

Evaluation of combinations of hierarchies

Deise SANTANA MAIA

Arnaldo de ALBUQUERQUE ARAUJO, Jean COUSTY, Laurent NAJMAN,
Benjamin PERRET, Hugues TALBOT

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HIERARCHY OF SEGMENTATIONS

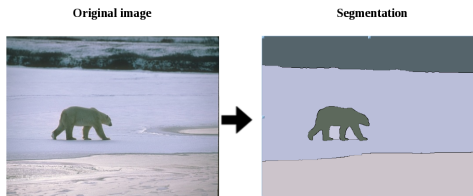
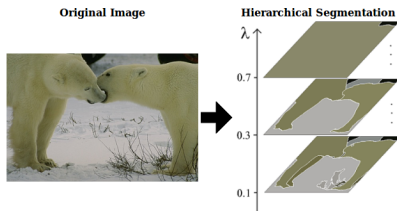


Image segmentation.



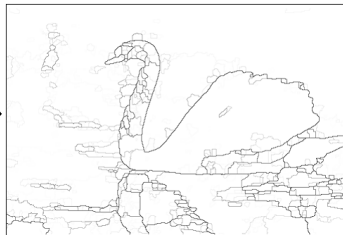
Hierarchy of image segmentations (Arbelaez).

SALIENCY MAP: A CHARACTERISTIC FUNCTION FOR A HIERARCHY

Original image I



**Saliency map of a
hierarchy of segmentations of I**



MOTIVATION TO COMBINE HIERARCHIES

- Why combining hierarchies?



Original image, saliency maps of hierarchies and segmentations containing 50 regions extracted from each hierarchy.

MAIN CONTRIBUTIONS

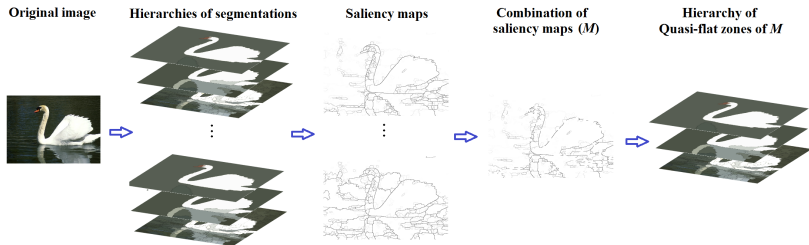
- ▶ Definition of five combinations of hierarchies
- ▶ Practical evaluation of these combinations:
 - ▶ on Berkeley dataset (500 images)
 - ▶ versus manual segmentations
- ▶ In half of the cases, the combined hierarchy scores better than any of its individual hierarchies
- ▶ Best result: combination achieved a score of **0.569** against **0.513** and **0.527** for individual hierarchies

OUTLINES

1. Method for combining hierarchies
2. Types of combinations
3. Experiments
4. Conclusion
5. Future work

1. METHOD FOR COMBINING HIERARCHIES

► How to combine hierarchies?

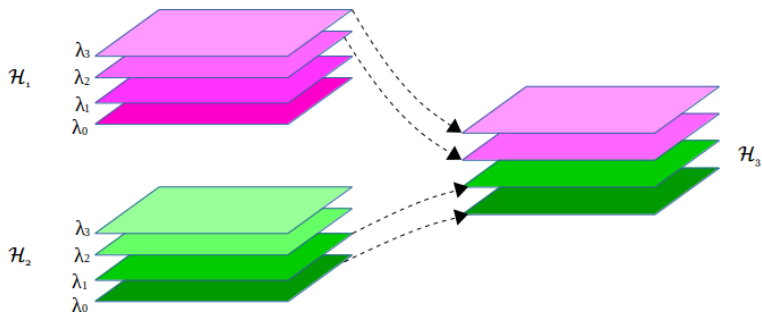


2. TYPES OF COMBINATIONS

- ▶ Infimum (\wedge)
- ▶ Supremum (\vee)
- ▶ Linear combination (\oplus_{Θ})
- ▶ Average (A)
- ▶ *Split and glue* (\uplus_{Θ})

2. TYPES OF COMBINATIONS

Split-and-glue (intuitive illustration)



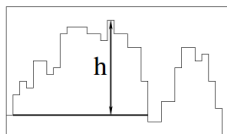
Combination of two hierarchical segmentations \mathcal{H}_1 and \mathcal{H}_2 at level λ_2 , resulting in \mathcal{H}_3 .

