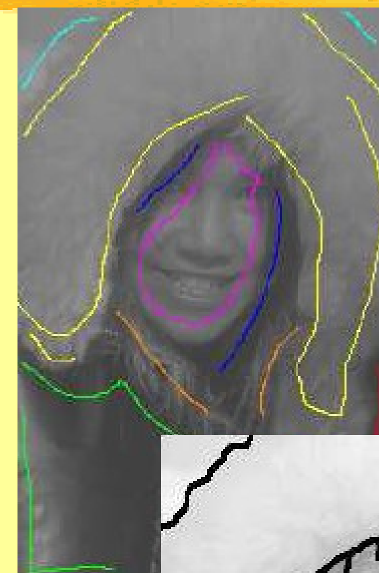
Oversegmentation control for inexact graph matching



Luis A. Consularo (UNIMEP – Brazil)
Roberto M. Cesar-Jr (USP – Brazil)
Luiz H. de Figueiredo (IMPA - Brazil)
Isabelle Bloch (ENST - France)
Alexandre Noma (USP – Brazil)

(FAPESP, CNPq, Capes/Cofecub)

Summary

- Introduction
- Model-based image segmentation
- Graph matching
- Markers detection
- Experimental results
- Concluding remarks

Summary

- **Introduction**
- Model-based image segmentation
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Introduction

Structural Pattern Recognition (**SPR**)

The Representation and Matching of Pictorial Structures

MARTIN A. FISCHLER AND ROBERT A. ELSCHLAGER

Abstract—The primary problem dealt with in this paper is the following. Given some description of a visual object, find that object in an actual photograph. Part of the solution to this problem is the specification of a descriptive scheme, and a metric on which to base the decision of "goodness" of matching or detection.

We offer a combined descriptive scheme and decision metric which is general, intuitively satisfying, and which has led to promising experimental results. We also present an algorithm which takes the above descriptions, together with a matrix representing the intensities of the actual photograph, and then finds the described object in the matrix. The algorithm uses a procedure similar to dynamic programming in order to cut down on the vast amount of computation otherwise necessary.

One desirable feature of the approach is its generality. A new programming system does not need to be written for every new description; instead, one just specifies descriptions in terms of a certain set of primitives and parameters.

There are many areas of application: scene analysis and description, map matching for navigation and guidance, optical tracking, stereo compilation, and image change detection. In fact, the ability to describe, match, and register scenes is basic for almost any image processing task.

Index Terms—Dynamic programming, heuristic o
picture description, picture matching, picture processing
tation.

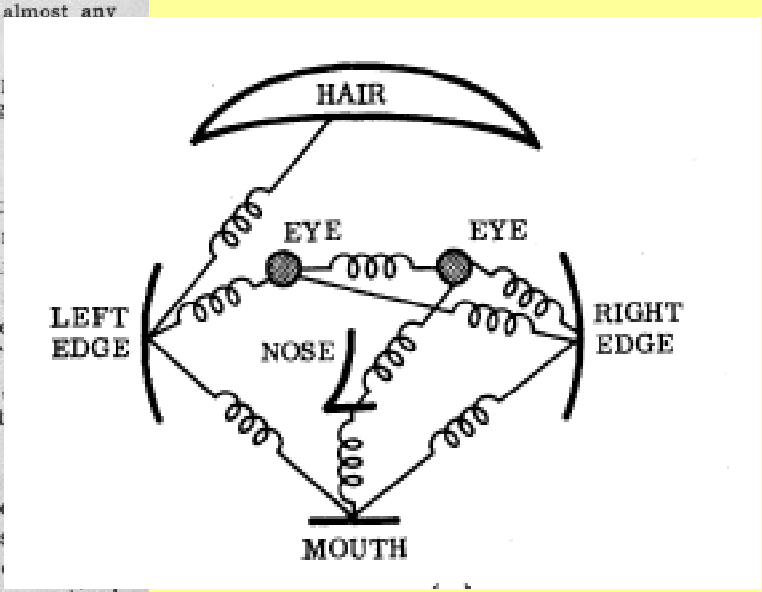
Manuscript received November 30, 1971; revised May 22, 1972, and August 21, 1972.

The authors are with the Lockheed Palo Alto Research Laboratory, Lockheed Missiles & Space Company, Inc., Palo Alto, Calif. 94304.

INTRODUCTION

THE PRIMARY PROBLEM dealt wit
paper is the following. Given some desc
a visual object, find that object in an actu
graph. The object might be simple, such as
complicated, such as an ocean wave, and the de
can be linguistic, pictorial, procedural, etc. T
photograph will be called the "sensed scene
dimensional array of gray-level values, while t
being sought is called the "reference."

This ability to find a reference in a sensed
equivalently, to match or register the image
scenes, is basic for almost any image process
Application to such areas as scene analysis an
tion, map matching for navigation and guidance, optical



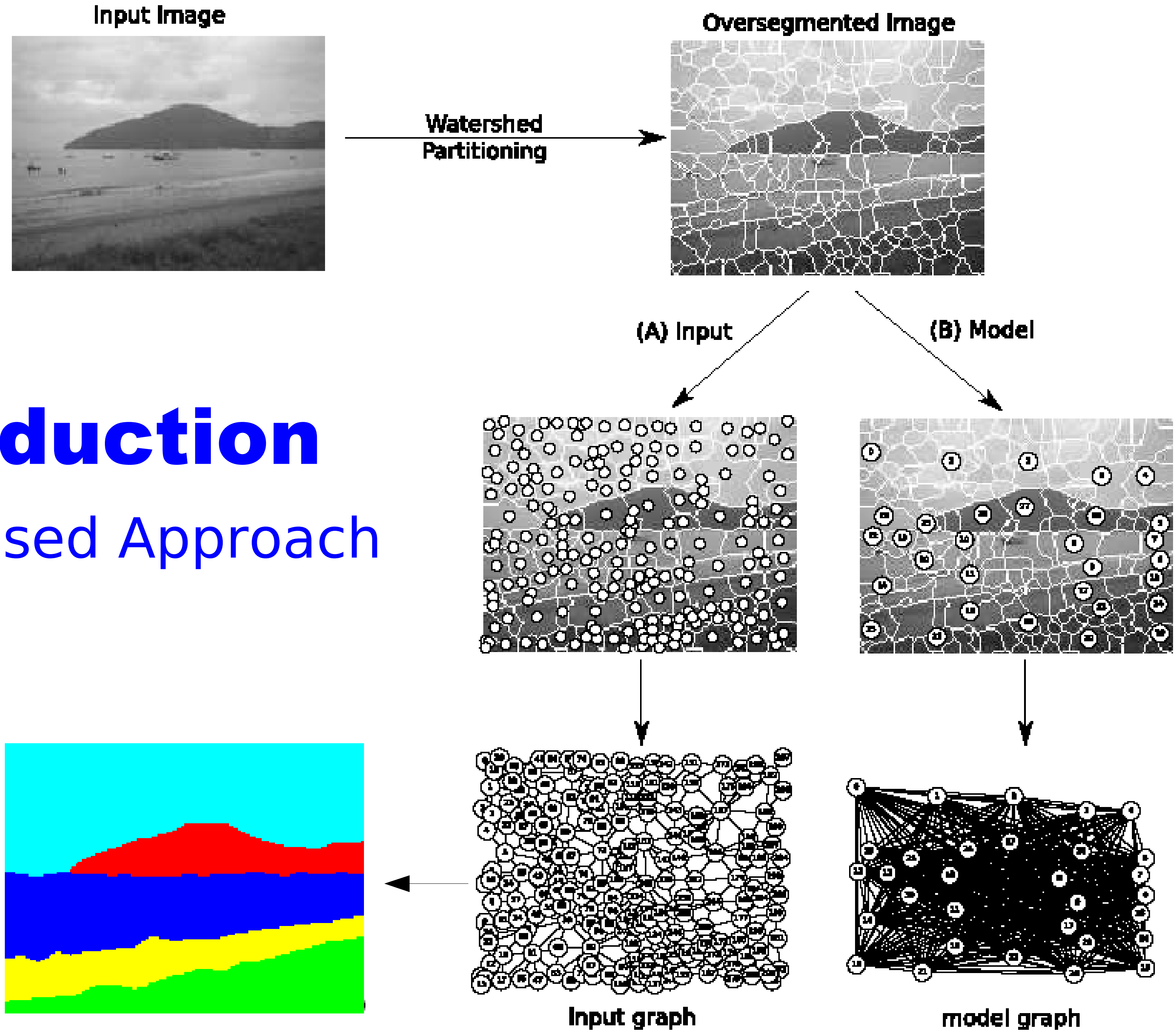
IEEE TRANSACTIONS ON COMPUTERS, VOL. C-22, NO. 1, JANUARY 1973

Introduction: SPR

- Ledley, 1964: Syntactic decomposition
- Barrow and Popplestone, 1971: High-level models
- Minsky 1972: Frames
- Pavlidis, 1977: SPR and shape analysis
- Fu, 1982: Syntactic PR and Graphs
- Bunke & Allerman, 1983: Inexact matching
- Bloch, 1999, 2000: Spatial relations, graph fuzzy homomorphism
- Hancock, 2001: EM formulation
- Felzenswalb & Huttenlocher, 2004: Dynamic Programming, shape priors

Introduction

- Proposed Approach



Summary

- Introduction
- **Model-based image segmentation**
- Graph matching
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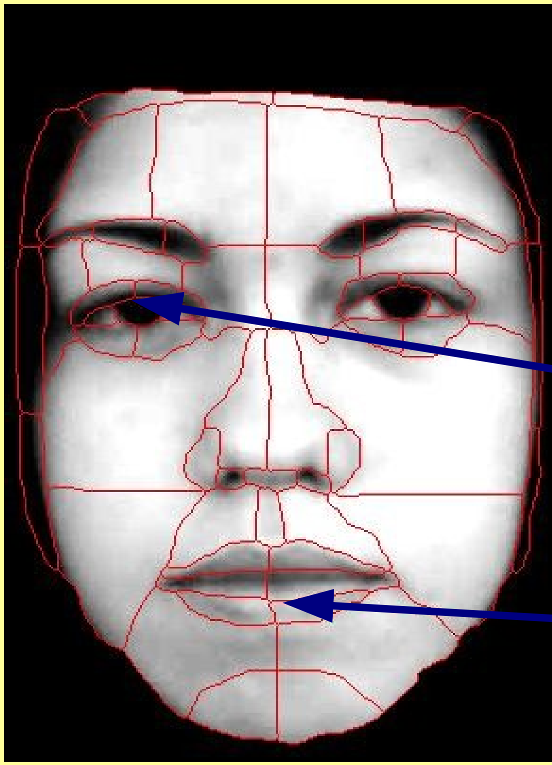
- Experimental results
- Concluding remarks

Model-based image segmentation



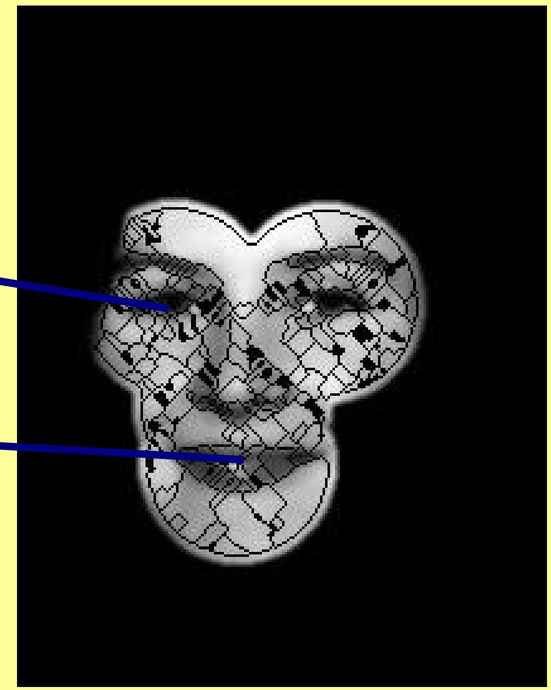


Image segmentation and recognition of image parts

Model image

Oversegmented input image

(R. Cesar et al., *Pattern Recognition*, 2005)

Model-based image segmentation

Attributed relational graphs

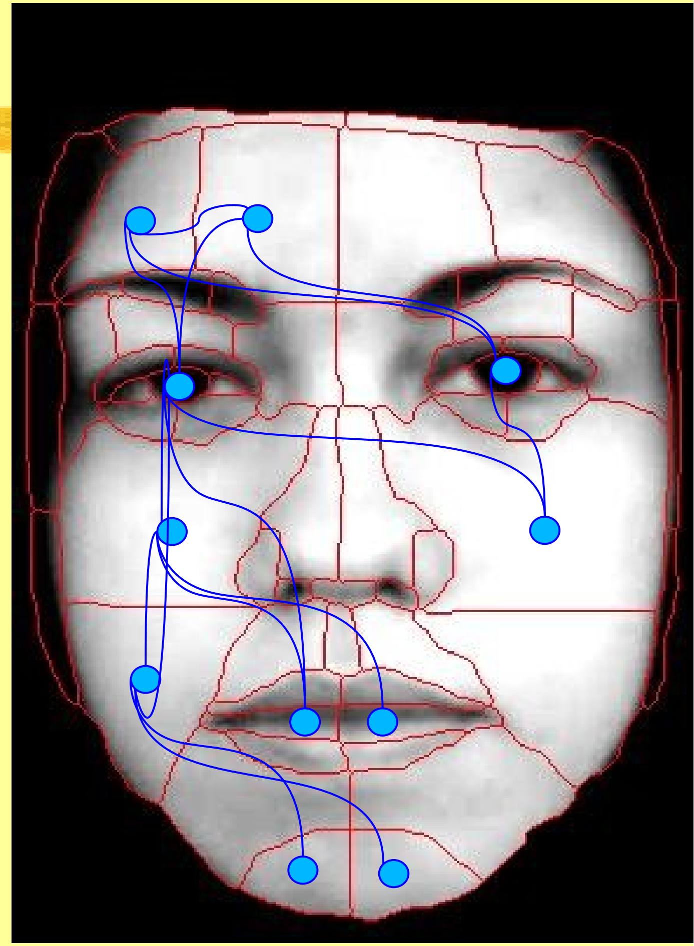
Image objects (parts)

Object feature vector

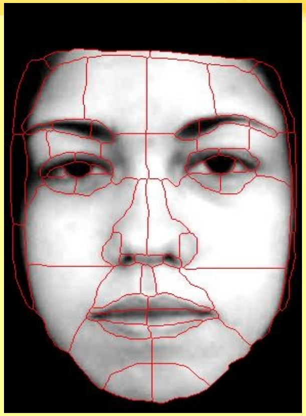
$$G=\left(V\,,E\,,\mu\,,\nu\right)$$

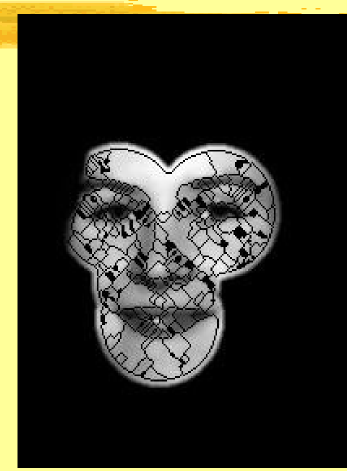
Structural relation between objects

Relational feature vector

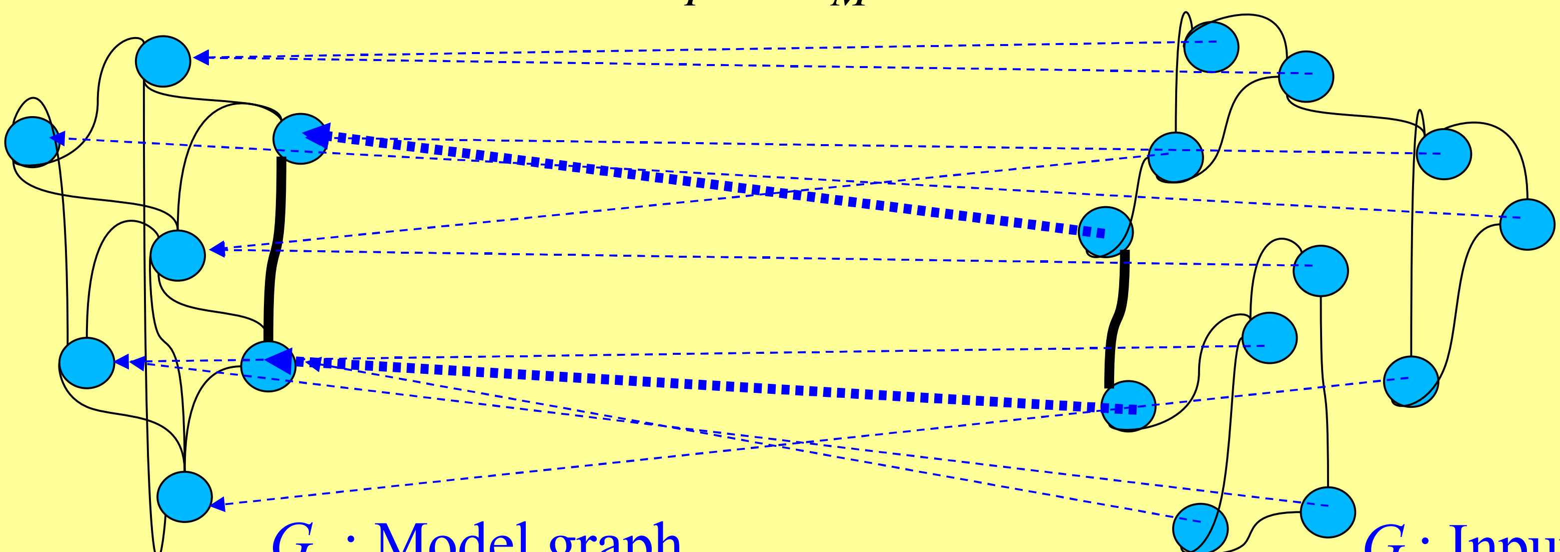


Model-based image segmentation





$$f : V_I \rightarrow V_M$$



G_M: Model graph

G_I: Input graph

Model-based image segmentation

Big problem: too many possible solutions! $\left|V_M\right|^{\left|V_I\right|}$

Objective function to be optimized in order to search a good solution

$$f(G_S) = \frac{\alpha}{|N_S|} \sum_{a_{im} \in N_S} c_V(a_{im}) + \frac{(1-\alpha)}{|E_S|} \sum_{e \in E_S} c_E(e)$$

