STARS RATED FOR EXCELLENCE 2012

Fpt University

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Object Selection

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I. **Introduction**

II. Literature review

III. Problem statement

IV. Interactive graph cut segmentation

V. Silent Lazy Snapping solution

VI. Experimental results

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Image selection

- An image is a set of sub-images that sometimes referred to as regions-of-interest, ROIs, or simply regions.
- One of the problem in image processing is image selection – how to cut out or select an area for later specific image processing operations.

Interactive single-image segmentation

Interactive single-image segmentation (image cutout or foreground/background separation), one of the typical case in region selection problem, is to select the object (e.g. human, flower, etc.) from the background that based on samples provided by the user.

Image segmentation from Lazy Snapping paper

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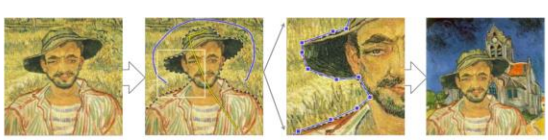
Literature review

- Greig et al, 1989: the first using min-cut max-flow algorithm to optimize certain energy function in vision.
- Boykov and Jolly, 2001: basing on the work of Greig, finding optimal segmentation which satisfies hard constraints imposed by user and soft constraints combining both region and boundary properties.
- Li, Tang, Sun and Shum, 2004: improving the method of Boykov and Jolly, working on super-pixel with an extra boundary-editing step.
- Rother, Kolgomorov and Blake, 2004: the iterated version of Boykov and Jolly's works, using color and contrast information with border matting for optimize the boundary.

Examples

Lazy Snapping



GrabCut

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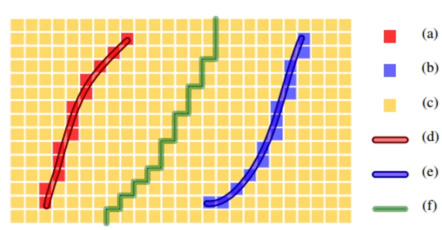
Problem statement

Suppose we have an input image N and some sets of pixels:

- Foreground set $\mathcal{F} = \{f_1, f_2, f_3, \ldots\}$: set of all pixels that are sample for the object.
- Background set $\mathcal{B} = \{b_1, b_2, b_3, \ldots\}$: set of all pixels that are sample for the background.
- Uncertain set $\mathcal{U} = \mathcal{N} - (\mathcal{F} \cup \mathcal{B})$: set of all pixels that are not in the both fore/background set.

How to figure out all pixels belong to the object in the image and separate them from the background?



(a) Foreground seeds $\mathcal{F}$ (b)Background seeds $\mathcal{B}$ (c)Uncertain regions $\mathcal{U}$
(d) Foreground marker (e) Background marker (f) Graph cut result

Binary images: foreground, background

- A binary image is an image in which each pixel belongs to one of only two possible discrete logical value: 1 or 0. In our problem:
  - The logical value 1 is known as "object".
  - The logical value 0 is known as "not object".
- We define the set of pixels which logical value is *1/0* as the temp *foreground/background* pixel.

Binary labelling problem

For all image pixels, we need to assign a unique label

$$x_i \in \{ foreground\,(=1), background\,(=0) \}$$

- If a pixel is in the *foreground/background* set, the label of it is *1/0*.
- If a pixel is not in the foreground and background set, the temporary label of it is "*uncertain*".

How to find a way to label all pixels in the image so that all pixels belong to object we want to select have same label, and so do to the another pixel?

Binary labelling problem - Constraint

Data constraint

If a pixel has it colors similar to at least one pixel belong to foreground seeds, it is more likely to get foreground label, and so do with background seeds.

Prior constraint

Pixels that belong to the object tend to group together, and so do with pixels that belong to background.

