

영상분석 I : Segmentation and Thresholding

김 동 우
삼성종합기술원

..... 많은 경우에 있어서 영상 처리의 최종 목적은 영상 데이터 안에 있는 중요한 특징(feature)들을 분리해내고 이것으로부터 영상 안의 상황을 기술하고 이해하는 것이다. 이러한 영상 분석의 예로서 의료 영상으로부터 종양을 찾아내고 경계선을 추출하는 것(tumor detection), 종양이나 내부 기관의 크기와 모양을 측정하는 것, 혈구의 개수를 세는 것(Blood cell count)등을 들 수 있다. 영상분석에서 사용되는 기술은 크게 feature extraction, segmentation, classification으로 분류할 수 있고, 영상 분석의 응용 분야로는 의료 영상 분석, 문자 인식, 공장 자동화, 원격 탐사, robotics 등이 있다.

1. Thresholding

- 주어진 영상에 대해서 밝기 값의 범위를 정하고, 범위 안에 들어오는 화소(pixel) 들은 물체로, 범위를 벗어나는 화소들은 배경으로 간주(그림1).
- 8-bit gray scale image : $2^8=256$ gray scale values.
- Thresholding 방법의 단점 : 화소의 위치정보 손실, 이웃한 화소들의 밝기 값 정도 손실, 많은 경우 히스토그램 상에서 분명한 봉우리(peak)가 존재하지 않음.

2. Multiband Images

- Multiband 영상의 예 : 의료 영상 분야의 MR 영상(그림 2), 원격 탐사의 위성 사진, 칼라 영상(그림 6)
- Multiband 영상의 경우 독립적인 band의 개수가 증가할수록 분할(segmentation) 성능이 향상되고 분할 과정이 쉬워진다.
- Multiband 영상의 thresholding(그림 3)

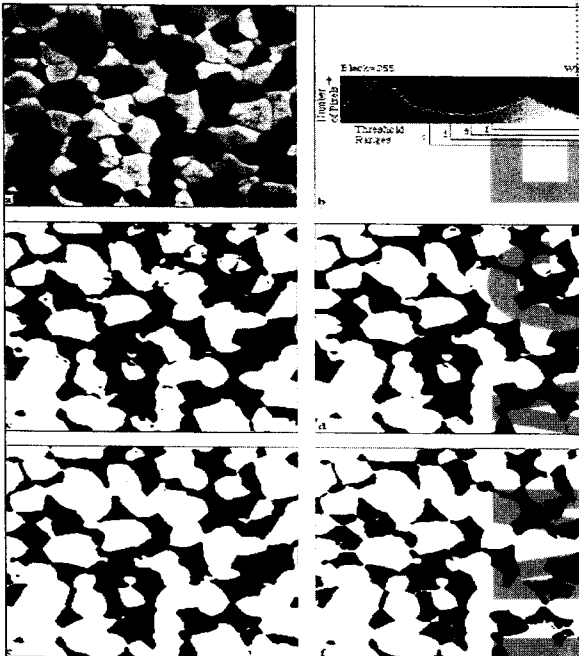


Fig 1. (a) A gray scale image; (b) brightness histogram; (c)-(f) several binary images.

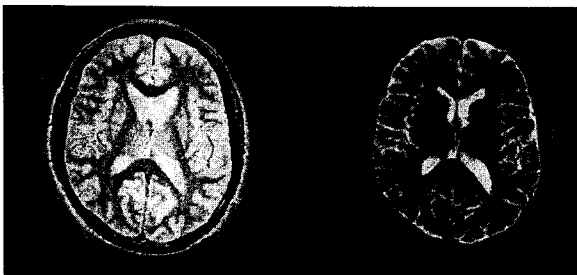


Fig 2. Proton-density and T2-weighted images

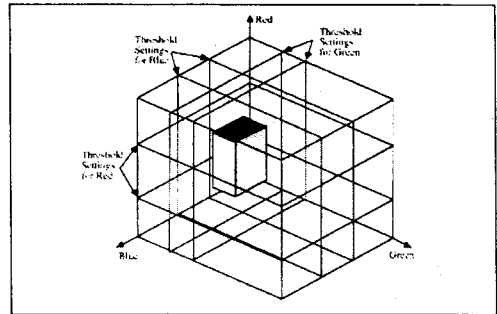


Fig 3. The combination of separate thresholds on individual color planes.

3. Two-dimensional thresholds

- Multiband 영상에서 2차원 히스토그램을 구성하고 2차원 평면 위에서 thresholding을 위한 범위 결정.
- HS plane(그림 4)

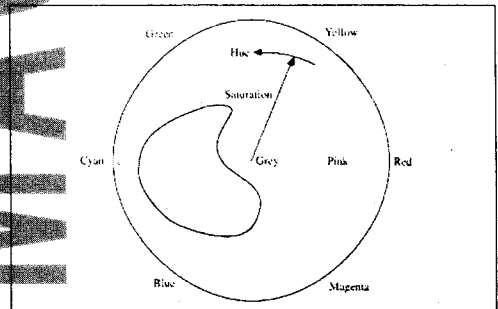


Fig 4. Selecting an arbitrary region in a two-dimensional parameter space.

- HIS cube(그림 5)
- Binning : 32 x 32 bins

4. Multiband thresholding

- RGB 색 좌표계(그림 6-9)
- HIS 색 좌표계(그림 10-13)
- 2차원 thresholding의 예 : 쥐의 소장 현미경 영상에서 음모분할, Hue와 saturation 이용(그림 14)

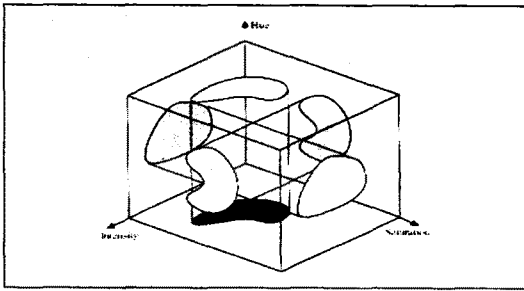


Fig 5. The combination of two-parameter threshold settings.

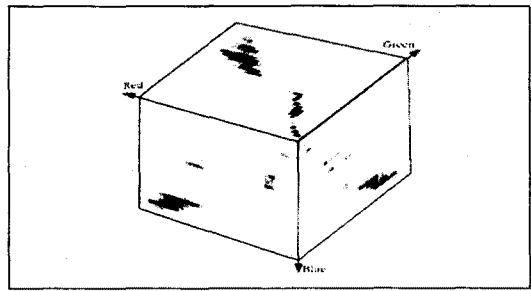


Fig 9. The data from Figure 10 projectd onto the faces of a cube.



