Pattern Recognition and Classification

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Pattern/Object Recognition/ Detection

- Locate the presence of objects with a bounding box and types or classes of the located objects in an image.
  - Input: An image with one or more objects, such as a brain Tumor.
  - Output: One or more bounding boxes (e.g. defined by a point, width, and height), and a class label for each bounding box.

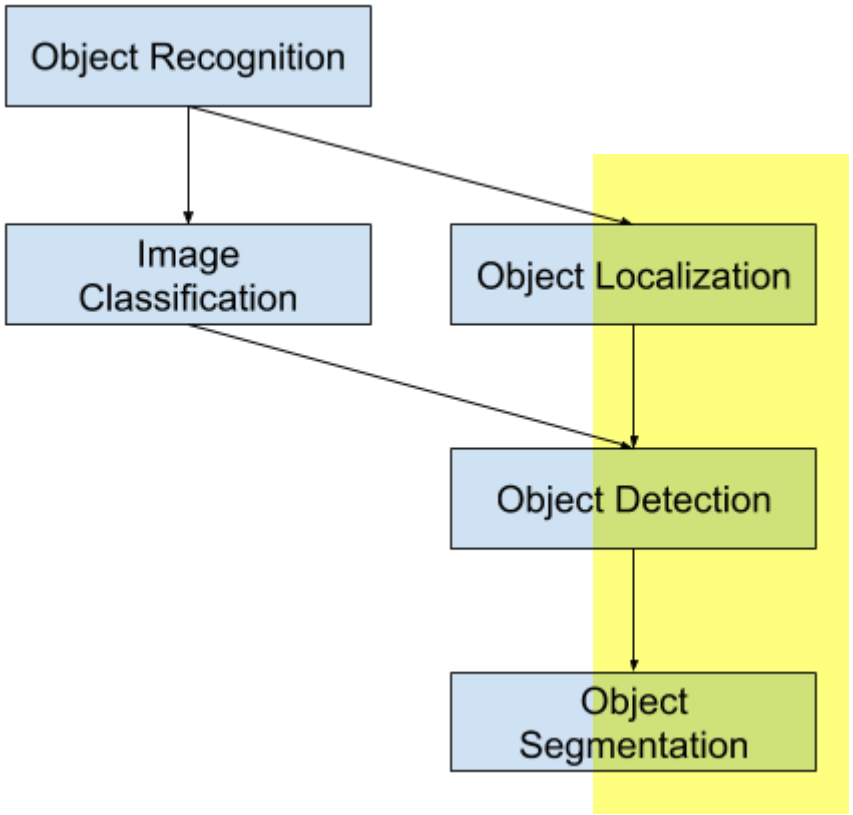
Pattern/Object Classification

- Predict the type or class of an object in an image.
  - Input: An image with a single object, such as a Tumor (Benign, Malignant).
  - Output: A class label (e.g. one or more integers that are mapped to class labels).

Applications

- Brain Tumor detection/Classification from MRI/CT
- Pneumonia Detection from X-rays/CT
- COVID-19 Detection from X-rays/CT
- etc.

