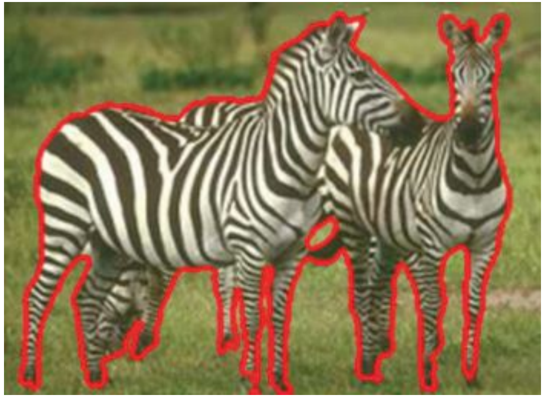
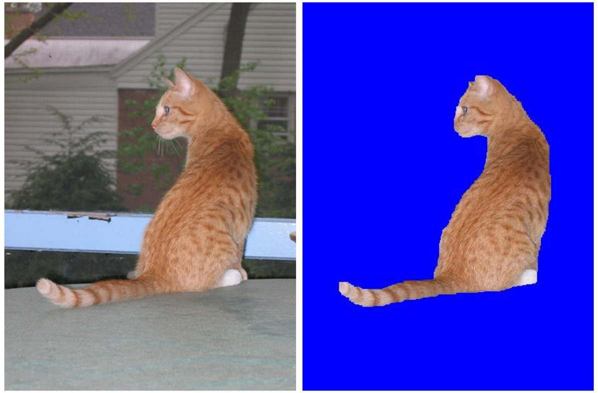
Foreground/Background Image Segmentation

