图像增强

——邻域处理方法

许 向 阳
xuxy@hust.edu.cn

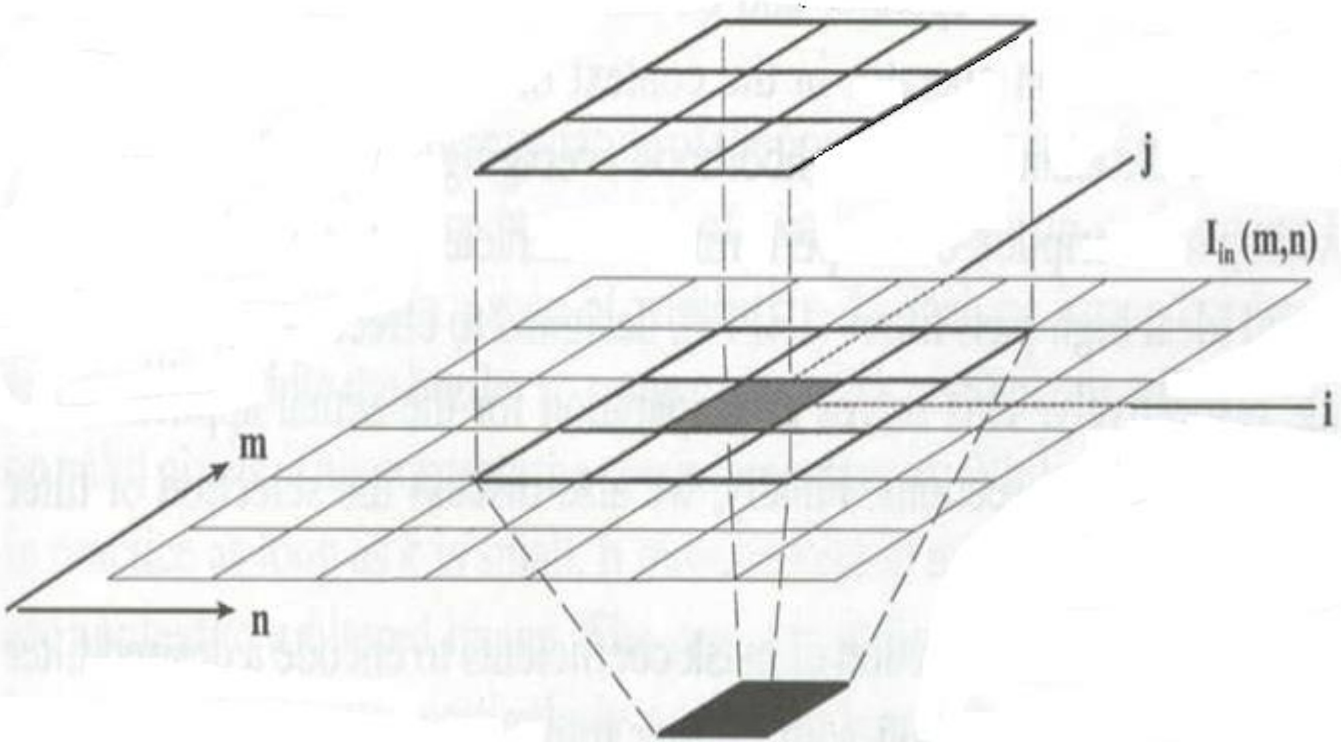
图像增强的邻域处理方法

华中科技大学

利用相邻像素的关系进行图像增强

- 分类
  - 平滑
    - 线性
    - 非线性
  - 锐化
    - 线性
    - 非线性

邻域处理的实现——模板操作



$$I_{out}(i,j) = \sum_{m,n} I_{in}(m,n)\ H(m-i, n-j)$$

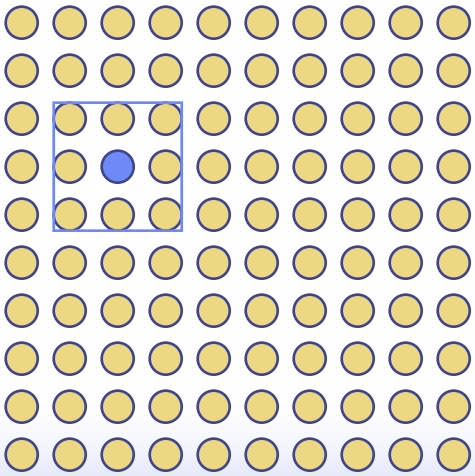
$$I(i,j)H(0,0)+I(i+1,j+1)H(1,1)+\ldots$$
$$+I(i-1,j-1)H(-1,-1)$$

邻域处理的实现——模板操作

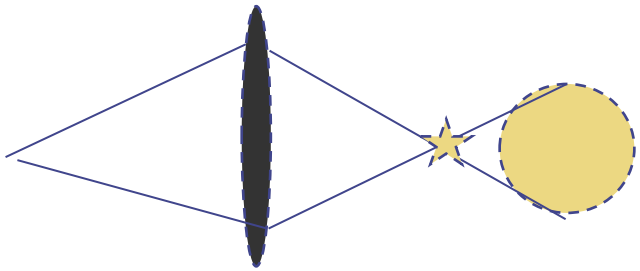
1. 模板在图像中漫游，并将模板中心与某像素重合
2. 将模板系数与模板下对应像素相乘
3. 将所有乘积相加
4. 将上述求和结果赋予模板中心对应像素

$K_{-1,-1}$	$K_{-1,0}$	$K_{-1,1}$
$K_{0,-1}$	$K_{0,0}$	$K_{0,1}$
$K_{1,-1}$	$K_{1,0}$	$K_{1,1}$

模板



邻域处理的实现——模板操作



点扩散函数 PSF

输入为一点光源时其输出像的光场分布

- 可以用一个模板来描述扩散系数
- 每个系数 大于等于 0
- 系数总和为 1

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

0	1/5	0
1/5	1/5	1/5
0	1/5	0

h_{-11}	h01	h11
h_{-10}	h00	h10
h_{-1-1}	h_{0-1}	h_{1-1}

平滑——物理学基础

图像平滑 与热扩散：　在一碗清水中滴一点墨水

用三点平均法对一维信号进行光滑处理 $\mathrm{f}(\mathbf{x})$

$$\mathrm{g}(\mathrm{x}) = \frac{1}{3}[f(x-1) + f(x) + f(x+1)]$$

平滑后的信号视为随时间变化的信号 $\mathrm{f}(\mathbf{x}, t)$

$$\mathrm{f}(\mathrm{x}, \mathrm{t}+1) = \frac{1}{3}[f(x-1,t) + f(x,t) + f(x+1,t)]$$

平滑——物理学基础

$$f(x,t+1)-f(x,t)=\frac{1}{3}f(x-1,t)-\frac{2}{3}f(x,t)+\frac{1}{3}f(x+1,t)$$

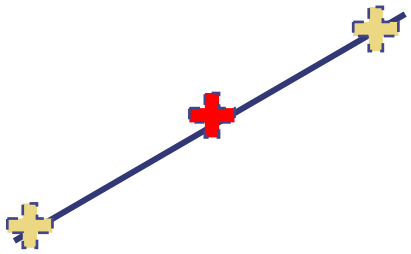
$$=\frac{1}{3}[f(x+1,t)-f(x,t)]-\frac{1}{3}[f(x,t)-f(x-1,t)]$$

$$\frac{\partial f(x,t)}{\partial t}=\frac{1}{3}\left[\frac{\partial f_{+}(x,t)}{\partial x}-\frac{\partial f_{-}(x,t)}{\partial x}\right]$$

$$=\frac{1}{3}\frac{\partial^2 f(x,t)}{\partial x^2}$$

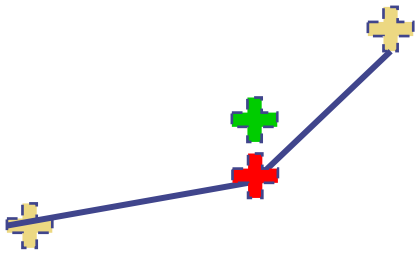
平滑——物理学基础

$$\frac{\partial f(x,t)}{\partial \mathrm{t}} = \frac{1}{3}\frac{\partial^2 f(x,t)}{\partial x^2}$$



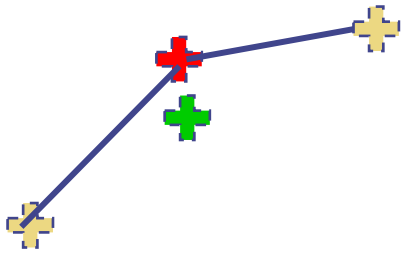
二阶导数为 0

平滑后值不变



二阶导数为正

平滑后值增加



二阶导数为负

平滑后值减少

平滑——物理学基础

$$f(x, t+1) = \frac{1}{4} f(x-1, t) + \frac{2}{4} f(x, t) + \frac{1}{4} f(x+1, t)$$

$$f(x, t+1) - f(x, t) = \frac{1}{4} f(x-1, t) - \frac{2}{4} f(x, t) + \frac{1}{4} f(x+1, t)$$

$$= \frac{1}{4}[f(x+1, t) - f(x, t)] - \frac{1}{4}[f(x, t) - f(x-1, t)]$$

$$\frac{\partial f(x, t)}{\partial t} = \frac{1}{4} \frac{\partial^2 f(x, t)}{\partial x^2}$$

平滑——物理学基础

讨论：平滑为什么会出现模糊效应？

从扩散的角度来理解。

一个点源 将其能量扩散到四周，

扩散系数为 滤波器模板旋转180度后的结果

平滑——物理学基础

各向同性的扩散：墨汁在水中的扩散

各向同性的高斯平滑

各向异性的扩散：油 在水面上扩散

各向异性的高斯平滑

方向？ 尺度？

Adaptive Steering Filter 自适应方向性滤波器

Nonlinear anisotropic structure tensor

非线性各向异性结构张量：估计图像的局部结构

图像增强——图像平滑

1、局部平均
2、中值滤波
3、多帧平均

一、局部平均法

$$g(x,y)=\frac{1}{M}\sum_{(m,n)\in N(x,y)}f(m,n)$$

0	1/5	0
1/5	1/5	1/5
0	1/5	0

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

邻域平均

$$g(x,y)=\sum_{m,n}f(m,n)H(x-m,y-n)$$

一、局部平均法

平均为何能够去噪声？

$$g(x,y)=f(x,y)+n(x,y) \qquad (2-3)$$

$$\begin{aligned}\overline{g}(x,y)&=\frac{1}{M}\sum_{(i,j)\in S}g(i,j)\\&=\frac{1}{M}\sum_{(i,j)\in S}f(i,j)+\frac{1}{M}\sum_{(i,j)\in S}n(i,j)\end{aligned} \qquad (2-4)$$

f(x,y)为原始图，n(x,y)为噪声

S：点(x,y)邻域内的点集，

M：S内总点数。

线性滤波

一、局部平均法

局部平均法的基本假设：

（1）图像由许多灰度恒定的小块组成。

（2）图像上的噪声是加性的、均值为零，且与图像信号互不相关。

根据假设（1），式（2-4）第一项非常接近 *f(x,y)*。

平滑后噪声方差

$$D\left\{\frac{1}{M}\sum_{(i,j)\in S} n(i,j)\right\}=\frac{1}{M^2}\sum_{(i,j)\in S} D\{n(i,j)\}=\frac{1}{M}\sigma_n^2$$