Vertex cost

Edge cost

Summary

- Introduction
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- **<u>Graph matching</u>**
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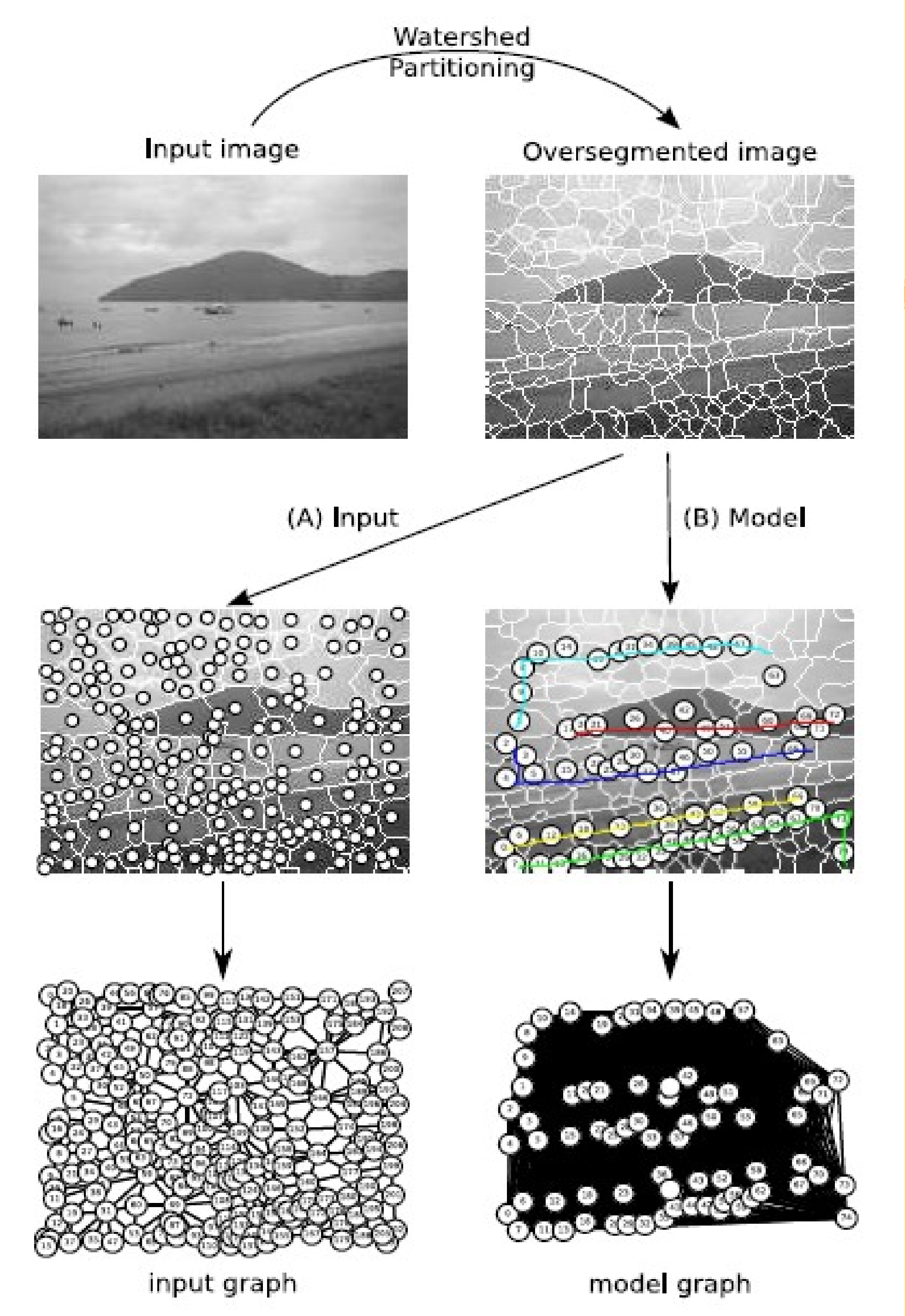
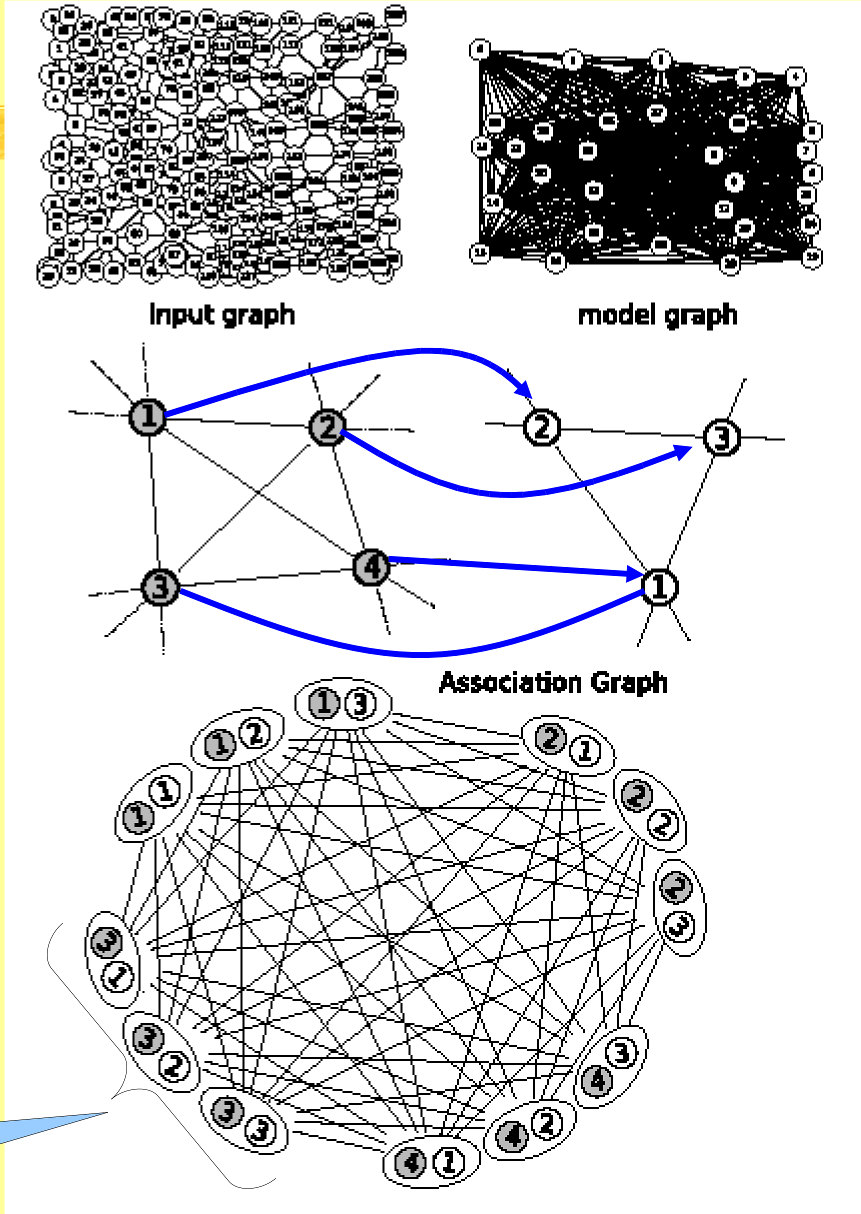
Graph matching

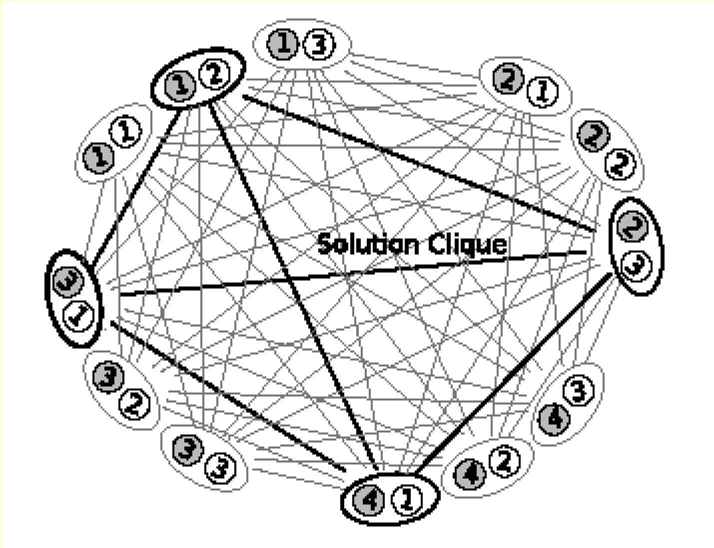
- Interactive model generation
- Model vertices are defined by watershed basins intercepted by user traces



Graph matching

Possible solutions are cliques of the association graph between G_I and G_M.

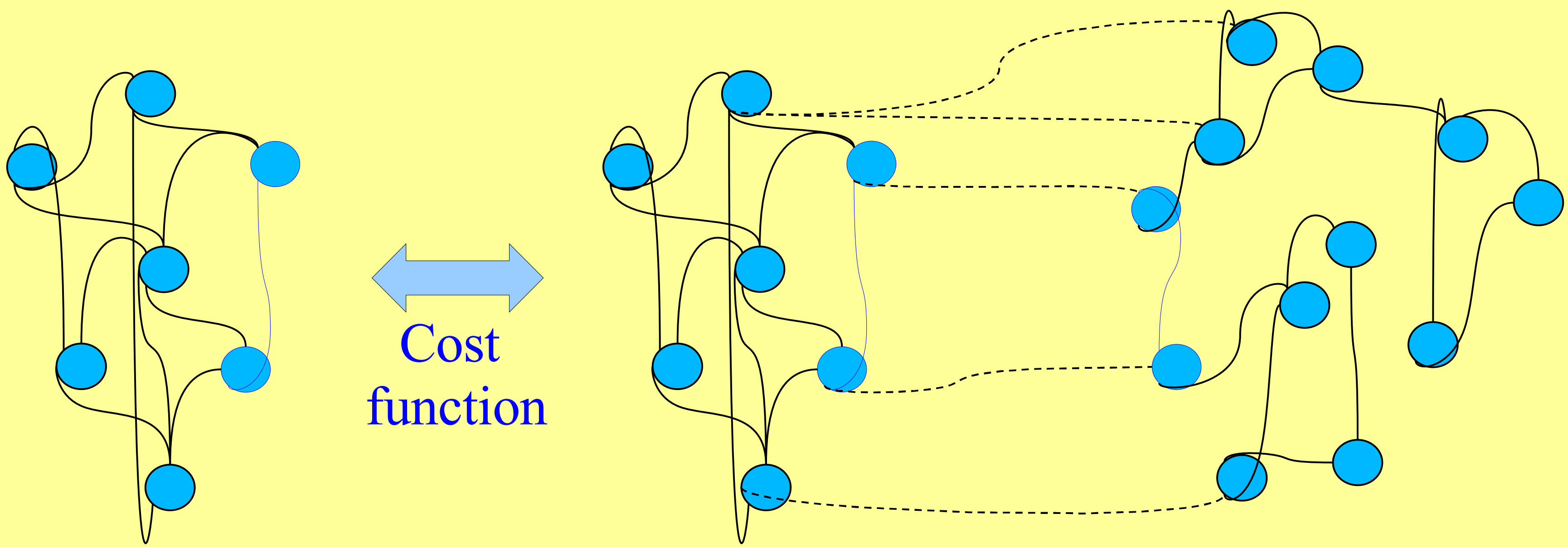




Optimization Algorithm: SFS

Supervertex

Graph matching



Model graph G_M Realization graph g_r Image graph g_i

$$max\{P(G_M = g_r)\}$$

New graph matching approach

Summary

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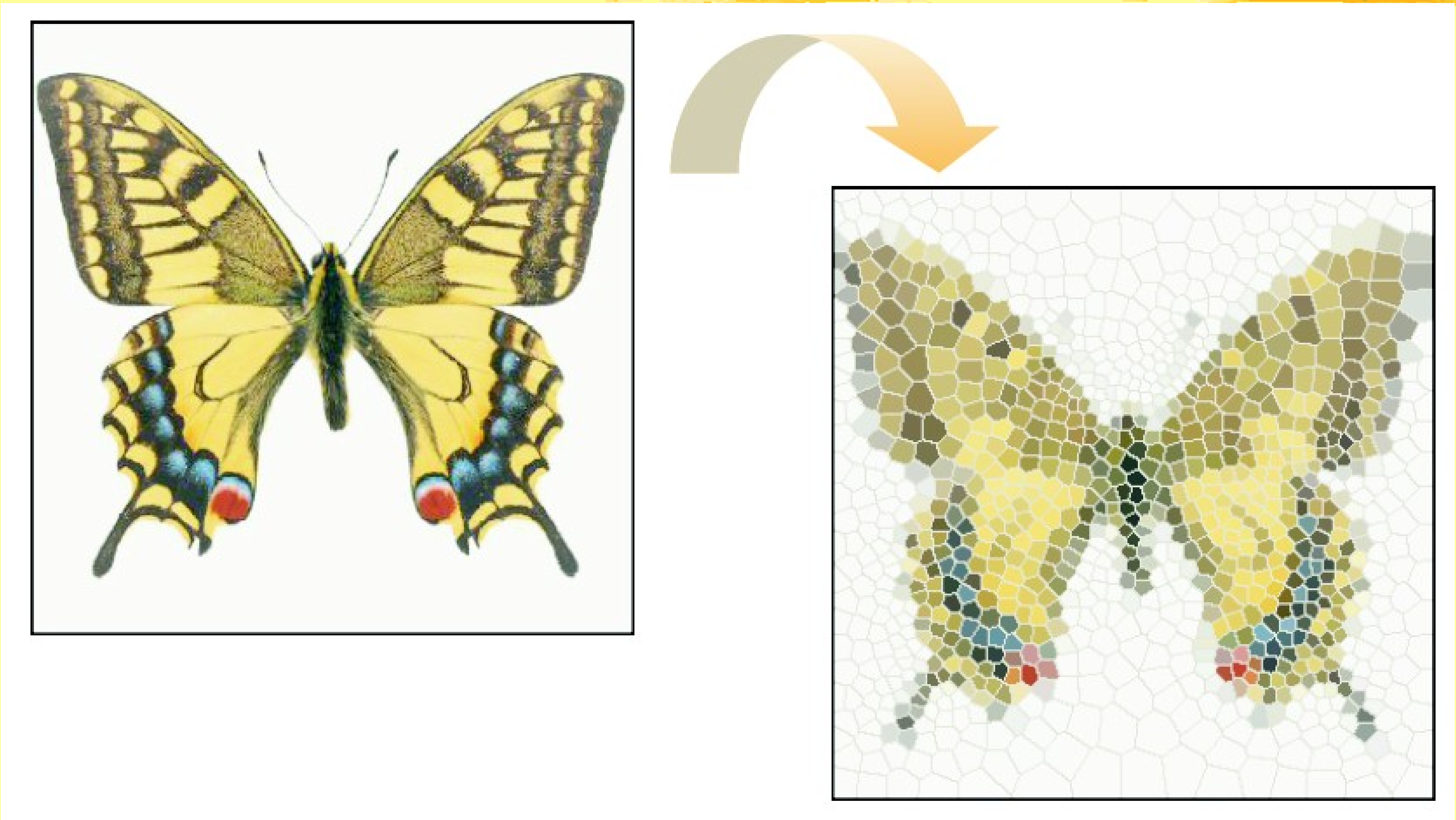
Markers detection

(Faustino & Figueiredo, *Sibgrapi*, 2005)

