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,

Most 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.**

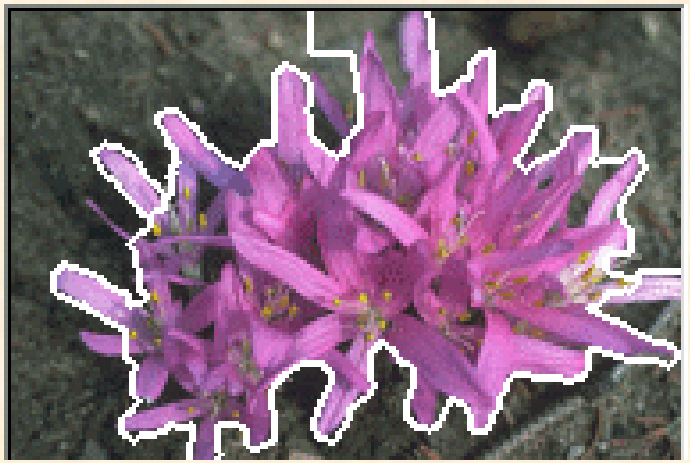
- **Edge-based techniques rely on discontinuities in image values between distinct regions, and the goal of the segmentation algorithm is to accurately demarcate the boundary separating these regions.**

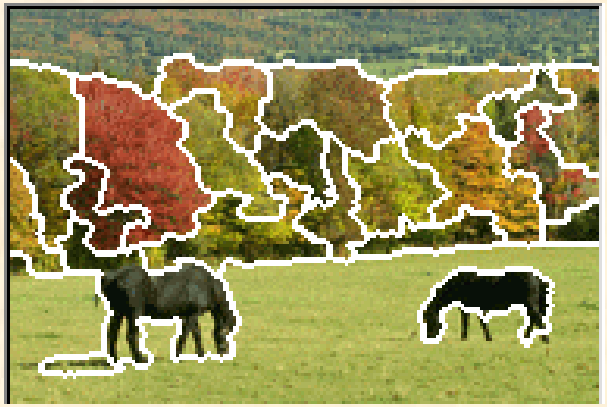
Segmentation **is a process of extracting and representing information from an image is to group pixels together into regions of similarity.**

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.





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.

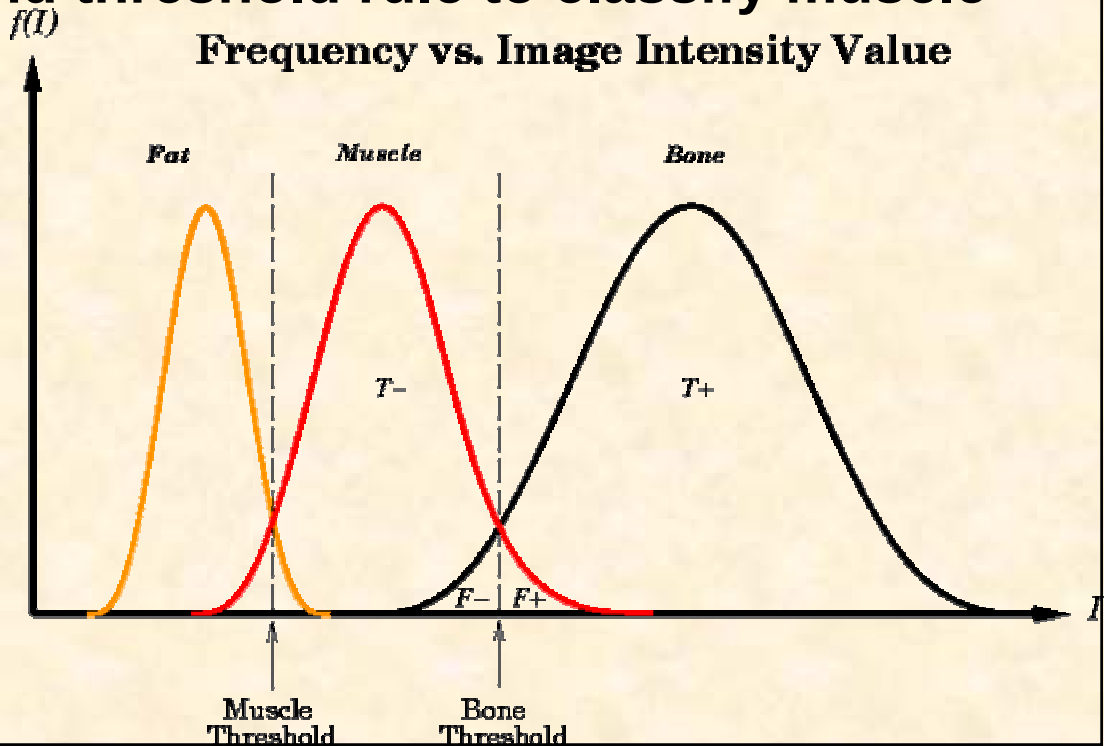
Thresholding is the simplest way to perform segmentation, and it is used extensively in many image processing applications. Thresholding is based on the notion that regions corresponding to different regions can be classified by using a range function applied to the intensity values of image pixels. 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).

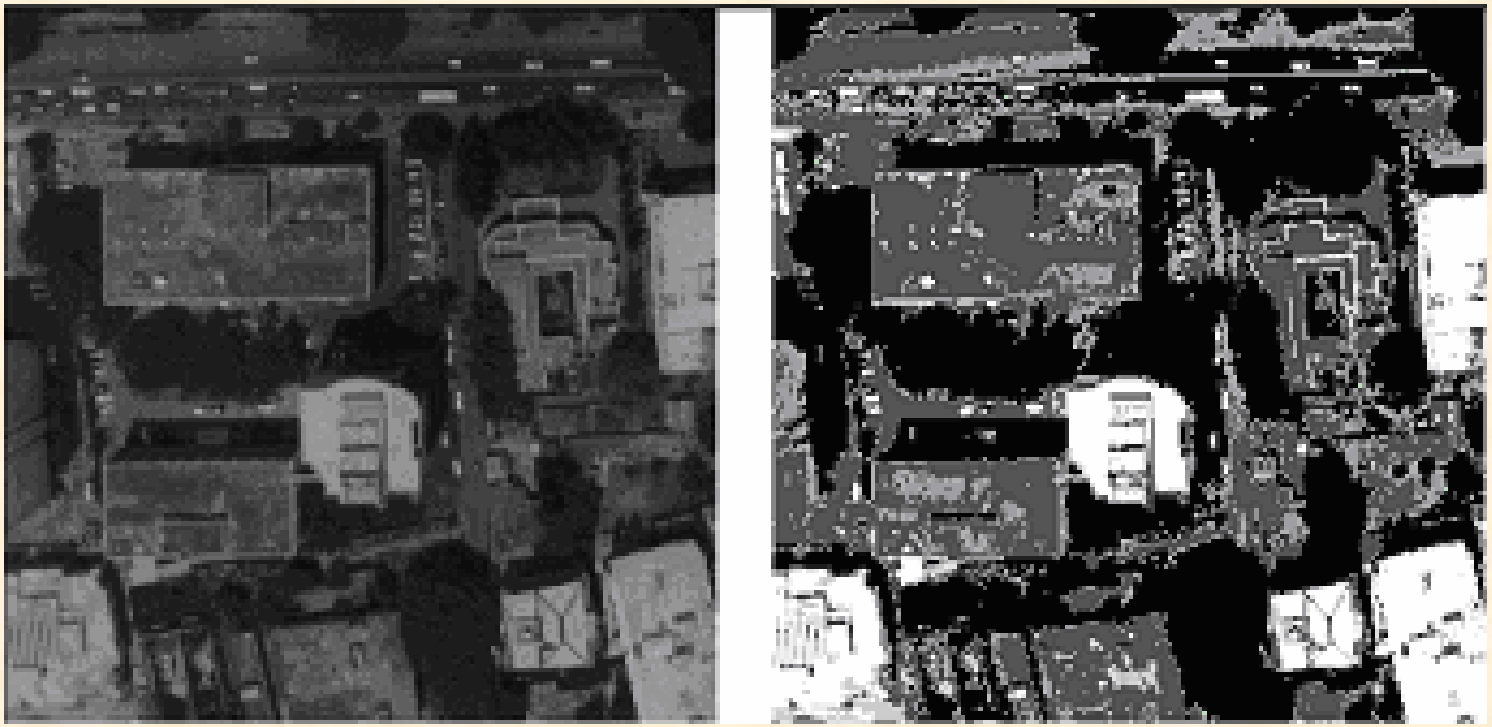
For example, given the histogram of a two-dimensional medical image I(x,y) , we can define a simple threshold rule to classify bony and fat tissues or a compound threshold rule to classify muscle tissue:

