



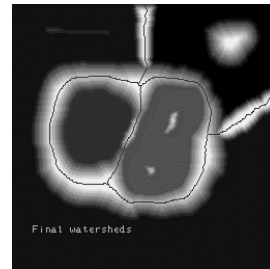
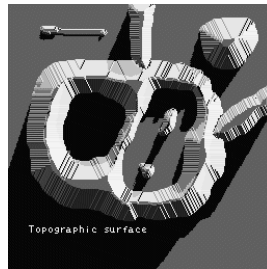
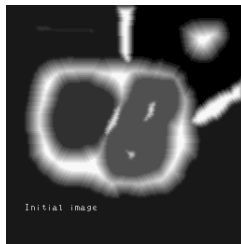
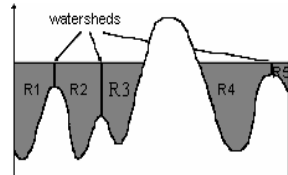
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Definition & Usage

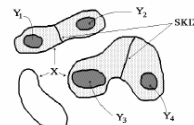
- Tool for morphological image segmentation.
- **Process:** Grey tone image → topographic surface → flooding → catchment basins → watershed lines



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Mathematical Background

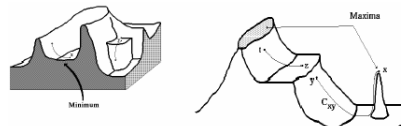
- **gradient**
detects the amplitude edges at which gray-levels change suddenly
- **geodesic zone of influence**
set of points closer to Y_i than Y_j
SKIZ = boundaries between



- **distance function**
the distance of every point to the complementary set



- **minima and maxima**



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Algorithms, Examples

Algorithmic definition by immersion (Vincent and Soille)

Recursion with the grey level increasing from h_{min} to h_{max} , in which the basins associated with the minima of the grey-value image are successively expanded.

The following figure shows a simple Example of how the algorithm works. This example is based on 4-connectivity:

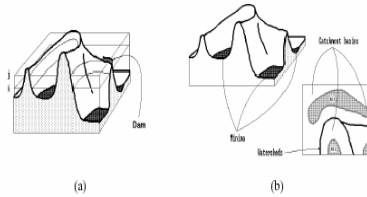


figure 5. Flooding of the relief and dam building (a) catchment basins and divide lines (b)

3	2	2	3	2	2	3	2	2	3	B	B	B	B	B
3	1	1	3	1	1	3	W	B	3	B	B	W	B	B
0	1	0	A	1	B	A	W	B	A	W	B	A	W	B

(a) (b) $h = 0$ (c) $h = 1$ (d) $h = 2$ (e) $h = 3$

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Algorithms, Examples

Algorithmic definition by topographical distance

$CB(m_i)$ is the set of points in the upstream of a single minimum m_i . The watershed consists of the points p which are in the upstream of at least two minima, i.e., there are at least two paths of steepest descent starting from p which lead to minima. Any pixel in the upstream of a watershed pixel is itself a watershed pixel (→ thick watersheds).

lower complete: each node which is not in a minimum has a neighbouring node of lower value

5	4	3	2	3	4	5	W	W	W	B	W	W	W	W	B	B	B	B	B	W
4	3	2	1	2	3	4	W	W	W	B	W	W	W	A	W	B	B	B	W	C
3	2	1	0	1	2	3	W	W	W	B	W	W	W	A	A	W	B	W	C	C
2	1	0	1	0	1	2	A	A	A	W	C	C	C	A	A	A	W	C	C	C
3	2	1	0	1	2	3	W	W	W	D	W	W	W	A	A	W	D	W	C	C
4	3	2	1	2	3	4	W	W	W	D	W	W	W	A	W	D	D	D	W	C
5	4	3	2	3	4	5	W	W	W	D	W	W	W	W	D	D	D	D	D	W

(a) (b) (c)

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Algorithms, Examples

Topographical distance by *Hill Climbing*

- 1: *Input: lower complete digital grey scale image (V,E, im).*
- 2: *Output: labelled image lab on V.**
- 3: `#define wshed 0 (* label of the watershed pixels *)`
- 4:
- 5: `LabelInit (*initialize image lab with distinct labels for minima *)`
- 6: `(* and special label mask for all other pixels *)`
- 7: `(* interior pixels of minima excluded *)`
- 8: `while not empty(S) do`
- 9: `select point p from S with minimal grey value;`
- 10: `remove p from S;`
- 11: `for all steepest upper neighbours of p`
- 12: `if lab[q] == mask then`
- 13: `lab[q] = lab[p];`
- 14: `else if ((lab[q] != wshed) and (lab[q] != lab[p])) then`
- 15: `lab[q] = wshed;`
- 16: `end if`
- 17: `end for`
- 18: `end while`

