

Segmentation of Images

SEGMENTATION

If an image has been preprocessed appropriately to remove noise and artifacts, segmentation is often the key step in interpreting the image. Image segmentation is a process in which *regions or features sharing similar characteristics are identified and grouped together*.

Image segmentation may use **statistical classification, thresholding, edge detection, region detection, or any combination of these techniques**. The output of the segmentation step is usually a set of classified elements,

Segmentation techniques are either **region-based or edge-based**.

- Region-based techniques rely on common patterns in intensity values within a cluster of neighboring pixels. The cluster is referred to as the region, and the goal of the segmentation algorithm is to group regions according to their anatomical or functional roles.
- Edge-based techniques rely on discontinuities in image values between distinct regions, and the goal of the segmentation algorithm is to accurately demarcate the boundary separating these regions.

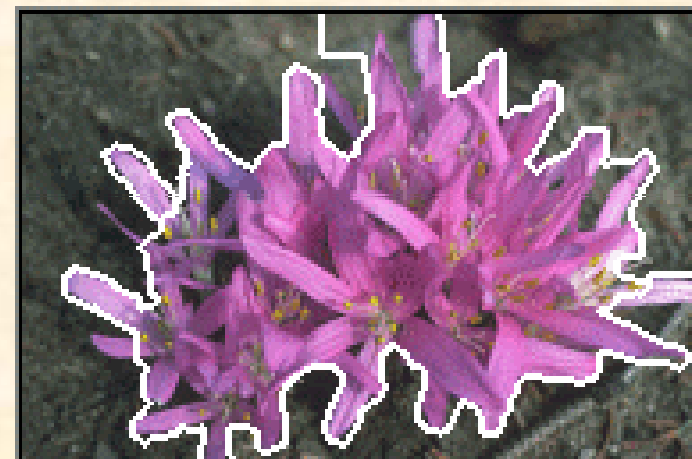
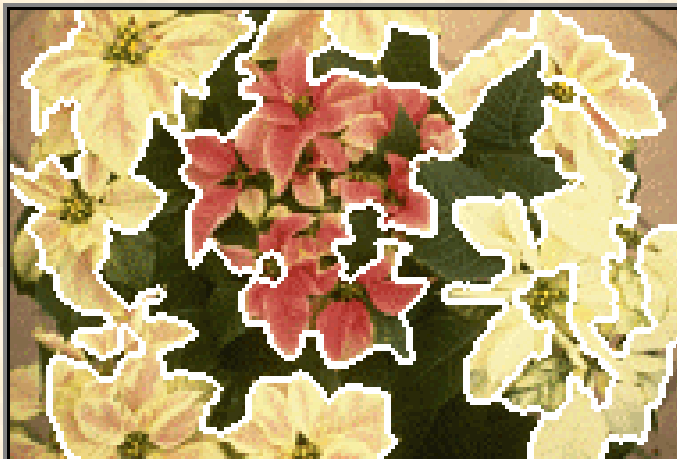
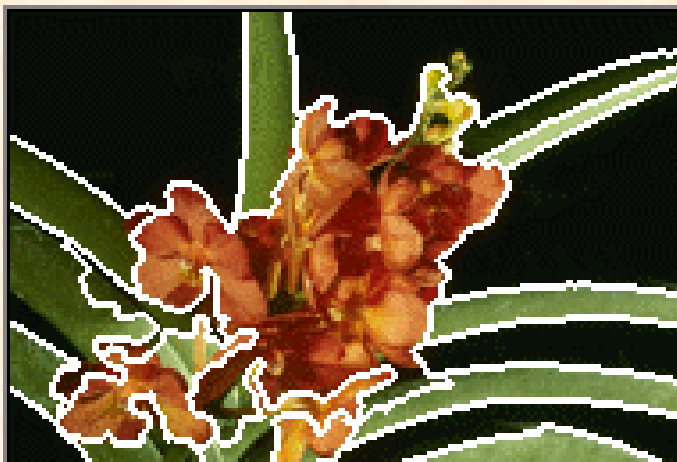
Segmentation is a **process of extracting and representing information** from an image is to group pixels together into regions of similarity.

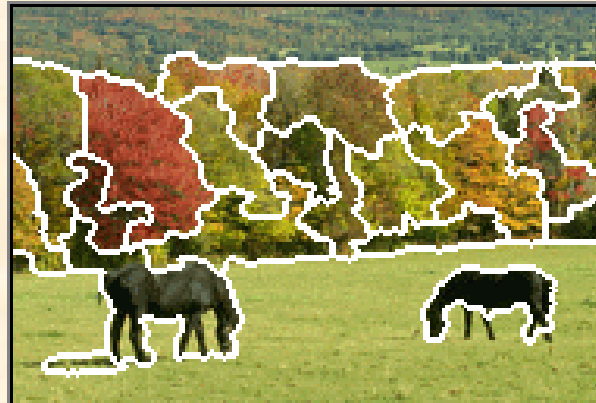
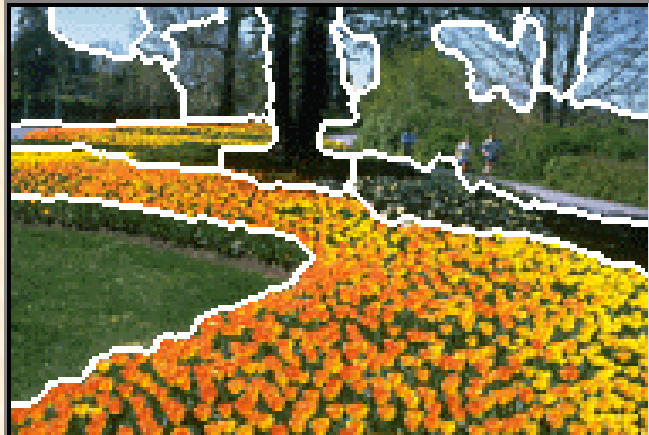
Region-based segmentation methods attempt to partition or group regions according to common image properties. These image properties consist of :

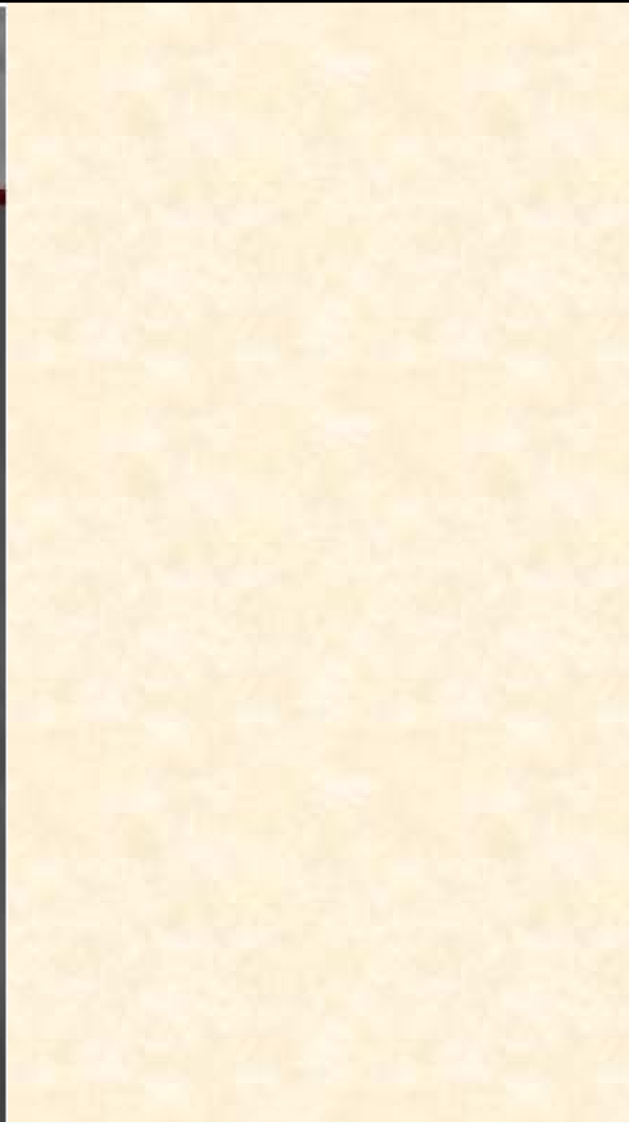
- **Intensity values** from original images, or computed values based on an image operator
- **Textures or patterns** that are unique to each type of region
- **Spectral profiles** that provide multidimensional image data

Elaborate systems may use a combination of these properties to segment images, while simpler systems may be restricted to a minimal set on properties depending of the type of data available.

Lets observe some examples from recent literature:







The problem of image Segmentation:

Decompose a given image into segments/regions/sub-areas/partitions/blobs, each containing similar pixels (or having similar statistical characteristics or similarity).

Target is to have regions of the image depicting the same object.

Semantics:

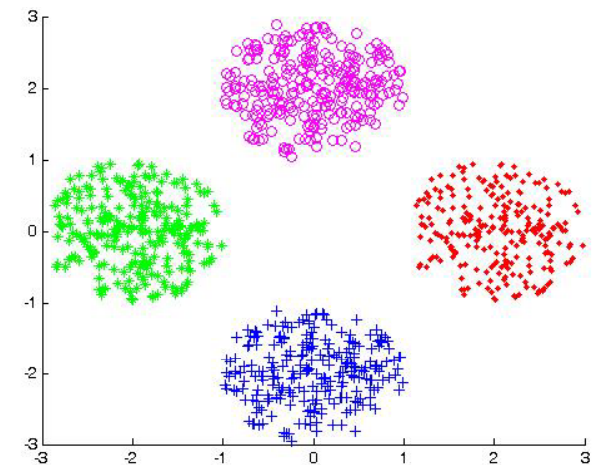
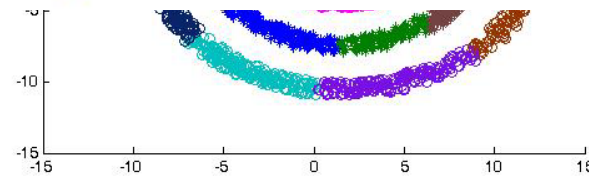
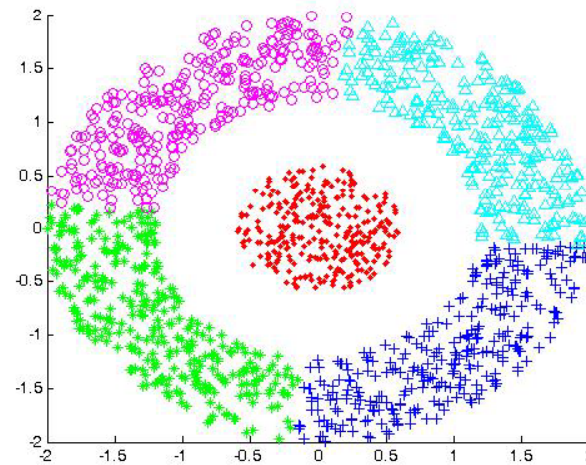
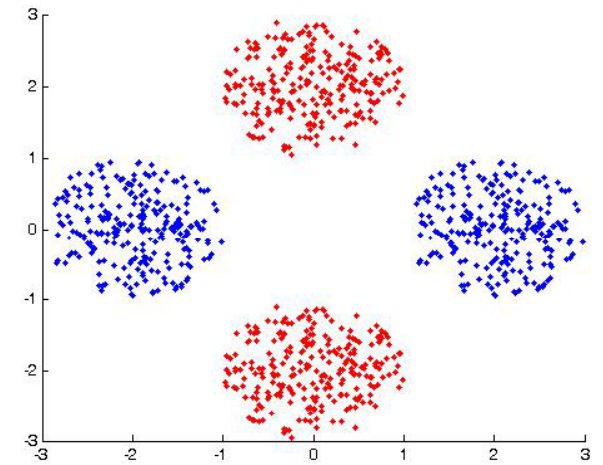
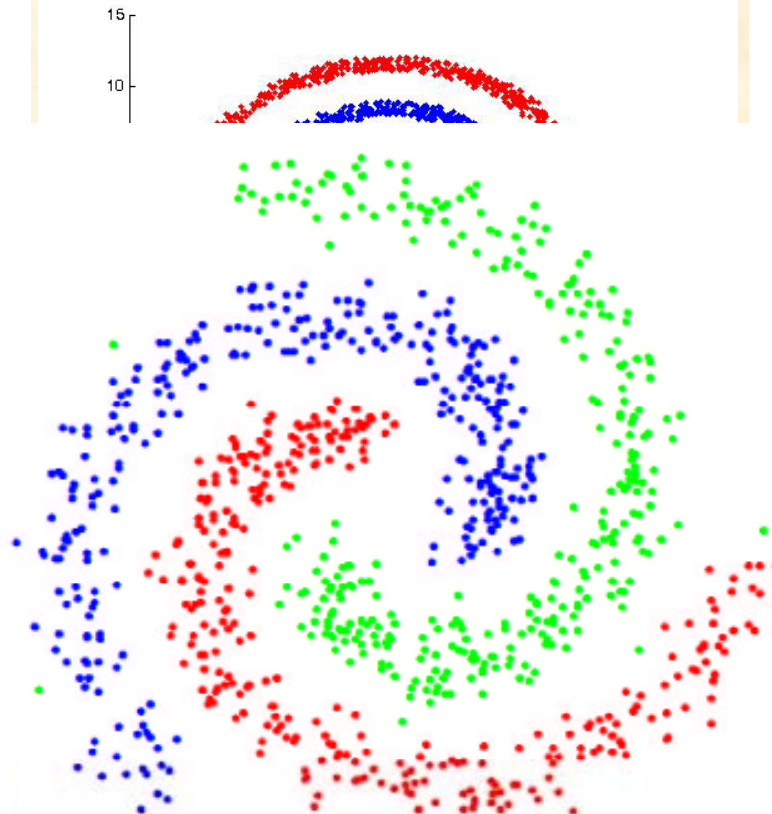
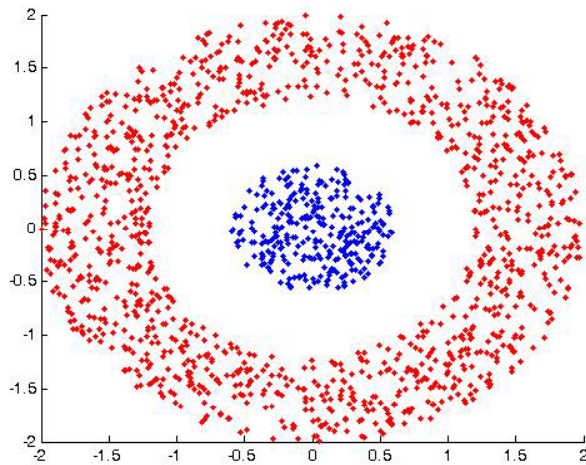
- How to get the idea of an object in the algorithm ?
- How should we infer the objects from segments ??