Binary labelling problem

Minimize the energy function (Greig et al., 1989)

$$E(L) = \sum_{p} D_p\left(L_p\right) + \lambda * \sum_{p,q \in N} \left|L_P - L_q\right| * g\left(C_{i,j}\right)$$

Where λ know as a balancing parameter between data constraint and the prior constraint:

- The larger lambda, the less discontinuities in the optimal labeling L.
- The smaller lambda, the more optimal labeling L.

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Energy function

Let A is a $\{\text{"object", "background"}\}$ binary vector of pixels that defines a segmentation

$$E(A) = \lambda \cdot R(A) + B(A) \ ,$$

where

$$R(A) = \sum_{p \in P} R_p(A_p)$$

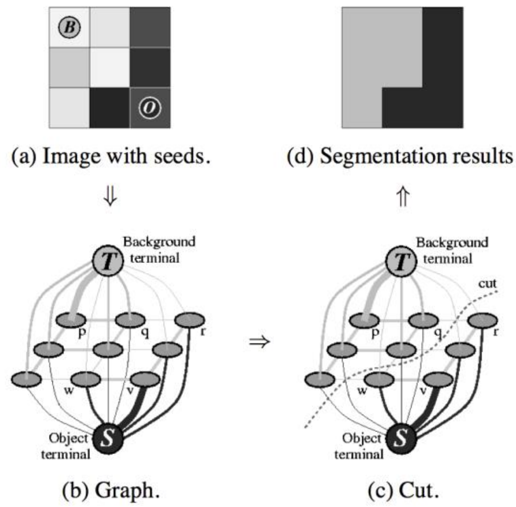
$$B(A) = \sum_{\{p,q\} \in \mathcal{N}} B_{\{p,q\}} \cdot \delta(A_p, A_q)$$

and

$$\delta(A_p, A_q) = \begin{cases} 1 \text{ if } A_p \neq A_q \\ 0 \text{ otherwise.} \end{cases}$$

Graph cut construction

A simple segmentation example for a 3x3 image.



Energy function (cont.)

edge	weight (cost)	for
$\{p,q\}$	$B_{\{p,q\}}$	$\{p,q\} \in \mathcal{N}$
$\{p,S\}$	$\lambda \cdot R_p(\text{"background"})$	$p \in \mathcal{P}, p \notin \mathcal{O} \cup \mathcal{B}$
	K	$p \in \mathcal{O}$
	0	$p \in \mathcal{B}$
$\{p,T\}$	$\lambda \cdot R_p(\text{"object"})$	$p \in \mathcal{P}, p \notin \mathcal{O} \cup \mathcal{B}$
	0	$p \in \mathcal{O}$
	K	$p \in \mathcal{B}$

where

$$K = 1 + \max_{p \in \mathcal{P}} \sum_{q:\{p,q\} \in \mathcal{N}} B_{\{p,q\}}.$$

Detailed implementation

- Negative log-likelihood of intensity for regional term

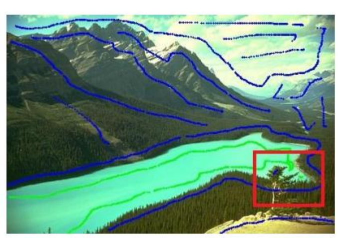
$$\begin{aligned} R_p(\text{"object"}) &= -\ln \Pr\left(I_p | \mathcal{O}\right) \\ R_p(\text{"background"}) &= -\ln \Pr\left(I_p | \mathcal{B}\right) \end{aligned}$$

- Ad hoc function for boundary term

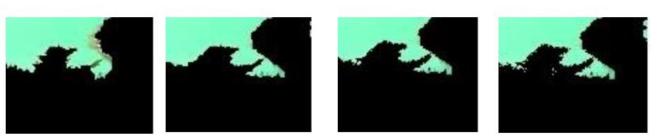
$$B_{\{p,q\}} \propto \exp\left(-\frac{\left(I_p - I_q\right)^2}{2\sigma^2}\right) \cdot \frac{1}{dist\left(p,q\right)}.$$

