A 1ST PARALLEL ALGORITHM TO COMPUTE THE MORPHOLOGICAL TREE OF SHAPES OF nD IMAGES

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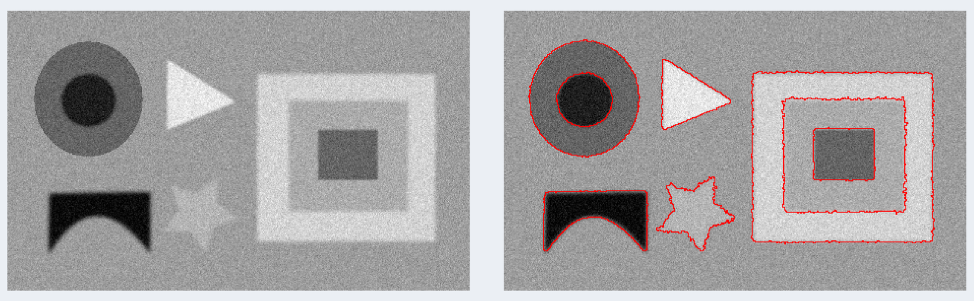
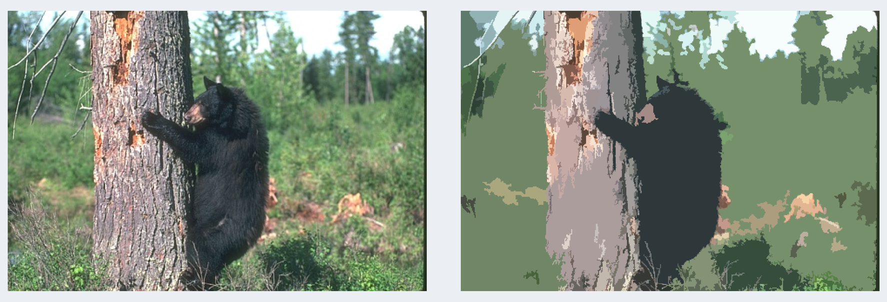
The Tree of Shapes [1,4] as a Versatile Tool

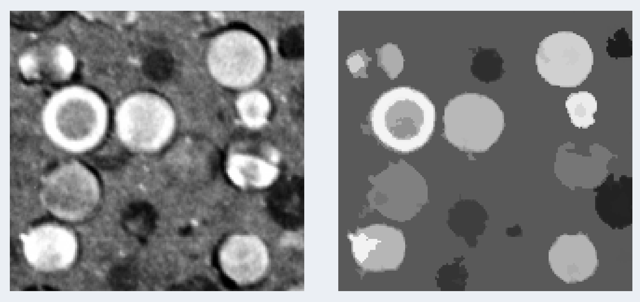


Object Detection (ICIP 2012)



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 $\rightsquigarrow$ 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 $\text{ComputeTree}(f, p_\infty)$
  $\mathcal{F} \leftarrow \text{Immerse}(f)$
  $(\mathcal{R}, \mathcal{F}^\flat) \leftarrow \text{Sort}(\mathcal{F}, p_\infty)$
  $par \leftarrow \text{UnionFind}(\text{reverse}(\mathcal{R}))$
  return $\text{Canonicalize}(par, \mathcal{R}, \mathcal{F}^\flat)$
end function

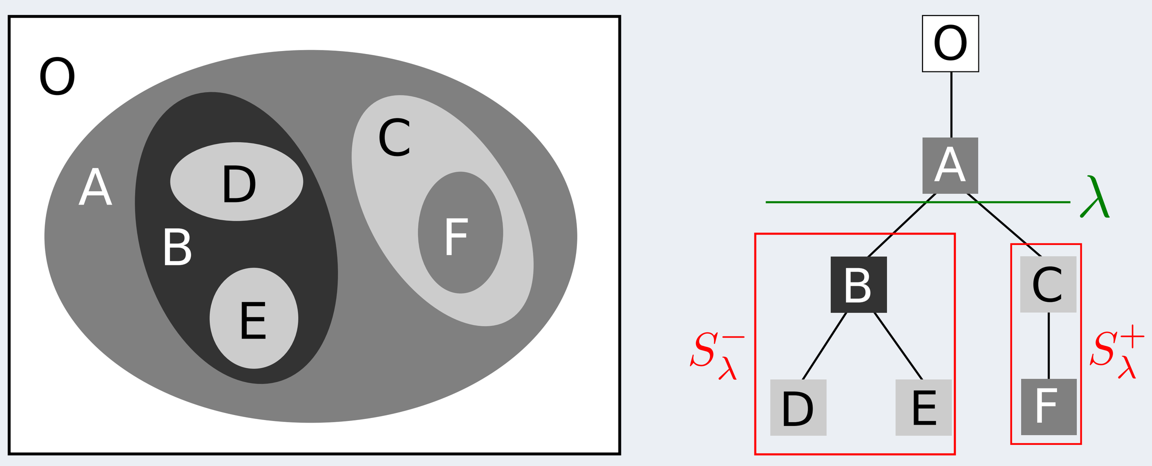
Algorithmic Scheme of the Parallel Version NEW!