Fig 6. Red, green, and blue color planes

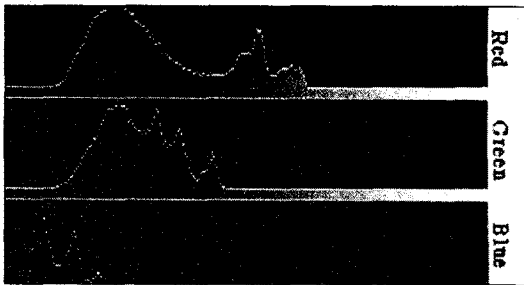


Fig 7. Brightness histograms for the color plane images in Figure 8.

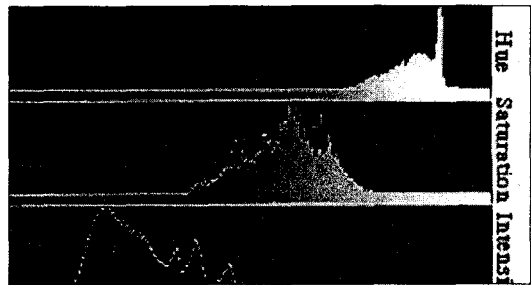


Fig 10. Brightness histograms for the color plane images in Figure 12.

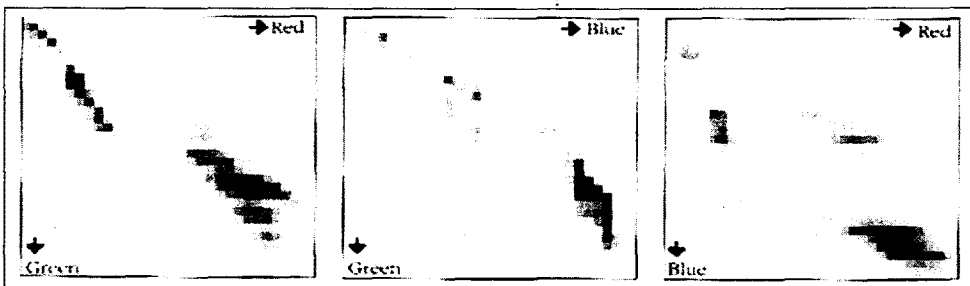


Fig 8. Pairs of values for the pixels in the images of Figure 8.



Fig 11. The same color information as in Figure 8, converted to hue saturation, and intensity components.

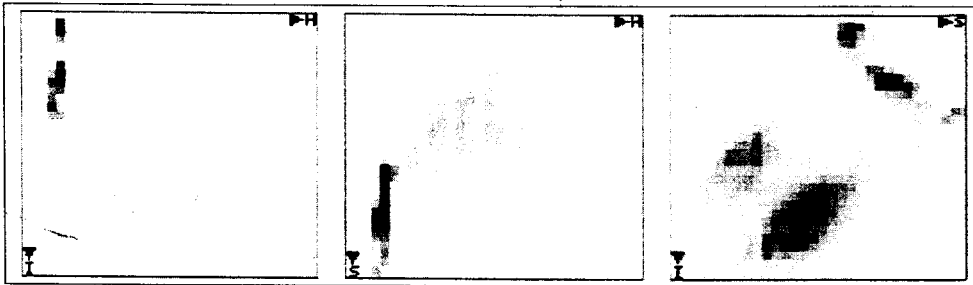


Fig 12. Hue, saturation, and intensity values for the pixels in Figure 12. projected onto HI, HS, and SI planes.



Fig 13. Thresholded Binary images; (a) thresholded on hue; (b) thresholded by a region in the two-dimensional saturation-intensity histogram.

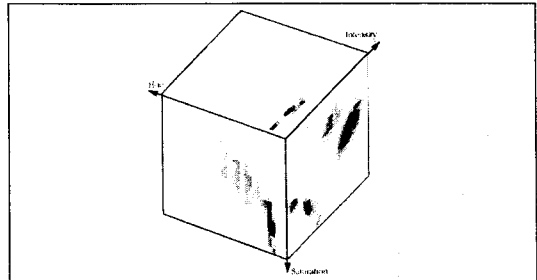


Fig 14. The data from Figure 13 projected onto the faces of a cube.

5, Thresholding from texture

- 실제 영상에서는 거의 모든 영역들이 텍스처를 갖는다.
- 텍스처 영상의 예 : 그림 15. 동일한 평균 밝기를 갖는 5개의 영역으로 구성

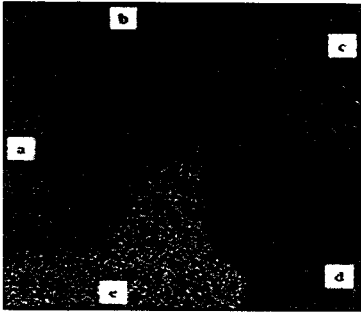


Fig 15. Test image containing five different regions to be distinguished by differences in the textures

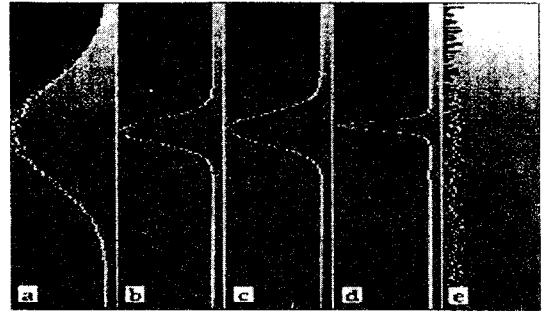


Fig 16. Brightness histograms of each area in Figure 15.

• 텍스춰 분석도구의 분류 : frequency-domain(그림17), spatial-domain(그림18)

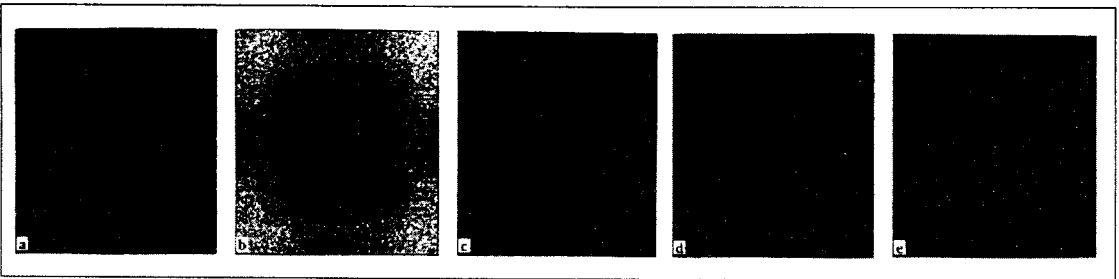


Fig 17. 2D FFT power spectra of the pattern in each area of Figure 15.

