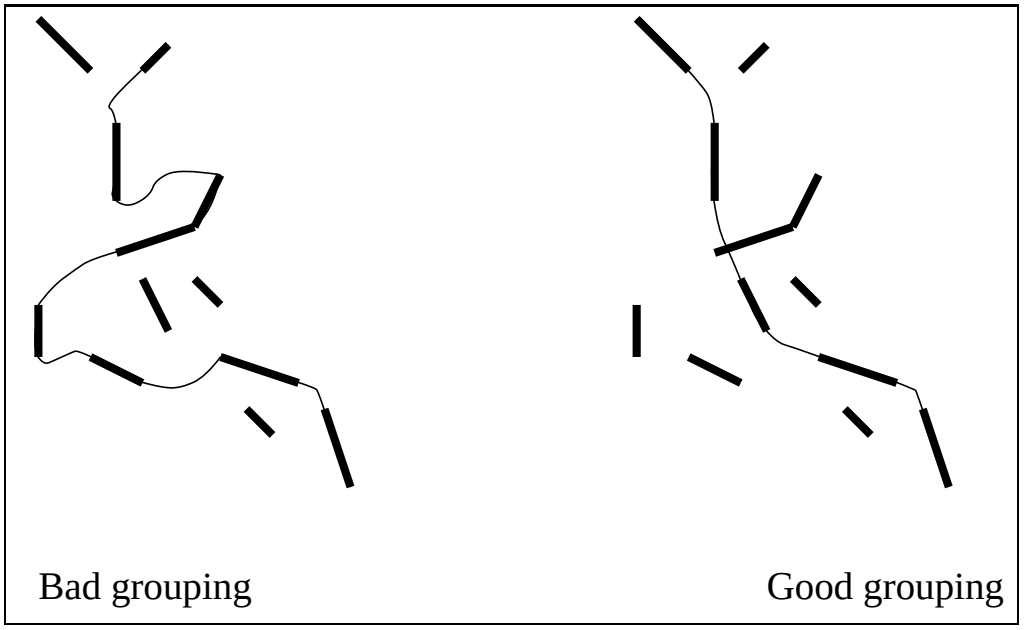

FIG. 3 - *Quality of the expected curve*

Recursive Optimization

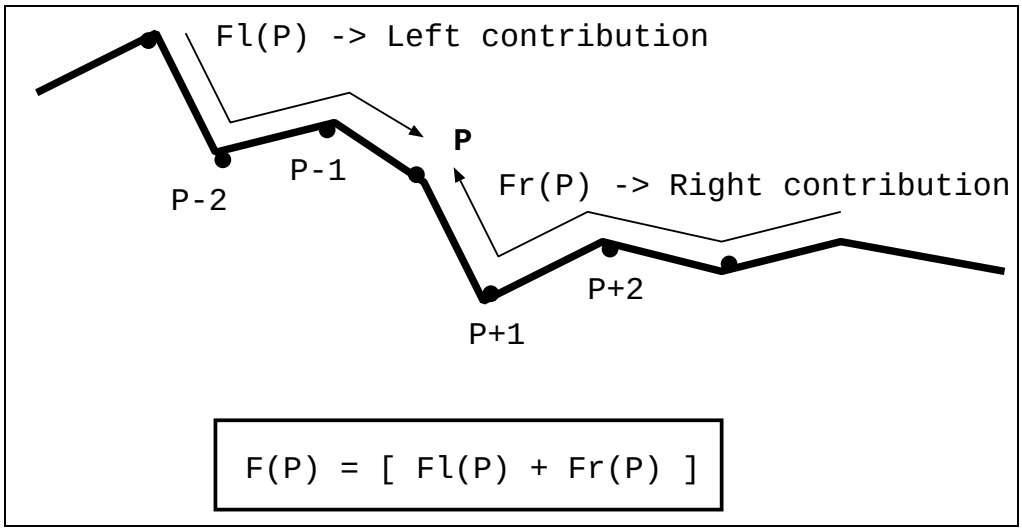

FIG. 4 - *Notations used for a quality term on a dynamic curve during the optimization*

Each quality term $\mathcal{F}$ is written as a **bi-lateral function of the trace**:

$$\mathcal{F}(P) = (\mathcal{F}_r(P) + \mathcal{F}_l(P)) \tag{1}$$

with a trace $\mathcal{F}_l(P)$ coming in P and a trace $\mathcal{F}_r(P)$ going from P.