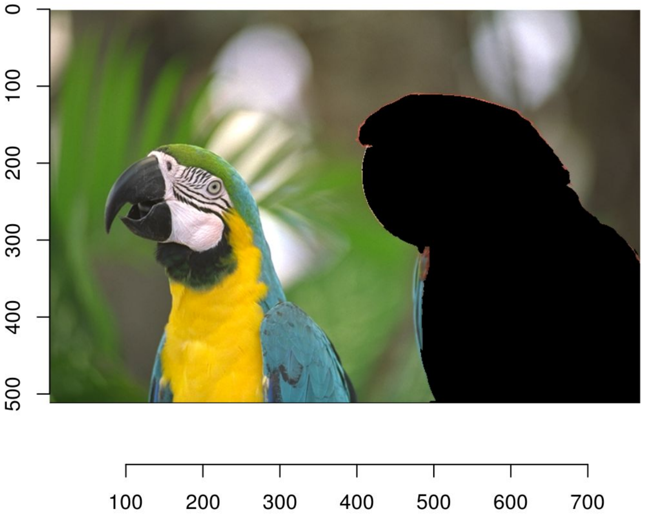
By Natalia Frumkin

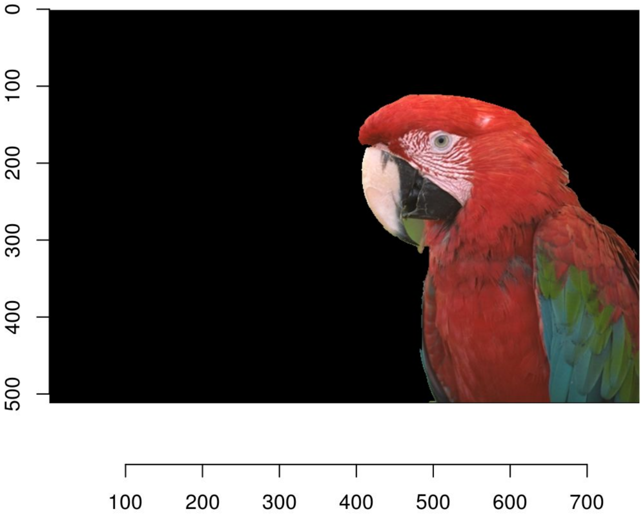




Problem Statement

Segment an image into background and foreground





Techniques

1. **Image Filtering**

2. **Max Flow Algorithms**

Otsu’s Method for Filtering

Big idea: automatic thresholding by minimizing intra-class variance

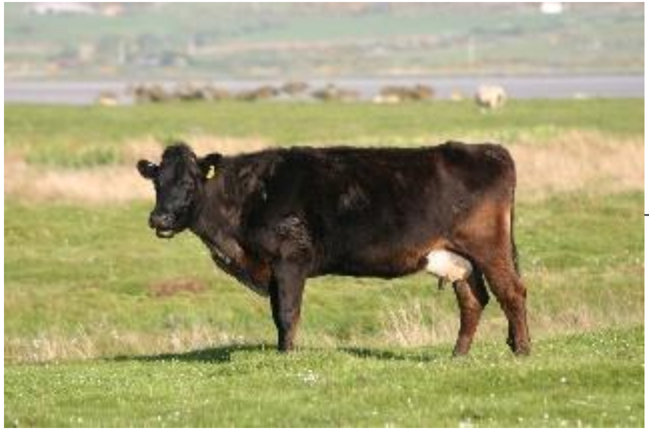
objective:

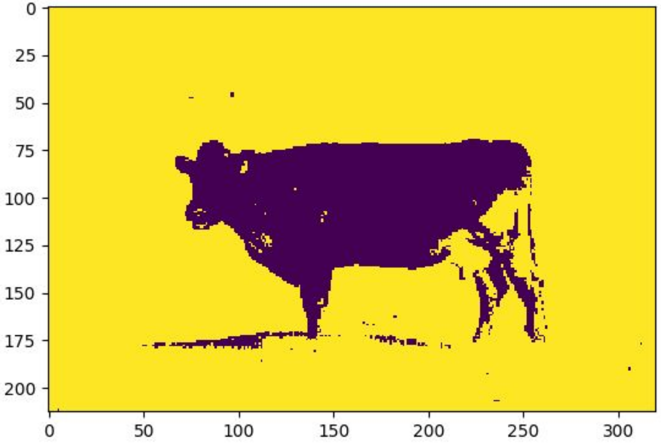
$$\sigma_w^2(t) = \omega_0(t)\sigma_0^2(t) + \omega_1(t)\sigma_1^2(t)$$

Class 0 variance

Class 1 variance

Results





Max-Flow Techniques

Energy Minimization

$$E(L) = \sum_{p \in \mathcal{P}} D_p(L_p) + \sum_{(p,q) \in \mathcal{N}} V_{p,q}(L_p, L_q).$$

Data Penalty Term
Individual pixel intensity

Interaction Potential Term
Promotes spatial coherence between neighboring pixels

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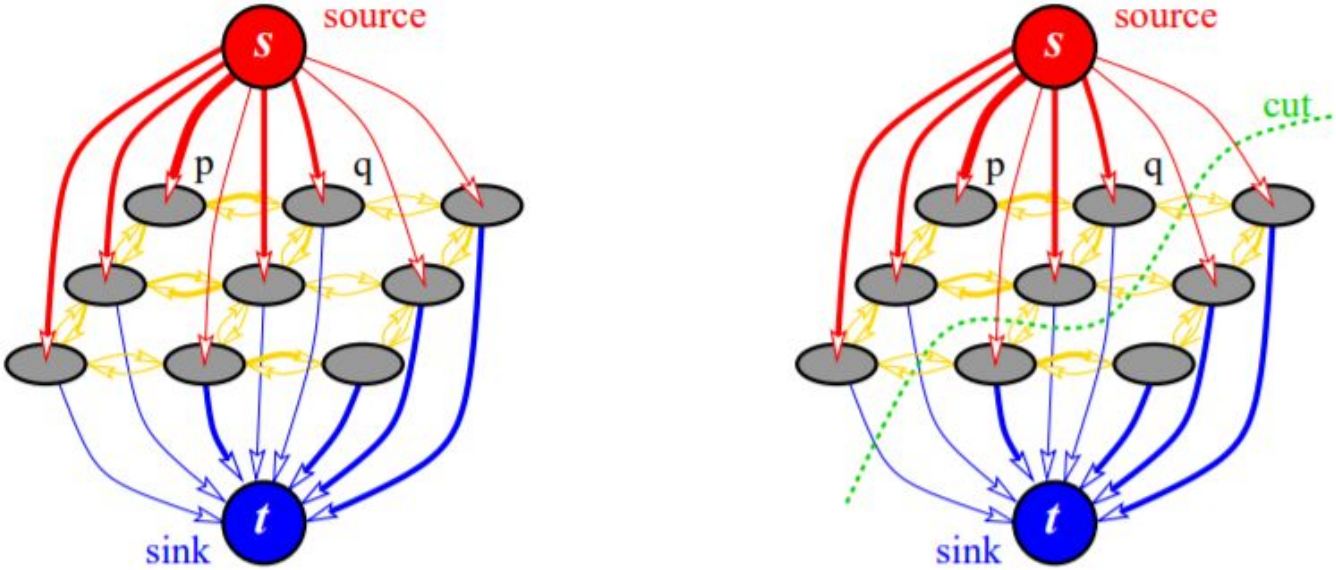
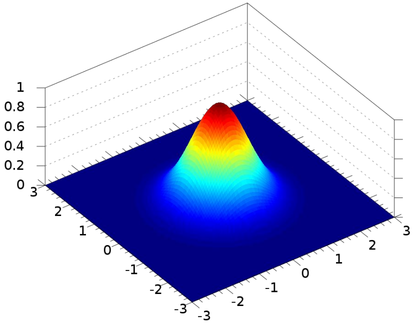
Graph Setup