If, I(x,y) > T1 => Bony

If, I(x,y) < T0 => Fat

If, T0 < I(x,y) < T1 => 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

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,….,N. which satisfy the following conditions:

$$R = \bigcup_{i=1}^{N} R_i; R_1 \bigcap R_j = \Phi, i \neq j$$

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

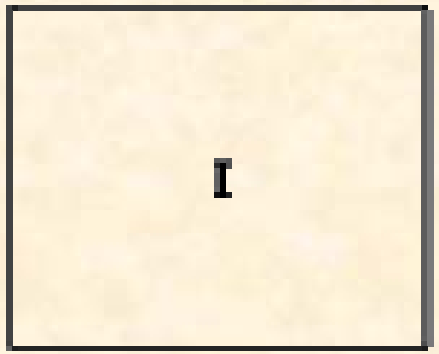
When, R_i and R_j are adjacent: $H(R_i \bigcup R_j) = False, i \neq j;$

Region Splitting

The basic idea of region splitting is to break the image into a set of disjoint regions, which are coherent within themselves:

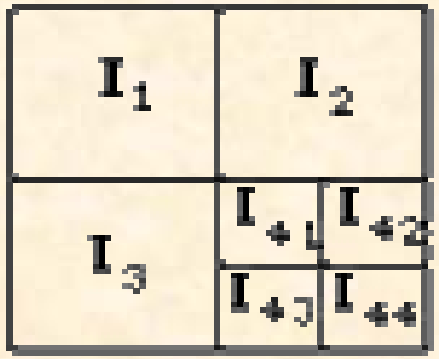
- **Initially take the image as a whole to be the area of interest.**
- **Look at the area of interest and decide if all pixels contained in the region satisfy some *similarity constraint*.**
- **If TRUE then the area of interest corresponds to an entire region in the image.**
- **If FALSE split the area of interest (usually into four equal sub-areas) and consider each of the sub-areas as the area of interest in turn.**
- **This process continues until no further splitting occurs. In the worst case this happens when the areas are just one pixel in size.**

This is a *divide and conquer* or *top down* method.

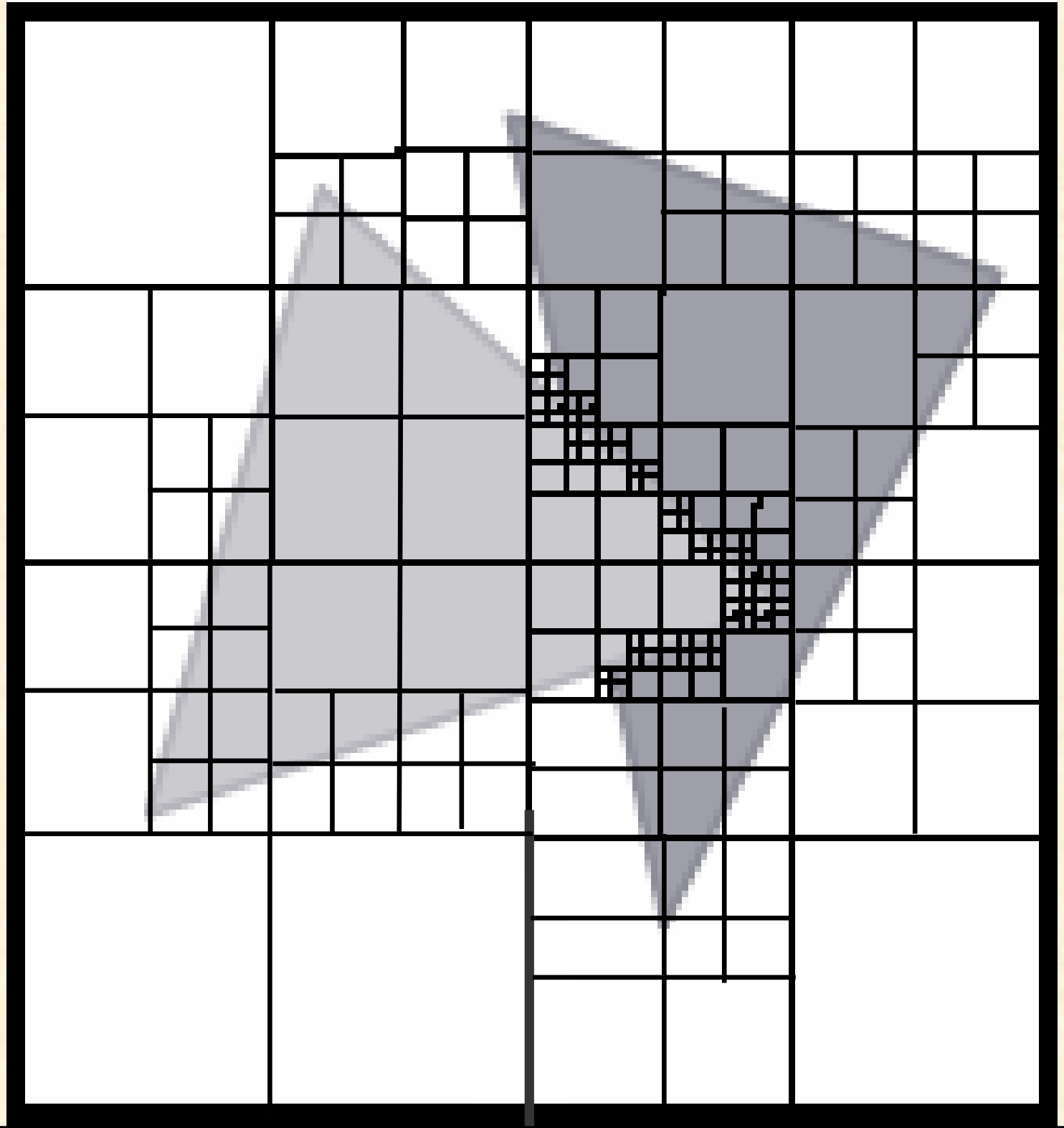


(a) Whole Image

(b) First Split



(c) Second Split



If only a splitting schedule is used then the final segmentation would probably contain many neighboring regions that have identical or similar properties. We need to merge these regions.

