A First Parallel Algorithm to Compute the Morphological Tree of Shapes of nD Images

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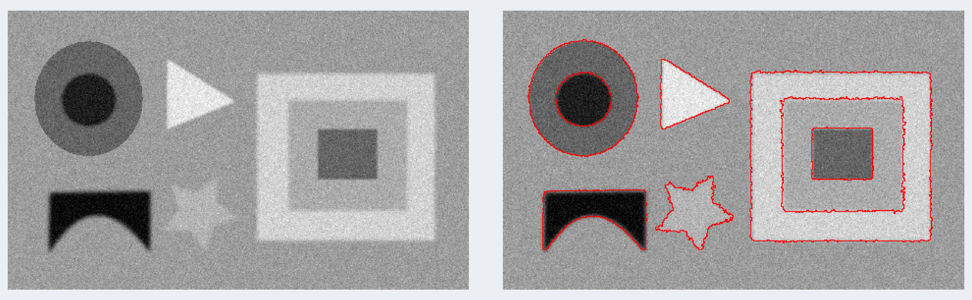
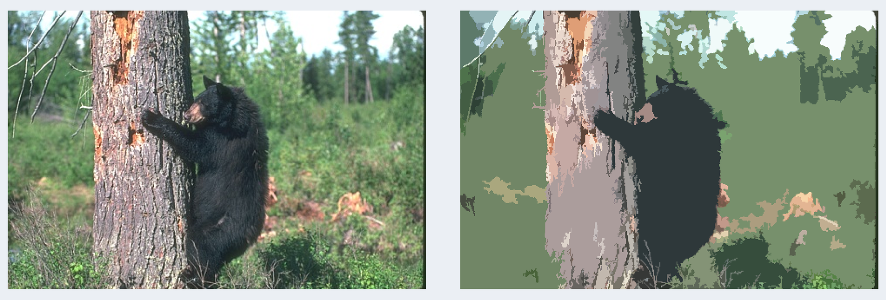
The Tree of Shapes [1,4] as a Versatile Tool

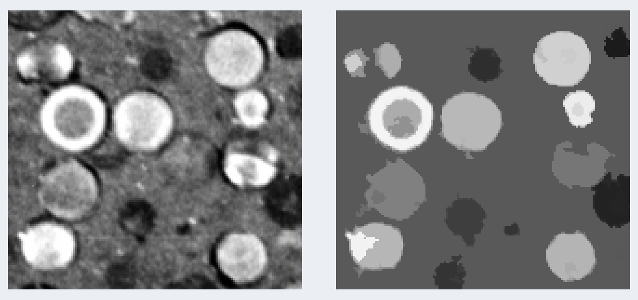


Object Detection (ICIP 2012)



Energy-Driven Simplification (ICIP 2013)

Hierarchy of Segmentations (ISMM 2013)



Shape Filtering (ICPR 2012)

All those results are from Yongchao Xu: http://www.lrde.epita.fr/wiki/User:Xu

At a Glance

Problem statement

- tree of shapes = self-dual morphological tree-based image representation
- a quasi-linear algorithm exists [5], yet it is sequential

Why is it interesting

- tree = easy structure to deal with
- nice properties: invariance to contrast changes and inversion
- numerous and powerful applications *(see the banner above)*

What our solution achieves

- a 1st parallel version of the quasi-linear algorithm, and ready for nD
- increasing size of data to process $\leadsto$ no problemo :)

What follows from our solution

- soon, processing 3D images with powerful self-dual morphological tools...