Object Recognition overview



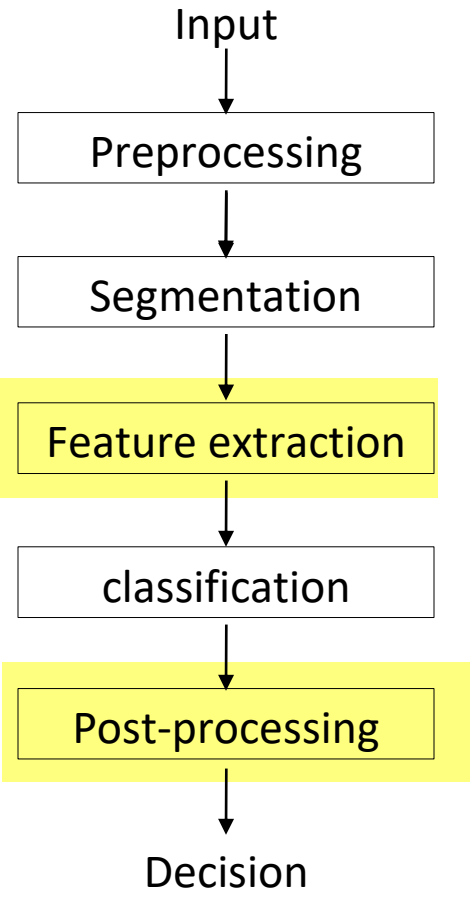
Pattern Recognition Systems

- Preprocessing
- Clustering and Segmentation
- Feature extraction and Reduction
- Classification

Diagram of a pattern recognition/ Classification system

Main steps

- Preprocessing
- Segmentation
- Feature extraction
- Classification
- Post processing