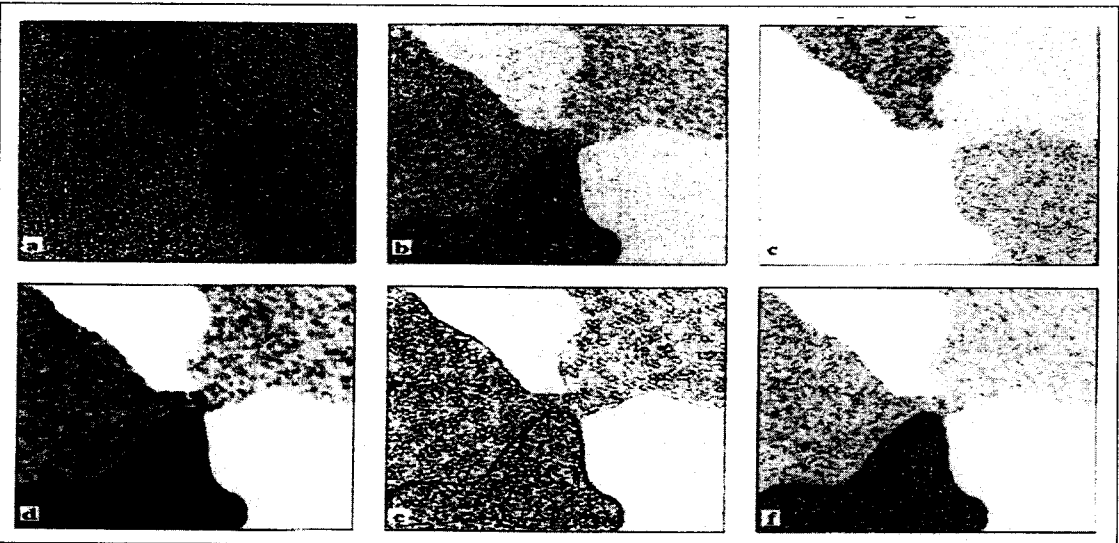


Fig 18. Application of various texture-sensitive operators to the image in Figure 15; (a) Laplacian; (b) Frei & Chen, (c) Haralick, (d) range; (e) Hurst; (f) variance.

- 평활화(그림 19, 20).

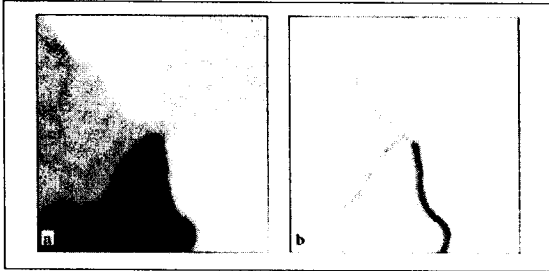


Fig 19. (a) Result of smoothing the variance image with a Gaussian Kernel with standard deviation equal to 1.6 pixels; (b) the Sobel edge detector applied to the smoothed image.



Fig 20. (a) Histogram of the variance image before smoothing; (b) histogram after smoothing.

- 평활화 시킨 영상의 히스토그램(그림 20a)을 이용한 thresholding(그림 21).
- Sobel operator를 이용하여 edge를 구하고(그림 19b), 세션화 시킴(그림 22).
- 텍스춰 분할의 또 다른 예(그림 23) : 금속 현미경 사진. Hurst texture operator.



Fig 21. Thresholding the smoothed variance image.

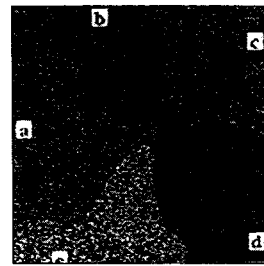


Fig 22. Results of segmentation by skeletonizing the edge from the Sobel operator.

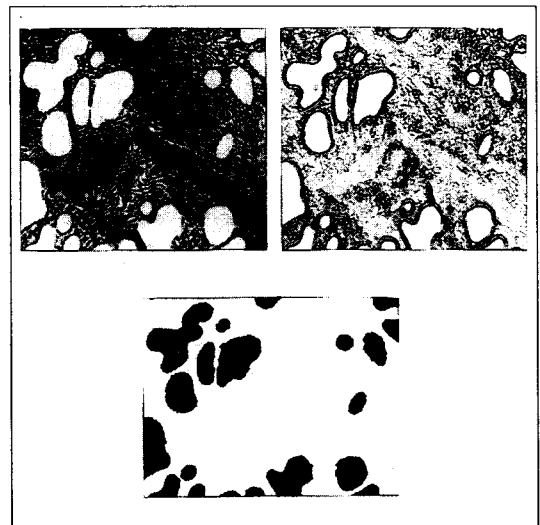


Fig 23. Application of Hurst texture operator to a microscope image of metal containing a eutectic : (a) original image; (b) application of a Hurst operator; (c) binary image formed by thresholding image b to select the low-texture regions.

6. Multiple threshold criteria

- 많은 경우의 텍스춰 분할에서는 두 개 이상의 특징을 사용해야 분할이 가능하다.(그림 24)

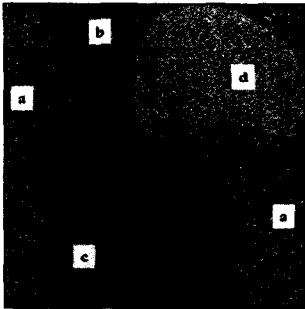


Fig 24. Another segmentation test image.

- 밝기 정보와 텍스춰 정보를 이용한 분할.(그림 25-28)

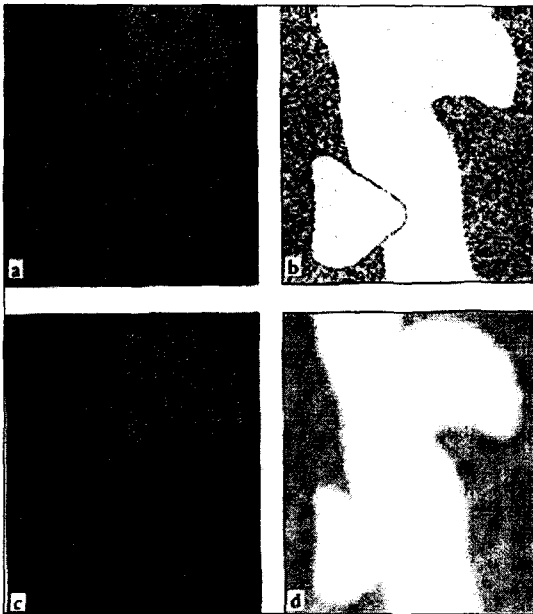


Fig 25. (a) The brightness image; (b) the variance image; (c) smoothing image a with a Gaussian filter; (d) smoothing image b with a Gaussian filter.

