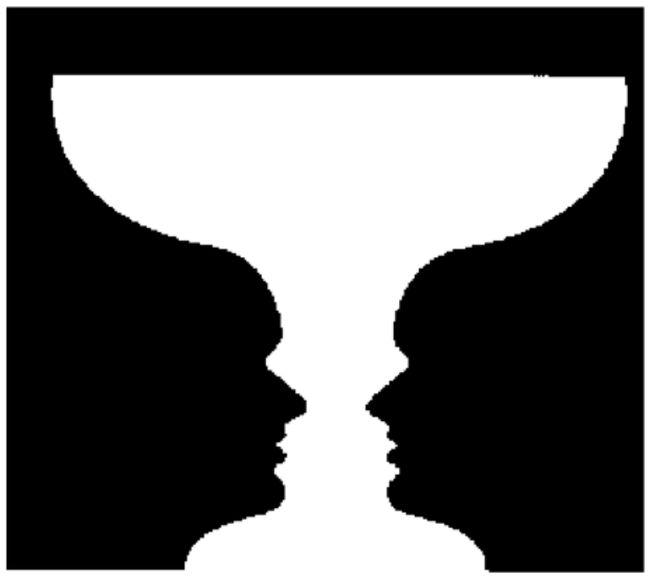
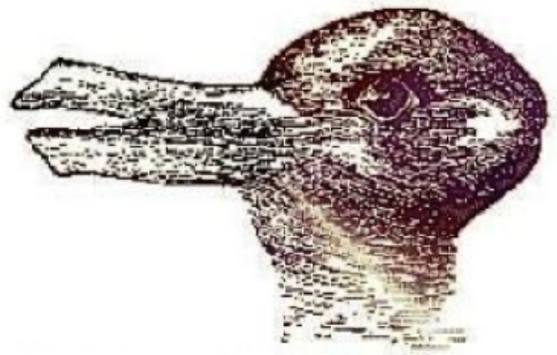
EE6310: Image and Video Processing Spring 2023

Binary Image Processing

Binary Images

Illusions





Binary Images

Definition

- Recall: A digital image is an array of sampled and quantized values

- For gray scale images, scale defined by $K = 2^B$ levels and B bits

- For binary images, $K = 2,\ B = 1$

Binary Images

Interpretation

- Common binary image meanings:
  - Intensity differentiator: low vs high
  - Presence or absence of object
  - Presence or absence of a property

- Why work with binary images?
  - Contain useful information: shape, structure, form
  - Compression (depending on application)

Binary Images

Generation

- Several ways to create binary images:
  - Specialised inputs: stylus (light pen), tablet etc.
  - Gray level thresholding:
    - Simple thresholding: pick a threshold T and make a binary decision
      - For an image $I(i,j)$ with K levels, pick $0 \leq T \leq (K-1)$
      - $$J(i,j) = \begin{cases} 1, \text{ if } I(i,j) \geq T, \\ 0, \text{ otherwise} \end{cases}$$