Recursive Optimization

For each lateral contribution :

$$\begin{aligned} \mathcal{F}_l(\,P\,) = \quad & \tfrac{1}{2}\cdot Q(\,P\,) \\ & +\rho\cdot Q_P(\,P-1\,) \\ & +\rho^2\cdot Q_{P-1}(\,P-2\,)+... \end{aligned} \tag{2}$$

This term written in a recursive way gives, for a distance n from P :

$$\mathcal{F}_l^{(\,n\,)}(\,P\,) = Q_P(\,P\,) + \rho\cdot \mathcal{F}_l^{(\,n-1\,)}(\,P-1\,) \tag{3}$$

where $Q(\,P\,)$ is the local quality term for the primitive P and $Q_P(\,P-1\,)$ represents the evaluation of a contribution from the primitive $(\,P-1\,)$ viewed from P.

Optimization and Grouping

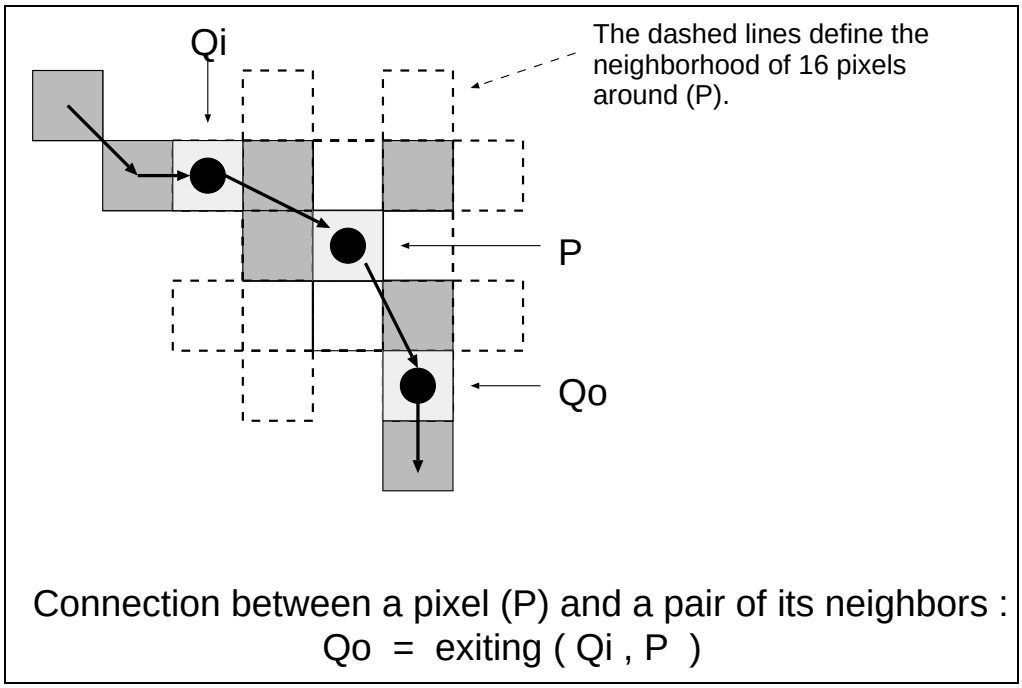

FIG. 5 - *Example of a grouping of pixels*

For each pixel:

- A local grouping is done by selecting the pairs of neighbors giving the best value for the quality function.