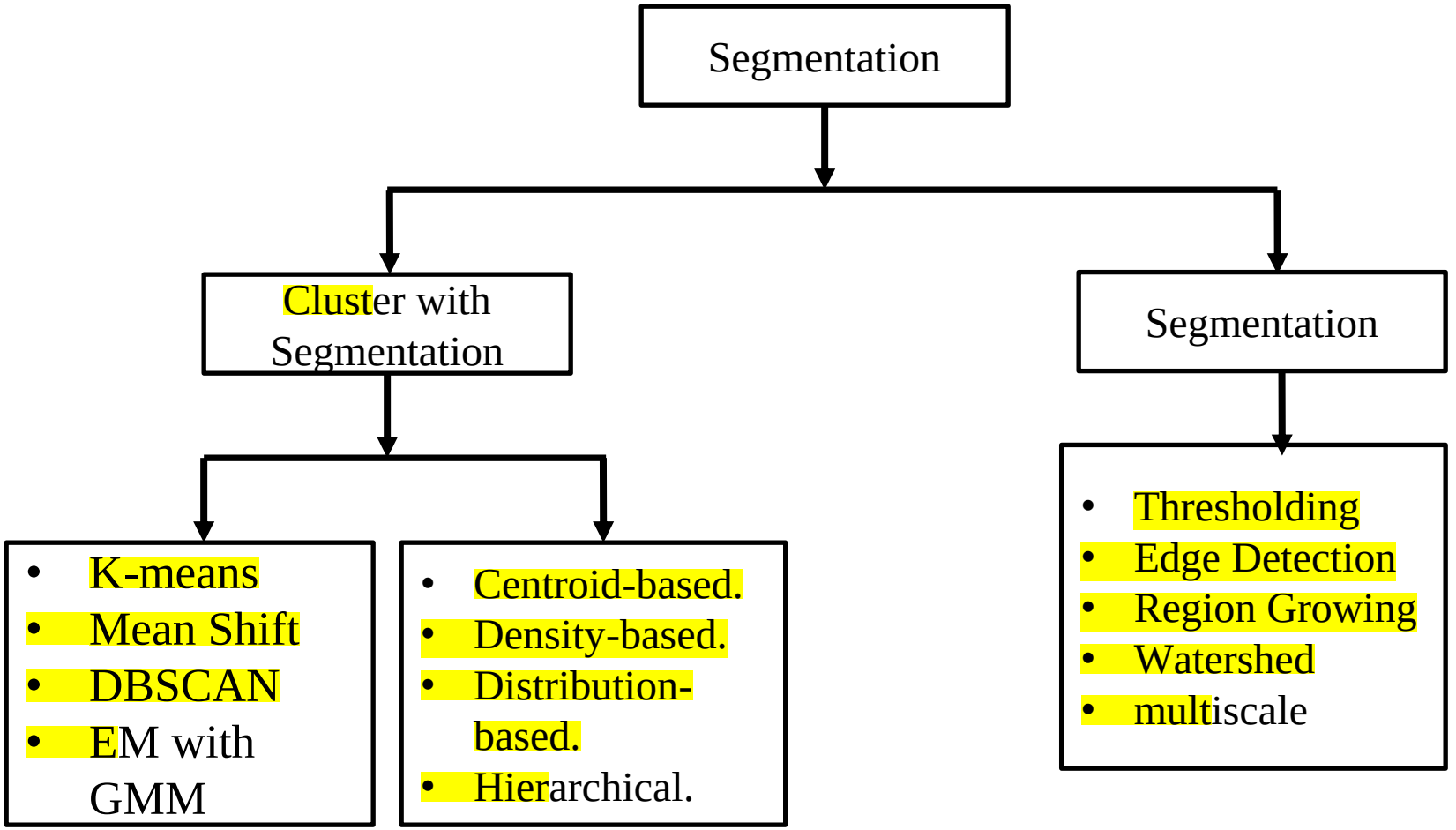
Preprocessing

- Outlier removal
  - A point that lies very far from the mean of the corresponding random variable.
- Data normalization
  - Normalizing via the respective estimates of the mean and variance.
  - Linear technique that limits the range of [0, 1] or [-1, 1]
  - Softmax scaling
- Object Smoothing

Preprocessing

- Object Smoothing
  - Filtering (Gaussian, Median, Mean filtering, etc.)
- Object Resizing

Segmentation



Feature Extraction

- Feature Extraction
  - **Wavelet Transform**
  - **Histogram of Oriented Gradients**
  - Scale invariant feature transform
  - **Hough Transform**
- Feature Reduction
  - **Independent Component Analysis (ICA)**
  - **Principal Component Analysis (PCA)**
  - Kernel PCA

Classification

- Supervised Classification
- Unsupervised Classification
- Object Based Analysis
- Nearest Neighbor Classification
- Support Vector Machine (SVM)
- **Kernel SVM**
- **Deep Learning**

Detection and Classification

Segmentation + Feature Extraction + Classification:

- Neural Network (NN)
- **Convolutional Neural Network (CNN)**
- **Recurrent Neural Network (RNN)**
- Feedforward Neural Network (FNN)
- R-CNN
- Fast R-CNN
- CNN-LSTM
- GAN-CNN