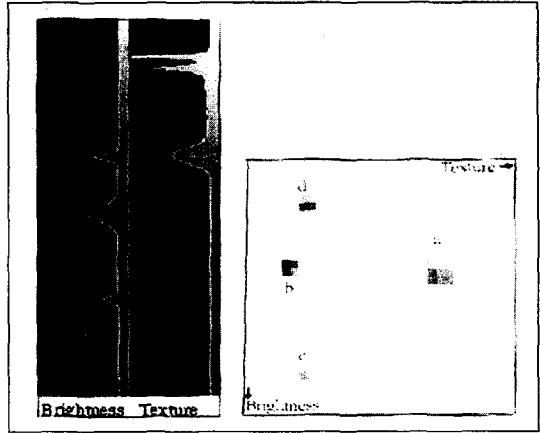


Fig 26. Histograms of the individual images in figure 25c and 25d, and the two way histogram of the pixels showing the separation of the four regions.

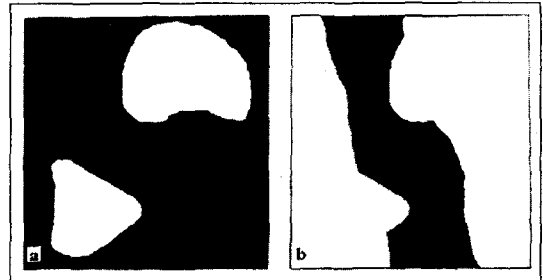


Fig 27. Thresholding of images in Figure 25: (a) selecting intermediate brightness values(regions a and b); (b) selecting only region b by its brightness AND texture.

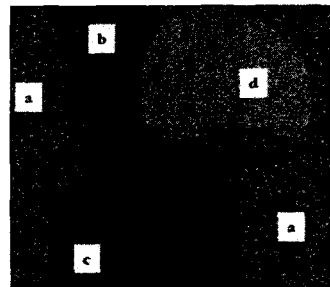


Fig 28. Result of segmenting Figure 24 by thresholding on the two-dimensional histogram.

- 두개 이상의 criteria를 이용하여 텍스취 영상을 분할하는 또 다른 예(그림 29-30)

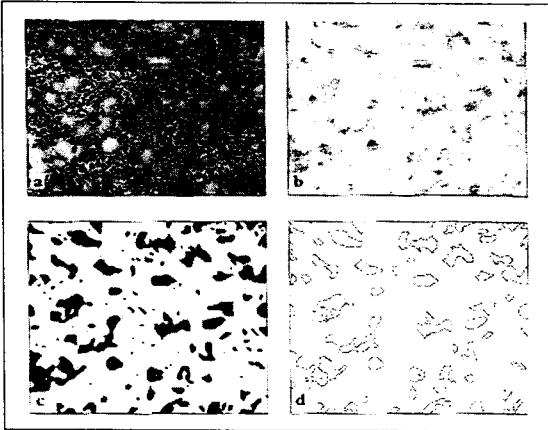


Fig 29. Texture thresholding of curds and whey: (a) original image; (b) application of the Haralick texture operator; (c) thresholding image b and applying an opening(erosion and dilation); (d) measuring feature area to select just the large regions.

7. Textural orientation

- 방향정보를 이용한 텍스취 영상의 분할.(그림 31)
- Frequency-domain processing
 - 2차원 Fourier 변화를 수행하고 wedge-shaped mask를 이용하여 서로 다른 방향성을 갖는 영역들을 분할한다.(그림 32)
 - Range operator, thresholding, closing operation. (그림 33-34)
- Spatial-domain processing
 - Sobel operator를 적용하여 각 화소 위치에서의 gradient의 방향을 구한다.(그림 35)
 - Thresholding, closing operation.(그림 36-37)
- 밝기 정보와 텍스취 정보를 이용한 텍스취 영상 분할의 또 다른 예: 골수의 현미경 영상.(그림 38-41)

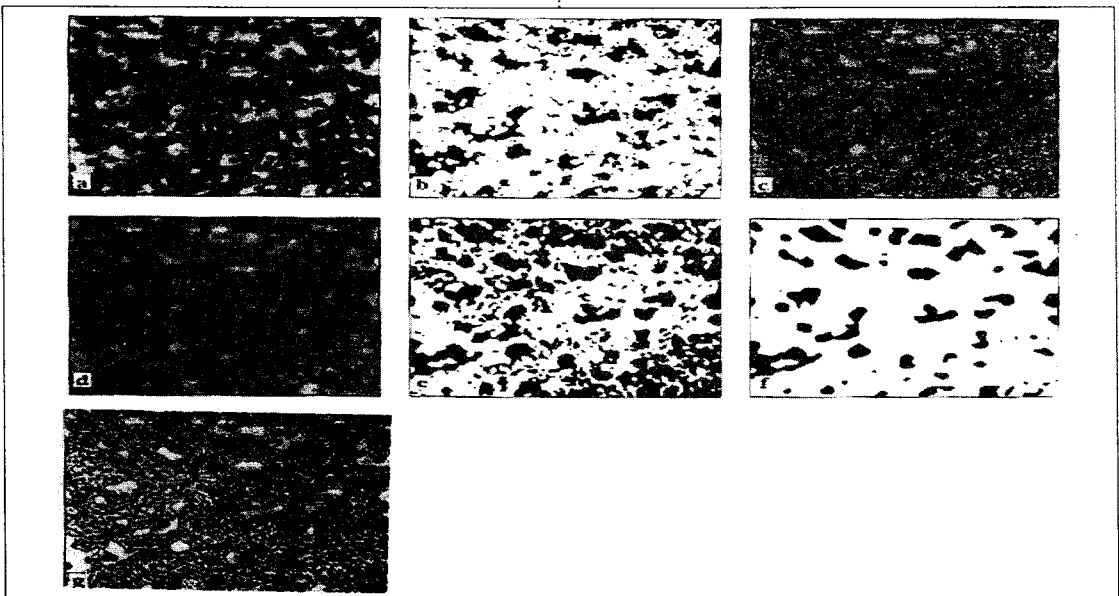


Fig 30. Texture and brightness thresholding of the curds and whey image: (a) range image; (b) thresholding image a; (c) leveled original image; (d) smoothing of image c; (e) thresholding image d; (f) Boolean AND of images b and e; (g) outlines from image f(superimposed on original).

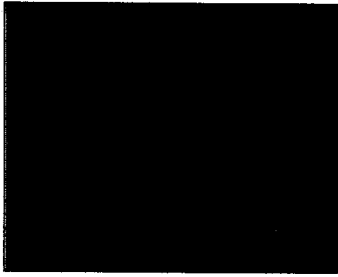


Fig 31. An image containing regions that have different textural orientations, but the same average brightness, standard deviation and spatial scale.