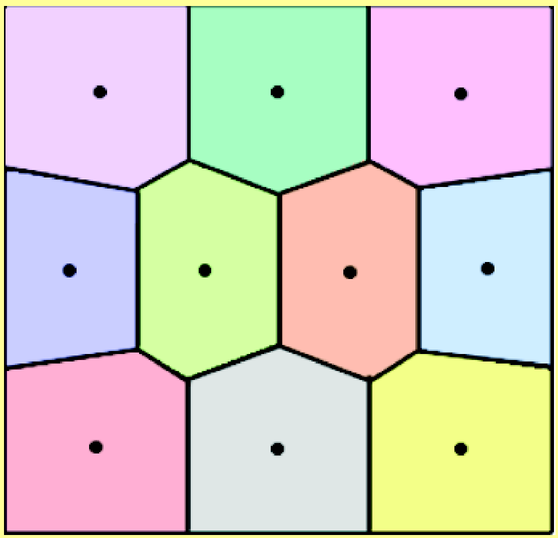
Markers detection

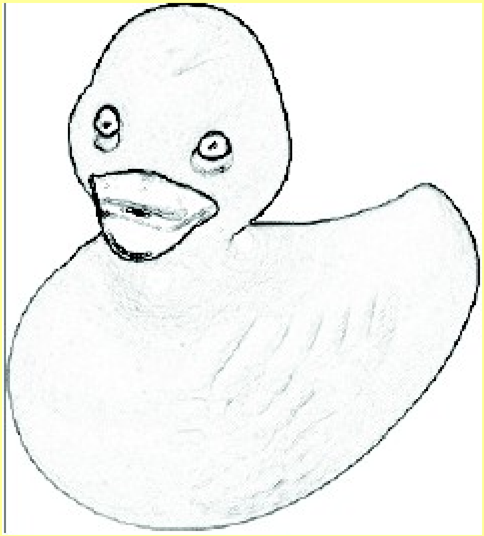


(Faustino & Figueiredo, *Sibgrapi*, 2005)

Markers detection

Centroidal Voronoi diagrams:
each site is the centroid of its cell

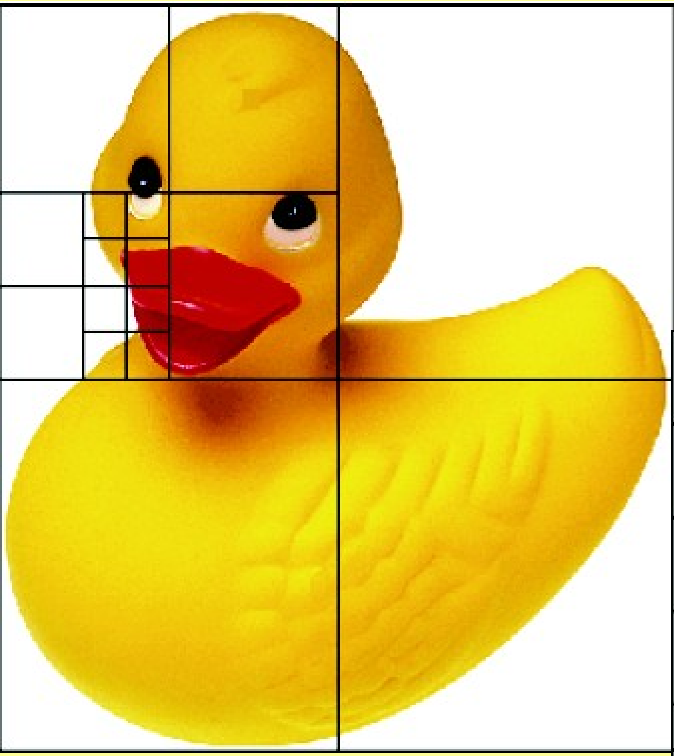




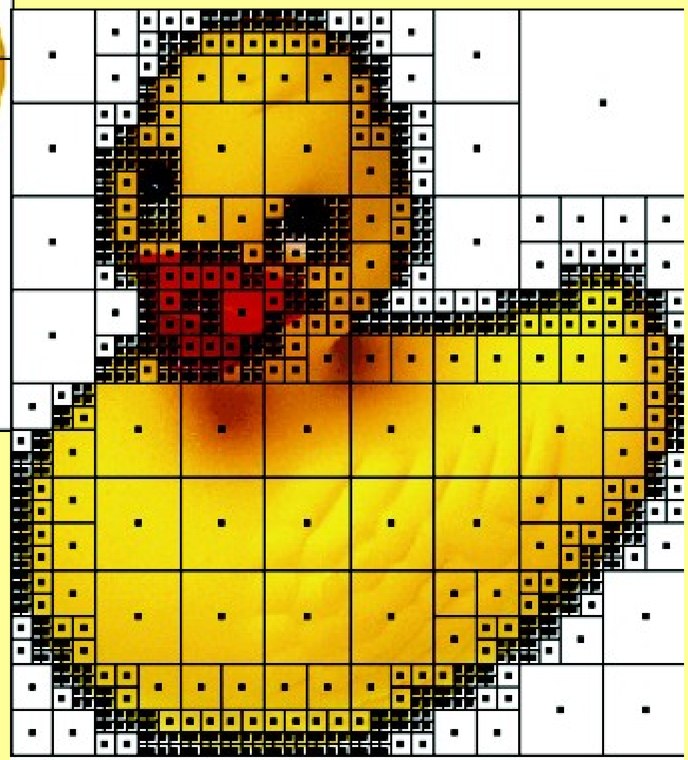
Density function

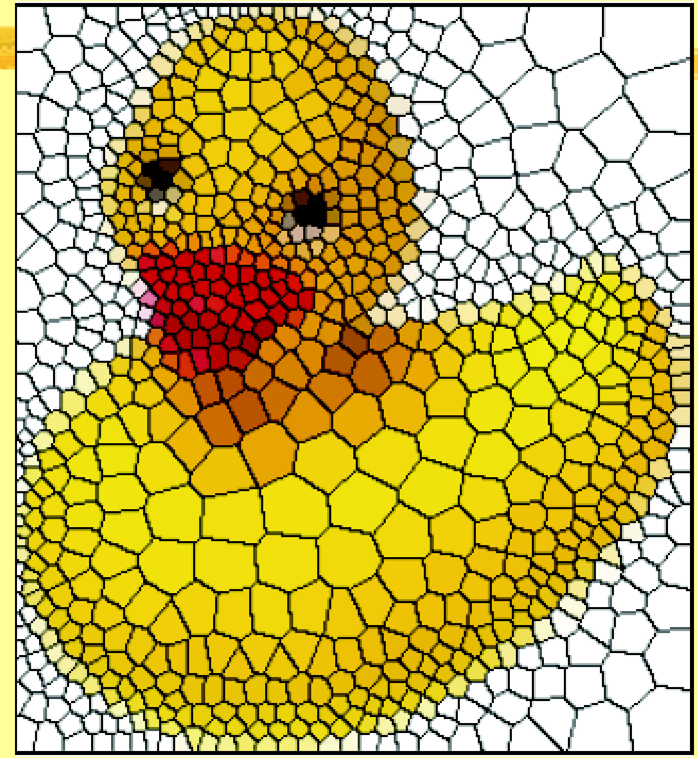
(Faustino & Figueiredo, *Sibgrapi*, 2005)

Markers detection



Quadtrees





Lloyd relaxation

(Faustino & Figueiredo, *Sibgrapi*, 2005)

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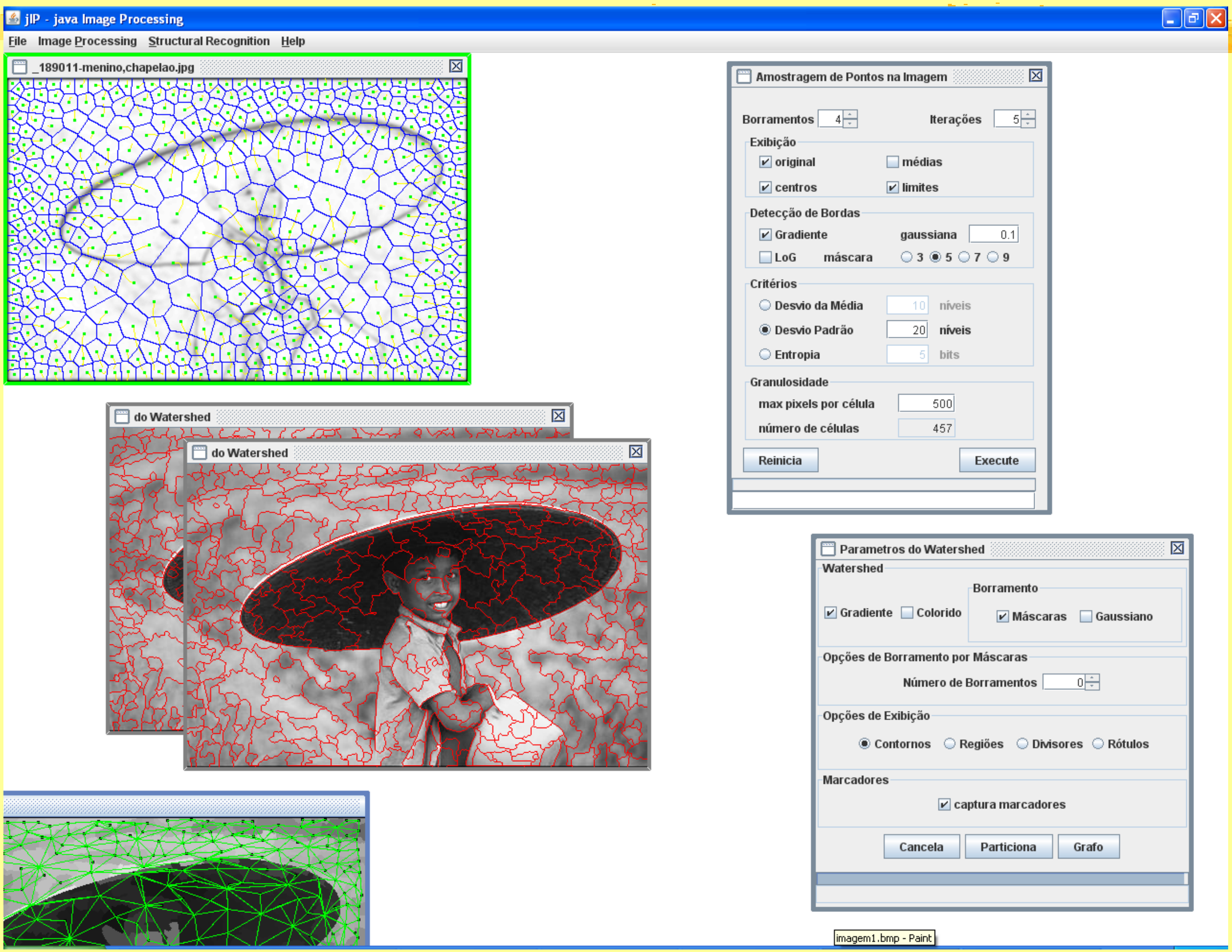
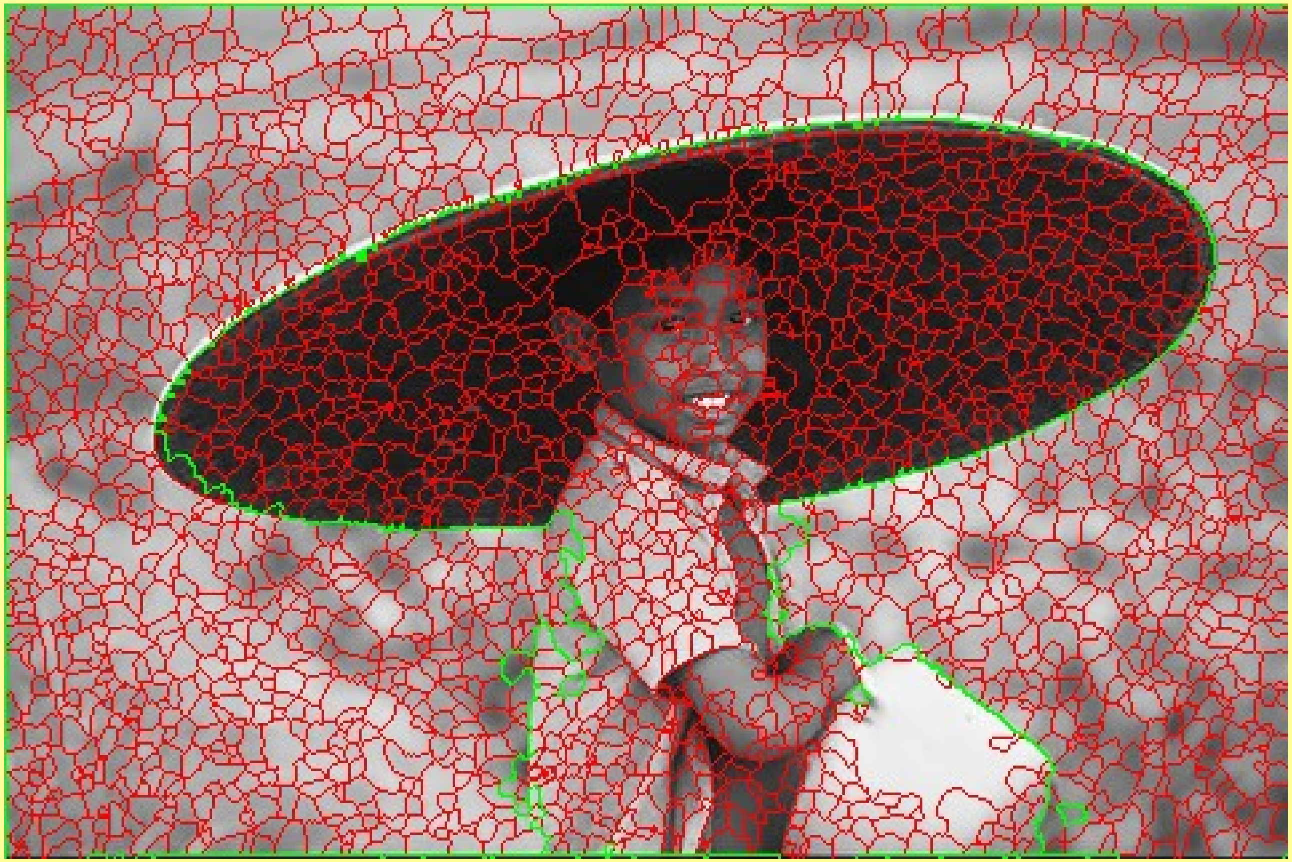
Experimental results