一、局部平均法

- 邻域加大，图像的模糊程度加剧
- 邻域偏小，图像的平滑程度不够

若 $$|f(x,y)-\frac{1}{M}\sum_{(m,n)\in N(x,y)}f(m,n)|>T$$

则 $$g(x,y)=\frac{1}{M}\sum_{(m,n)\in N(x,y)}f(m,n)$$

否则 $$g(x,y)=f(x,y)$$

二、中值滤波法

用局部中值代替局部平均值。

令[*f(x,y)*]--原始图像阵列，

[*g(x,y)*]--中值滤波后图像阵列，

f(x,y) --灰度级，

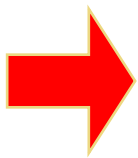
g(x,y) --以(x,y)为中心的窗口内各像素的灰度中间值。

非线性滤波

二、中值滤波法

例　取3X3窗口

212	200	198
206	202	201
208	205	207



212	200	198
206	205	201
208	205	207

从小到大排列，取中间值

198　200　201　202　205　206　207　208　212

二、中值滤波法

取N=3

… 80 90 200 110 120 …

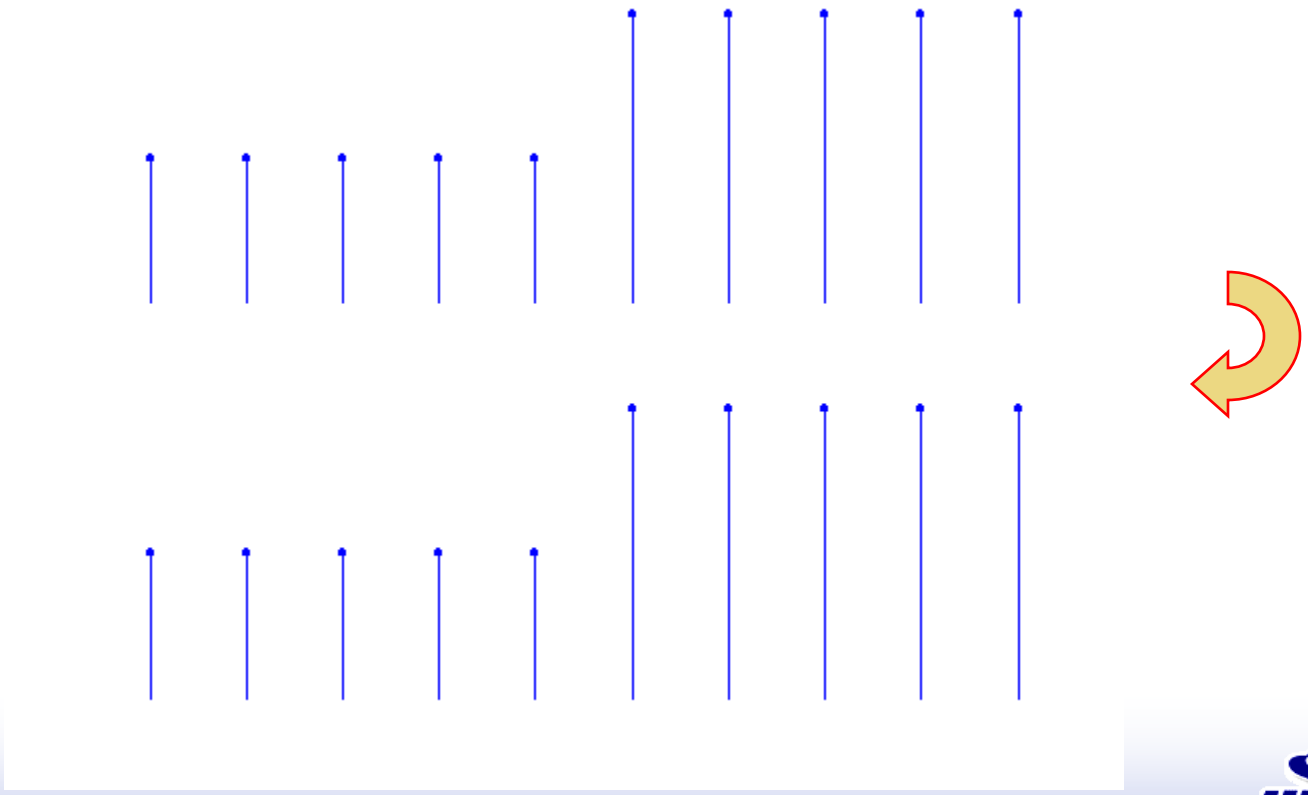
200显然是个噪声。

… 80 90 110 120 120 …

二、中值滤波法

抑制持续期小于窗宽（N=5）的1/2的脉冲

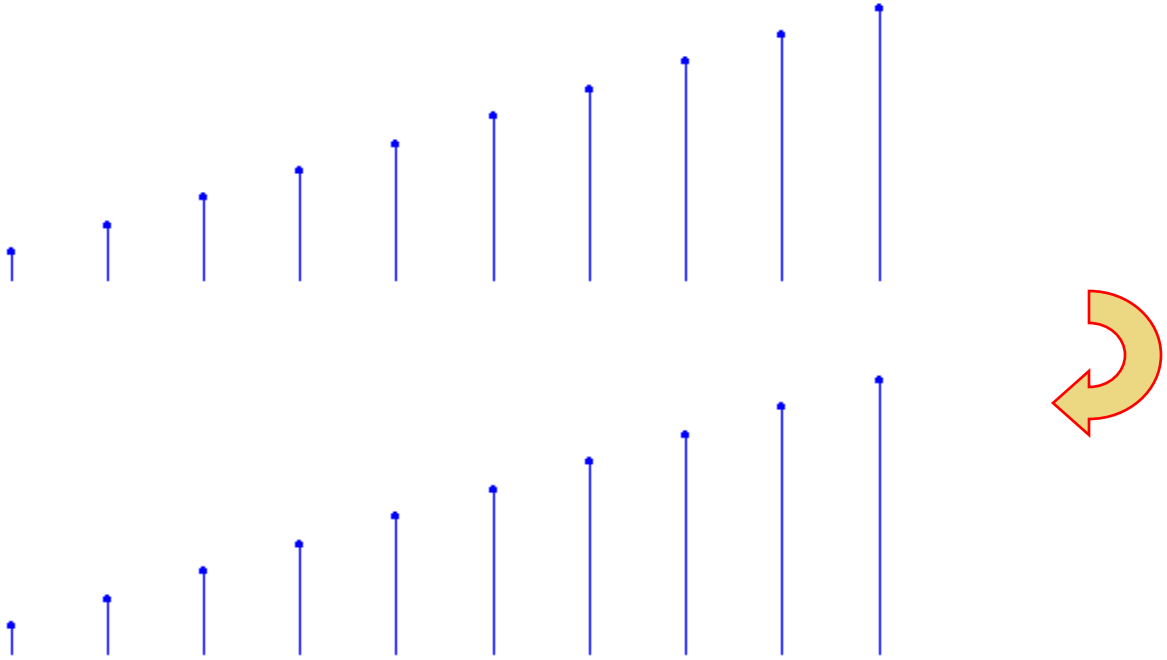
阶跃



二、中值滤波法

抑制持续期小于窗宽（N=5）的1/2的脉冲

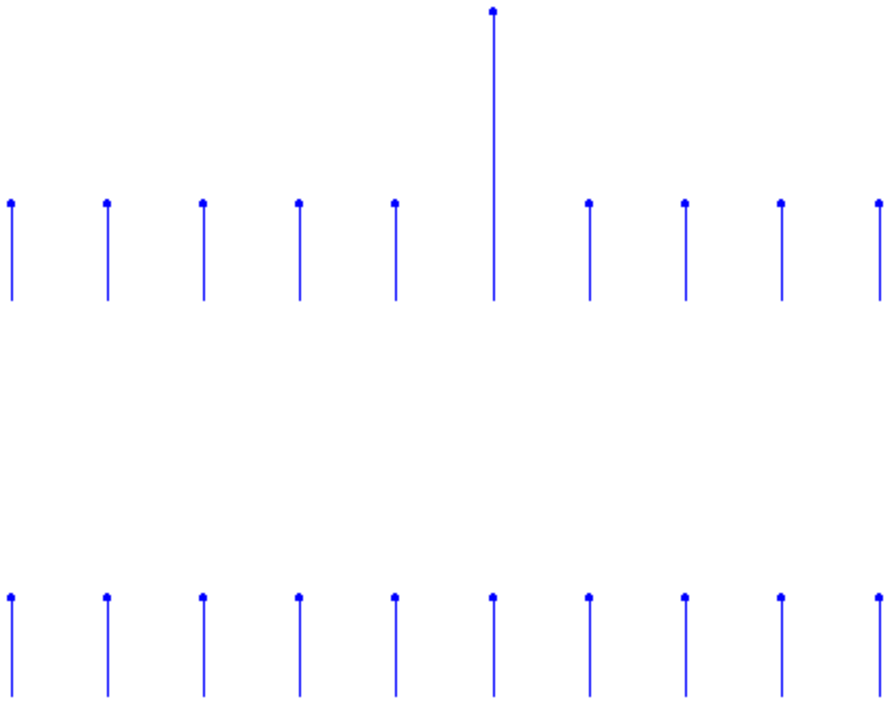
斜坡



二、中值滤波法

抑制持续期小于窗宽（N=5）的1/2的脉冲

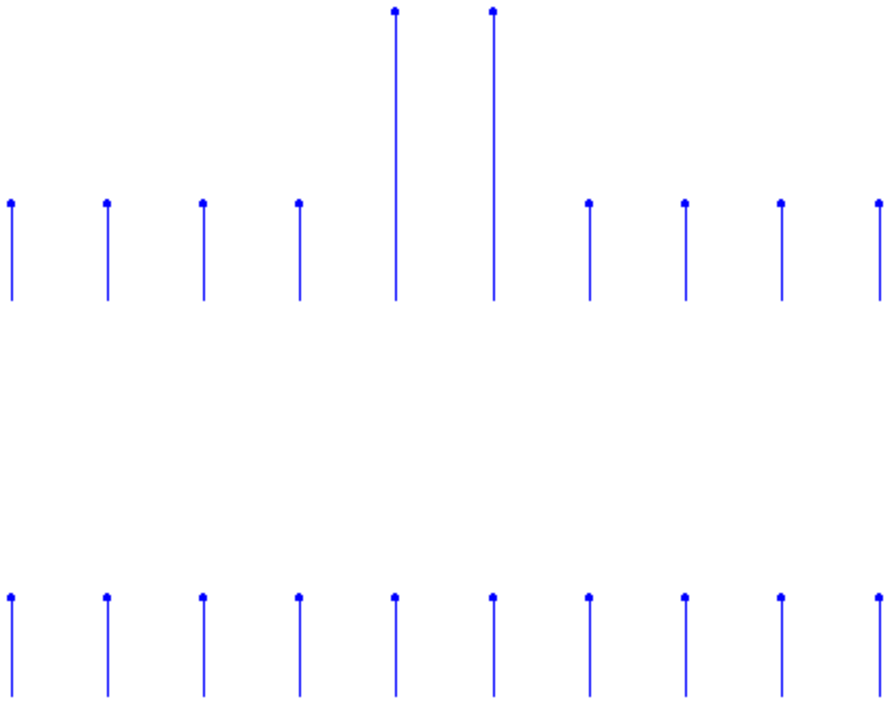
单脉冲



二、中值滤波法

抑制持续期小于窗宽（N=5）的1/2的脉冲

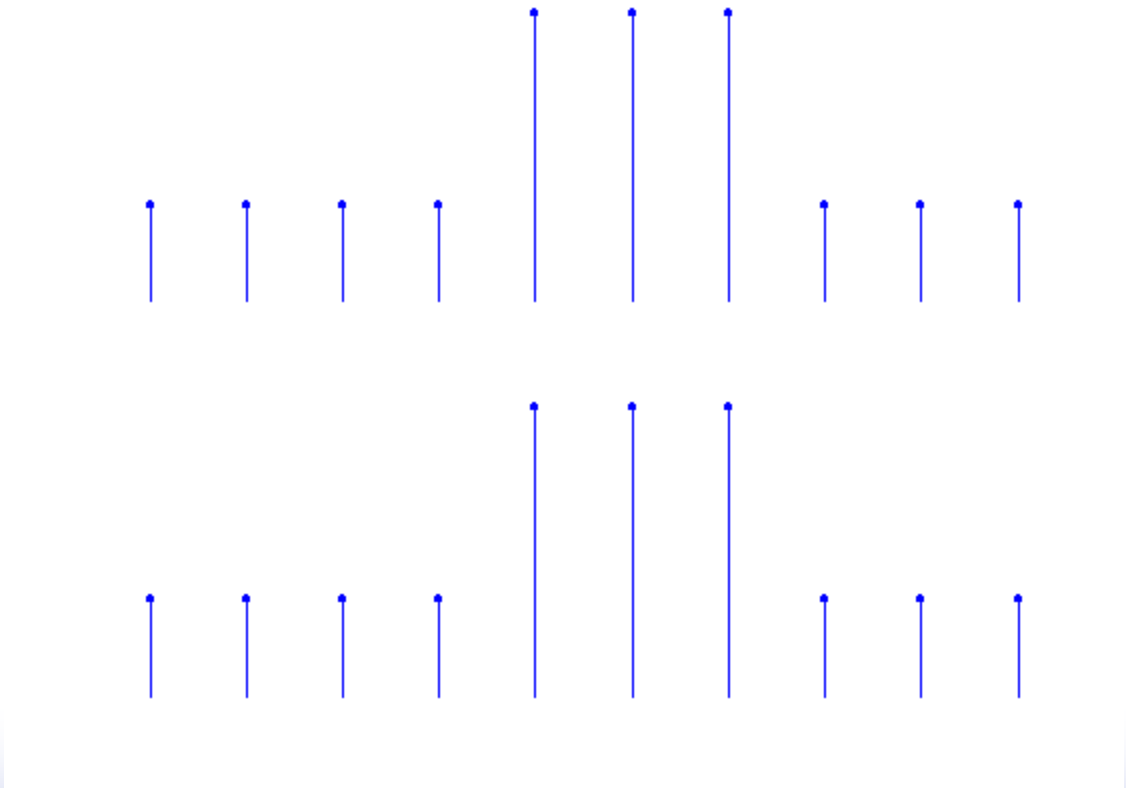
双脉冲



二、中值滤波法

抑制持续期小于窗宽（N=5）的1/2的脉冲

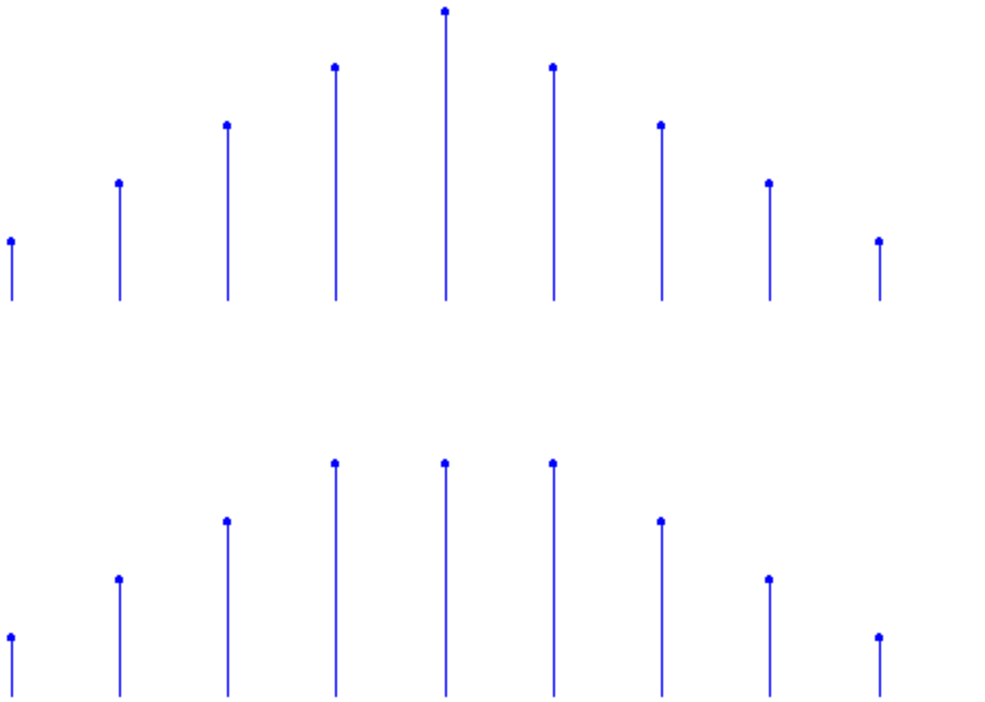
三脉冲



二、中值滤波法

抑制持续期小于窗宽（N=5）的1/2的脉冲

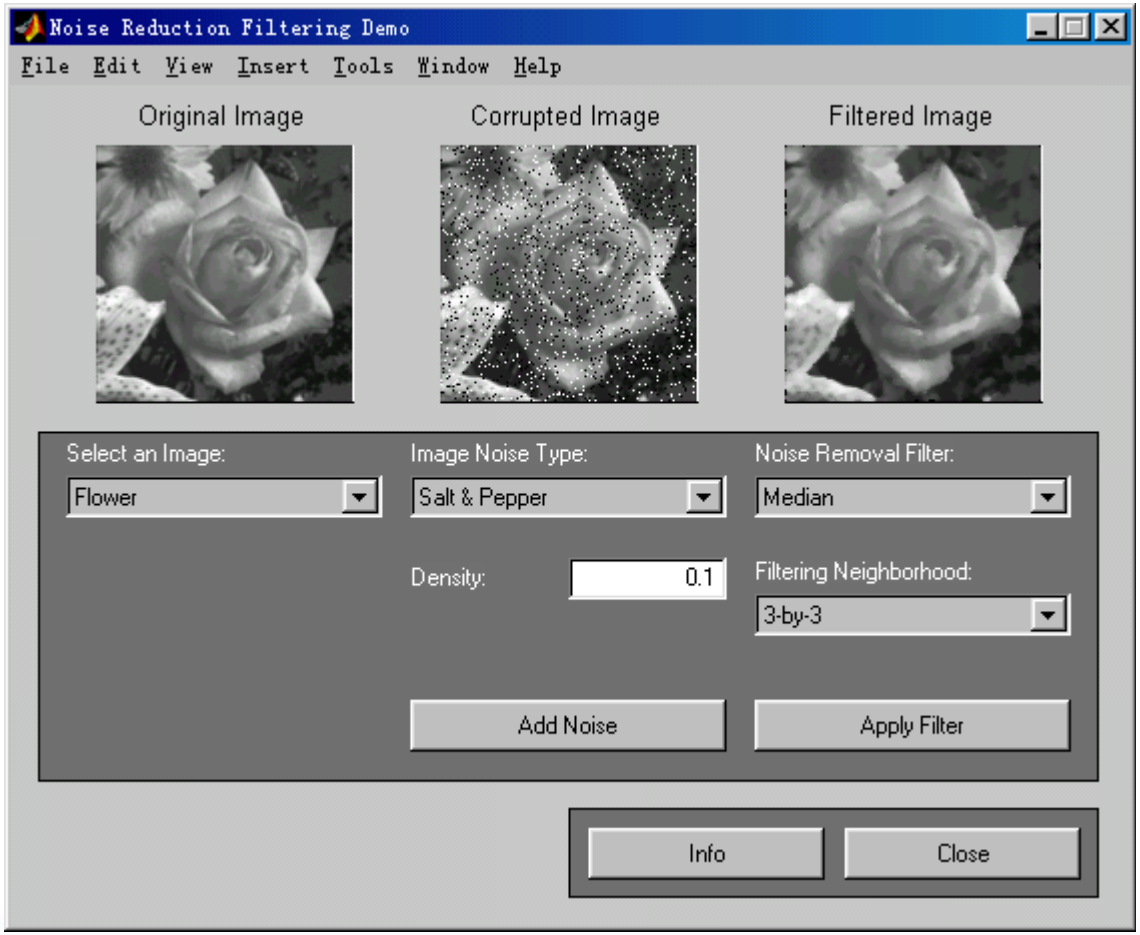
三角形



二、中值滤波法

中值滤波在抑制图像随机脉冲噪声方面甚为有效，且运算速度快，可硬化，便于实时处理。

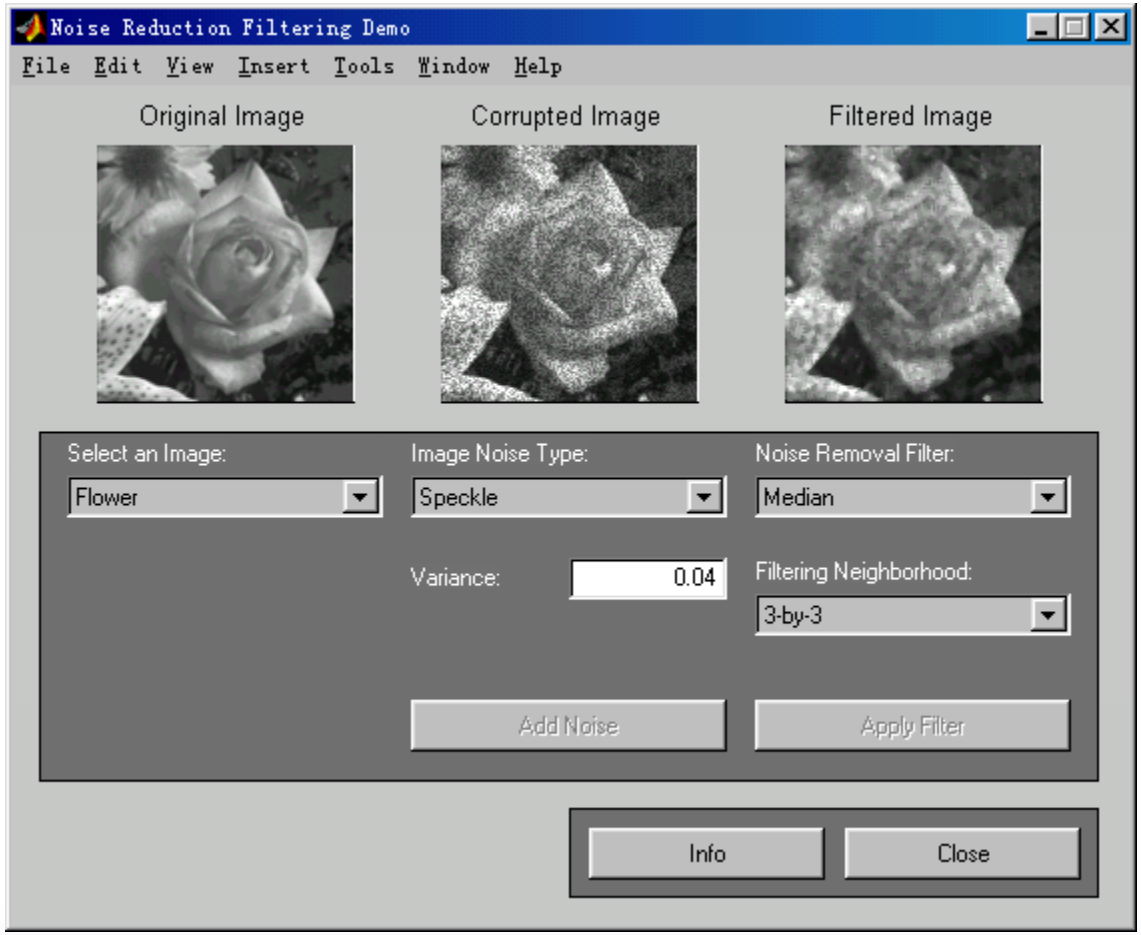
二、中值滤波法


Noise Reduction Filtering Demo
File Edit View Insert Tools Window Help
Original Image
Corrupted Image
Filtered Image
Select an Image:
Flower
Image Noise Type:
Salt & Pepper
Noise Removal Filter:
Median
Density:
0.1
Filtering Neighborhood:
3-by-3
Add Noise
Apply Filter
Info
Close