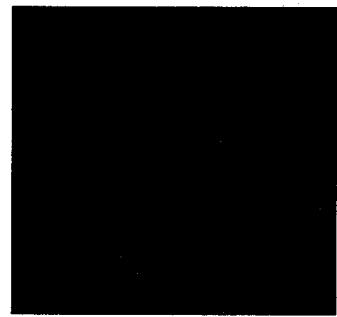


Fig 34. Regions selected by thresholding the images in Figure 33.

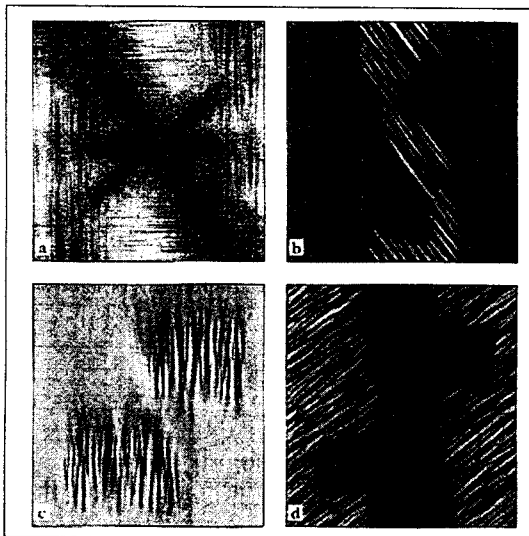


Fig 32. Isolating the directional texture in frequency space: (a) two-dimensional frequency transform of the image in Figure 31; (b)-(d) retransformation using masks to select each of the orientations.

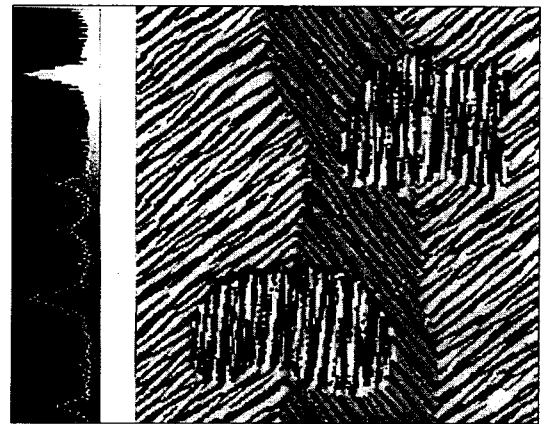


Fig 35. Application of the Sobel operator to the image in Figure 31, calculating the orientation of the gradient at each pixel. The brightness histogram shows six peaks, in pairs for each principal textural orientation

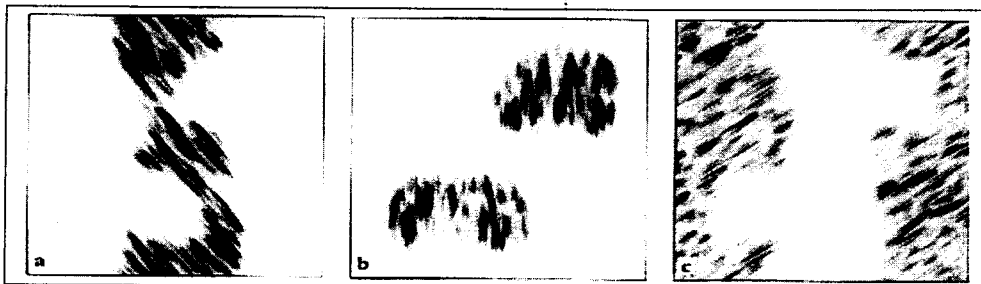


Fig 33. Application of a range operator to the images in Figure 32 b, c, and d.



Fig 36. Thresholding binary images from Figure 35.



Fig 37. Outlines showing the regions defined by applying a closing operation to each of the images in Figure 36.

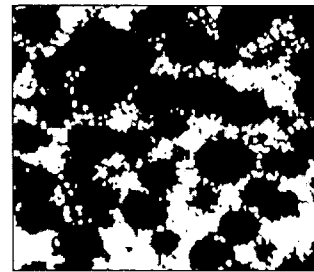


Fig 40. Binary image produced by thresholding Figure 38a.

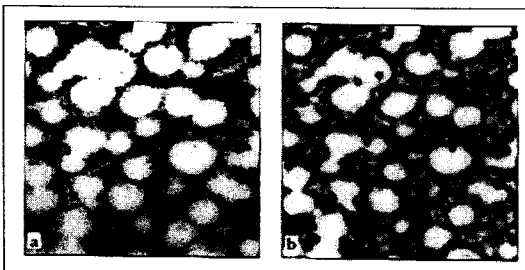


Fig 38. (a) Light microscope image of bone marrow; (b) the result of applying a variance operator.

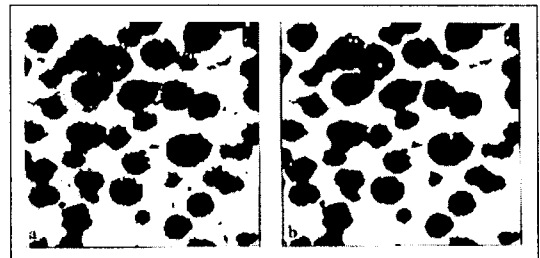


Fig 41. Two-dimensional thresholding: (a) ANDing together binary images selected by thresholding the two images individually; (c) using a non-rectangular threshold region directly on the two-dimensional histogram.

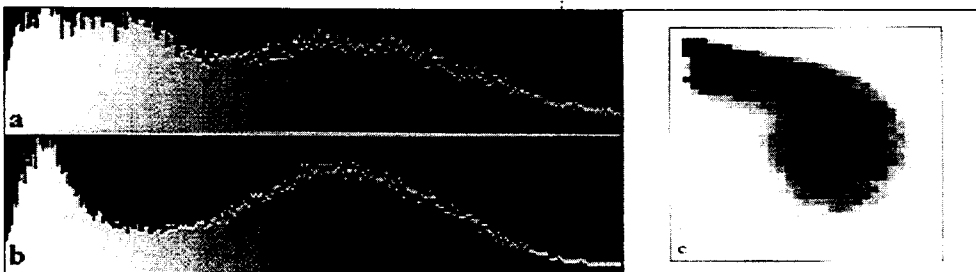


Fig 39. (a) and (b) Brightness histograms for the images in Figure 38; (c) the two-dimensional histogram

8. Including position information

- 히스토그램은 여러 가지 밝기 값을 갖는 화소들의 빈도만을 나타내고, 화소들의 위치나 이웃 화소의 밝기 값 정보는 갖지 않는다.
- 히스토그램에서의 최소값 결정 문제.(그림 42)
- 서로 다른 영역의 밝기 값들이 겹칠 경우 히스토그램의 최소값으로 thresholding 해도 잘못 분류되는 화소들이 발생하게 된다.(그림 43)
- 그림 44 : Sparse dot map.