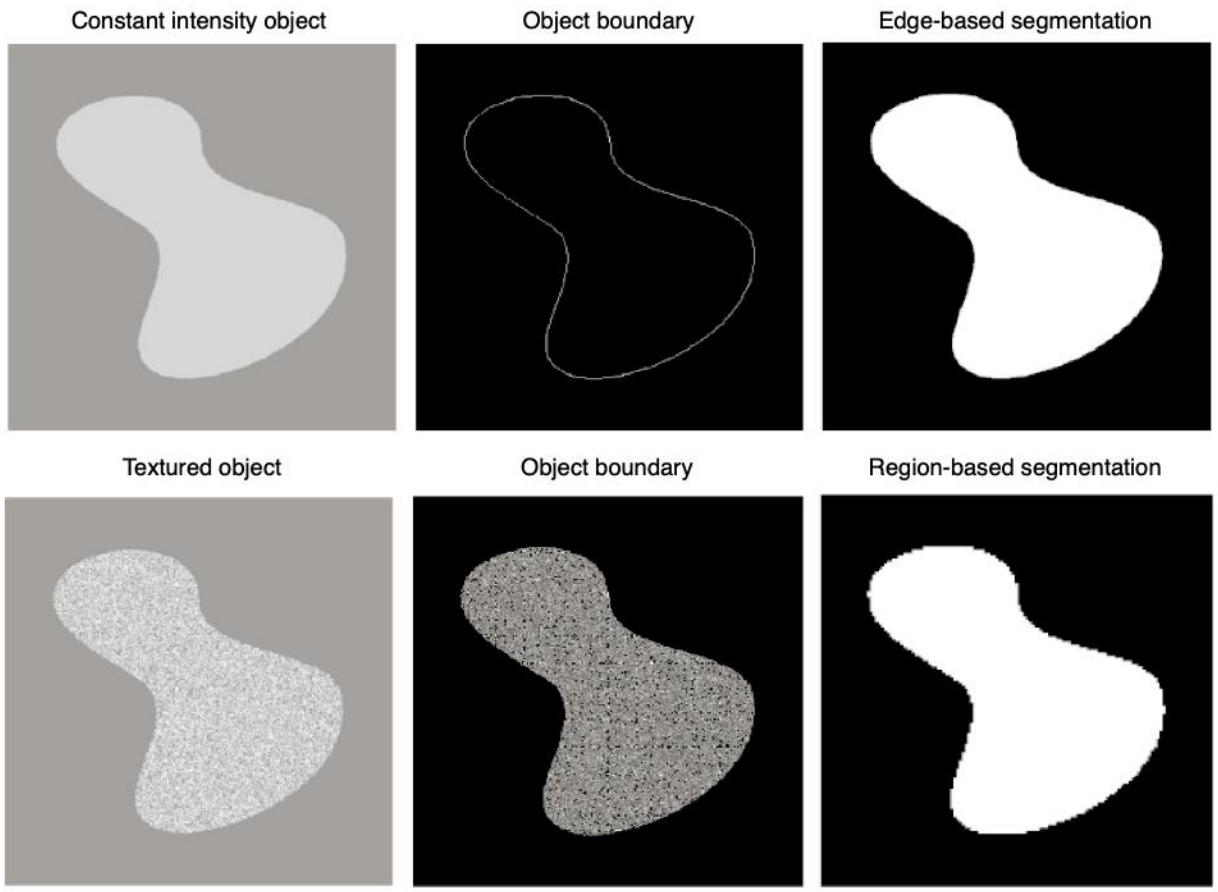
Image Segmentation

- Segmentation divides an image into its constituent regions or objects.
- Segmentation of images is a difficult task in image processing. Still under research.
- Segmentation allows to extract objects in images.

What it is useful for

- After a successful segmenting the image, the contours of objects can be extracted using edge detection and/or border techniques.
- Shape of objects can be described.
- Based on shape, texture, and color objects can be identified.
- Image segmentation techniques are extensively used in similarity searches.

Image Segmentation Example



Applications

- 3D – Imaging : A basic task in 3-D image processing is the segmentation of an image which classifies voxels/pixels into objects or groups.
- 3-D image segmentation makes it possible to create 3-D rendering for multiple objects and perform quantitative analysis for the size, density and other parameters of detected objects.
- Several applications in the field of Medicine like magnetic resonance imaging (MRI), CT.

Segmentation Algorithms

- Segmentation algorithms are based on one of two basic properties of color, gray values, or texture: discontinuity and similarity.
- First category is to partition an image based on abrupt changes in intensity, such as edges in an image.
- Second category are based on partitioning an image into regions that are similar according to a predefined criteria. Histogram thresholding approach falls under this category.

Segmentation Algorithms

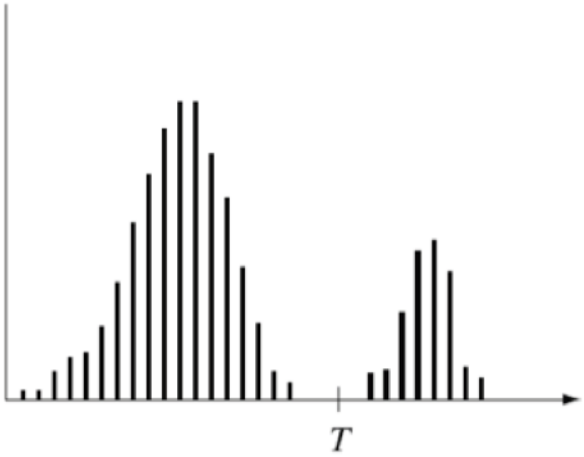
- Grey-Level Segmentation
  - Thresholding with a single threshold
  - Thresholding with a pair of thresholds