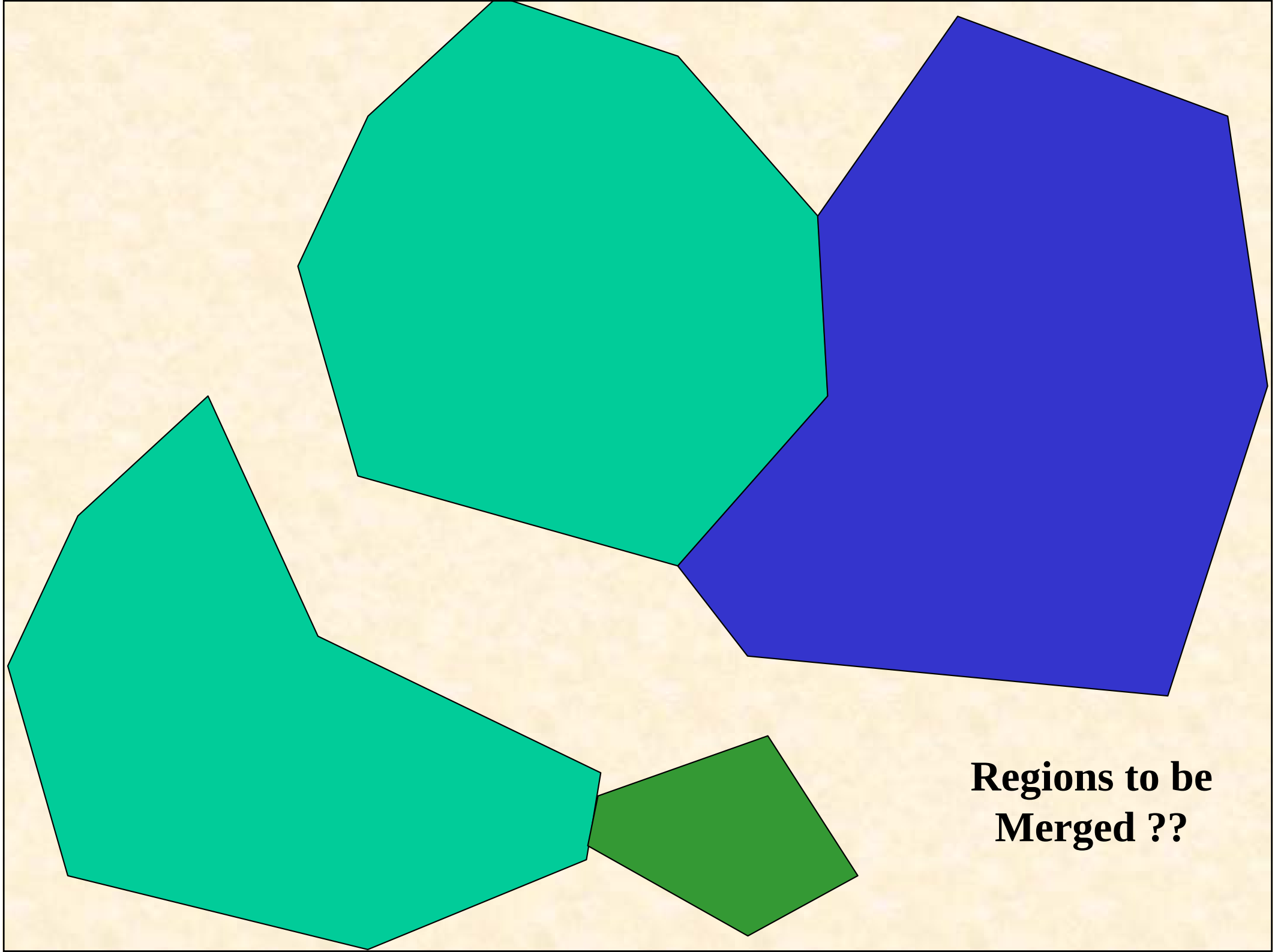
Region Merging

The result of region merging usually depends on the order in which regions are merged. The simplest methods begin merging by starting the segmentation using regions of 2x2, 4x4 or 8x8 pixels.

Region descriptions are then based on their statistical gray level properties.

A region description is compared with the description of an adjacent region; if they match, they are merged into a larger region and a new region description is computed. Otherwise regions are marked as non-matching.

Merging of adjacent regions continues between all neighbors, including newly formed ones. If a region cannot be merged with any of its neighbors, it is marked `final' and the merging process stops when all image regions are so marked.


Regions to be
Merged ??

Merging heuristics:

- **Two adjacent regions are merged if a significant part of their common boundary consists of weak edges**

- **Two adjacent regions are also merged if a significant part of their common boundary consists of weak edges, but in this case not considering the total length of the region borders.**

Of the two given heuristics, the first is more general and the second cannot be used alone because it does not consider the influence of different region sizes.

Region merging process could start by considering

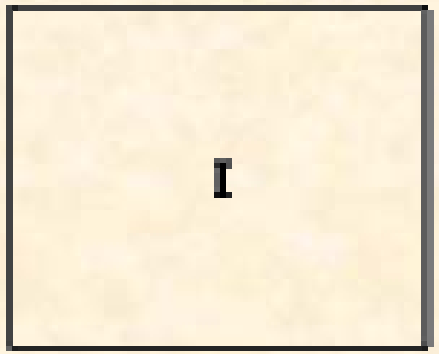
- **small segments (2*2,…,8*8) selected a priori from the image**
- **segments generated by thresholding**
- **regions generated by a region splitting module**

The last case is called as “Split and Merge” method. Region merging methods generally use similar criteria of homogeneity as region splitting methods, and only differ in the direction of their application.

SPLIT and MERGE

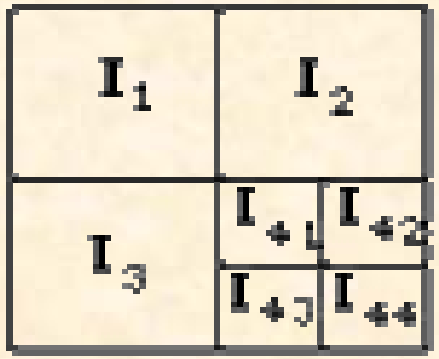
To illustrate the basic principle of split and merge methods, let us consider an imaginary image.

- **Let I denote the whole image shown in Fig. (a) (see next page).**
- **Not all the pixels in Fig (a) are similar. So the region is split as in Fig. (b).**
- **Assume that all pixels within each of the regions I_1, I_2 and I_3 are similar, but those in I_4 are not.**
- **Therefore I_4 is split next, as shown in Fig. (c).**
- **Now assume that all pixels within each region are similar with respect to that region, and that after comparing the split regions, regions I_{43} and I_{44} are found to be identical.**
- **These pair of regions is thus merged together, as in shown in Fig. (d).**



(a) Whole Image

(b) First Split



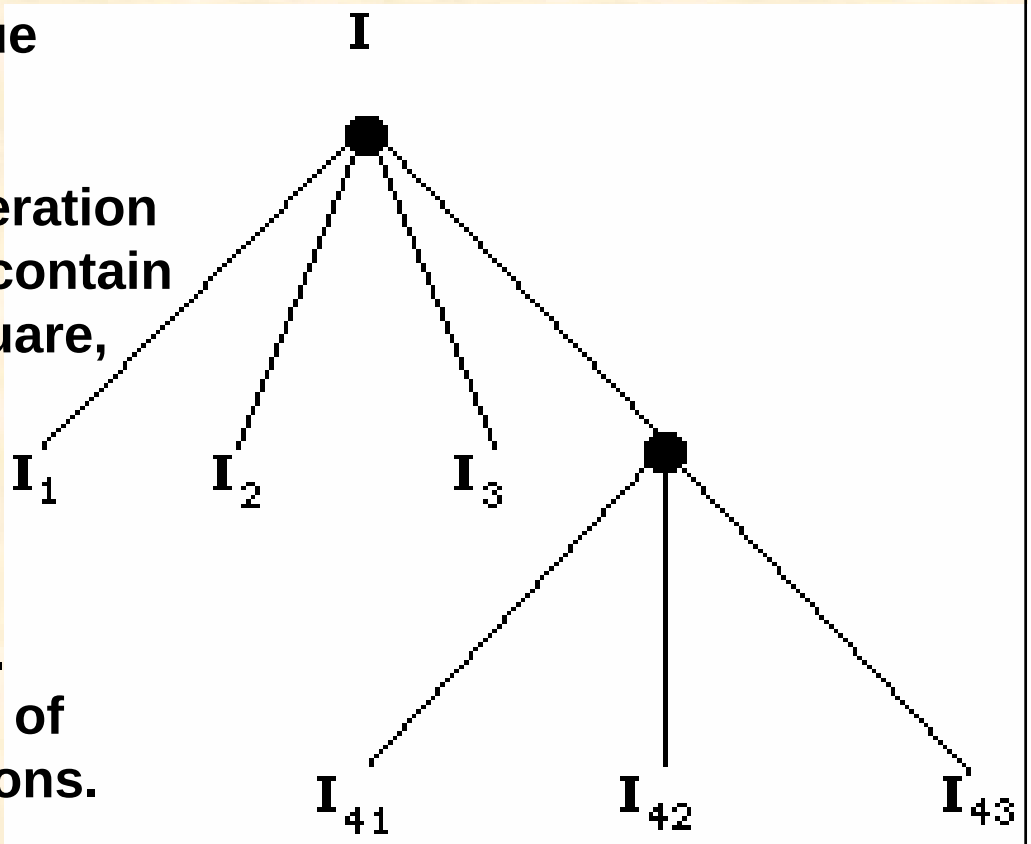
(c) Second Split

A combination of splitting and merging may result in a method with the advantages of both the approaches. Split-and-merge approaches work using pyramid image representations. Regions are square-shaped and correspond to elements of the appropriate pyramid level.

If any region in any pyramid level is not homogeneous (excluding the lowest level), it is split into four sub-regions -- these are elements of higher resolution at the level below. If four regions exist at any pyramid level with approximately the same value of homogeneity measure, they are merged into a single region in an upper pyramid level.

We can also describe the splitting of the image using a tree structure, called a modified *quadtree*. Each non-terminal node in the tree has at most four descendants, although it may have less due to merging.

Quadtree decomposition is an operation that subdivides an image into blocks that contain "similar" pixels. Usually the blocks are square, although sometimes they may be rectangular. For the purpose of this demo, pixels in a block are said to be "similar" if the range of pixel values in the block are not greater than some threshold. Quadtree decomposition is used in variety of image analysis and compression applications.