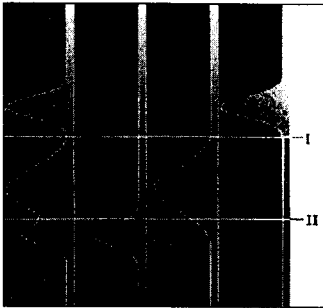


Fig 42. An example histogram from a specimen with three distinct regions.

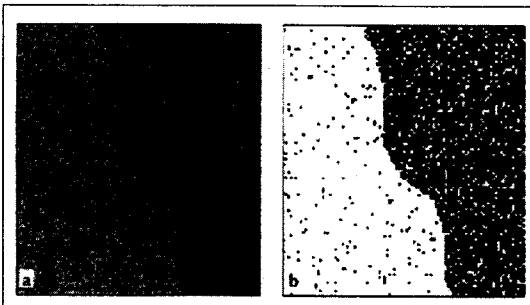


Fig 43. A test image containing two whose mean brightness levels are different, but which have variations in individual pixels are overlap: (a) original image; (b) result of setting a simple threshold at the minimum point.

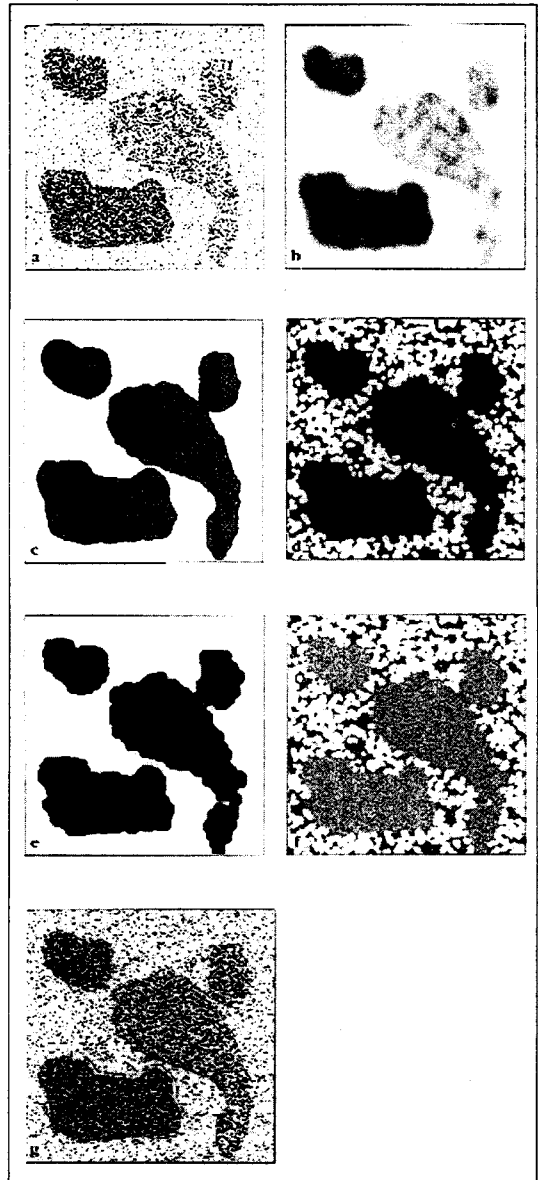


Fig 44. Thresholding a sparse dot image: (a) X-ray dot map; (b) gray scale image formed by counting the dots within a 15-pixel-diameter circle centered on each pixel; (c) boundary determined by thresholding image b; (d) application of closing operation to fill the gaps between closely spaced pixels in the image a; (e) application of an opening operation to remove small dark regions.

- 평활화, median filter 등을 이용하여 히스토그램을 분할하기 쉽도록 바꾸어줌.(그림 45-46)

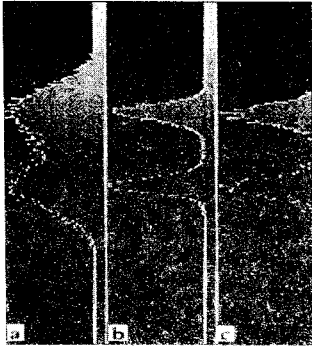


Fig 45. Histogram of an image in Figure 42: (a) original; (b) after smoothing; (c) after median filtering.

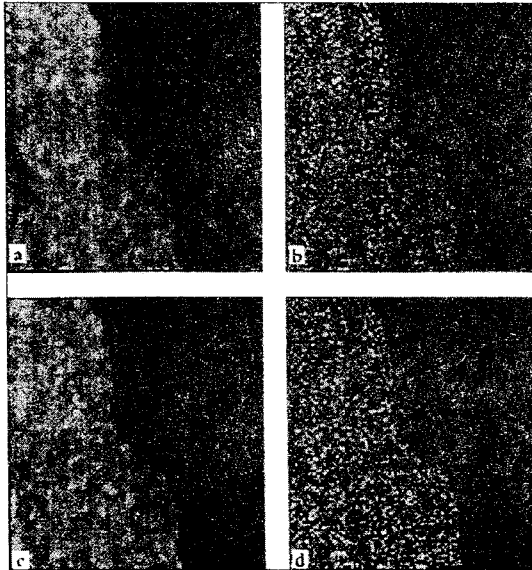


Fig 46. Processing the image in Figure 42 to modify the histogram: (a) smoothing with a Gaussian kernel; (b) the boundary produced by thresholding image a; (c) median processing; (d) the boundary produced by thresholding image c.

- Threshold 값에 대한 영역들의 전체 면적, 전체 둘레 길이, 면적의 변화량, 둘레 길이의 변화량 그래프를 이용하면 더욱 유용한 threshold 값을 구할 수 있다.(그림 47-50)



Fig 47. A test image for automatic threshold adjustment, and its brightness histogram.

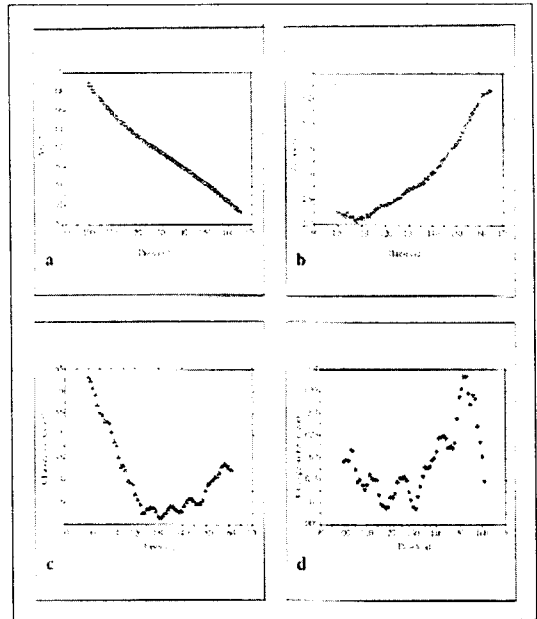


Fig 48. (a) Plot of total area of the dark phase; (b) plot of total boundary perimeter; (c) plot of change in area; (d) plot of change in perimeter.