(a) A graph $\mathcal{G}$

(b) A cut on $\mathcal{G}$

Graph Weights

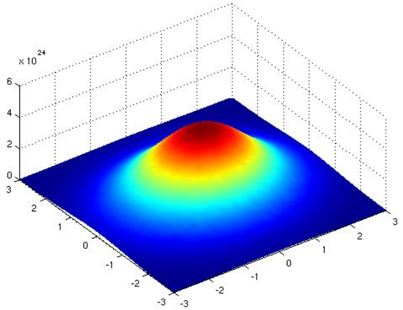


Intensity weights (Data Penalty)

distribution of individual pixels match src/sink labels

computed by:

$$exp\left(-\frac{(I_p - I_q)^2}{2\sigma^2}\right)$$

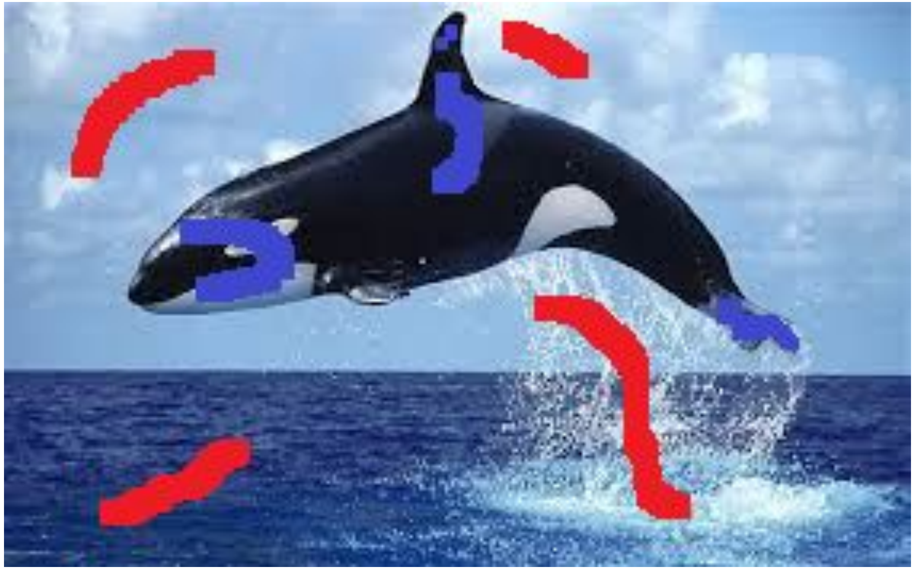


Interpixel weights (Interaction Potential)

