Colour image filtering with component-graphs

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Motivation

Input image

Result

Problematic

How to filter a colour image without altering its contours?

Outline

Outline

Connected filters

Definition

- A filter is said *connected* if it acts by merging image flat-zones.
- A connected filter preserves the image contours: a contour is either entirely preserved or entirely removed.
- Designed in the field of mathematical morphology.

Applications

- Attribute filtering
- Object detection
- Segmentation

Connected filters

Image simplification

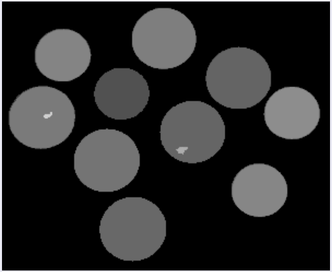
Input image

Area filtering

Connected filters

Shape detection

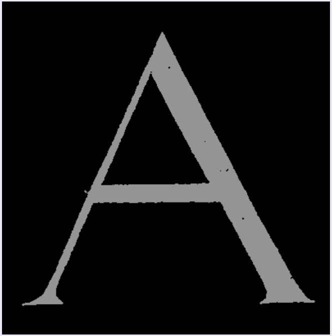

Input image


Compacity filtering

Connected filters

Segmentation

Input image

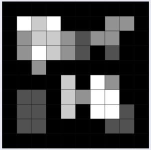


Segmentation

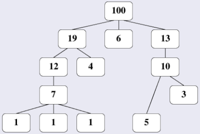
Connected filtering

Threshold decomposition

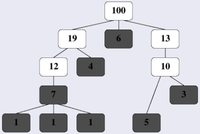
- A class of connected filters is based on image *threshold decomposition*.
- Efficient filters based on a tree-based image representation: the component-tree (or max-tree/min-tree).
- Limitation: applicable only on monovalued (grey-level) images.
- Purpose of this work: how to extend this scheme to colour images ?



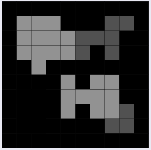
Input image



Component-tree



Tree filtering

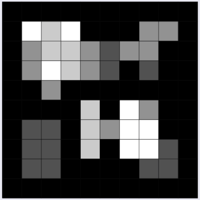


Result image

Outline

Component-tree (or max-tree) [Salembier98, Najman06]

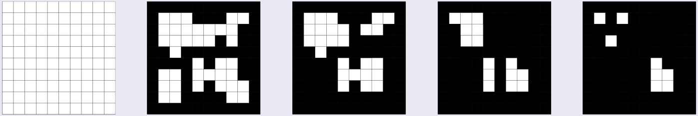
Definition



I

Threshold sets

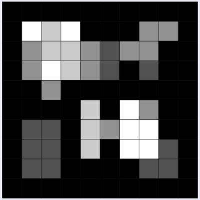
- Image $I : \Omega \to V$.
- Threshold sets of I : $\lambda_v(I) = \{x \in \Omega \mid v \leqslant I(x)\}$
- Connected components of threshold sets: $\mathcal{C}[\lambda_v(I)]$
- Union of all components: $\Phi = \bigcup_{v \in V} \mathcal{C}[\lambda_v(I)]$



$\lambda_0(I)$ $\lambda_1(I)$ $\lambda_2(I)$ $\lambda_3(I)$ $\lambda_4(I)$

Component-tree (or max-tree) [Salembier98, Najman06]

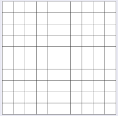
Definition



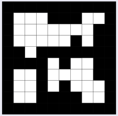
I

Component-tree $\mathfrak{T}$ of I

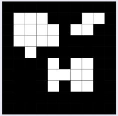
- Connected component $\rightarrow$ node
- Inclusion relation between two (different) connected components of successive threshold sets $\rightarrow$ edge
- Equivalent to the Hasse diagram of the partially ordered set $(\Phi, \subseteq)$.