Experimental results

Berkeley image segmentation database

Experimental results

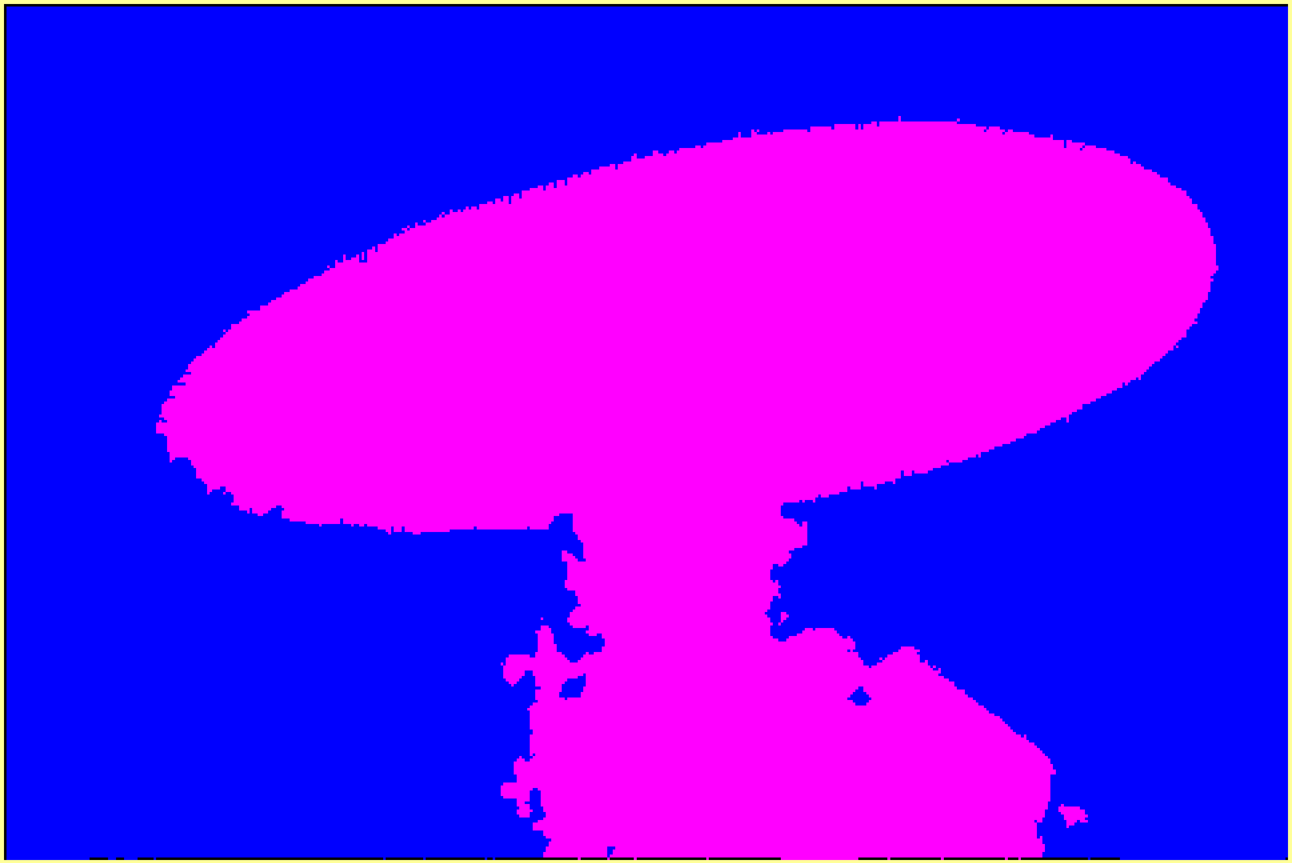


$|V|=209$

$33\,s$

Berkeley image segmentation database

Experimental results

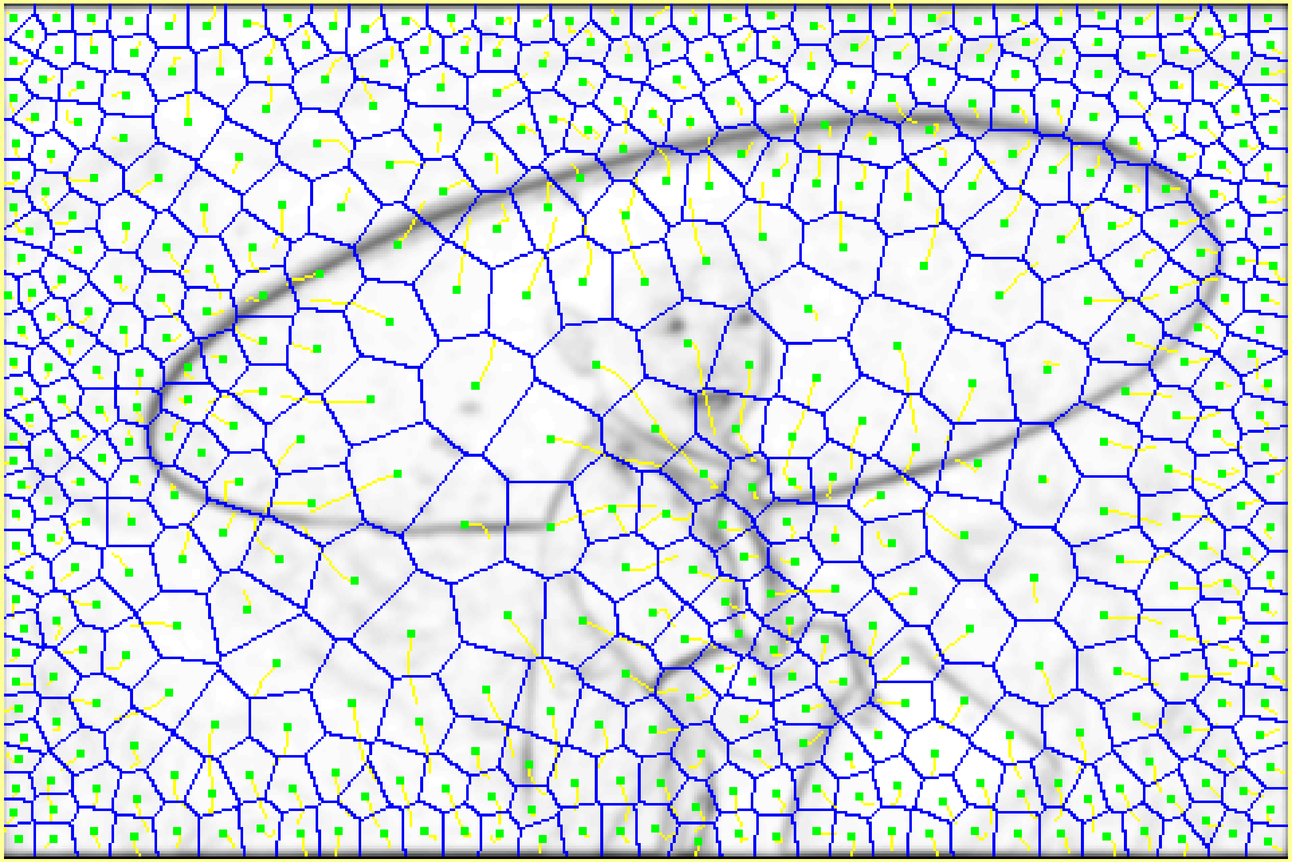


$|V| = 209$

$33\,s$

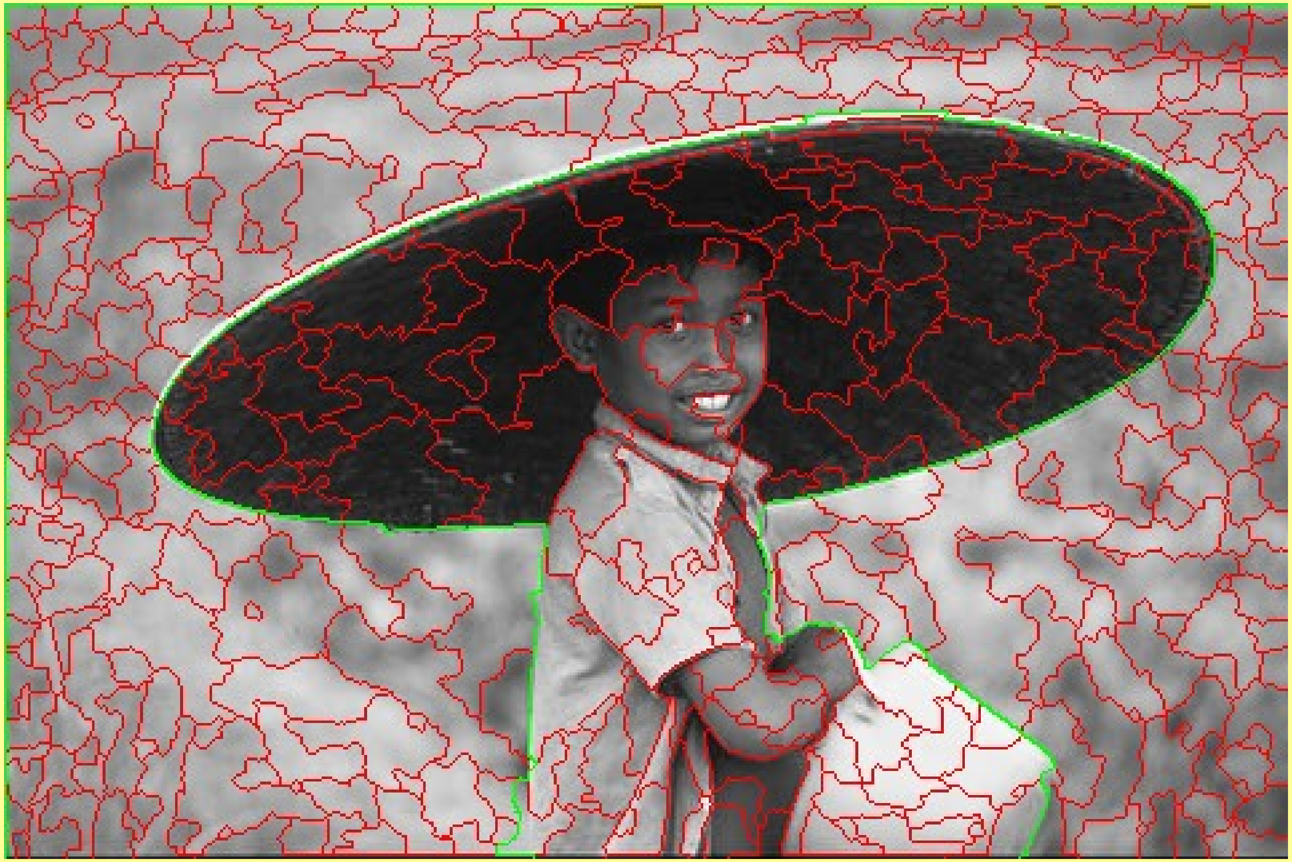
Berkeley image segmentation database

Experimental results



Berkeley image segmentation database

Experimental results



$|V|=77$

$735ms$

Berkeley image segmentation database

Experimental results

$|V|=77$

$735ms$

Berkeley image segmentation database

Experimental results

$|V|=77$

$735ms$

Experimental results

$|V| = 141$

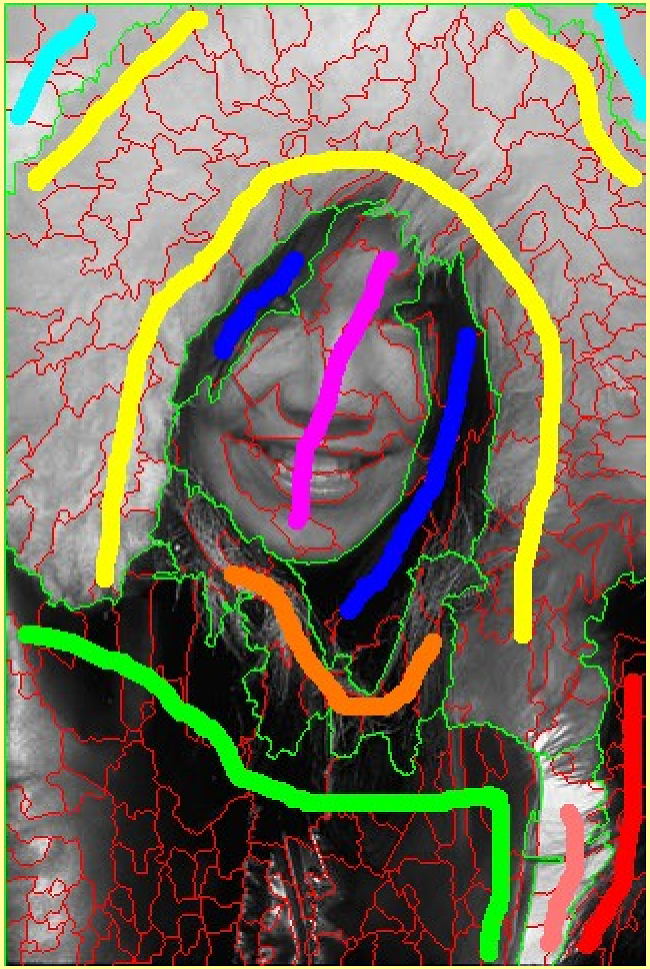
$2735\, ms$

Experimental results

$|V| = 141$

$2735\,ms$

Experimental results



$|V|=141$

$2735\,ms$

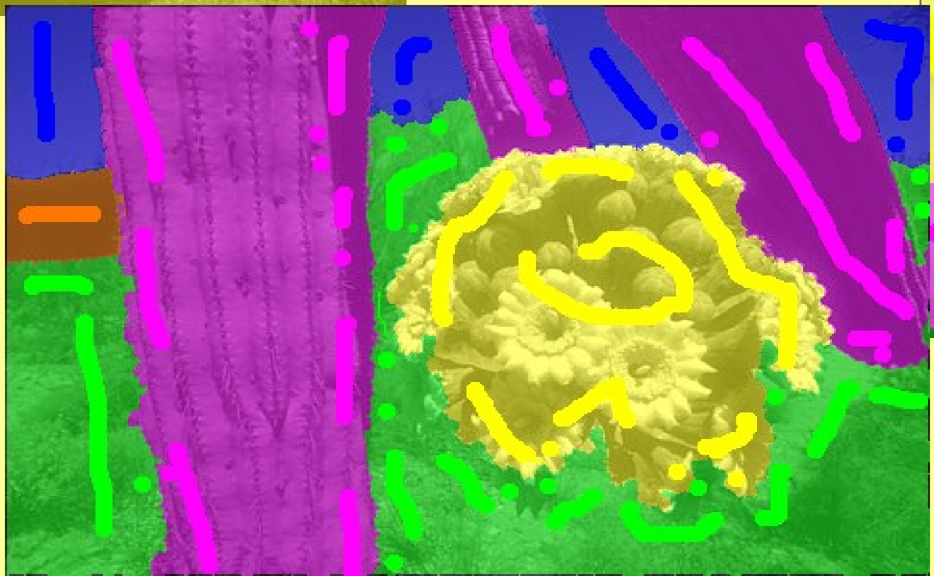
Berkeley image segmentation database

Experimental results

$|V|=141$

$2735\,ms$

Experimental results



Summary

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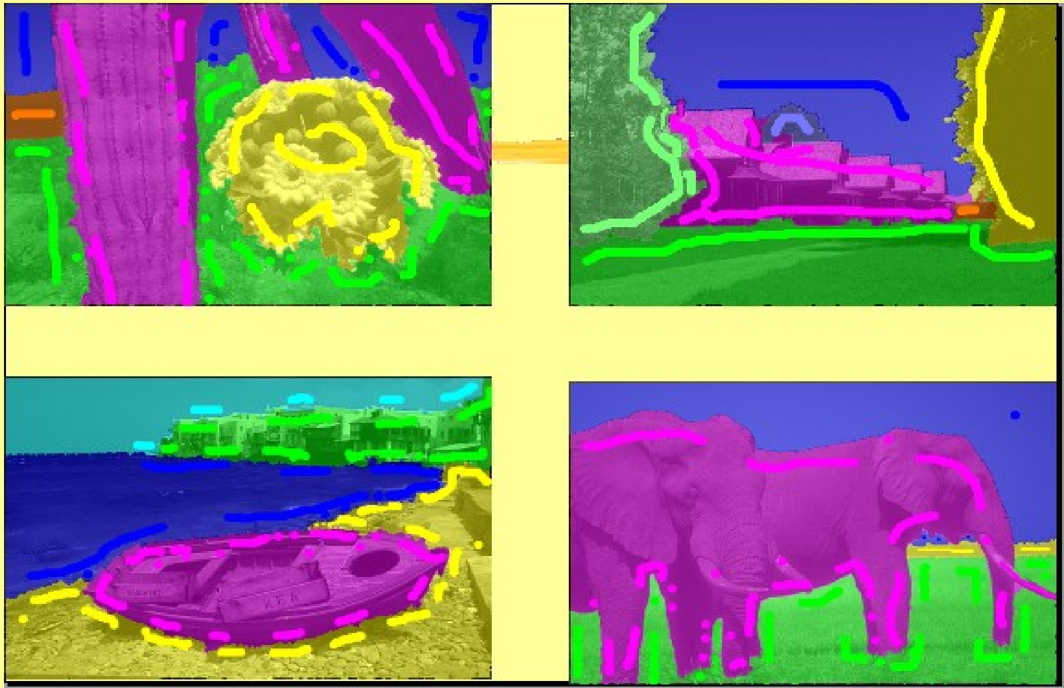
Concluding remarks

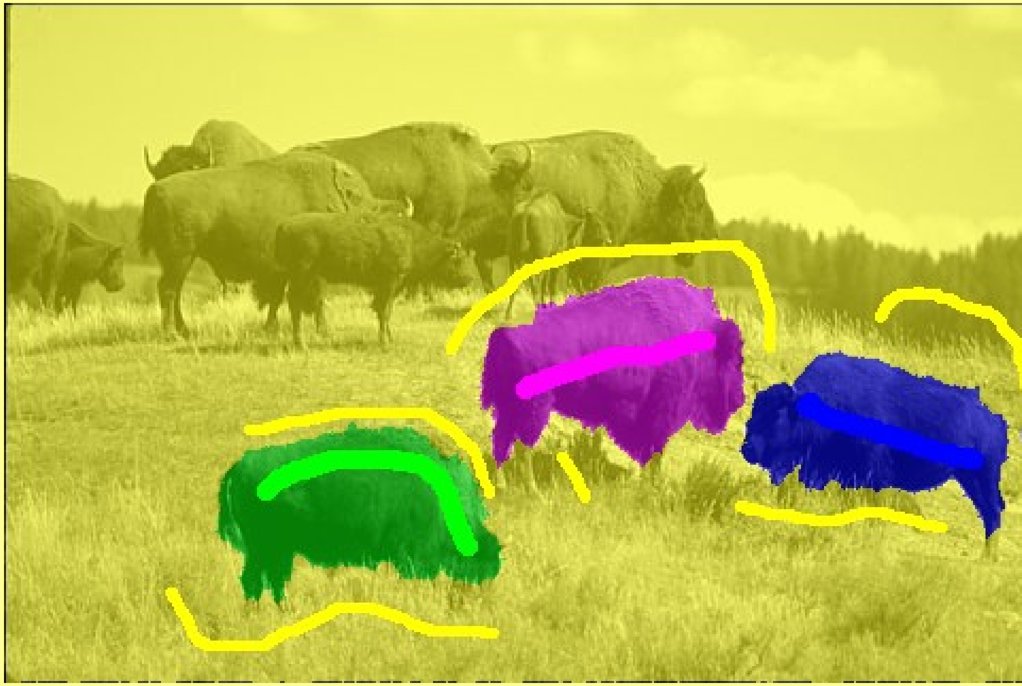
- Contributions:
  - Interactive image segmentation as model generation for SPR
  - Segmentation of multiple objects / parts in one pass (not limited to foreground / background applications)
  - Graph matching algorithm based on SFS
  - Generated model: segmentation of different images

