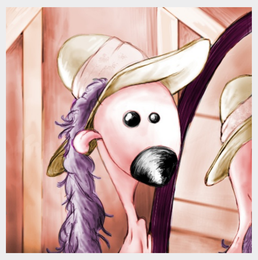

Context-Based Energy Estimator: Application to Object Segmentation on the Tree of Shapes

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Demo available at http://olena.lrde.epita.fr/ICIP2012

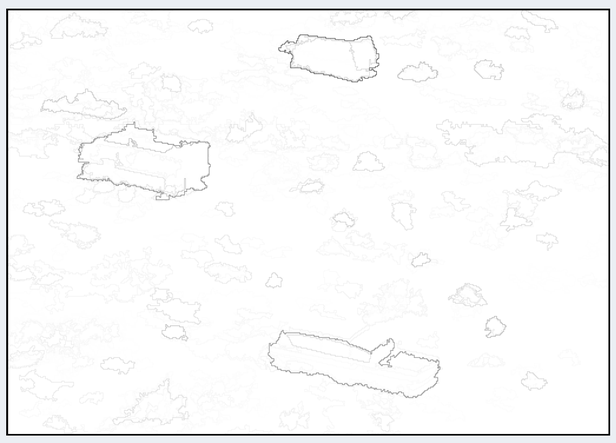
Main Contributions

Novel efficient ratio-cut estimator:
- well suited to characterize object contours;
- integrates some contextual information.

Fully automated approach to retrieve the significant objects:
- no need for prior knowledge on the number of objects;
- produces a saliency map representing the meaningfulness of objects.

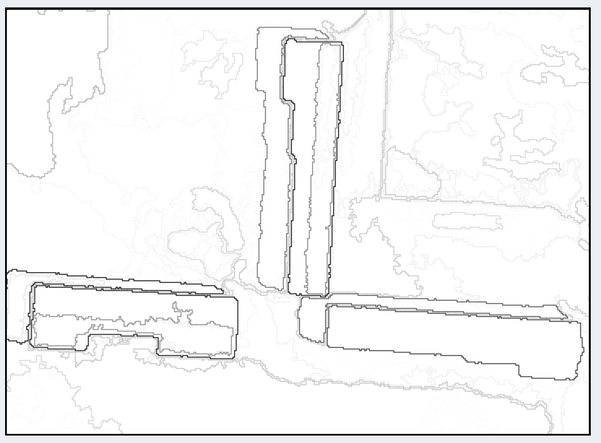
Effective results

Segmented objects.



Saliency map.

Segmented objects.



Saliency map.

Context-based energy estimator

For a given image u and a curve $\partial\tau$ (contour of a region τ, composed of pixel edges e), the energy estimator is defined by:

$$E(u,\partial\tau) \;=\; \alpha E_{int}(u,\partial\tau) \;+\; E_{ext}(u,\partial\tau) \;+\; \beta E_{con}(u,\partial\tau)$$

Internal energy smoothness of the contour $\partial\tau$,

$$E_{int}(u,\partial\tau) \;=\; \sum_{e\in\partial\tau} |curv(u)(e)| \,/\, L(\partial\tau)$$

Constraint energy constraint to avoid small objects,

$$E_{con}(u,\partial\tau) \;=\; 1 \,/\, L(\partial\tau)$$

- $curv$: curvature of u;
- L: length of $\partial\tau$;
- $\mathcal{R}^{\varepsilon}_{in}(\partial\tau)$ and $\mathcal{R}^{\varepsilon}_{out}(\partial\tau)$: the sets of points of maximal distance ε from $\partial\tau$, respectively inside and outside of $\partial\tau$;
- $V(u,\mathcal{R})$: segmentation error for region $\mathcal{R}$.