distribution using intensity difference between neighboring pixels

computed through closed-form gaussian estimation

Annotation: Supervised Method



Ford Fulkerson Algorithm

1. Growth Phase

    Find path from source to sink using BFS

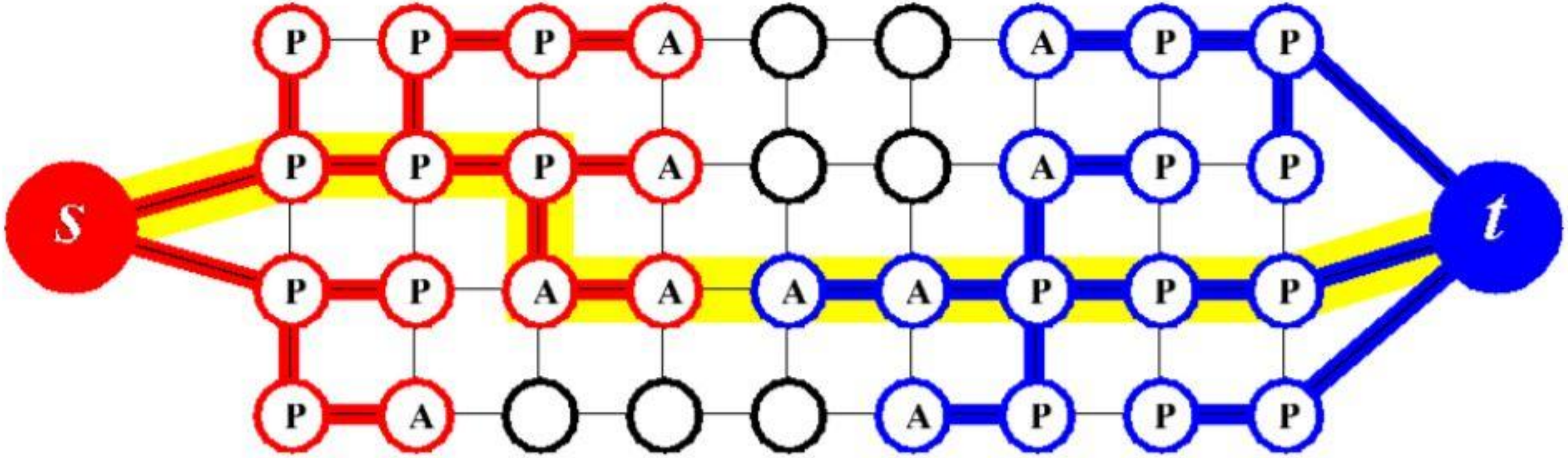
2. Augment Phase

    Push flow from s → t

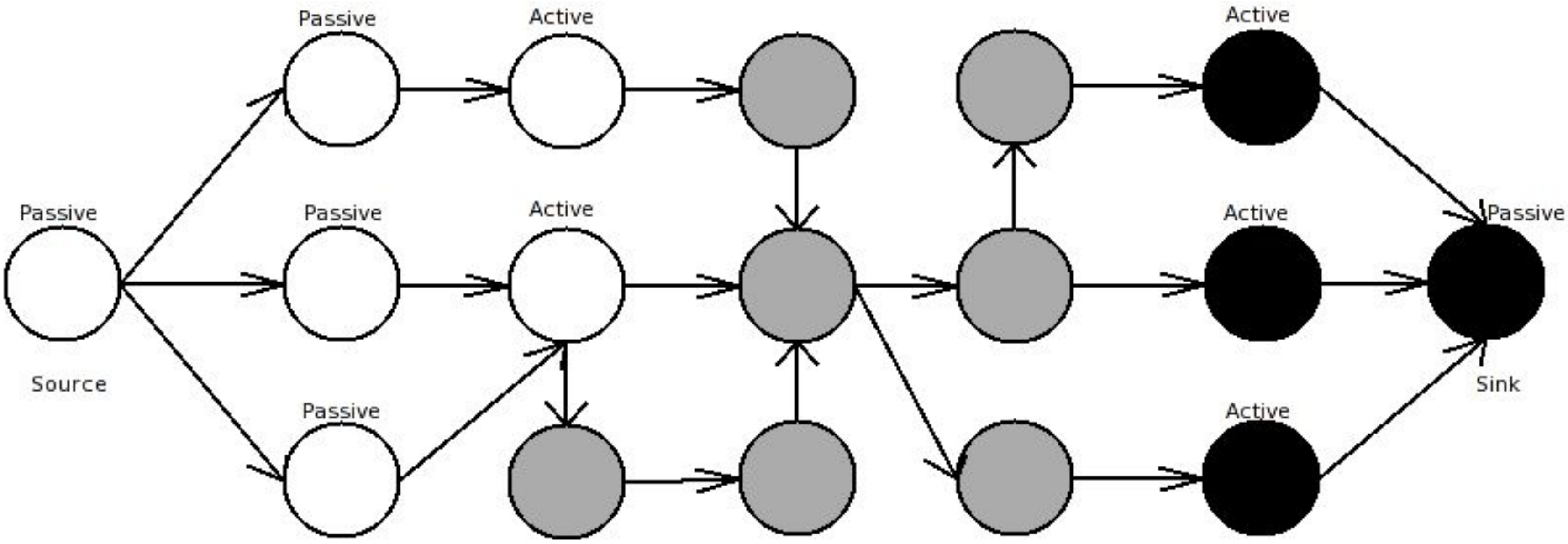
    Update residual graph and max-flow

Repeat until no paths can be found between source & sink

The Boykov-Kolmogorov Max-Flow Algorithm



The Boykov-Kolmogorov Max-Flow Algorithm



Example with labeled vertices and active/passive status

The Boykov-Kolmogorov Max-Flow Algorithm

1. Growth Phase

   Search trees S and T grow until they touch giving an s→ t path

2. Augment Phase

