華中科技大學

Image Enhancement

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- Automated contrast enhancement
- Rank Filtering
- Adaptive Filters
- Mode Filter
- Image Math

Automated contrast enhancement

- allows a certain percentage of the pixels in the output image must be saturated either full black or full white.
- utilizes the cumulative distribution function to identify the intensity values at which the appropriate percentages will saturate when a linear contrast enhancement is performed.

Automated contrast enhancement

Step 1: locate the value of blow such that

$b_{low} = b_k$ where $c(b_k) >= P_{low}$.

(The search starts at k =0 and proceeds through increasing values of k.)

Step 2: locate b_{hi}

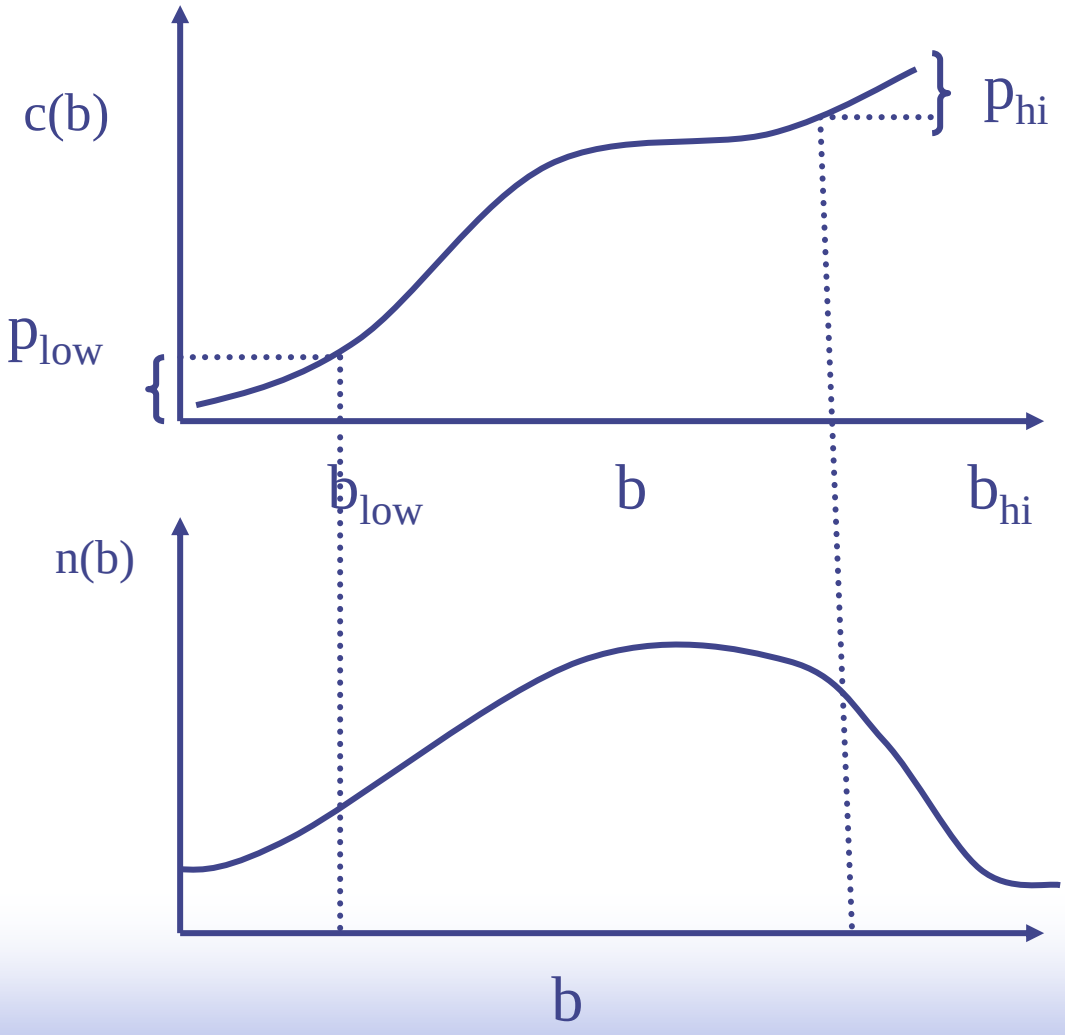
$b_{hi} = b_k$ where $[1- c(b_k)] > p_{hi}$

(where the search starts at $k = k_{max}$ and proceeds downward in k.)

