Saliency Transformation*

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28 February 2013

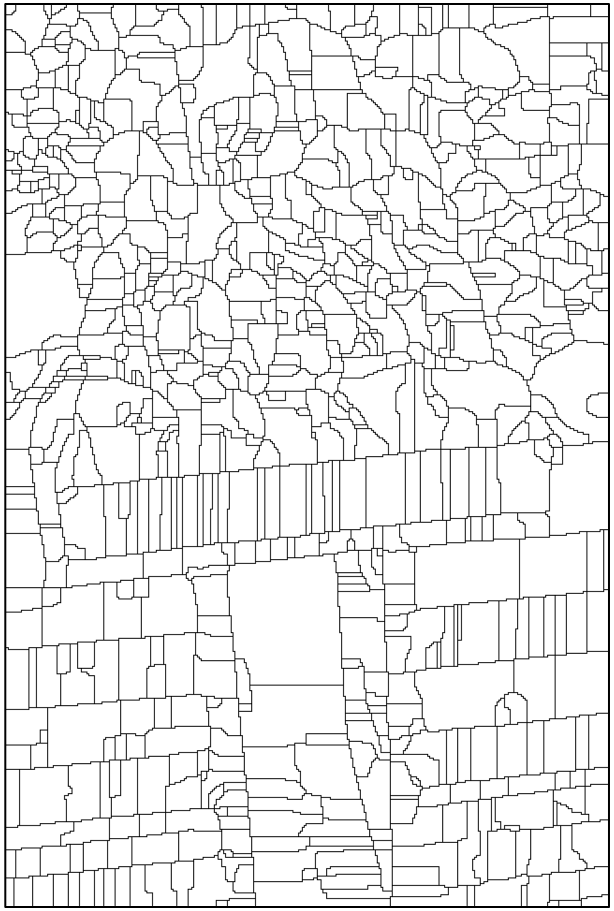
*Accepted at SSVM 2013 (Scale Space and Variational Methods)

Problem context

1. Developing the theory of optimal cuts. (Pattern Recognition Letters Journal 2013)
2. Ground truth energies (ISMM 2013)
3. Saliency transforms (SSVM 2013)

A Problem: Inputs

Input Image 25098 Berkeley Database



Partitions in input hierarchy of segmentations H

Ground truth: Evaluation of Hierarchies

Input Image $\qquad G_2 \qquad G_7$

Hand drawn ground truth by multiple users or experts for each image.
No inclusion ordering assumed in the ground truths.

A problem: Transforming hierarchies

- Classically the Ground truth is a model to evaluate a given hierarchy of segmentations H.

- But conversely could the ground truth be used to modify and improve the hierarchy itself ?

- If a hierarchy is characterized by its saliency s, how to synthesize a new saliency that incorporates the ground truth?

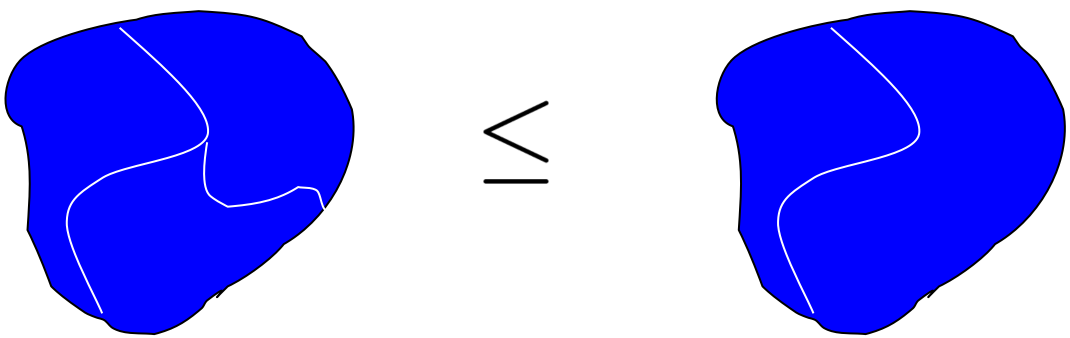
- Can we generate a hierarchy based on the proximity to the ground truth?

Hierarchy, or pyramid, of partitions

A hierarchy of partitions is a chain of increasing partitions of some finite set E.

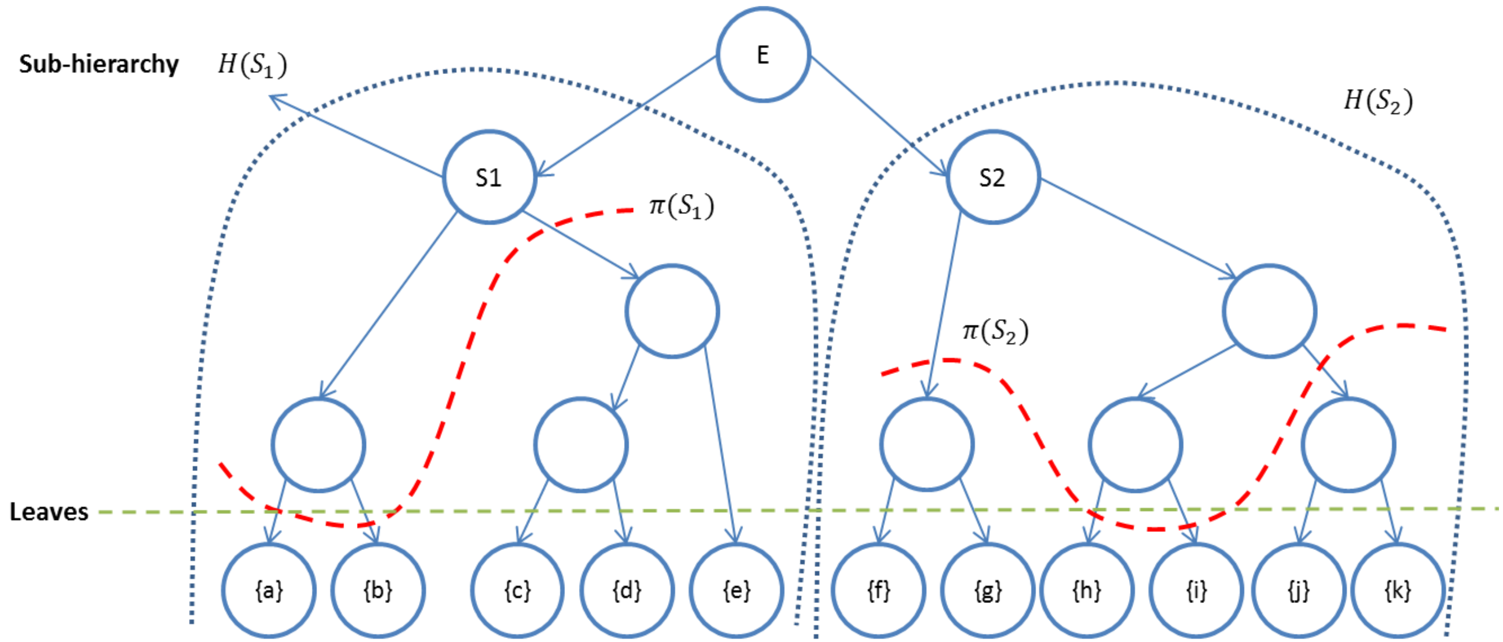
$$H = \{\pi_i, 0 \leq i \leq n \mid i \leq k \leq n \Rightarrow \pi_i \leq \pi_k\},$$

Example of ordered partial partitions



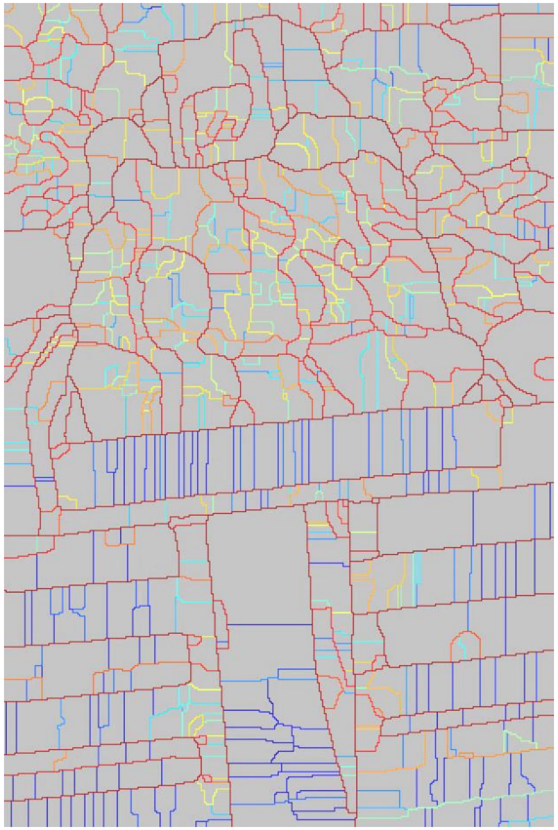
$\pi_1 \leq \pi_2$

Representations of Hierarchies: Dendrogram



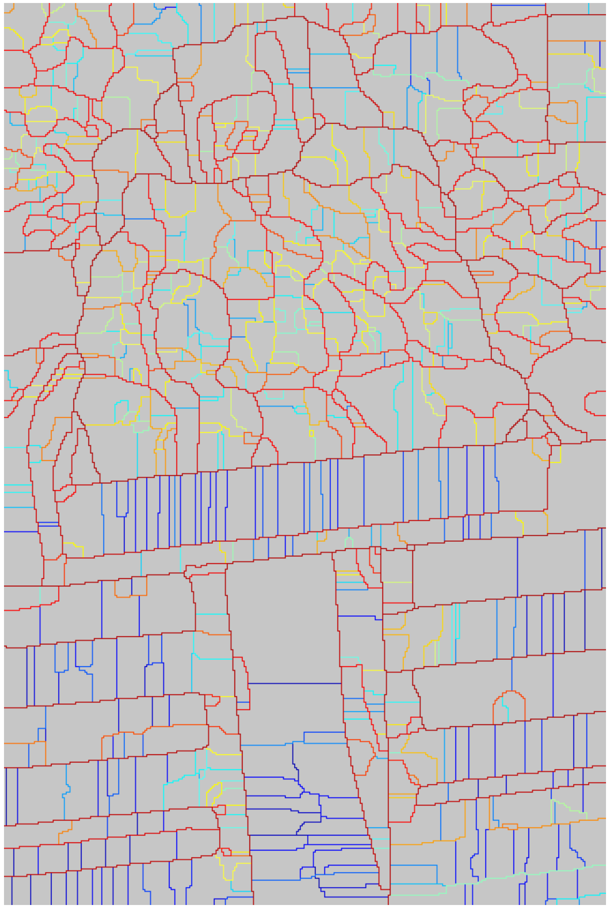
Representations of Hierarchies: Saliency function

1. Weighting function associated with the edges between classes of hierarchy H.
2. For a given edge, this function, constant along the edge, is the level of H when the edge disappears.
3. Clearly, a distribution of arbitrary weights on the edges may not be saliency. It is also required that by removing one edge one still maintains a partition, i.e. that one does not create pending edges.



