MEANINGFUL DISJOINT LEVEL LINES SELECTION

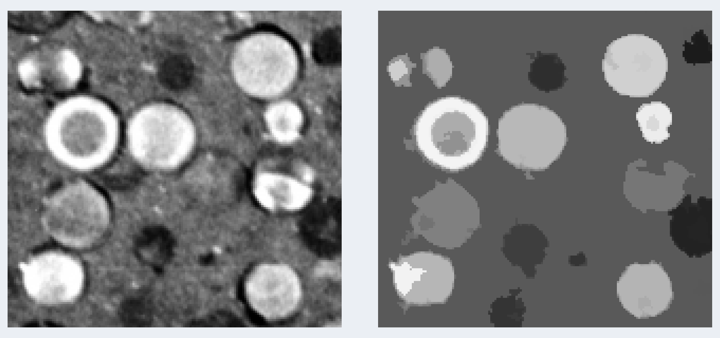
Yongchao Xu[1,2], Edwin Carlinet[1,2], Thierry Géraud[1], Laurent Najman[2]

[1]EPITA Research and Development Laboratory (LRDE), France

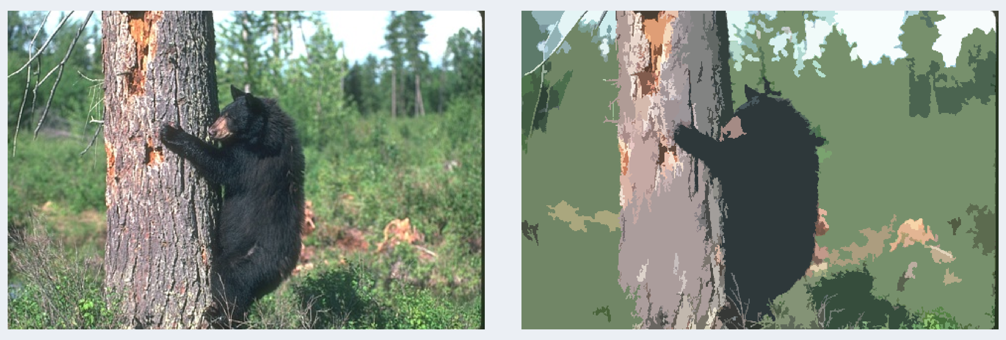
[2]Université Paris-Est, Laboratoire d'Informatique Gaspard-Monge (LIGM), ESIEE Paris, France

{firstname.lastname}@lrde.epita.fr, l.najman@esiee.fr

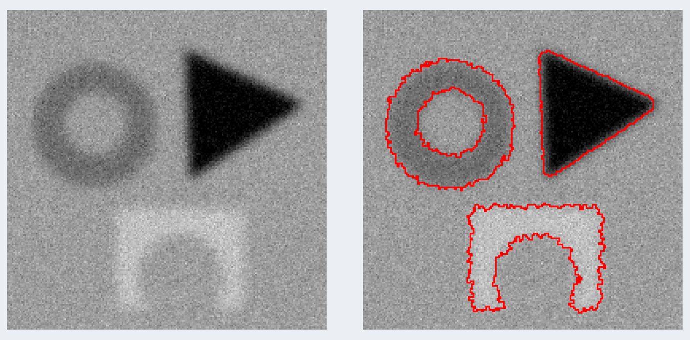
Tree of shapes $\mathcal{T}$ [1, 2]: a versatile tool for many applications



Shape filtering (ICPR 2012).



Energy-driven simplification (ICIP 2013).



Object segmentation (ICIP 2012).

Hierarchical image segmentation (ISMM 2013).

These results are from the PhD work [3] supervised by T. Géraud & L. Najman available in http://www.lrde.epita.fr/wiki/User:Xu ⟶

At a glance

Motivation

- Significant contours of objects ⇔ segments of level lines [1]
- Inclusion relationship ⇒ tree of shapes $\mathcal{T}$ [2]: a versatile representation
- The knowledge of tree structure is fundamental for a deep tree analysis

