Lecture 22-1 Watershed Segmentation

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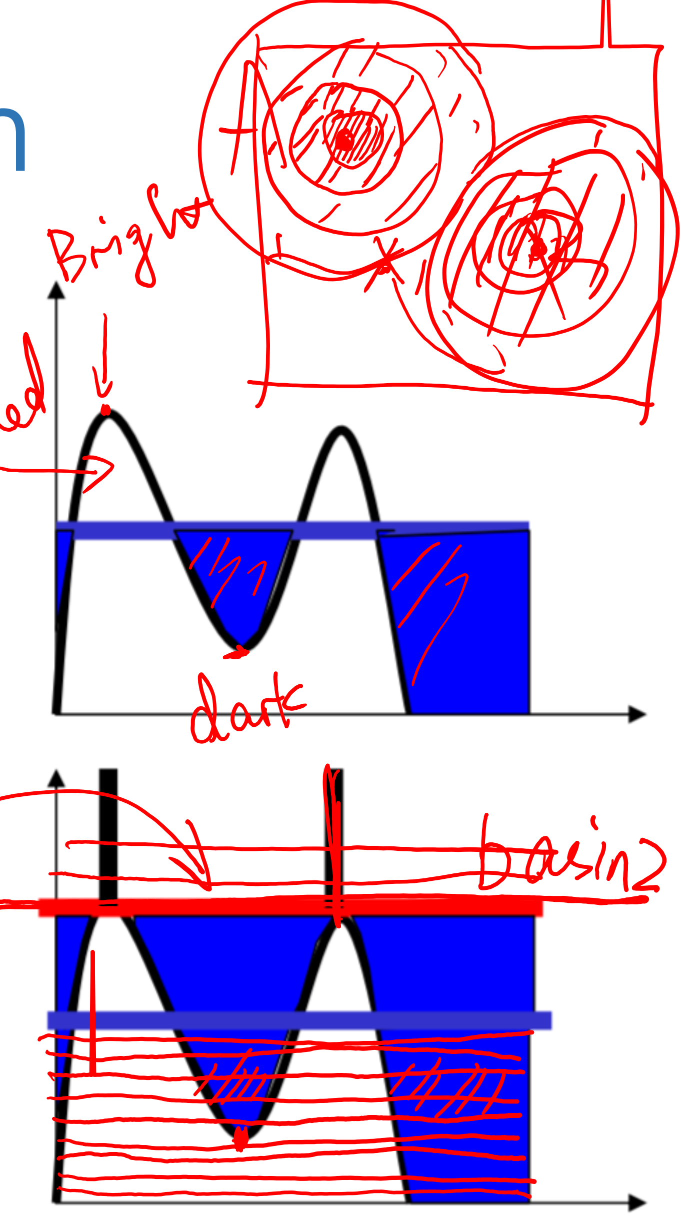
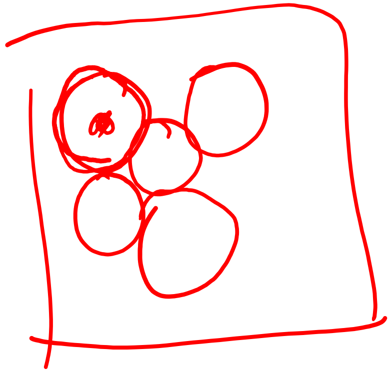
Watershed segmentation

- Look at the image as a 3D topographic surface, (x,y,intensity), with both valleys and mountains.
- Assume that there is a hole at each minimum, and that the surface is immersed into a lake.
- The water will enter through the holes at the minima and flood the surface.
- To avoid two different basins to merge, a dam is built.
- Final step: the only thing visible would be the dams.
- The connected dam boundaries correspond to the watershed lines.