Segmentation problem is often posed or solved by pattern **classification or CLUSTERING (unsupervised)**.

Are features from pixels from a particular region form a unique cluster or pattern ??

Segments must be connected regions assigned to the same cluster.

EXAMPLES of CLUSTERING



Purpose:

Segment an entire image R into smaller sub-images, R_i , $i=1,2,\dots,N$. which satisfy the following conditions:

$$R = \bigcup_{i=1}^N R_i; R_i \cap R_j = \Phi, i \neq j$$

$$H(R_i) = \text{True}; i = 1,2,\dots, N;$$

When, R_i and R_j are adjacent: $H(R_i \cup R_j) = \text{False}, i \neq j;$

Typical algorithms of clustering data:

- **Agglomerative clustering**
- **K-means, K-medoids, DB-SCAN**
- **check PR literature for more (cluster validity index etc.)**

Categories of Image Segmentation Methods

- **Clustering Methods**
- **Histogram-Based Methods**
- **Edge Detection Methods**
- **Region Growing Methods**
- **Level Set Methods**
- **Graph Partitioning Methods**
- **Watershed Transformation**
- **Neural Networks Segmentation**
- **Multi-scale Segmentation**
- **Model based Segmentation/knowledge-based segmentation** - involve active shape and appearance models, active contours and deformable templates.
- **Semi-automatic Segmentation** - Techniques like Livewire or Intelligent Scissors are used in this kind of segmentation.

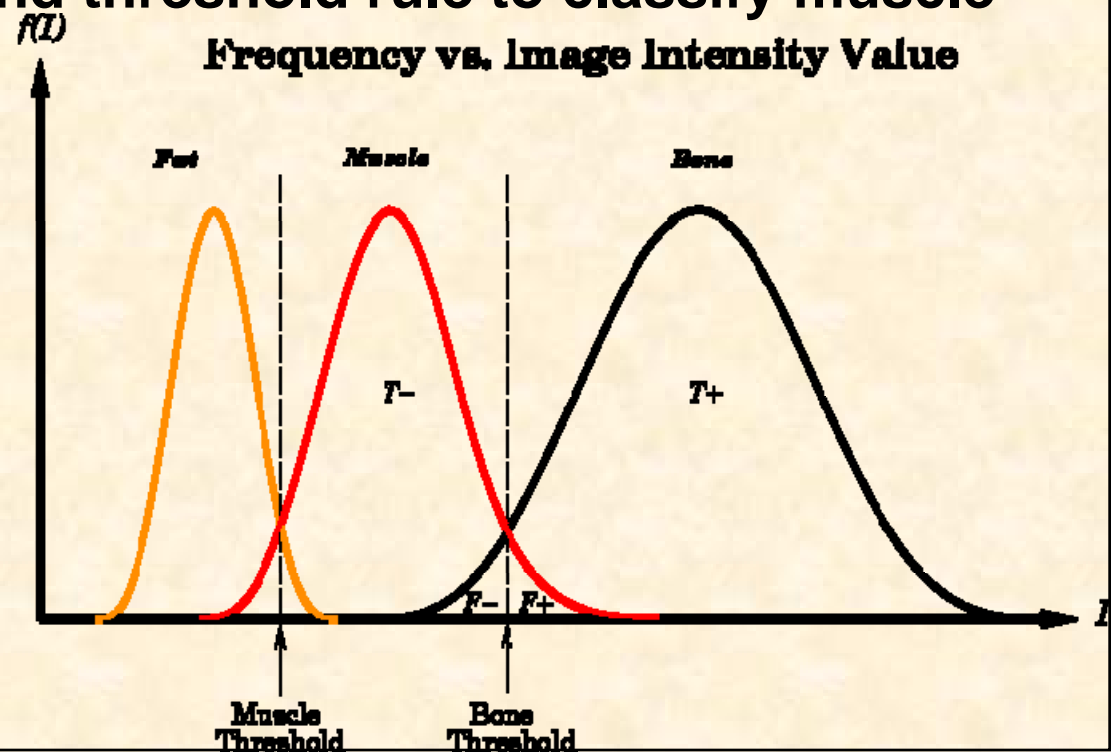
Thresholding is the simplest way to perform segmentation, and it is used extensively in many image processing applications. Thresholding is based on the notion that regions corresponding to different regions can be classified by using a range function applied to the intensity values of image pixels. The assumption is that different regions in an image will have a distinct frequency distribution and can be discriminated on the basis of the mean and standard deviation of each distribution (see Figure).

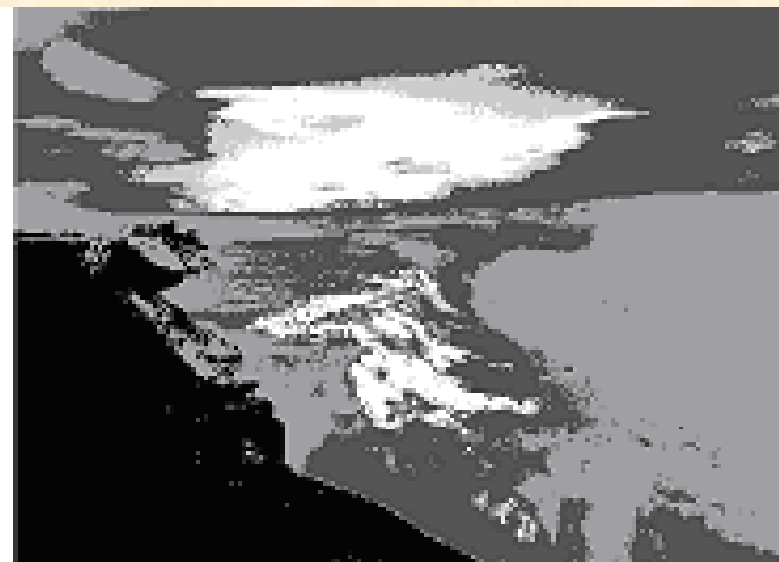
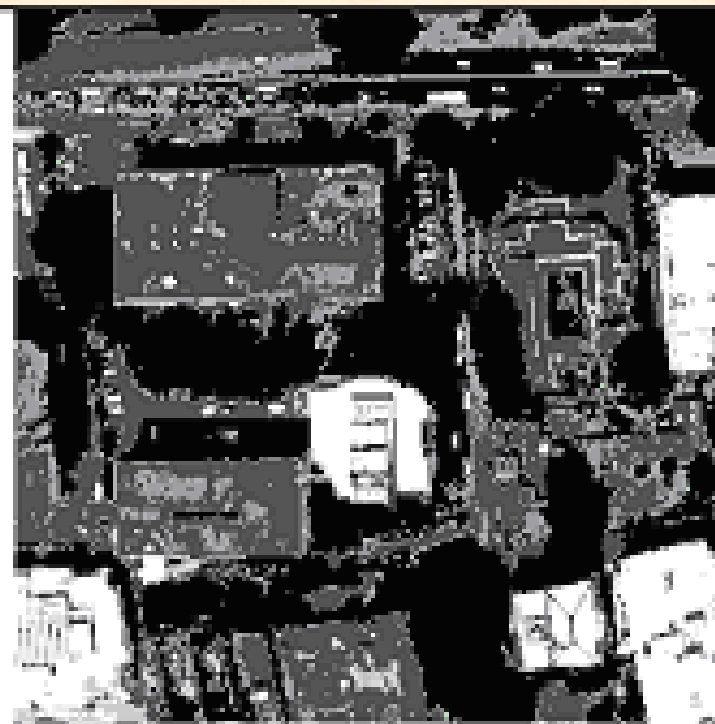
For example, given the histogram of a two-dimensional medical image $I(x,y)$, we can define a simple threshold rule to classify bony and fat tissues or a compound threshold rule to classify muscle tissue:

If, $I(x,y) > T_1 \Rightarrow$ Bony

If, $I(x,y) < T_0 \Rightarrow$ Fat

If, $T_0 < I(x,y) < T_1 \Rightarrow$ Muscle





**Two examples of gray level thresholding
based segmentation**



**Typical segmentation output of a satellite image
using recursive multi-level thresholding method
with statistical features**

Read Otsu's method of multi-modal thresholding:

Limitations of thresholding:

- **The major drawback to threshold-based approaches is that they often lack the sensitivity and specificity needed for accurate classification.**
- **The problem gets severe in case of multi-modal histograms with no sharp or well-defined boundaries.**
- **It is often difficult to define functional and statistical measures only on the basis of gray level value (histogram).**

Solution:

Region Growing based segmentation techniques, such as:

Region splitting, Region merging, Split and Merge and Region growing techniques.

Region-Growing based segmentation

Homogeneity of regions is used as the main segmentation criterion in region growing.

