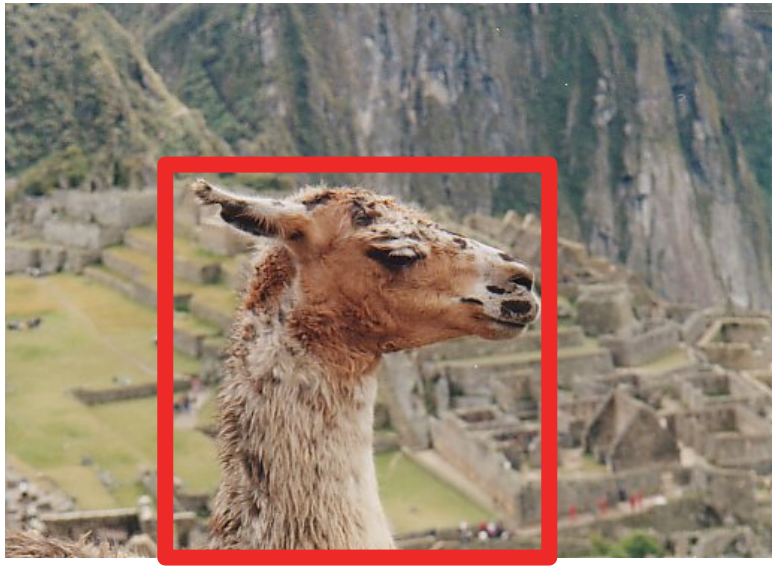
Q&A of GrabCut

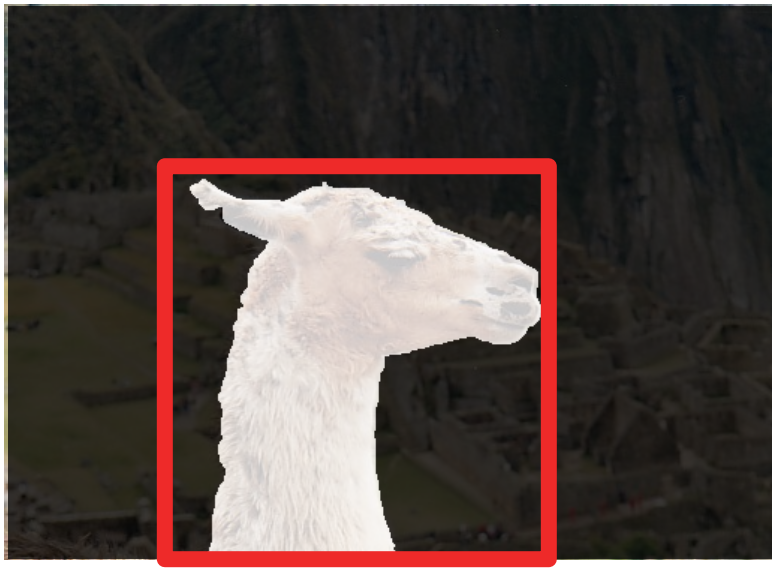
Philipp Krähenbühl

Goal



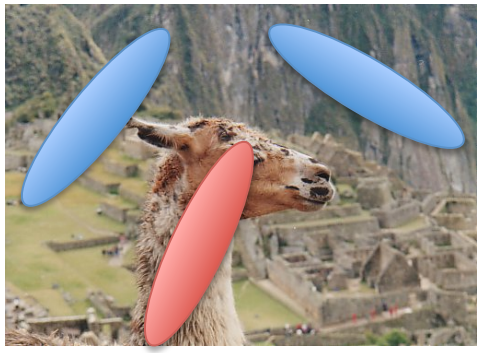
- Bounding Box
  - provided

Goal



- Segmentation of object within bounding box

Overview



- Boykov & Jolly segmentation model

$$E(\alpha, z) = \sum_n D(\alpha_n, z_n) + \gamma \sum_{n,m} w_{n,m} [\alpha_n \neq \alpha_m]$$

  - Segmentation using Graph Cuts
- GMM foreground and background model

$$D(\alpha_n, \theta, z_n)$$

  - Iterative optimization
    - Graph Cuts
    - GMM estimation

Initialisation

- User initialises trimap T by supplying only T_B. The foreground is set to $T_F = \emptyset$; $T_U = \overline{T}_B$, complement of the background.
- Initialise $\alpha_n = 0$ for $n \in T_B$ and $\alpha_n = 1$ for $n \in T_U$.
- Background and foreground GMMs initialised from sets $\alpha_n = 0$ and $\alpha_n = 1$ respectively.

Iterative minimisation

1. *Assign GMM components to pixels:* for each n in T_U,
$$k_n := \arg\min_{k_n} D_n(\alpha_n, k_n, \theta, z_n).$$
2. *Learn GMM parameters* from data $\mathbf{z}$:
$$\underline{\theta} := \arg\min_{\underline{\theta}} U(\underline{\alpha}, \mathbf{k}, \underline{\theta}, \mathbf{z})$$
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$$\min_{\{\alpha_n:\, n \in T_U\}} \min_{\mathbf{k}} \mathbf{E}(\underline{\alpha}, \mathbf{k}, \underline{\theta}, \mathbf{z}).$$
4. Repeat from step 1, until convergence.
5. Apply border matting (section 4).

User editing

- *Edit:* fix some pixels either to $\alpha_n = 0$ (background brush) or $\alpha_n = 1$ (foreground brush); update trimap T accordingly. Perform step 3 above, just once.
- *Refine operation:* [optional] perform entire iterative minimisation algorithm.