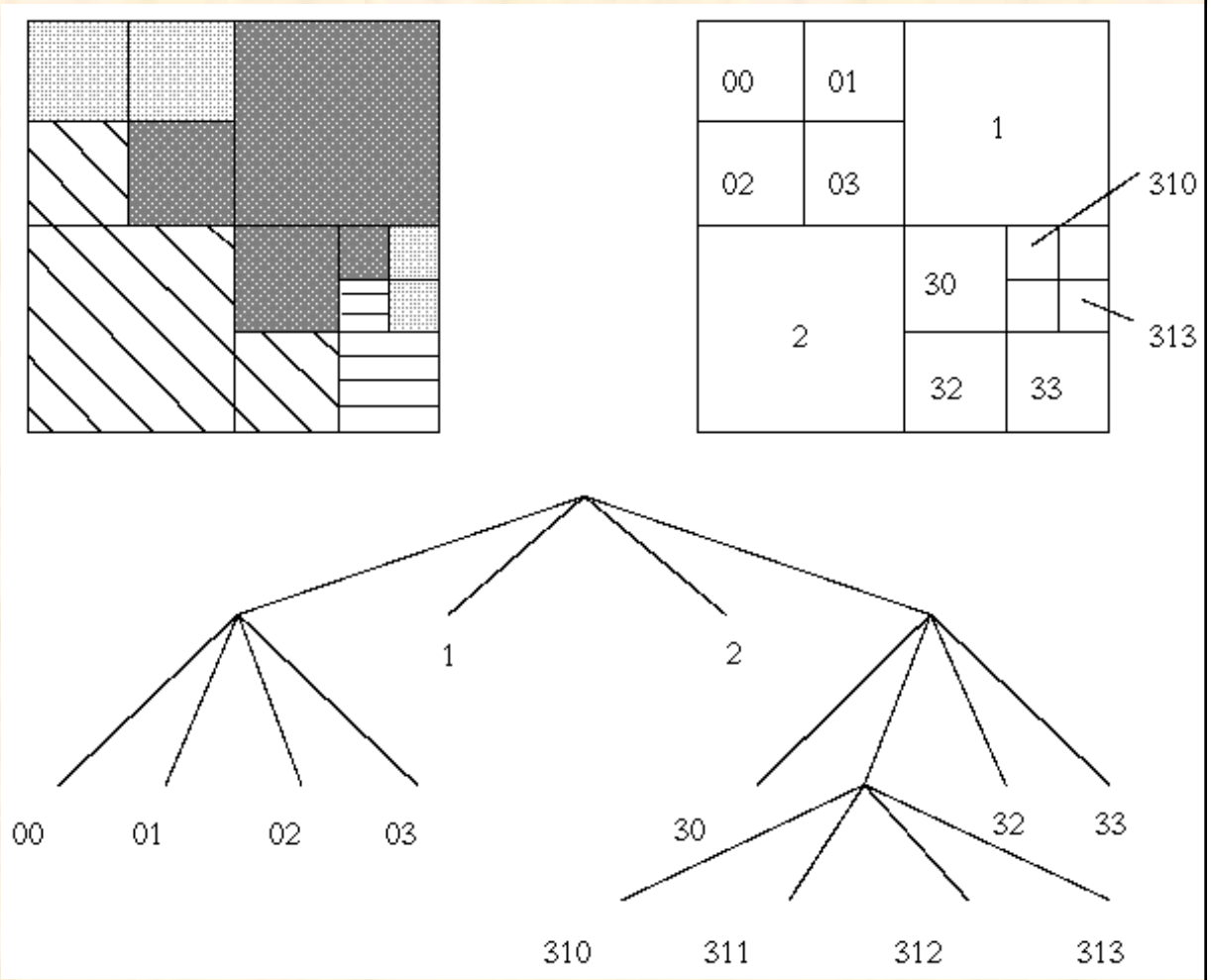
An unpleasant drawback of segmentation quadtrees, is the square region shape assumption.

It is not possible to merge regions which are not part of the same branch of the segmentation tree.

Because both split-and-merge processing options are available, the starting segmentation does not have to satisfy any of the homogeneity conditions.

The segmentation process can be understood as the construction of a segmentation quadtree where each leaf node represents a homogeneous region.

Splitting and merging corresponds to removing or building parts of the segmentation quadtree.

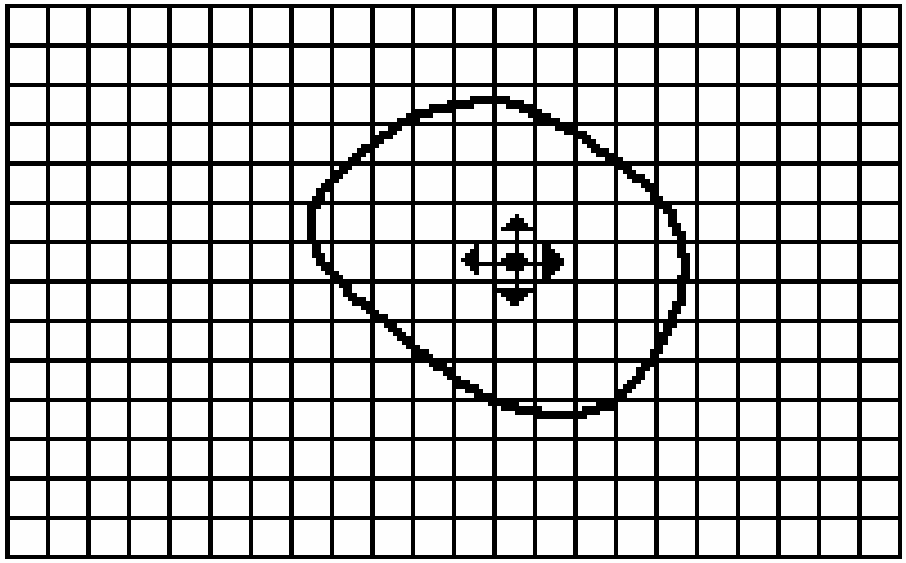


Region Growing

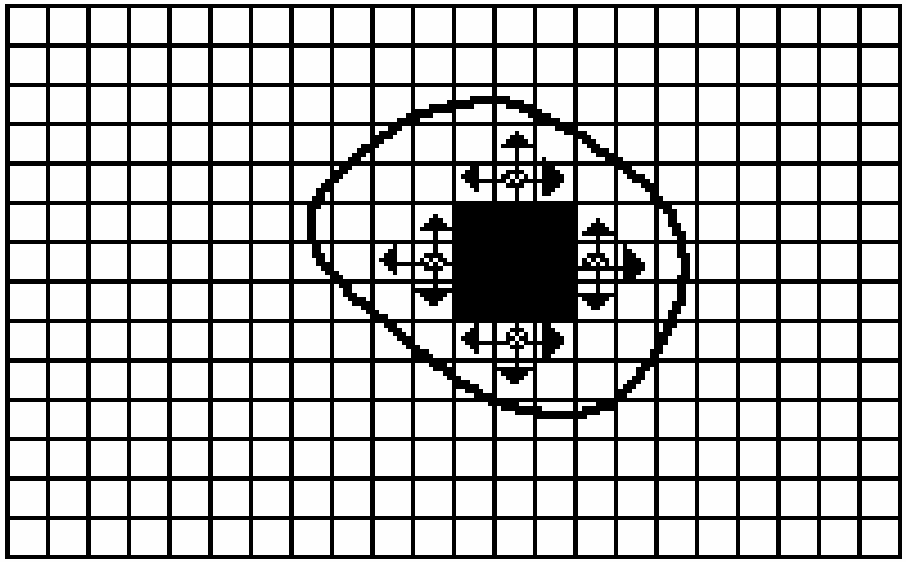
Region growing approach is the opposite of the split and merge approach:

- **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.