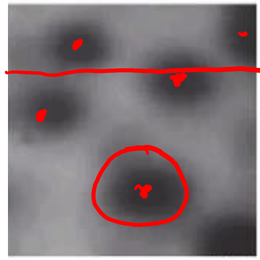
Watershed segmentation



- Can be used on images derived from:
  - The intensity image
  - Edge enhanced image
  - Distance transformed image

    Thresholded image. From each foreground pixel, compute the distance to a background pixel.
  - Gradient of the image
- Most common: gradient image

Watershed algorithm



- Let $g(x, y)$ be the input image (often a gradient image).
- Let $M_1, \cdots, M_R$ be the coordinates of the regional minima.
- Let $\boxed{C(M_i)}$ be a set consisting of the coordinates of all points belonging to the catchment basin associated with the regional minimum M_i.

  Mi basin

- Let $\boxed{T[n]}$ be the set of coordinates (s, t) where $g(s, t) < t$

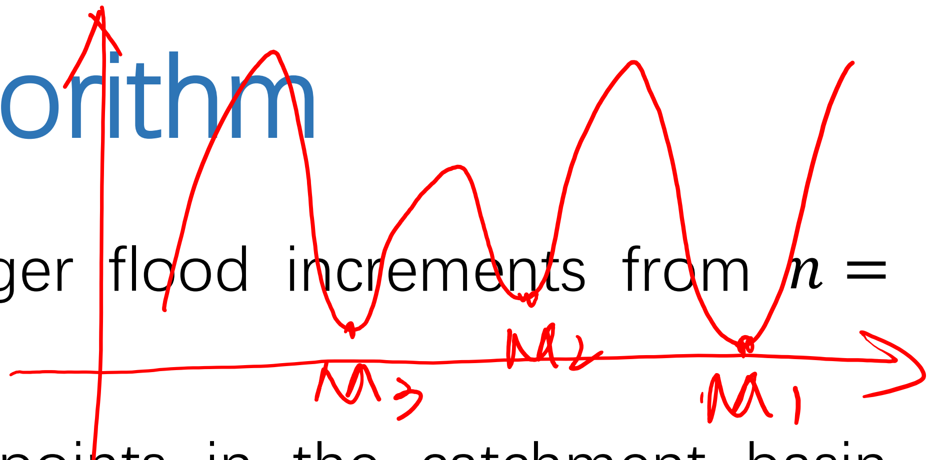
  flood

$$T[n] = \{(s, t) | g(s, t) < n\}$$

This is the set of coordinates lying below the plane $g(x, y) = n$

This is the candidate pixels for inclusion into the catchment basin, but we must take care that the pixels do not belong to a different catchment basin.

Watershed algorithm



- The topography will be flooded with integer flood increments from $n = \min - 1$ to $n = \max + 1$.
- Let $C_n(M_i)$ be the set of coordinates of points in the catchment basin associated with M_i, flooded at stage n.
- This must be a connected component and can be expressed as $C_n(M_i) = C(M_i) \cap T[n]$