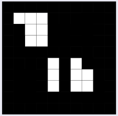
$\lambda_0(I)$



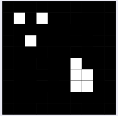
$\lambda_1(I)$



$\lambda_2(I)$



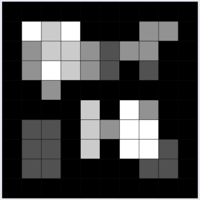
$\lambda_3(I)$



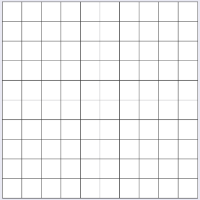
$\lambda_4(I)$

Component-tree (or max-tree) [Salembier98, Najman06]

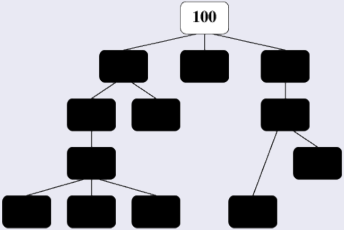
Construction



I



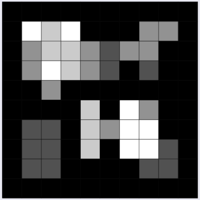
$\lambda_0(I)$



Component-tree of I : area attribute

Component-tree (or max-tree) [Salembier98, Najman06]

Construction



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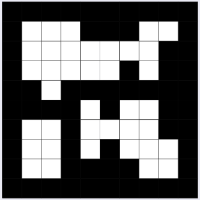
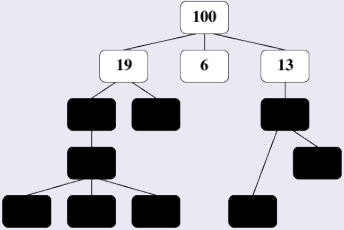


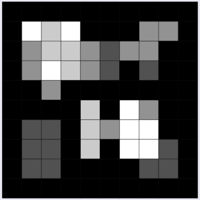
$\lambda_1(I)$



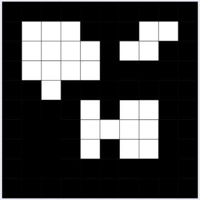
Component-tree of I : area attribute

Component-tree (or max-tree) [Salembier98, Najman06]

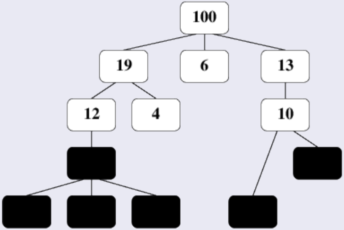
Construction



I



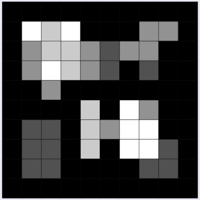
$\lambda_2(I)$



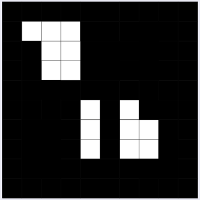
Component-tree of I : area attribute

Component-tree (or max-tree) [Salembier98, Najman06]

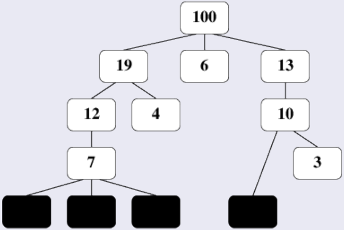
Construction



I



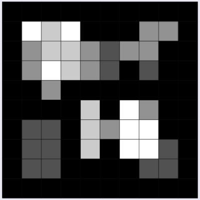
$\lambda_3(I)$



Component-tree of I : area attribute

Component-tree (or max-tree) [Salembier98, Najman06]

Construction



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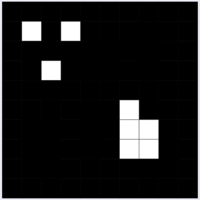
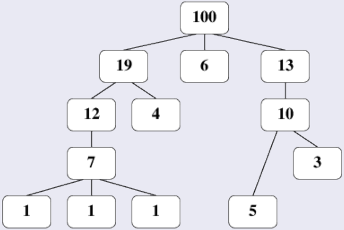


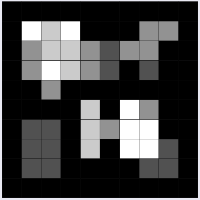
$\lambda_4(I)$



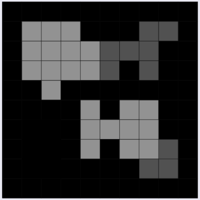
Component-tree of I : area attribute

Component-tree (or max-tree) [Salembier98, Najman06]

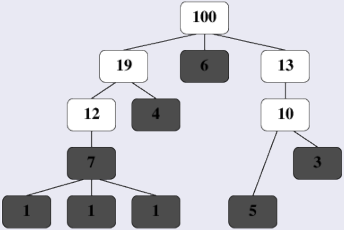
Pruning



I



Filtered image (area filtering)



Tree pruning based on the criterion:
$T(N) = area \geq 10$

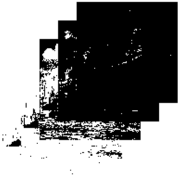
Outline

Component-graph

Problematic

- How to extend threshold based approaches to multivalued images ?