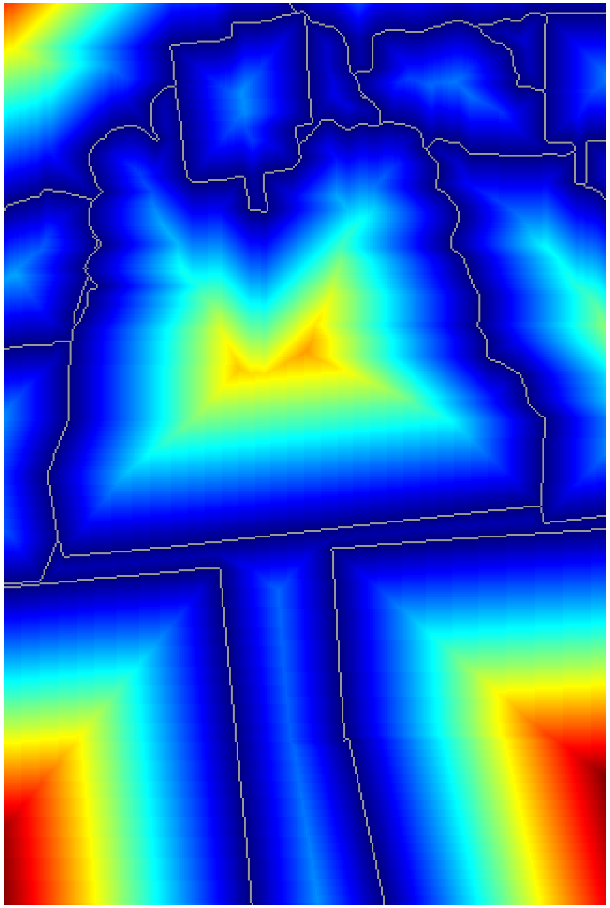
Saliency
Ultrametric contour Map (UCM)