- Max-flow algorithm provided by Boykov and Kolgomorov (2001)

Sample result and comment



a. Image with seeds and selected red regions for zooming in in results



b. $\lambda = 0$ c. $\lambda = 0.5$ d. $\lambda = 1$ e. $\lambda > 1$

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Silent Lazy Snapping model

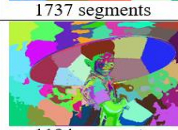
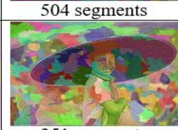
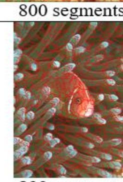
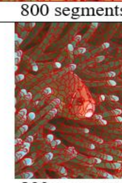
a. Input image *b. Object marking* *c. Presegmentation* *d. Final segmentation* *e. Output Composition*

Step 1: Sample definition

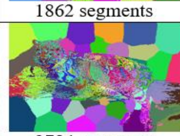
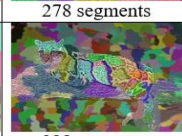
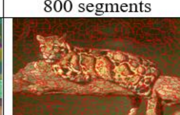
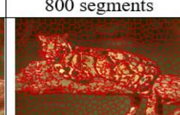
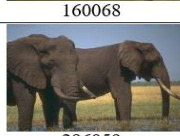
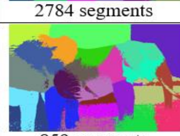
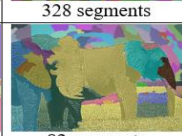
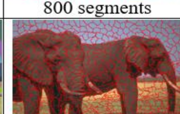
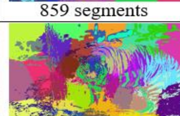
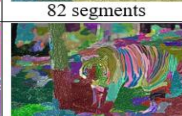
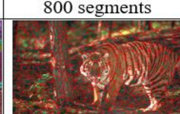
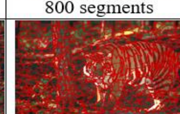
Step 2: Pre-segmentation

Experimental result on pre-segmentation (1)

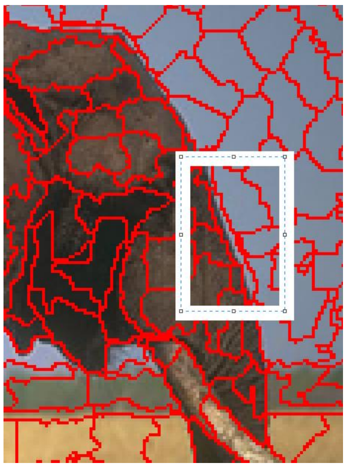
Table 6. Results of different segmentation methods

Image Size	Original Image	K-means method	Watershed method	SEEDs Superpixels method	SEEDs Revised Mean Pixels
481 x 321 pixel	 124084	 1737 segments	 504 segments	 600 segments	 800 segments
481 x 321 pixel	 189011	 1194 segments	 351 segments	 800 segments	 800 segments
321 x 481 pixel	 210088	 1534 segments	 436 segments	 800 segments	 800 segments

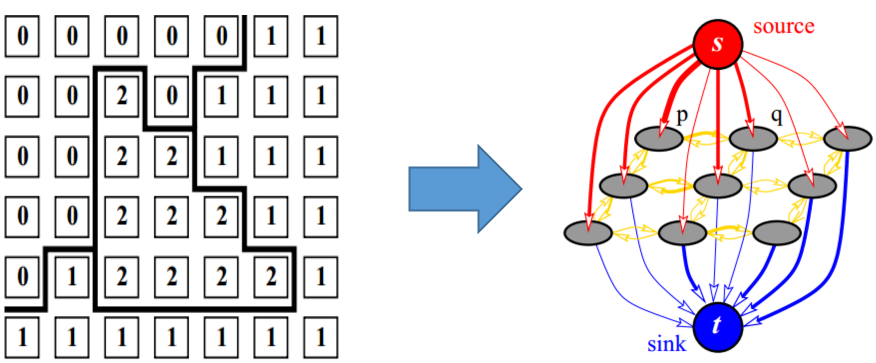
Experimental result on pre-segmentation (2)