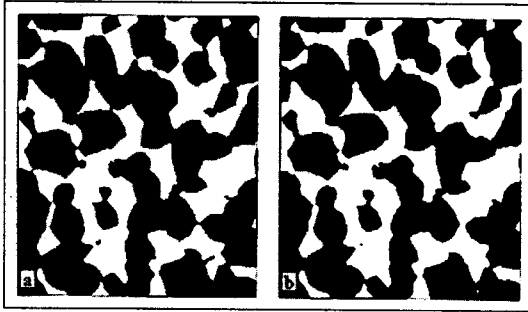


Fig 49. (a) Binary image produced by the application of threshold at brightness level of 119; (b) 131.

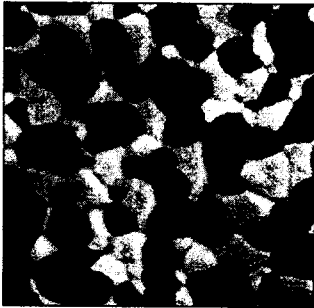


Fig 50. Superposition of the boundary selected with a threshold setting of 119 on the original image.

9. Selective histograms

- 최적 threshold 값을 구할 때의 문제점 : 영역들의 경계 부분에 있는 중간 밝기 값을 갖는 화소들의 영향.
- Edge 부분은 화소들을 제외하고 히스토그램을 구해서 threshold 값을 정하면 더욱 정확한 결과를 얻을 수 있음.(그림 51-54)
- 그림 52 : Sobel operator, 상위 20%의 gradient 크기의 값을 갖는 화소들로 thresholding.
- 그림 54 : Range operator, non-maximum suppression, 상위 20%의 값을 갖는 화소들로 thresholding

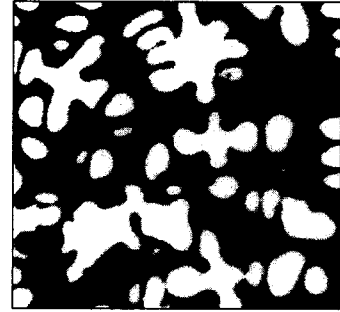


Fig 51. A test image containing three distinct phase regions.

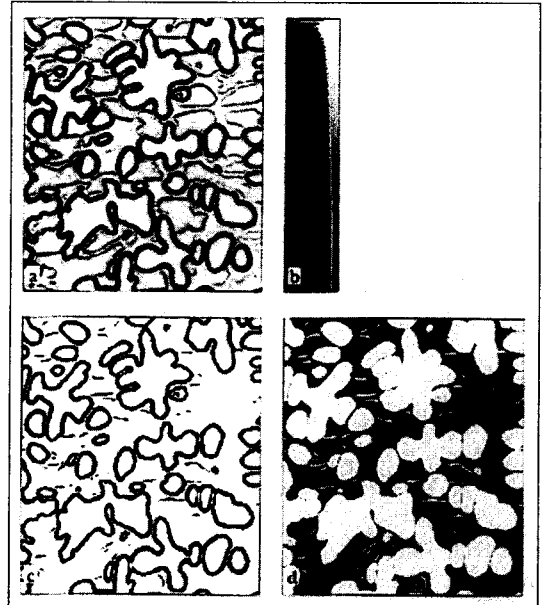


Fig 52. (a) Application of a gradient(Sobel) operator; (b) the histogram of the gradient; (c) thresholding image a to select the 20% of the pixels with the largest gradient; (d) elimination of many of the edge-straddling pixels.

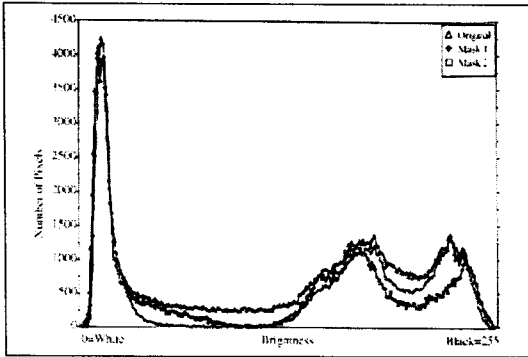


Fig 53. Brightness histograms from the original image in Figure 51 and the masked images.

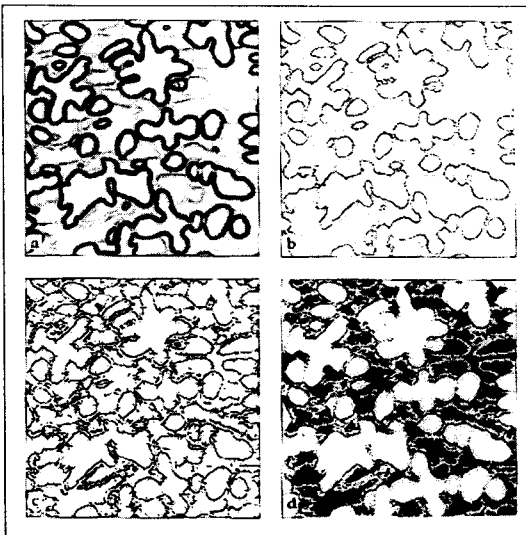


Fig 54. Another gradient mask; (a) application of a 5-pixel wide octagonal range operator; (b) non-maximum suppression applied to image a; (c) thresholding image b to keep the darkest 20% of the pixels; (d) masking of original image with image c.

10. Contours

• 특징을 추출하는 또다른 방법 : contour를 이용한

경계선 정보 추출, 지형도의 등고선.

• contour의 성질 : 연속성(그림 55-56)

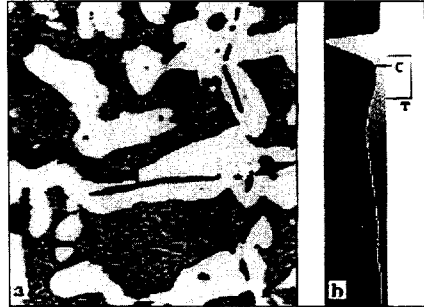


Fig 55. Cast iron with ferrite(white) and graphite(black): (a) original image; (b) brightness histogram showing levels used for contour(c) and threshold(t): (c) contour lines drawn using the value shown in b; (d) pixels selected by the threshold setting shown in b.