Introducing an external function



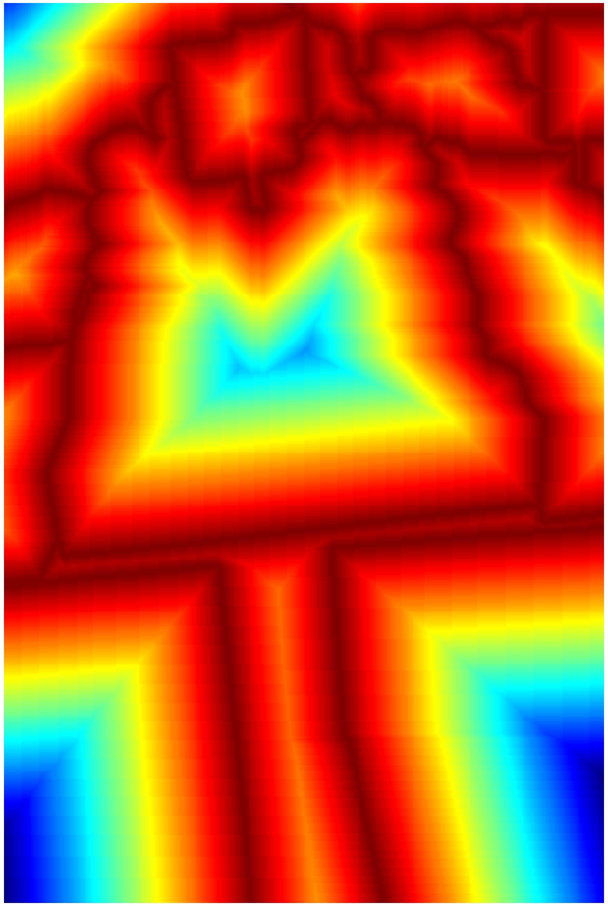
s

Saliency



g

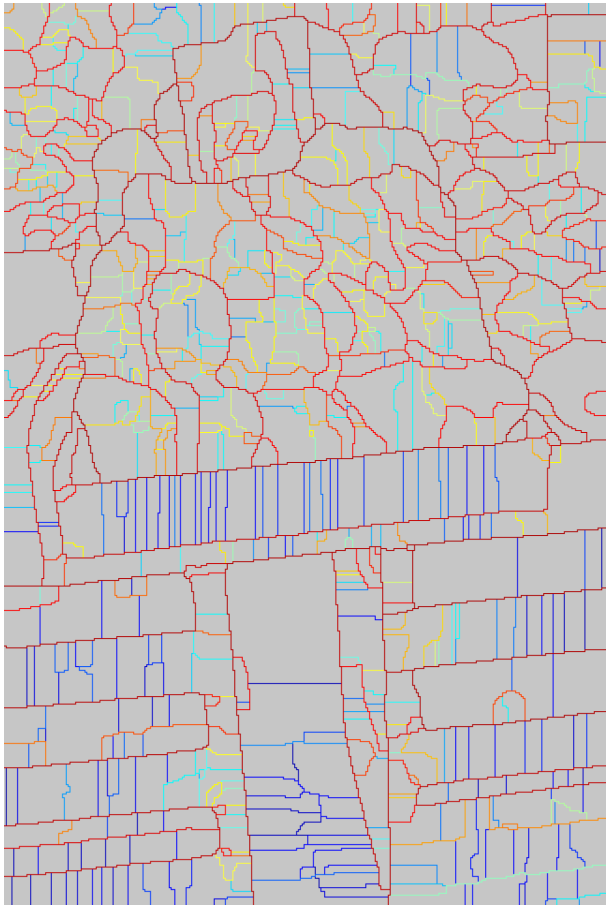
Ground truth distance function



$max(g) - g$

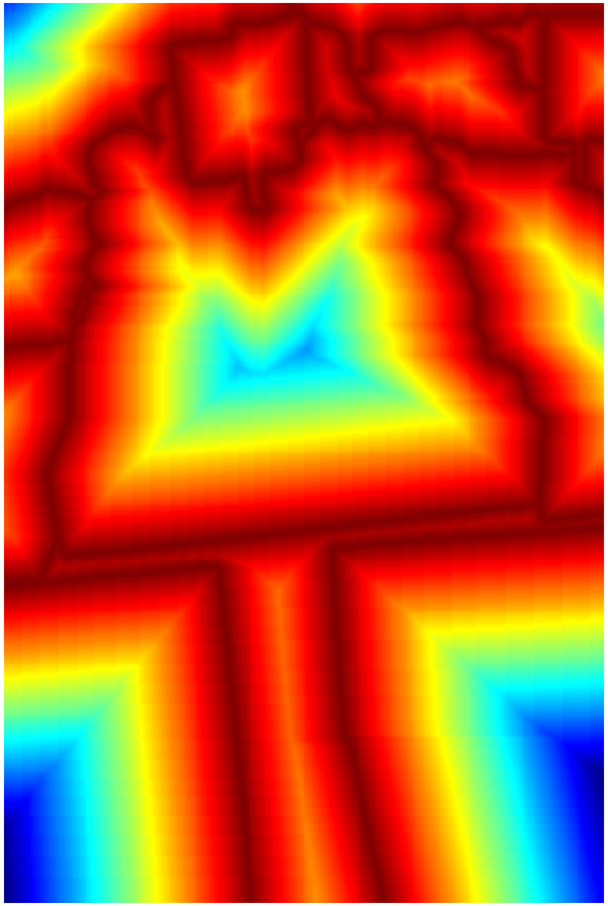
Inverted distance function

Introducing an external function



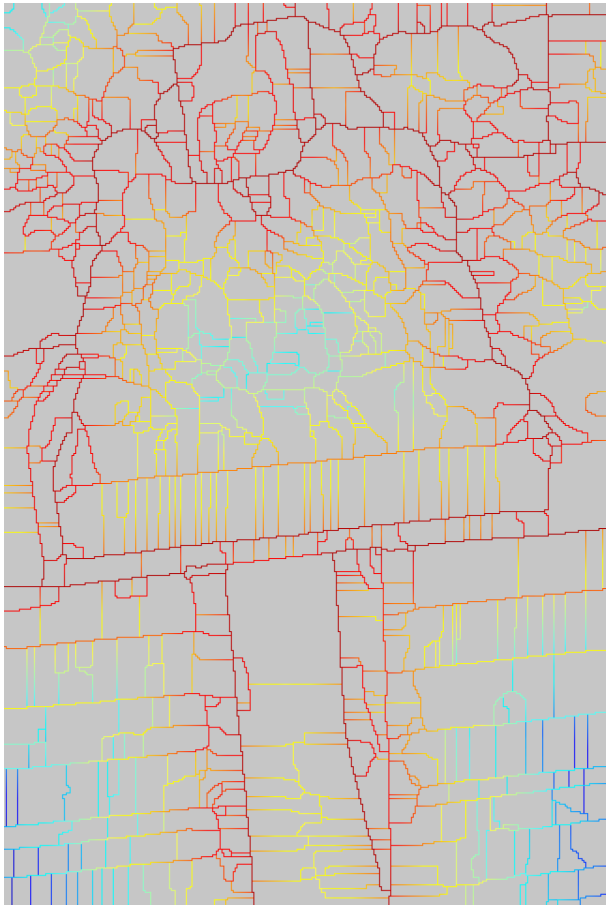
s

Saliency



$max(g) - g$

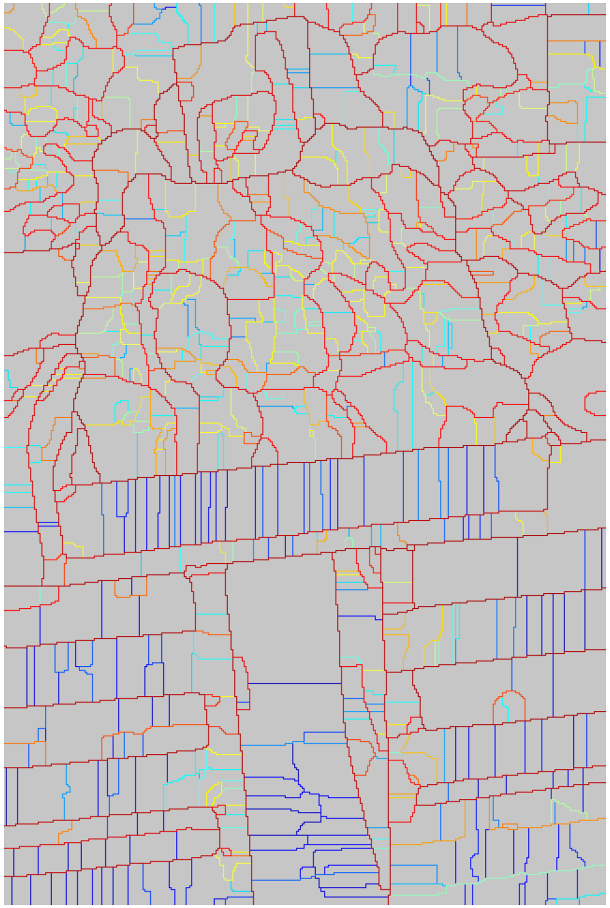
Inverted distance function



$\varphi = s + max(g) - g$

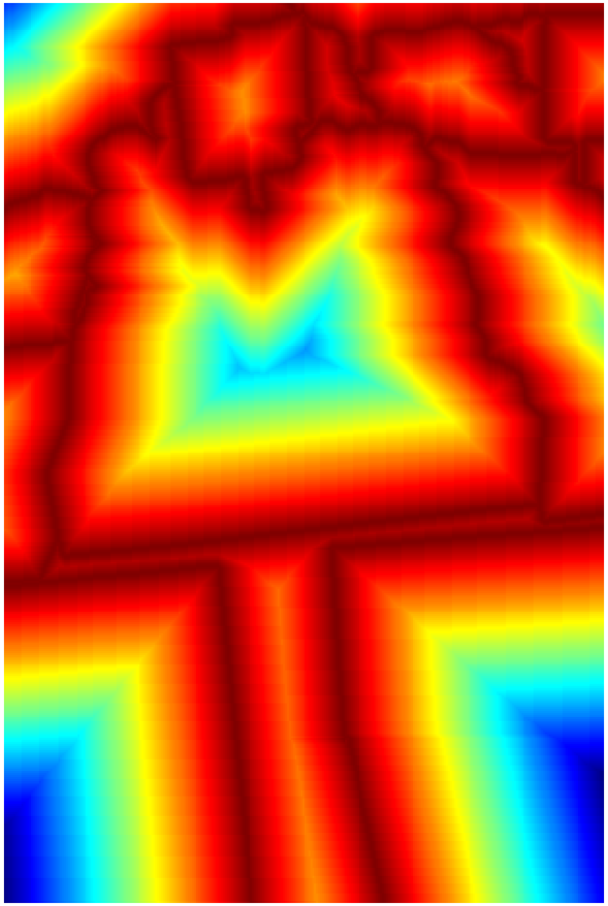
Similarity Function

Introducing an external function



s

Saliency



$max(g) - g$

Inverted distance function

$\varphi = s + max(g) - g$

Similarity Function

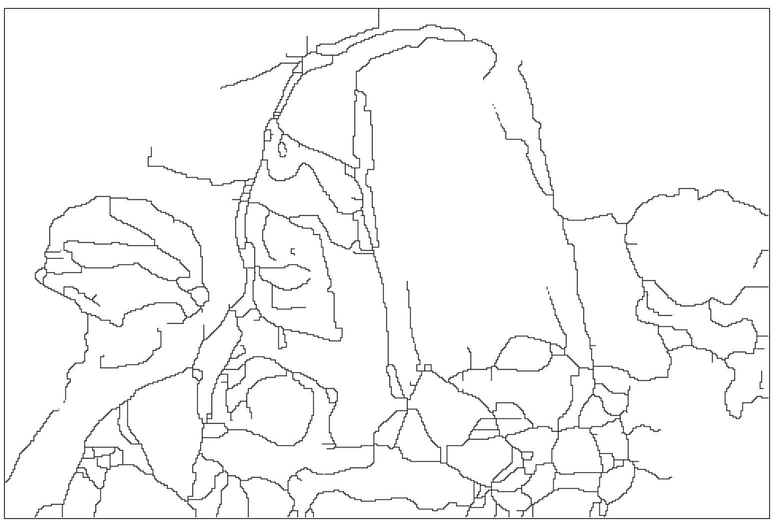
Binary Class Opening

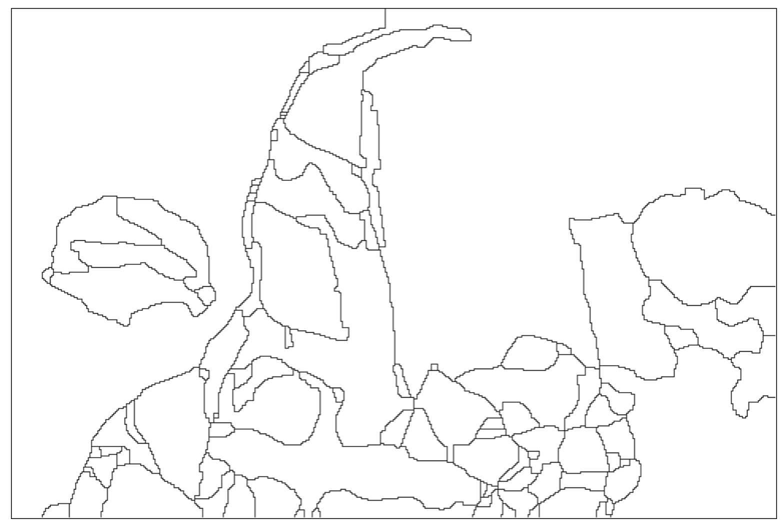
Given a finite set of simple arcs $\mathcal{P}(E_0)$ in 2D space E, we define

$$\gamma : \mathcal{P}(E_0) \to \mathcal{P}(E_0)$$

$\gamma(X)$ reduces each set of arcs $X \in \mathcal{P}(E_0)$ to the closed contours it may produce.

Theorem *the operation* $\gamma : \mathcal{P}(E_0) \to \mathcal{P}(E_0)$ *is an opening.*





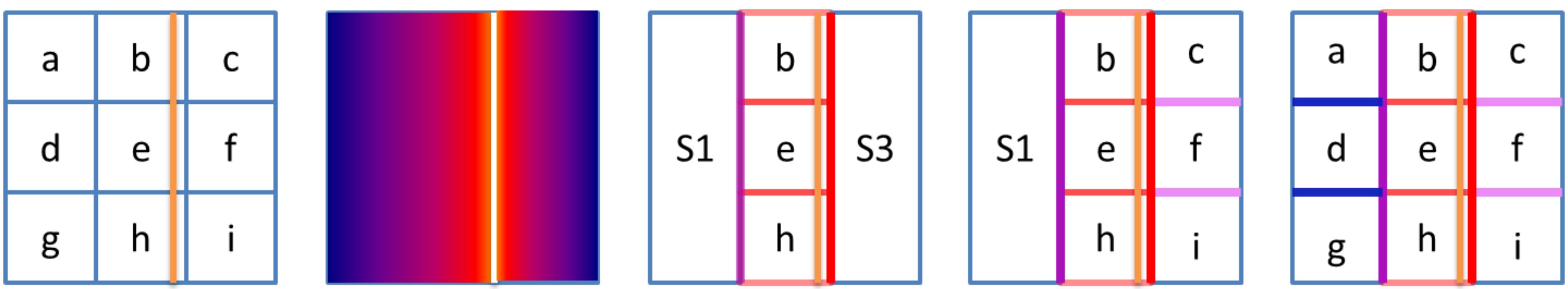
Numerical (grayscale) class opening

The numerical extension of γ the class opening, holds now on a numerical function φ on the edges of the leaves.