EXPERIMENTS

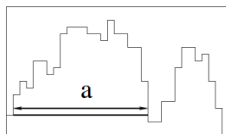
1. Set-up of experiments
2. Visual inspection
3. Assessment methodology
4. Evaluation
5. Comparison with other techniques

3.1 SET-UP OF EXPERIMENTS

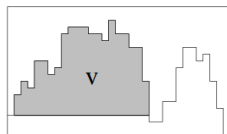
- ▶ **Watershed-cut hierarchies built from the following attributes**
 - ▶ Area
 - ▶ Dynamics
 - ▶ Volume
 - ▶ Topological Height
 - ▶ Number of Descendants
 - ▶ Diagonal of Bounding Box
 - ▶ Number of Minima



Height



Area



Volume

Illustration of the height, the area and the volume of a component (Najman and Couprie, 2011)

3.1 SETUP OF EXPERIMENTS

Image dataset

- ▶ Berkeley Segmentation Dataset and Benchmark 500 (BSDS500)

Methods for computing image gradient

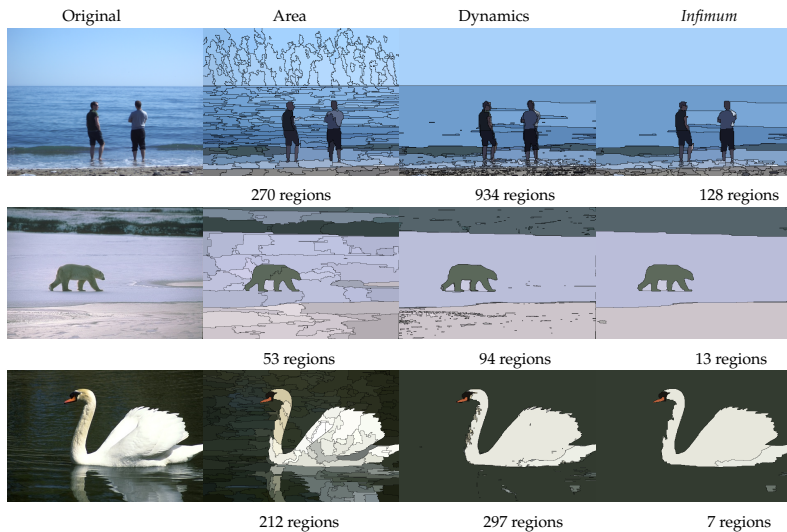
- ▶ Euclidean distance on **Lab space**
- ▶ Structured Edge detector (SE) (Dollar and Zitnick, 2013)



Original color image from BSDS500 and its gradient using SE

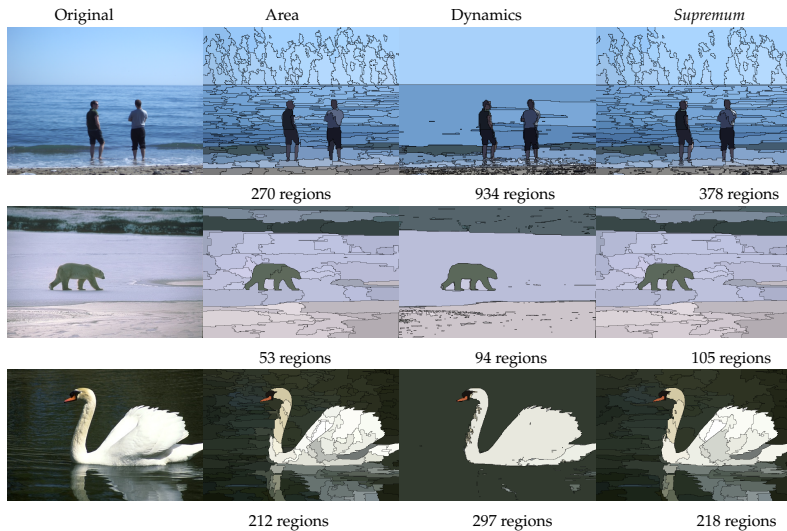
3.2 VISUAL INSPECTION

INFIMUM (人)



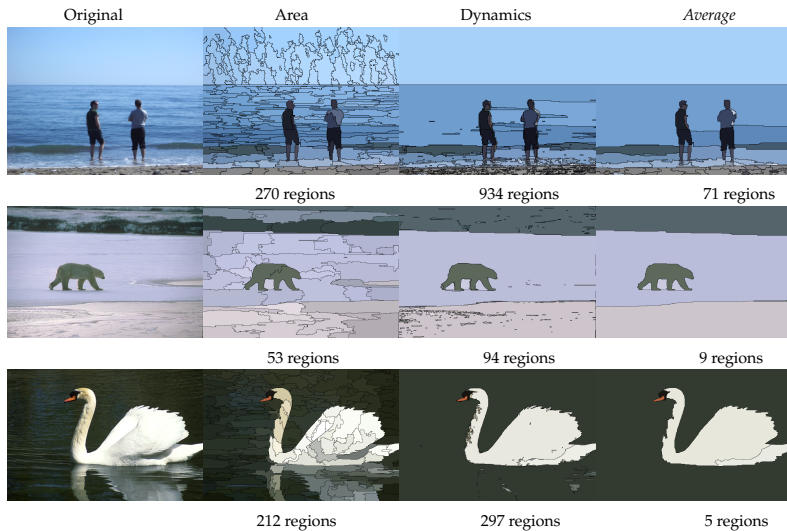
3.2 VISUAL INSPECTION

SUPREMUM (Υ)