Concluding remarks

- Future work:
  - Watershed simplification (hierarchical, connected filters)
  - Software (soon available)
  - Color and texture
  - Video sequences



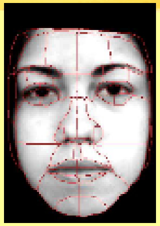
Concluding remarks

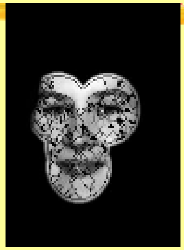


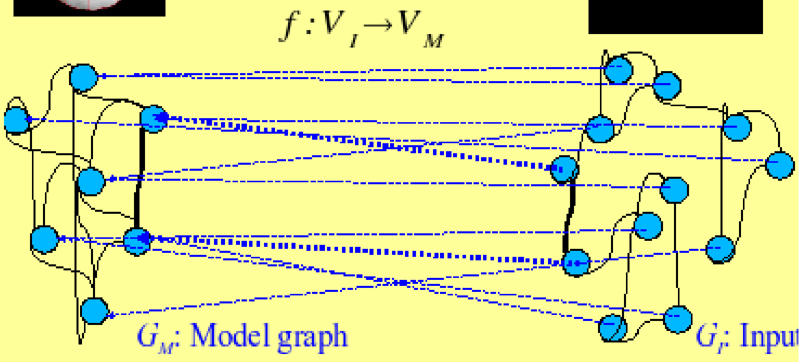
Random Extras

Introduction

- Our method:
  - Structural pattern recognition approach (SPR)
  - Structure together with features
  - Graph models
  - Interactive model generation
  - Graph matching
  - Optimization problems



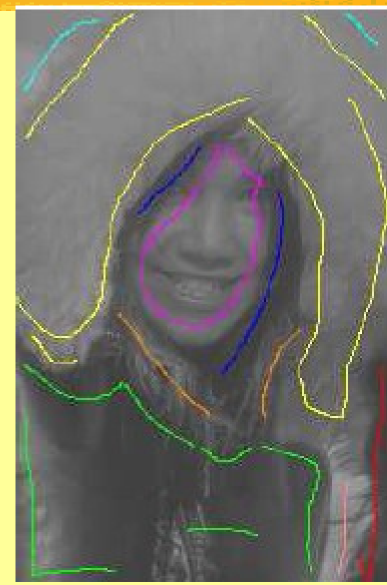




Introduction: Image segmentation

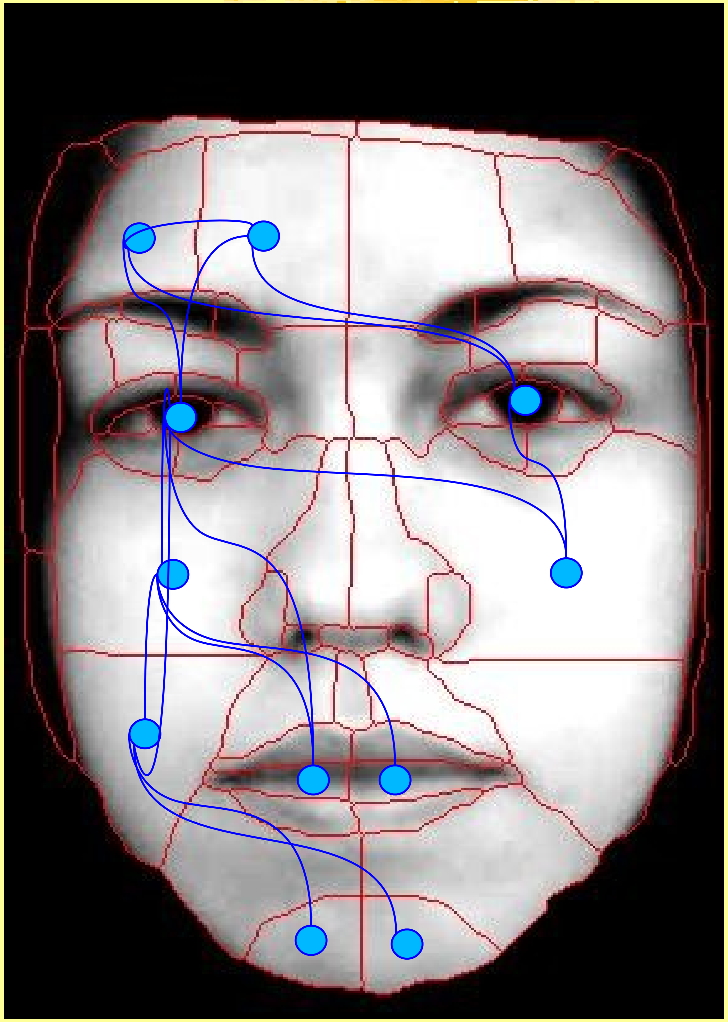
User interaction (seeds):

- Watershed with markers (Vincent, 1991)
- IFT (Falcão, 2004)
- Graph cuts (Boykov, 2001; Rother, 2004)
- Random walker (Grady, 2006)
- ...



Model-based image segmentation

Image graph



Each region corresponds to a graph node.

The arcs represent structural relations between regions.

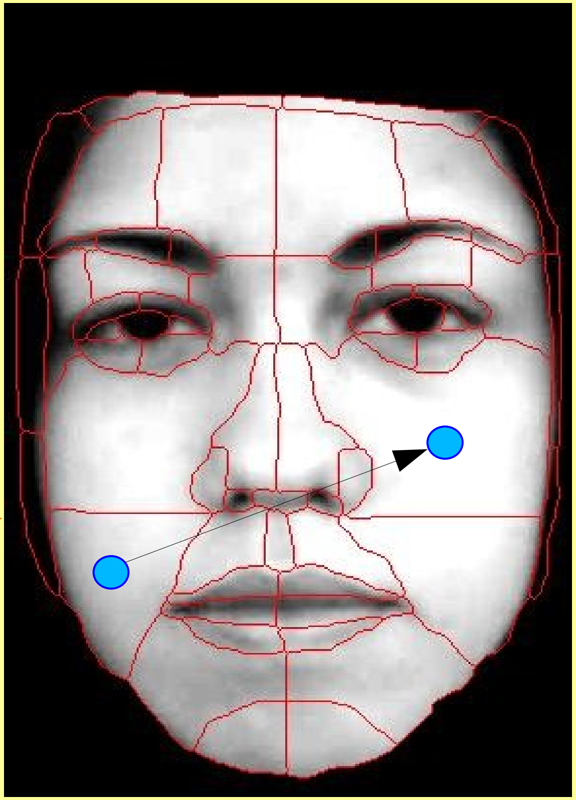
Model-based image segmentation

Attributed relational graphs

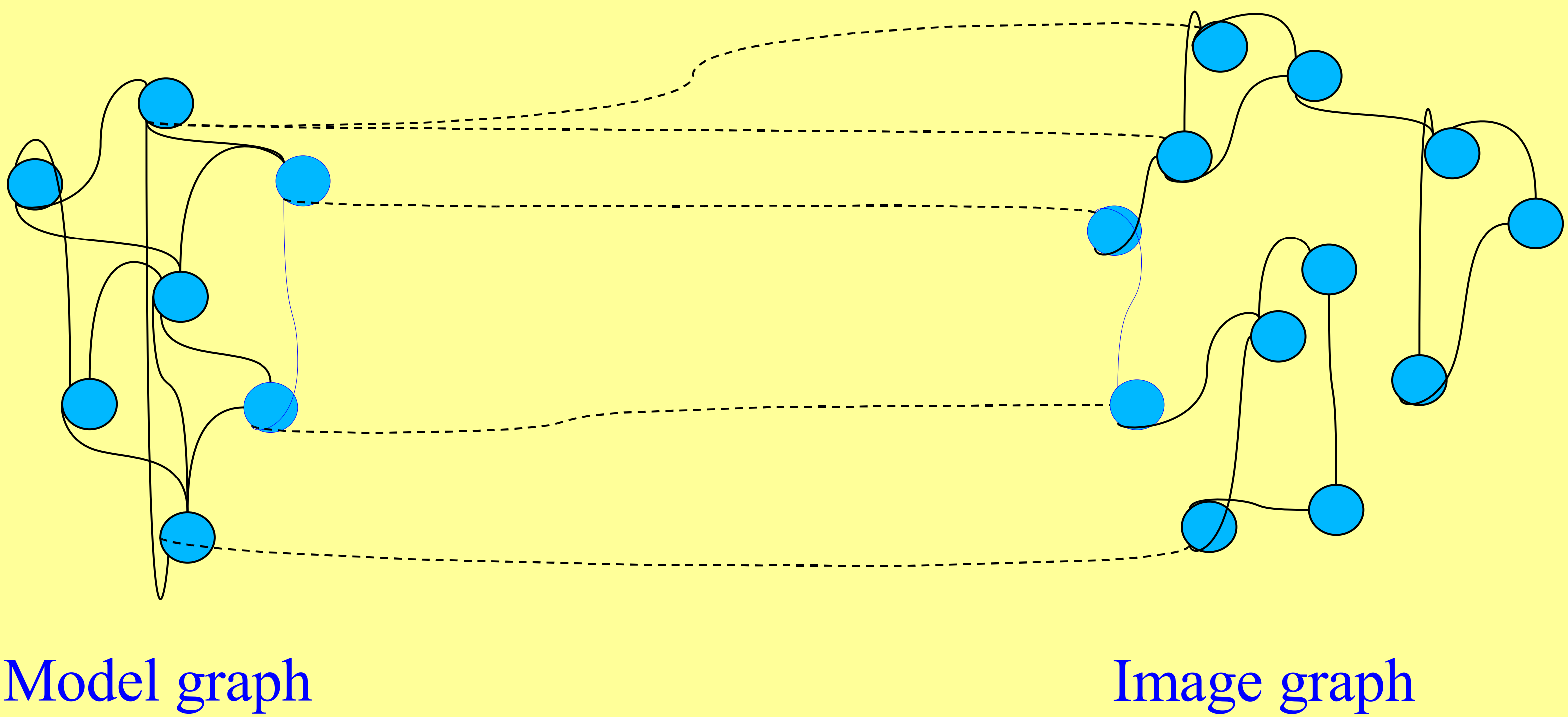
$$G = \left(V\,,\,E\,,\,\mu\,,\,\nu\right)$$

Average gray level

Vector coordinates defined by corresponding centroids



Graph matching



Original graph matching approach

Graph matching

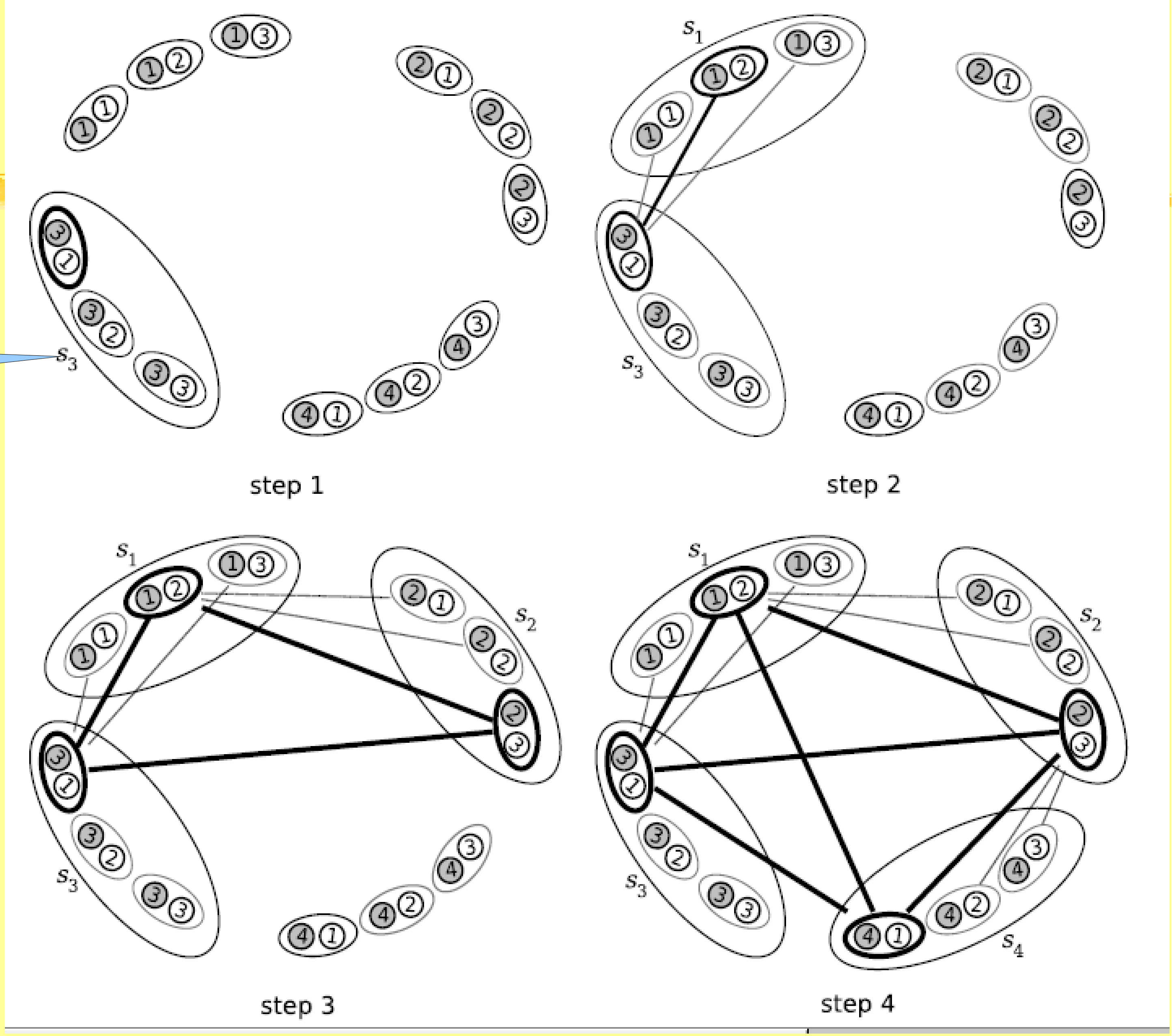
- Optimization algorithms:
  - Gradient descent
  - Beam search (tree search)
  - Integer and linear programming
  - Cliques
  - EDAs (estimation of distribution)
    - Genetic algorithms
    - Bayesian networks