Grey-Level Segmentation

- Thresholding with a single threshold
- Grey-level thresholding applies to every pixel by the rule:

$$g(x,y) = \begin{cases} 0, f(x,y) < T \\ 1, f(x,y) \geq T \end{cases}$$

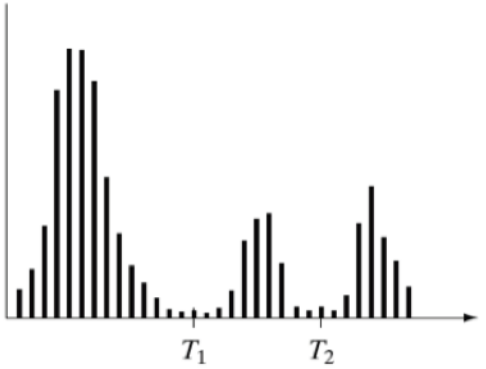
- Where T is the threshold value.



Grey-Level Segmentation

- Thresholding with a pair threshold
- Grey-level thresholding using a pair of threshold value applies to every pixel by the rule:

$$g(x,y) = \begin{cases} 0 & f(x,y) < T_1 \\ 1 & T_1 \le f(x,y) \le T_2 \\ 0 & f(x,y) > T_2 \end{cases}$$



- Where T_1 and T_2 are two threshold value that defines a range of acceptable grey levels.

Grey-Level Segmentation

- Optimal Thresholding (Iterative threshold determination)

1. Compute μ_1, themeangreylevelofthecornerpixels
2. Compute μ_2, themeangreylevelofallotherpixels
3. $T_{old} = 0$
4. $T_{new} = (\mu_1 + \mu_2)/2$
5. While $T_{new} \neq T_{old}$ do
   - *i.* $\mu_1 =$ meangreylevelofpixelsforwhich$f(x, y) < T_{new}$
   - *ii.* $\mu_2 =$ meangreylevelofpixelsforwhich$f(x, y) \geq T_{new}$
   - *iii.* $T_{old} = T_{new}$
   - *iv.* $T_{new} = (\mu_1 + \mu_2)/2$
6. End while

Other Segmentation method

- Edge-based
  - Point
  - Line
  - Edge detection
- Region-based
  - Seeded region growing
  - Unseeded region growing
  - Fast scanning

Edge-based segmentation

- There are three basic types of gray-level discontinuities in a digital image: points, lines, and edges
- The most common way to look for discontinuities is to run a mask through the image.
- We say that a point, line, and edge has been detected at the location on which the mask is centered if $|R| \geq T$, where