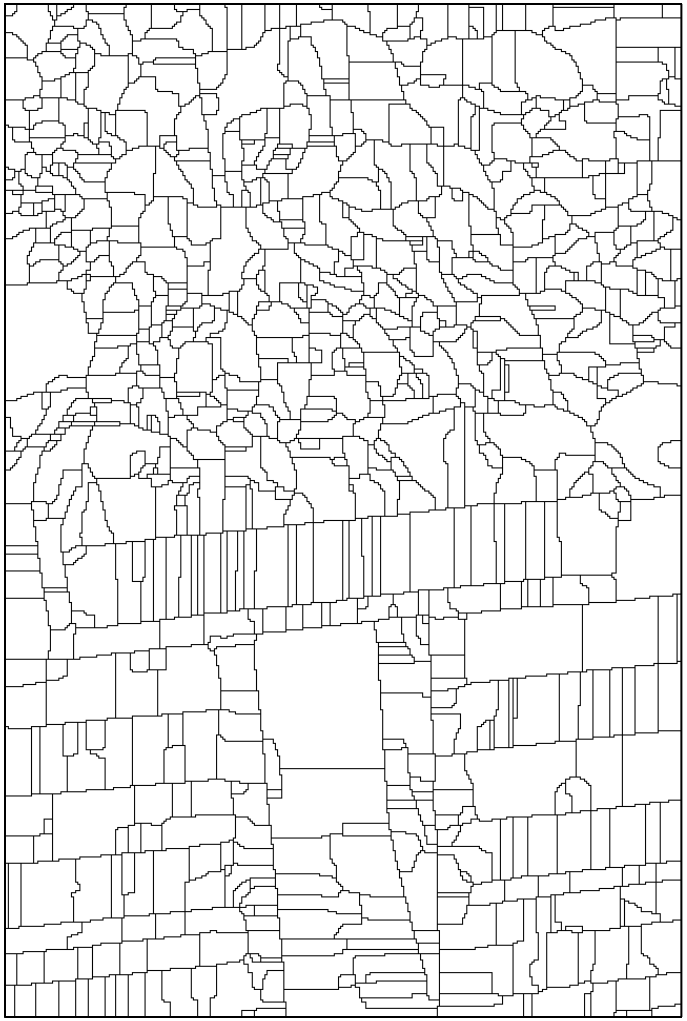
$X_t(\varphi) = \varphi \geq t$, and we define the numerical opening $\gamma(\varphi)$ by its level sets $X_t[\gamma(\varphi)]$ by putting

$$X_t[\gamma(\varphi)] = \gamma[X_t(\varphi)], \quad t > 0.$$

When φ spans the class of all positive functions, then $\gamma(\varphi)$ produces all possible saliencies.

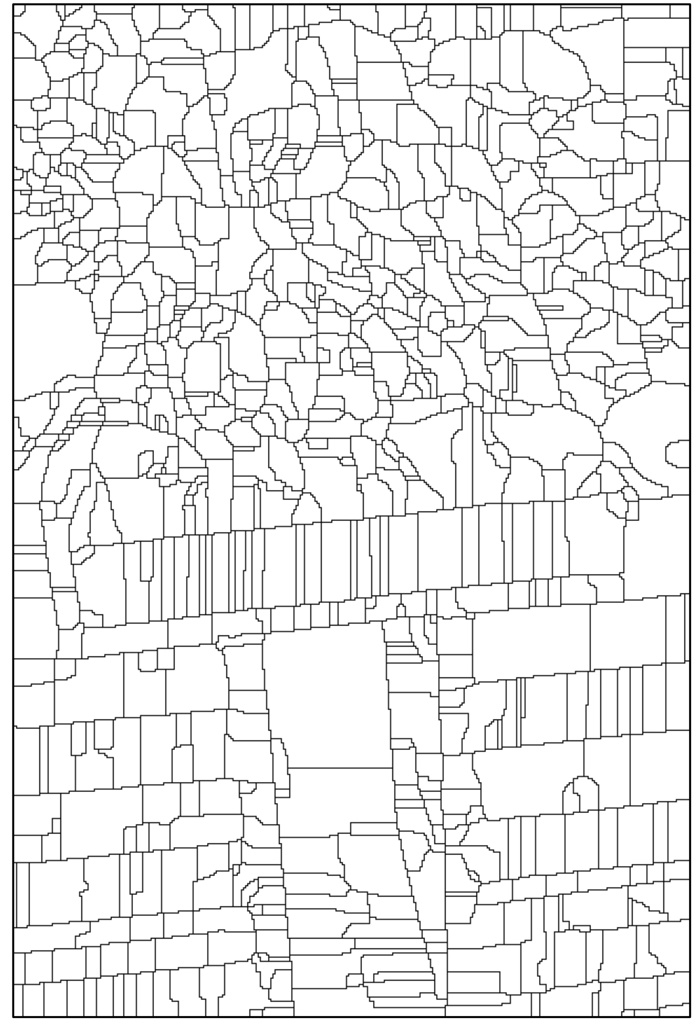


Example: Class Opening



Thresholded similarity function

φ_t



Class opening

$\gamma(\varphi_t)$

Properties of class opening I

Let g_1 and g_2 be two positive functions on $\mathbb{R}^2$ or $\mathbb{Z}^2$, then:

i) $\gamma(g_1)$ (resp. $\gamma(g_2)$) is the largest saliency under g_1 (resp. g_2);

ii) $\gamma(g_1) \vee \gamma(g_2)$ is the largest saliency whose value at each edge is under that of $\gamma(g_1)$ or $\gamma(g_2)$;

iii) if $g_1 \circledast g_2$ denotes an operation from $\mathcal{G} \times \mathcal{G} \rightarrow \mathcal{G}$, such as $+, -, \times, \div, \vee$,or $\wedge$, then $\gamma(g_1 \circledast g_2)$ is the largest saliency under $g_1 \circledast g_2$ and in particular,

$$\gamma(g_1 \vee g_2) \leq \gamma(g_1 + g_2)$$

In all cases the resulting saliency is unique.

Properties of class opening II

Given an input saliency function s, and 3 external positive functions g_1, g_2, g_3

$$s = \gamma(s) \leq \gamma(s + g_1) \leq \gamma(s + g_1 + g_2) \leq \gamma(s + g_1 + g_2 + g_3)$$

The same can be applied for the difference operations if the similarity function representing this difference remains positive (doesn't introduce zeros).

And similarly for the supremum:

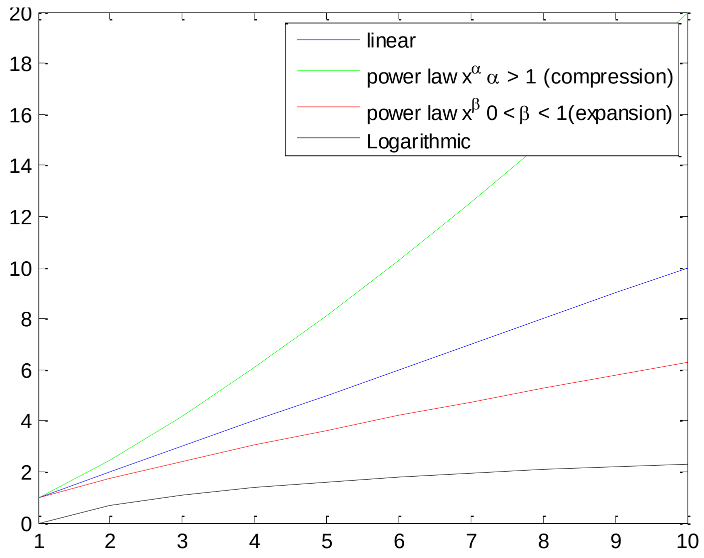
$$s = \gamma(s) \leq \gamma(s \vee g_1) \leq \gamma(s \vee g_1 \vee g_2) \leq \gamma(s \vee g_1 \vee g_2 \vee g_3)$$

All these class openings are ordered thus they form granulometric semigroups.

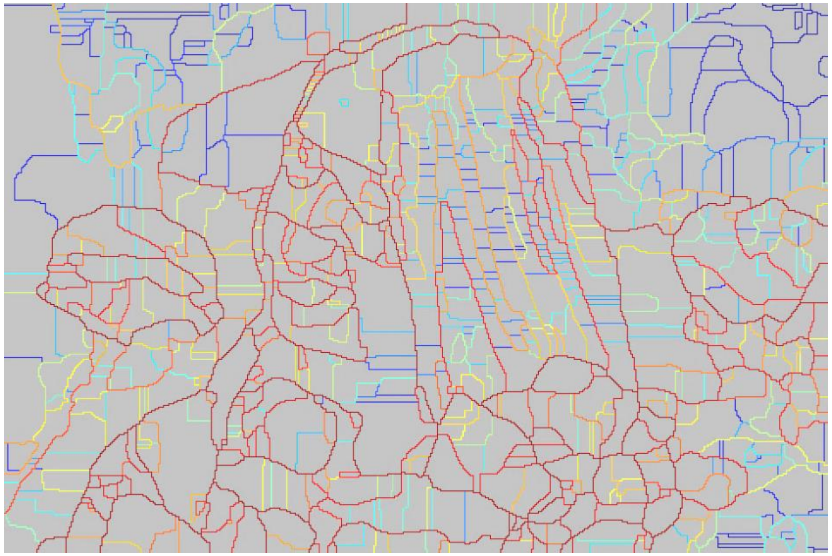
Saliency degeneracy

Class opening $\gamma(\varphi)$ orders φ to obtain a saliency, which corresponds to a hierarchy H_φ.

Degeneracy: Any strictly increasing mapping of the grey levels $\varphi' = \alpha(\varphi)$, e.g. square root, log, etc., yields a $\gamma(\varphi')$ that generates the same hierarchy $H_{\varphi'}$ as $\gamma(\varphi)$ does.