Algorithmic Scheme of the Sequential Version [5]

function COMPUTETREE(f, p_∞)
  $\mathcal{F} \leftarrow$ IMMERSE(f)
  $(\mathcal{R}, \mathcal{F}^\flat) \leftarrow$ SORT($\mathcal{F}$, p_∞)
  $par \leftarrow$ UNIONFIND(reverse($\mathcal{R}$))
  return CANONICALIZE(par, $\mathcal{R}$, $\mathcal{F}^\flat$)
end function

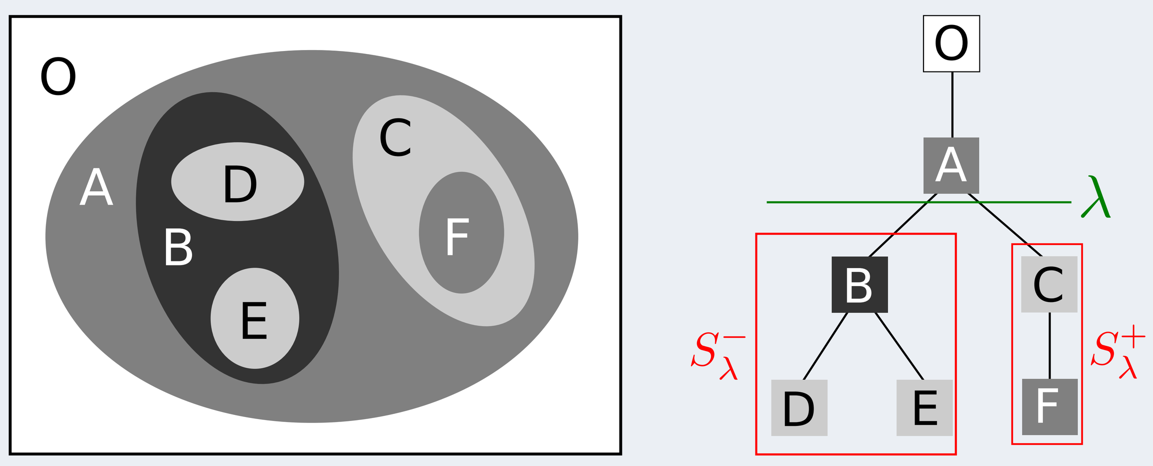
Algorithmic Scheme of the Parallel Version NEW!

function COMPUTETREE(f, p_∞)
  $\mathcal{F} \leftarrow$ PARALLELIMMERSE(f) ▷ trivial
  $\lambda \leftarrow$ mean($\mathcal{F}(p_\infty)$)
  $Q[\lambda] \leftarrow p_\infty$
  $\mathcal{F}^{ord} \leftarrow$ PARALLELSORT($\mathcal{F}$, Q, λ, 0) →
  $par \leftarrow$ PARALLELMAXTREE($\mathcal{F}^{ord}$) ▷ see [2] and [3]
  return CANONICALIZE(par, $\mathcal{F}^{ord}$)
end function

Parallel Sort NEW!

procedure PARALLELSORT($\mathcal{F}$, Q, $\mathcal{F}^{ord}$, λ, ord)
  $Q[\lambda] \leftarrow p_\infty$
  while any queue of Q is not empty **do**
    while $Q[\lambda]$ is not empty **do**
      $p \leftarrow$ POP($Q[\lambda]$), $\mathcal{F}^{ord}(p) \leftarrow ord$
      for all $n \in \mathcal{N}_4(p)$ that has not been visited yet **do**
        if $\lambda \in \mathcal{F}(n)$ **then** PUSH($Q[\lambda]$, n)
        else if $\lambda < \min(\mathcal{F}(n))$ **then** PUSH($Q[\min(\mathcal{F}(n))]$, n)
        else PUSH($Q[\max(\mathcal{F}(n))]$, n)
        end if
      end for
    end while
    $ord \leftarrow ord + 1$
    $S^-_\lambda \leftarrow Q[0..\lambda]$, $S^+_\lambda \leftarrow Q[\lambda..$max value$]$
    $\lambda' \leftarrow$ highest level having faces on S^-_λ
    Run PARALLELSORT($\mathcal{F}$, $S^-_{\lambda'}$, $\mathcal{F}^{ord}$, λ', ord) on another thread.
      ▷ This thread continues with S^+_λ
    $Q \leftarrow S^+_\lambda$
    $\lambda \leftarrow$ smallest level having faces on S^+_λ
  end while
  Wait for all child processes.
end procedure