Step 3: Perform linear contrast Enhancement.

Example: automated ends-in search contrast enhancement

Automated contrast enhancement



Non-linear Filtering

- Homomorphic Filters
- Polynomial Filters
- Order Statistics Filters
- Morphological Filters

同态滤波器、多项式滤波器
形态滤波器、排序统计滤波器

赵春晖，数字形态滤波器理论及其算法研究，博士论文

Rank Filtering

- Non-linear filters known collectively as “order statistic” filters or rank filters
- Compile a list of intensity values in the neighborhood of a given pixel, sort this list into ascending order, then select a value from a particular position in the list to use as the new value for the pixel.

Rank Filtering

- **Median Filter**
- **Minimum Filter**
- **Maximum Filter**
- **Range Filter**
- **Hybrid Median**

Minimum Filter

- The minimum filter is a rank filter in which the lowest (darkest) intensity value from the neighborhood is selected
- Causes darker regions of an image to increase in size and dominate the lighter regions
- Also known as greyscale dilation

Maximum Filter

- The maximum filter is a rank filter in which the highest (brightest) intensity value from the neighborhood is selected
- Causes brighter regions of an image to increase in size and dominate the darker regions
- Also known as greyscale erosion

Range Filter

The range filter is a rank filter in which the difference between the maximum and minimum intensity values in a neighborhood is selected

– An omnidirectional, non-linear edge-detector

Hybrid Median

Edge-preserving median

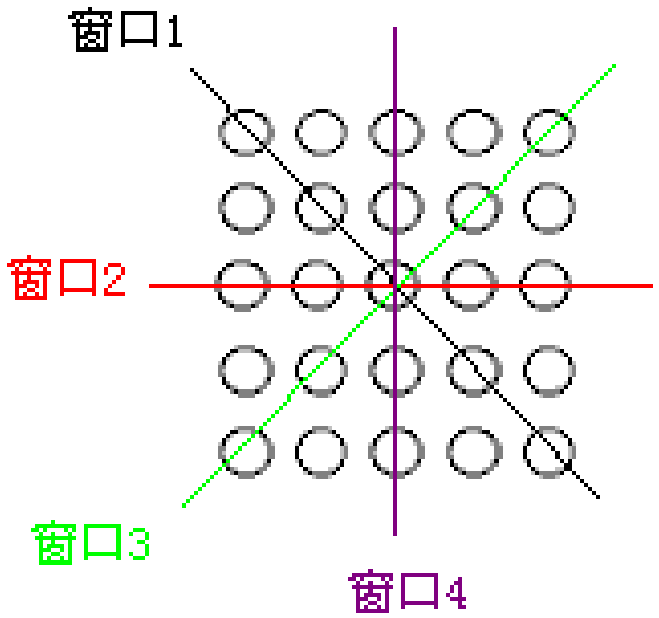
– In a 5×5 neighborhood, pixels are ranked into two different groups (*a* and *b*)

– Median values from both groups are compared to the central pixel

– The median of that set is the new pixel value

b		*a*		*b*
	b	*a*	*b*	
a	*a*	X	*a*	*a*
	b	*a*	*b*	
b		*a*		*b*

Multi-stage Median



(1)求各窗口中的中值

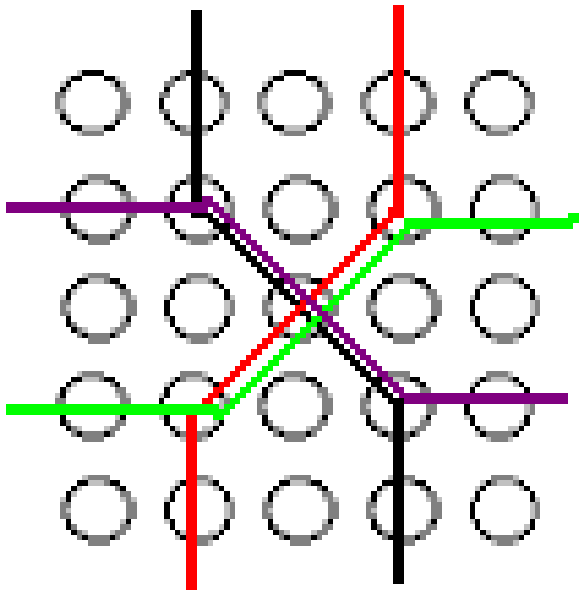
M1,M2,M3,M4

(2) V1=MIN(M1,M2,M3,M4)

(3) V2=MAX(M1,M2,M3,M4)

(4) MEDIAN(V1,V2,CENTER)

Multi-stage Median



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Median Filtering

- Repeated application of the median filter can cause ***posterization***
- Reducing the number of intensity values so that regions become uniform in intensity and edges between regions become abrupt
- Extremum filters replace the pixel value with either the maximum or minimum, whichever is closer to the mean value.