  These pairs represent the directions of arrival and departure for every possible grouping between the pixels.

- Along the iterations, the importance of individual pixels decreases with regard to pixels included in large structures.

Extraction of the curves

FIG. 6 - *Quality map and example of a following*

– **Number of possible groupings is reduced the to a single optimized grouping for each possible starting point.**

Pixels of high local quality are most likely to belong to large structures ; they give the starting points of a first selection of good solutions.

– **The groupings are extracted by following the local connections from one pixel to another.**

The following stops when the grouping comes to a dead end (a loop or the boundaries of the image).

Selection of the curves

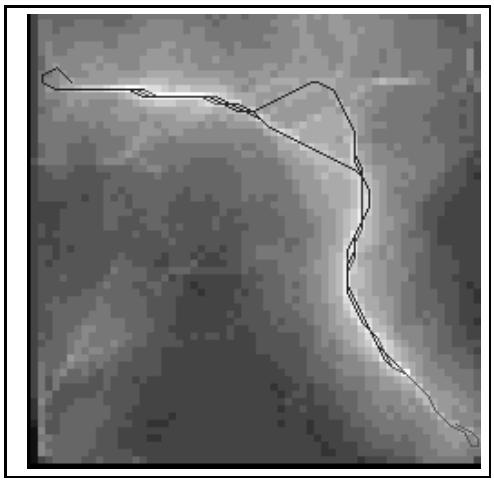

FIG. 7 - *Quality map and example of a following*

The optimized curves are divided into classes of similar curves

A selection process is necessary to extract the best solution from each class.

- **Global quality for each curve.**

  Sum of the local qualities for the connections along the curve.

- **Possible solutions are refined by a "badness" factor.**

  Number of pixels from the crest lines image relatively to the number of pixels added to fill gaps.

- **Selection of the curves.**

  The selected curves correspond to starting points representing a local maximum for the corrected global quality.

  This method proposes a first "automatic" selection of curves. Other curves may have to be rejected or added manually after this selection.