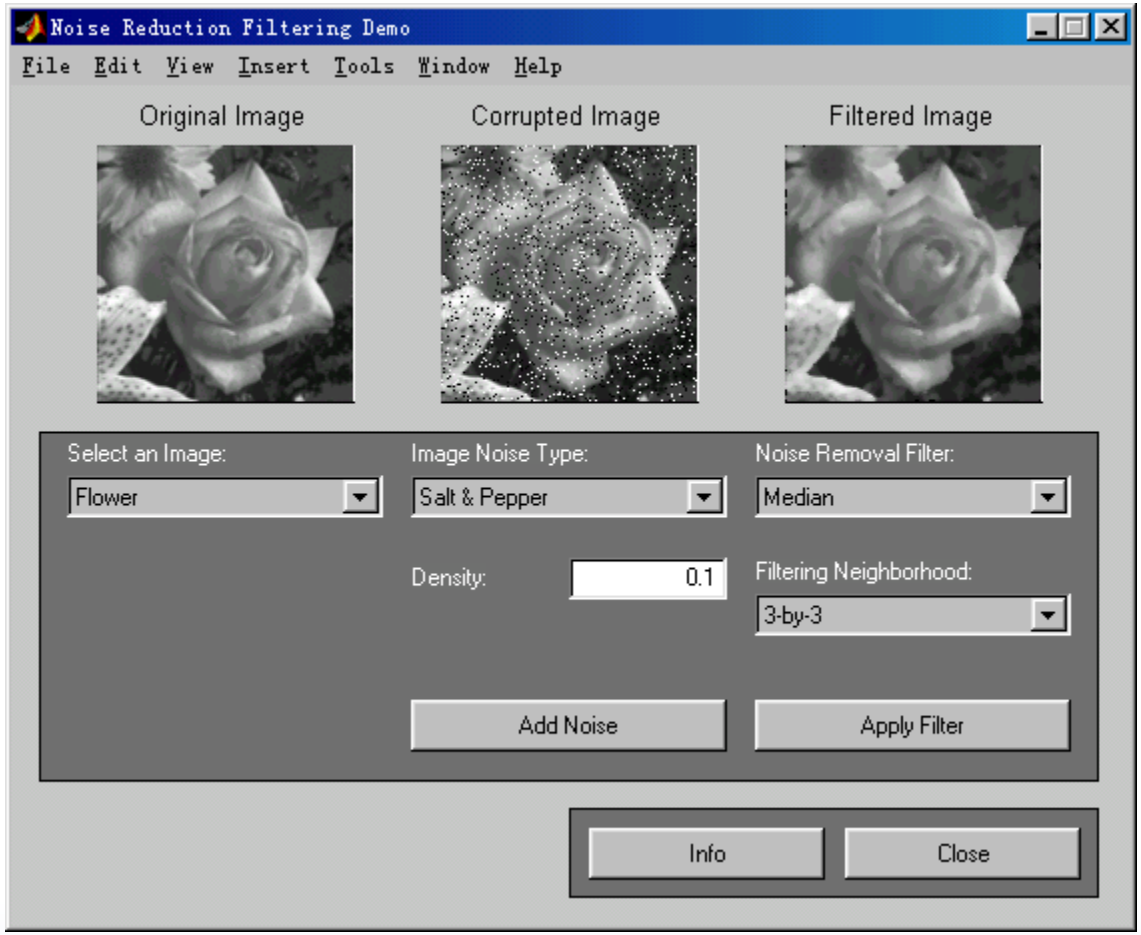
二、中值滤波法


Noise Reduction Filtering Demo
File Edit View Insert Tools Window Help
Original Image
Corrupted Image
Filtered Image
Select an Image:
Flower
Image Noise Type:
Gaussian
Noise Removal Filter:
Median
Mean:
0.0
Variance:
0.005
Filtering Neighborhood:
3-by-3
Add Noise
Apply Filter
Info
Close

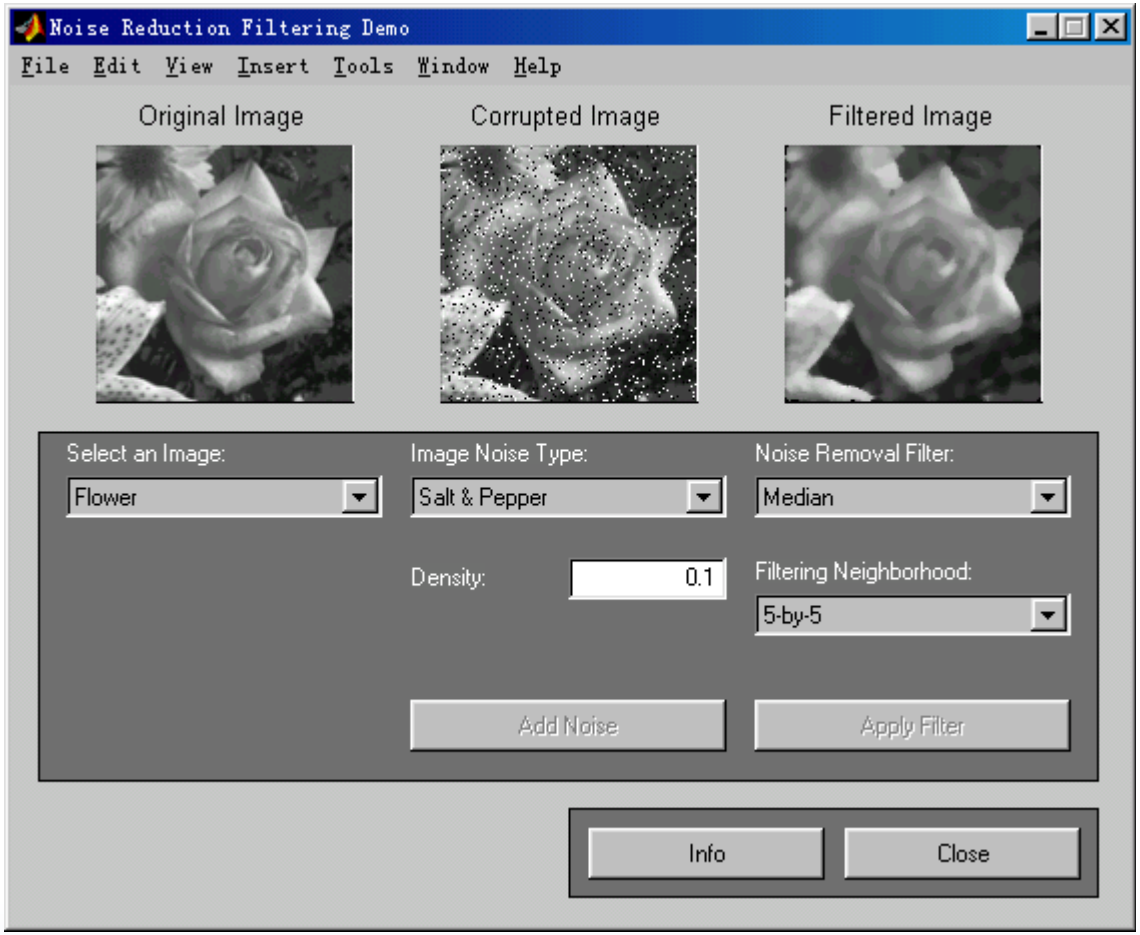
二、中值滤波法


Noise Reduction Filtering Demo
File Edit View Insert Tools Window Help
Original Image
Corrupted Image
Filtered Image
Select an Image:
Flower
Image Noise Type:
Speckle
Noise Removal Filter:
Median
Variance:
0.04
Filtering Neighborhood:
3-by-3
Add Noise
Apply Filter
Info
Close

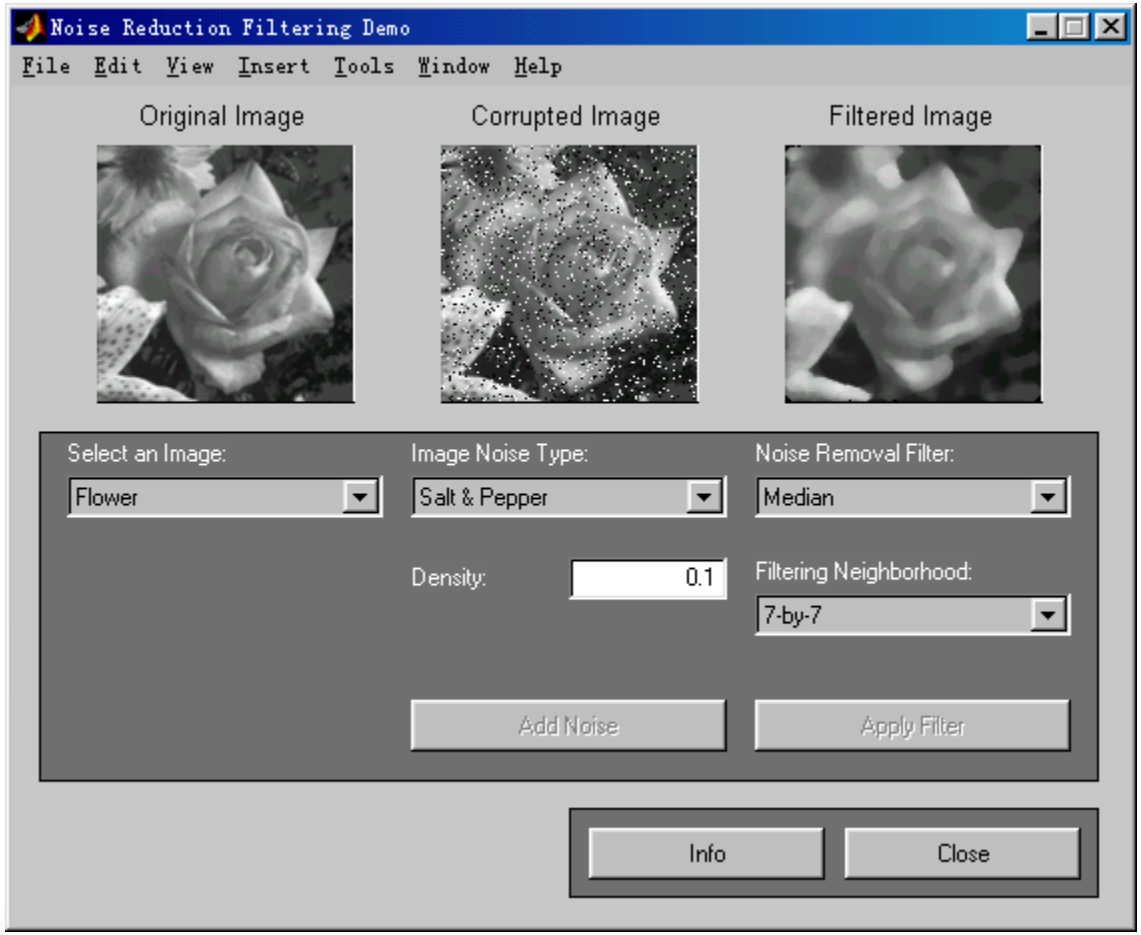
二、中值滤波法


Noise Reduction Filtering Demo
File Edit View Insert Tools Window Help
Original Image
Corrupted Image
Filtered Image
Select an Image:
Flower
Image Noise Type:
Salt & Pepper
Noise Removal Filter:
Median
Density:
0.1
Filtering Neighborhood:
3-by-3
Add Noise
Apply Filter
Info
Close

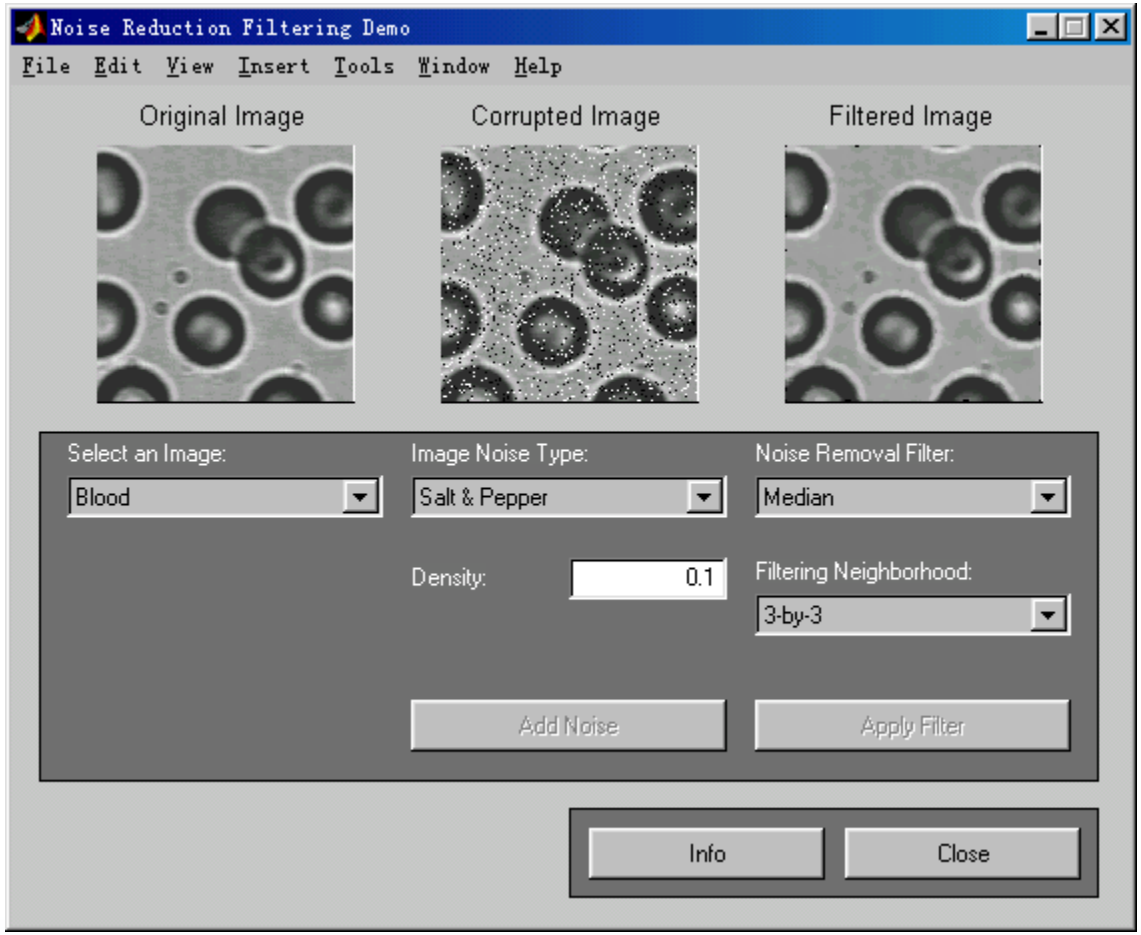
二、中值滤波法


Noise Reduction Filtering Demo
File Edit View Insert Tools Window Help
Original Image
Corrupted Image
Filtered Image
Select an Image:
Flower
Image Noise Type:
Salt & Pepper
Noise Removal Filter:
Median
Density:
0.1
Filtering Neighborhood:
5-by-5
Add Noise
Apply Filter
Info
Close