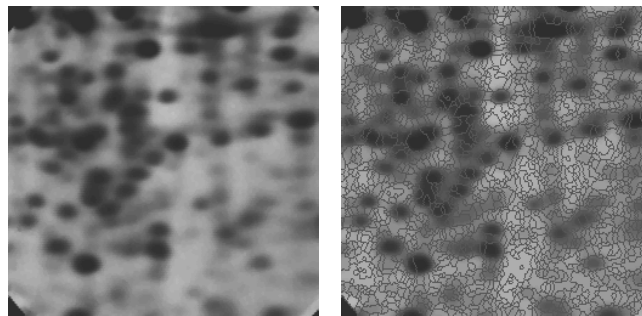
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Problems

- *Oversegmentation*

The original watershed method produces severe oversegmentation.

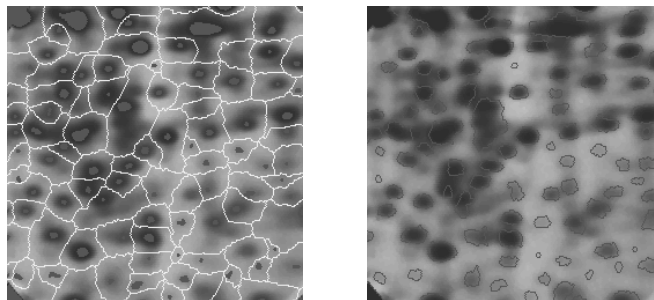
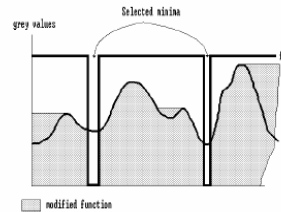
many local minima → small basins → a lot of watersheds



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Solutions

- **Marker controlled watershed**
 Mark patterns to be segmented →
 make minima of the marker set M →
 As many catchment basins as there are
 markers

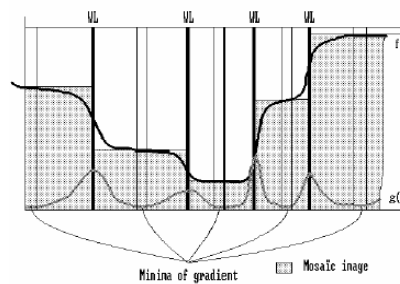


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Solutions

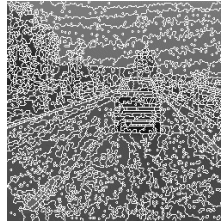
- **The mosaic image: Hierarchical segmentation**

watershed of gradient → label every catchment basin
 with grey value of initial image corresponding to the
 minima of the gradient → simplified image → fusion
 criteria → repeat process



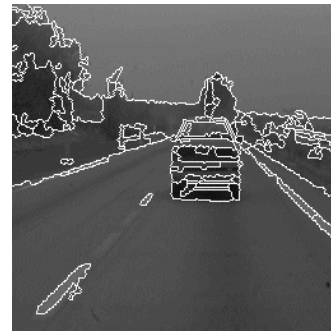
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Solutions



Initial image (left) and initial watershed of the gradient (right).

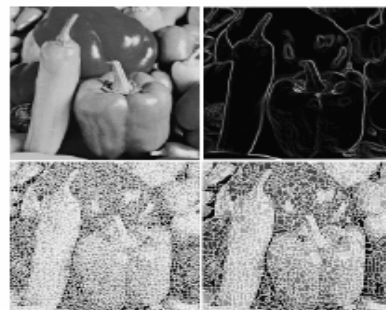
Mosaic image (left) and first level of hierarchy (right).



Conclusion & Outlook

- Provides closed contours.
- Good match of contours even if over-segmented.
- Can be applied in many situations.
- Preprocessing (markers) necessary.

- WT applied to colour prints
- Local WT, extracting regions of interest (ROI)



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References

- <http://cmm.ensmp.fr/~beucher/publi/pfefferkorn.pdf>
- <http://oldwww.rug.nl/hpc/people/arnold/articles/fundamenta.pdf>
- <http://www.gris.uni-tuebingen.de/publics/paper/Stoev-2000-RafSi.pdf>
- <http://cmm.ensmp.fr/~beucher/wtshed.html>

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