The criteria for homogeneity:

- **gray level**
- **color**
- **texture**
- **shape**
- **model**

The basic purpose of region growing is to segment an entire image R into smaller sub-images, R_i , $i=1,2,\dots,N$. which satisfy the following conditions:

$$R = \bigcup_{i=1}^N R_i; R_i \cap R_j = \Phi, i \neq j$$

$$H(R_i) = True; i = 1,2,\dots, N;$$

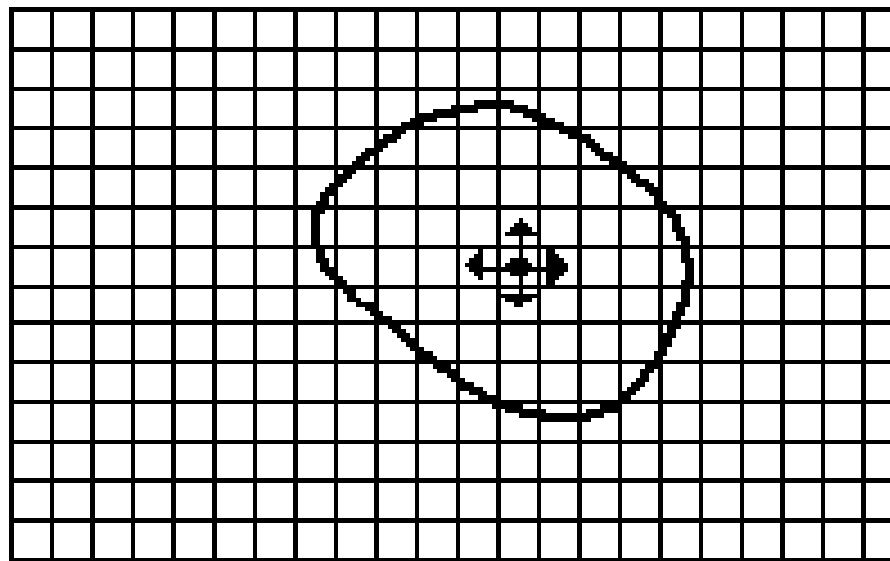
When, R_i and R_j are adjacent: $H(R_i \cup R_j) = False, i \neq j$;

Region Growing

Region growing approach is the opposite of the split and merge approach:

- **An initial set of small areas is iteratively merged according to similarity constraints.**
- **Start by choosing an arbitrary *seed pixel* and compare it with neighboring pixels (see Fig).**
- **Region is *grown* from the seed pixel by adding in neighboring pixels that are similar, increasing the size of the region.**
- **When the growth of one region stops we simply choose another seed pixel which does not yet belong to any region and start again.**
- **This whole process is continued until all pixels belong to some region.**
- ***A bottom up* method.**

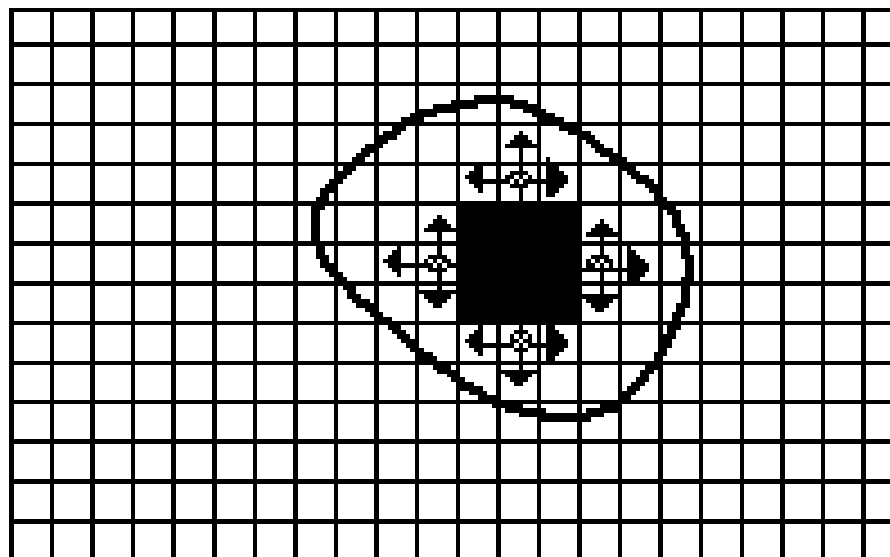
Region growing methods often give very good segmentations that correspond well to the observed edges.



• Seed Pixel

↑ Direction of Growth

(a) Start of Growing a Region



■ Grown Pixels

○ Pixels Being Considered

(b) Growing Process After a Few Iterations

However starting with a particular seed pixel and letting this region grow completely before trying other seeds biases the segmentation in favour of the regions which are segmented first.

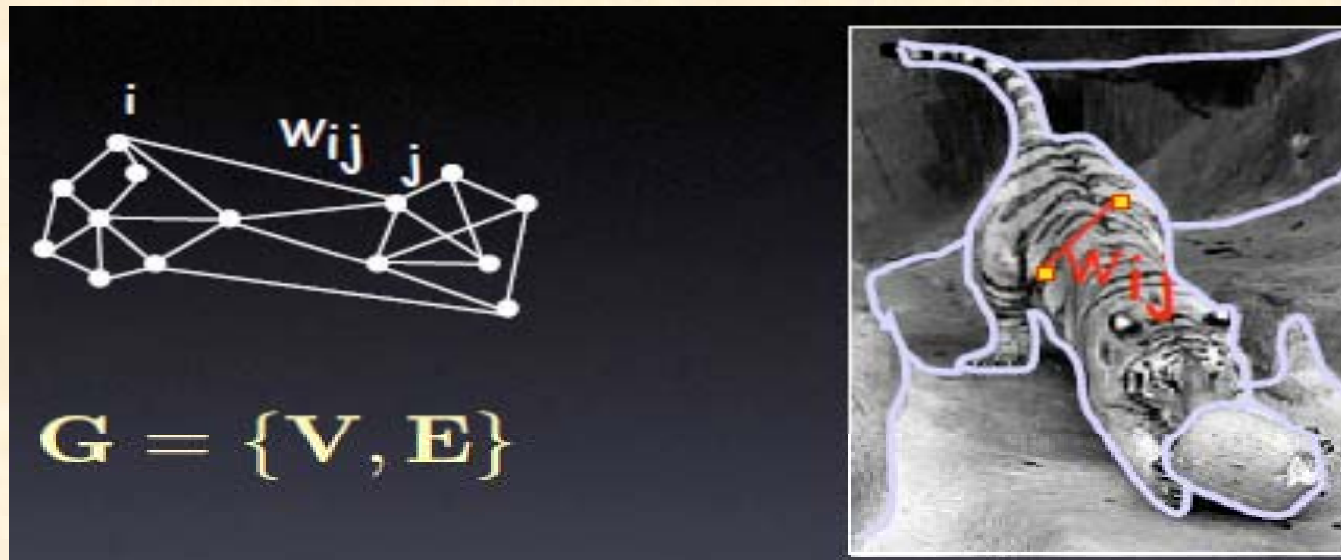
This can have several undesirable effects:

- **Current region dominates the growth process -- ambiguities around edges of adjacent regions may not be resolved correctly.**
- **Different choices of seeds may give different segmentation results.**
- **Problems can occur if the (arbitrarily chosen) seed point lies on an edge.**

To counter the above problems, *simultaneous region growing* techniques have been developed.

- **Similarities of neighboring regions are taken into account in the growing process.**
- **No single region is allowed to completely dominate the proceedings.**
- **A number of regions are allowed to grow at the same time.**
- **Similar regions will gradually coalesce into expanding regions.**
- **Control of these methods may be quite complicated but efficient methods have been developed.**
- **Easy and efficient to implement on parallel computers.**

NORMALIZED GRAPH CUT



V: graph nodes: \longleftrightarrow Image = { pixels }

E: edges connection nodes: \longleftrightarrow Pixel similarity

A graph $G = \{V, E\}$ can be partitioned into two disjoint sets: A, B ; $A \cup B = V$, $A \cap B = \phi$, by simply removing edges connecting the two parts.

The degree of dissimilarity between these two pieces can be computed as total weight of the edges that have been removed.

In graph theoretic language, it is called the cut:

$$cut(A, B) = \sum_{u \in A, v \in B} w(u, v)$$

In grouping, we seek to partition the set of vertices into disjoint sets V_1, V_2, \dots, V_m , where by some measure the similarity among the vertices in a set V_i is high and, across different sets V_i, V_j is low.

Mincut creates a optimal bi-partitioning of the graph. Instead of looking at the value of total edge weight connecting the two partitions, a normalized measure computes the cut cost as a fraction of the total edge connections to all the nodes in the graph.

This disassociation measure is called the normalized cut (Ncut):

Minimize the cut, while maximize the association

$$H^{\text{NCut}}(A, B) = \frac{\text{cut}(A, B)}{\text{assoc}(A, V)} + \frac{\text{cut}(B, A)}{\text{assoc}(B, V)}$$

where, $\text{assoc}(A, V)$ is the total connection from nodes in A to all nodes in the graph.

$$\text{assoc}(A, V) = \sum_{u \in A, t \in V} w(u, t);$$

$$\text{cut}(A, B) = \sum_{u \in A, v \in B} w(u, v)$$

Example Normalized Cut



(a)

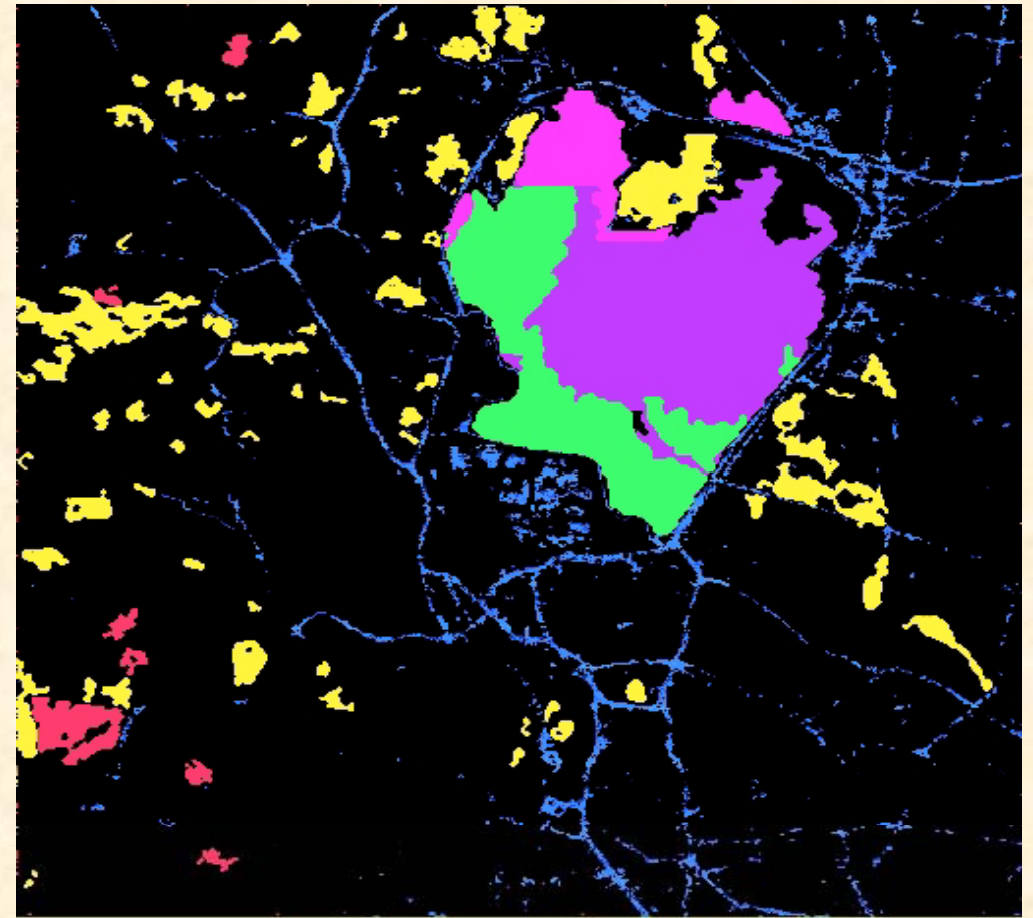


(b)

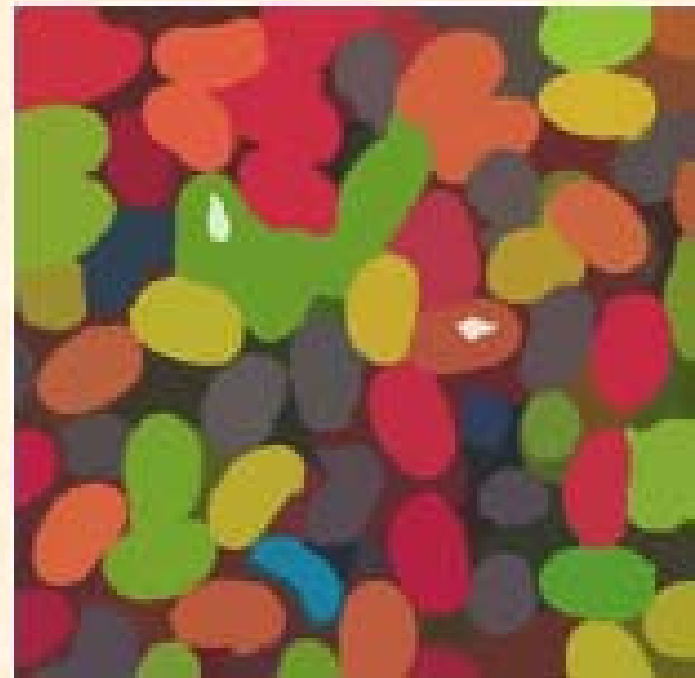
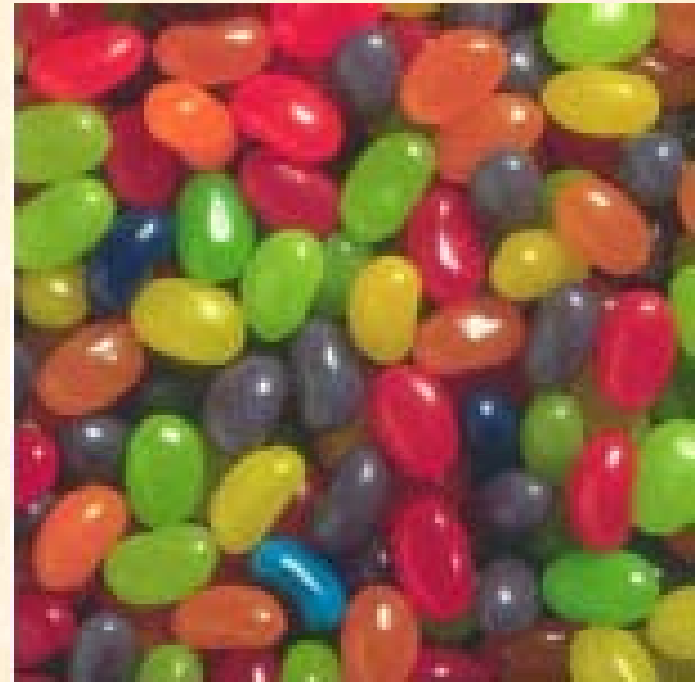