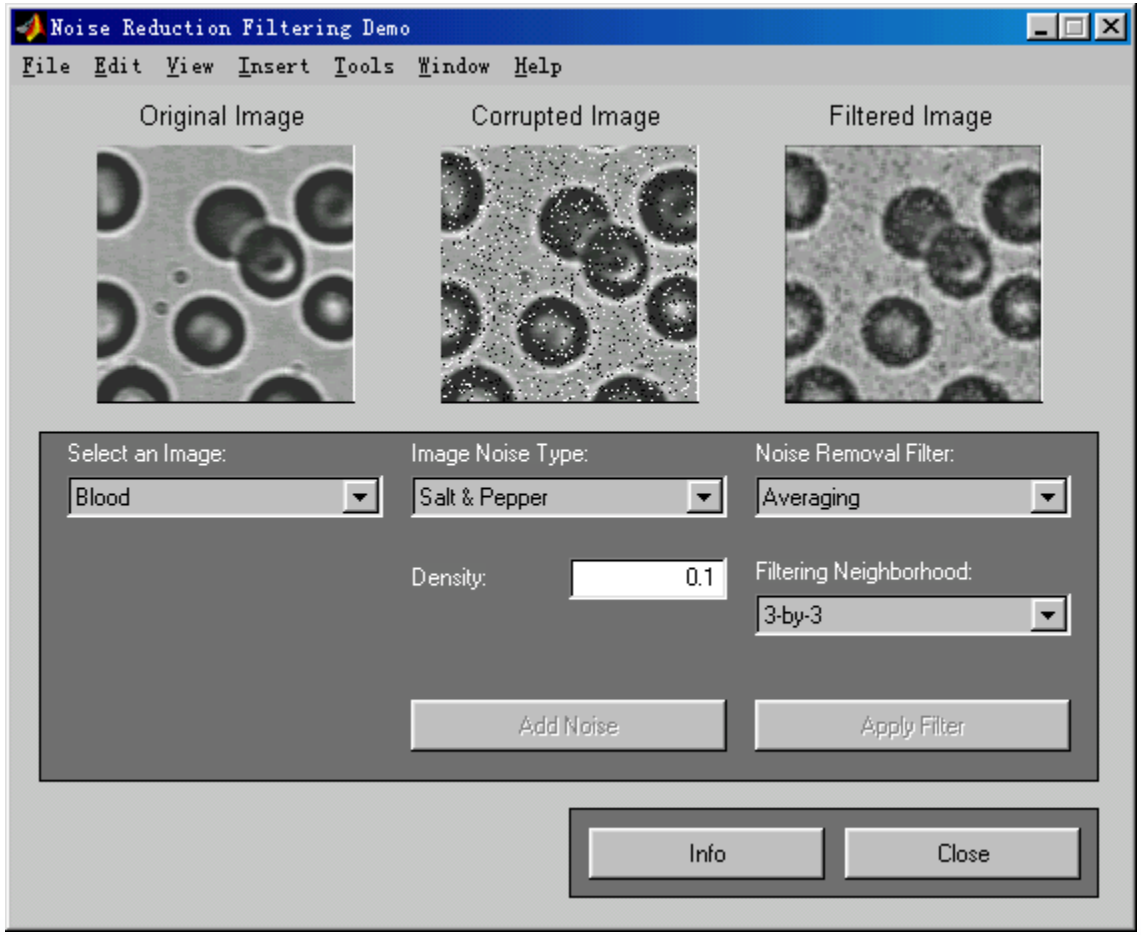
二、中值滤波法

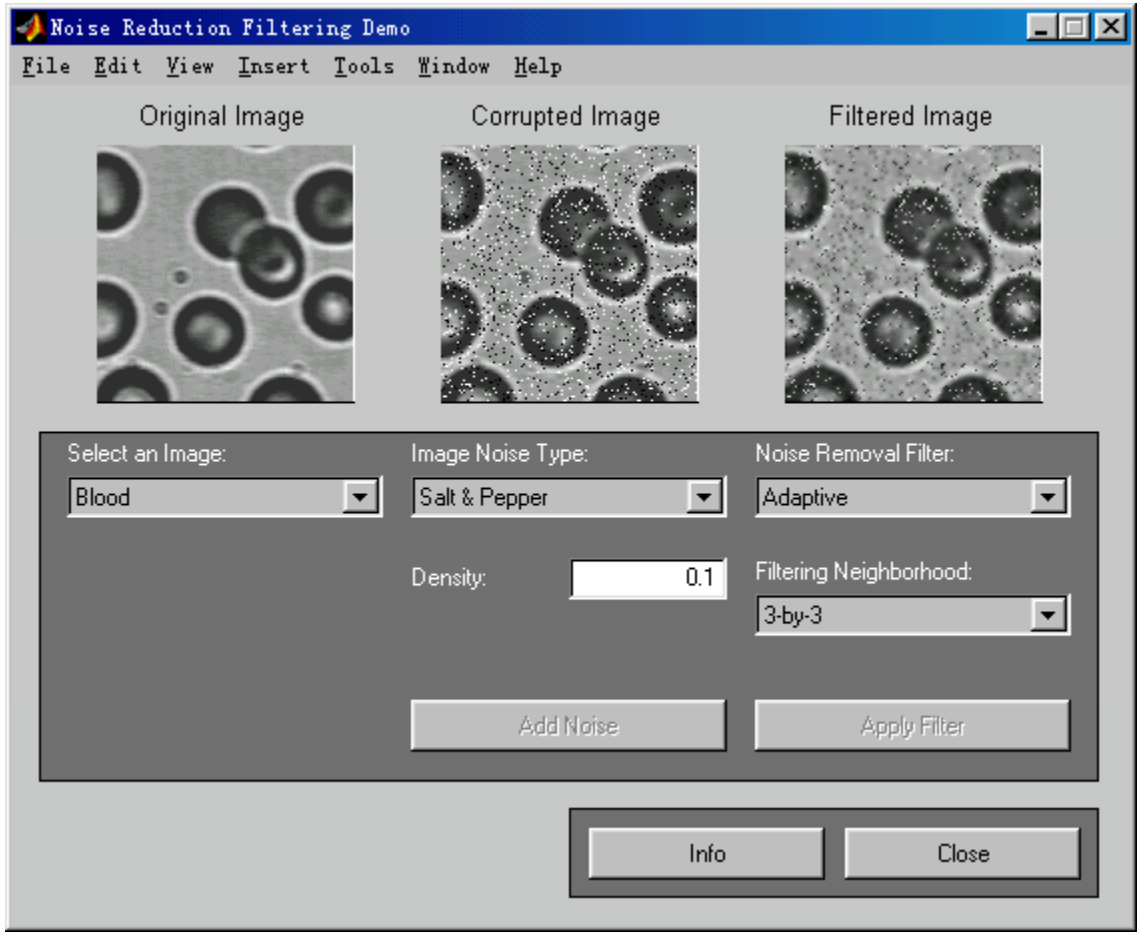

Noise Reduction Filtering Demo
File Edit View Insert Tools Window Help
Original Image
Corrupted Image
Filtered Image
Select an Image:
Flower
Image Noise Type:
Salt & Pepper
Noise Removal Filter:
Median
Density:
0.1
Filtering Neighborhood:
7-by-7
Add Noise
Apply Filter
Info
Close

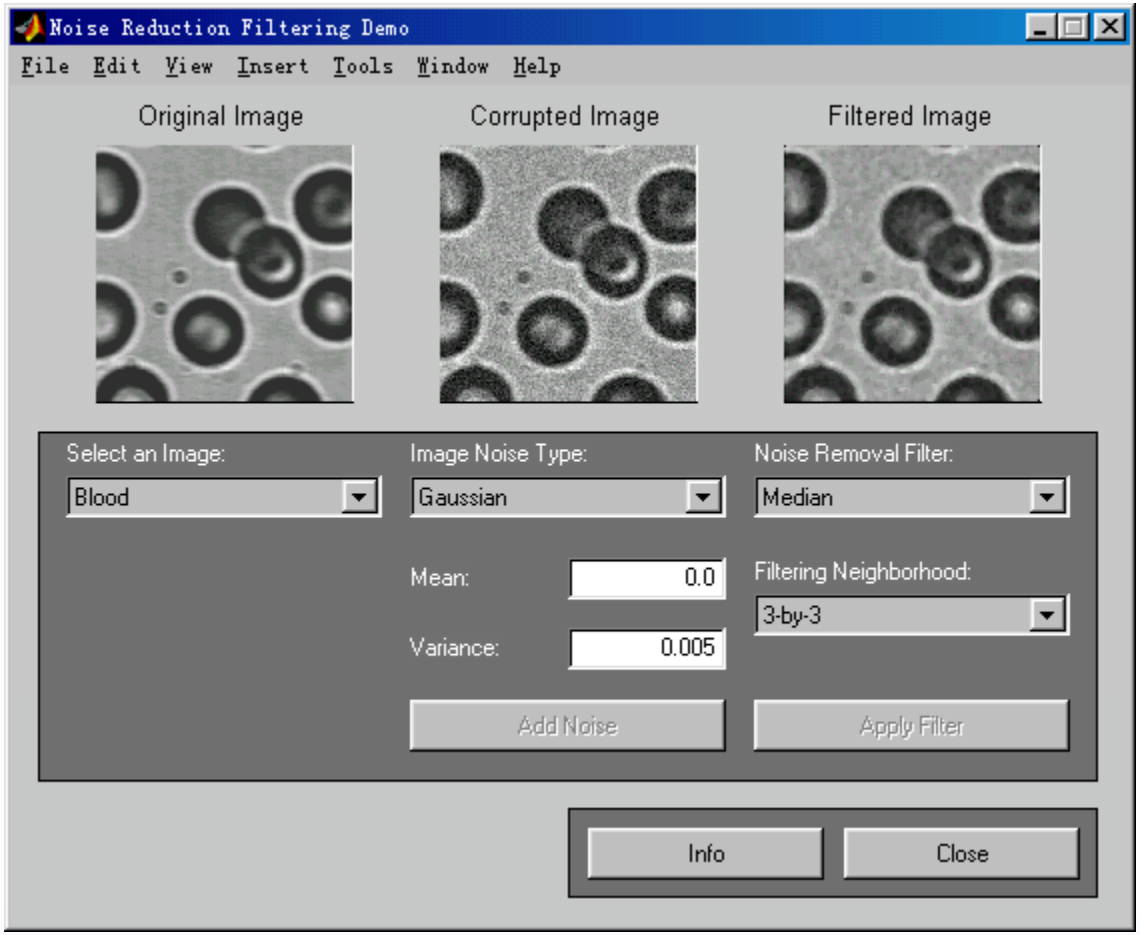
二、中值滤波法

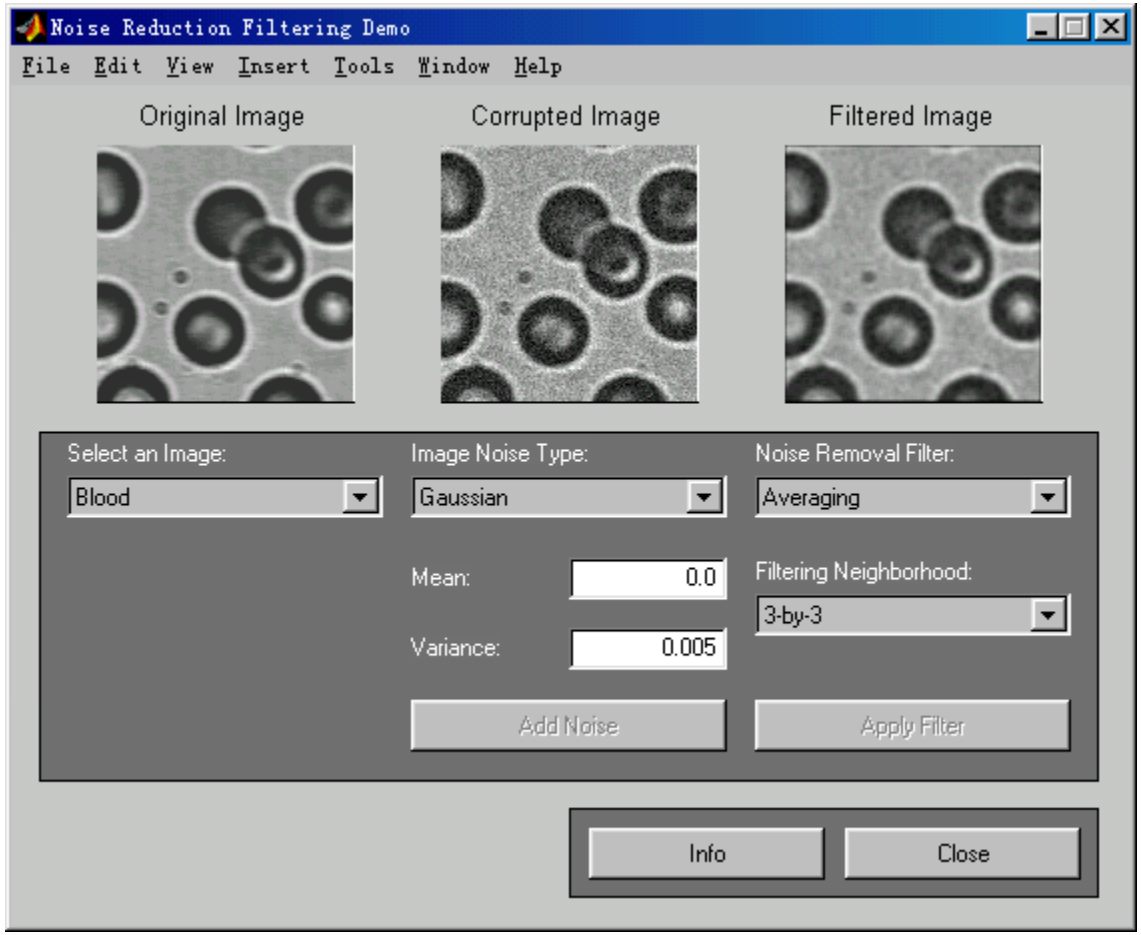

Noise Reduction Filtering Demo
File Edit View Insert Tools Window Help
Original Image
Corrupted Image
Filtered Image
Select an Image:
Blood
Image Noise Type:
Salt & Pepper
Noise Removal Filter:
Median
Density:
0.1
Filtering Neighborhood:
3-by-3
Add Noise
Apply Filter
Info
Close

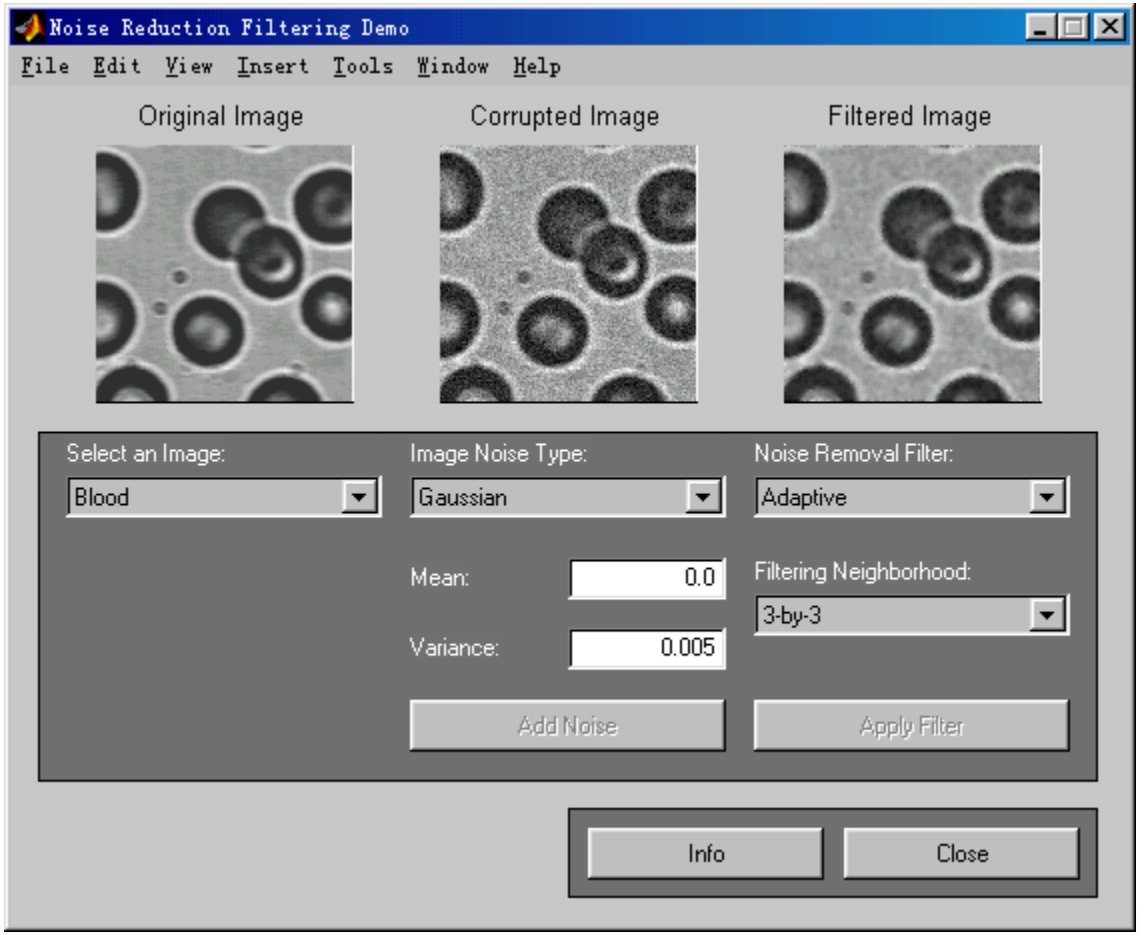
二、中值滤波法

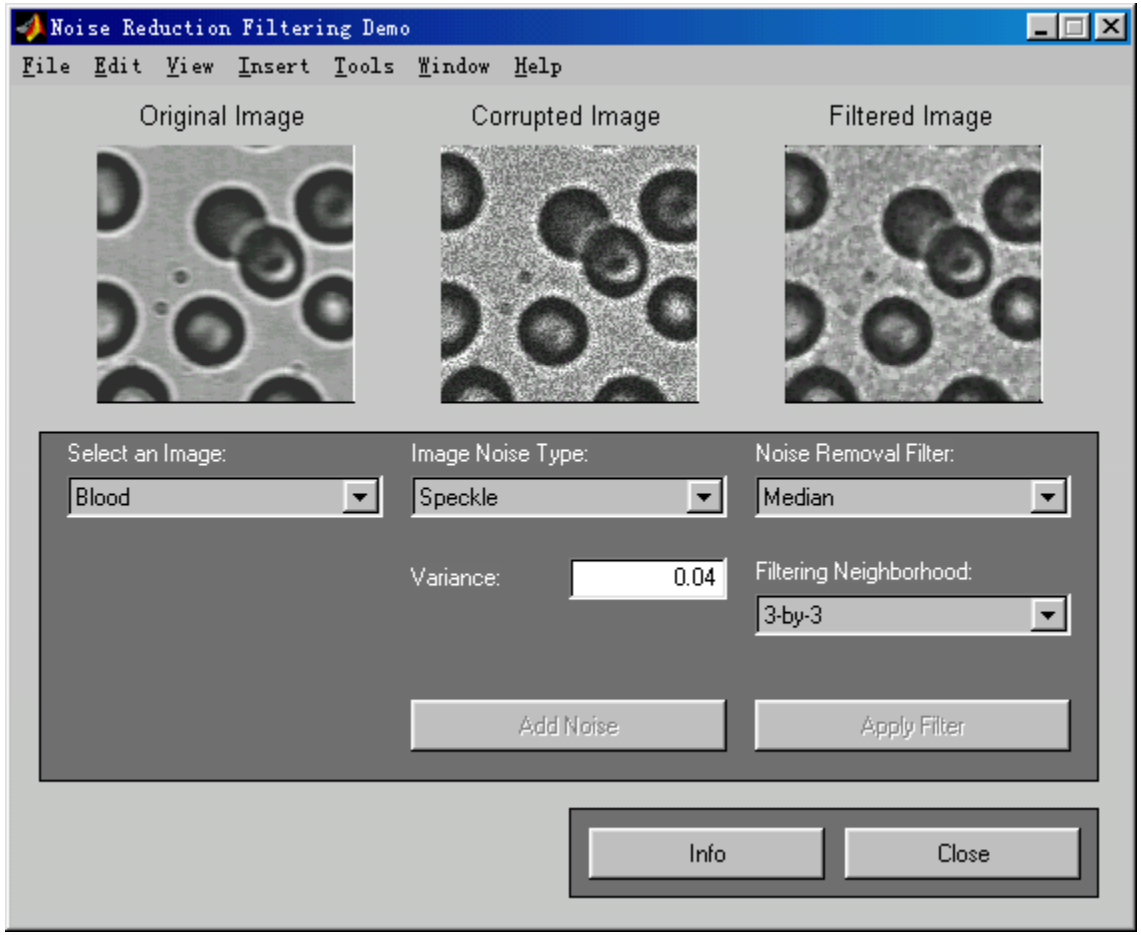

Noise Reduction Filtering Demo
File Edit View Insert Tools Window Help
Original Image
Corrupted Image
Filtered Image
Select an Image:
Blood
Image Noise Type:
Salt & Pepper
Noise Removal Filter:
Averaging
Density:
0.1
Filtering Neighborhood:
3-by-3
Add Noise
Apply Filter
Info
Close