Mode Filter

- The mode of the distribution of intensity values in each neighborhood is the most likely value
  ≈ truncated median filter
  For an asymmetric distribution the mode is the highest point.
- To calculate the mode filter:
  Discard a few values from the neighborhood so that the median is shifted towards the mode.

Mode Filter

For example:

- In a 3×3 neighborhood, discard the two intensity values which are most different from the mean.
- Rank the remaining seven.
- Assign the median to the central pixel.

Has the effect of sharpening steps.

Hybrid Filters

Hybrids of linear and nonlinear filters

α-trimmed Mean Filter

– Sorts values from a neighborhood into ascending order, discards a certain number of these values from either end of the list and outputs the mean of the remaining values

– If the ordered set of values is $f_1 \le f_2 \le \ldots \le f_{n^2}$ then the α-trimmed mean is:

$$\frac{1}{n^2-2\alpha}\sum_{i=\alpha+1}^{n^2-\alpha} f_i$$

Adaptive Filters

Properties of an image can vary spatially

- e.g. Gaussian random noise in an image
  - Normal smoothing is effective in homogeneous regions, adverse blurring effect in regions that are meant to be heterogeneous (due to the presence of edges)
- These effects can be minimised using an adaptive filter
  - Most compute local intensity level statistics within the neighborhood of a pixel and base their behavior on this information

Adaptive Filters

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Minimal Mean Square Error Filter

$$g(x,y) = f(x,y) - \frac{\sigma_n^2}{\sigma^2(x,y)}\left[f(x,y) - \overline{f}(x,y)\right]$$

- σ_n^2 is an estimate of noise variance
- $\sigma^2(x,y)$ is the intensity variance computed for the neighborhood centred on (x,y)
- f(x,y) is the mean intensity value in that neighborhood

Image Math

Useful for masking and compositing of images

Two types of image combination:

arithmetic (image math) -〉 grayscale images

logical (boolean) -〉 binary images

Image Addition

Image addition superimposes information

- Pixels in the resulting image have values in the range 0-510
- Normalise the resulting image
  - divided by two → image averaging or converted to 16-bit
- Primarily used for noise removal

"Alpha blending"