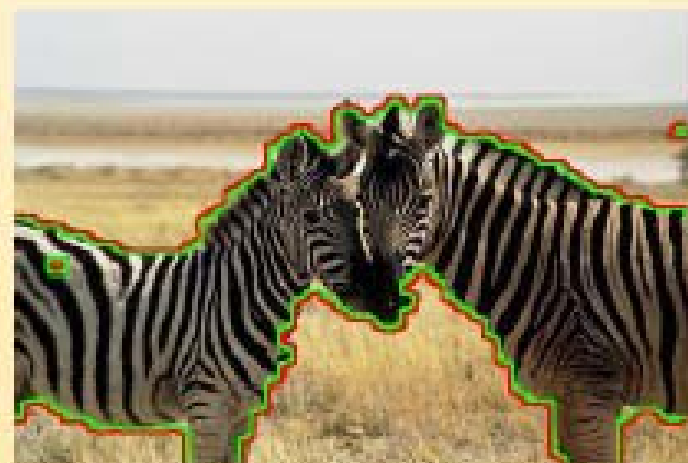
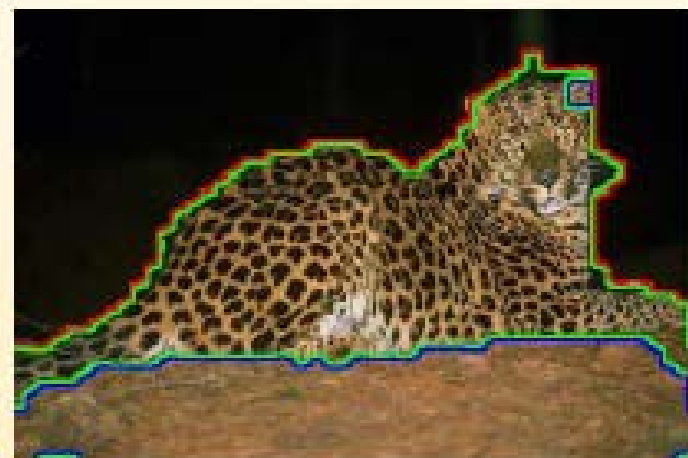
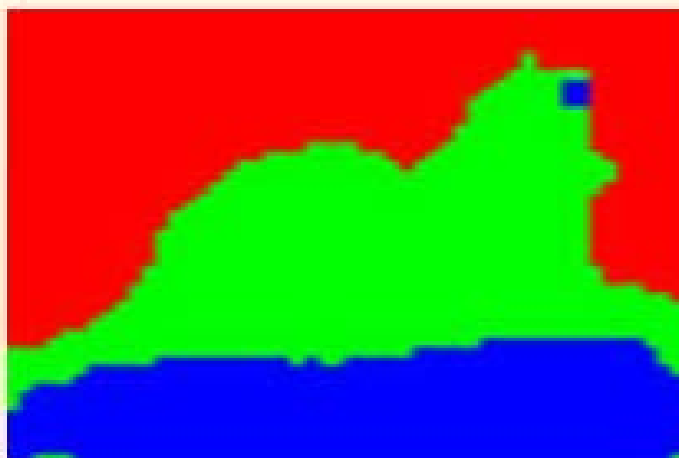
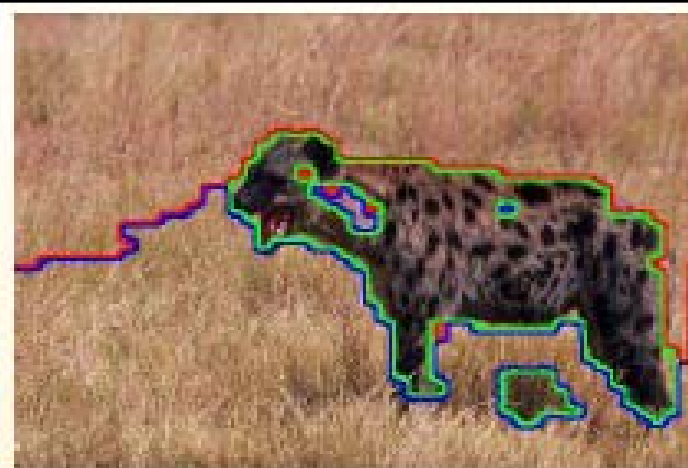
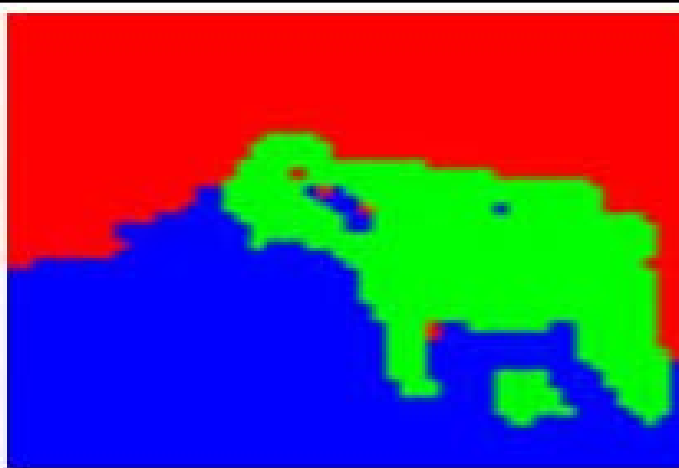
Shi & Malik, 2000





**Terrain classification based on color properties
of a satellite Image of Hyderabad lake area**





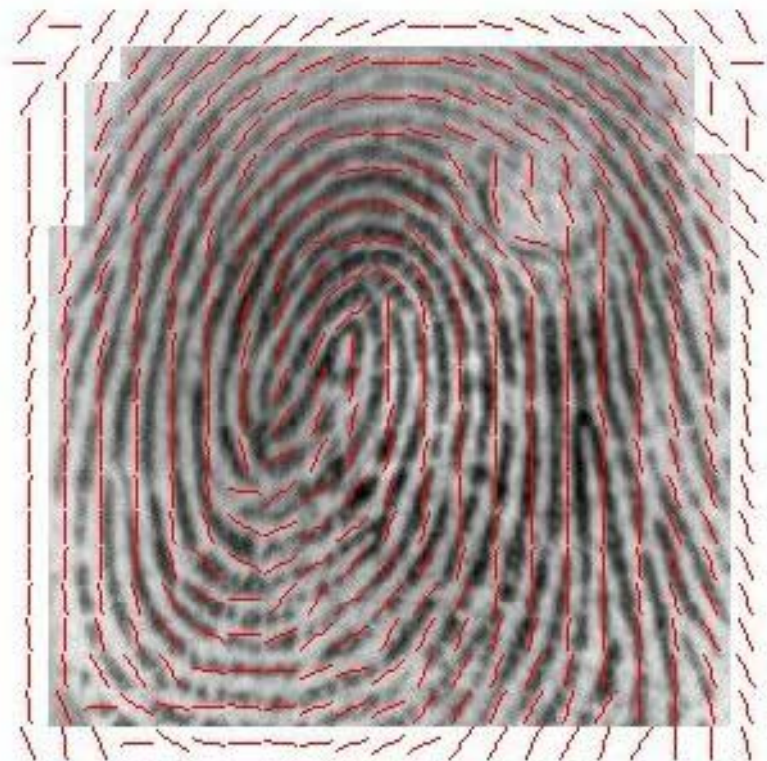
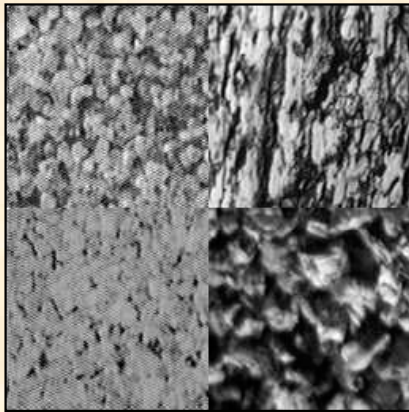