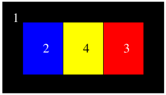
Grey-level image →



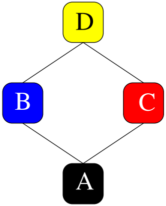
Threshold sets

Colour image →

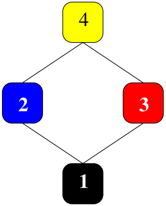
Component-graph



Input image I



Hasse diagram of values V



Component-graph of I

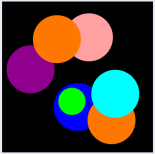
Threshold sets of I: partial ordering

Component-graph

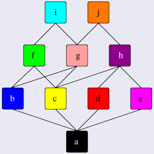
→ New structure introduced in [Passat2009, Naegel2013, Passat 2014]: the *component-graph*

Component-graph

Definition



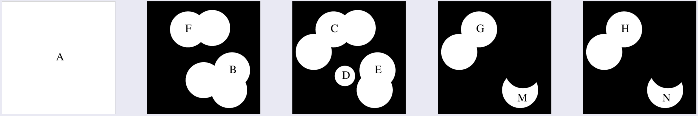
I



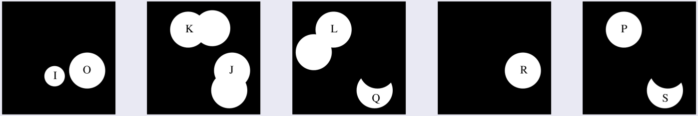
V

Set of valuated threshold components

- $\Theta = \bigcup_{v \in V} \mathcal{C}[\lambda_v(I)] \times \{v\}$
- Ordering relation: $(X_1, v_1) \trianglelefteq (X_2, v_2) \Leftrightarrow (X_1 \subset X_2) \vee ((X_1 = X_2) \wedge (v_2 \leqslant v_1))$



$\lambda_a(I)$ $\lambda_b(I)$ $\lambda_c(I)$ $\lambda_d(I)$ $\lambda_e(I)$

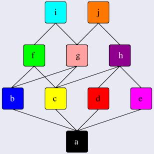


$\lambda_f(I)$ $\lambda_g(I)$ $\lambda_h(I)$ $\lambda_i(I)$ $\lambda_j(I)$

Component-graph

Definition

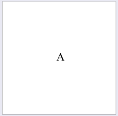
I



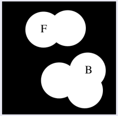
V

Component-graph

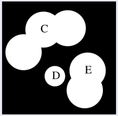
- The component-graph $\mathfrak{G}$ of I is the Hasse diagram $(\Theta, \blacktriangleleft)$ of the partially ordered set $(\Theta, \trianglelefteq)$.