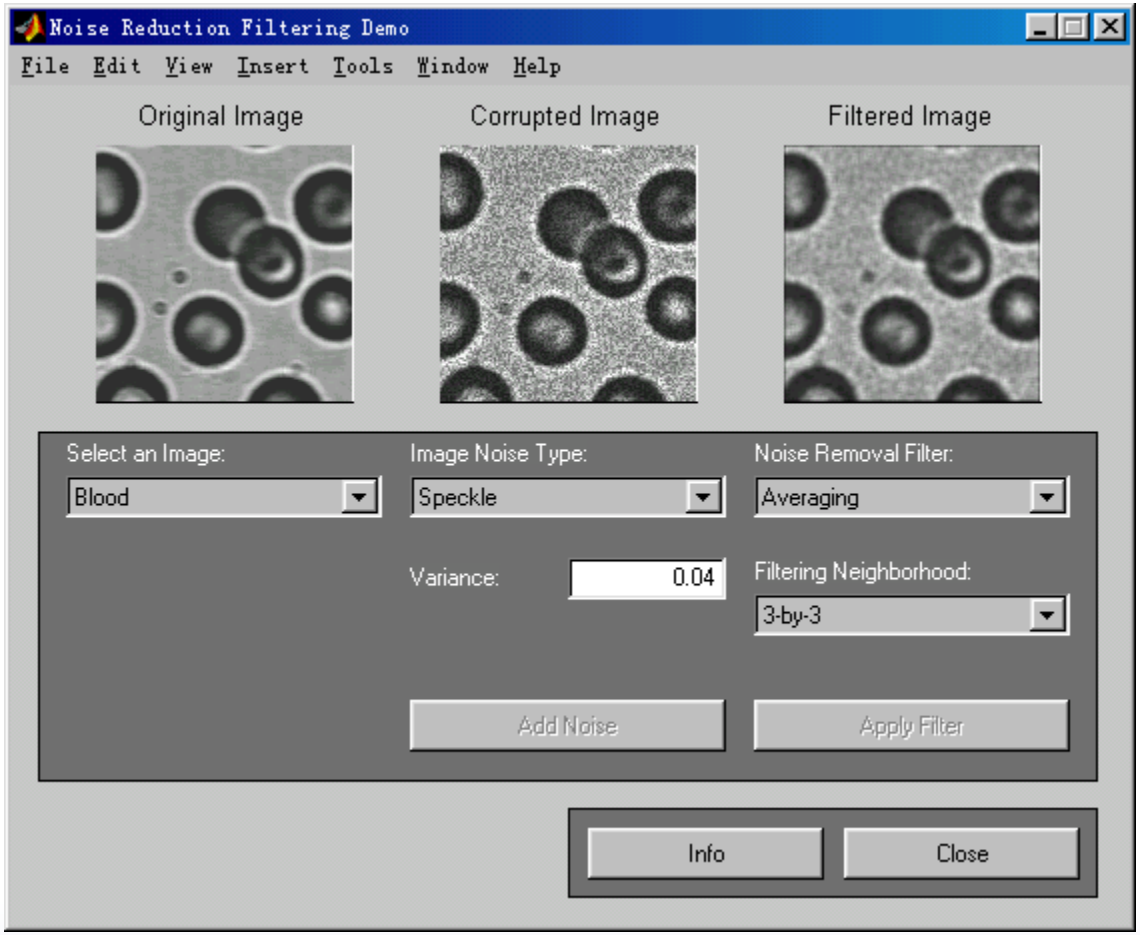

Noise Reduction Filtering Demo
File Edit View Insert Tools Window Help
Original Image
Corrupted Image
Filtered Image
Select an Image:
Blood
Image Noise Type:
Salt & Pepper
Noise Removal Filter:
Adaptive
Density:
0.1
Filtering Neighborhood:
3-by-3
Add Noise
Apply Filter
Info
Close

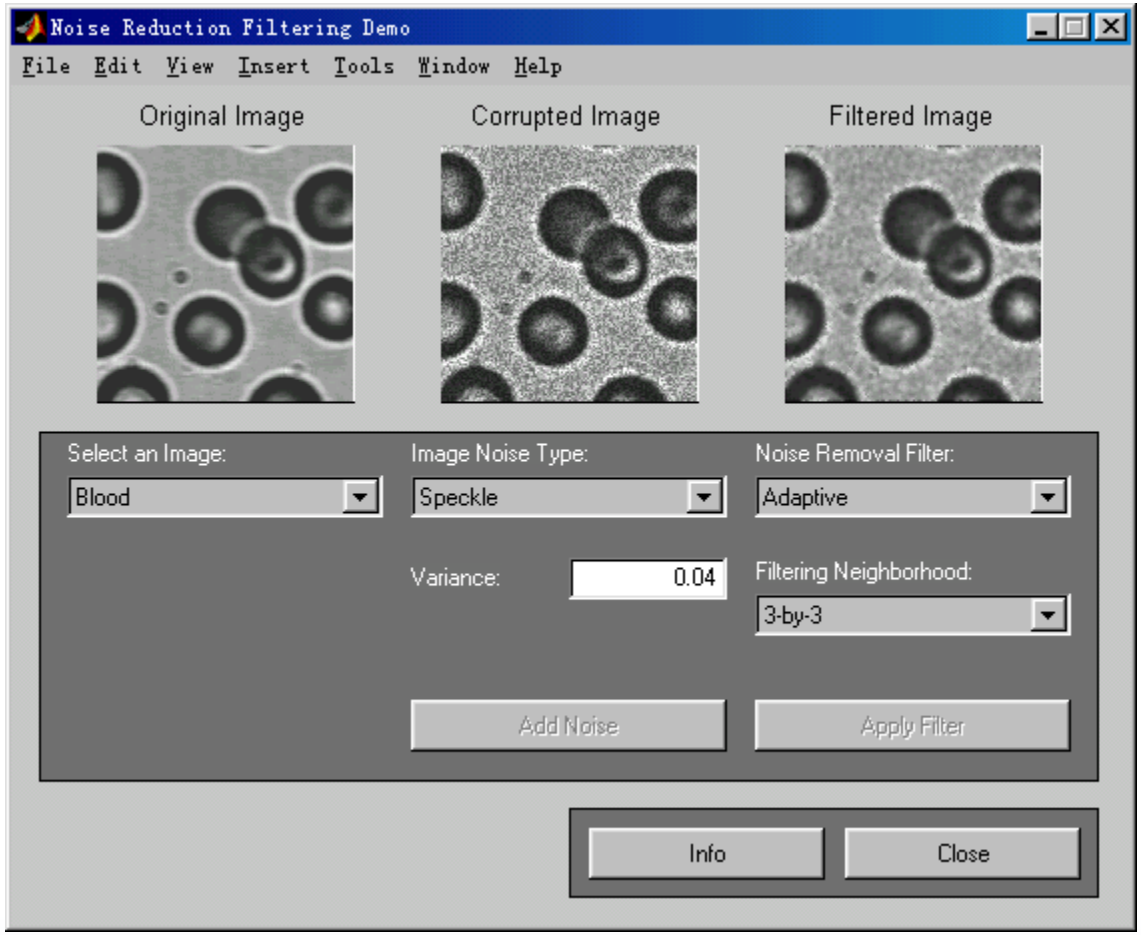

Noise Reduction Filtering Demo
File Edit View Insert Tools Window Help
Original Image
Corrupted Image
Filtered Image
Select an Image:
Blood
Image Noise Type:
Gaussian
Noise Removal Filter:
Median
Mean:
0.0
Variance:
0.005
Filtering Neighborhood:
3-by-3
Add Noise
Apply Filter
Info
Close

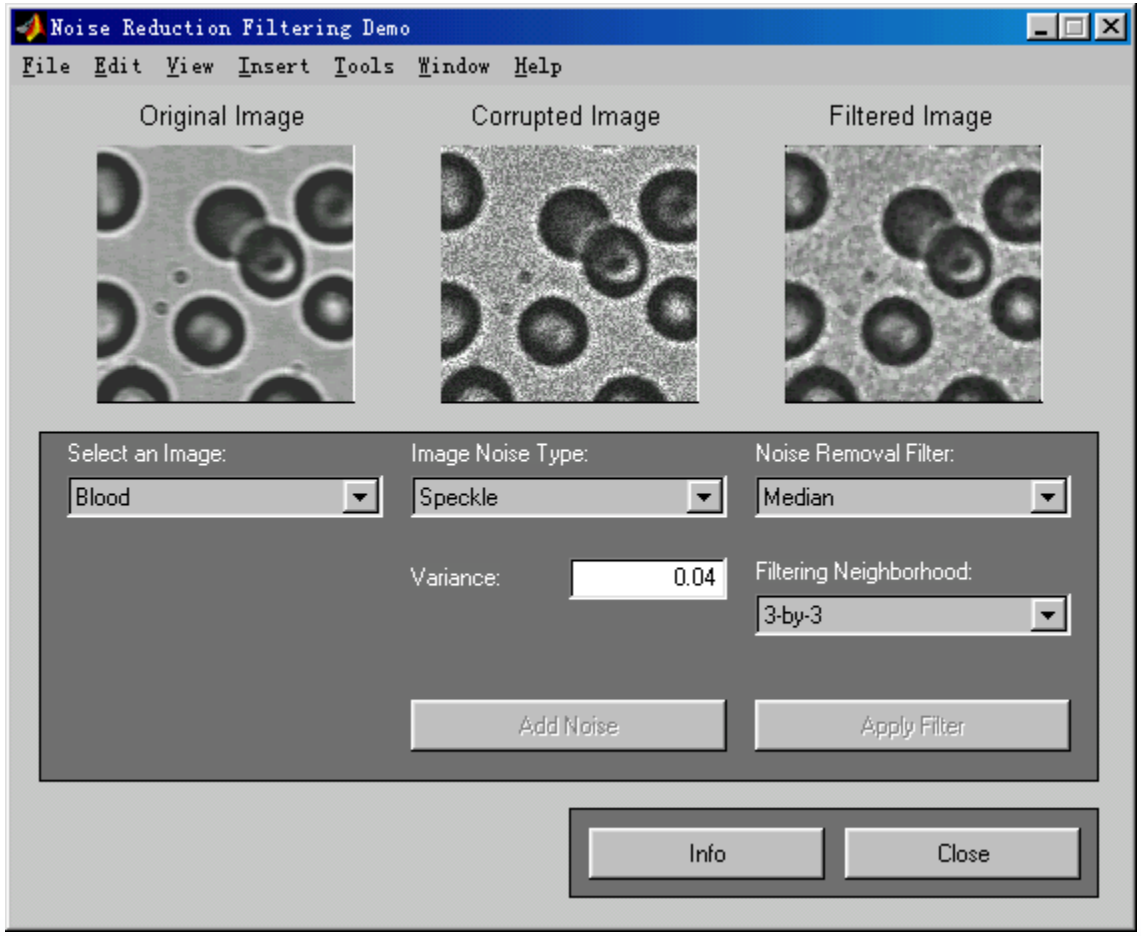

Noise Reduction Filtering Demo
File Edit View Insert Tools Window Help
Original Image
Corrupted Image
Filtered Image
Select an Image:
Blood
Image Noise Type:
Gaussian
Noise Removal Filter:
Averaging
Mean:
0.0
Variance:
0.005
Filtering Neighborhood:
3-by-3
Add Noise
Apply Filter
Info
Close

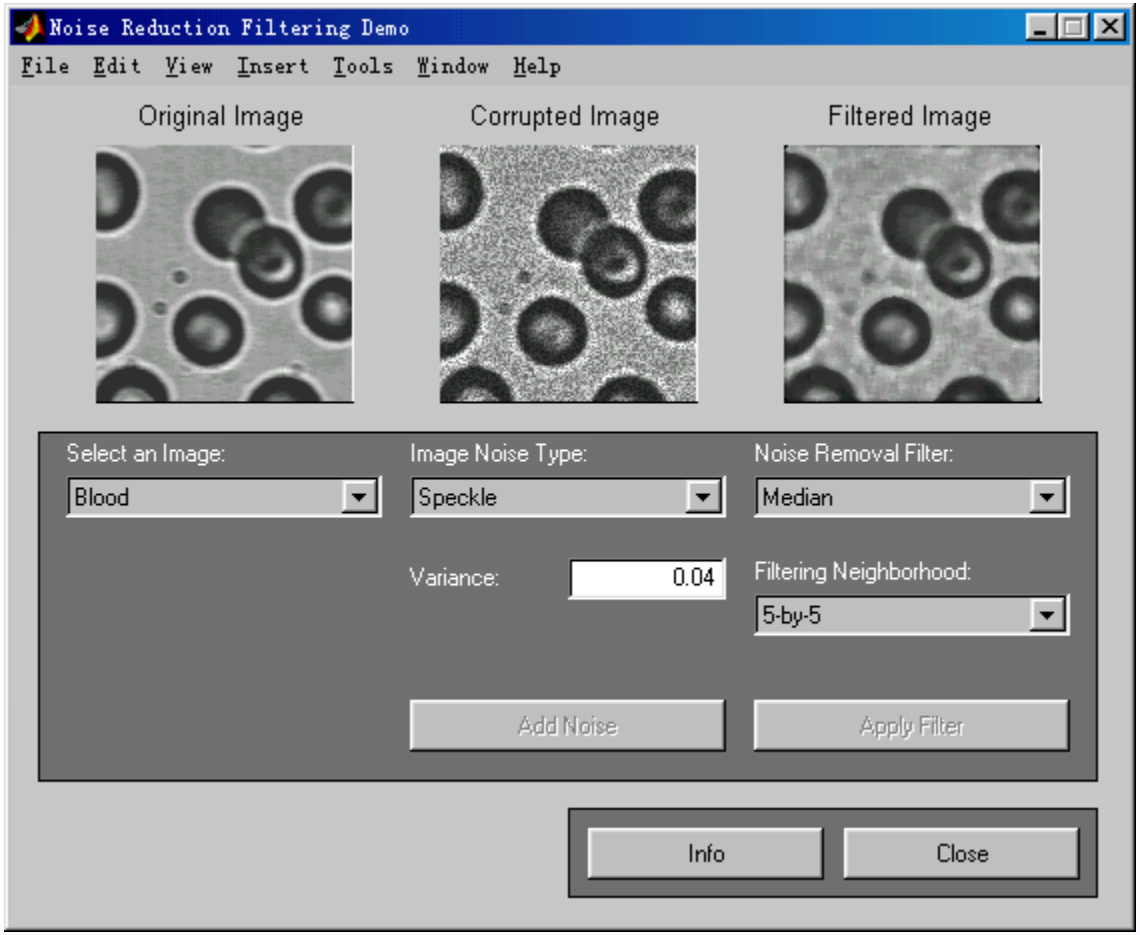

Noise Reduction Filtering Demo
File Edit View Insert Tools Window Help
Original Image
Corrupted Image
Filtered Image
Select an Image:
Blood
Image Noise Type:
Gaussian
Noise Removal Filter:
Adaptive
Mean:
0.0
Variance:
0.005
Filtering Neighborhood:
3-by-3
Add Noise
Apply Filter
Info
Close


Noise Reduction Filtering Demo
File Edit View Insert Tools Window Help
Original Image
Corrupted Image
Filtered Image
Select an Image:
Blood
Image Noise Type:
Speckle
Noise Removal Filter:
Median
Variance:
0.04
Filtering Neighborhood:
3-by-3
Add Noise
Apply Filter
Info
Close


Noise Reduction Filtering Demo
File Edit View Insert Tools Window Help
Original Image
Corrupted Image
Filtered Image
Select an Image:
Blood
Image Noise Type:
Speckle
Noise Removal Filter:
Averaging
Variance:
0.04
Filtering Neighborhood:
3-by-3
Add Noise
Apply Filter
Info
Close


Noise Reduction Filtering Demo
File Edit View Insert Tools Window Help
Original Image
Corrupted Image
Filtered Image
Select an Image:
Blood
Image Noise Type:
Speckle
Noise Removal Filter:
Adaptive
Variance:
0.04
Filtering Neighborhood:
3-by-3
Add Noise
Apply Filter
Info
Close


Noise Reduction Filtering Demo
File Edit View Insert Tools Window Help
Original Image
Corrupted Image
Filtered Image
Select an Image:
Blood
Image Noise Type:
Speckle
Noise Removal Filter:
Median
Variance:
0.04
Filtering Neighborhood:
3-by-3
Add Noise
Apply Filter
Info
Close


Noise Reduction Filtering Demo
File Edit View Insert Tools Window Help
Original Image
Corrupted Image
Filtered Image
Select an Image:
Blood
Image Noise Type:
Speckle
Noise Removal Filter:
Median
Variance:
0.04
Filtering Neighborhood:
5-by-5
Add Noise
Apply Filter
Info
Close