function $\text{ComputeTree}(f, p_\infty)$
  $\mathcal{F} \leftarrow \text{ParallelImmerse}(f)$ ▷ trivial
  $\lambda \leftarrow \text{mean}(\mathcal{F}(p_\infty))$
  $Q[\lambda] \leftarrow p_\infty$
  $\mathcal{F}^{\text{ord}} \leftarrow \text{ParallelSort}(\mathcal{F}, Q, \lambda, 0)$ →
  $par \leftarrow \text{ParallelMaxTree}(\mathcal{F}^{\text{ord}})$ ▷ see [2] and [3]
  return $\text{Canonicalize}(par, \mathcal{F}^{\text{ord}})$
end function

Parallel Sort NEW!

procedure $\text{ParallelSort}(\mathcal{F}, Q, \mathcal{F}^{\text{ord}}, \lambda, ord)$
  $Q[\lambda] \leftarrow p_\infty$
  while any queue of Q is not empty **do**
    while $Q[\lambda]$ is not empty **do**
      $p \leftarrow \text{Pop}(Q[\lambda])$, $\mathcal{F}^{\text{ord}}(p) \leftarrow ord$
      for all $n \in \mathcal{N}_4(p)$ that has not been visited yet **do**
        if $\lambda \in \mathcal{F}(n)$ **then** $\text{Push}(Q[\lambda], n)$
        else if $\lambda < \min(\mathcal{F}(n))$ **then** $\text{Push}(Q[\min(\mathcal{F}(n))], n)$
        else $\text{Push}(Q[\max(\mathcal{F}(n))], n)$
        end if
      end for
    end while
    $ord \leftarrow ord + 1$
    $S^-_\lambda \leftarrow Q[0..\lambda]$, $S^+_\lambda \leftarrow Q[\lambda..\text{max value}]$
    $\lambda' \leftarrow$ highest level having faces on S^-_λ
    Run $\text{ParallelSort}(\mathcal{F}, S^-_\lambda, \mathcal{F}^{\text{ord}}, \lambda', ord)$ 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 $S^-_\lambda = \partial C$.

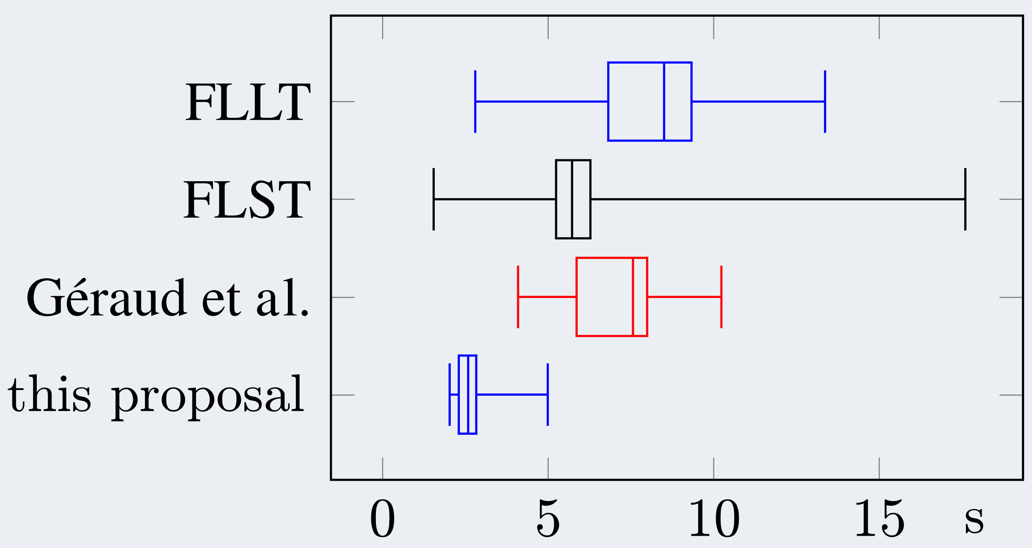
Reproducible Research

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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