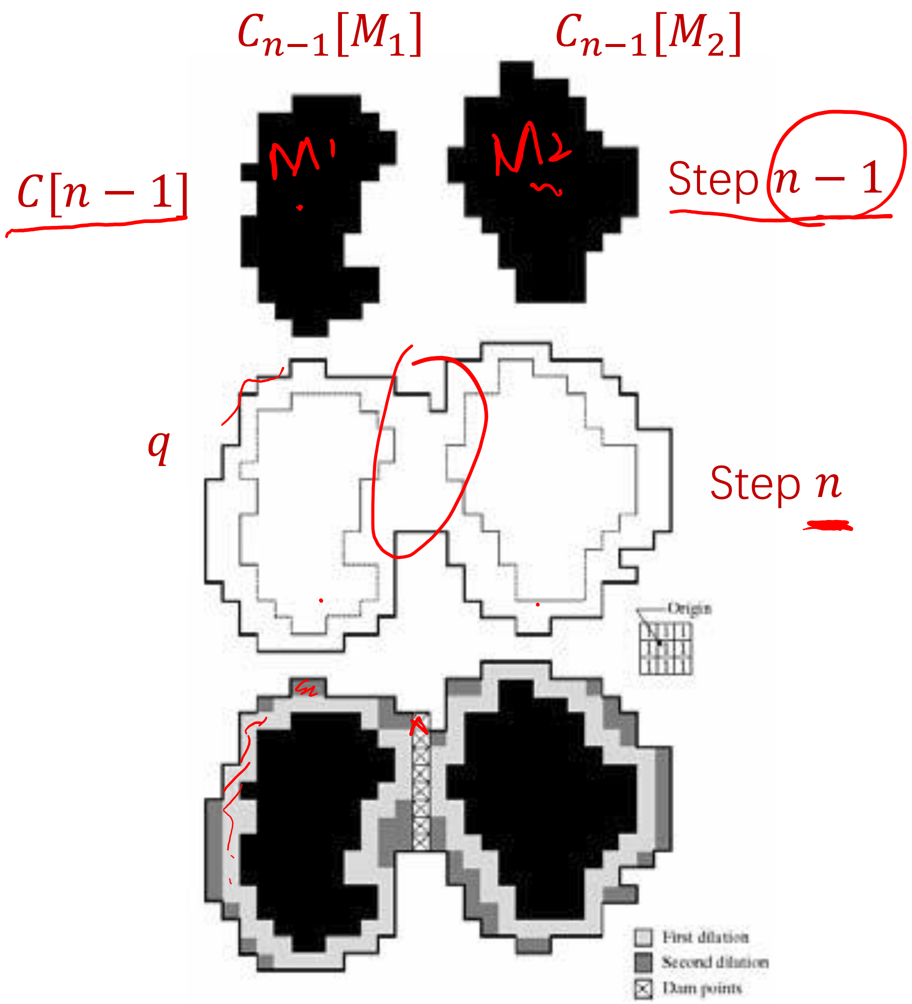
  $T[n] = \{(s,t) \mid g(s,t) < n\}$

  (only the portion of $T[n]$ associated with basin M_i)
- Let $T[n]$ be the set of flooded water, let $C[n]$ be union of all flooded catchments at stage n:

$$C[n] = \cup_{i=1}^{R} C_n(M_i) \text{ and } C[max+1] = \cup_{i=1}^{R} C(M_i)$$

Dam construction

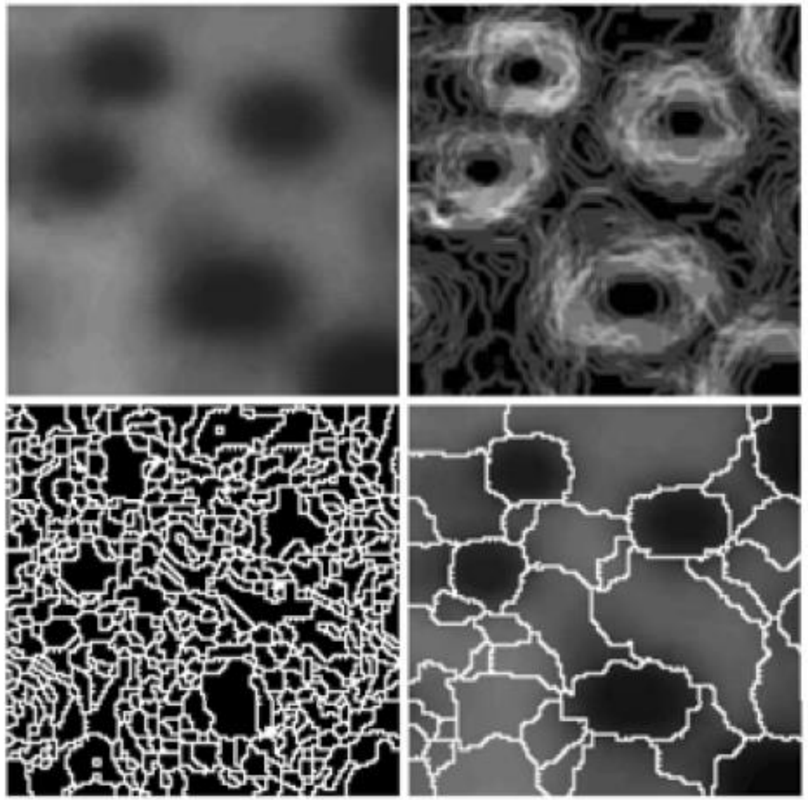
- Stage $n-1$: two basins forming separate connected components.
- To consider pixels for inclusion in basin k in the next step (after flooding), they must be part of $T[n]$, and also be part of the connected component q of $T[n]$ that $C_{n-1}[k]$ is included in.
- Use morphological dilation iteratively.
- Dilation of $C[n-1]$ is constrained to q.
- The dilation can not be performed on pixels that would cause two basins to be merged (form a single connected component)