三、加权平均法

华中科技大学

单幅图像(一帧内)的加权平均

$$g(x,y)=\sum_{(i,j)\in S} w(i,j)\left[f(i,j)+n(i,j)\right]$$

其中 $w(i,j)$ 为权值，且 $\sum_{(i,j)\in S} w(i,j)=1$

平均法是加权平均法的特例

多帧平均法

$$\overline{g}(x,y)=\frac{1}{M}\sum_{i=1}^{M}[f_i(x,y)+n_i(x,y)]$$

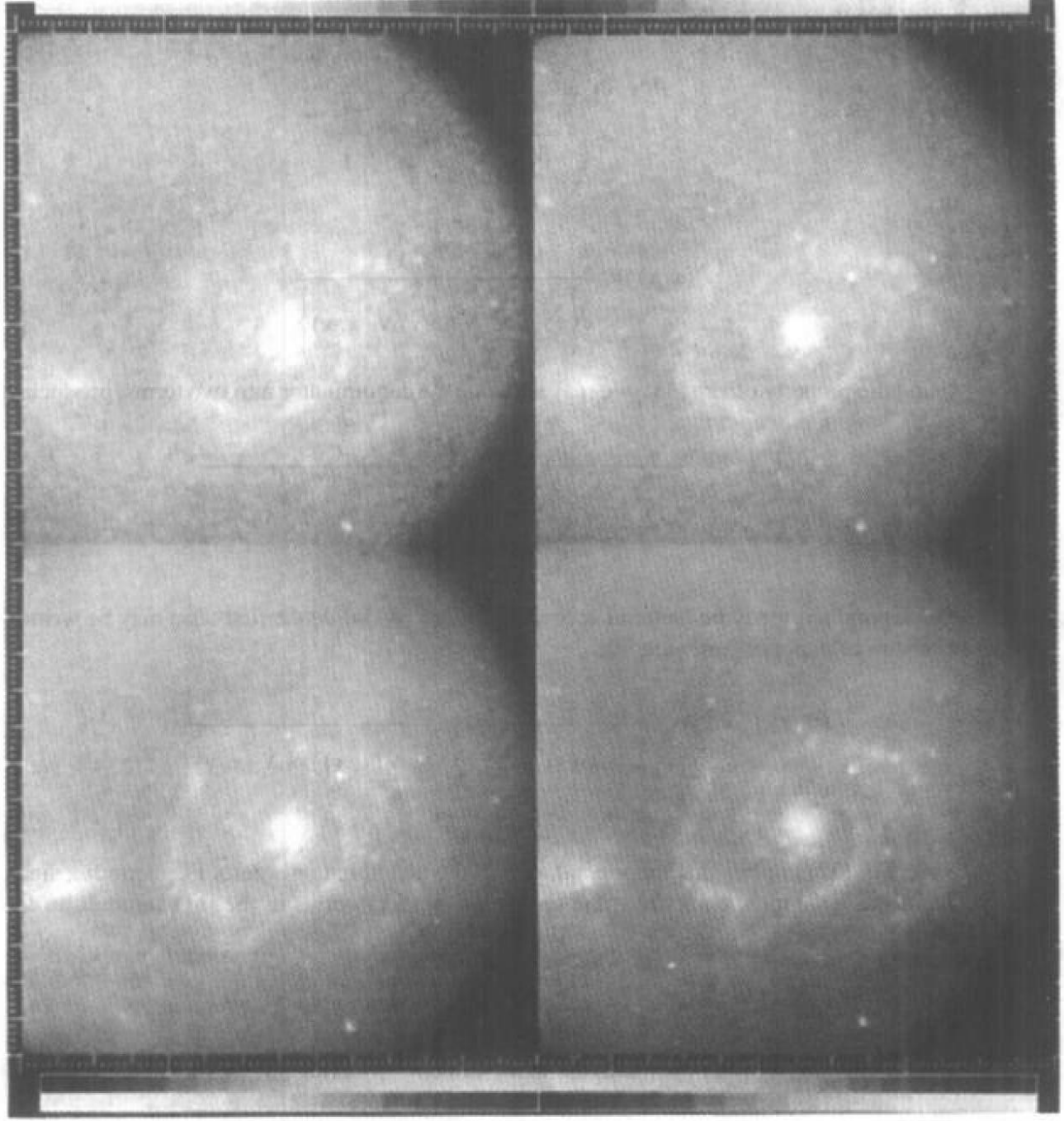
$$=f(x,y)+\frac{1}{M}\sum_{i=1}^{M}n_i(x,y)$$

信噪功率比增加M倍，噪声方差减小M倍。

pp.106-108

原图

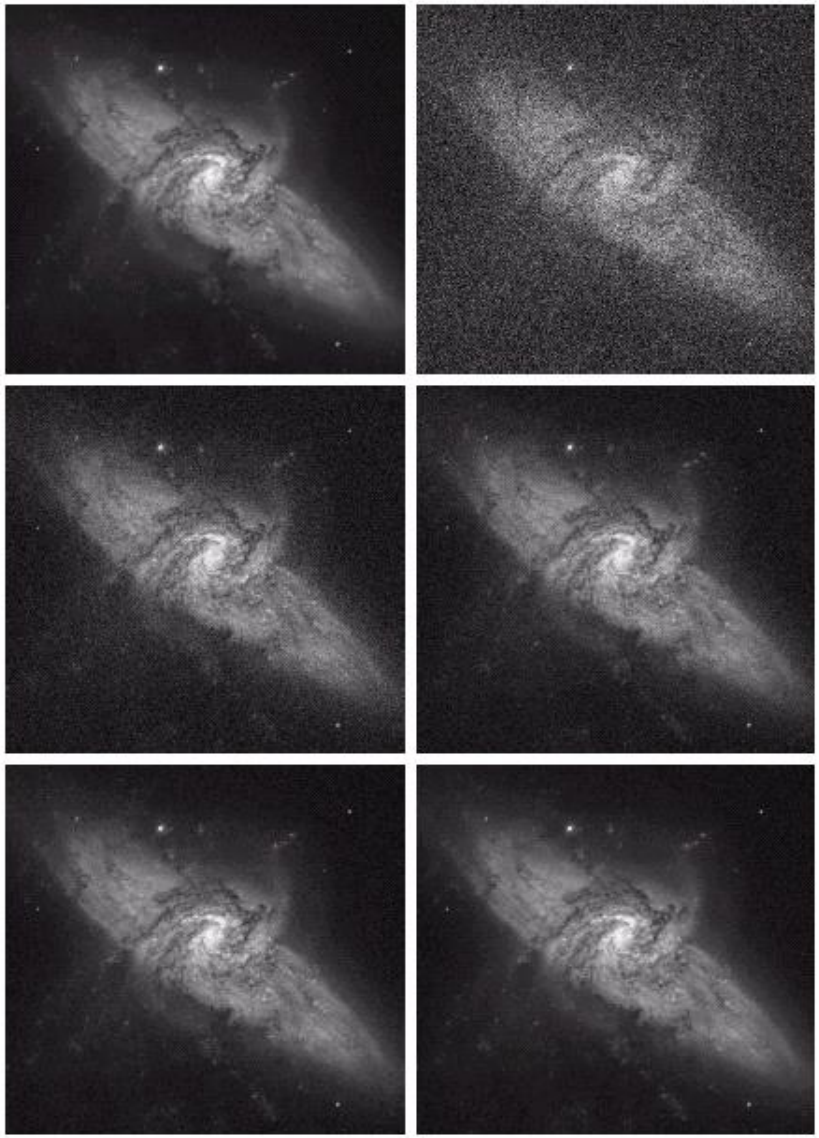
平均2次



平均4次

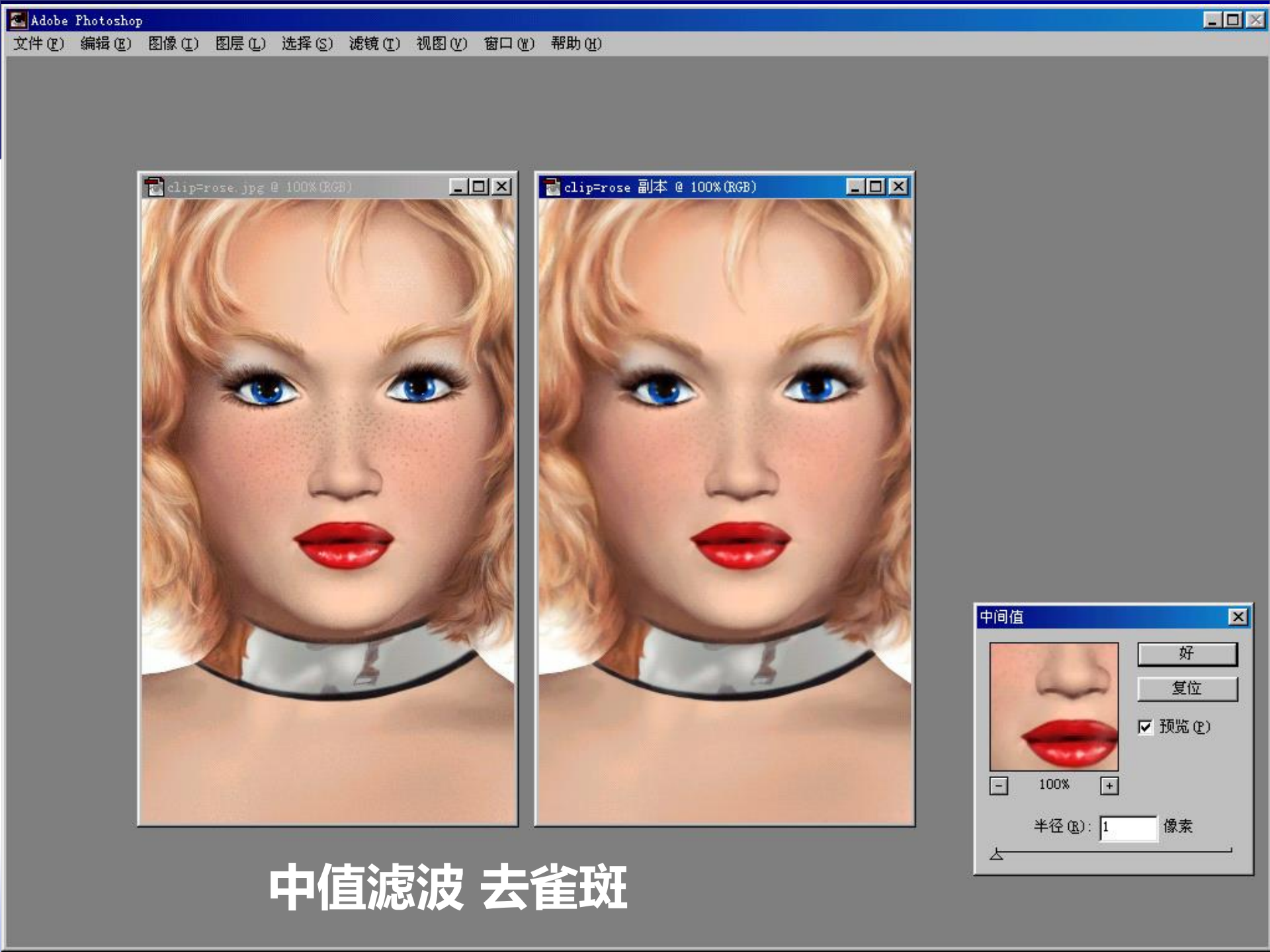
平均8次

Figure 7–2 Image averaging to reduce film grain noise (Courtesy NASA-JPL)

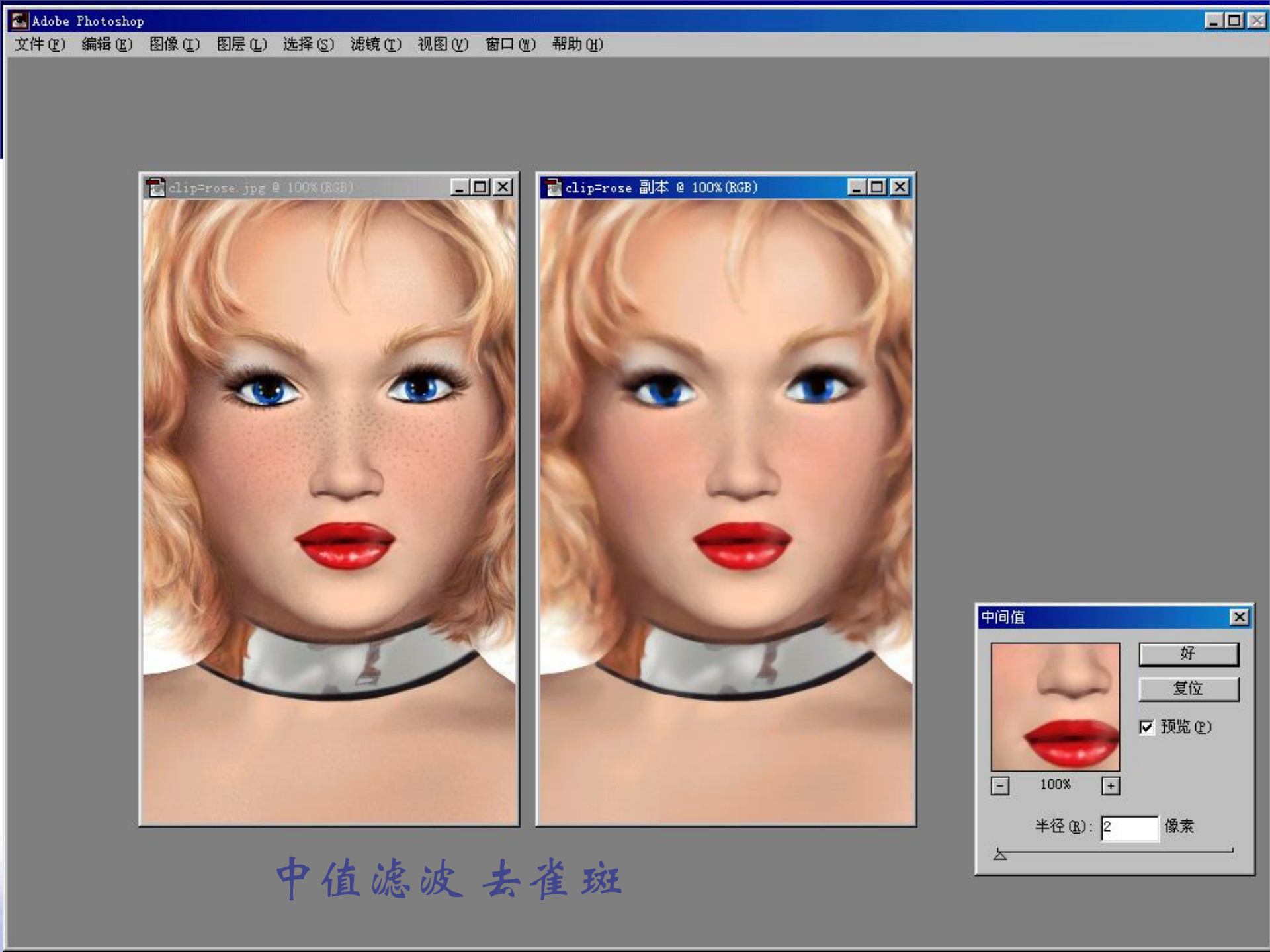


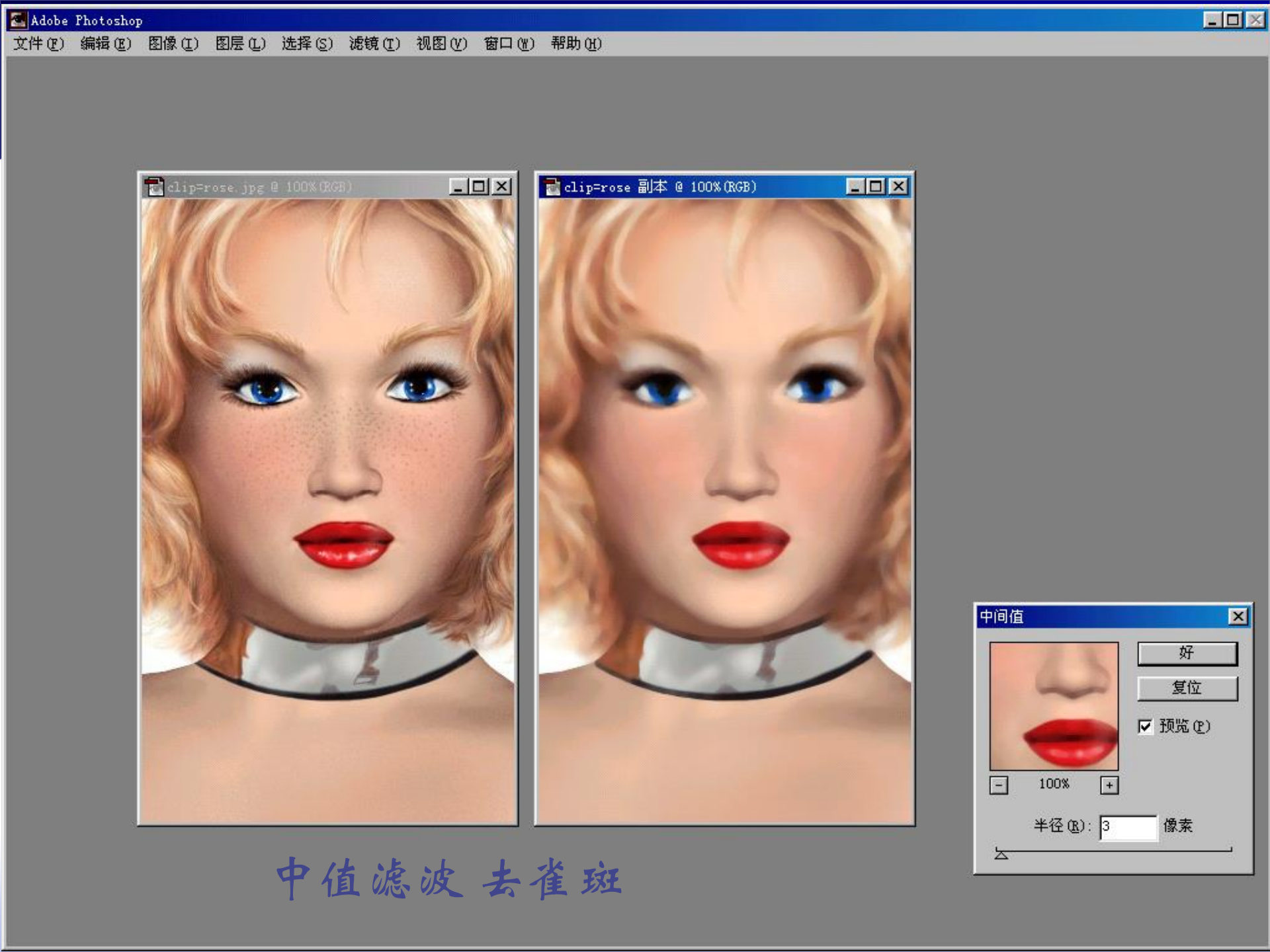
a b
c d
e f

FIGURE 3.30 (a) Image of Galaxy Pair NGC 3314. (b) Image corrupted by additive Gaussian noise with zero mean and a standard deviation of 64 gray levels. (c)–(f) Results of averaging $K = 8, 16, 64,$ and 128 noisy images. (Original image courtesy of NASA.)