Problem

- The number of shapes is about as large as the number of pixels

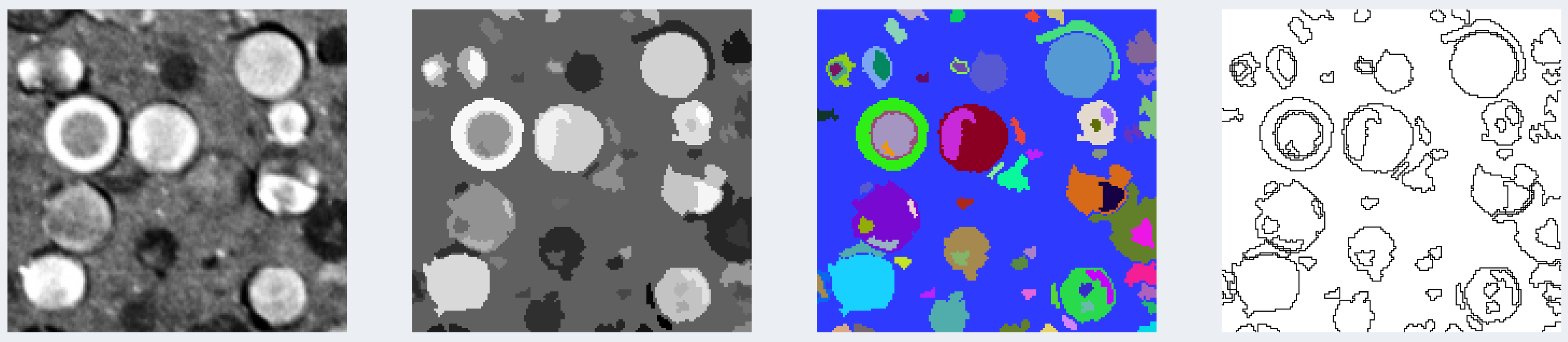
Objective

- Select a subset of level lines representing the main tree structure

Contribution

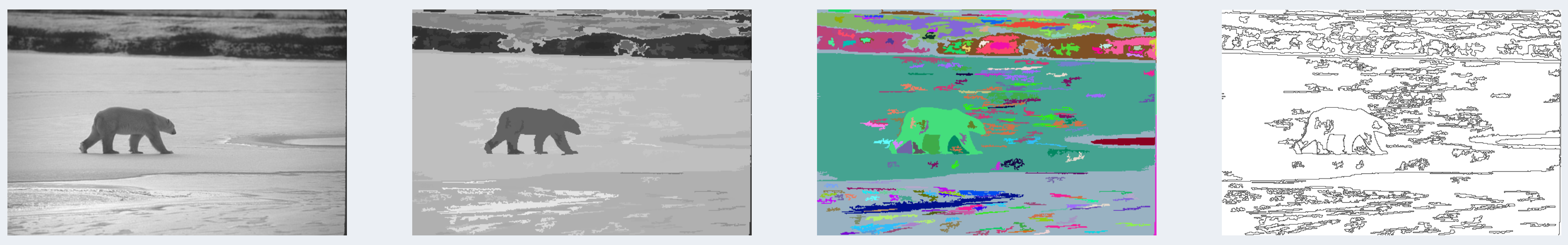
- An efficient algorithm for extracting meaningful and disjoint level lines
- A simplified image providing an intuitive idea about main tree structure

Some effective results



Input f 9944 level lines. Output f' 72 level lines. Randomly colorized f'. Extracted level lines.

Selection based on decreasing order of circularity



Input f 45578 level lines. Output f' 220 level lines. Randomly colorized f'. Extracted level lines.

Selection using decreasing order of mean gradient ∇

Basic idea

Select a subset of meaningful and disjoint level lines from the tree of shapes $\mathcal{T}$ to represent the main tree structure; Two main ideas:

1. $\forall \mathcal{N} \in \mathcal{T}$, find its lowest ancestor shape $\mathcal{N}'$: Smallest Enclosing Shape $\mathrm{SES}(\mathcal{N})$, such that $\mathcal{N} \subseteq \mathcal{N}', \partial\mathcal{N}' \cap \partial\mathcal{N} = \emptyset$.
2. $\forall \mathcal{N} \in \mathcal{T}$ in some *Order*, select $\mathcal{N}$ if it is not deactivated by any descendant, and none of $[\mathcal{N} \rightsquigarrow \mathrm{SES}(\mathcal{N})[$ is selected, then deactivate $[\mathcal{N} \rightsquigarrow \mathrm{SES}(\mathcal{N})[$.

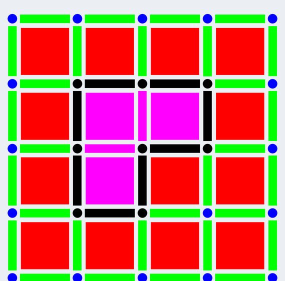
Algorithm overview: three main steps

1. Tree of shapes construction: use the union-find-based algorithm in [4] to compute the set of all level lines.
2. SES computation: bottom-up traversal updating based on the nodes' depth
3. Level lines selection: sequential test based on the status of $[\mathcal{N} \rightsquigarrow \mathrm{SES}(\mathcal{N})[$

Smallest Enclosing Shape (SES) computation

The algorithm in [4] works on Khalimsky grid $\mathcal{K}_\Omega$. A shape is represented by a 2-face; *parent*: inclusion relationship; getCanonical: canonical element.