example ▼

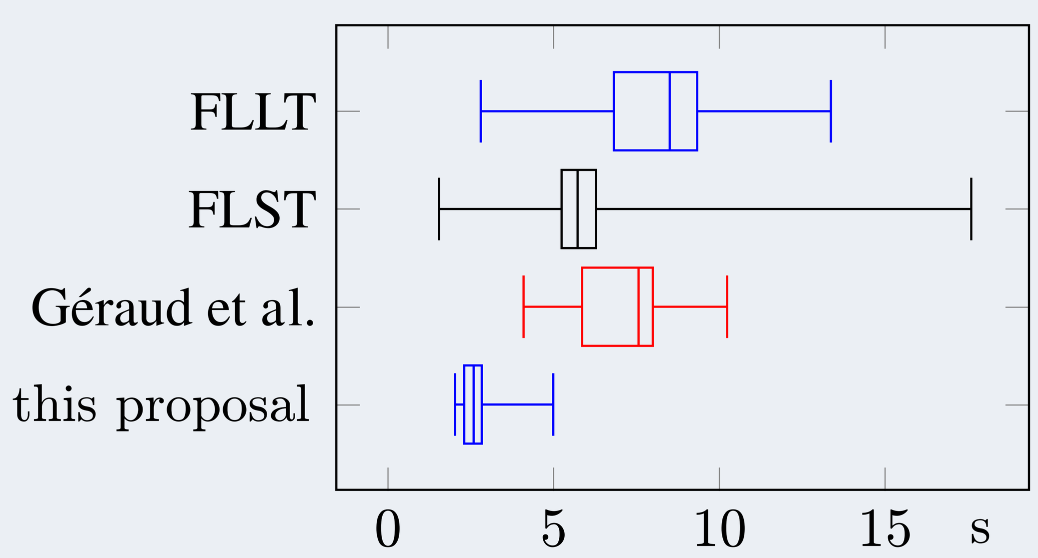


An image and its tree of shapes. The nodes O and A have already been visited. The hierarchical queue contains the interior contour of B and C. It is partitioned in two sets $S^+_\lambda = \partial B$ and $S^-_\lambda = \partial C$.

Reproducible Research Evangelization from the Church of Mathematical Morphology

our C++ image processing library "Milena" → http://olena.lrde.epita.fr
full source code of our method → http://publis.lrde.epita.fr/crozet.14.icip →

Comparison



Computation times (in seconds) on a classical image test set of the following algorithms: FLLT [1], FLST [4], Géraud *et al.* [5], and this paper proposal.

Bibliography

[1] P. Monasse and F. Guichard, "**Fast Computation of a Contrast-Invariant Image Representation**," in *IEEE Trans. on Image Processing*, vol. 9, no. 5, pp. 860–872, 2000.

[2] P. Matas *et al.*, "**Parallel Algorithm for Concurrent Computation of Connected Component Tree**," *Adv. Concepts for Intelligent Vision Systems*, pp. 230–241, 2008.

[3] M.H.F. Wilkinson *et al.*, "**Concurrent Computation of Attribute Filters on Shared Memory Parallel Machines**," *IEEE Trans. on PAMI*, vol. 30, no. 10, pp. 1800–1813, 2008.

[4] V. Caselles and P. Monasse, "**Geometric Description of Images as Topographic Maps**," in *Lecture Notes in Computer Science* ser., vol. 1984, Springer, 2009.

[5] T. Géraud and E. Carlinet and S. Crozet and L. Najman, "**A Quasi-Linear Algorithm to Compute the Tree of Shapes of n-D Images**," in *Proc. of the Intl. Symposium on Mathematical Morphology (ISMM)*, vol. 7883 of LNCS, Springer, pp. 98–110, 2013.

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