(a) Start of Growing a Region



(b) Growing Process After a Few Iterations

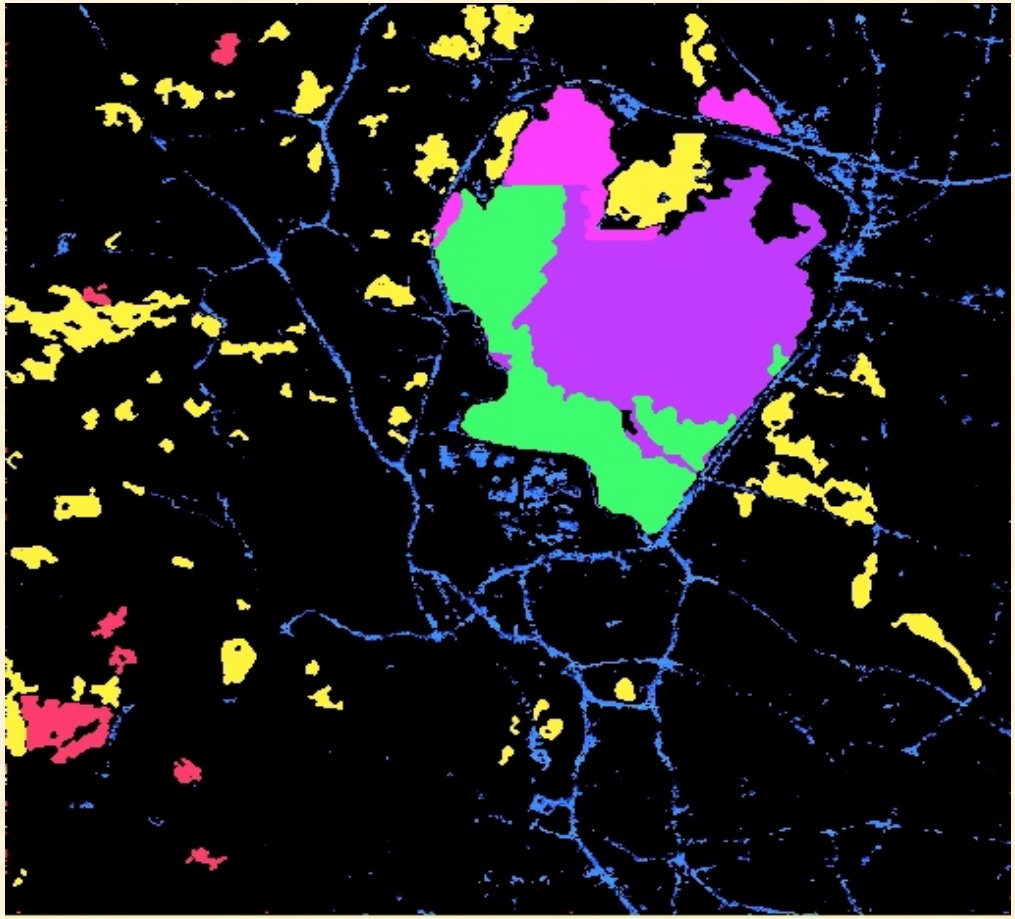
However starting with a particular seed pixel and letting this region grow completely before trying other seeds biases the segmentation in favour of the regions which are segmented first.

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.**



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


original image


original image

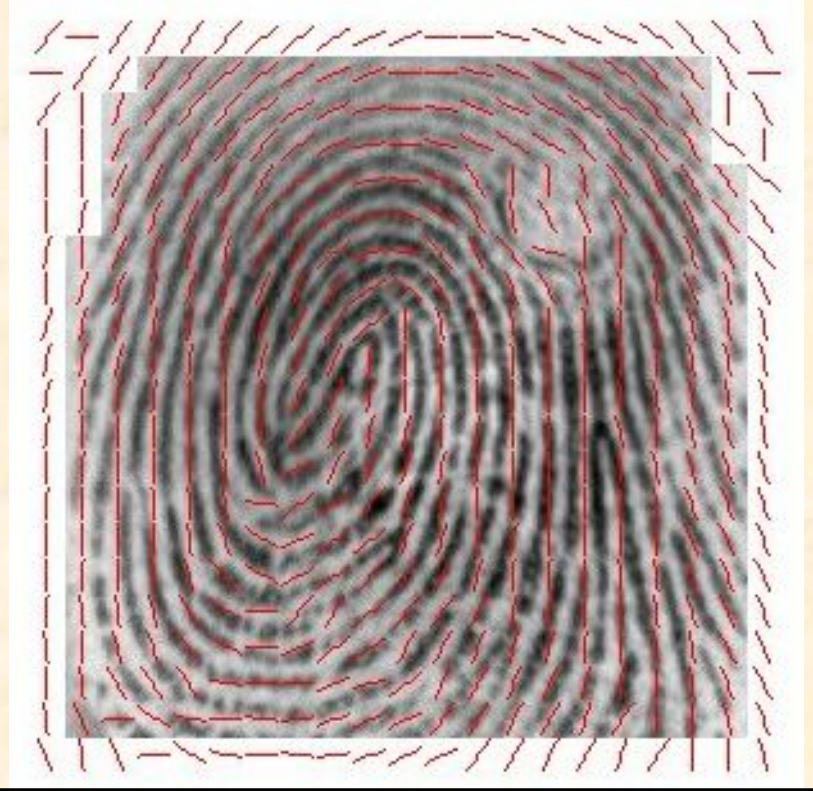
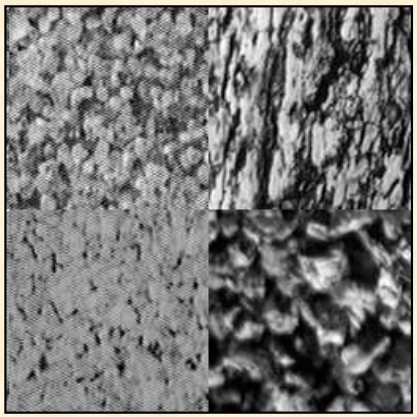


Image Segmentation - Combining edge and region information

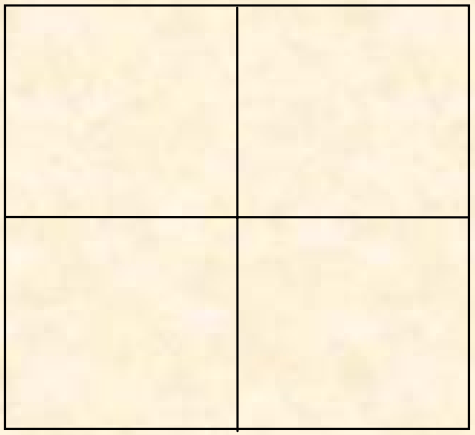
Example of Image Segmentation (ideal) based on fusion

Input Image



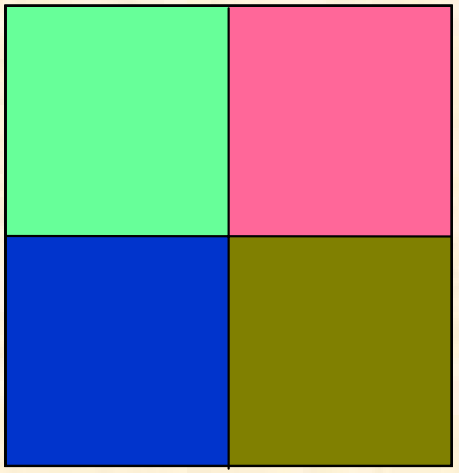
Region Based Segmentation

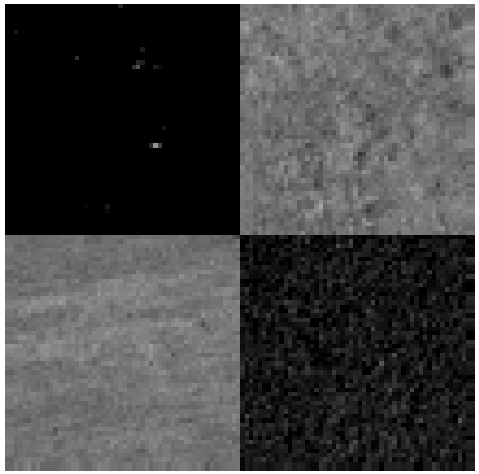
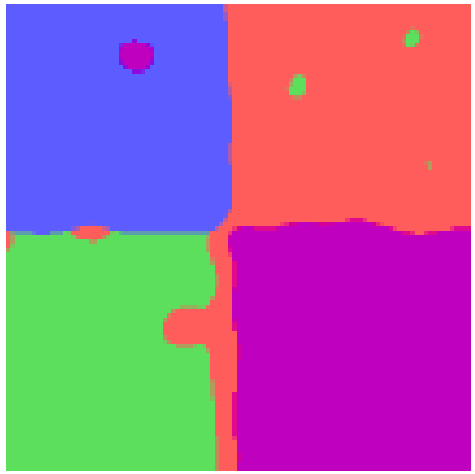
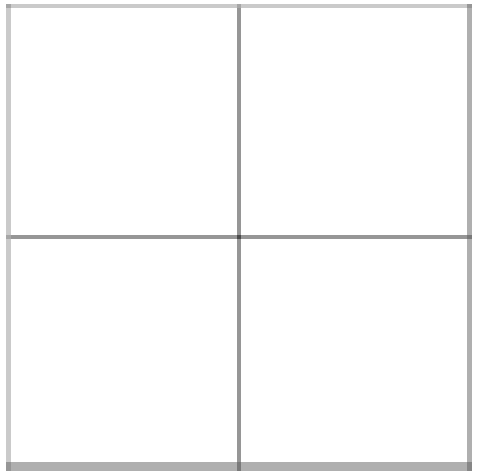
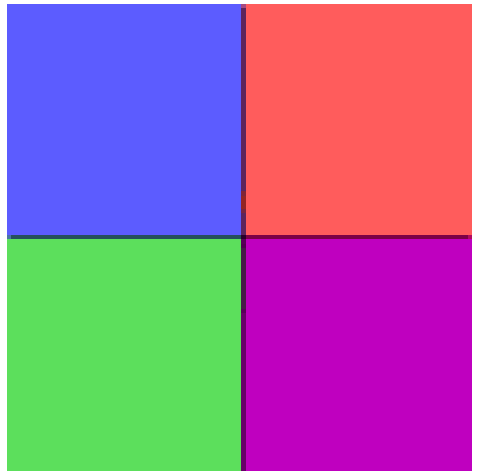
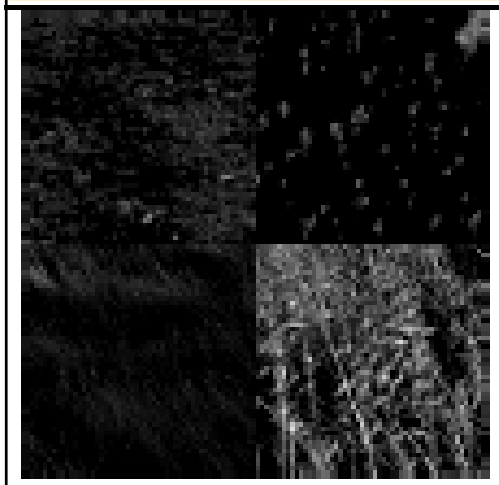
Edge Detection (ideal)