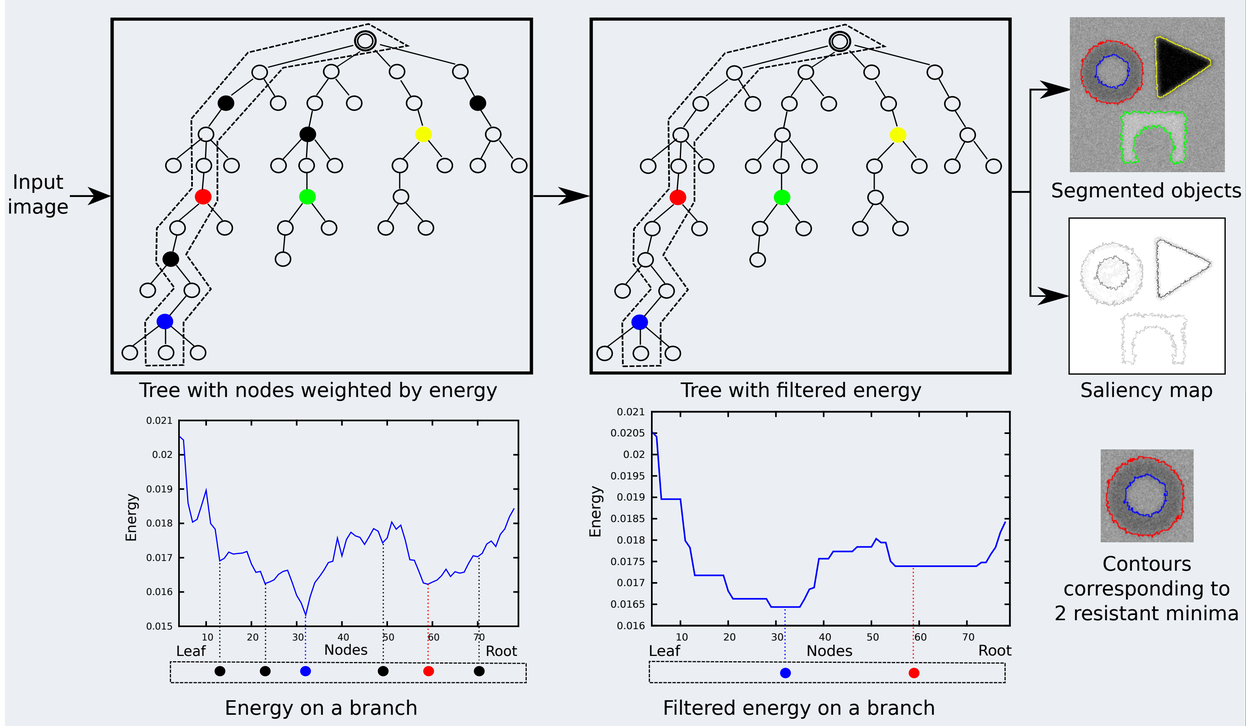
External energy significance of the contour $\partial\tau$ regarding to its context,

$$E_{ext}(u,\partial\tau) \;=\; \frac{V\big(u,\,\mathcal{R}^{\varepsilon}_{in}(\partial\tau)\big) \;+\; V\big(u,\,\mathcal{R}^{\varepsilon}_{out}(\partial\tau)\big)}{V\big(u,\,\mathcal{R}^{\varepsilon}_{in}(\partial\tau)\cup\mathcal{R}^{\varepsilon}_{out}(\partial\tau)\big)}$$

$$V(u,\mathcal{R}) \;=\; \sum_{p\in\mathcal{R}} \big(u(p) \;-\; \overline{u}(\mathcal{R})\big)^2$$

- $E_{int}(u,\partial\tau)$ *local* to the curve $\partial\tau$, and invariant to scale.
- $E_{ext}(u,\partial\tau)$ take into account some context along $\partial\tau$ by looking at $\mathcal{R}^{\varepsilon}_{in}(\partial\tau)$ and $\mathcal{R}^{\varepsilon}_{out}(\partial\tau)$ around it.
- $E_{con}(u,\partial\tau)$ discourage objects being too small.
- $E(u,\partial\tau)$ minima correspond to contours of objects.