- Give more emphasis to one image than the other

$$g(x,y) = \alpha f_1(x,y) + (1-\alpha) f_2(x,y)$$

- When α=0.5, g(x,y) becomes a simple, even-weighted average

Image Addition

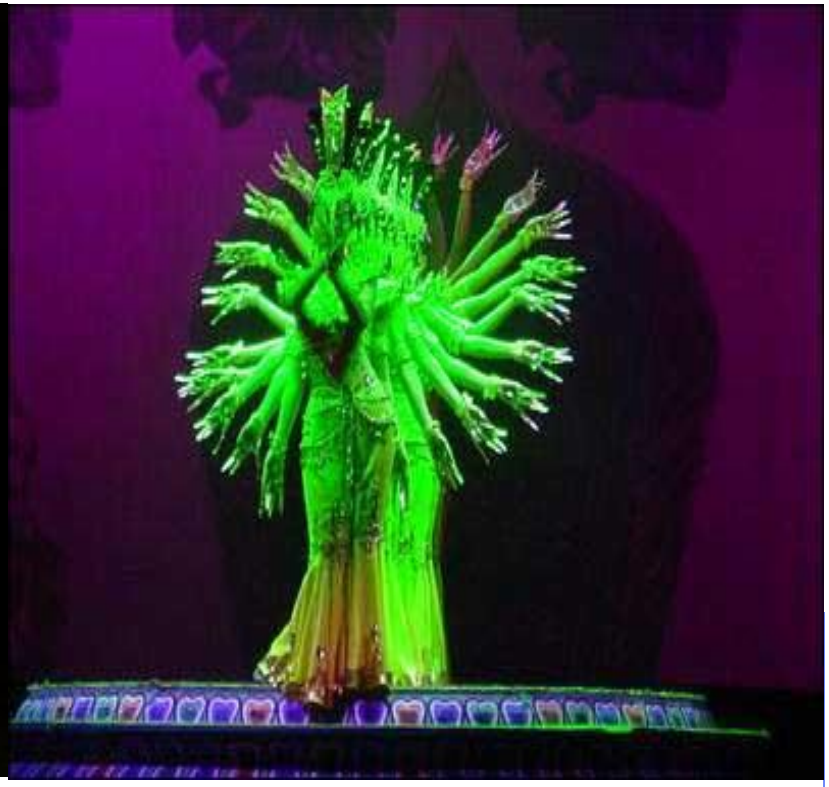


Image Addition

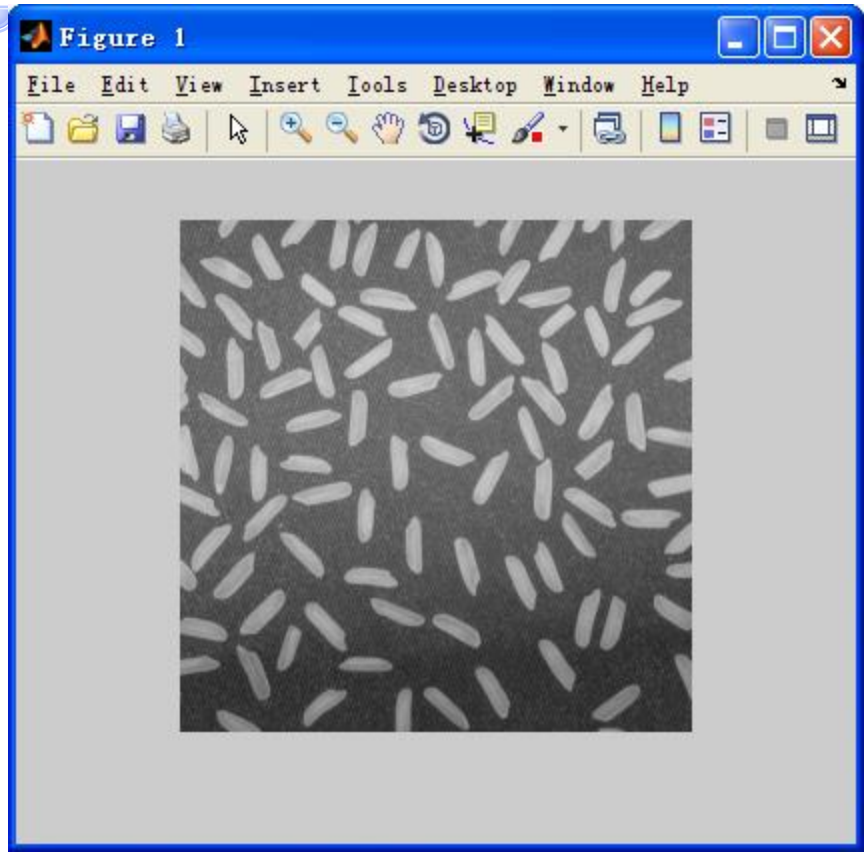
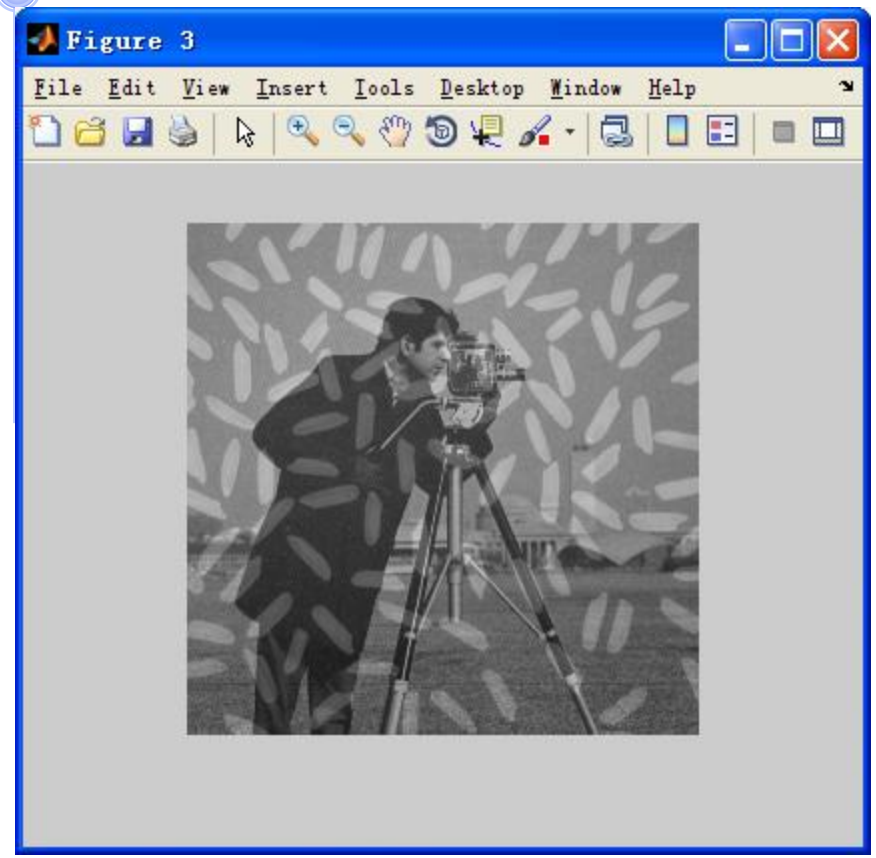
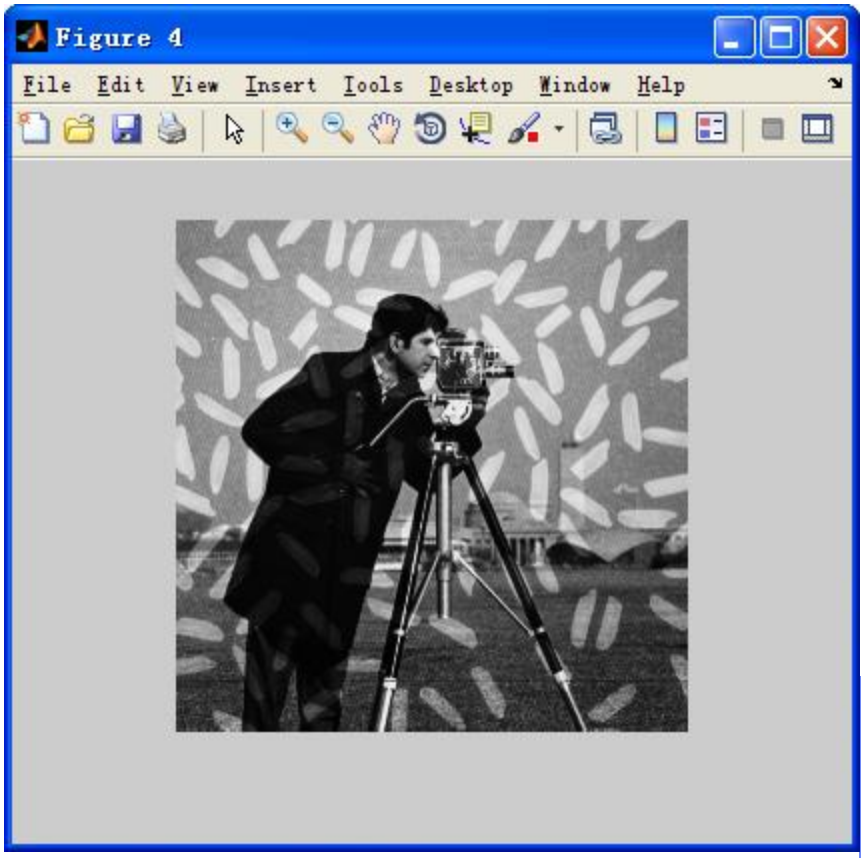