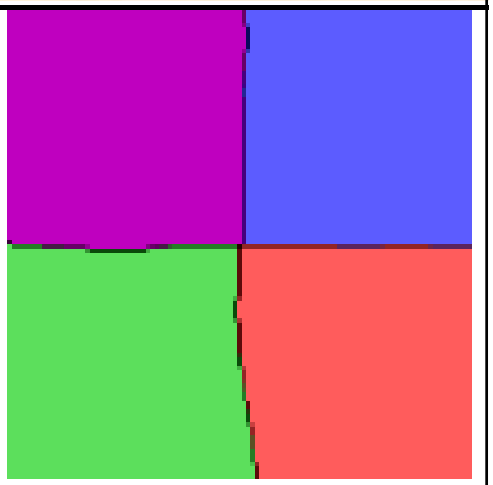


Output segmented Image

(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**

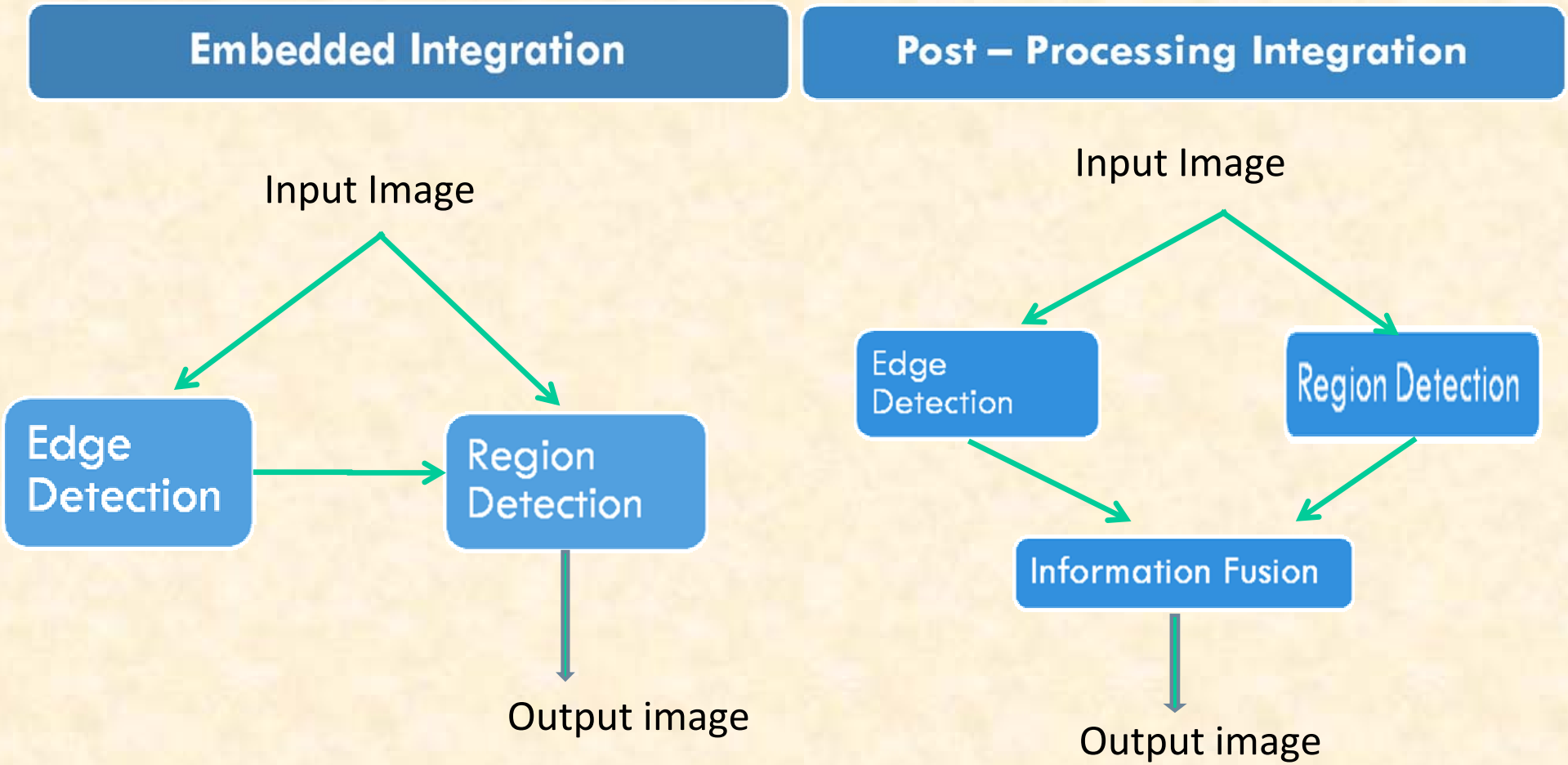
Integration Techniques

- 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



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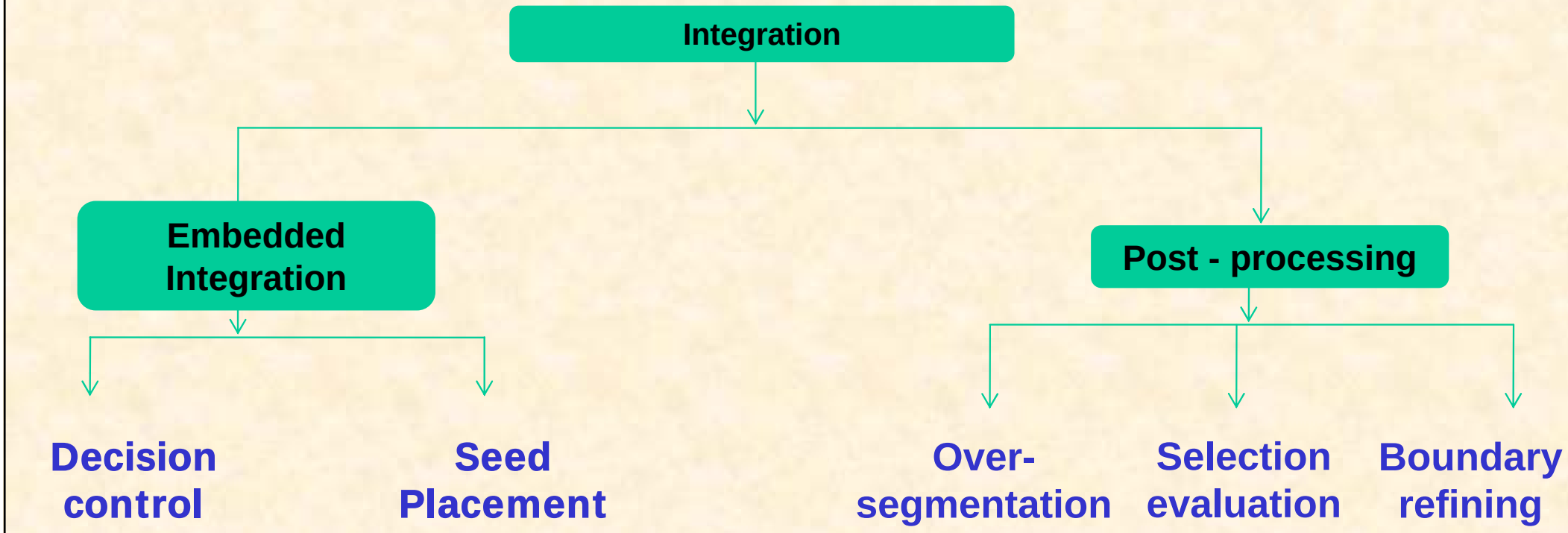
Integration Techniques