Project 2

Not required

Optional

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Notation

- Trimaps
  - Sets of pixels
  - T_B: background
  - T_F: foreground
  - T_U: undecided
- Segmentation
  - α_i for each pixel i

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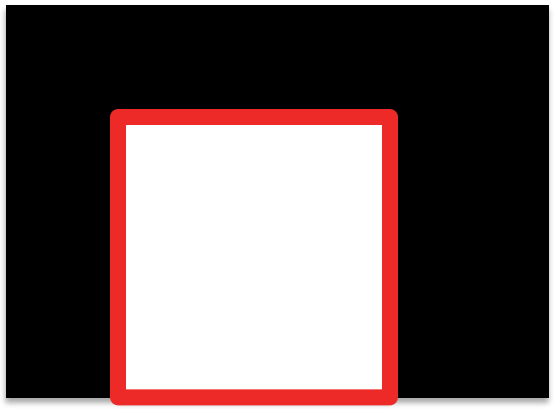

- Outside
  - Background (**fixed**)
  - α_n=0
- Inside
  - Initial foreground
  - α_n=1
  - **updated**

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GMM Initialization

- Find parameters θ
- Standard method
  - random + EM
- Re-estimate θ in step 2
  - Initialization only needed for step 1
  - Trick: Initialize k instead

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GMM Initialization

- Trick: Initialize k
  - k-means clustering
  - skip step 1 in first iteration

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GMM assignment

- Gaussian log prob.

$$D_n(\alpha_n, k_n, \theta, z_n) =$$
$$-\log \pi(\alpha_n, k_n) + \frac{1}{2}\log\det\Sigma(\alpha_n, k_n)$$
$$+\frac{1}{2}\left[z_n - \mu(\alpha_n, k_n)\right]^T \Sigma(\alpha_n, k_n)^{-1}\left[z_n - \mu(\alpha_n, k_n)\right]$$

- Enumerate all k_n
- Each pixel already assigned to FG or BG (**α_n fixed**)

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GMM leaning

- Mixture param.

$$\pi(\alpha = 1, k) = \frac{|F(k)|}{\sum_k |F(k)|}$$

$$\mu(\alpha = 1, k) = \operatorname*{mean}_{n \in F(k)}(z_n)$$

$$\Sigma(\alpha = 1, k) = \operatorname*{cov}_{n \in F(k)}(z_n)$$

- F(k) set of FG pixels assigned to comp. k

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Segmentation

- Find segmentation that minimizes

$$\min_k E(\alpha, k, \theta, z) =$$

$$\sum_n \underbrace{\min_{k_n} D(\alpha_n, k_n, \theta, z_n)}_{D(\alpha_n, \theta, z_n)} + \gamma \sum_{n,m} w_{n,m} [\alpha_n \neq \alpha_m]$$

  - Reduces to Boykov & Jolly
  - Solved using GraphCut

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Use **energy.h** and **maxflow.cpp**

```
// initialization
std::vector<Energy::Var> vars(N);
Energy e;

// add a node
vars[i] = e.add_variable();

// add the unary term for a node
e.add_term1(vars[i], u0, u1);
// add the pairwise term for an edge
e.add_term2(vars[i], vars[j], p00,
p01, p10, p11);

// perform energy minimization
Energy::TotalValue mnE = e.minimize();

// get new labels
if (e.get_var(vars[i])) label[i] = 1;
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```

$D(0, \theta, z_n)$ $D(1, \theta, z_n)$

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$$v_{ij} = \gamma \exp(-\beta \|z_i - z_j\|^2)$$

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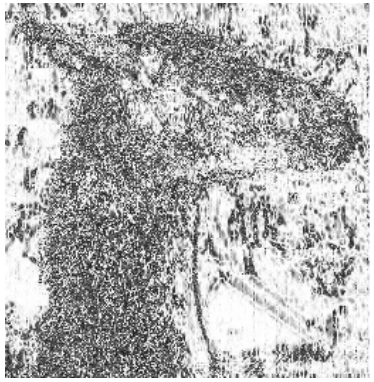

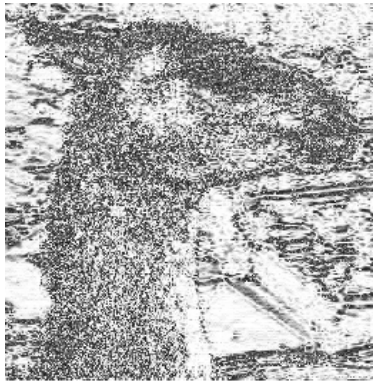

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Optimizations

- Use MEX files for Graph Cut
  - Call C/C++ code from matlab
  - complile: “mex a.cpp b.cpp c.cpp …”
- Vectorize
  - f: Nx3 matrix of RGB color values
  - a: N-dimensional binary vector (segmentation)
  - f(a==1,:): foreground features
  - f(a==0,:): background features

Implementation Questions?

Extensions

- User interaction or border matting
- Play with GMMs
  - Vary number of components
  - Different initialization
  - Different color space (Lab)
- Different Color model
  - Histogram based model

Extensions

- Different Neighborhood System
  - 4 connected
  - 8 connected
  - fully connected (DenseCRF)
    - Efficient Inference in Fully Connected CRFs with Gaussian Edge Potentials [Krähenbühl and Koltun 2011]
- Different "affinity"
  - Lab color difference
  - Contour detector gPb
    - Contour Detection and Hierarchical Image Segmentation [Arbelaez etal 2010]

Questions?