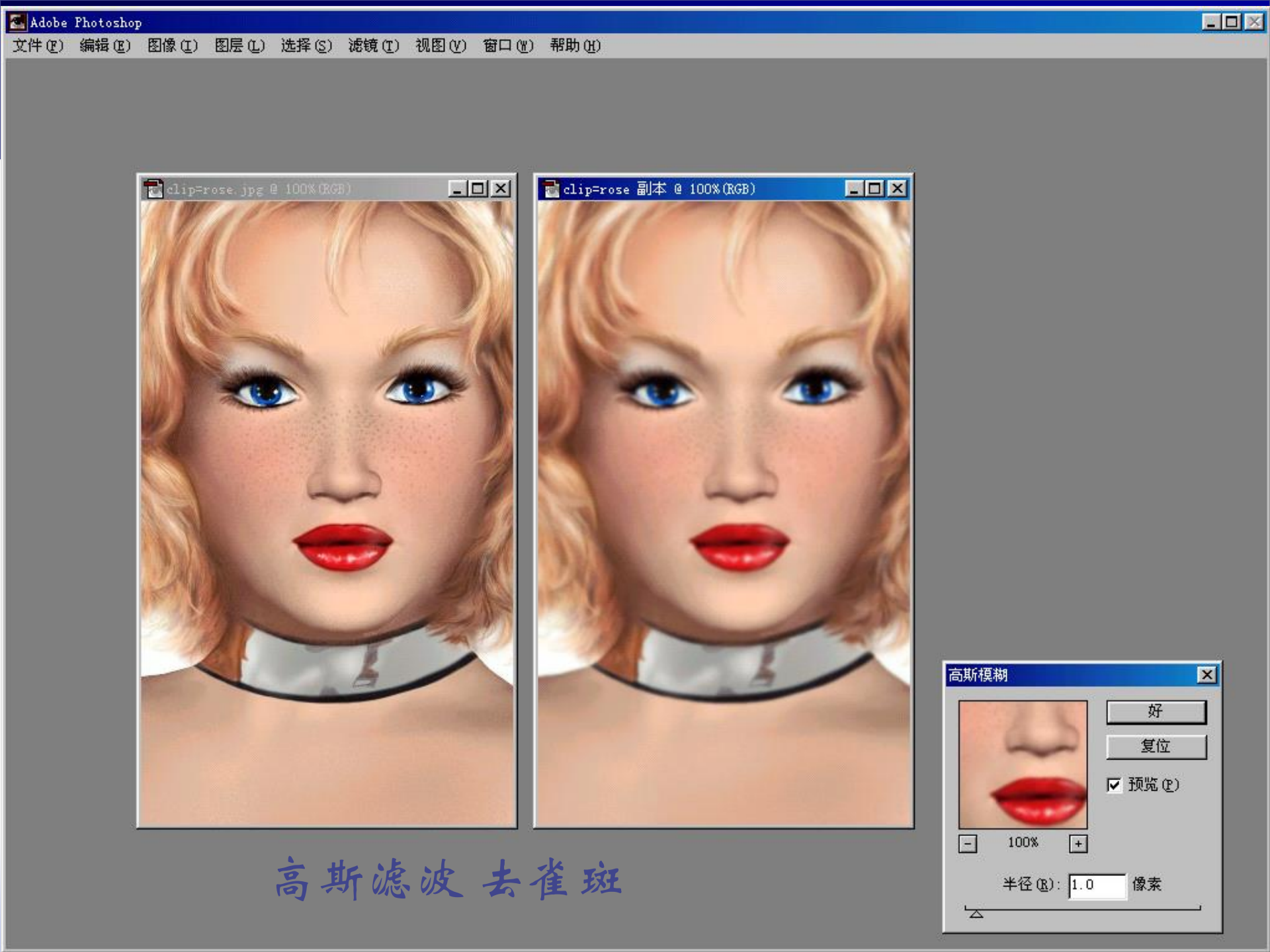

Adobe Photoshop
文件(F) 编辑(E) 图像(I) 图层(L) 选择(S) 滤镜(T) 视图(V) 窗口(W) 帮助(H)
clip=rose.jpg @ 100%(RGB)
clip=rose 副本 @ 100%(RGB)
中间值
好
复位
预览(P)
100%
半径(R): 1 像素

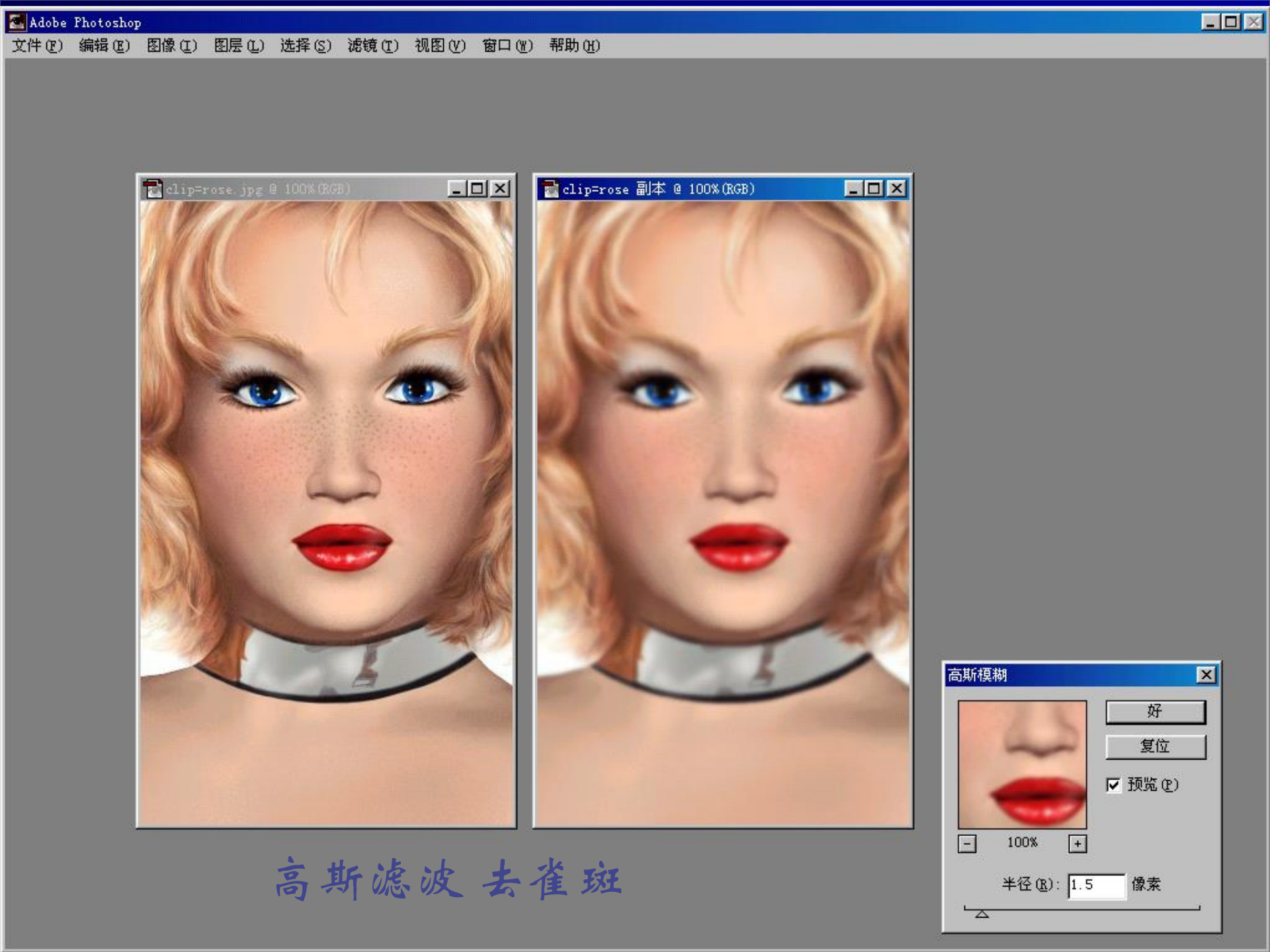
中值滤波 去雀斑

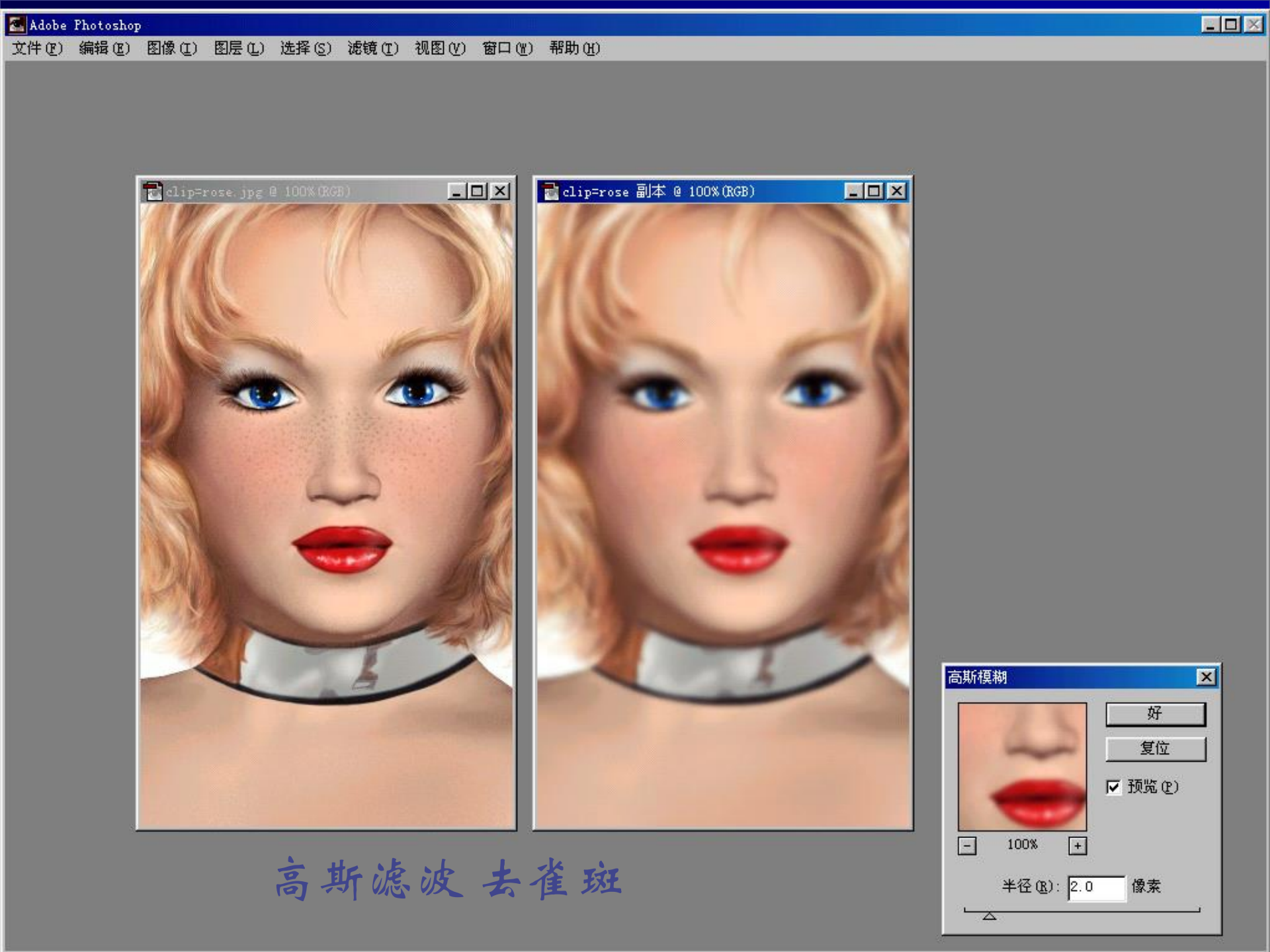

Adobe Photoshop
文件(F) 编辑(E) 图像(I) 图层(L) 选择(S) 滤镜(T) 视图(V) 窗口(W) 帮助(H)
clip=rose.jpg @ 100%(RGB)
clip=rose 副本 @ 100%(RGB)
中间值
好
复位
预览(P)
100%
半径(R): 2 像素
中值滤波 去雀斑

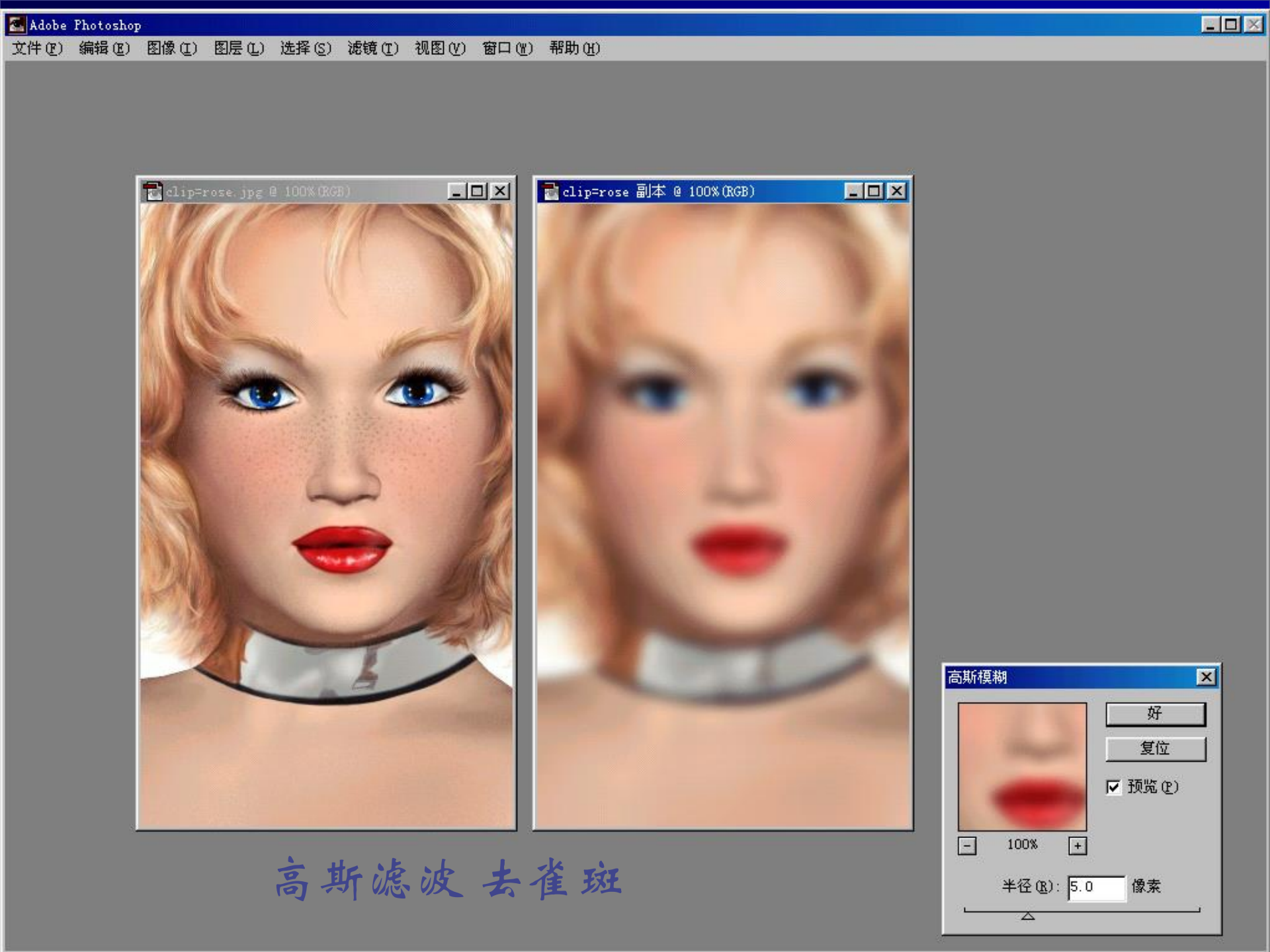

Adobe Photoshop
文件(F) 编辑(E) 图像(I) 图层(L) 选择(S) 滤镜(T) 视图(V) 窗口(W) 帮助(H)
clip=rose.jpg @ 100%(RGB)
clip=rose 副本 @ 100%(RGB)
中间值
好
复位
预览(P)
100%
半径(R): 3 像素

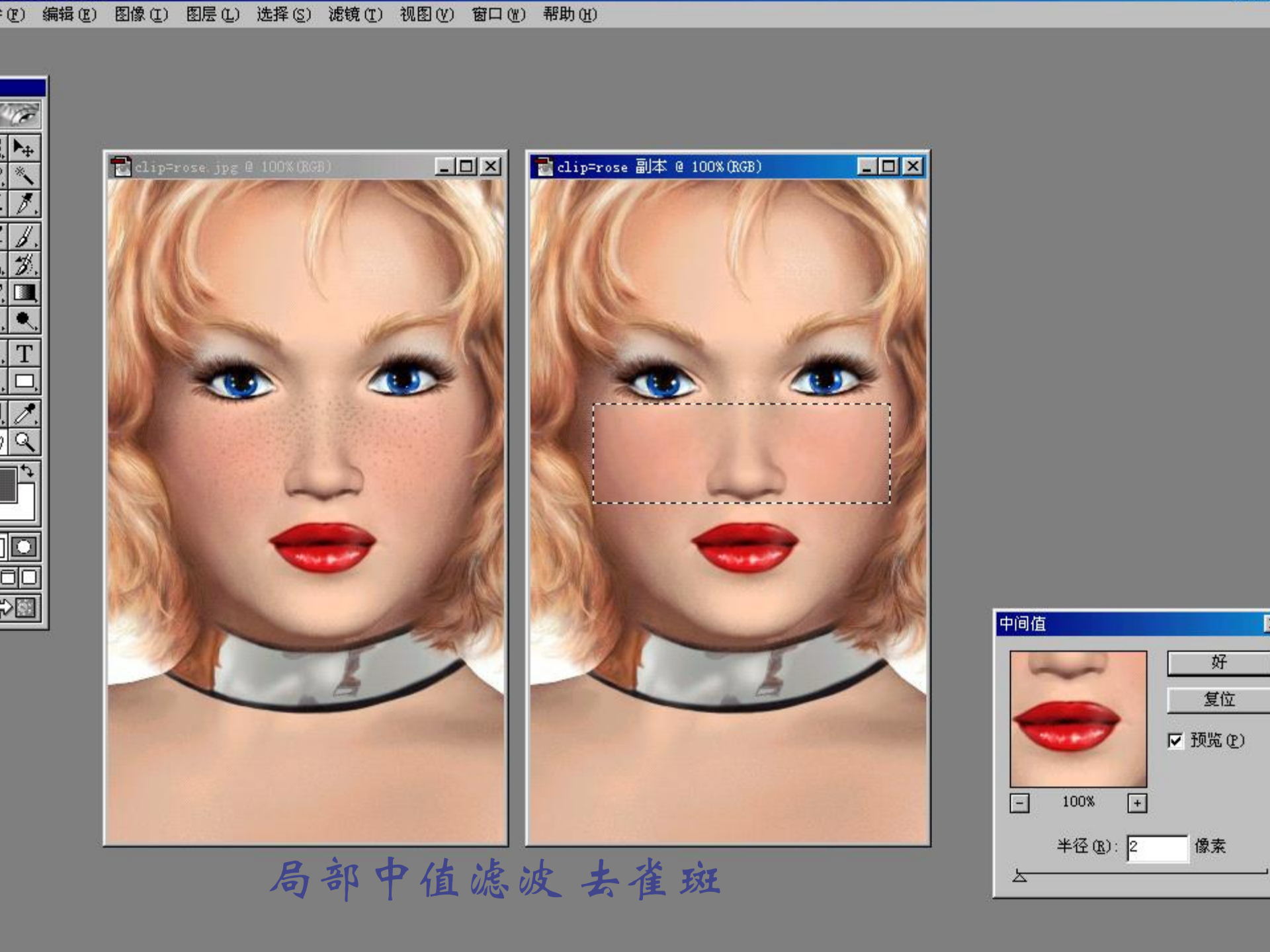
中值滤波 去雀斑


Adobe Photoshop
文件(F) 编辑(E) 图像(I) 图层(L) 选择(S) 滤镜(T) 视图(V) 窗口(W) 帮助(H)
clip=rose.jpg @ 100%(RGB)
clip=rose 副本 @ 100%(RGB)
高斯模糊
好
复位
预览(P)
100%
半径(R): 1.0 像素
高斯濾波 去雀斑

