Segmentation By Morphological Watersheds

The aim of Segmentation is to separate regions wrt brightness, color, reflectivity, texture, etc. Segmentation based on three principal concepts: (a) detection of discontinuities,

(b) thresholding, and (c) region processing.

1. Basic Concepts

The concept of watersheds is based on visualizing an image in three dimensions: two spatial coordinates versus gray levels. In such a "topographic" interpretation, we consider three types of points:

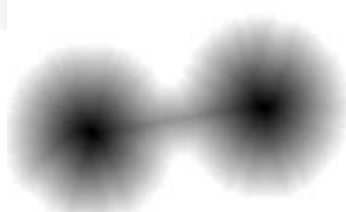
a. Points belonging to a regional minimum b. Catchment basin / watershed of a regional minimum

Points at which a drop of water will certainly fall to a single minimum

c. Divide lines / Watershed lines Points at which a drop of water will be equally likely to fall to more than one minimum. Crest lines on the topographic surface

This technique is to identify all the third type of points for segmentation

1. Piercing holes in each regional minimum of I
2. The 3D topography is flooded from below gradually
3. When the rising water in distinct catchment basins is about to merge, a dam is built to prevent the merging
4. The dam boundaries correspond to the watershed lines to be extracted by a Watershed segmentation algorithm



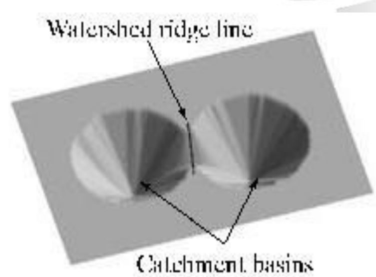
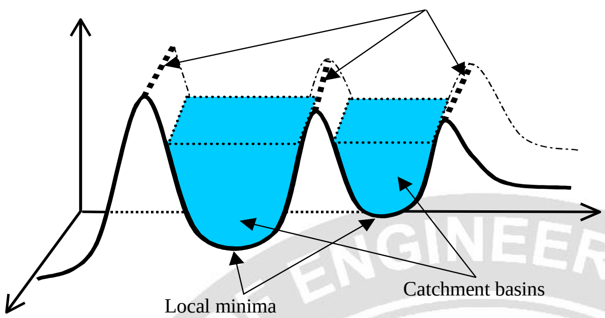


Fig4.4.1: Beginning of merging of water from two catchment basins (a short dam was built between them). (g) Longer dams. (h) Final Watershed (segmentation) lines. (Courtesy of Dr. S. Beucher, CMM/ Ecole des Mines de Paris.)
(Source: Rafael C. Gonzalez, Richard E. Woods, ‗Digital Image Processing', Pearson, Third Edition, 2010.-Page-770)



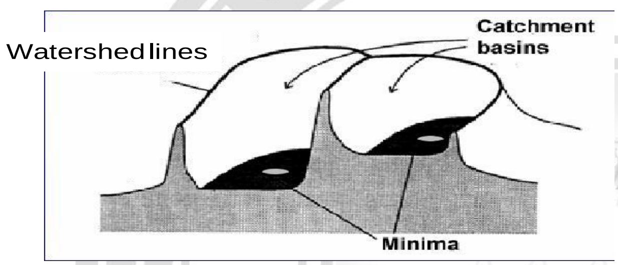


Fig4.4.2: (a) Original image. (b) Topographic view. (c)– (d) Two stages of flooding.

(Source: Rafael C. Gonzalez, Richard E. Woods, ‗Digital Image Processing', Pearson, Third Edition, 2010.-Page-770.)_

The principal objective of segmentation algorithms based on these concepts is to find the watershed lines. The basic idea is simple: Suppose that a hole is punched in each regional minimum and that the entire topography is flooded from below by letting water rise through the holes at a uniform rate. When the rising water in distinct catchment basins is about to merge, a dam is built
to prevent Merging.

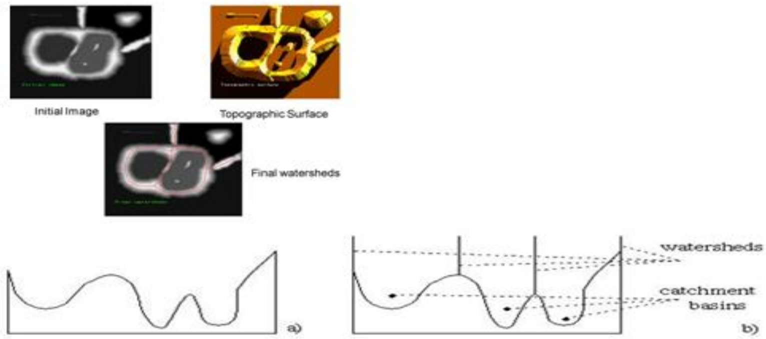
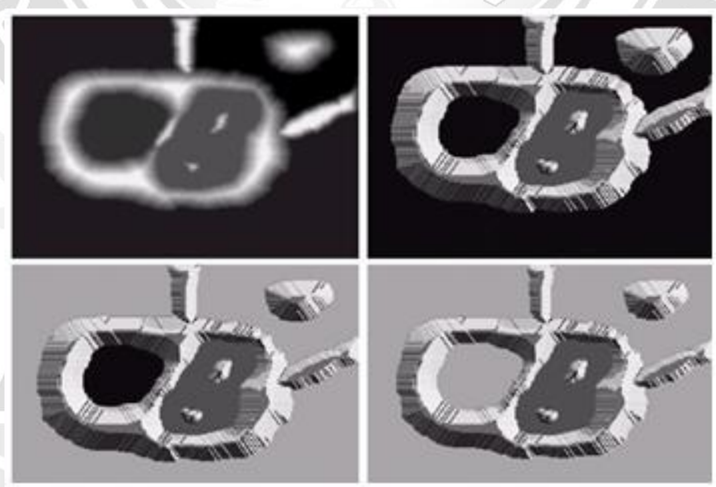