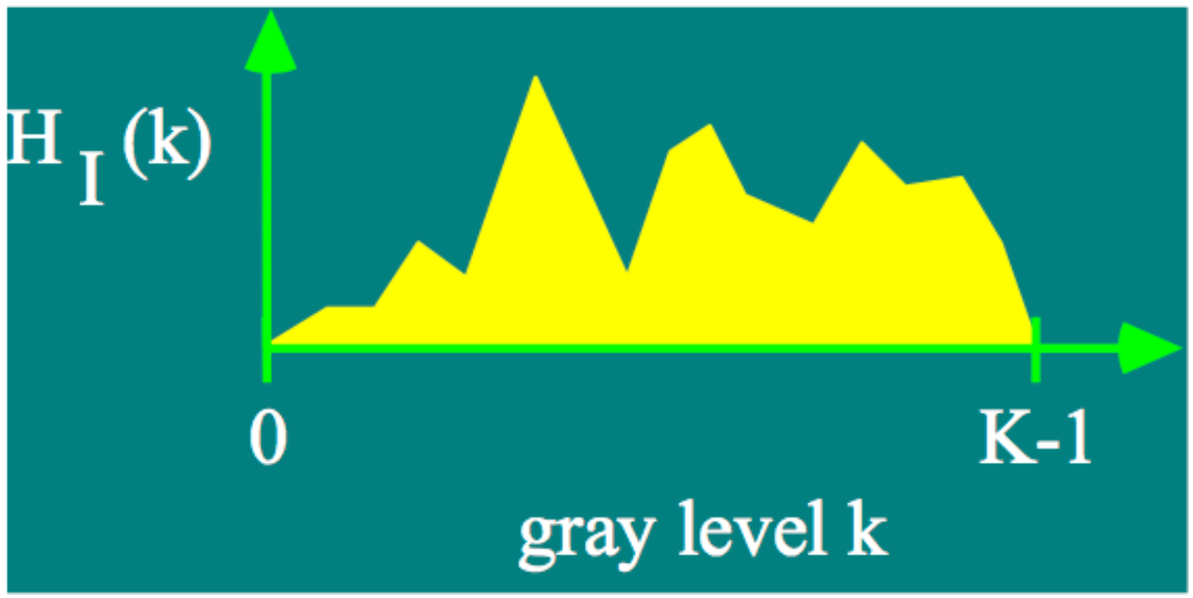
Binary Images

Threshold Selection

- Why is threshold selection important?
  - Quality of binary image directly depends on it
  - Different thresholds may lead to different insights
  - It may not always be able to produce useful binary images for any threshold
- Questions:
  - Is thresholding useful/possible?
  - How do we pick a good threshold T?

Binary Images

Gray Level Image Histogram

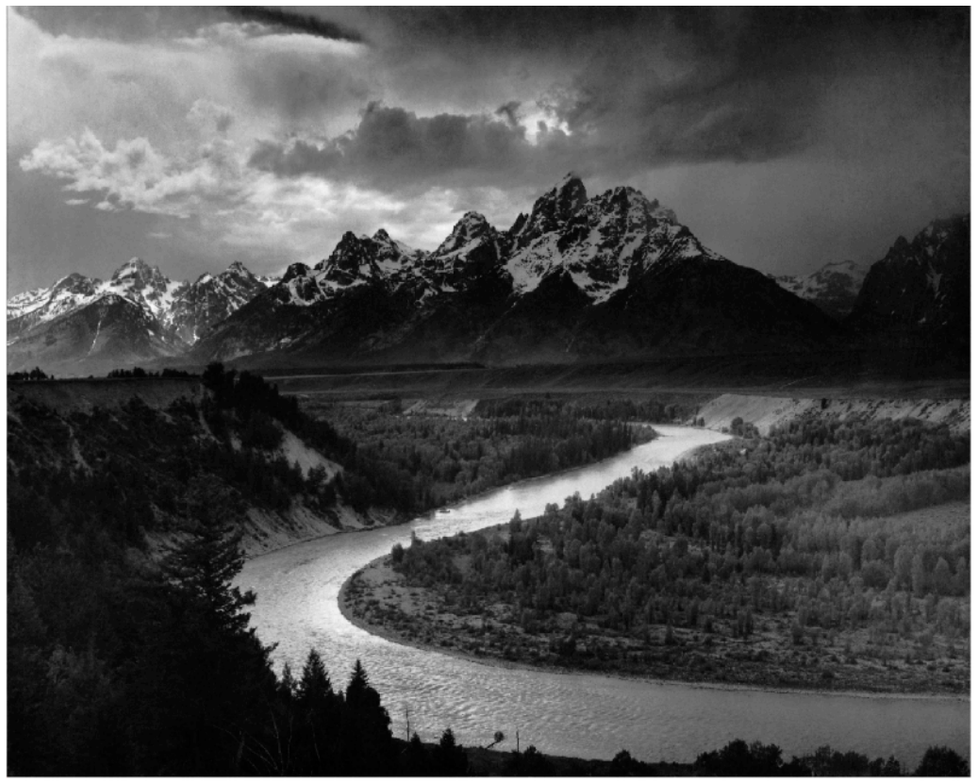


- Histogram H_I of an image I is the graph of the gray-level frequency - like a probability mass function
- A one dimensional function defined on the gray scale i.e., $0 \leq k \leq (K-1)$
- $H_I(k) = n$ means that the intensity k occurs n times in the image
- Histograms reveal a lot about images