Image Segmentation - Combining edge and region information

Example of Image Segmentation (ideal) based on fusion

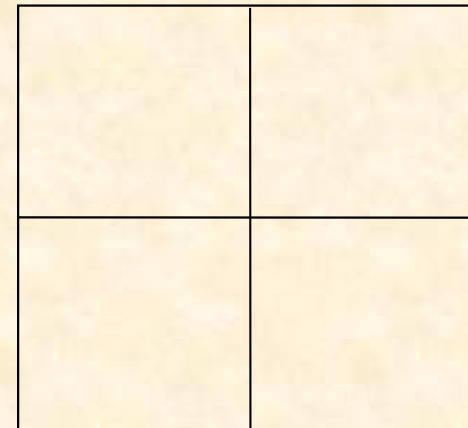
Input Image



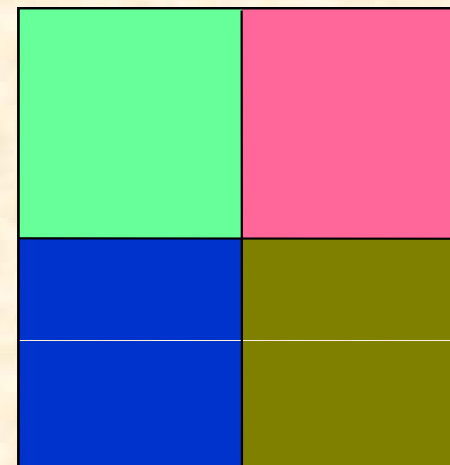
Region Based Segmentation

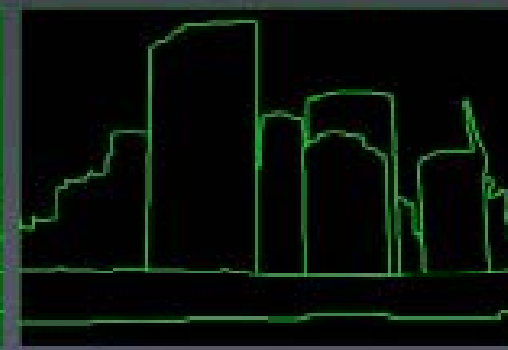
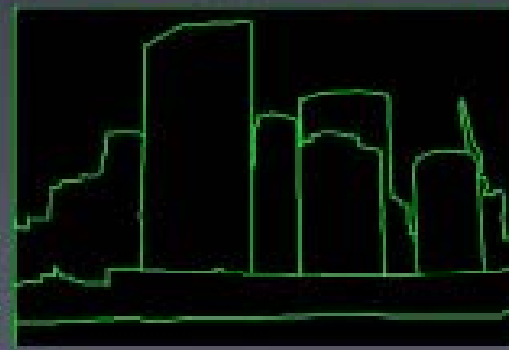
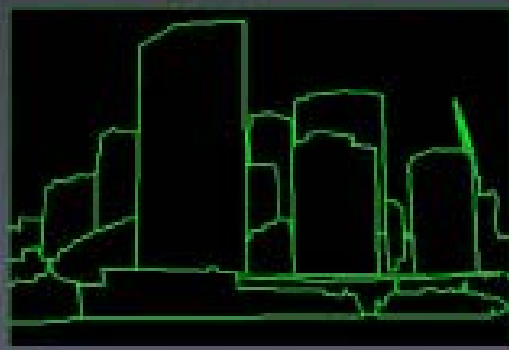
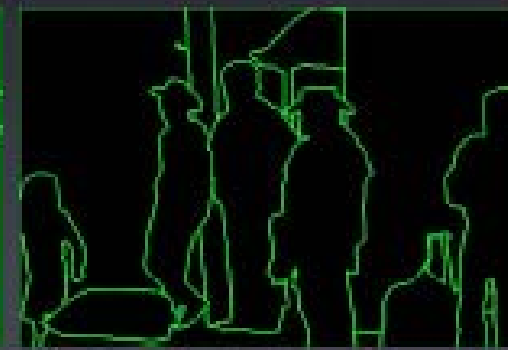
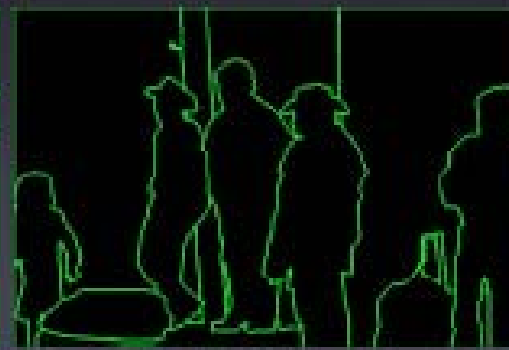
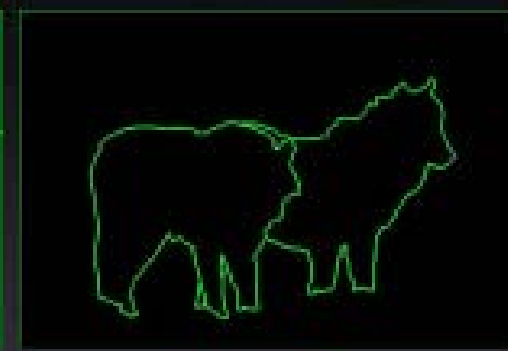
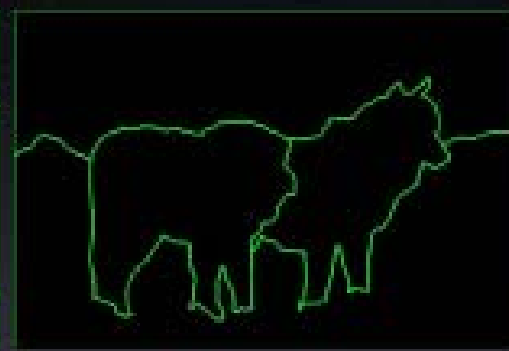
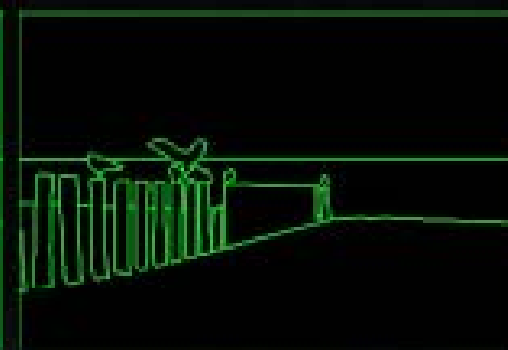
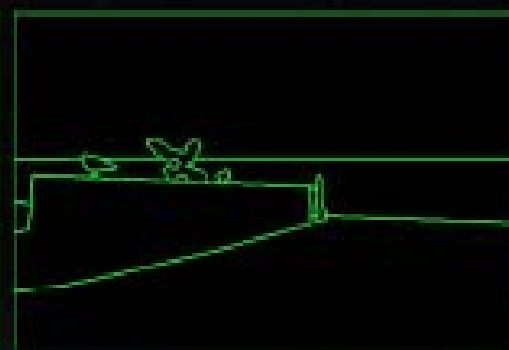
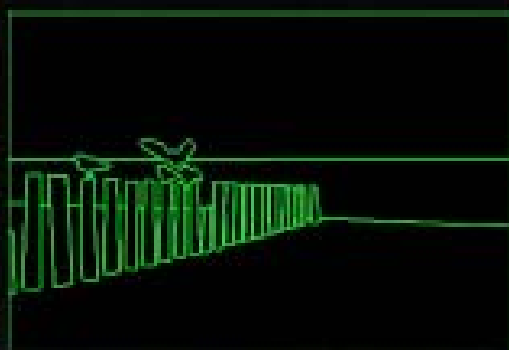
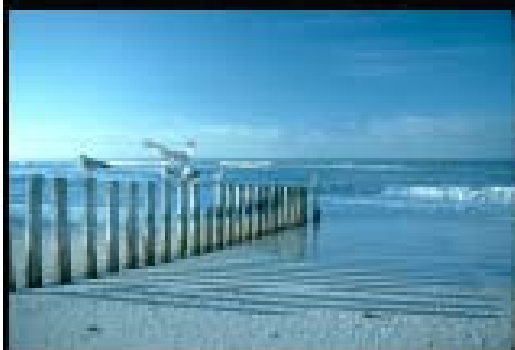


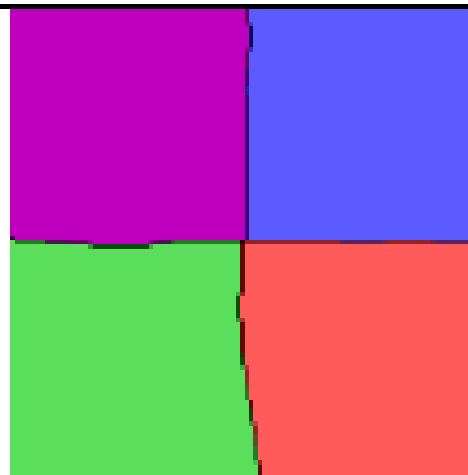
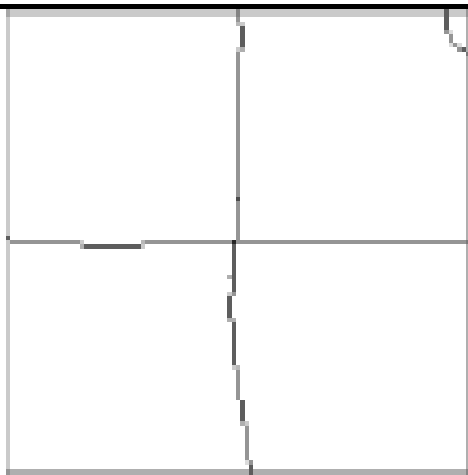
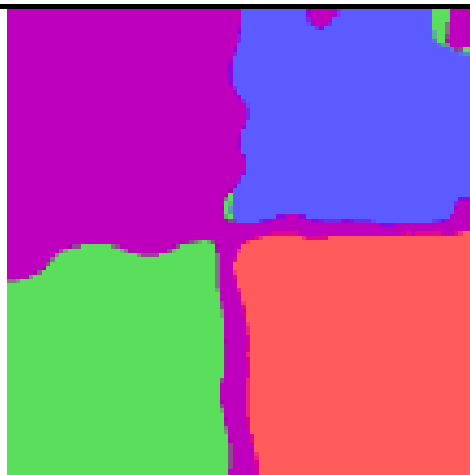
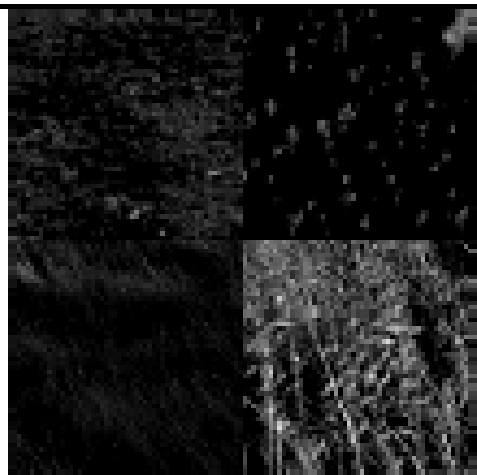
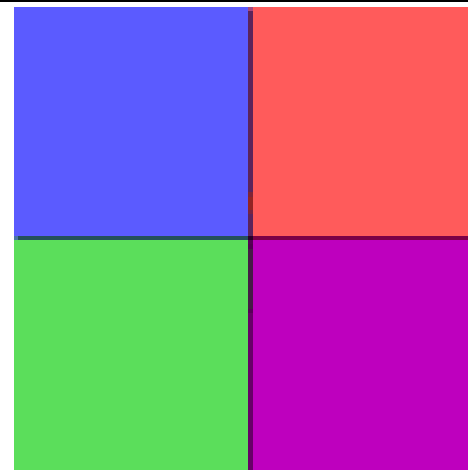
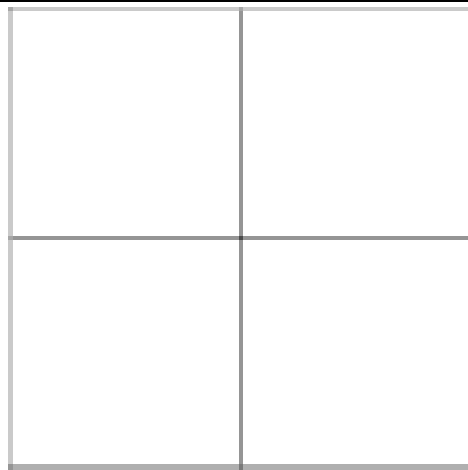
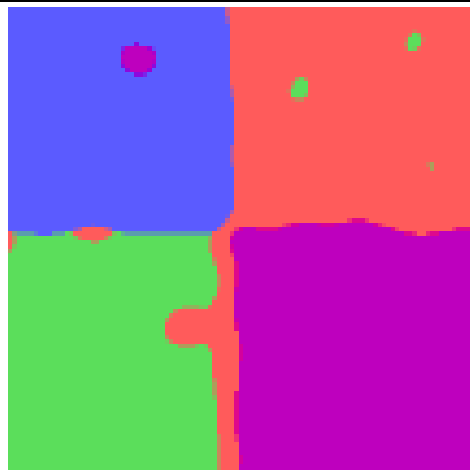
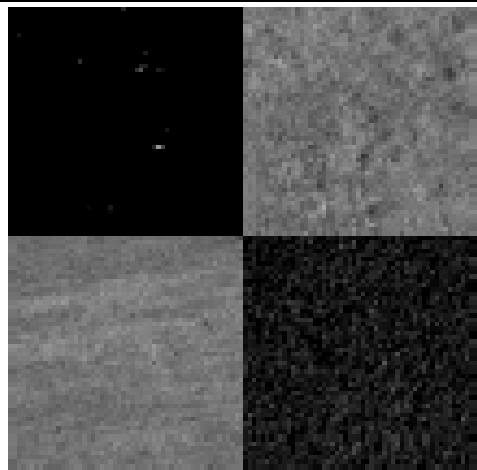
Edge Detection (ideal)



Output segmented
Image
(ideal)







Fusion of Complimentary Information

- **Region-based methods** sacrifices resolution and details in the image while calculating useful statistics for local properties – leads to segmentation errors at the boundaries
- **Difficult to choose initial seed points and stopping criteria** in the absence of priori information.
- **Boundary-based methods fail** if image is noisy or if its attributes differ only by a small amount between regions
- **Both Boundary-based and region based method often fail** to produce accurate segmentation results, although the location in which each of these methods fail may not be identical (often complimentary).
- **Both approaches suffer from a lack of information** since they rely on ill-defined hard thresholds, which may lead to wrong decisions

Integration Techniques

- By using the complementary information of edge-based and region-based information, it is possible to reduce the problems that arise in each individual methods.