   Augment s → t path by pushing flow

3. Adoption Phase

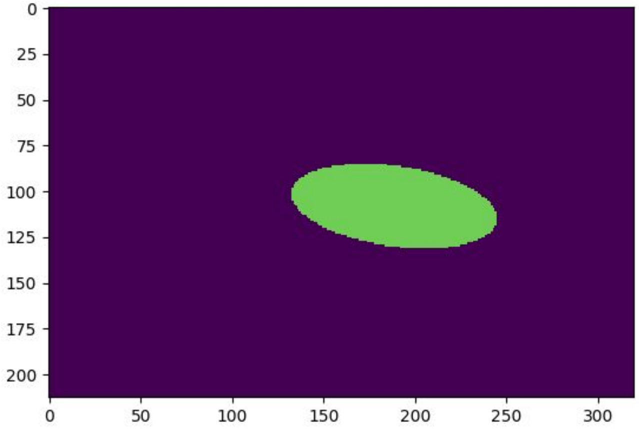
   Restore single-tree structure of sets S and T

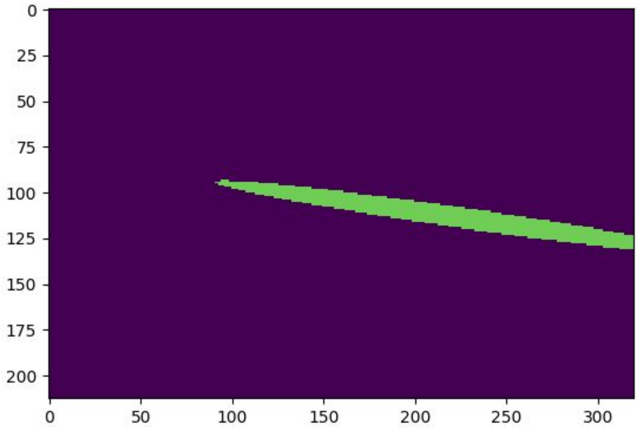
The Boykov-Kolmogorov Max-Flow Algorithm

Repeat three phases until end conditions are satisfied:

1) S & T Trees can not grow (no active nodes)
2) Trees are separated by saturated edges

Issues: Parameter Fitting





Next Steps:

- Grid search for optimal lambda and sigma
- Use Gaussian Mixture Models for weights

Runtime

Otsu’s Method

O(max(N_pixels, N_bins*N_bins) *real runtime: 0.0017 sec*

Ford-Fulkerson Method

$O(V*E^2)$ *real runtime: Too long :(*

Boykov-Kolmogorov Method

$O(V^2 * E * |C|)$ *real runtime: 10.6+0.00088 sec*

Demo!