Results on Noisy Images

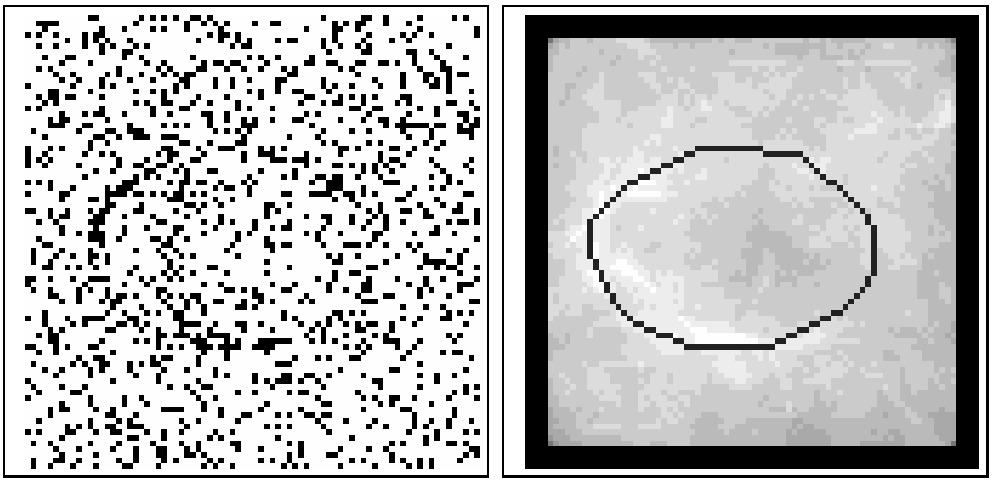

FIG. 8 - *Ellipse with with noise*

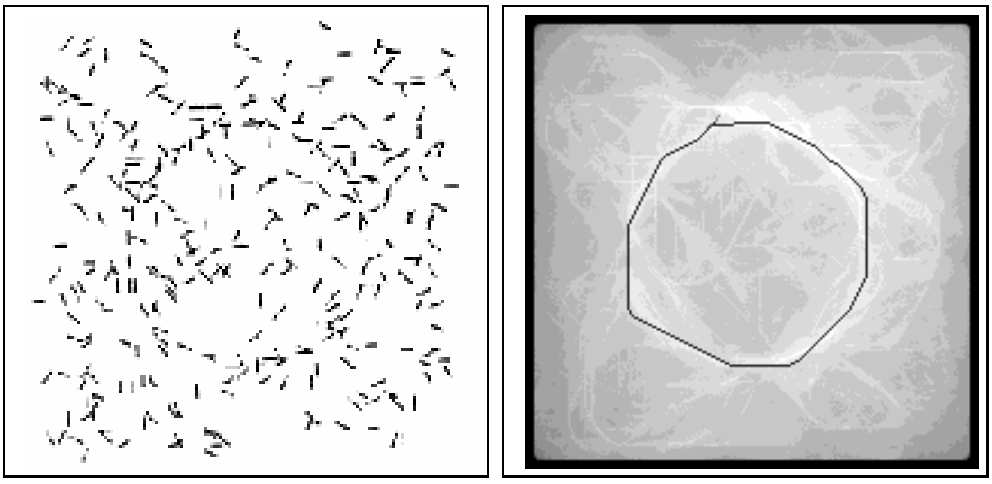

FIG. 9 - *Circle with Segments Noise*

Results on Noisy Images

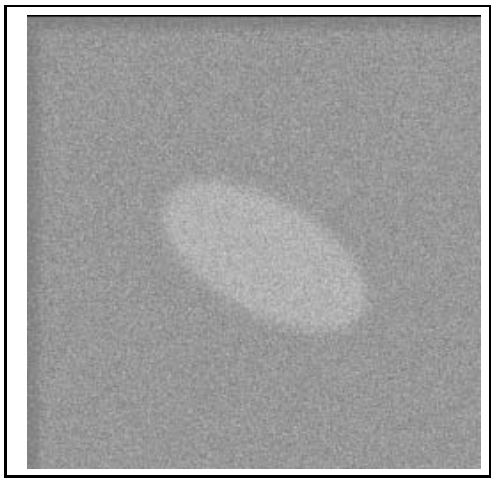

FIG. 10 - *Ellipse with Gaussian Noise*

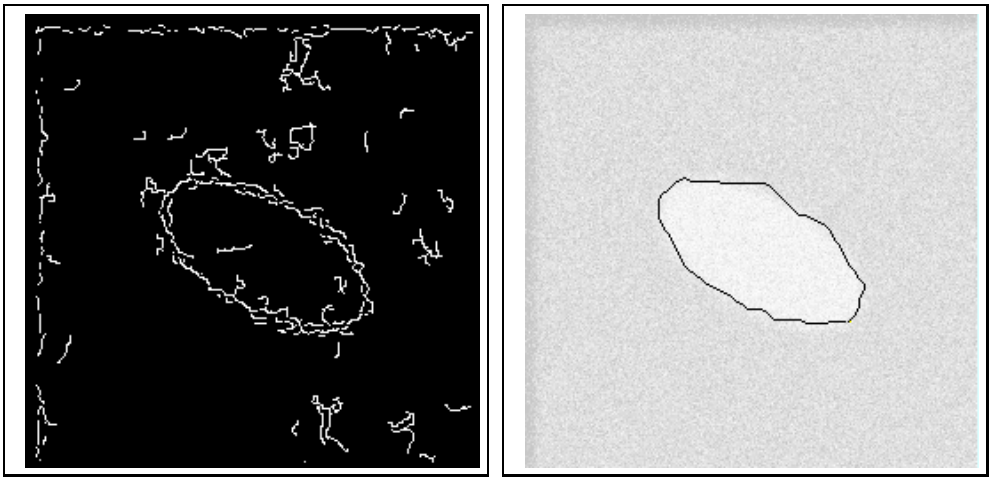

FIG. 11 - *Ellipse with Gaussian Noise*

Results on Real Applications

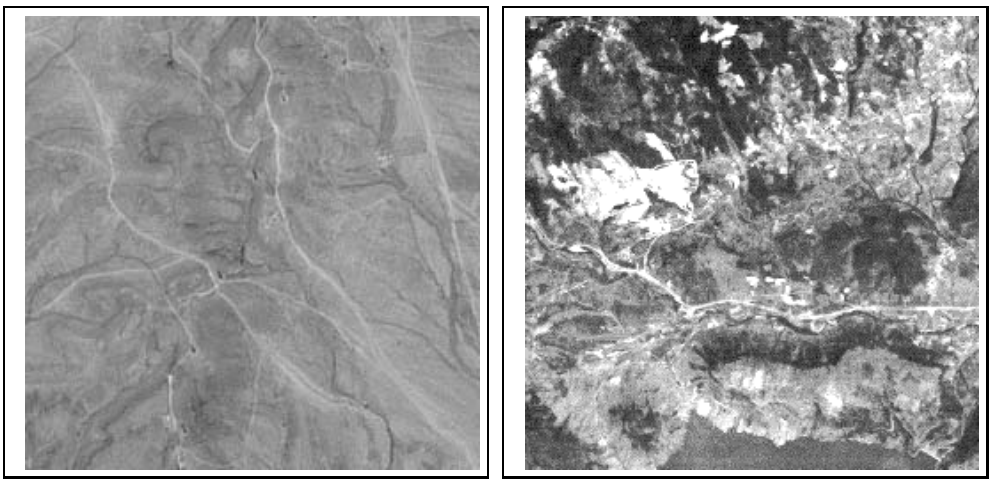

FIG. 12 - *Mountain scenes - Original Images*