Image Addition





两幅图简单平均相加

$$I \oplus J = \psi^{-1}(\psi(I) + \psi(J))$$

$$\psi(I) = \log((M - I) / I)$$

$$M = 255$$

Image Subtraction

Image subtraction calculates the differences between images

- Used primarily for change detection

Pixels in the resulting image have values in the range –255 to +255

$$g(x,y) = \left| f_1(x,y) - f_2(x,y) \right|$$

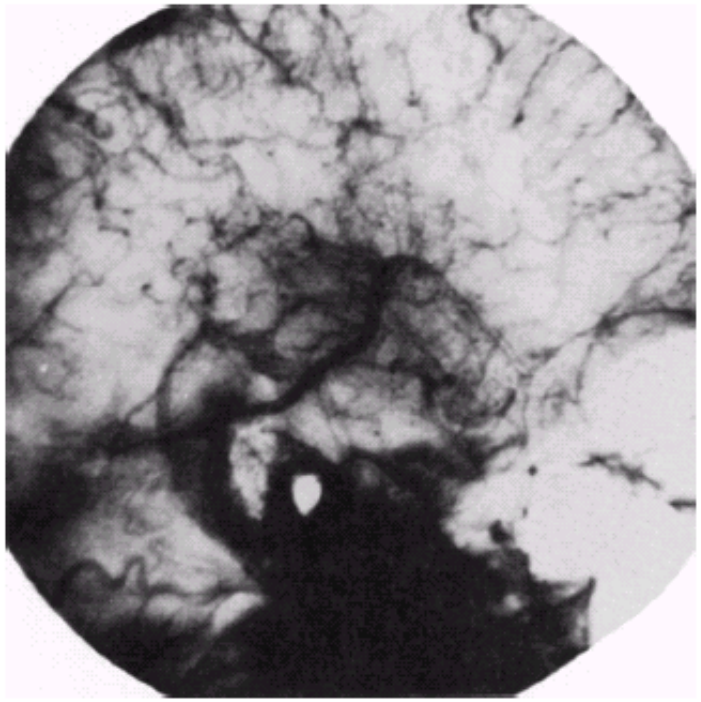
Changes will be indicated by pixels in the difference image which have non-zero values.

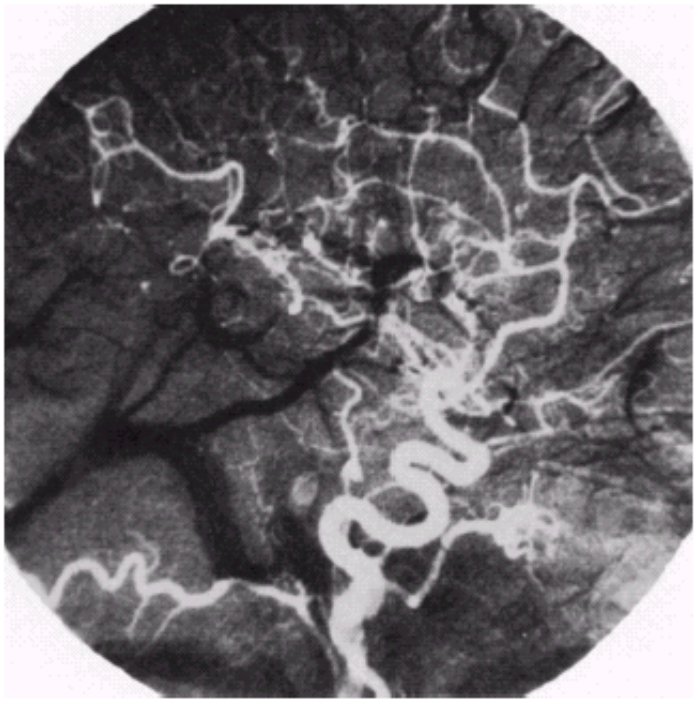
- The difference image will contain only features that change

Image Subtraction

- Sensor noise, slight intensity changes, and various other factors result in small differences which are of no significance.
- It is usual to apply a threshold to the difference image.
- Object motion can be measures through subtraction
  e.g. track the motion of cells in response to chemical cues.

Image Subtraction





a b

FIGURE 3.29
Enhancement by image subtraction. (a) Mask image. (b) An image (taken after injection of a contrast medium into the bloodstream) with mask subtracted out.

Image Minimum & Maximum

Image combination using min (or max) involves retaining the darker (or lighter) intensity values at each location

$$g(x,y) = \min(f_1(x,y), f_2(x,y))$$

e.g. To build up a confocal scanning light microscope (CSLM) image with greater depth of field

图像的空间域增强讨论

(1)模板个数　单个模板 VS 多个模板
(2)模板形状　正方形 VS 五变形 VS 六边形
　　其他形状
(3)模板大小　3×3 VS 5×5 VS 3×1 …
(4)像素选择　所有像素 VS 部分像素
　选择依据　固定个数 VS 可控范围 (Sigma)
(5)像素权重　等权重 VS 非等权重
(6)权重大小　固定权重 VS 自适应权重
(7)模板组合　从多个模板中选择一个 VS
　　模板有不同权重