481 x 321 pixel	 41004	 1862 segments	 278 segments	 800 segments	 800 segments
481 x 321 pixel	 160068	 2784 segments	 328 segments	 800 segments	 800 segments
481 x 321 pixel	 296059	 859 segments	 82 segments	 800 segments	 800 segments
481 x 321 pixel	 108005	 4520 segments	 303 segments	 800 segments	 800 segments

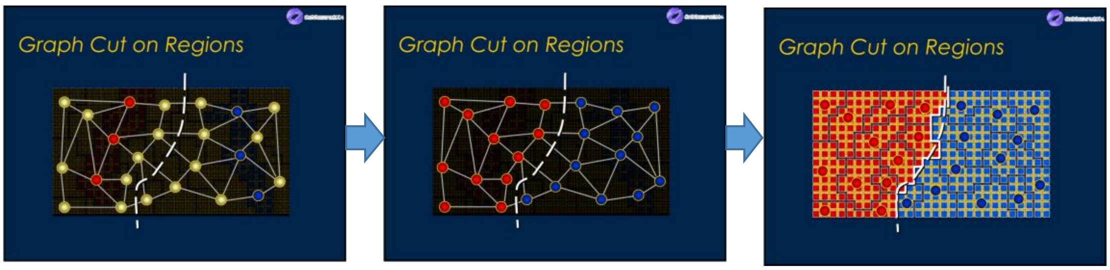
Experimental result on pre-segmentation (3)

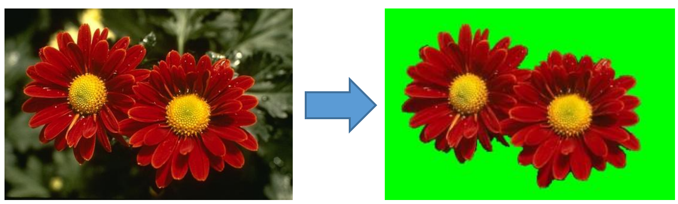



Step 3: Graph initialization



Step 4: Graph cut and final segmentation





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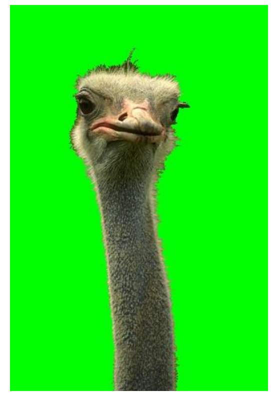
Limitation 1: Pixel loss in thin area

189080 with samples

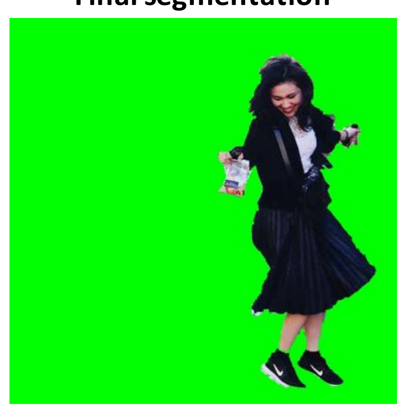
Final segmentation



Limitation 2: Unsmooth boundary

Dancing_Emily with samples

Final segmentation



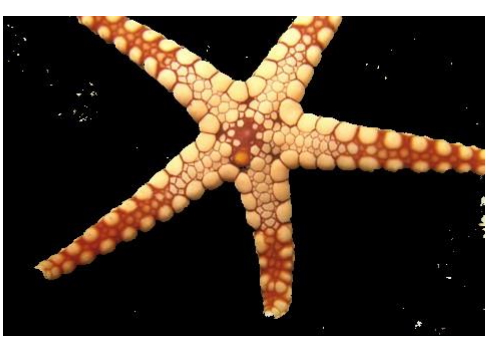
Limitation 3: Poor performance when foreground and background have similar color distribution