1. Embedded Integration

2. Post- processing integration.

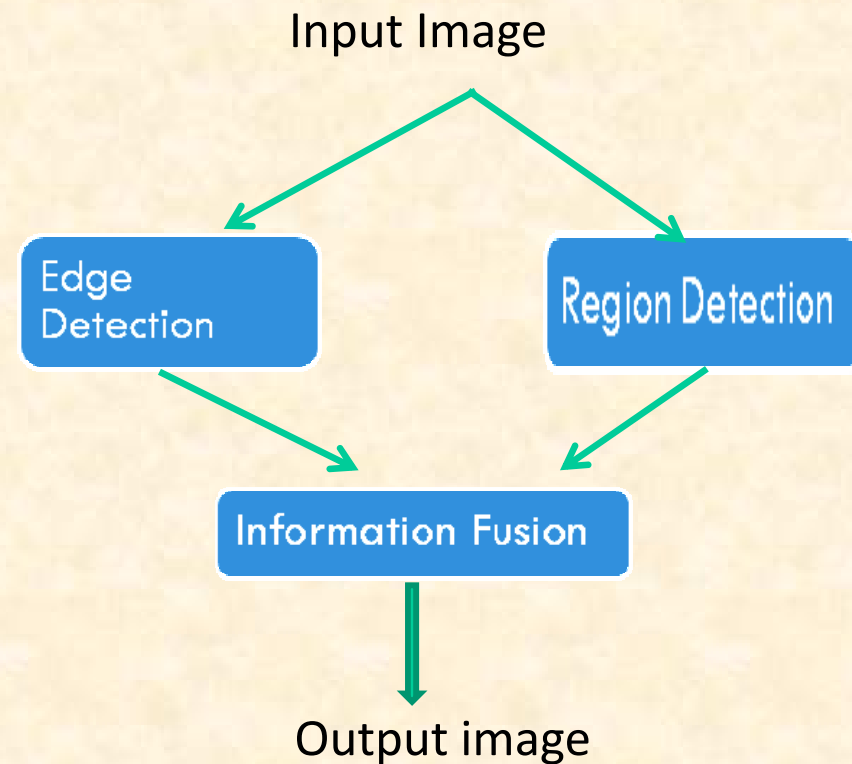
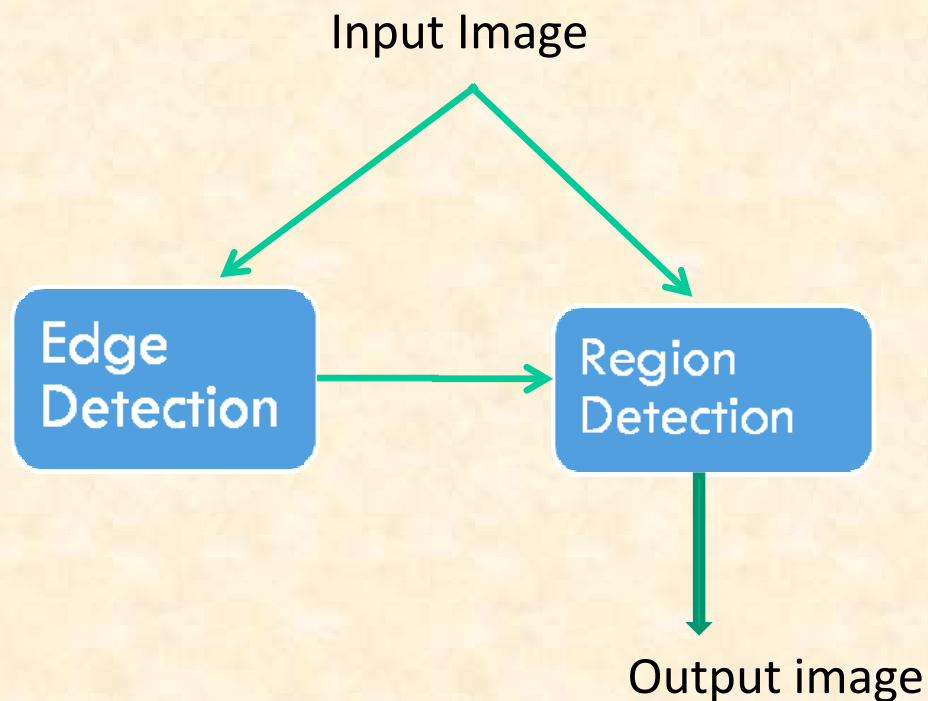
X. Munoz, J. freixenet, X. Cufi, J. Marti,

Strategies for image segmentation combining region and boundary information, Pattern Recognition Letters 24 (2003).

Integration Techniques

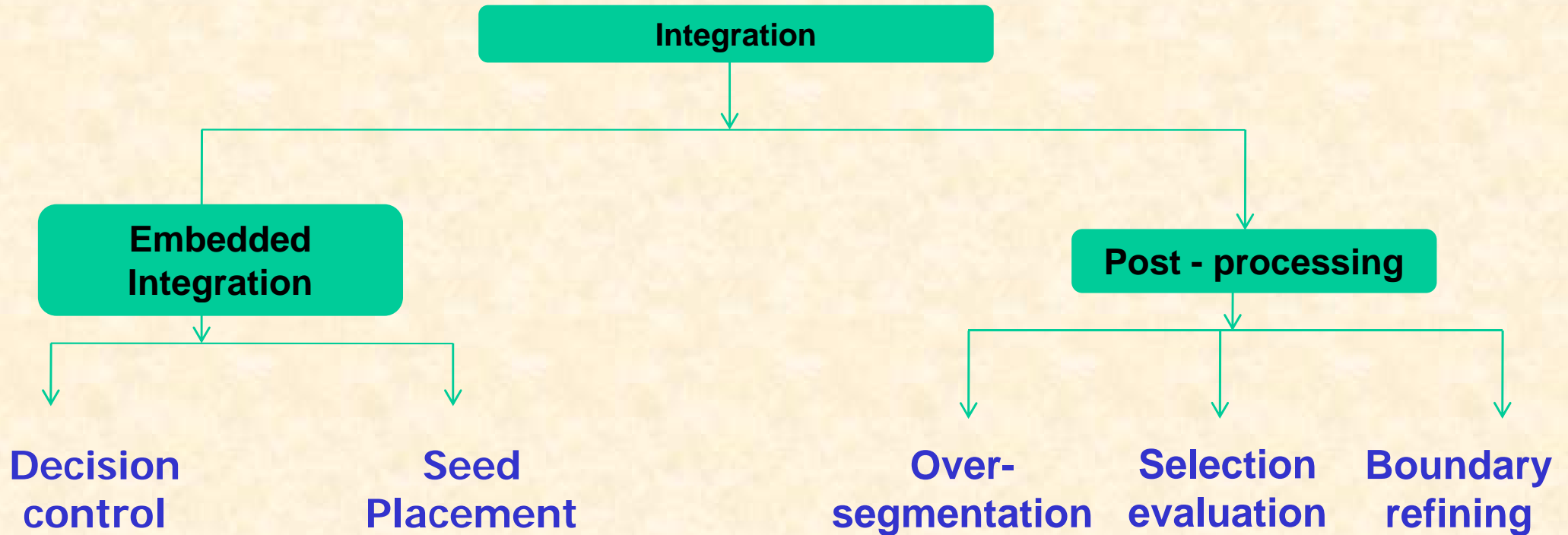
Embedded Integration

Post – Processing Integration



X. Munoz, J. freixenet, X. Cufi, J. Marti,
Strategies for image segmentation combining region and boundary information, Pattern Recognition Letters 24 (2003).

Integration Techniques



- edge information to control the growth of the region.

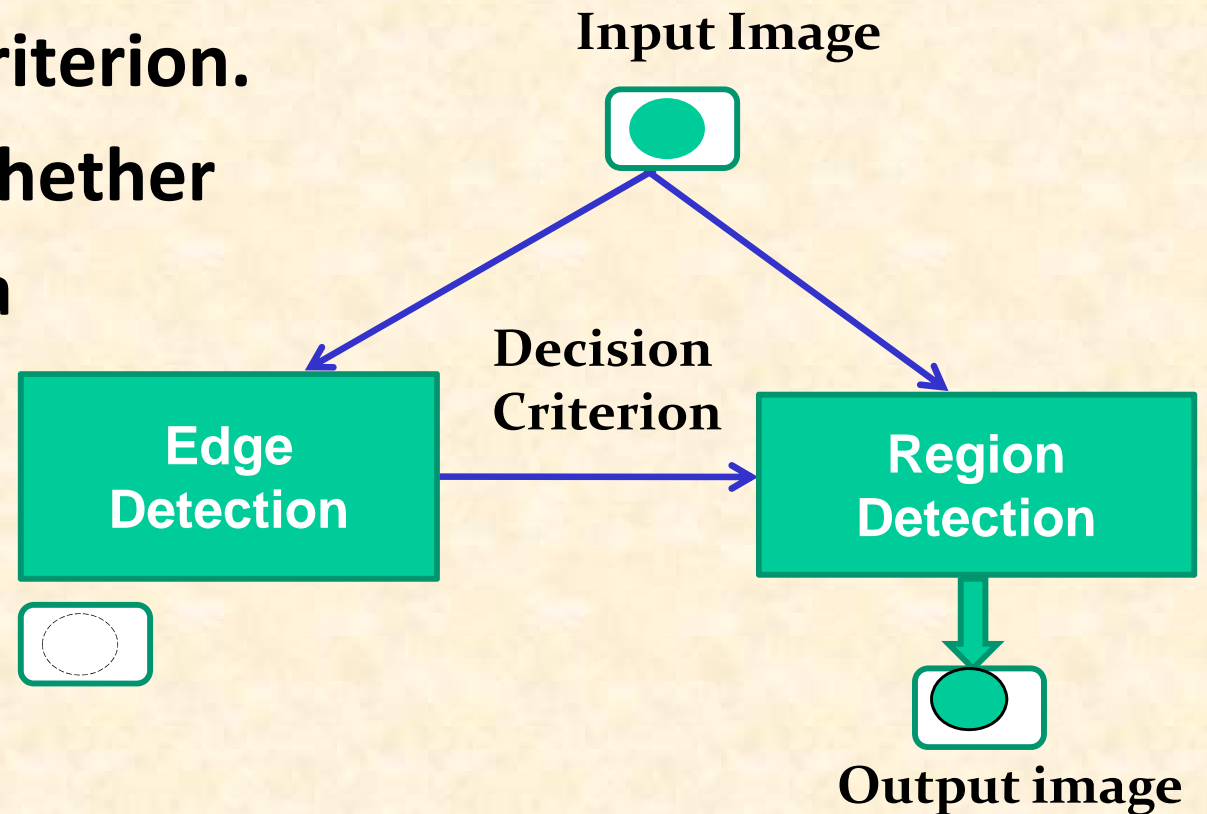
- Use of edge information to place the seed.

Embedded Integration

- Extracted edge information is used within region segmentation algorithm.
- Edge Information can be used in two ways
 1. ***Control of decision criterion*** - edge information is included in the definition of decision criterion which controls the growth of the region.
 2. ***Seed placement guidance*** - edge information used to decide which is the most suitable position to place the seed of the region region growing process.

Decision control-based Region Growing

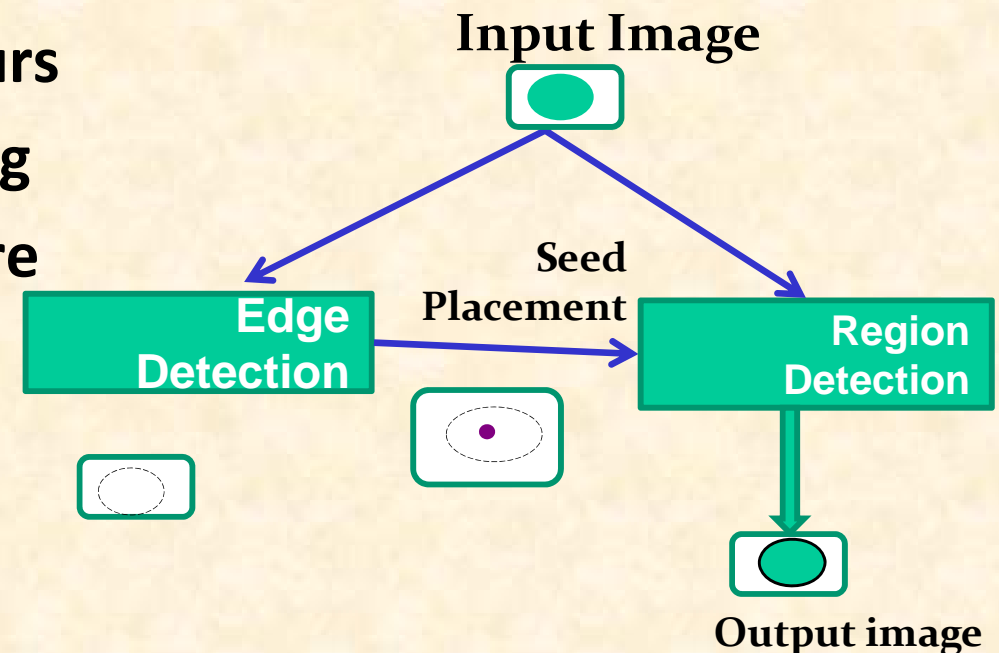
- Choose a starting point or a pixel.
- Add neighboring pixels that are similar based on homogeneity criterion.
- Criterion determines whether or not a pixel belongs to a growing region
 - ▣ Region growing stops if there is a edge
- Merge if there is no edge