Binary Images

Histogram Types

- Modal: histograms with distinct peaks or modes
- Bimodal: two peaks or modes
    - Images with two distinct gray levels that are well separated
    - Choosing T between modes *may* give good results
    - Exact location of T is hard to guess
- Multimodal: multiple peaks or modes
    - Images with multiple distinct gray levels
    - Varying T produces different results
- Flat: uniform or flat intensity distribution
    - Images with greater complexity, non-uniform background etc.
    - Choosing a threshold is hard



Binary Images

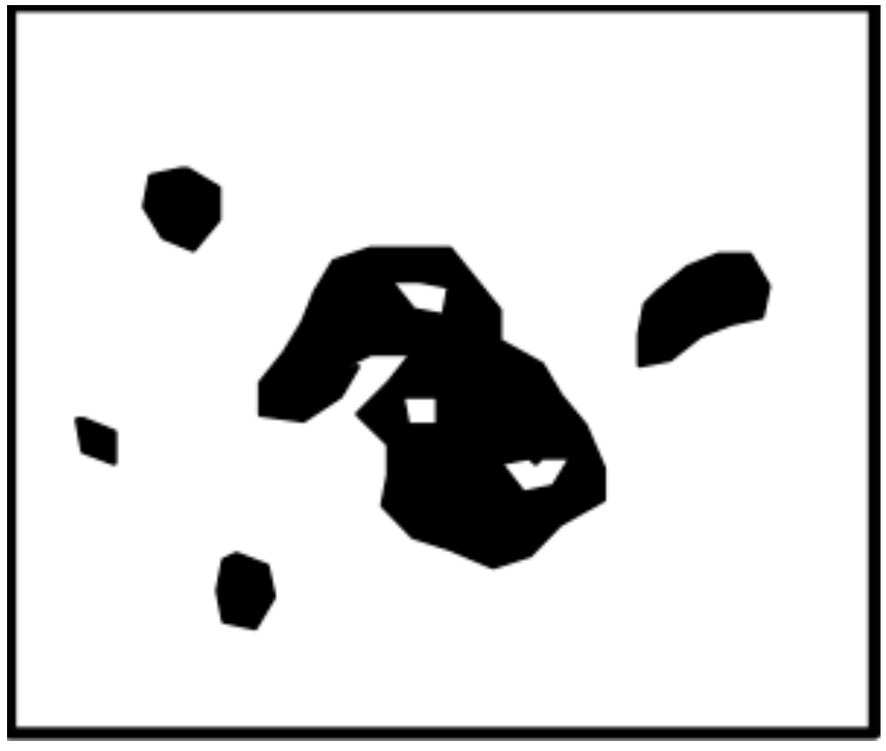
Otsu's Algorithm

- One way to binarise images
- Pick a threshold such that:
  - Intra-class variance is minimised
  - Or equivalently, inter-class variance is maximised
  - Implemented in an iterative fashion over $0 \leq k \leq (K-1)$ gray levels
- Very popular and most standard image processing libraries implement it
- Deep learning variants have been proposed as well!

Binary Images

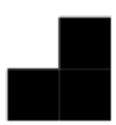
Connected Components

- We have a binary image, now what? Let's process it!
- How? The Connected Components Algorithm or "blob colouring" or "region labelling"
- Why?
  - Thresholding leads to imperfect binary images
  - Extraneous blobs or holes due to noise or low-interest regions
- Blob colouring is a method for labelling/ colouring/indexing objects