- 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

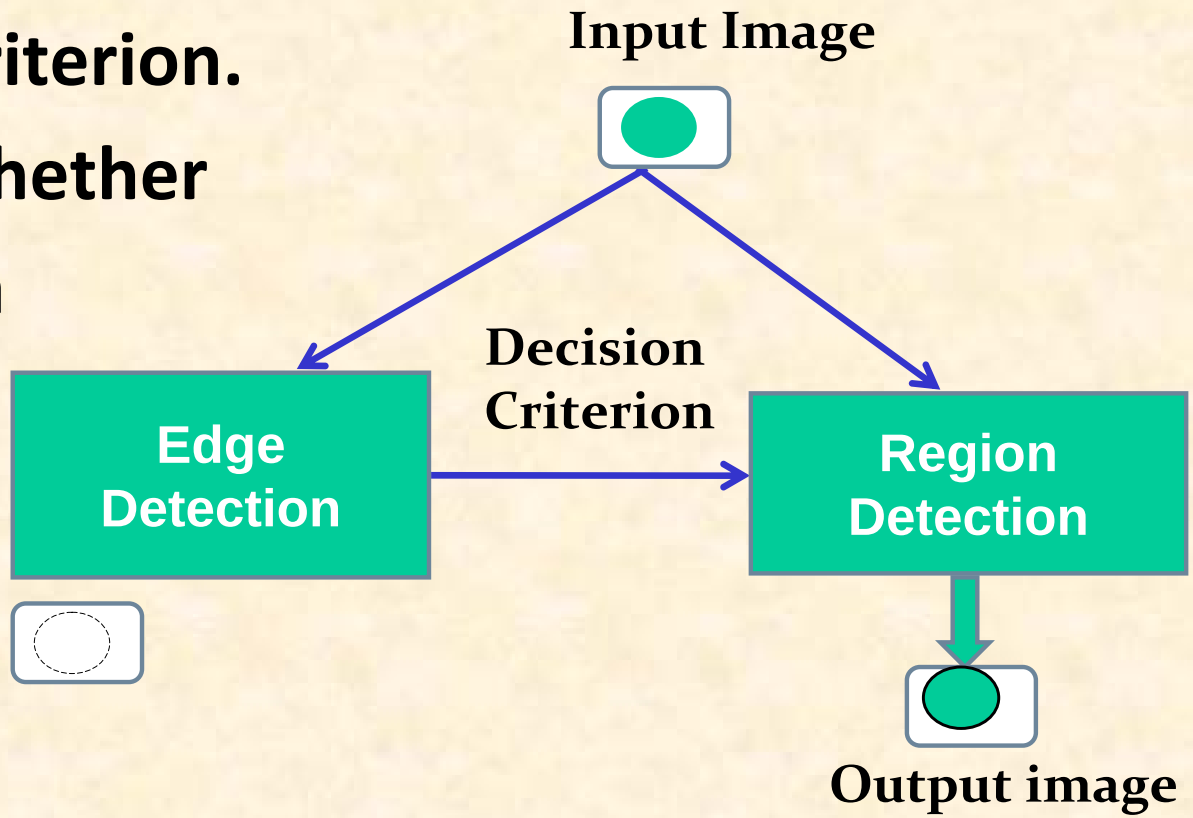
1. ***Control of decision criterion -*** edge information is included in the definition of decision criterion which controls the growth of the region.

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.

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

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

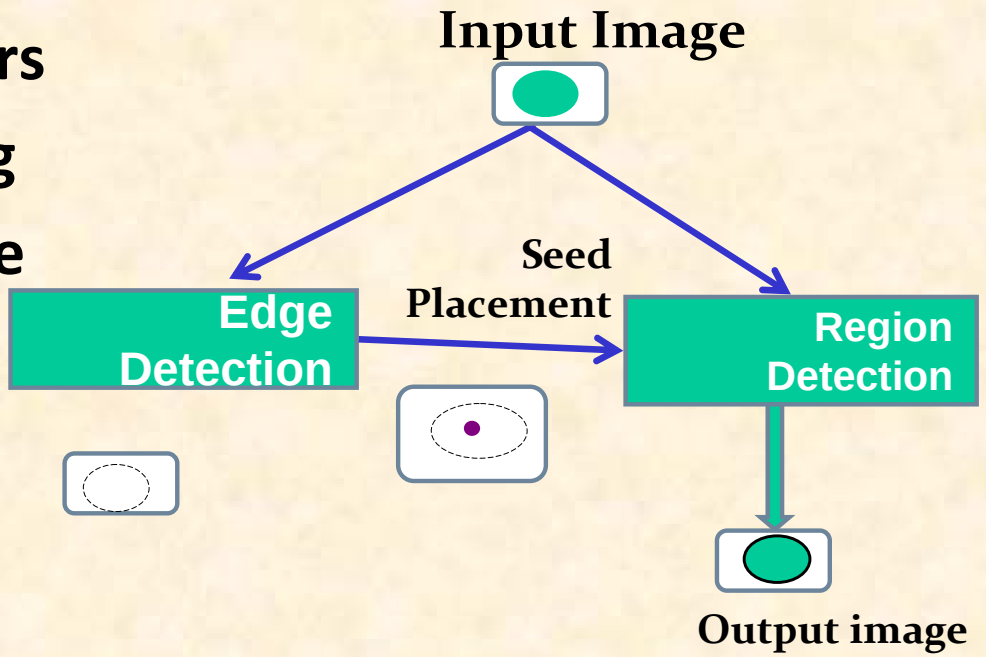


X. Munoz, J.freixenet, X. Cufi, J. Marti,
Strategies for image segmentation combining region and boundary information, Pattern Recognition Letters 24 (2003).

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.