Seed placement guidance

- Placement of initial seed points influences the result of region- based segmentation.
- Edge information is used to decide the best position to place the seed point

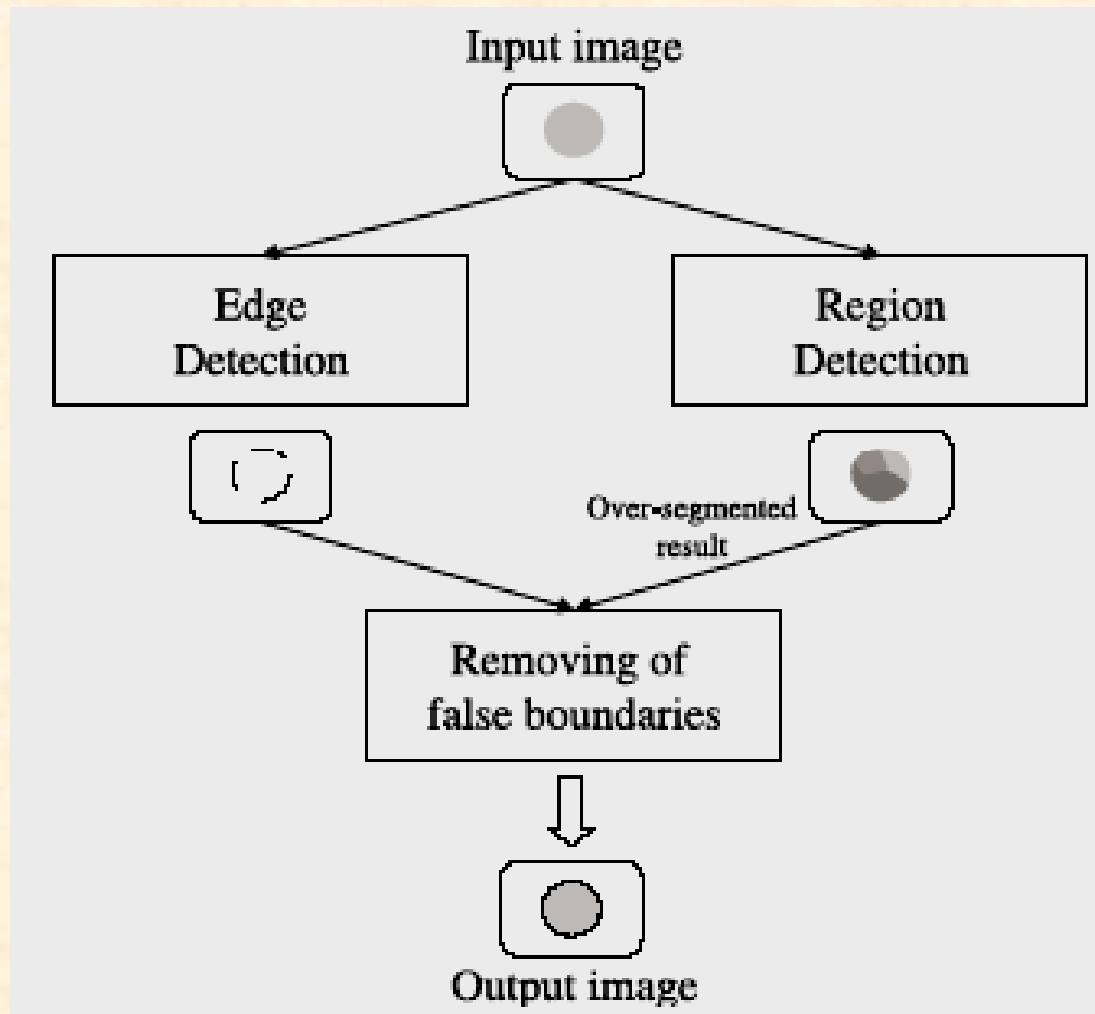
- ▣ Seeds are placed in the core of regions which are far away from contours
- ▣ Disadvantage of region growing and merging – sequential nature



Post-processing Integration

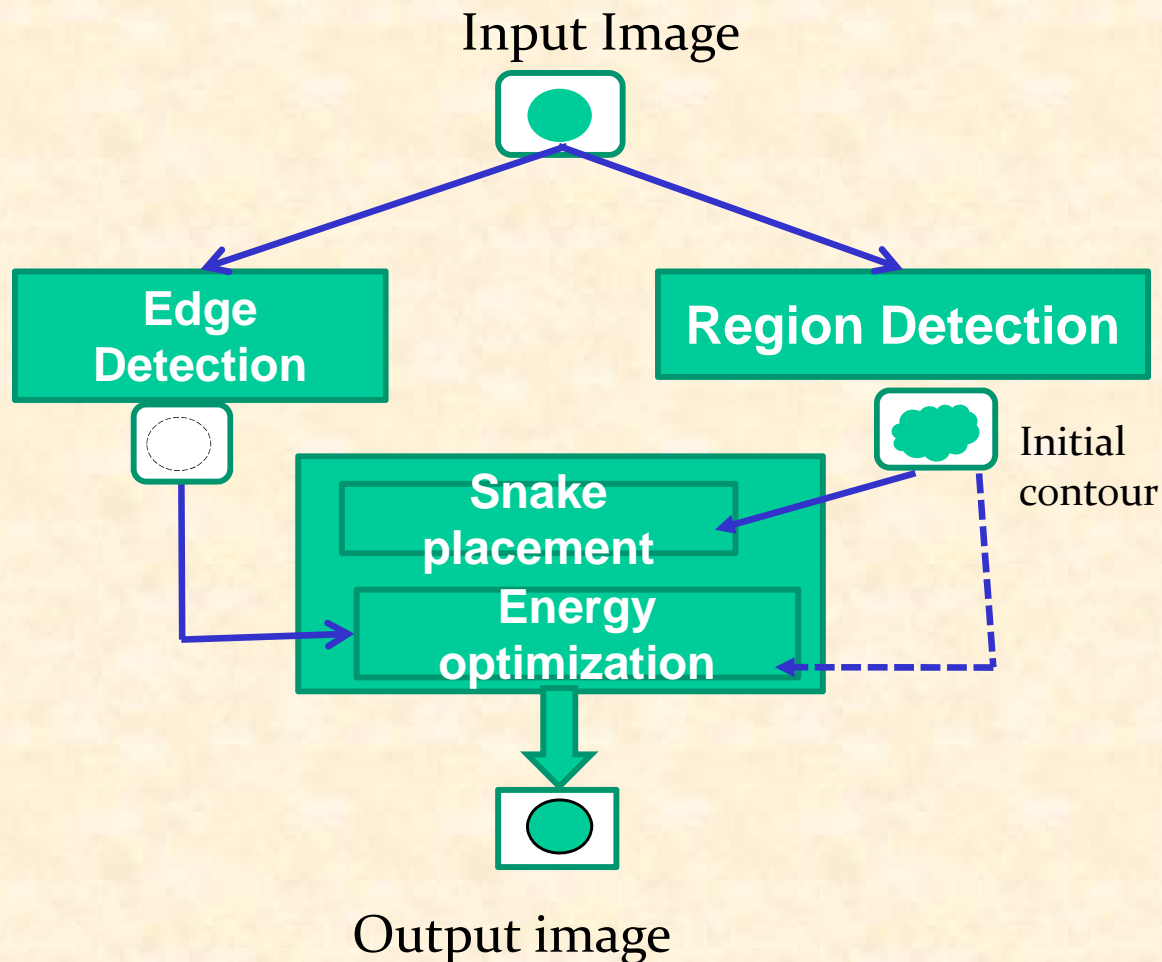
- Combines the map of regions and the map of edge outputs with the aim of providing an accurate and meaningful segmentation.
- Three different approaches
 - (1) Over- segmentation*
 - (2) Boundary refinement*
 - (3) Selection- evaluation*

Over-segmentation



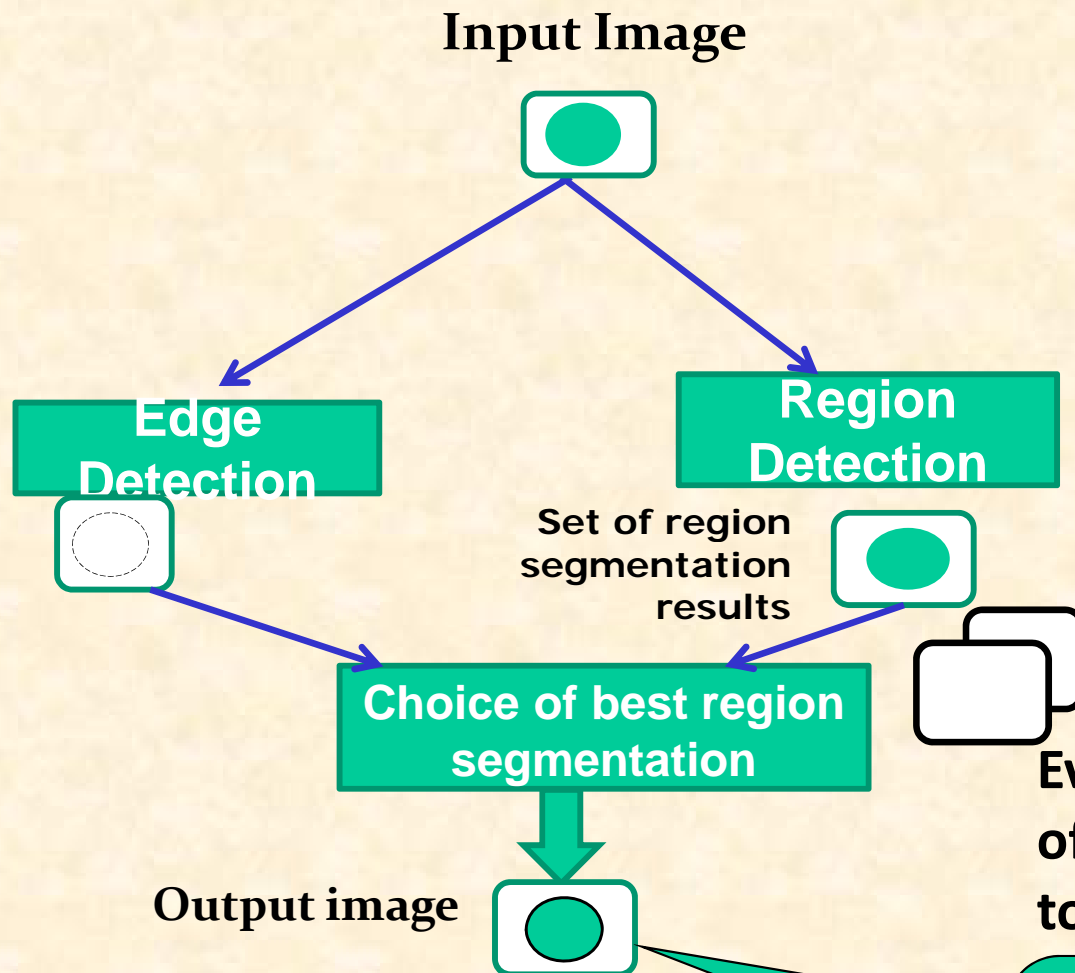
- Region segmentation algorithm may produce false boundaries
- It is compared with edge detection results.
- Eliminate boundaries that are not in Edge detection results
- Only real boundaries are preserved.

Boundary refinement



- A region-based segmentation is used to get an initial estimate of the region.
- It is combined with salient edge information to achieve more accurate representation of the target boundary

Selection- evaluation



- Different results are achieved by changing parameters and thresholds in a region- segmentation algorithm

- Evaluation function is used to choose the best result obtained.