参考书：贾永红，《数字图像处理》，2003年

图像的空间域增强讨论

可用的信息：

灰度

空间

出发点：

灰度的连续性

空间的连续性

边缘出现的变迁（空间的跳跃性）

点之间的相互影响

多模板—> 寻找同质区域。

一、局部平均法

取一个邻域内的平均值，作为该中心的输出值。

- 算法简单，处理速度快；
- 缺点是在降低噪声的同时使图像产生模糊，特别在边缘和细节处；
- 邻域越大，去噪能力增强，模糊程度更严重。

二、超限像素平均法

以(x,y)为中心，计算其邻域内的平均值。若(x,y)点的灰度与平均值之间的差大于某个阈值，则用平均值代替，否则保持不变。

- 算法对抑制椒盐噪声比较有效，对保护仅有微小灰度差的细节及纹理也有效。
- 随着邻域增大，去噪能力增强，但模糊程度也变大。
- 同局部平滑法相比，超限像素平滑法去椒盐噪声效果更好。

三、灰度最相近的K个邻点平均法

窗口中心像素的灰度值用窗口内与中心像素灰度最接近的K个邻像素的平均灰度来代替。

较小的K值使噪声方差下降少，但保持细节较好；而较大的是值平滑噪声较好，但会使图像边缘模糊。

经验：对于3x3的窗口，取K = 6为宜。

三、灰度最相近的K个邻点平均法

Sigma 滤波

求方差Sigma，在[Gc-k*Sigma, Gc+k*Sigma]内求平均。

k= 0.1 ~ 2

四、梯度倒数加权平均法

梯度：中心点与窗口内某个点的灰度差。

若梯度为0，取梯度倒数为2。否则，梯度倒数取为 1/灰度差的绝对值。

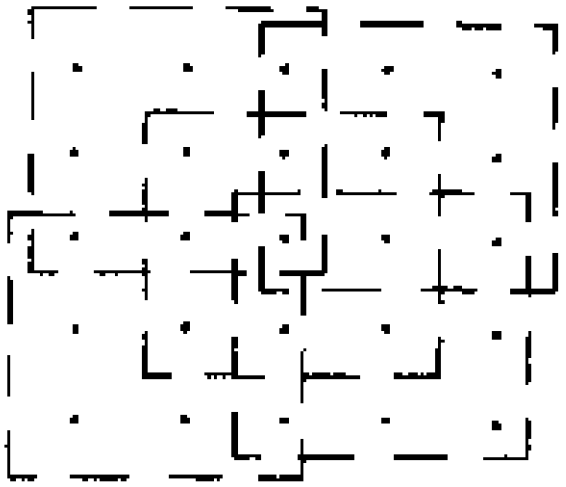
最后，将模板内各系数进行归一化处理。

（即所有系数的总和视为1）

五、最大均匀性平滑法

取包含(x,y)点的五个窗口。用梯度衡量灰度变化大小。将灰度变化最小的窗口作为最均匀窗口。

最均匀窗口的平均值取代(x,y)处的灰度值。

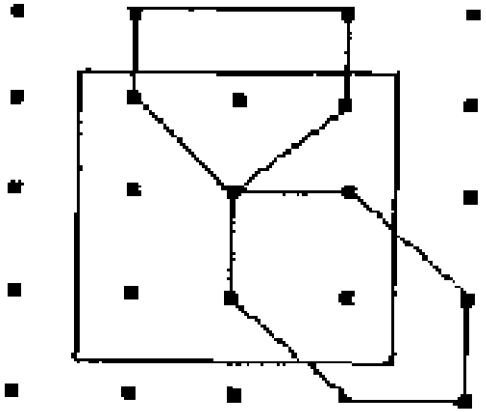


六、有选择保持边缘平均法

模板：1个3×3；

4个5边形；

4个六边形



计算各模板内各的均值和方差。最小方差的模板对应的均值为中心点的灰度值。

方法五的改进。

核心思想：

找出同质区域，并在该区域平均

参考文献

Weighted median filters: a tutorial , IEEE Trans Circuits Syst,1996,43:(3)

Center Weighted median filters and their application to image enhancement, IEEE Trans. Circuits Syst.1991 38(9)

Optimak weighted median filter under structural constrains.
IEEE Trans Signal Process,1995,43(3)

Tri-state median filter for image denoising, IEEE Trans Image Process,1999

Noise adaptive soft-switching median filter, IEEE Trans Image Process,2001

基于方向的自适应多级中值滤波

贾永红，《数字图像处理》，2003年