COMPUTE_SES(*parent*, *S*, *depth*)
foreach x *in* $\mathcal{K}_\Omega$ **do** $\mathrm{SES}(x) \leftarrow \mathrm{getCanonical}(x)$
foreach 2-face x in reverse order of S **do**
    foreach 0 and 1-face e in $\bar{x}$ **do**
        if $depth(e) < depth(\mathrm{SES}(x))$ **then**
            $\mathrm{SES}(x) \leftarrow \mathrm{getCanonical}(e)$
    $q \leftarrow parent(x)$;
    if $depth(\mathrm{SES}(x)) < depth(\mathrm{SES}(q))$ **then**
        $\mathrm{SES}(q) \leftarrow \mathrm{SES}(x)$
return SES

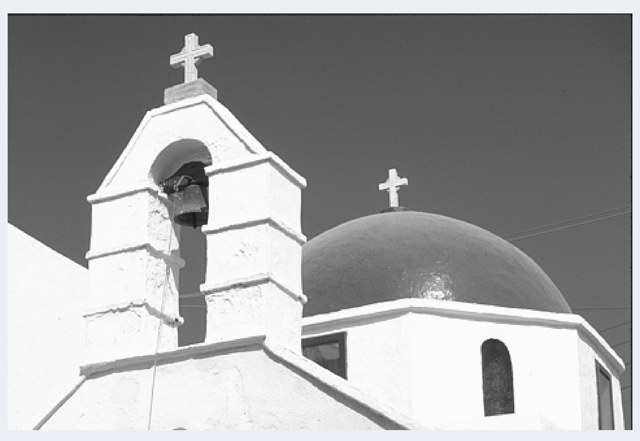


Khalimsky grid: 0-faces (small disks), 1-faces (strips), and 2-faces (squares).

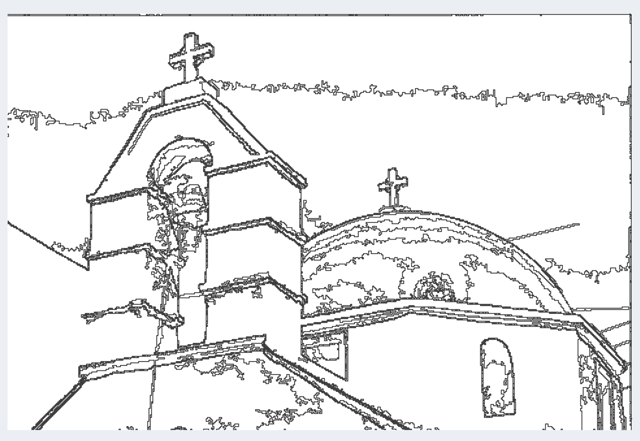
Final disjoint level lines S' selection

SELECT_LEVEL_LINES(*parent*, SES, *Order*)
foreach x *in* $\mathcal{K}_\Omega$ **do** $status(x) \leftarrow Null$;
$S' = \emptyset$;
foreach canonical element x in *Order* **do**
    if $status(x) \neq Unactive$ **then**
        $y \leftarrow parent(x)$;
        while $y \neq \mathrm{SES}(x)$ **and** $status(y) \neq Active$ **do** $y \leftarrow parent(y)$;
        if $y = \mathrm{SES}(x)$ **then**
            $status(x) \leftarrow Active$;
            $S' \leftarrow S' \cup \{x\}$;
            $y \leftarrow parent(x)$;
            while $y \neq \mathrm{SES}(x)$ **do** $status(y) \leftarrow Unactive$; $y \leftarrow parent(y)$;
return S'

Comparison with different selection orders



Input image; 35990 level lines;



Every 15 levels; 99 level lines.

Bottom-up selection; 121 level lines.

Top-down selection; 89 level lines.

Decreasing of mean ∇; 86 level lines.

References

[1] V. Caselles, B. Coll, and J. Morel, "**Topographic maps and local contrast changes in natural images**," *International Journal of Computer Vision*, vol. 33, no. 1, pp. 5–27, 1999.

[2] P. Monasse and F. Guichard, "**Fast computation of a contrast-invariant image representation**," *IEEE Transactions on Image Processing*, vol. 9, no. 5, pp. 860–872, 2000.

[3] Y. Xu, "**Tree-based shape spaces: Definition and applications in image processing and computer vision**," *PhD Thesis, Univ. Paris-Est, Marne-la-Vallée, France*, Dec 2013.

[4] T. Géraud, E. Carlinet, S. Crozet, and L. Najman, "**A quasi-linear algorithm to compute the tree of shapes of nD images**," in *Proc. of ISMM*, LNCS 7883, pp. 98–110, 2013.

21st International Conference on Image Processing (ICIP) Paris, France -- October 27-30, 2014