Fig4.4.3: One dimensional example of Watershed Segmentation

(Source: Rafael C. Gonzalez, Richard E. Woods, ‗Digital Image Processing', Pearson, Third Edition, 2010 --Page-771)

The flooding will eventually reach a stage when only the tops of the dams arc visible above the water line. These dam boundaries correspond to the divide lines of the watersheds. Therefore, they are the (continuous) boundaries extracted by a watershed segmentation algorithm. These ideas can be explained further with the aid of Fig.



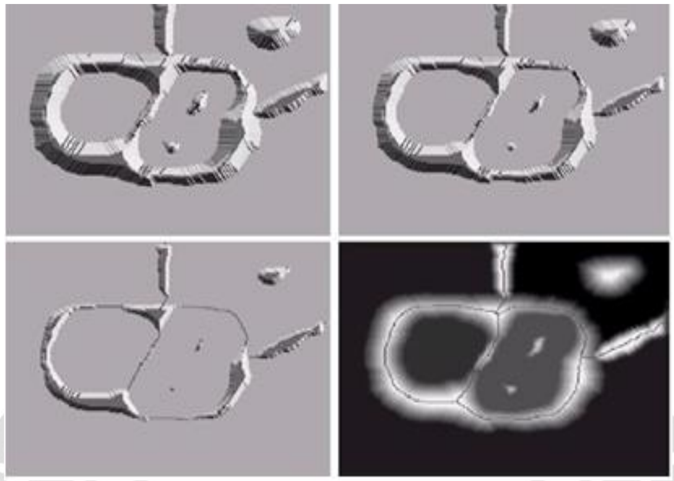


Figure: 4.4.4 shows a simple gray-scale image and Fig. (b) is a topographic view, in which the height of the "'mountains'' is proportional to gray-level values in the input image.

(Source: Rafael C. Gonzalez, Richard E. Woods, ‗Digital Image Processing', Pearson, Third Edition, 2010-Page 773)

For ease of interpretation, the backsides of structures are shaded. This is not to be confused with gray-level values; only the general topography of the three-dimensional representation is of interest. In order to prevent the rising water from spilling out through the edges of the structure, we imagine the perimeter of the entire topography (image) being enclosed by dams of height greater than the highest possible mountain, whose value is determined by the highest possible gray-level value in the input image.

Suppose that a *hole* is punched in each regional minimum [shown as dark areas in Fig. (b)] and that the entire topography is flooded from below by letting water rise through the holes *at* a uniform rate. Figure (c) shows the first stage of flooding, where the "water" shown in light gray, has covered only areas that correspond to the very dark background in the image. In Figs. (d) and (e) we see that the water now has risen into the first and second catchment basins, respectively. As the water continues to rise, it will eventually overflow from one catchment basin into another. The first indication of this is shown in (f). Here, water from the left basin actually overflowed into the basin on the right and a short "dam" (consisting of single pixels) was built to prevent water from merging at that level of flooding (the details of dam building are discussed in the following section), The effect is more pronounced as water continues to rise, as shown in Fig. (g).This figure shows a longer dam between the two catchment basins and another dam in the top part of the right basin. The latter dam was built to prevent merging of water from that basin with water from areas corresponding lo the background. This process is continued until the maximum level of flooding (corresponding to the highest gray-level value in the image) is reached. The final dams correspond to the watershed lines, which are the desired segmentation result. The result for this example is shown in Fig. (h) as a dark, one-pixel-thick path superimposed on the original image. Note the important property that the watershed lines form a connected path, thus giving continuous boundaries between regions.

One of the principal applications of watershed segmentation is in the extraction of nearly uniform (blob like) objects from the background. Regions characterized by small variations in gray levels have small gradient values. Thus, in practice, we often see watershed segmentation applied to the gradient of an image, rather than to the image itself. In this formulation, the regional minima of catchment basins correlate nicely with the small value of the gradient corresponding to the objects of interest, From one catchment basin into another. The first indication of this is shown in (f). Here, water from the left basin actually overflowed into the basin on the right and a short "dam" (consisting of single pixels) was built to prevent water from merging at that level of flooding (the details of dam building are discussed in the following section), The effect is more pronounced as water continues to rise, as shown in Fig. (g).This figure shows a longer dam between the two catchment basins and another dam in the top part of the right basin. The latter dam was built to prevent merging of water from that basin with water from areas corresponding lo the background. This process is continued until the maximum level of flooding (corresponding to the highest gray-level value in the image) is reached. The final dams correspond to the watershed lines, which are the desired segmentation result. The result for this example is shown in Fig. (h) as a dark, one-pixel-thick path superimposed on the original image. Note the important property that the watershed lines form a connected path, thus giving continuous boundaries between regions.

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