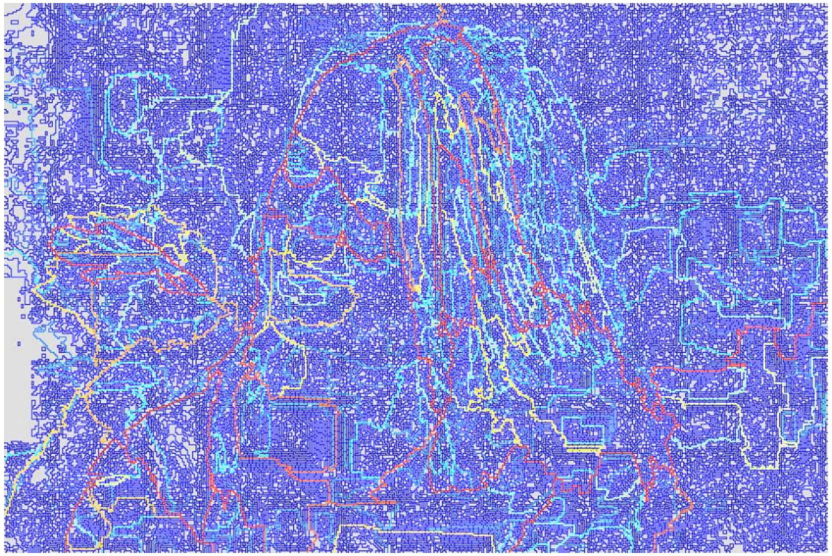


Evaluating Hierarchies w.r.t Ground Truth



s_1

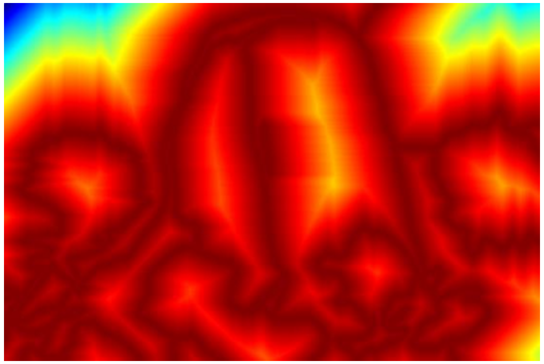
Ultrametric Contour Map



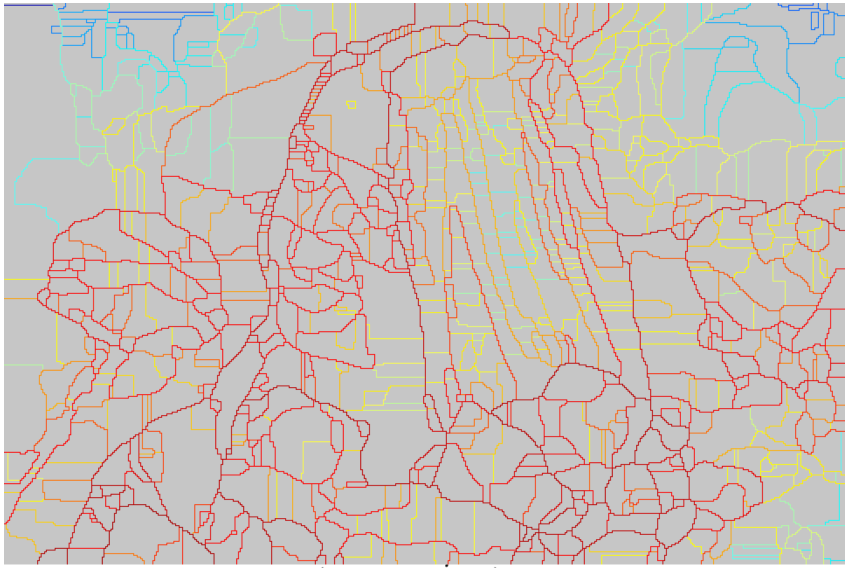
s_2

Volume attribute based watershed flooding

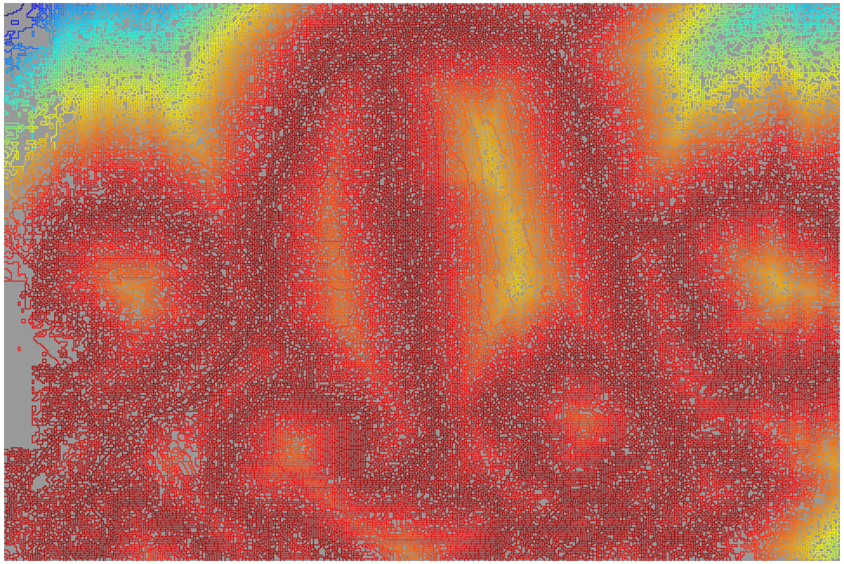
Evaluating Hierarchies w.r.t Ground Truth