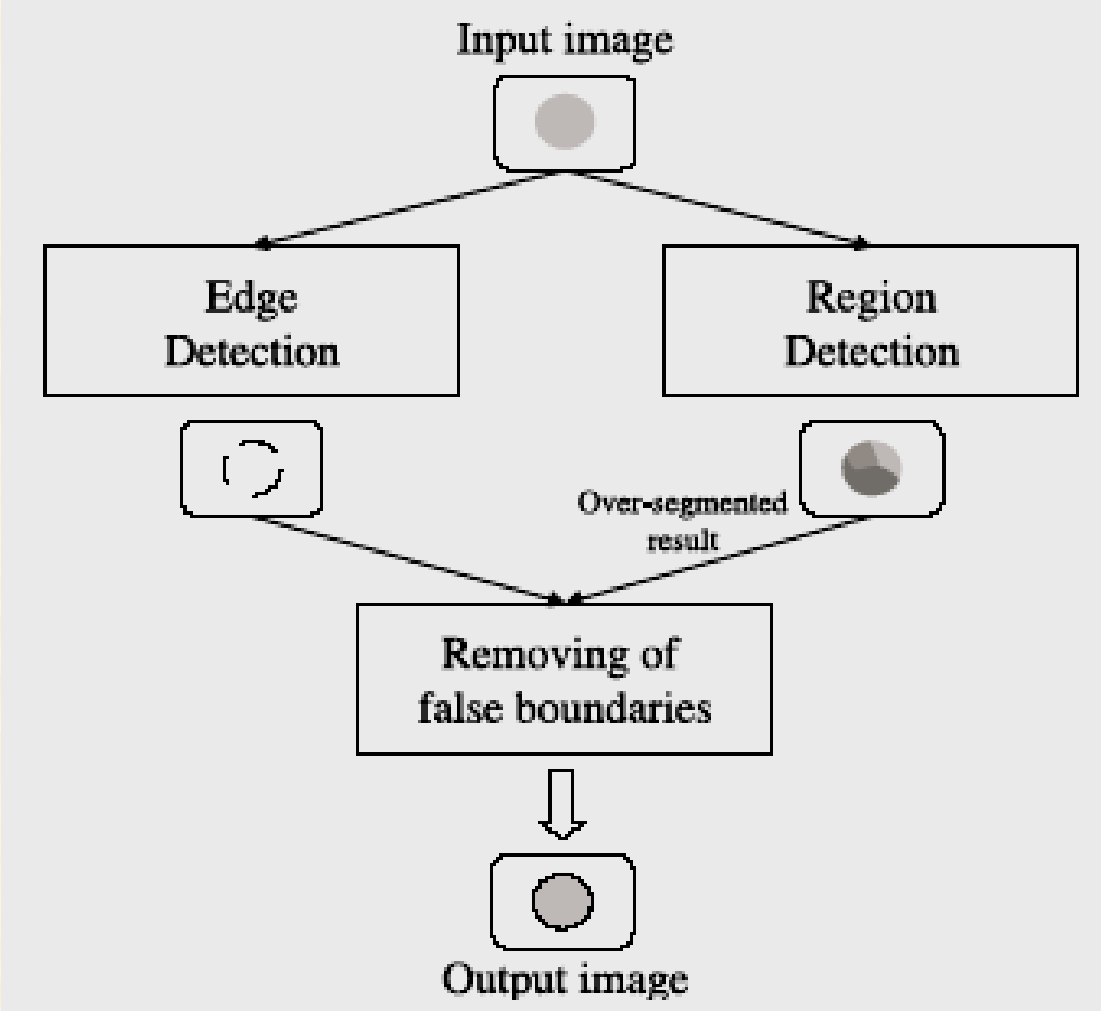
- Three different approaches

  (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.**

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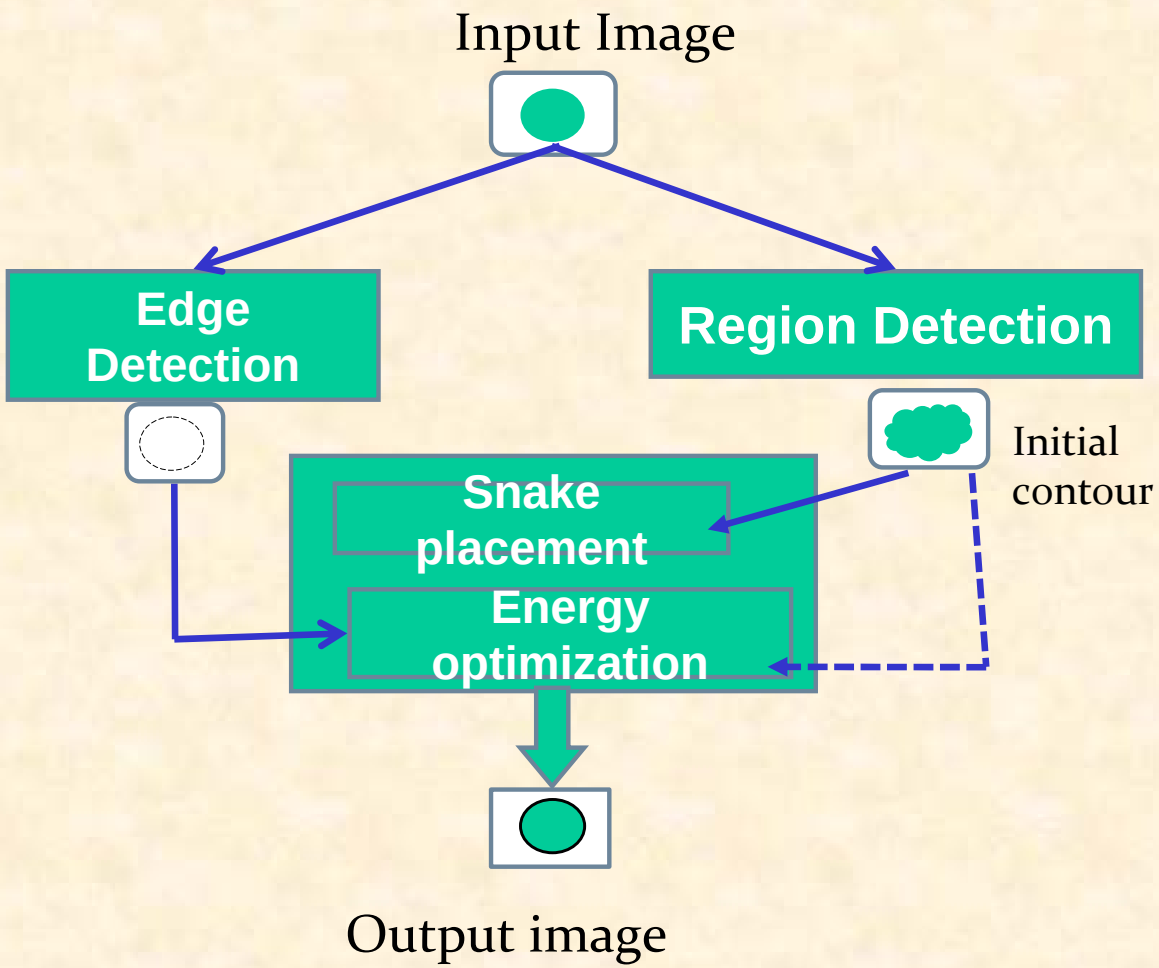
Strategies for image segmentation combining region and boundary information, Pattern Recognition Letters 24 (2003).

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**

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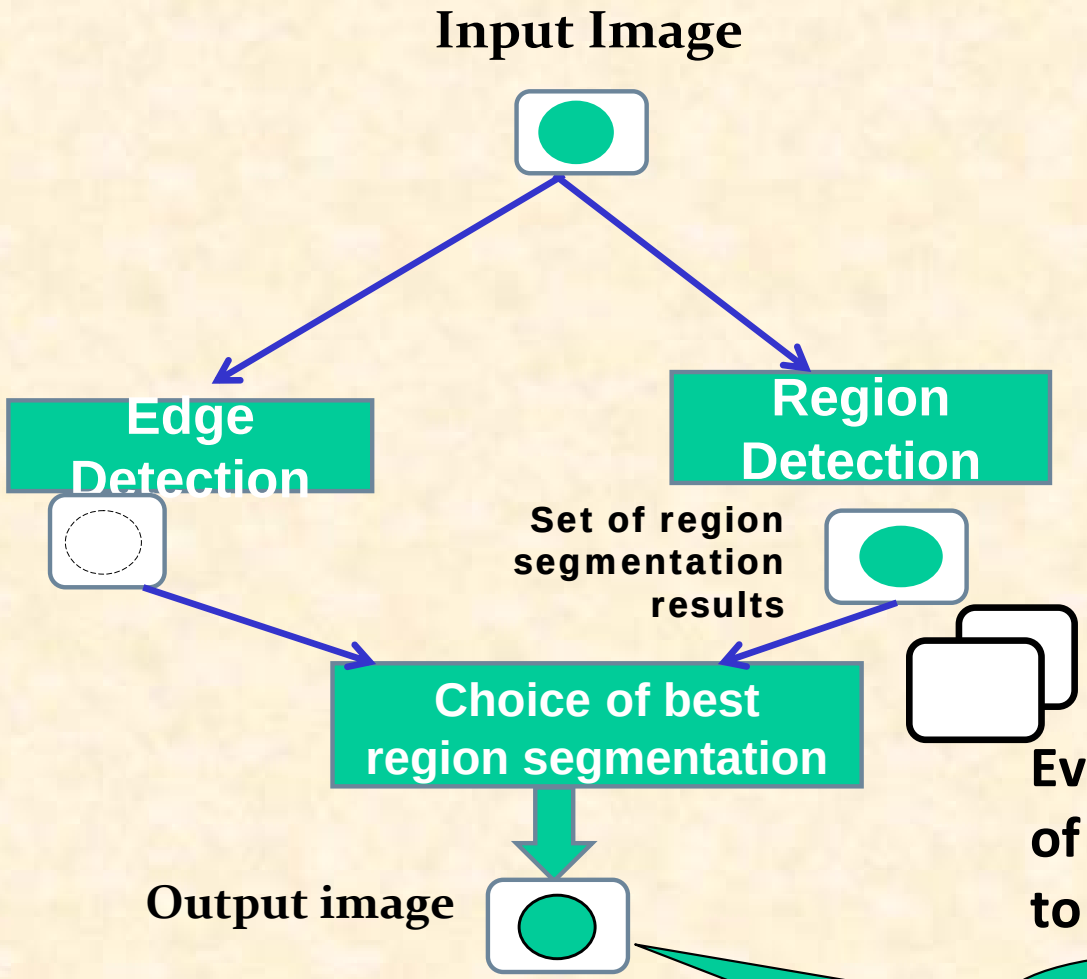
Selection- evaluation



- 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

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Modern methods for Image segmentation involve:

- **Multi-resolution and multi-channel features**
- **Feature fusion techniques**
- **Multi-classifier decision combination**
- **HMM, GMM, CRF- and GMRF-based techniques**
- **Artificial Neural Networks – SVM and FFNN**
- **Neuro-fuzzy and soft-computing (SA) techniques**
- **Active contours, watershed transform**
- **Decision Trees and hierarchical analysis**
- **Probabilistic approaches**
-