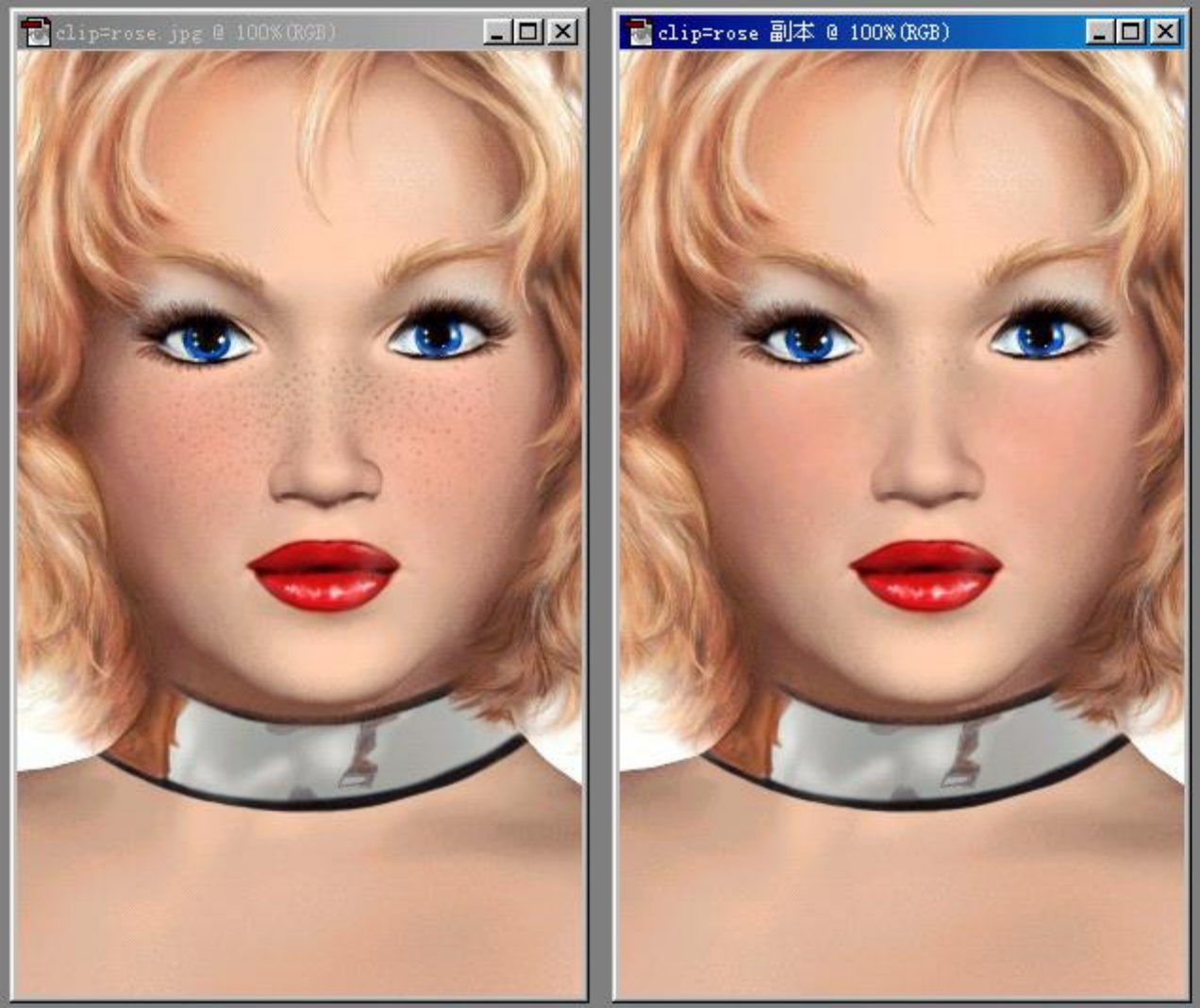

Adobe Photoshop
文件(F) 编辑(E) 图像(I) 图层(L) 选择(S) 滤镜(T) 视图(V) 窗口(W) 帮助(H)
clip=rose.jpg @ 100%(RGB)
clip=rose 副本 @ 100%(RGB)
高斯模糊
好
复位
预览(P)
100%
半径(R): 1.5 像素
高斯滤波 去雀斑


Adobe Photoshop
文件(F) 编辑(E) 图像(I) 图层(L) 选择(S) 滤镜(T) 视图(V) 窗口(W) 帮助(H)
clip=rose.jpg @ 100%(RGB)
clip=rose 副本 @ 100%(RGB)
高斯模糊
好
复位
预览(P)
100%
半径(R): 2.0 像素
高斯滤波 去雀斑


Adobe Photoshop
文件(F) 编辑(E) 图像(I) 图层(L) 选择(S) 滤镜(T) 视图(V) 窗口(W) 帮助(H)
clip=rose.jpg @ 100%(RGB)
clip=rose 副本 @ 100%(RGB)
高斯模糊
好
复位
预览(P)
100%
半径(R): 5.0 像素
高斯滤波 去雀斑

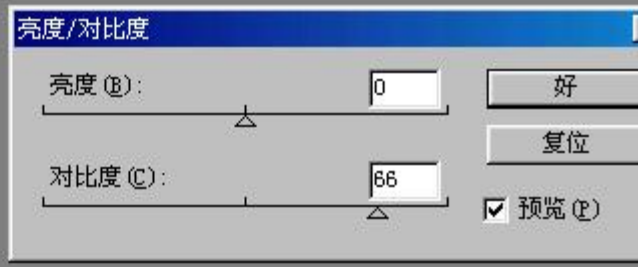

(F) 编辑(E) 图像(I) 图层(L) 选择(S) 滤镜(T) 视图(V) 窗口(W) 帮助(H)
clip=rose.jpg @ 100%(RGB)
clip=rose 副本 @ 100%(RGB)
中间值
好
复位
预览(P)
100%
半径(R): 2 像素
局部中值滤波 去雀斑

(F) 编辑(E) 图像(I) 图层(L) 选择(S) 滤镜(T) 视图(V) 窗口(W) 帮助(H)



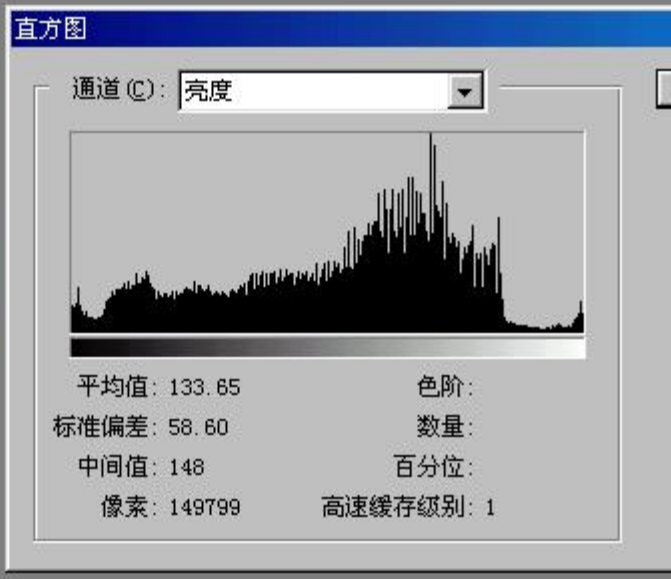
局部中值滤波 去雀斑

(F) 编辑(E) 图像(I) 图层(L) 选择(S) 滤镜(T) 视图(V) 窗口(W) 帮助(H)



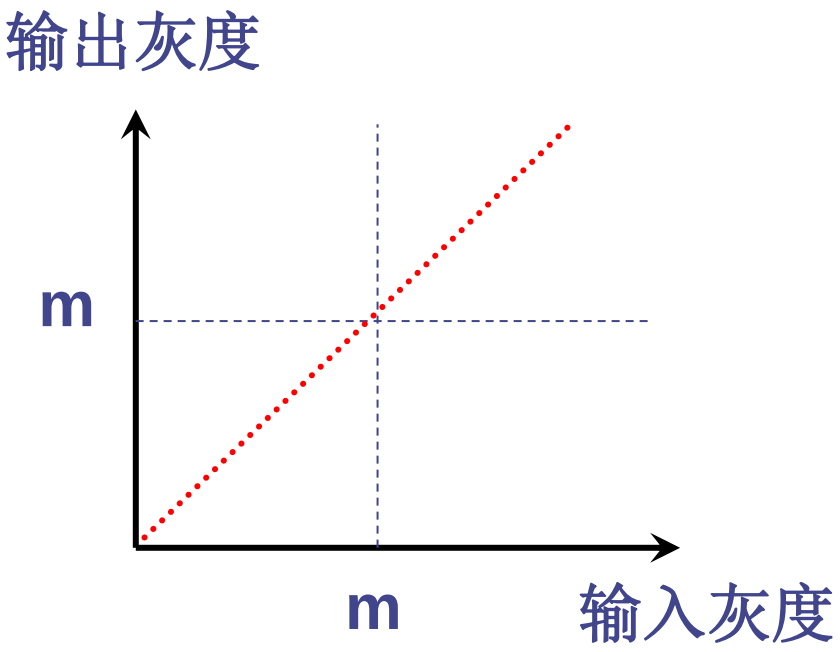
对比度增强

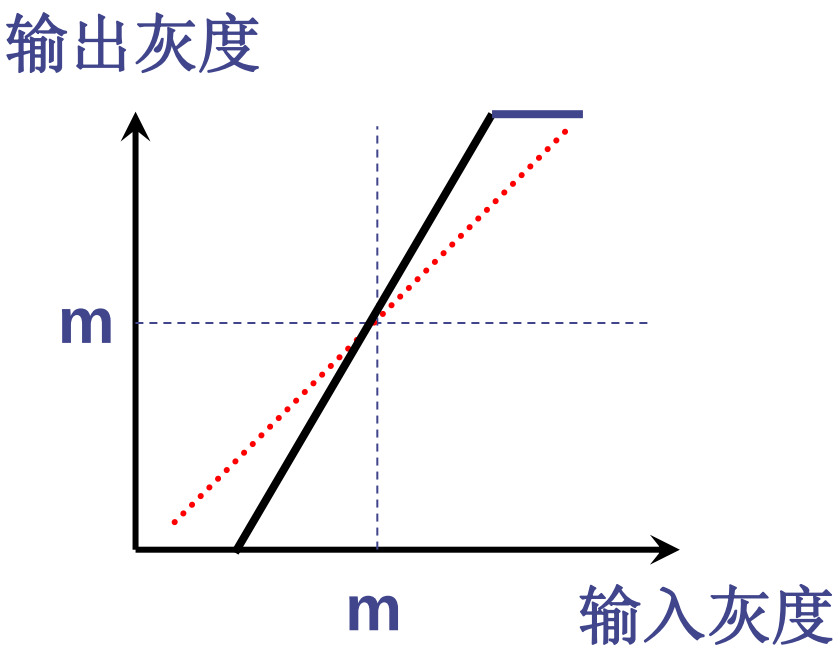
(F) 编辑(E) 图像(I) 图层(L) 选择(S) 滤镜(T) 视图(V) 窗口(W) 帮助(H)



直方图均衡化

对比度的概念

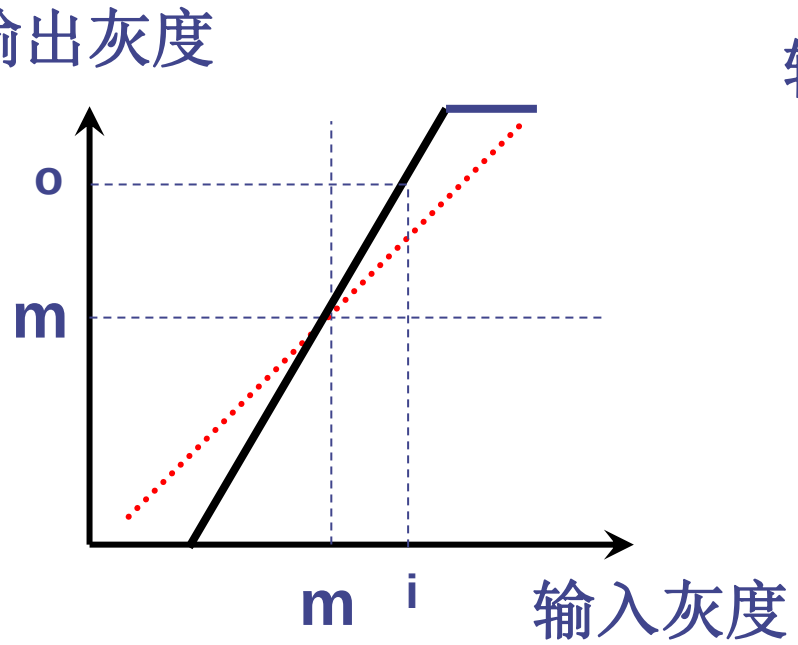




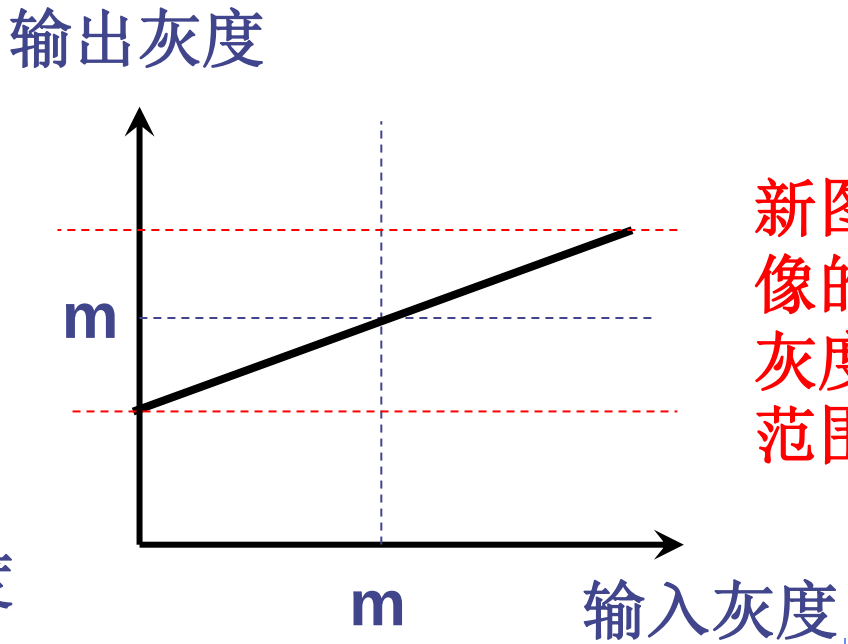
对比度为0时，
输出灰度=输入灰度
M为图像的灰度均值

对比度〉0

对比度的概念



对比度〉0



对比度 < 0

$$O = \min(255, i + (i - m) \times C) \quad i >= m$$
$$\max(0, i + (i - m) \times C) \quad i < m$$

邻域处理的实现——模板操作

常见的模板

0	1/5	0
1/5	1/5	1/5
0	1/5	0

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

邻域平均

1/10	1/10	1/10
1/10	1/5	1/10
1/10	1/10	1/10

1/16	1/8	1/16
1/8	1/4	1/8
1/16	1/8	1/16

加权平均

Terms

Image smoothing: 图象平滑
Image averaging: 图象平均
Expectation: 数学期望
Mean: 均值
Variance: 方差
Median filtering: 中值滤波
Neighborhood: 邻域
Filter: 滤波器
Lowpass filter: 低通滤波器

Terms

Highpass filter: 高通滤波器

Bandpass filter: 带通滤波器

Bandreject filter、Bandstop filter: 带阻滤波器

Ideal filter: 理想滤波器

Butterworth filter: 巴特沃思滤波器

Exponential filter: 指数滤波器

Trapezoidal filter: 梯形滤波器

Transfer function: 传递函数

Terms

華中科技大學

Frequency response: 频率响应

Cut-off frequency: 截止频率

Spectrum: 频谱

Amplitude spectrum: 幅值谱

Phase spectrum: 相位谱

Power spectrum: 功率谱

Blur: 模糊

Terms

華中科技大學

Random: 随机

Additive: 加性的

Uncorrelated: 互不相关的

Salt & pepper noise: 椒盐噪声

Gaussian noise: 高斯噪声

Speckle noise: 斑点噪声

Grain noise: 颗粒噪声

Terms

Bartlett window: 巴特雷窗

Hamming window: 汉明窗

Hanning window: 汉宁窗

Blackman window: 布赖克曼窗

Convolution: 卷积

Convolution kernel: 卷积核