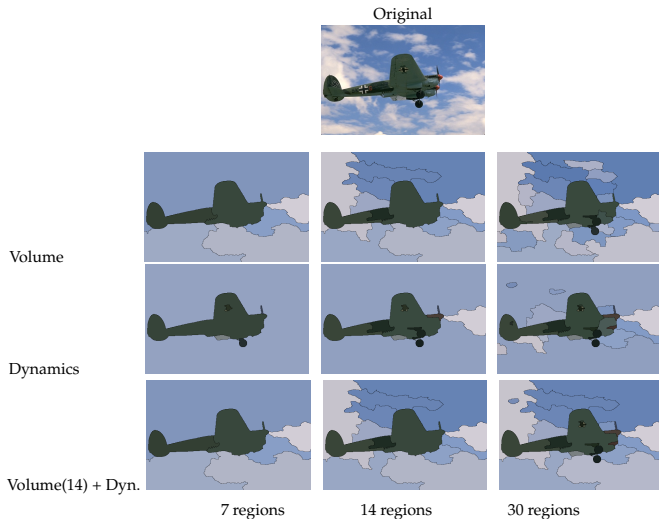
3.2 VISUAL INSPECTION

AVERAGE (A)

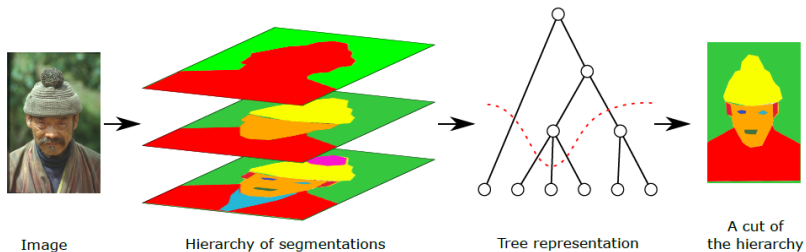


3.2 VISUAL INSPECTION

SPLIT AND GLUE (Ψ_{Θ})



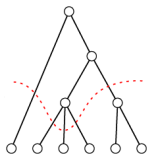
3.3 ASSESSMENT METHODOLOGY OF HIERARCHIES OF SEGMENTATIONS



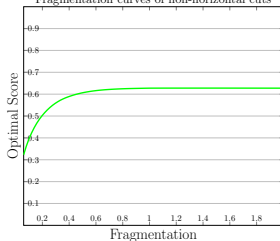
A cut in a hierarchy (Benjamin *et al*, 2017)

3.3 ASSESSMENT METHODOLOGY OF HIERARCHIES OF SEGMENTATIONS

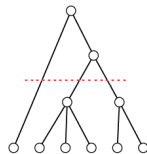
► Fragmentation curves (Perret *et al*, 2017)



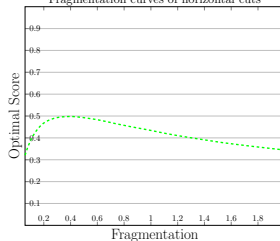
Fragmentation curves of non-horizontal cuts



— Area based watershed hierarchy, AUC-FOC: 0.60



Fragmentation curves of horizontal cuts



- - - Area based watershed hierarchy, AUC-FHC: 0.42

► Bidirectional Consistency Error (BCE)

3.4 EVALUATION: PARAMETER-FREE COMBINATIONS (λ, γ, A) AND SPLIT AND GLUE

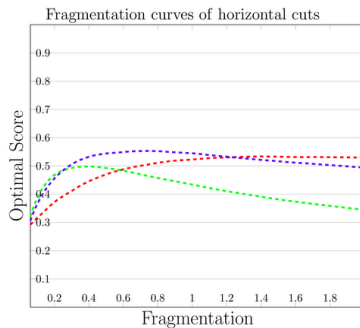
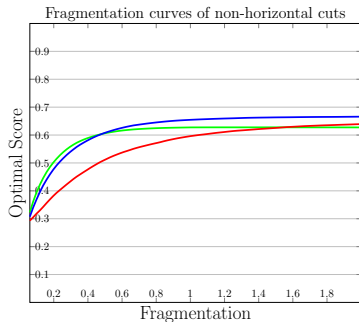
- ▶ Combinations using *infimum*, *supremum* and *average*:
 - ▶ Average improved the results in **10/21** combinations, against **11/21** and **10/21** for supremum and infimum
 - ▶ The highest score (**0.568**) obtained from combinations using average