$$R = w_1 z_1 + w_2 z_2 + \ldots\ldots + w_9 z_9$$

w_1	w_2	w_3
w_4	w_5	w_6
w_7	w_8	w_9

- Point/edge detection

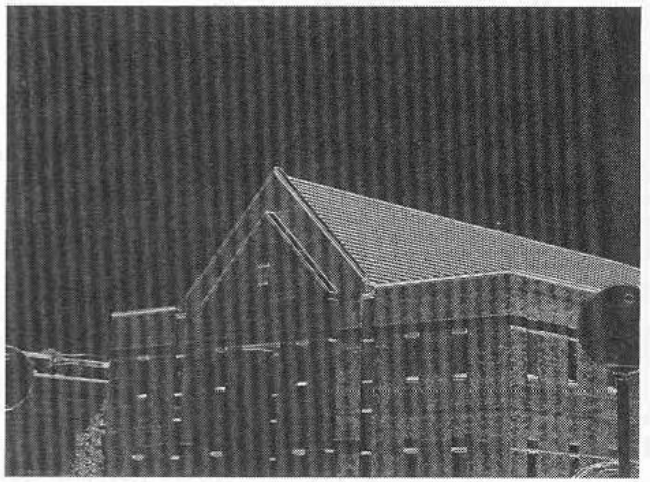
-1	-1	-1
-1	8	-1
-1	-1	-1

a point detection mask

- Line detection

-1	-1	-1
2	2	2
-1	-1	-1

a line detection mask



PREWITT KERNELS

-1	-1	-1
0	0	0
1	1	1

vertical

-1	0	1
-1	0	1
-1	0	1

horizontal

0	1	1
-1	0	1
-1	-1	0

diagonal

-1	-1	0
-1	0	1
0	1	1

diagonal

SOBEL KERNELS

-1	-2	-1
0	0	0
1	2	1

vertical

-1	0	1
-2	0	2
-1	0	1

horizontal

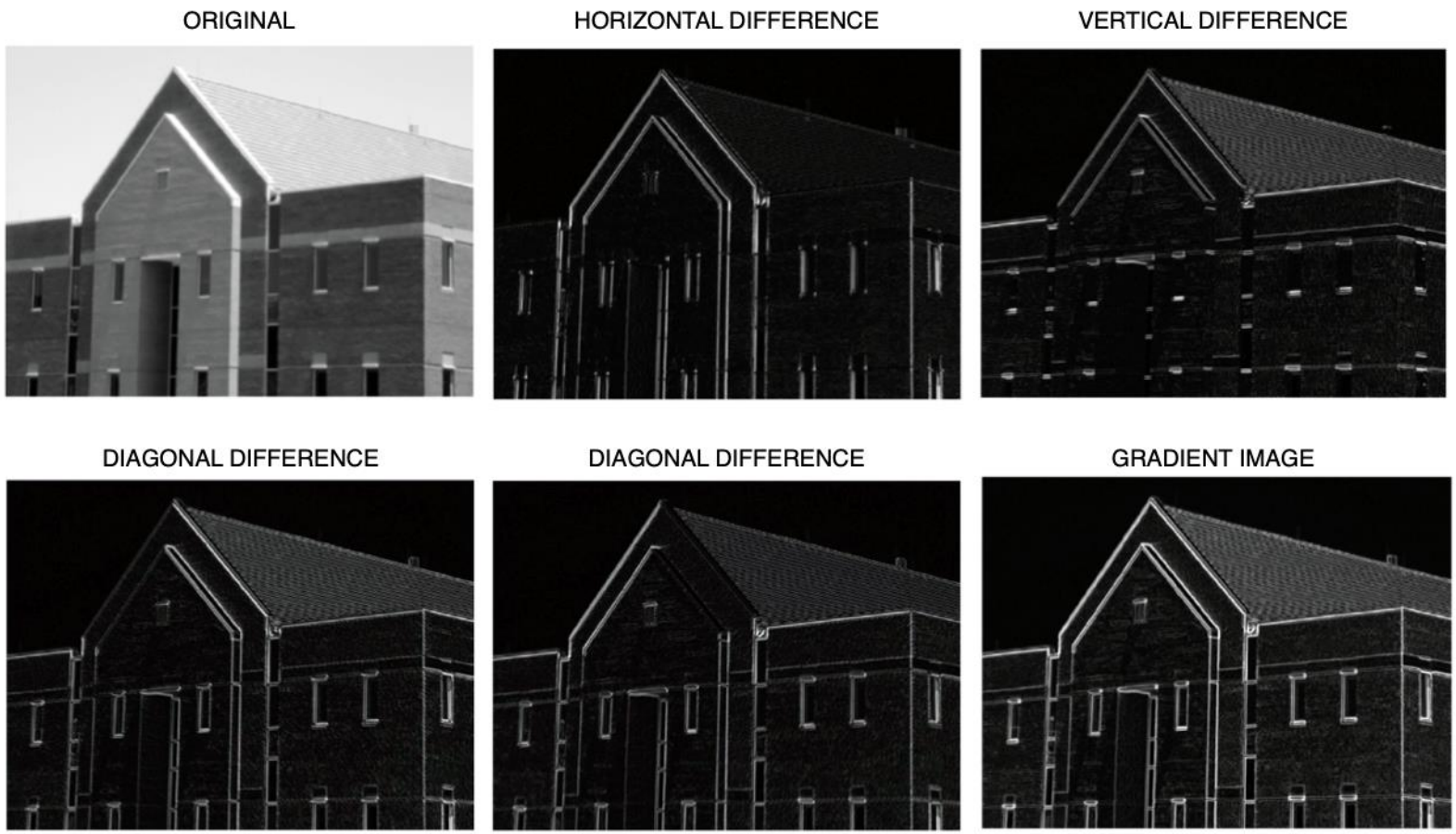
0	1	2
-1	0	1
-2	-1	0

diagonal

-2	-1	0
-1	0	1
0	1	2

diagonal

Edge-based segmentation



Canny Edge Detection

- Canny edge detection is a multi-step algorithm that can detect edges with noise suppressed at the same time.
  - Smooth the image with a Gaussian filter to reduce noise and unwanted details and textures.
  - Compute gradient of $g(m,n)$ using any of the gradient operations (Roberts, Sobel, Prewitt, etc) to get.
  - Thresholding

http://fourier.eng.hmc.edu/e161/lectures/canny/node1.html

Region-based segmentation

- Region-based segmentation is a technique for determining the region directly. The basic formulation is:

  (a) $R = \bigcup_{i=1,..N} R(i)$

  (b) $R(i) \cap R(j) = 0$ for $i \neq j$

  (c) $P(R(i)) = TRUE$ for $i = 1,2,\ldots,N$

  (d) $R(i)$ is a connected region, $I = 1,\ldots,N$

  (e) $P(R(i) \cup R(j)) = FALSE$ for $i \neq j$

P(R(i)) is a logical predicate defined over the points in set and is the null set:

- (a) means that the segmentation must be complete; that is, every pixel must be in a region.
- (b) requires that points in a region must be connected in some predefined sense.