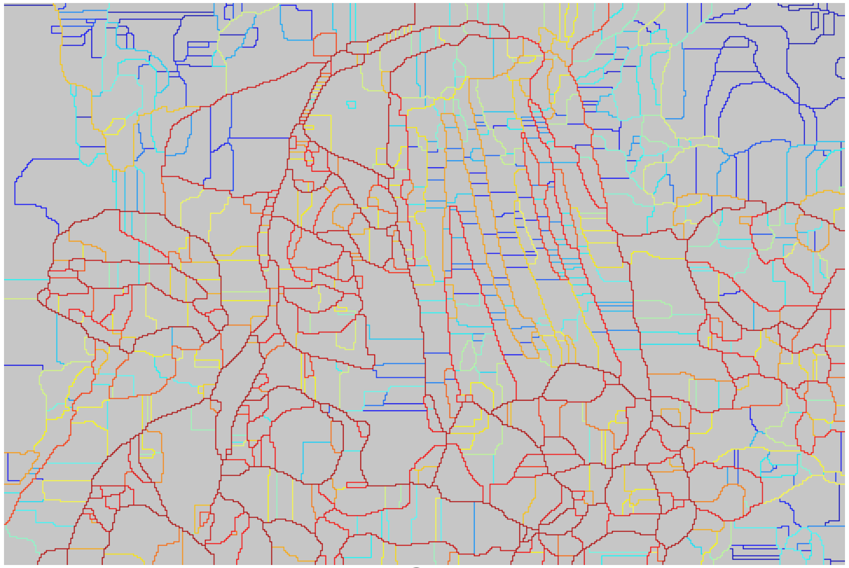
g^{inv}



$\gamma(s_1 + g^{inv})$

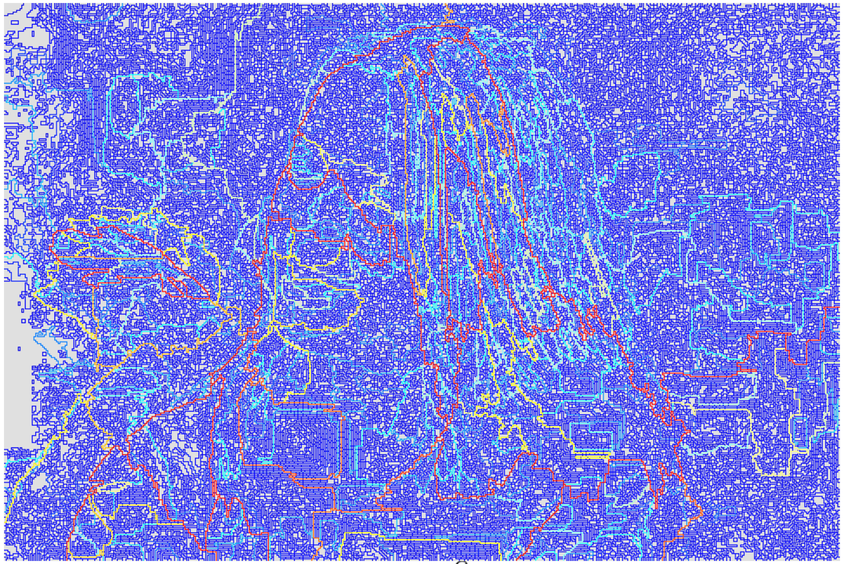


$\gamma(s_2 + g^{inv})$



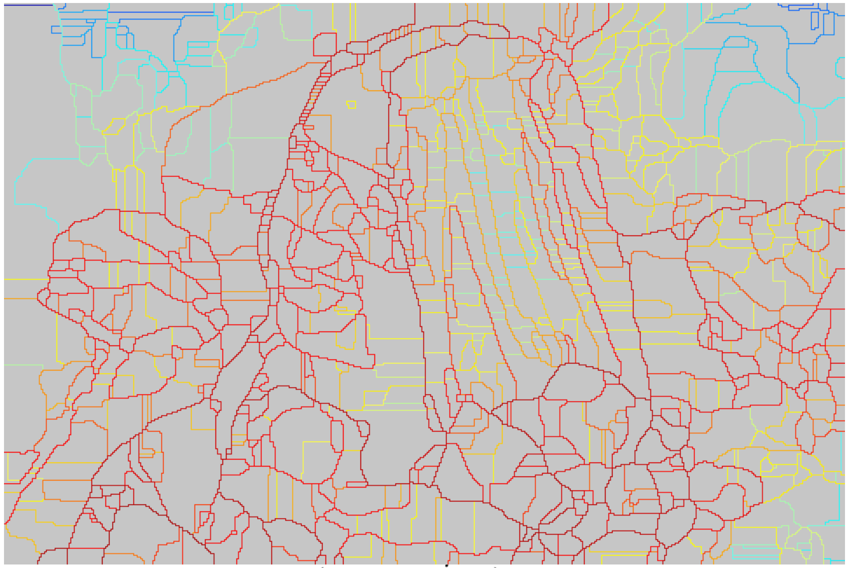
s_1

Ultrametric Contour Map

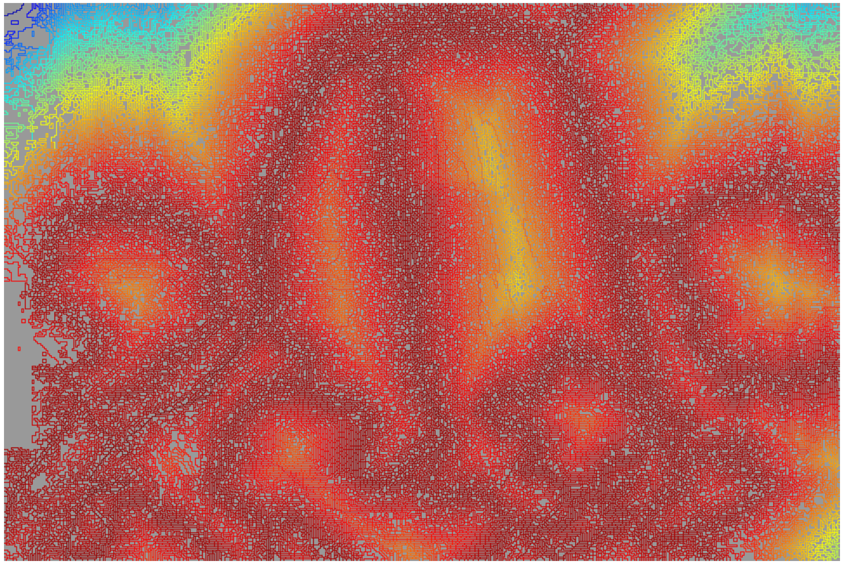


s_2

Volume attribute based watershed flooding

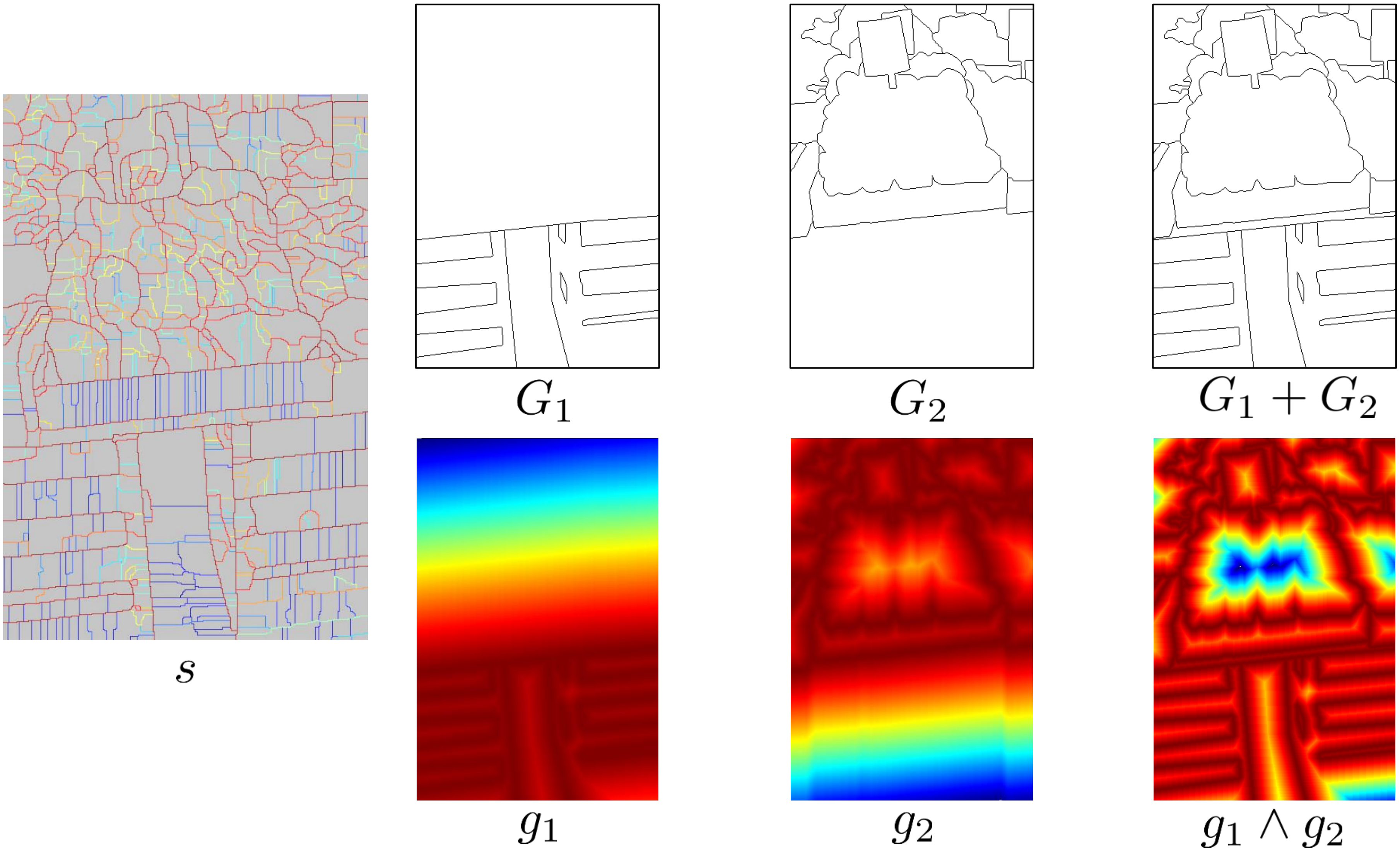


$\gamma(s_1 + g^{inv})$

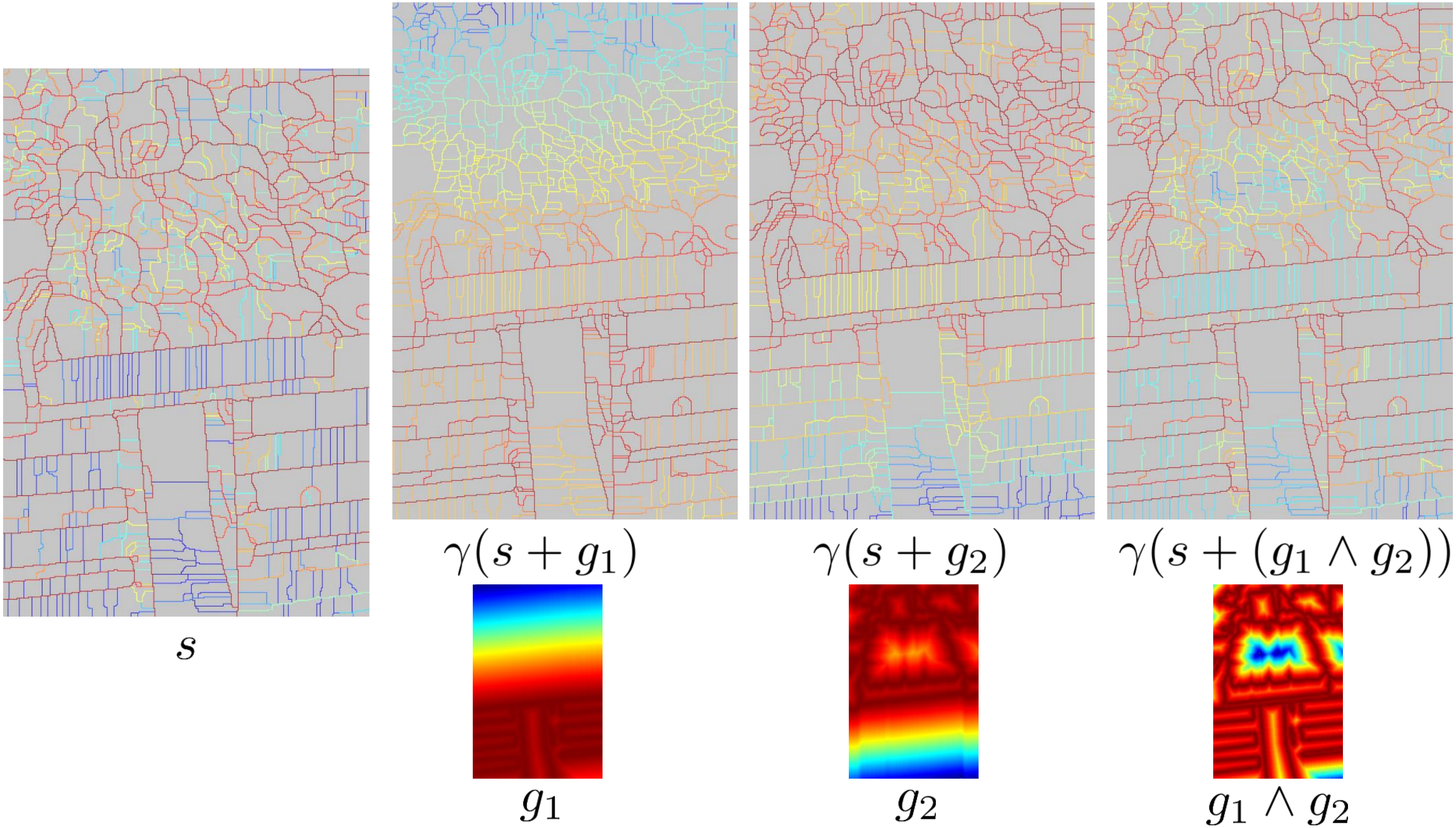