General schema of object segmentation on the tree of level lines

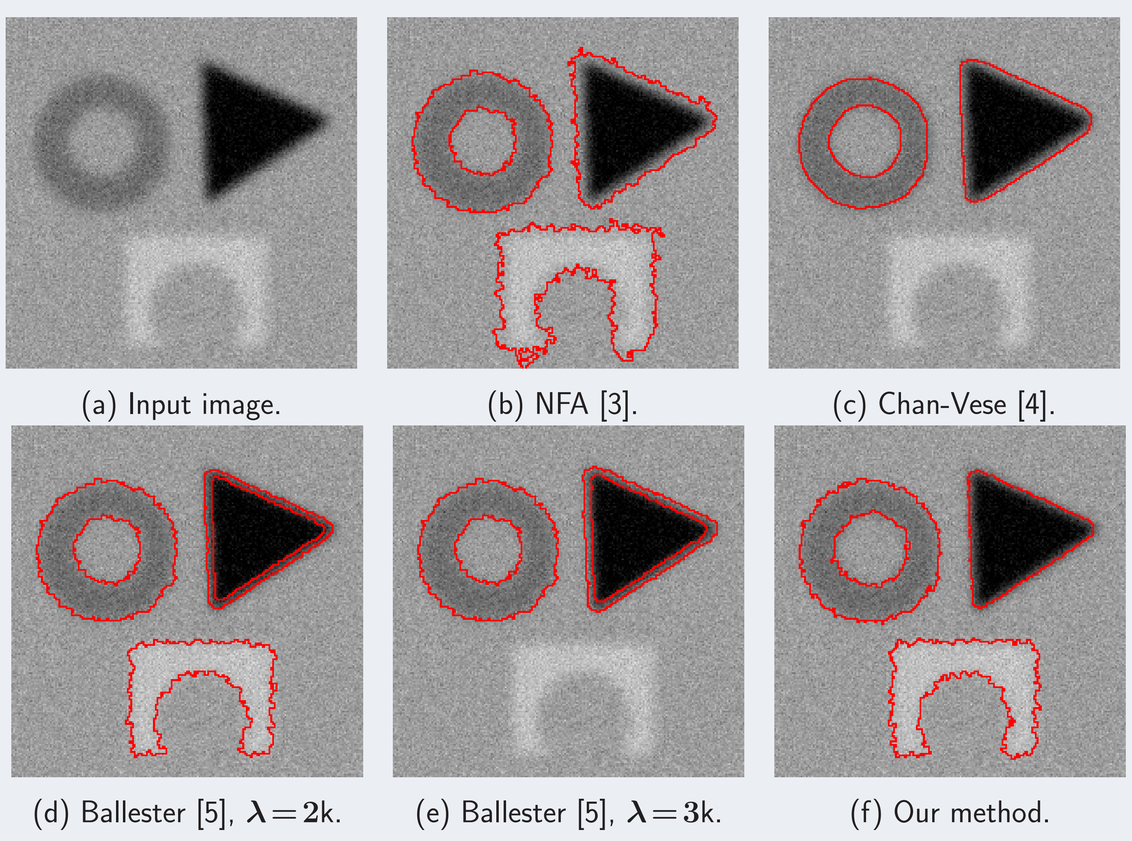


Circle : node on the tree; Double circle : the root (i.e. whole image);
Filled circle : local minima; Colorized filled circle : resistant minima.

Complete process:

1. Tree construction [1]: quasi-linear complexity based on union-find process.
2. Energy computation: incremental computation during the tree construction.
3. Morphological filtering on the tree [2]: tree with nodes weighted by energy $\Leftrightarrow$ nodes weighted graph. Morphological closing removes meaningless minima.
4. Resistant minima $\Leftrightarrow$ meaningful objects.
   - selection of segmented objects;
   - weight each minima (so the corresponding objects) by the filtering force at which this minimum vanishes $\Rightarrow$ saliency map.

Qualitative comparison with other approaches



(a) Input image. (b) NFA [3]. (c) Chan-Vese [4].

(d) Ballester [5], $\lambda = 2$k. (e) Ballester [5], $\lambda = 3$k. (f) Our method.

References

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