“Over-segmentation” or fragmentation

Image I

Gradient magnitude image (G)



Watershed of G

Watershed of smoothed G

- Using the gradient image directly can cause over-segmentation because of noise and small irrelevant intensity changes.
- Improved by smoothing the gradient image or using markers

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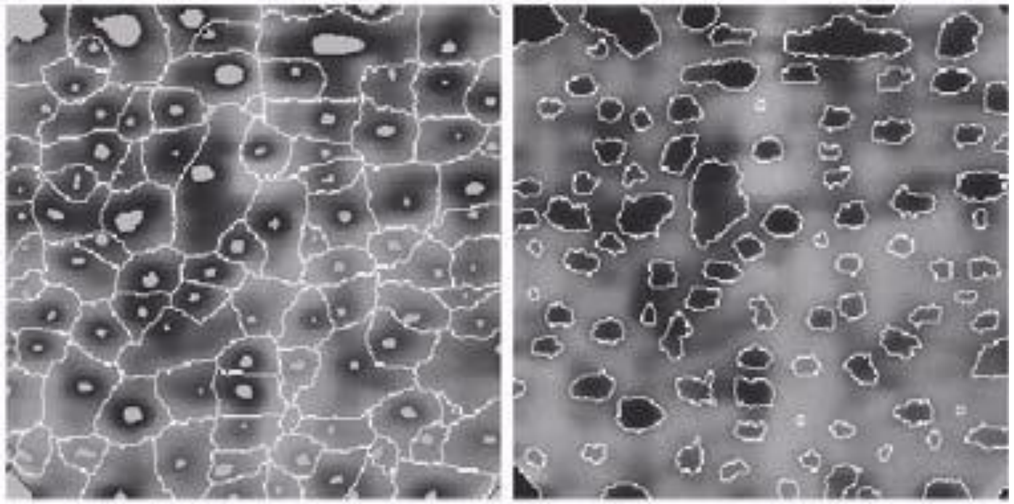
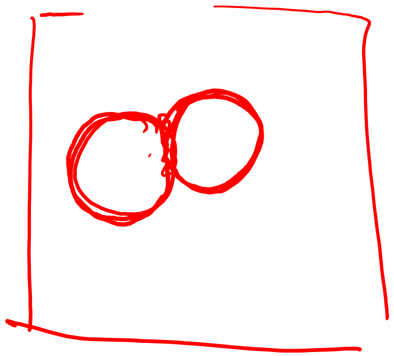
Solution: Watershed with markers



- A marker is an extended connected component in the image
- Can be found by intensity, size, shape, texture etc
- Internal markers are associated with the object (a region surrounded by bright point (of higher altitude))
- External markers are associated with the background (watershed lines)
- Segment each sub-region by some segmentation algorithm

Watershed



- Advantages
  - Gives connected components
  - A priori information can be implemented in the method using markers
- Disadvantages :
  - Often needs preprocessing to work well
  - Fragmentation or “over-segmentation” can be a problem