$\gamma(s_2 + g^{inv})$

Composing two external functions

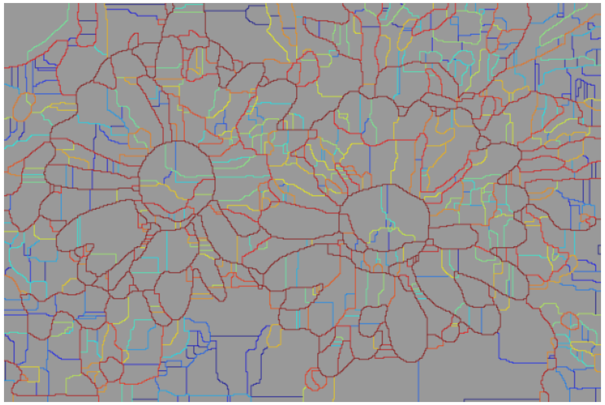


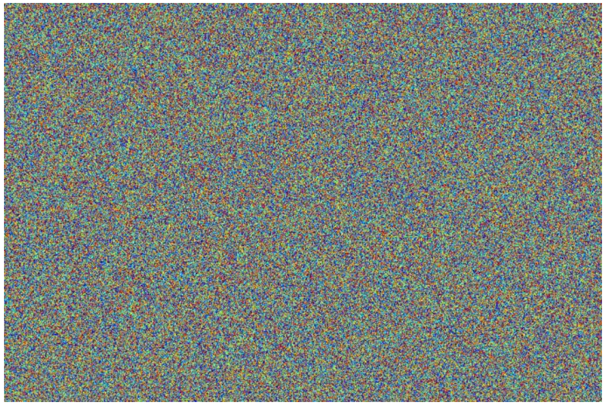
Composing two external functions

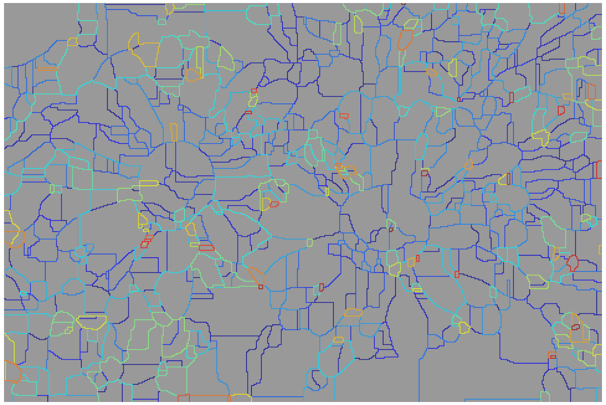


Generating Random Hierarchies

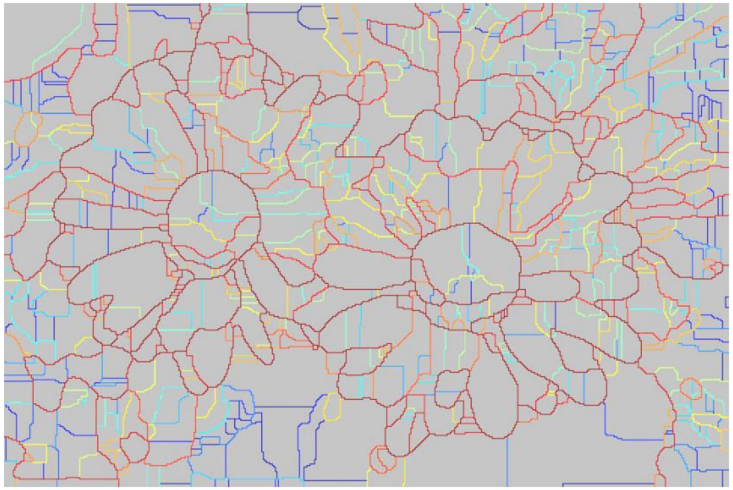
Creating random hierarchies using random permutation matrices as external function