- (c) indicates that the regions must be disjoint.
- (d) deals with the properties that must be satisfied by the pixels in a segmented region. For example if all pixels in have the same grayscale.
- (e) indicates that region and are different in the sense of predicate .

Seeded Region Growing (SRG)

- Region growing: Groups pixels or sub-region into larger regions.
  - step1:
    - Start with a set of “seed” points and from these grow regions by appending to each seed those neighboring pixels that have properties similar to the seed.
  - step2:
    - Region splitting and merging

- Advantage:
  - With good connectivity

- Disadvantage:
  - Initial seed-points:
    - different sets of initial seed-point cause different segmented result
  - Time-consuming problem

- Unseeded region growing:
  - no explicit seed selection is necessary, the seeds can be generated by the segmentation procedure automatically.
  - It is similar to SRG except the choice of seed point

- Advantage:
  - easy to use
  - can readily incorporate high level knowledge of the image composition through region threshold

- Disadvantage:
  - slow speed

Region-based segmentation
fast scanning

- Fast scanning Algorithm:
  - The fast scanning algorithm somewhat resembles unseeded region growing
  - the number of clusters of both two algorithm would not be decided before image passing through them.

255	250	254	80	150	149	152	150
250	82	81	85	88	149	151	149
84	85	82	84	89	188	193	152
79	81	83	80	79	195	191	155
81	83	123	121	123	120	122	124
40	85	120	125	120	230	235	229

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Region-based segmentation
fast scanning