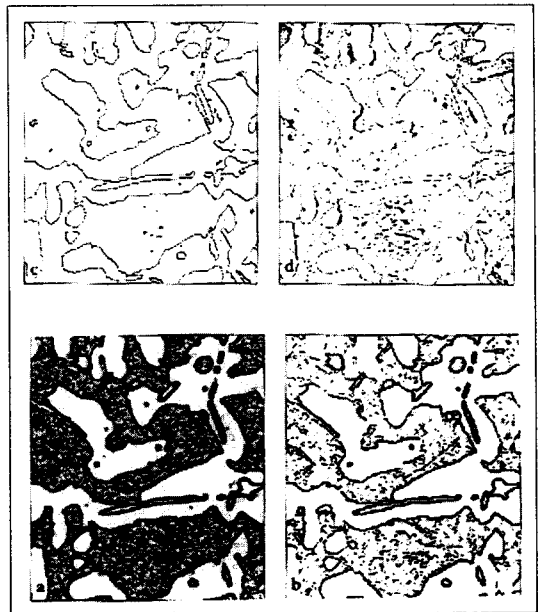


Fig 56. (a) Gradient image obtained by applying a Sobel operator; (b) the pixels selected by thresholding the 20% darkest values.

• contour를 이용한 영상 분석의 예 : 그림 57-60

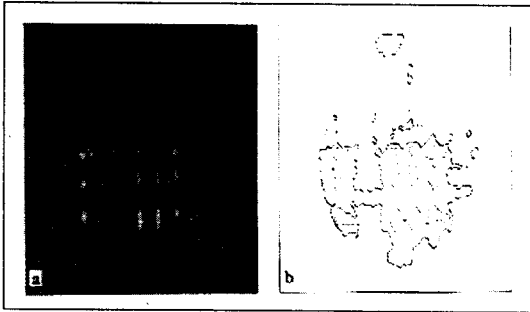


Fig 57. Ion microprobe image of boron implanted in a silicon wafer: (a) original image; (b) two iso-brightness or iso-concentration contour values.

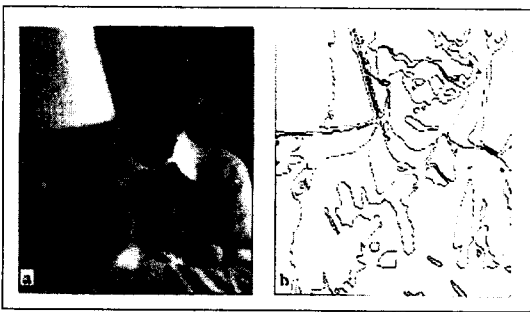


Fig 58. (a) Real-world image; (b) four contour lines drawn at selected brightness values.

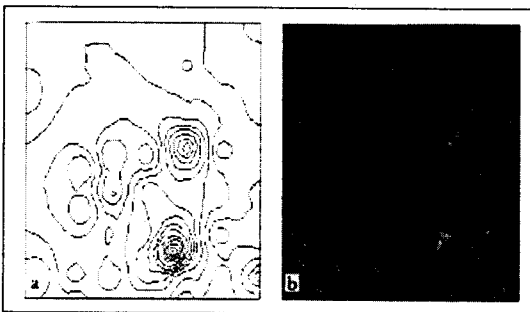


Fig 59. (a) Elevation contour map from a range image; (b) a reconstructed and rendered view of the surface.

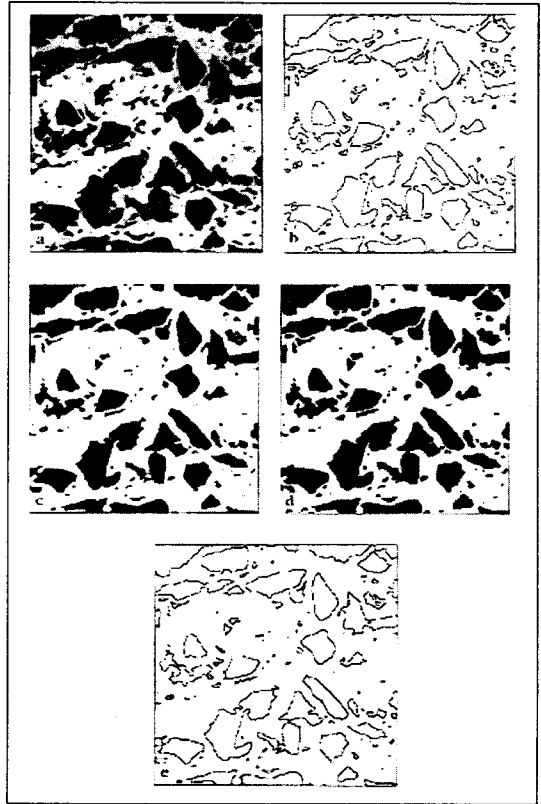


Fig 60. Selection of features in image: (a) light micrograph of a cross section of a coating on a metal; (b) outlines of particles and voids obtained by setting a contour level; (c) features or regions obtained by thresholding; (d) regions obtained by automatically filling the boundaries from b; (e) outlines obtained by taking the custer of c.

II. Image representation

- 이진 영상의 여러 가지 표현 방법 : 화소 기반, 경계선 기반(그림 61)
- Run-length encoding : 이진 영상의 압축에 사용됨. Fax transmission(그림 62). 면적 측정이 쉬운 반면 영역의 모양과 둘레 길이를 알기 어렵다.
- Boundary representation : 영역의 모양과 둘레 길

이를 쉽게 알 수 있다. 구멍이 있는 영역을 표현하기 어려운 것이 단점.

- Chain coding : 영역의 둘레 길이를 가장 빨리 계산할 수 있음.

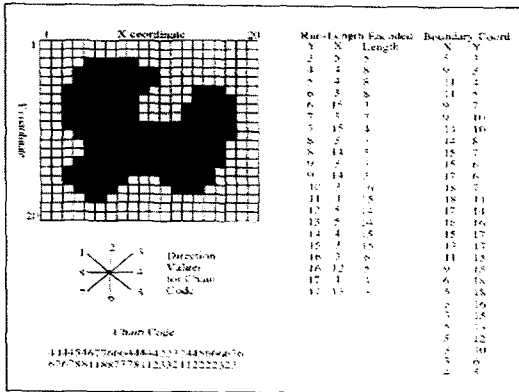


Fig 61. Encoding the same region in a binary image by run-length encoding, boundary polygonal representation, or chain code.



(a)



(b)

Fig 62. Representating a black-and-white image for fax transmission: (a) original; (b) run-length encoded.