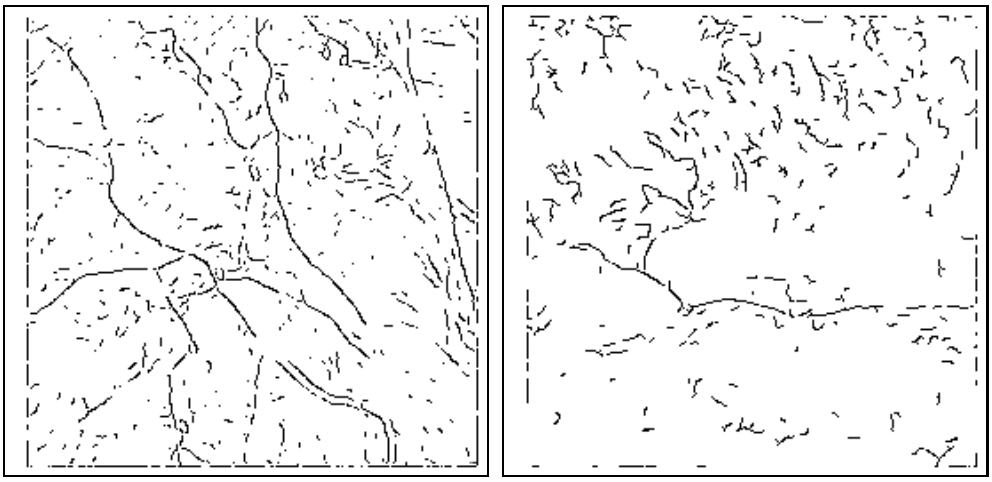

FIG. 13 - *Mountain scenes - After crest lines detection*

FIG. 14 - *Mountain scenes - Final selection of the main groupings*

Results on Real Applications

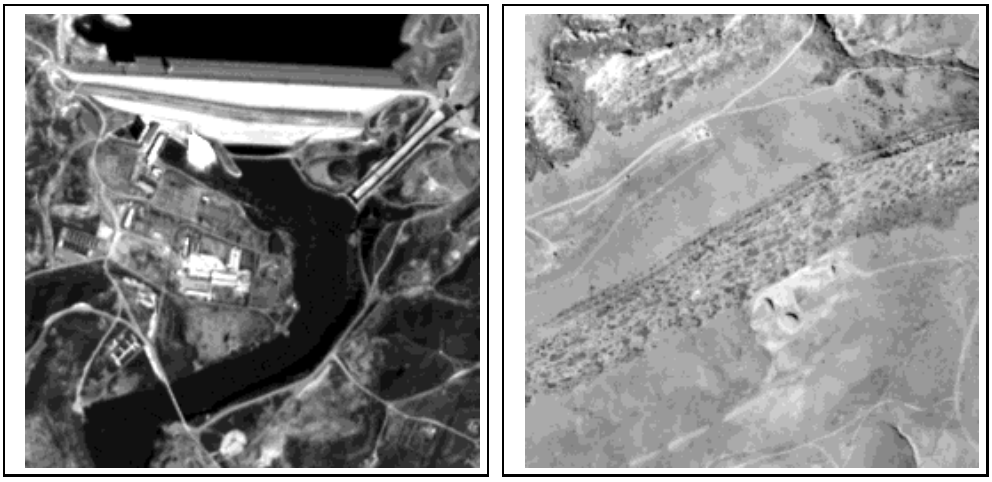

FIG. 15 - *Dam and Desert scenes - Original Images*

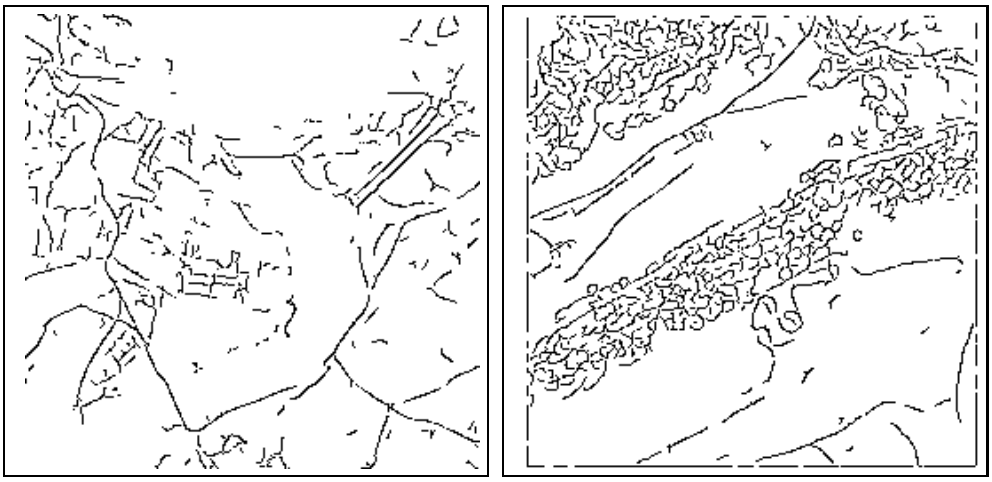

FIG. 16 - *Dam and Desert scenes - After crest lines detection*

FIG. 17 - *Dam and Desert scenes - Final selection of the main groupings*

Conclusion

- Extraction of main groupings automatically with no prior knowledge about the shapes.

- **Good initialization for further higher level processing** such as model based shape recognition or active contours optimization.

- **Robustness to noise** and **adaptability to different situations with little changes in the parameters** (once the correct settings are found, the detection remains significantly good for different images).

- In the future, we plan to focus on **more complex groupings** and adapt this method to the **extraction of 2D and 3D curves**.