Binary Images

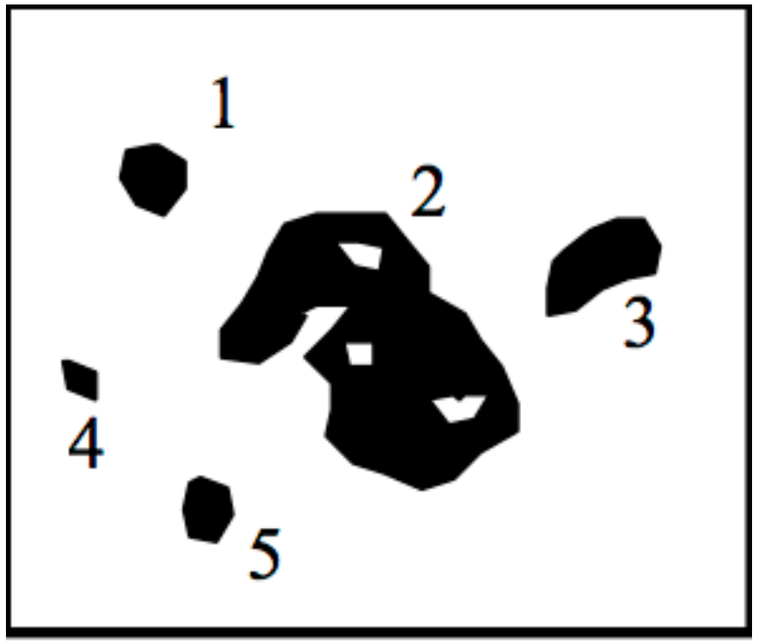
Connected Components Algorithm (4 connectivity)

- For a binary image I, define a region colour array R, where $R(i, j)$ is the region number of pixel $I(i, j)$
- Set $R = 0$ (all zeros) and region number counter $k = 1$
- **Assumption:** border pixels are *background* and have the *same value*
- While scanning the image from the top left to the bottom right, do the following:
  -  If $I(i, j) = 0$ and $I(i, j - 1) = 1$ and $I(i - 1, j) = 1$, then set $R(i, j) = k$ and $k = k + 1$
  -  If $I(i, j) = 0$ and $I(i, j - 1) = 1$ and $I(i - 1, j) = 0$, then set $R(i, j) = R(i - 1, j)$
  -  If $I(i, j) = 0$ and $I(i, j - 1) = 0$ and $I(i - 1, j) = 1$, then set $R(i, j) = R(i, j - 1)$
  -  If $I(i, j) = 0$ and $I(i, j - 1) = 0$ and $I(i - 1, j) = 0$, then set $R(i, j) = \min(R(i, j - 1), R(i - 1, j))$; if $R(i, j - 1) \neq R(i - 1, j)$ link the regions