Vango with samples

Final segmentation

Berkeley dataset – 12003.jpg

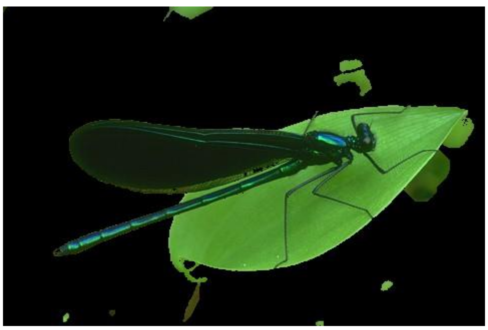
Interactive Graph Cut



Silent Lazy Snapping

Berkeley dataset – 35070.jpg

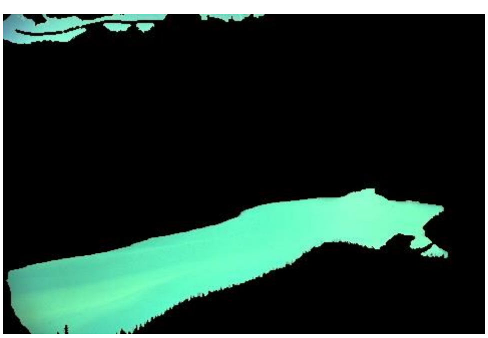
Interactive Graph Cut



Silent Lazy Snapping

Berkeley dataset – 176035.jpg

Interactive Graph Cut



Silent Lazy Snapping

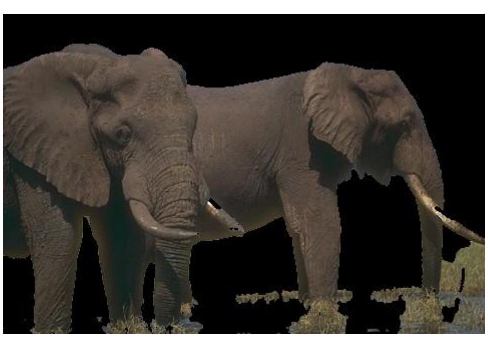
Berkeley dataset – 187029.jpg

Interactive Graph Cut

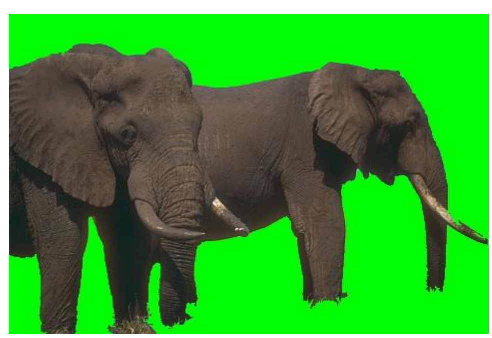
Silent Lazy Snapping

Berkeley dataset – 207056.jpg

Interactive Graph Cut



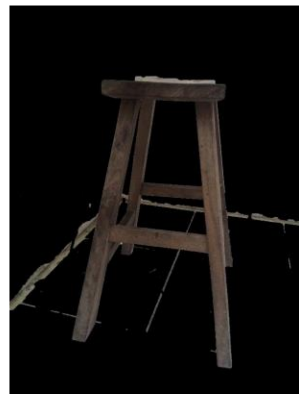
Silent Lazy Snapping



Khoi's dataset – 5.jpg

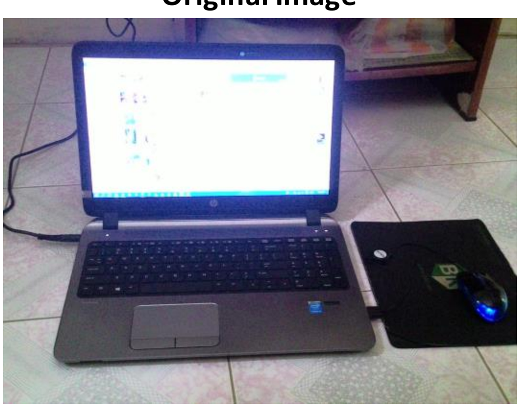
Original Image

Interactive Graph Cut

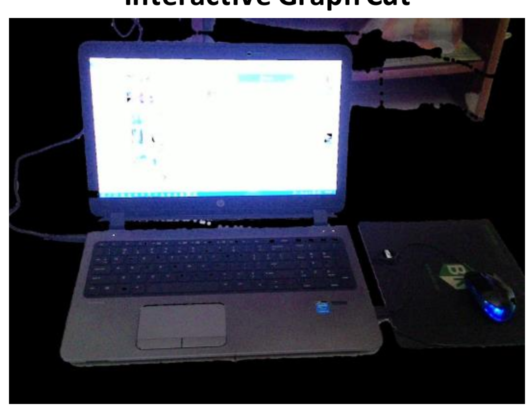


Khoi's dataset – 6.jpg

Original Image

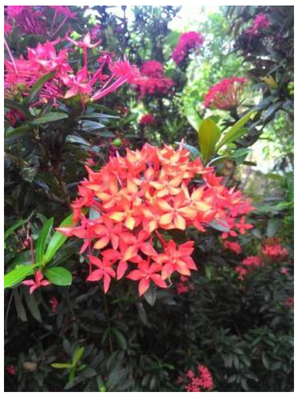


Interactive Graph Cut

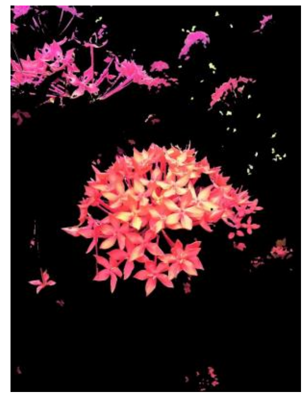


Khoi's dataset – 7.jpg