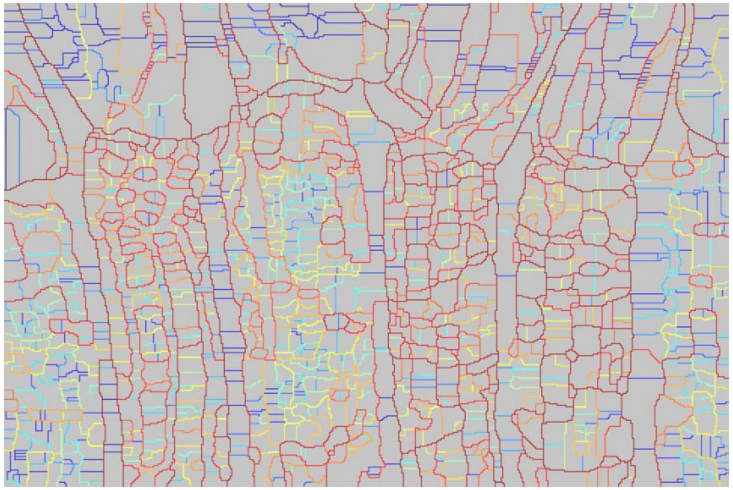




Hierarchy Fusion: Matching hierarchies

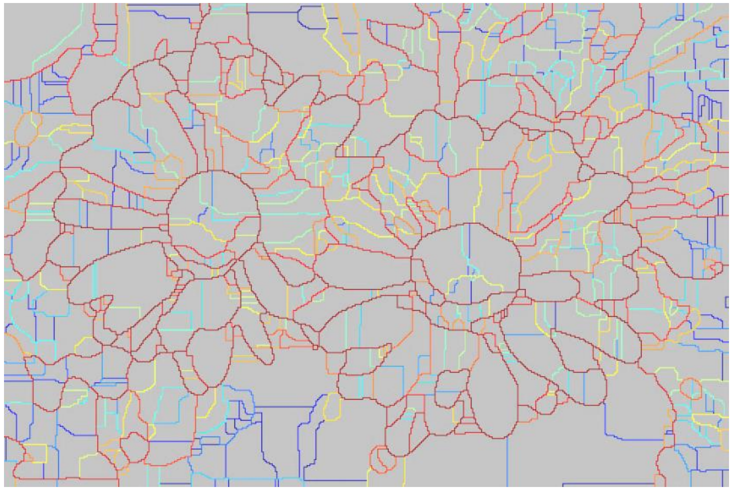


s_1

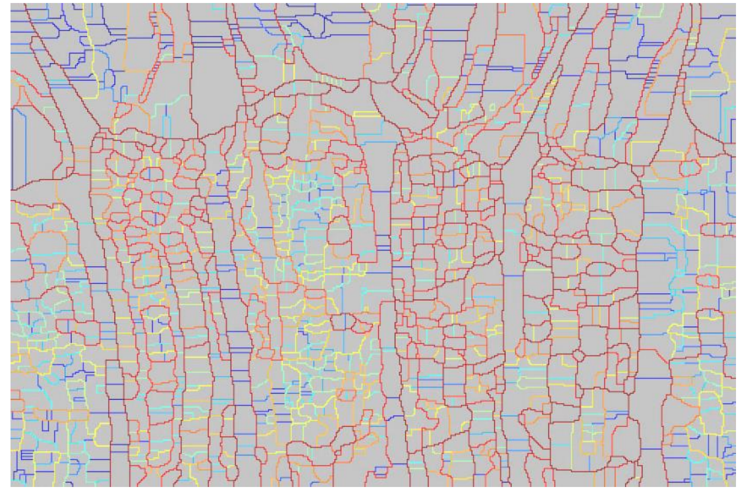


s_2

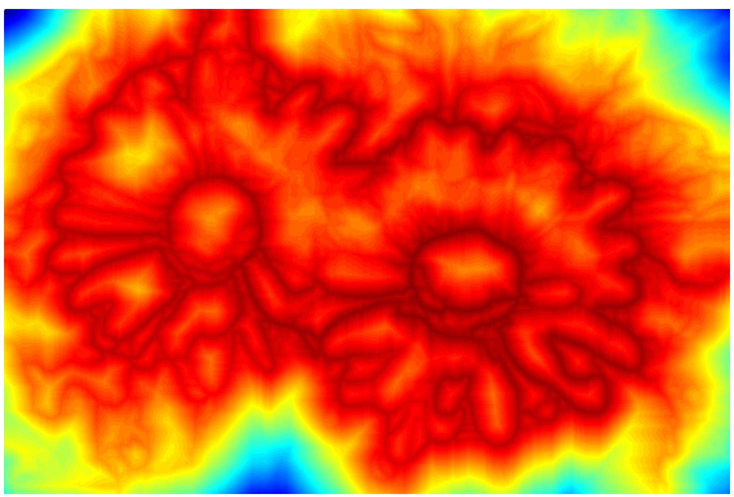
Hierarchy Fusion: Matching hierarchies



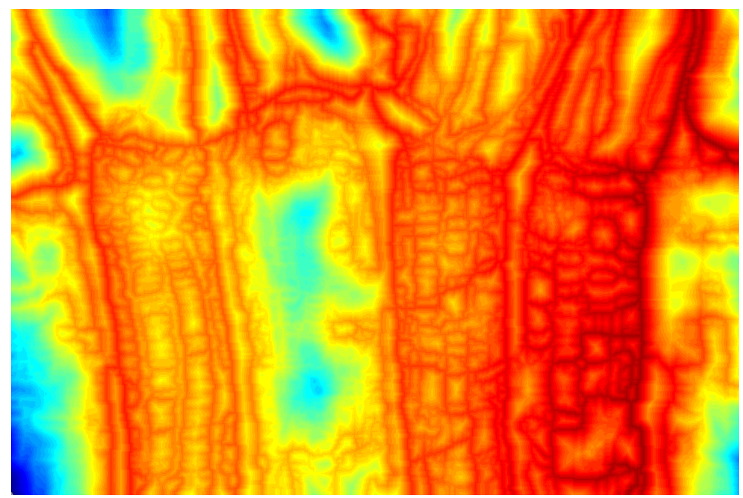
s_1



s_2

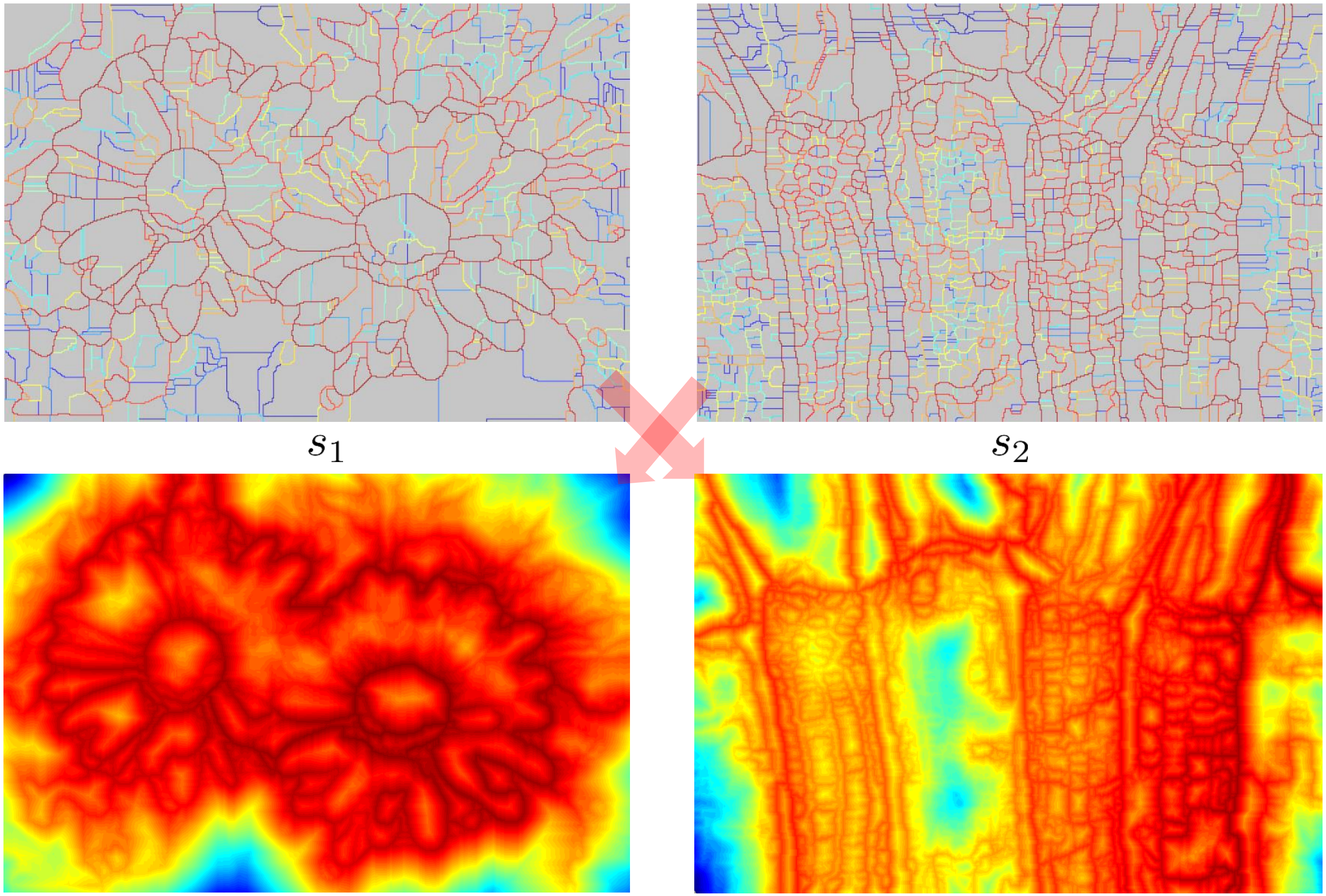


$$d_{\sum}(s_1) = \sum_{t \in range(s_1)} d(s_1 \geq t)$$



$$d_{\sum}(s_2) = \sum_{t \in range(s_2)} d(s_1 \geq t)$$

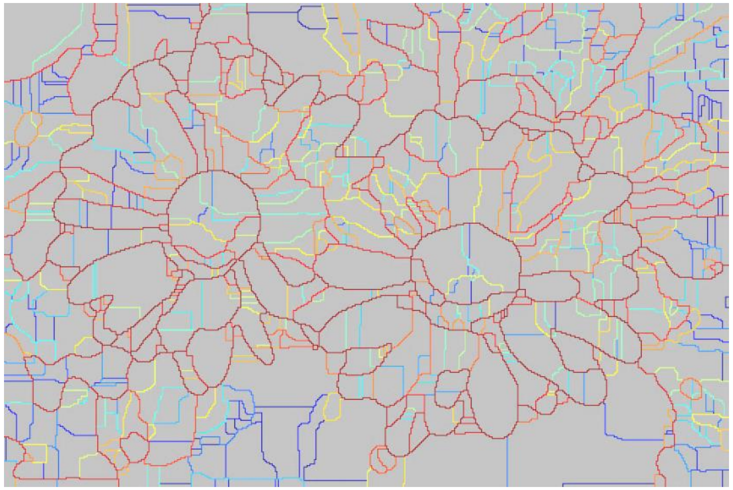
Hierarchy Fusion: Matching hierarchies



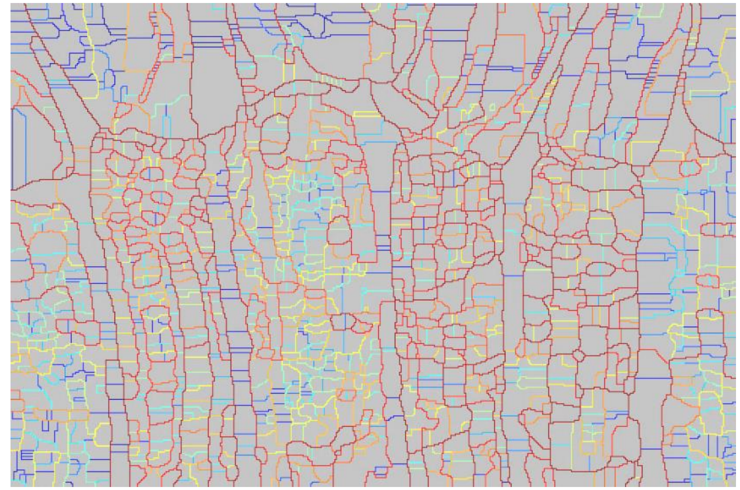
$$d_{\sum}(s_1) = \sum_{t \in range(s_1)} d(s_1 \geq t)$$

$$d_{\sum}(s_2) = \sum_{t \in range(s_2)} d(s_1 \geq t)$$

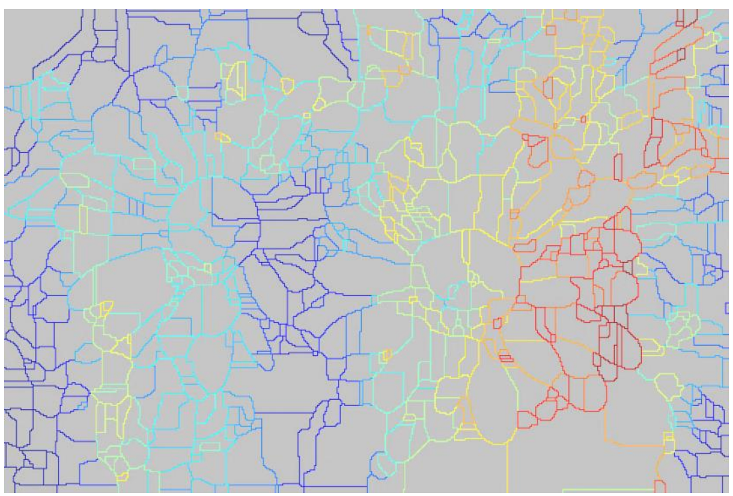
Hierarchy Fusion: Matching hierarchies



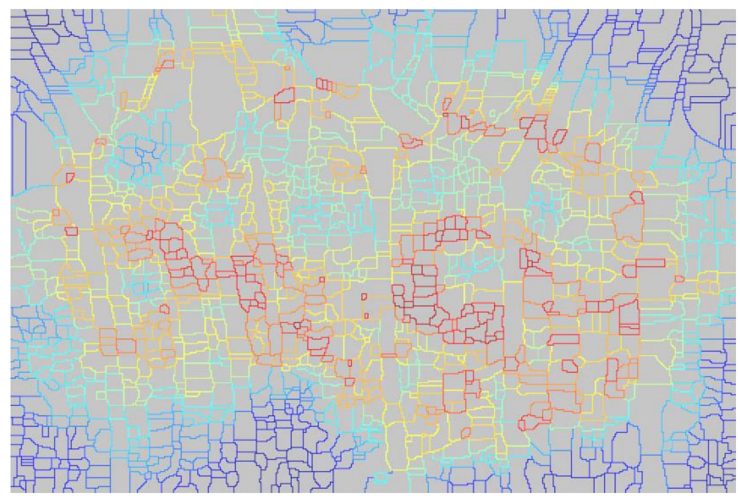
s_1



s_2



$s_{12} = \gamma(d_{\sum}(s_2) + s_1)$



$s_{21} = \gamma(d_{\sum}(s_1) + s_2)$

Conclusion

- Generation of family of saliencies using the *Class opening* $\gamma(s)$ by composition with external function g.

  Results for ground truth distance function.

- Composition of multiple external functions.

- Fuse two or more hierarchies (saliencies).

Code will be available shortly here: http://www.esiee.fr/~kiranr/HierarchEvalGT.html

Future work

- Develop the converse approach where we interchange the roles of saliency and the ground truth.
- Define energies which yield significant optimal cuts.
- Analyse the changes in dendrograms under saliency transformation.
- Introduce conditional saliency transform based on attributes like volume, area, dynamic.
- Use the approach for time varying hierarchies.

Merci beaucoup pour

- Votre patience
- Et votre attention

Avez vous des questions ?