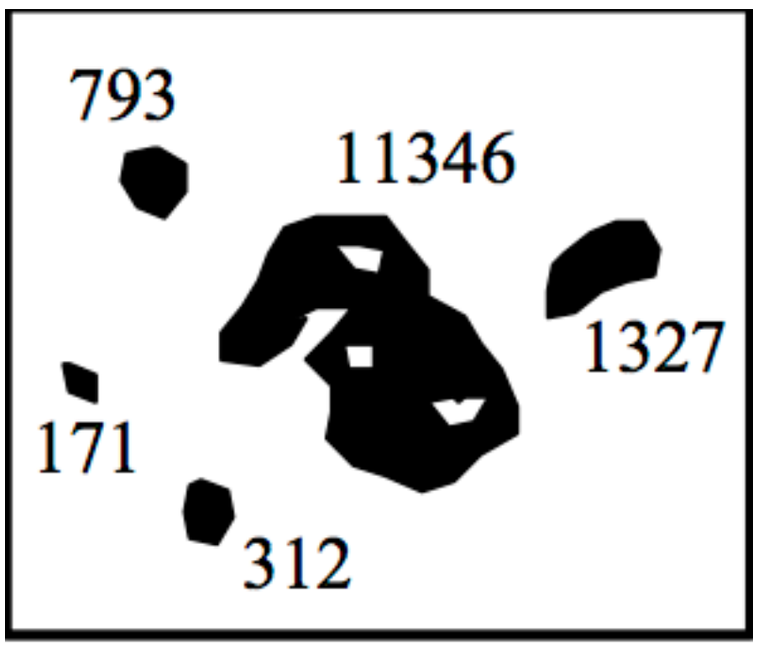
Binary Images

Blob Colouring Example

- Blob colouring result



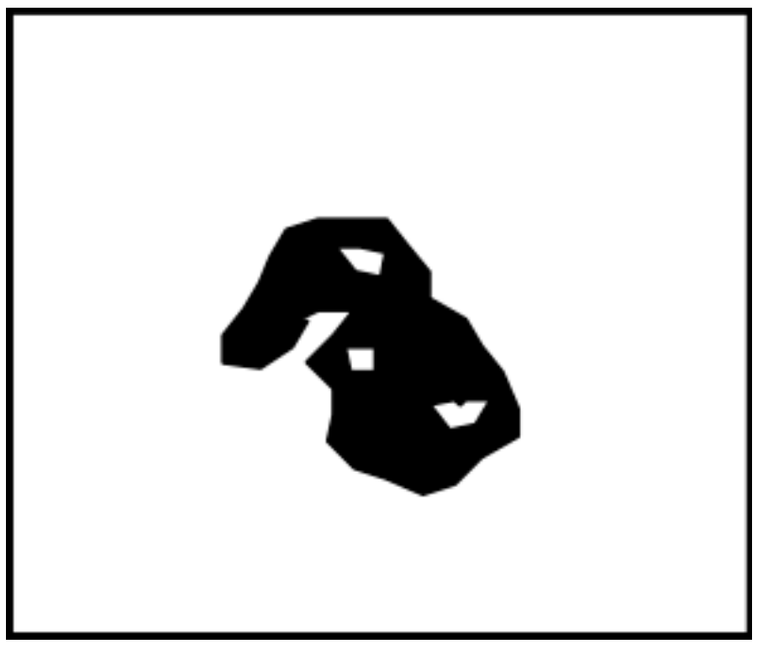
- Blob counting result



Binary Images

Minor Blob Removal

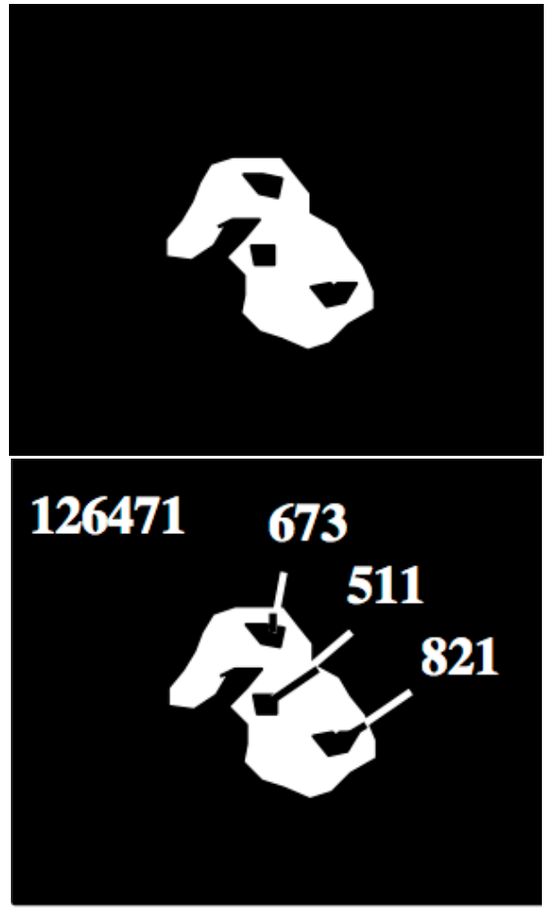
- Let m be the label of the largest blob
- While scanning the image from the top left to the bottom right: if $I(i,j) = 0$ and $R(i,j) \neq m$, set $I(i,j) = 1$



Binary Images

Minor Blob Removal

- To clean up:
  - Complement
  - Count blobs
  - Minor blob removal
  - Complement



Binary Images

Connected Components