- ▶ Combination using *split and glue*:
 - ▶ **50%(5/10)** of combinations presented higher scores than the individual hierarchies

3.4 EVALUATION: SUPERVISED LINEAR COMBINATIONS

- ▶ Supervised search of parameters to combine pairs of hierarchies (training set of BSDS500)
- ▶ The results were improved in **52%(11/21)** of combinations
- ▶ Highest score (**0.569**):
 - ▶ Area / Topological height: 51%/49%
 - ▶ Dynamics / Number of Descendants: 38%/62%
 - ▶ Topological height / Number of descendants: 42%/58%

3.4 EVALUATION: SUPERVISED LINEAR COMBINATIONS



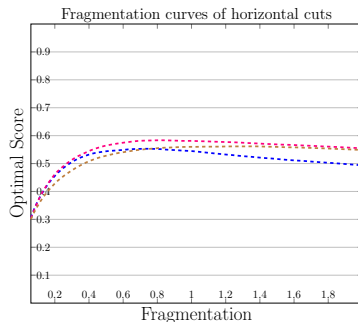
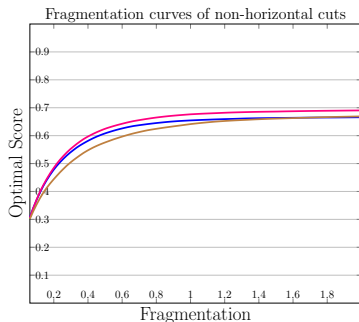
— Area, AUC-FOC: 0.60
— Height, AUC-FOC: 0.56
— Comb. Area and Height, AUC-FOC: 0.62

- - Area, AUC-FHC: 0.42
- - Height, AUC-FHC: 0.49
- - Comb. Area and Height, AUC-FHC: 0.52

Fragmentation curves of area, topological height and their linear combination

3.5 COMPARISON WITH OTHER TECHNIQUES

- ▶ Multiscale combinatorial grouping - MCG (Pont-Tuset *et al*, 2015)
- ▶ Ultrametric Contour Map - UCM (Arbelaez *et al*, 2011)



— Comb. Area and Height, AUC-FOC: 0.62
— MCG, AUC-FOC: 0.64
— UCM, AUC-FOC: 0.61

⋯ Comb. Area and Height, AUC-FHC: 0.52
⋯ MCG, AUC-FHC: 0.55
⋯ UCM, AUC-FHC: 0.53

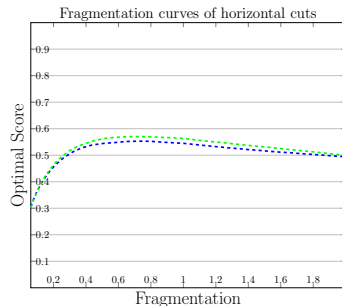
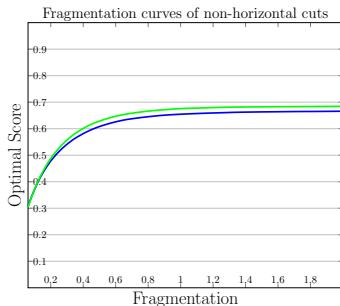
Comparison of PR for Boundaries and Marked Segmentation scores of linear combination of area and topological height and MCG.

4 CONCLUSION

- ▶ Our results show the potential of combination of hierarchies through the evaluation of combinations of watershed-cut hierarchies
- ▶ Half of the combinations presents better results compared to the ones of the individual hierarchies

5 FUTURE WORK

- Learning parameters of combinations per image



— Comb. Area and Height, AUC-FOC: 0.62
— Best hierarchy per image, AUC-FOC: 0.64

- - - Comb. Area and Height, AUC-FHC: 0.52
- - - Best hierarchy per image, AUC-FHC: 0.53

Thank you!

REFERENCES

- Arbelaez, P. Research Projects. Retrieved from <https://people.eecs.berkeley.edu/~arbelaez/UCM.html>
- Arbelaez, P., Maire, M., Fowlkes, C., Malik, J.: Contour Detection and Hierarchical Image Segmentation. IEEE PAMI. 898-916. 2011.
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- Pont-Tuset, J., Arbeláez, P., Barron, J. T., Marques, F., Malik, J. Multiscale Combinatorial Grouping for Image Segmentation and Object Proposal Generation. IEEE PAMI. 2015.