Starting points: Luo & Hancock, *PAMI*, 2001; R. Cesar et al., *PR*, 2005

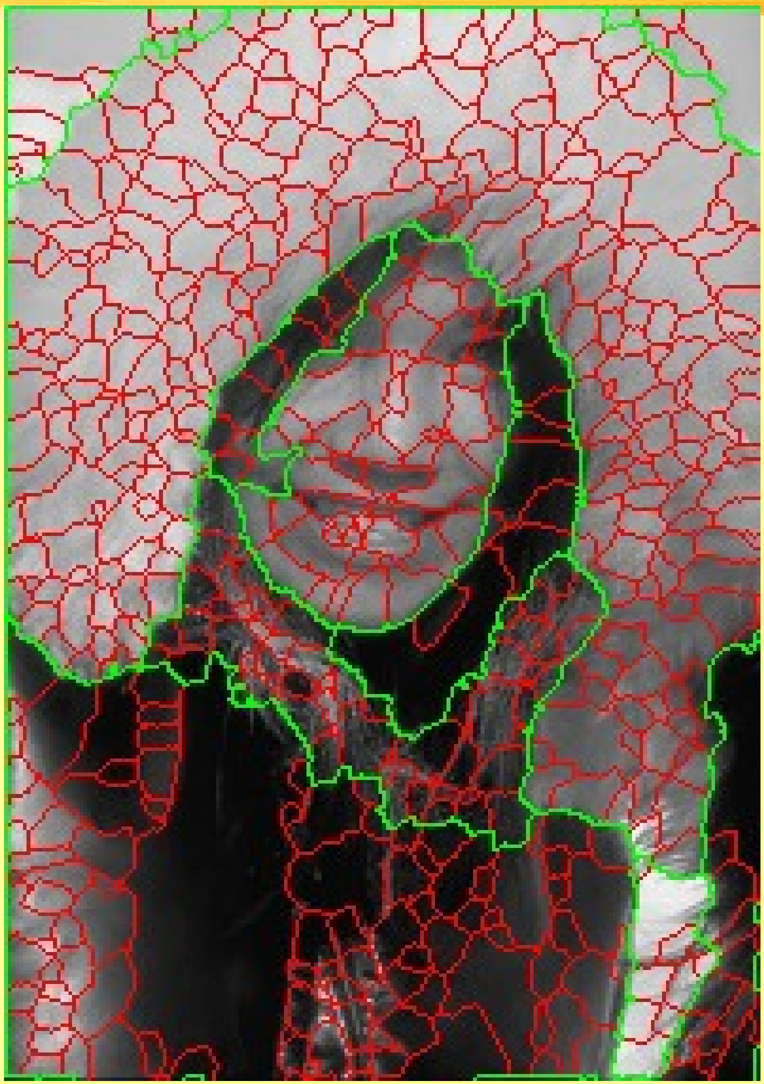
Graph matching

Supervertex

Optimization Algorithm: SFS

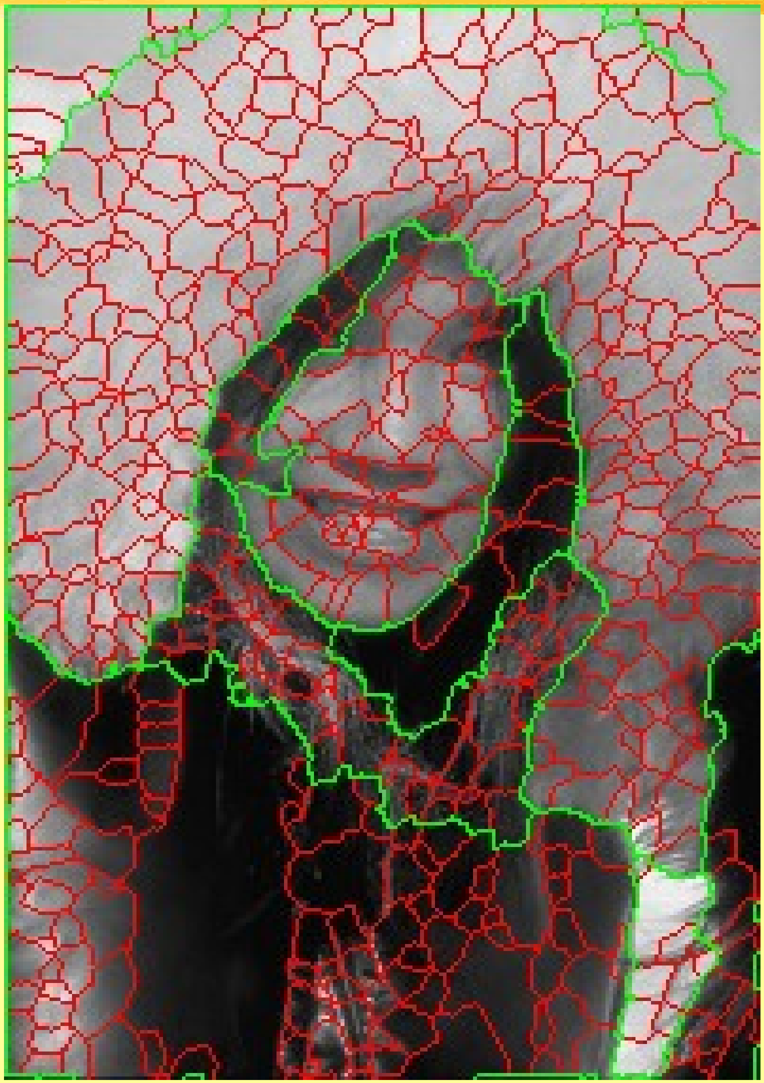


Experimental results



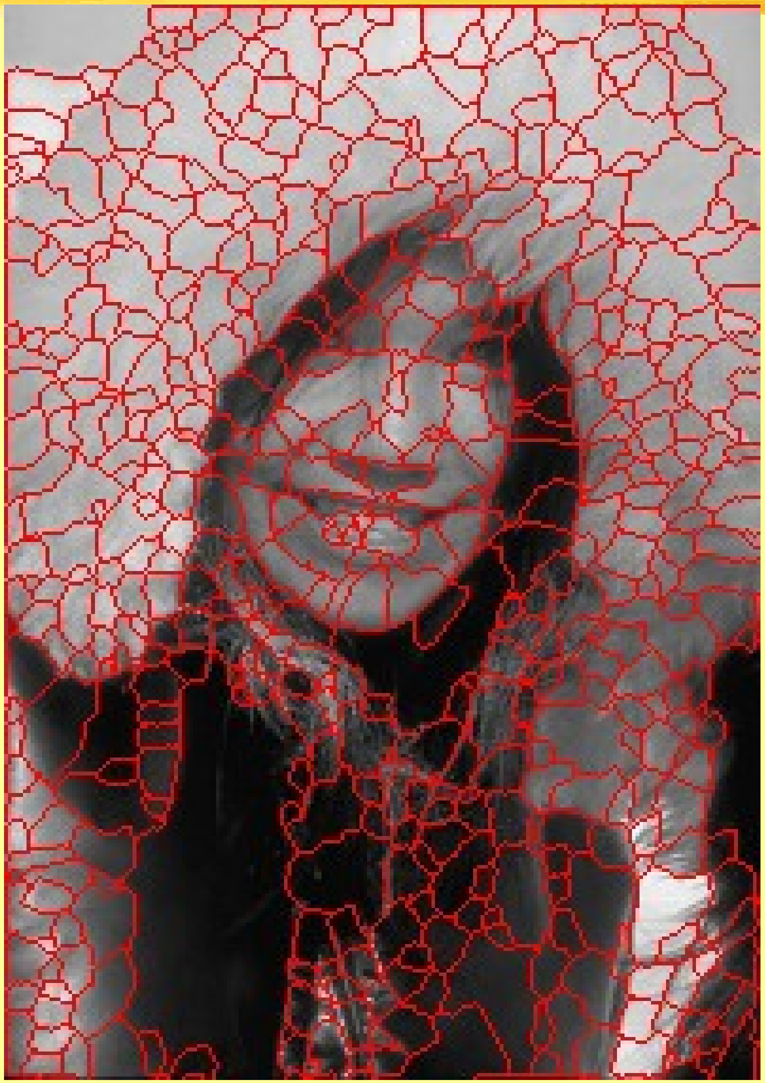
Berkeley image segmentation database

Experimental results



Berkeley image segmentation database

Experimental results

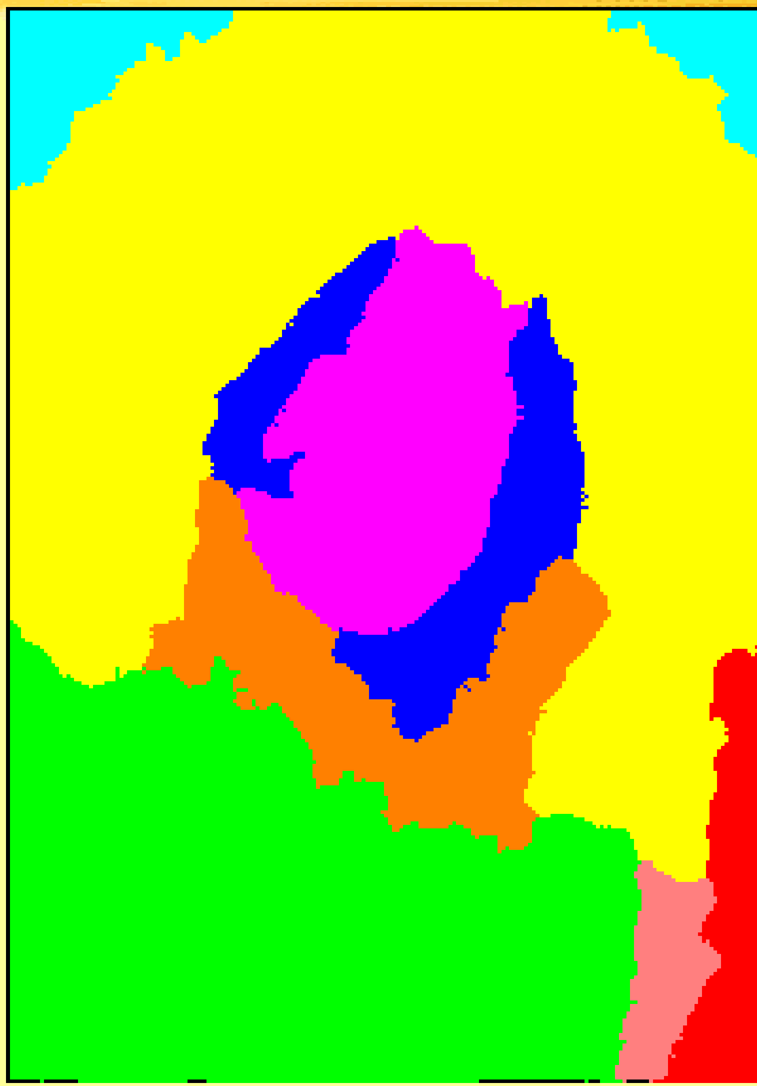


Berkeley image segmentation database

Experimental results

Berkeley image segmentation database

Experimental results



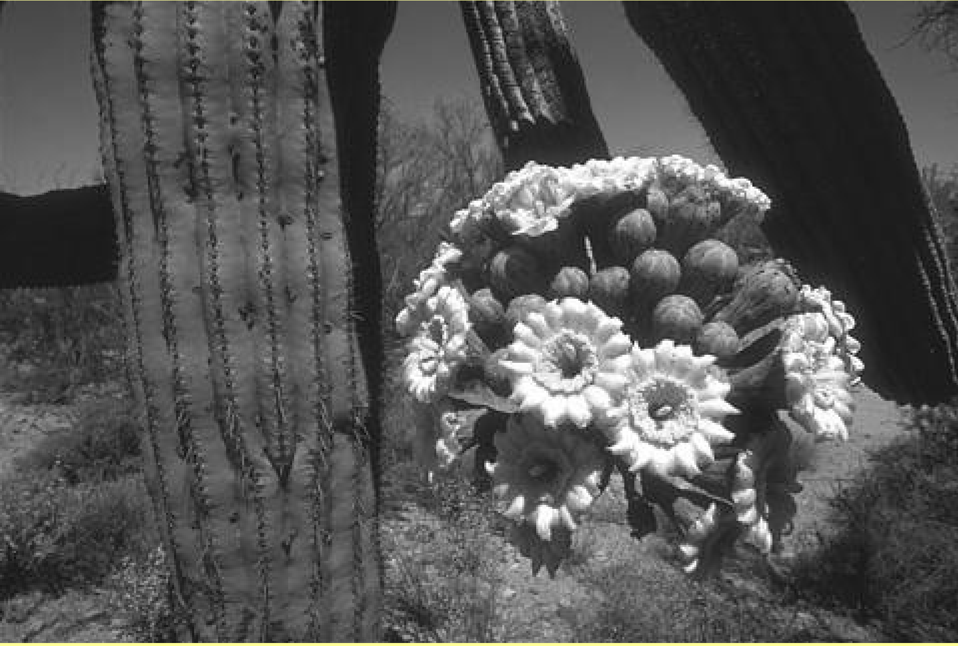
Berkeley image segmentation database

Experimental results

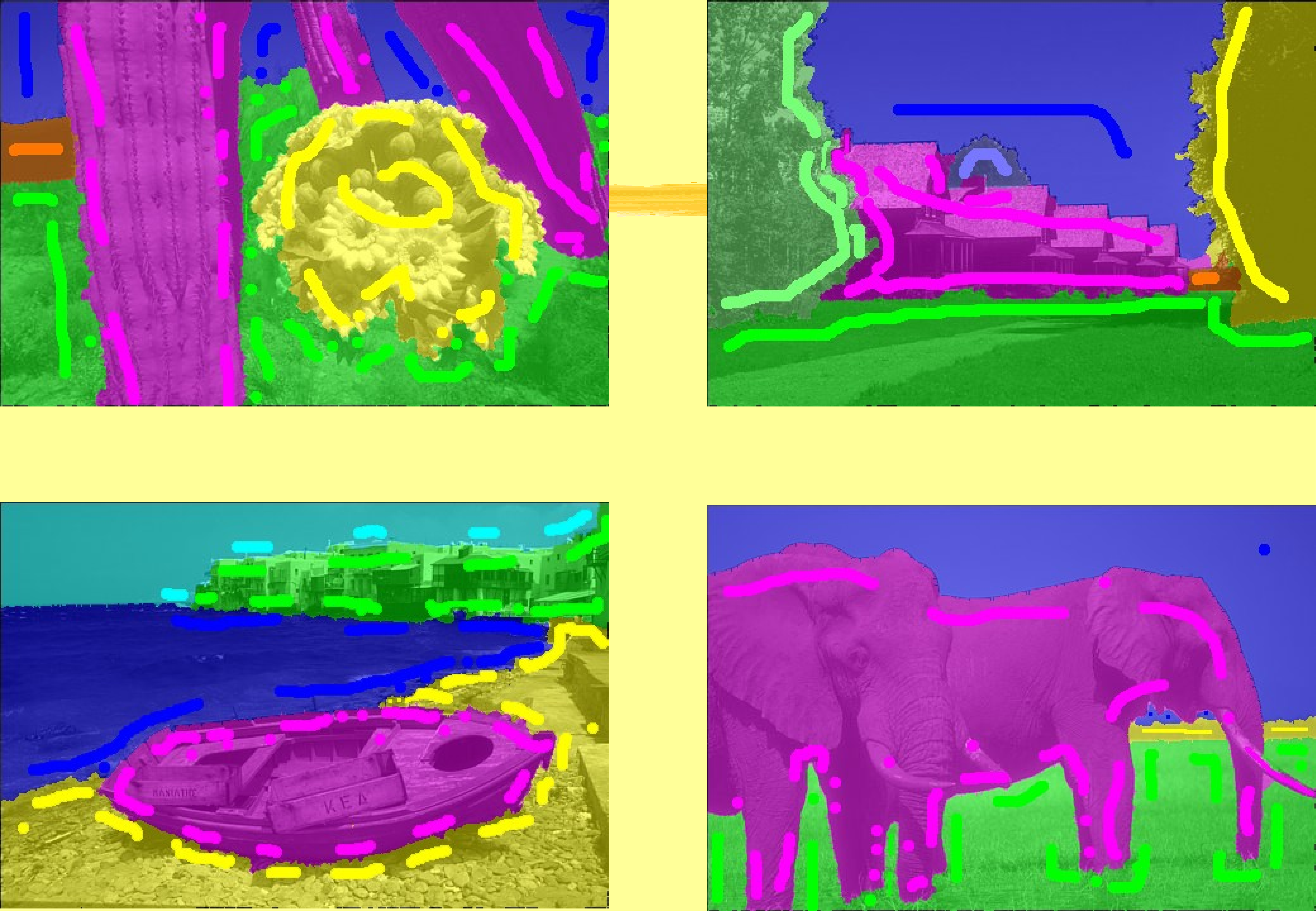
Berkeley image segmentation database

Experimental results

Berkeley image segmentation database




ΚΕΔ



Experimental results

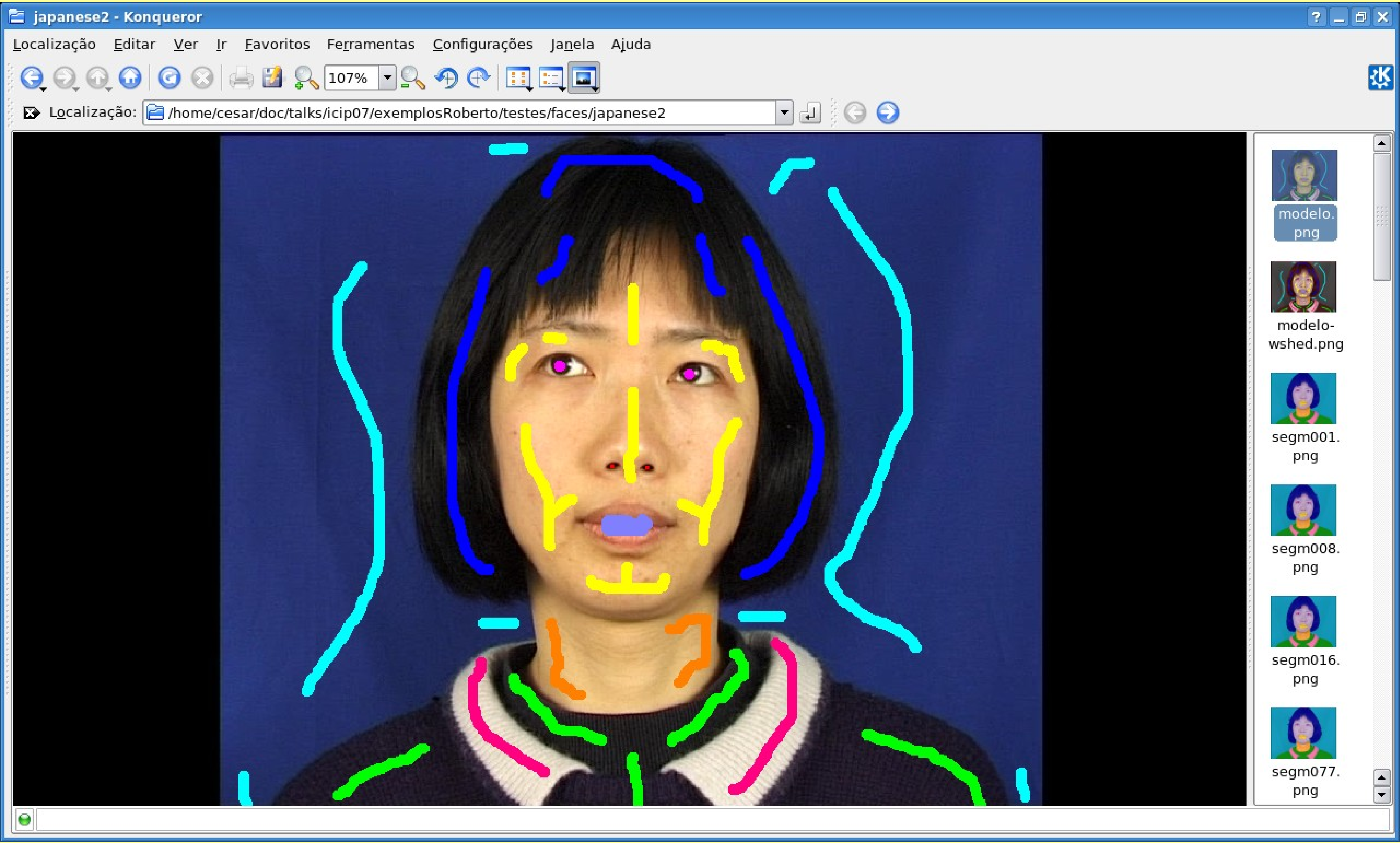
Foreground / background (particular case)