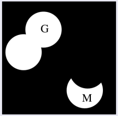
$\lambda_a(I)$



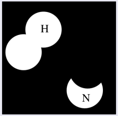
$\lambda_b(I)$



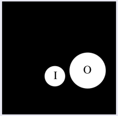
$\lambda_c(I)$



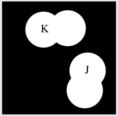
$\lambda_d(I)$



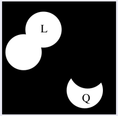
$\lambda_e(I)$



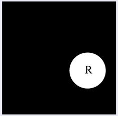
$\lambda_f(I)$



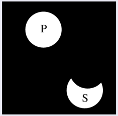
$\lambda_g(I)$



$\lambda_h(I)$



$\lambda_i(I)$

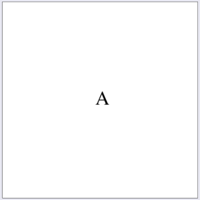


$\lambda_j(I)$

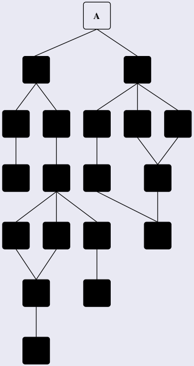
Component-graph

Definition

I



$\lambda_a(I)$

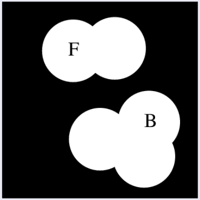


$\mathfrak{G}$

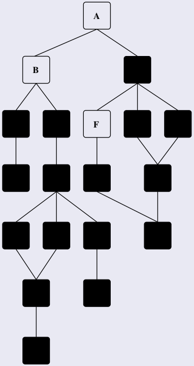
Component-graph

Definition

I



$\lambda_b(I)$

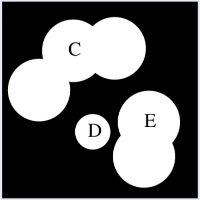


$\mathfrak{G}$

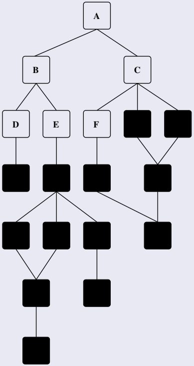
Component-graph

Definition

I



$\lambda_c(I)$

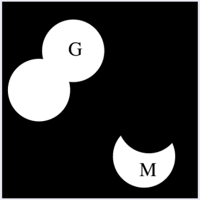


$\mathfrak{G}$

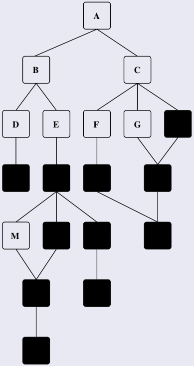
Component-graph

Definition

I



$\lambda_d(I)$

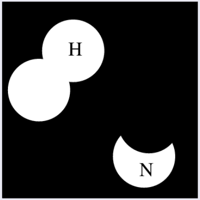


$\mathfrak{G}$

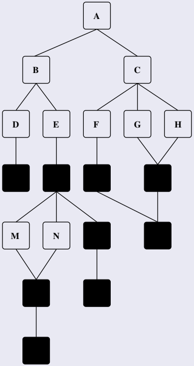
Component-graph

Definition

I



$\lambda_e(I)$

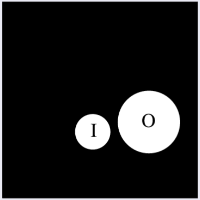


$\mathfrak{G}$

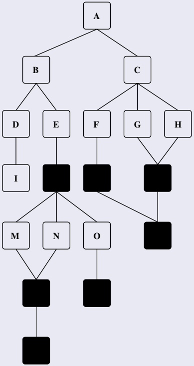
Component-graph

Definition

I



$\lambda_f(I)$

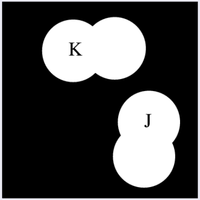


$\mathfrak{G}$

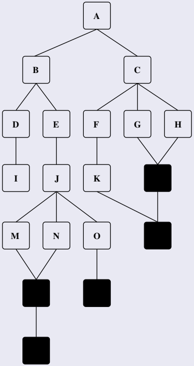
Component-graph

Definition

I



$\lambda_g(I)$

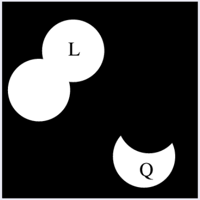


$\mathfrak{G}$

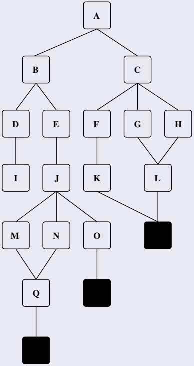
Component-graph

Definition

I



$\lambda_h(I)$

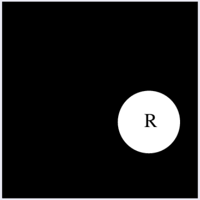


$\mathfrak{G}$

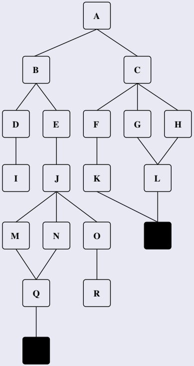
Component-graph

Definition

I



$\lambda_i(I)$

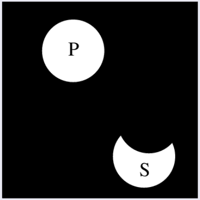


$\mathfrak{G}$

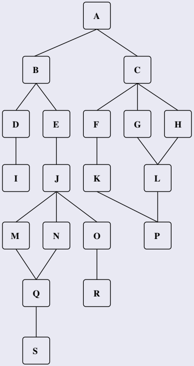
Component-graph

Definition

I



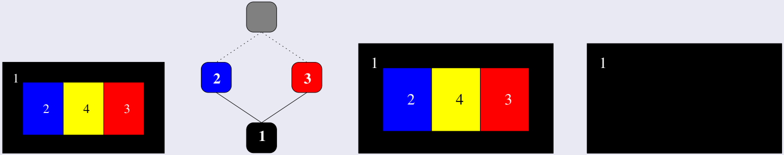
$\lambda_j(I)$



$\mathfrak{G}$

Component-graph pruning

Reconstruction problem



Input image Pruned graph Max policy Min policy

- How to reconstruct an image from the pruned graph (since blue and red are not comparable)?