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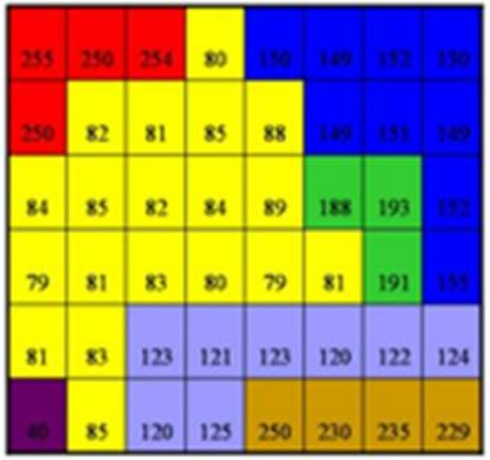
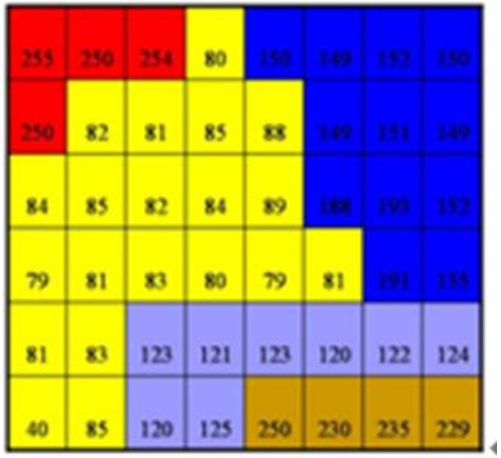




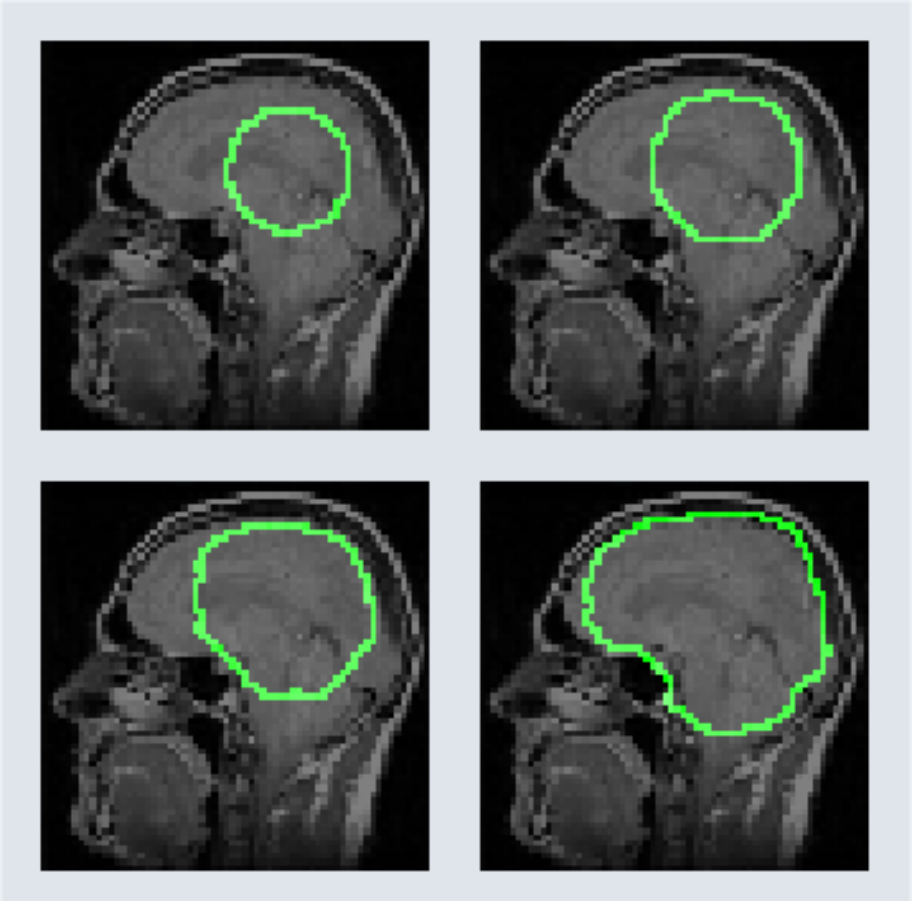
- Last step:
  - merge small region to big region

- Advantage:
  - The speed is very fast
  - The result of segmentation will be intact with good connectivity

- Disadvantage:
  - The matching of physical object is not good
    - It can be improved by morphology and geometric mathematics

Medical Image Segmentation

- Medical image analysis can be used as preliminary screening techniques to help doctors
- Partial Differential Equation (PDE) has been used for segmenting medical images



active contour model (snake)