Experimental results

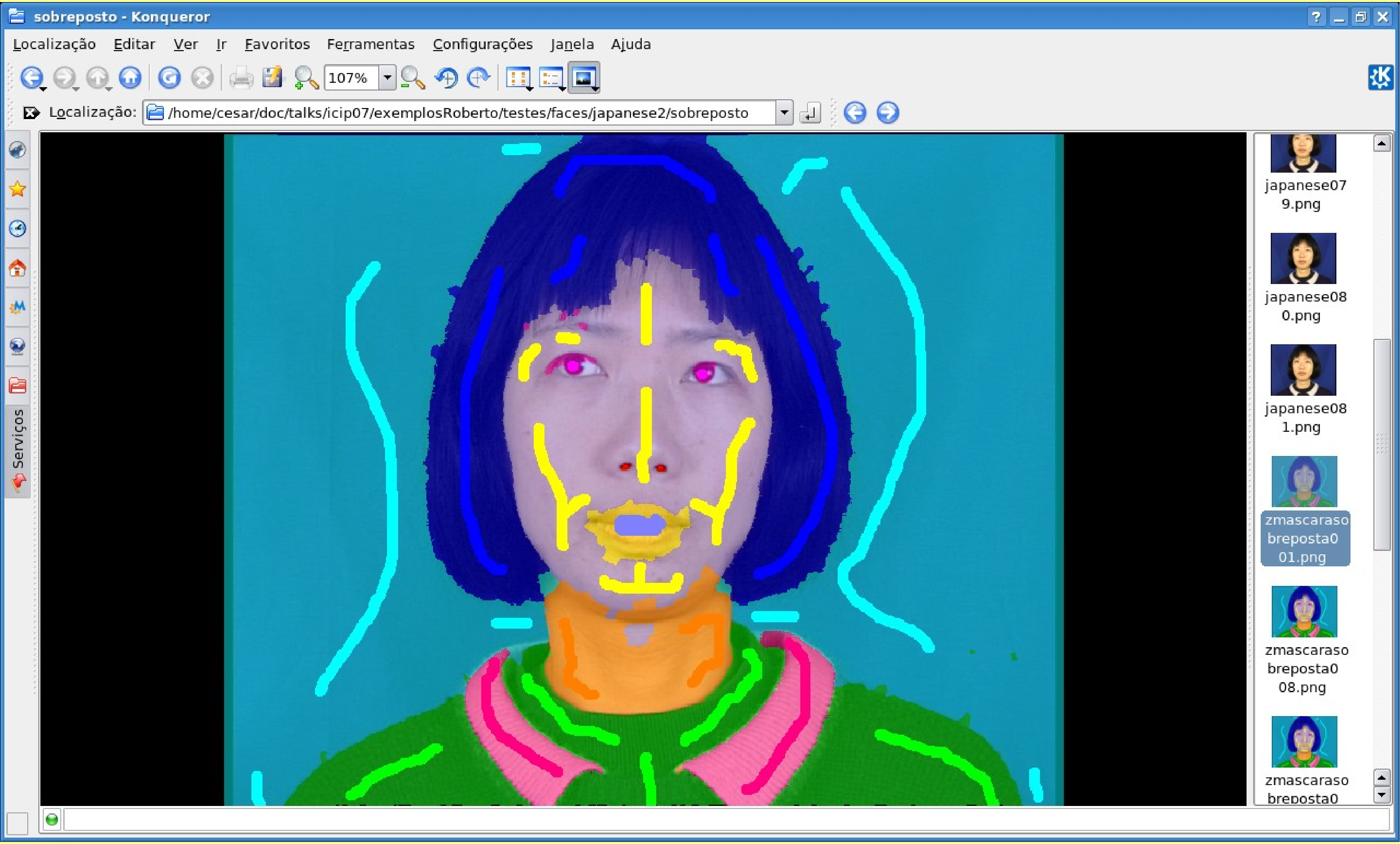
- Exploring the model to segment different images
- Example: some frames from a video sequence
- Model generated for the first frame

XM2VTS database

XM2VTS database

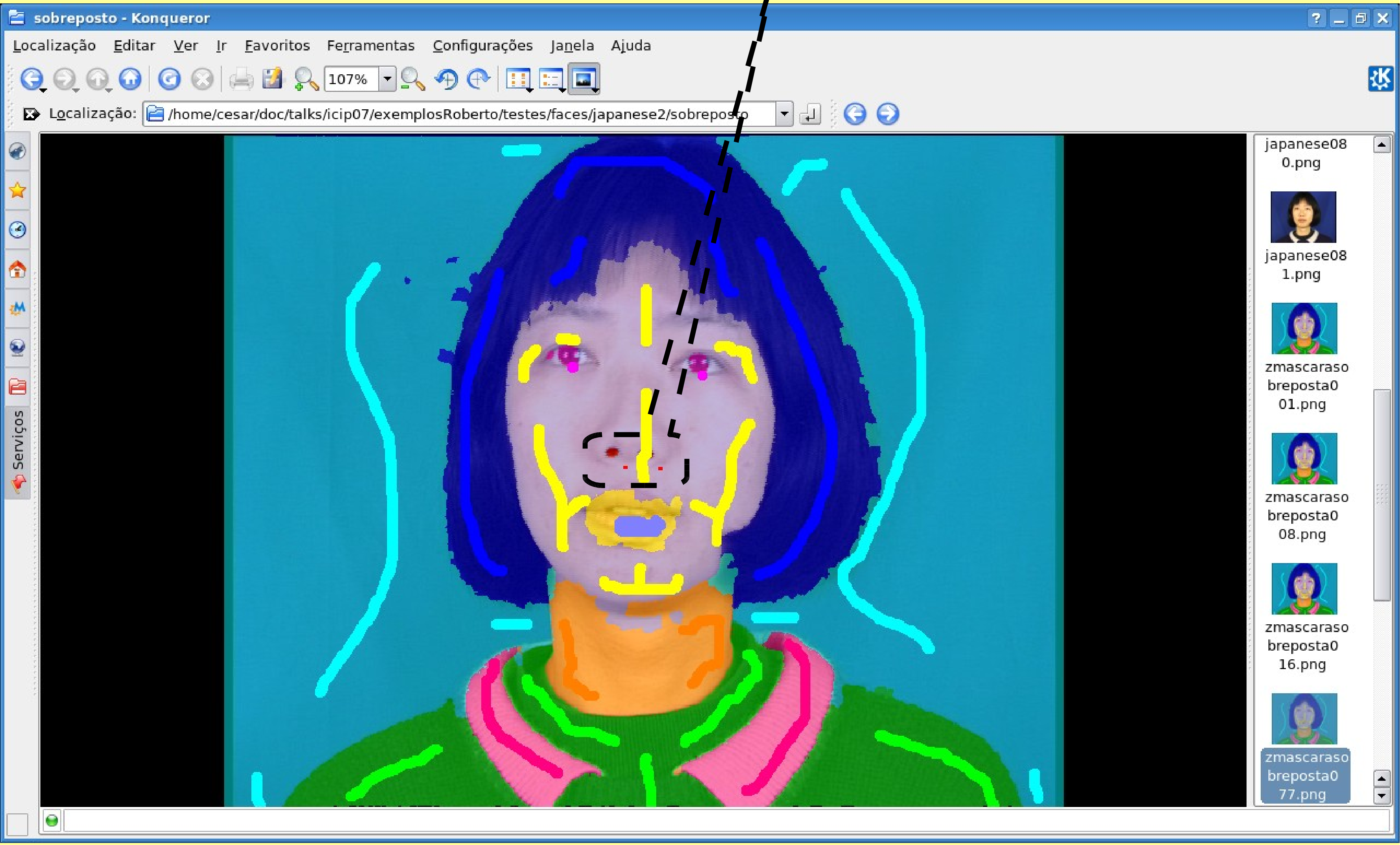


XM2VTS database



XM2VTS database

Non registered markers



XM2VTS database

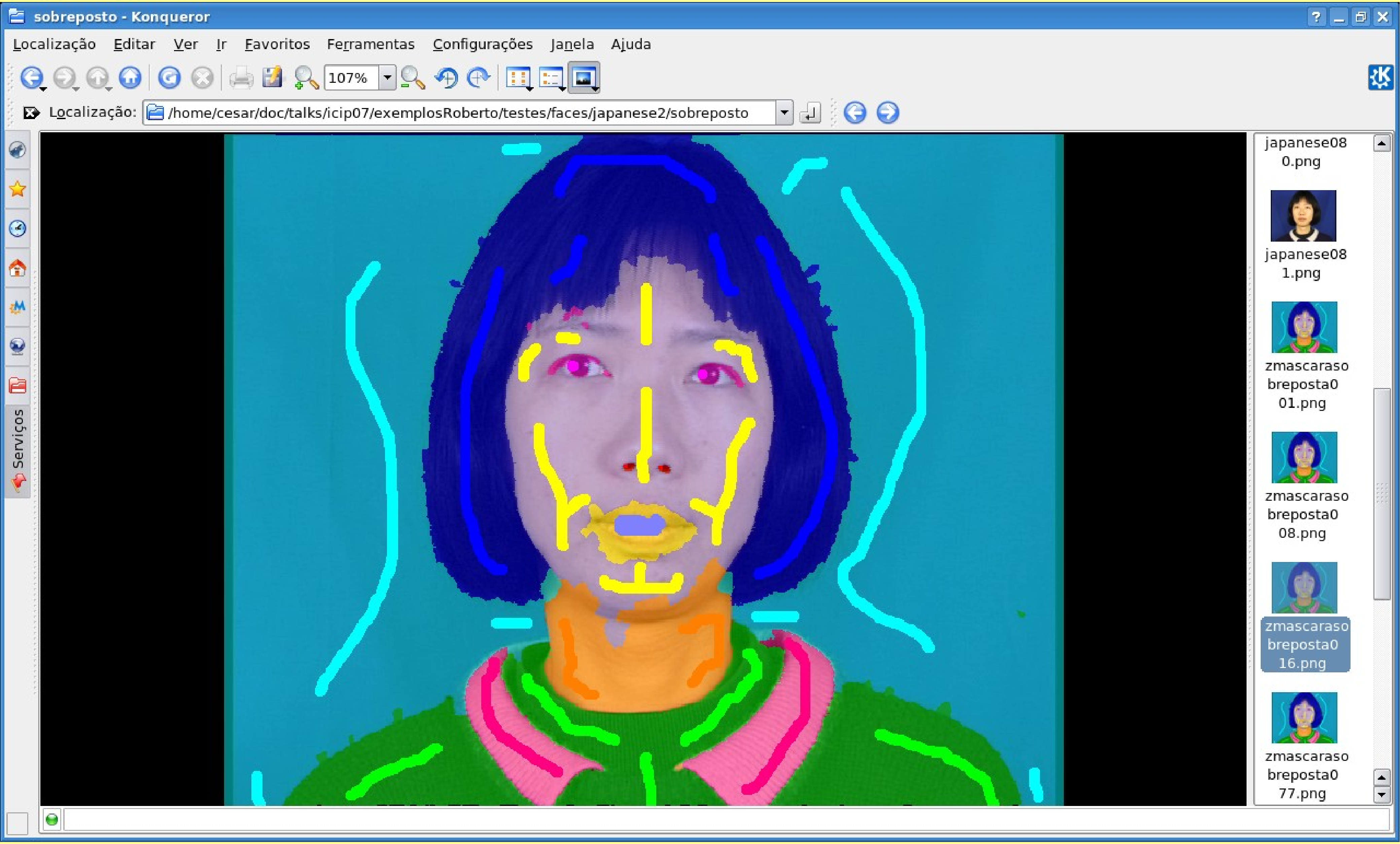


Image segmentation

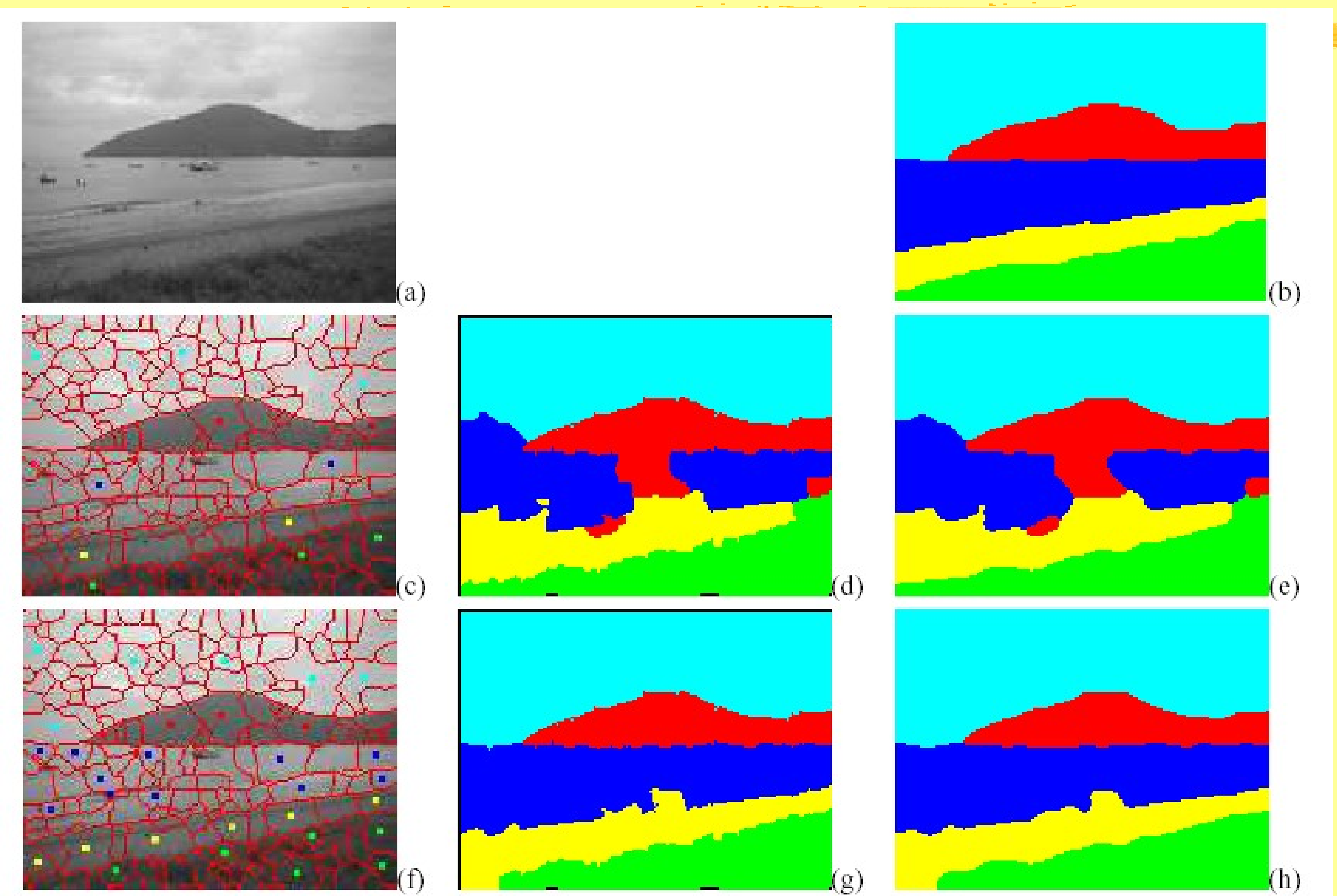
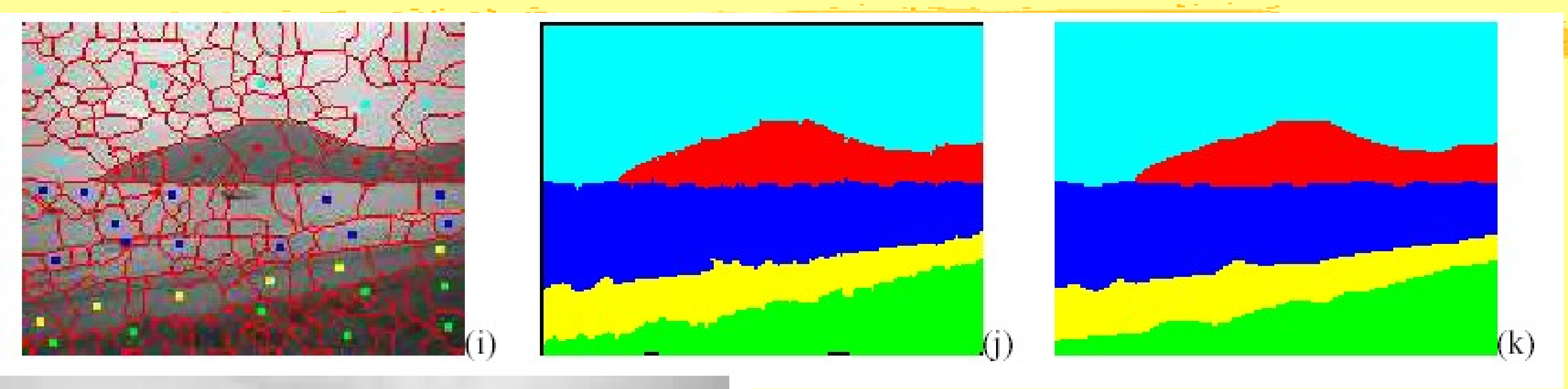