Outline

Colour images

Space of values ?

- RGB space: $V = [0, 255]^3$
- HSV space
- ...

Ordering ?

- Marginal ordering: $V = [0, 255]^3$:
  $\forall v = (r, g, b), v' = (r', g', b') \in V, v \leqslant v' \Leftrightarrow r \leq r' \wedge g \leq g' \wedge b \leq b'$

Reconstruction policy

- Attribute filtering: remove all components that do not satisfy the criterion

$\rightarrow$ Min policy

Main strategy

Problems

- Algorithmic complexity $\mathcal{O}(N^2)$
- Space complexity (RGB space=16 millions of values)

Patch decomposition

- Attribute filtering: area, contrast (the “height” of component)
- Multithreading: decomposition of image in covering patches
- Each patch is filtered independantly

Adaptive filtering

- Pruning criterion is adapted for each patch (percentile based thresholding)

Colour images

Experimenting with RGB space

Original

Filtered (118 patches, $\alpha = 0.5$)

Original

Filtered (13 patches, $\alpha = 0.3$)

Colour images

Adaptive filtering

Original

Contrast filtering ($\lambda = 166$)

Adaptive area filtering ($\alpha = 0.5$)

Adapt. contrast filtering ($\alpha = 0.5$)

Colour images

Experimenting with HSV space

- Partial ordering on [Saturation,Value] space closer from visual perception
- Component-graph pruning from [Saturation,Value] space
- The Hue value is unchanged

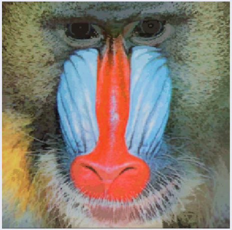
Colour images

Experimenting with HSV space

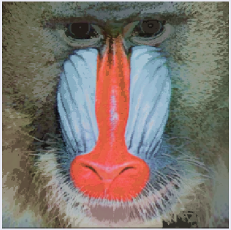
- Area attribute

Original

$\alpha = 0.3$



$\alpha = 0.2$

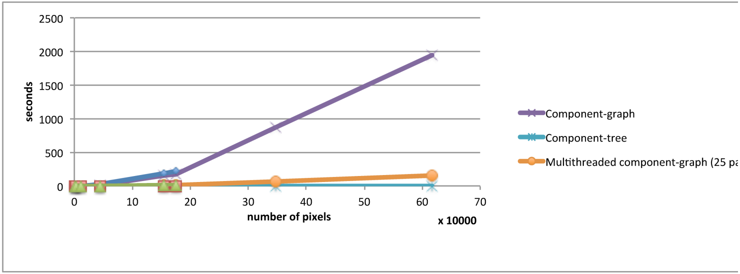


$\alpha = 0.1$

Colour images

Implementation

- C++ / Qt
  `code.google.com/p/cgraph`.



25 patches / threads - 4 cores.
In practice, $\mathcal{O}(N^{1.5})$ complexity.

Outline

Conclusion et perspectives

Conclusion

- Component-graph : extending component-tree filtering paradigm on multivalued images.
- Practical applications on colour images based on patch decomposition and adaptive filtering

Perspectives

- Component-graph based segmentation.
- Addressing space and algorithm complexity: pruning the space of values.

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