Original Image



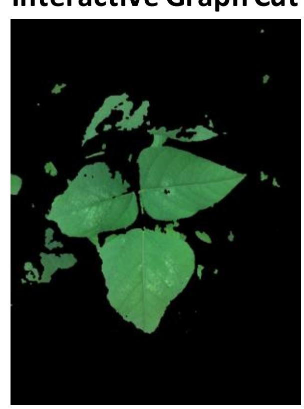
Interactive Graph Cut



Khoi's dataset – 8.jpg

Original Image

Interactive Graph Cut



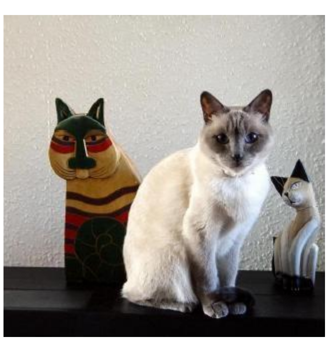
Khoi's dataset – 9.jpg

Original Image

Interactive Graph Cut

Nam's dataset – Cat.jpg

Original Image



Silent Lazy Snapping

Nam's dataset – TrangAn.jpg

Original Image

Silent Lazy Snapping

Nam's dataset – Nam_2.jpg

Original Image

Silent Lazy Snapping

Nam's dataset – WSpaper.jpg

Original Image

Silent Lazy Snapping

Nam's dataset – Emily_child.jpg

Original Image

Silent Lazy Snapping

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Future works

Graph Cut for Image Segmentation

- Try several other feature descriptor (such as HOG, etc.) for achieving the better results
- Add GUI options for easier experimenting

Lazy Snapping

- Add boundary editing function
- Add some filter

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THANK YOU FOR LISTENING!