Image segmentation



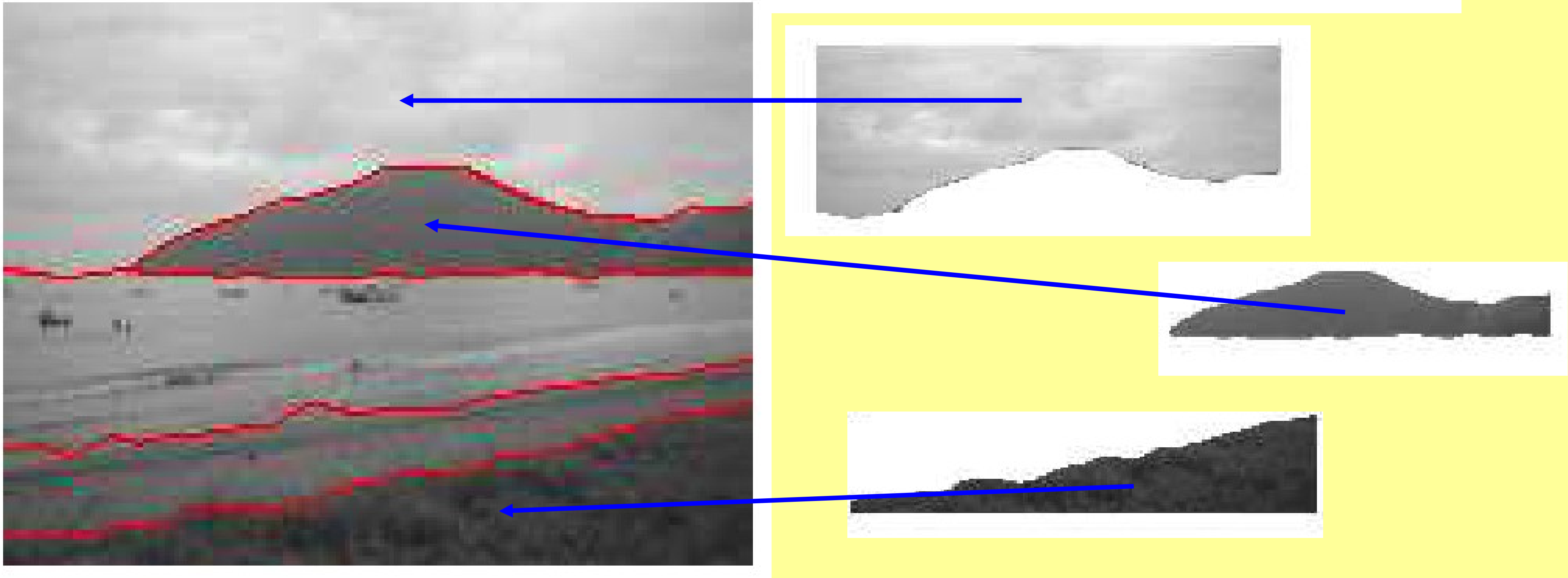


Image segmentation

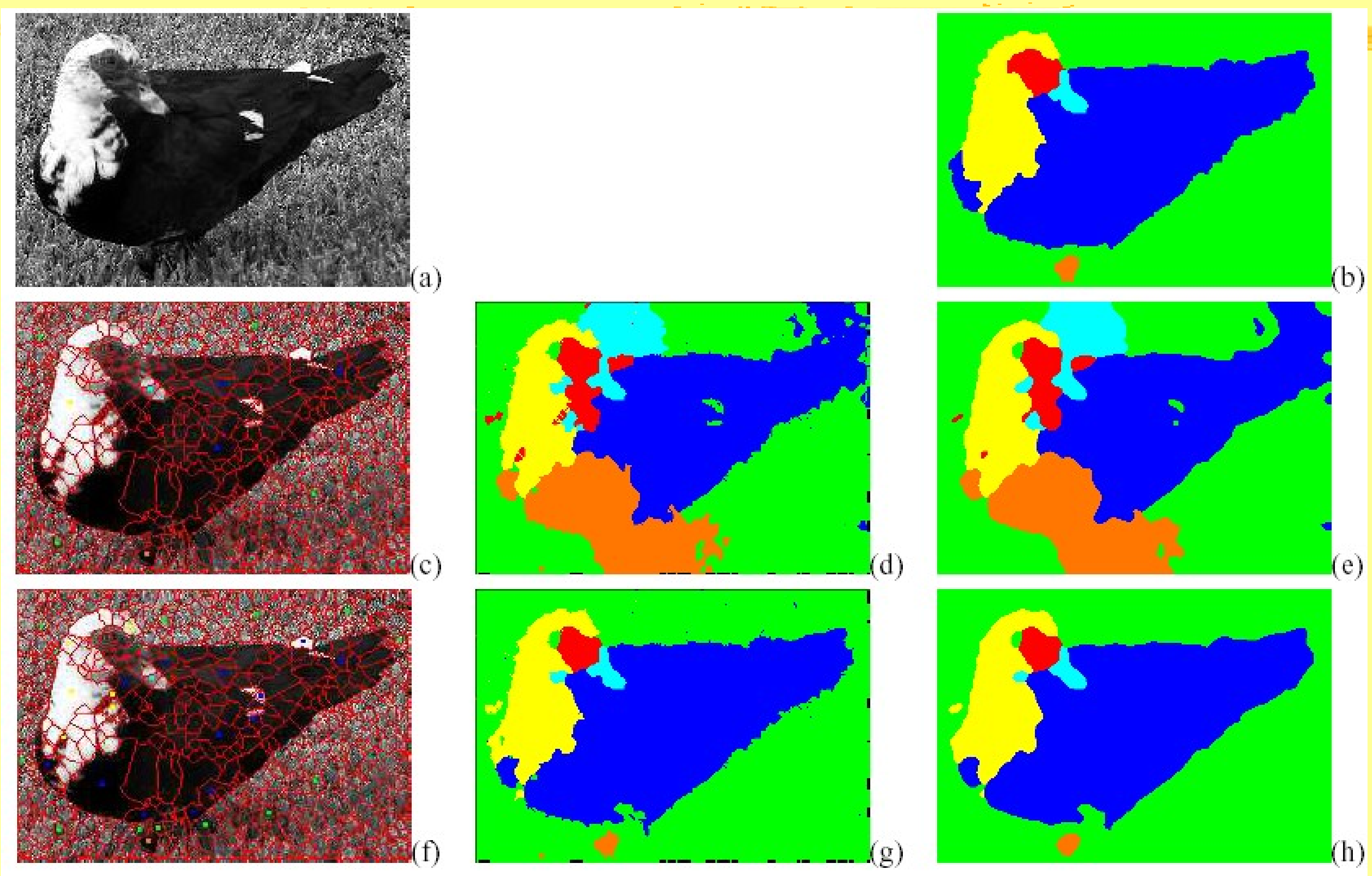
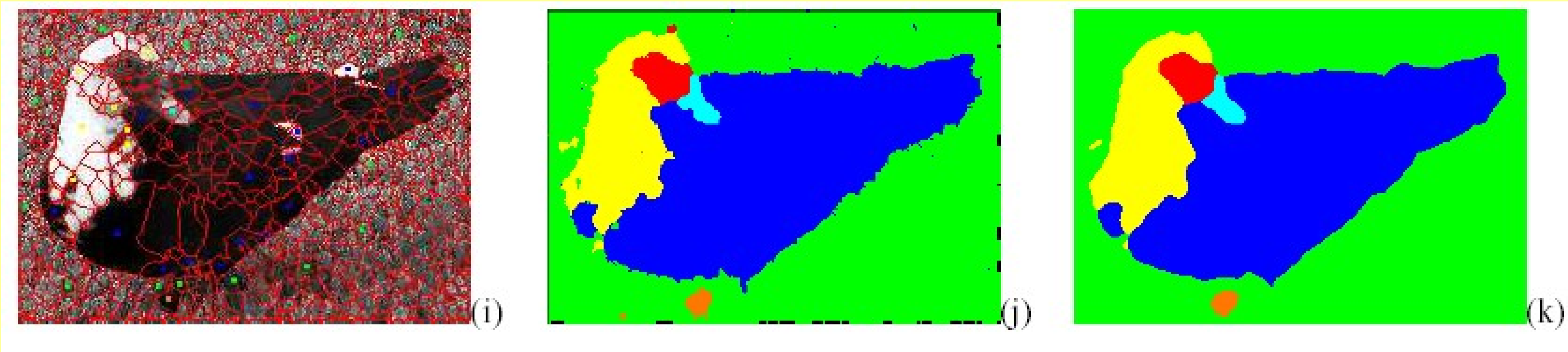


Image segmentation



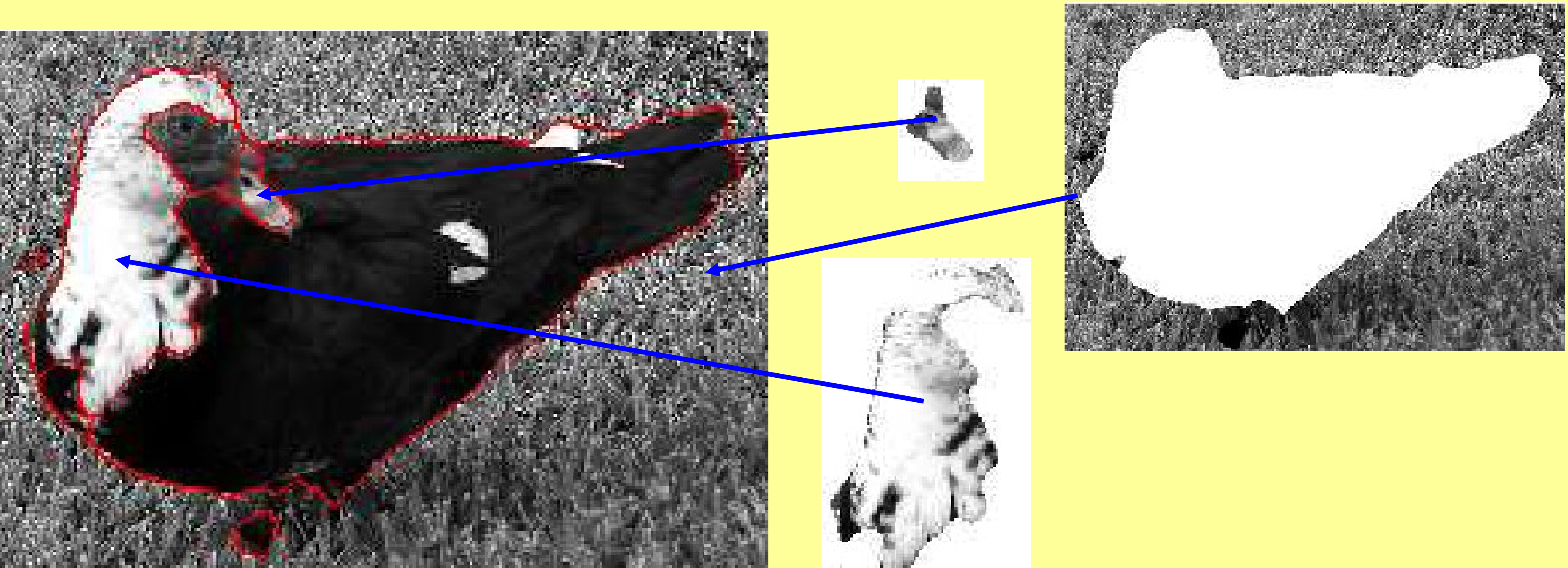


Image segmentation

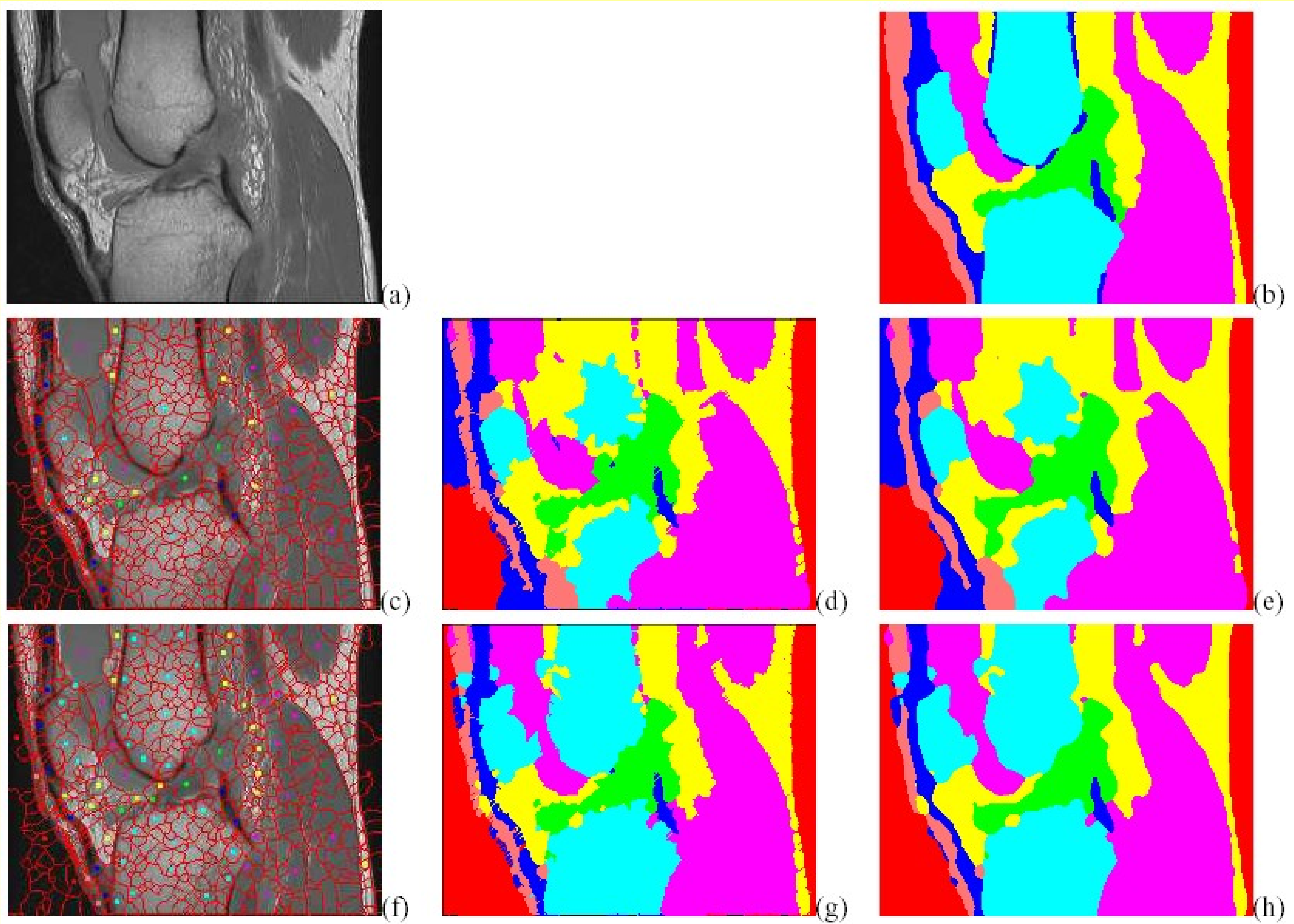


Image segmentation