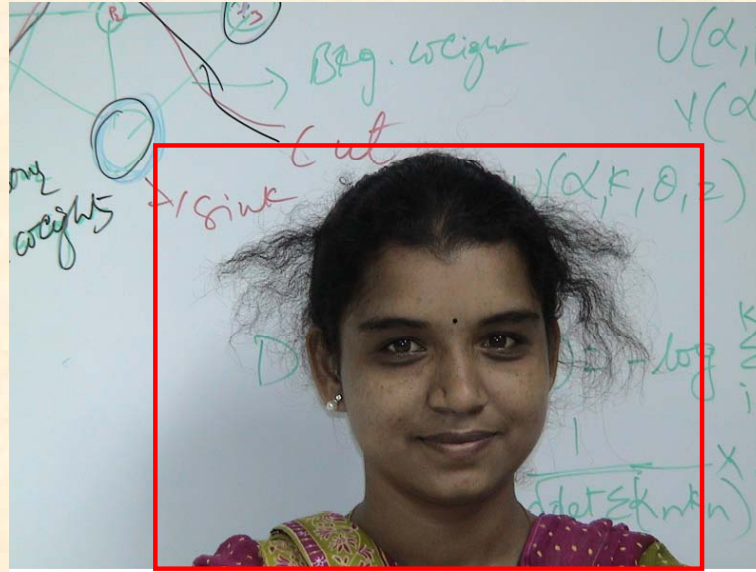
Evaluation function measures the quality of a region-based segmentation according to its consistency with the edge map

The best region segmentation is the one where the region boundaries correspond most closely to the contours

Modern methods for Image segmentation involve:

- **Multi-resolution and multi-channel features**
- **Feature fusion (selection) techniques**
- **Multi-classifier decision combination**
- **HMM, GMM, CRF- and GMRF-based techniques**
- **Artificial Neural Networks – SOM and Hopfield/Bolztmann**
- **Active contours, watershed transform**
- **Grabcut (Graph cut); normalized cut.**
- **Snake-cut**
- **Parametric Distributional clustering**
- **Deformable Templates, AAM, ASM**
- **Decision Trees and hierarchical analysis**
- **Probabilistic approaches**
- **Neuro-fuzzy and soft-computing (SA) techniques**
- **ACO, etc.**

Object Extraction From an Image



Snake



GrabCut



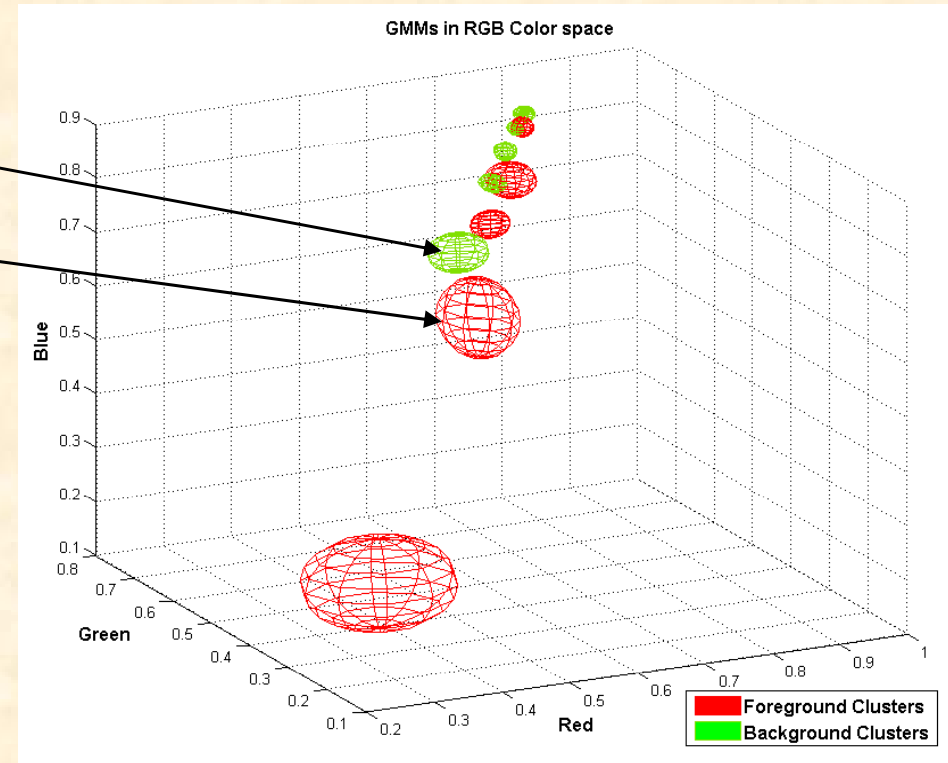
Object Extraction From an Image

Alpha-Matte based Foreground Extraction:



Unknown
foreground

Known
Background



Create GMMs with K components for foreground and background separately

Learn GMMs and perform GraphCut to find tentative classification of foreground and background

Object Extraction From an Image

Source (Fg)



Pixel type	Back T-link	Fore T-link
Foreground	0	constant X
Background	constant X	0
Unknown	D_{Fore}	D_{Back}

Sink (Bkg)

$$D(m) = -\log \sum_{i=1}^K \left[\pi_i \frac{1}{\sqrt{\det \Sigma_i}} \exp \left(\frac{1}{2} [z_m - \mu_i]^T \Sigma_i^{-1} [z_m - \mu_i] \right) \right]$$

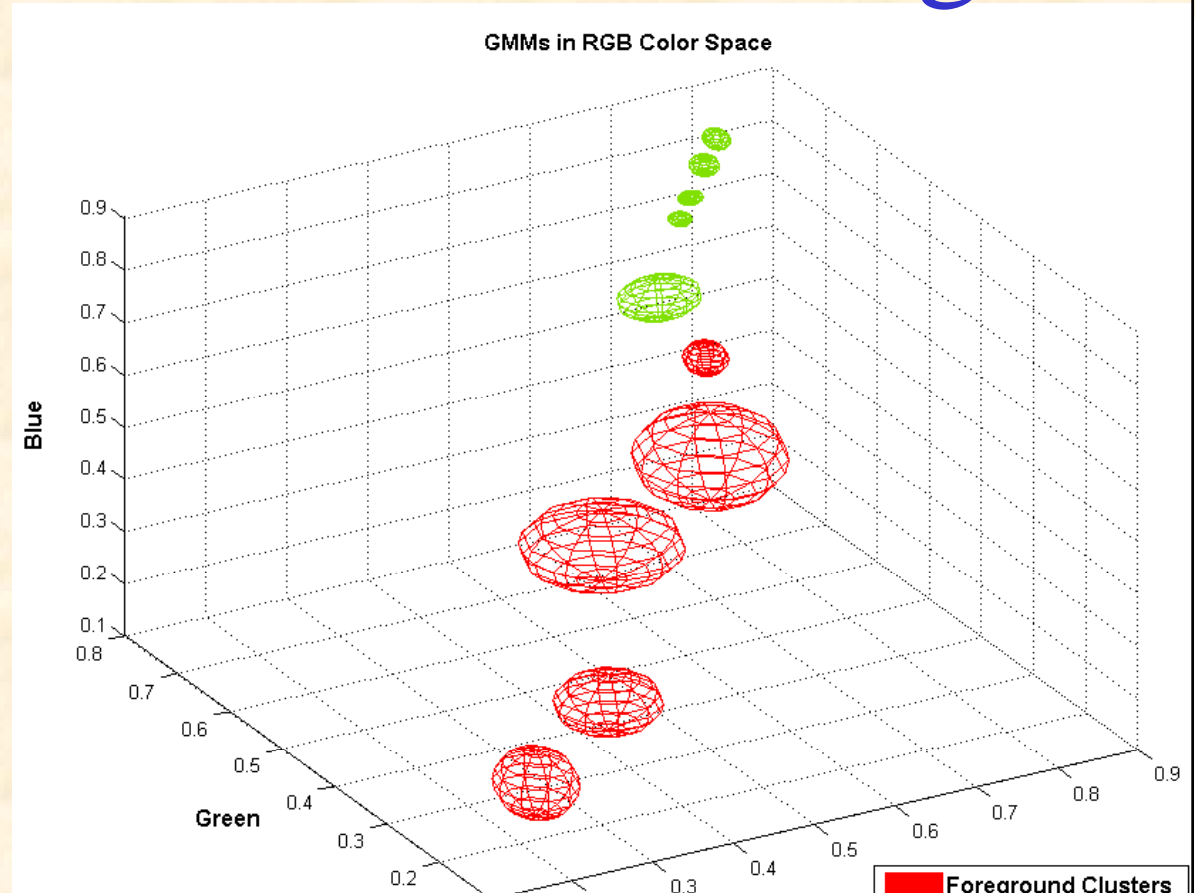
$$N(m, n) = \frac{50}{\text{dist}(m, n)} e^{-\beta \|z_m - z_n\|^2}$$

Learn GMMs with newly classified set, and repeat the process until classification converges

Object Extraction From an Image



Final State



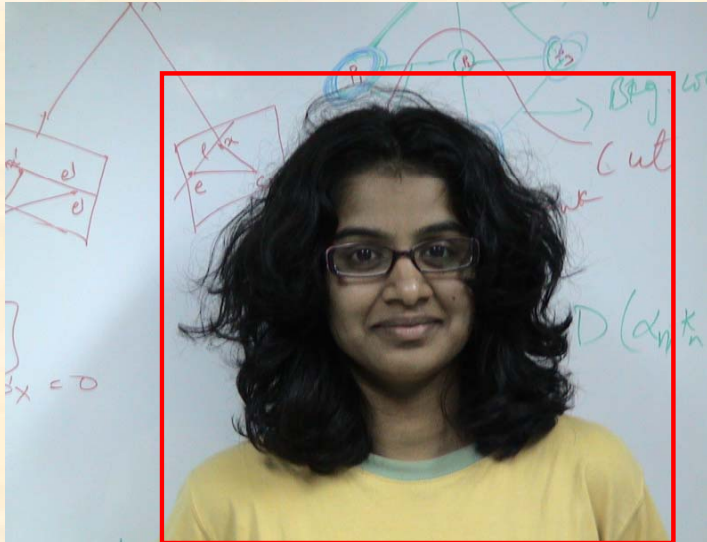
$$P(m) = \log \sum_{i=1}^K \left[w_i \frac{1}{\sqrt{\det \Sigma_i}} \times \exp \left(\frac{1}{2} [I_m - \mu_i]^T \Sigma_i^{-1} [I_m - \mu_i] \right) \right]$$

$$\alpha_m = \begin{cases} 1 & \text{if } (P_{fore}(m) - P_{back}(m)) > \tau \\ 0 & \text{if } (P_{back}(m) - P_{fore}(m)) > \tau \\ \text{unknown} & \text{if } |P_{fore}(m) - P_{back}(m)| < \tau \end{cases}$$



Object Extraction From an Image

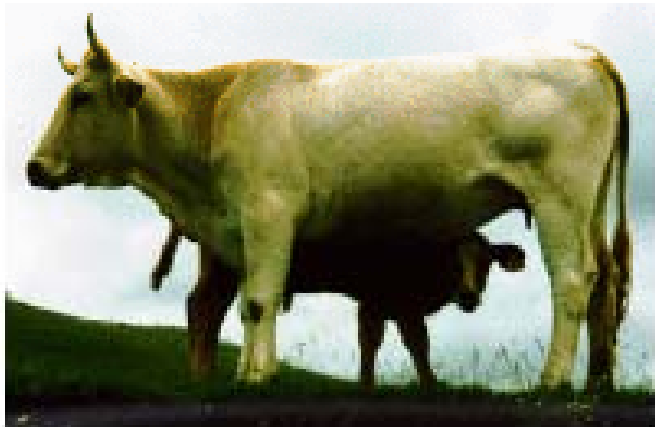
Results:



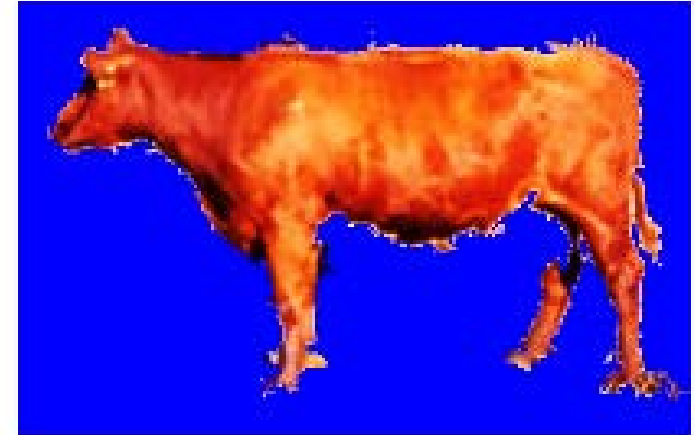
Object Extraction From an Image



Image



Segmentation



**Purposeful image segmentation – involves object
Detection and recognition modules (non-trivial tasks)**

REFERENCES

- Normalized Cuts and Image Segmentation; Jianbo Shi and Jitendra Malik, Member, IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE, VOL. 22, NO. 8, AUGUST 2000, pp 888-905.



Bruegel, 1564