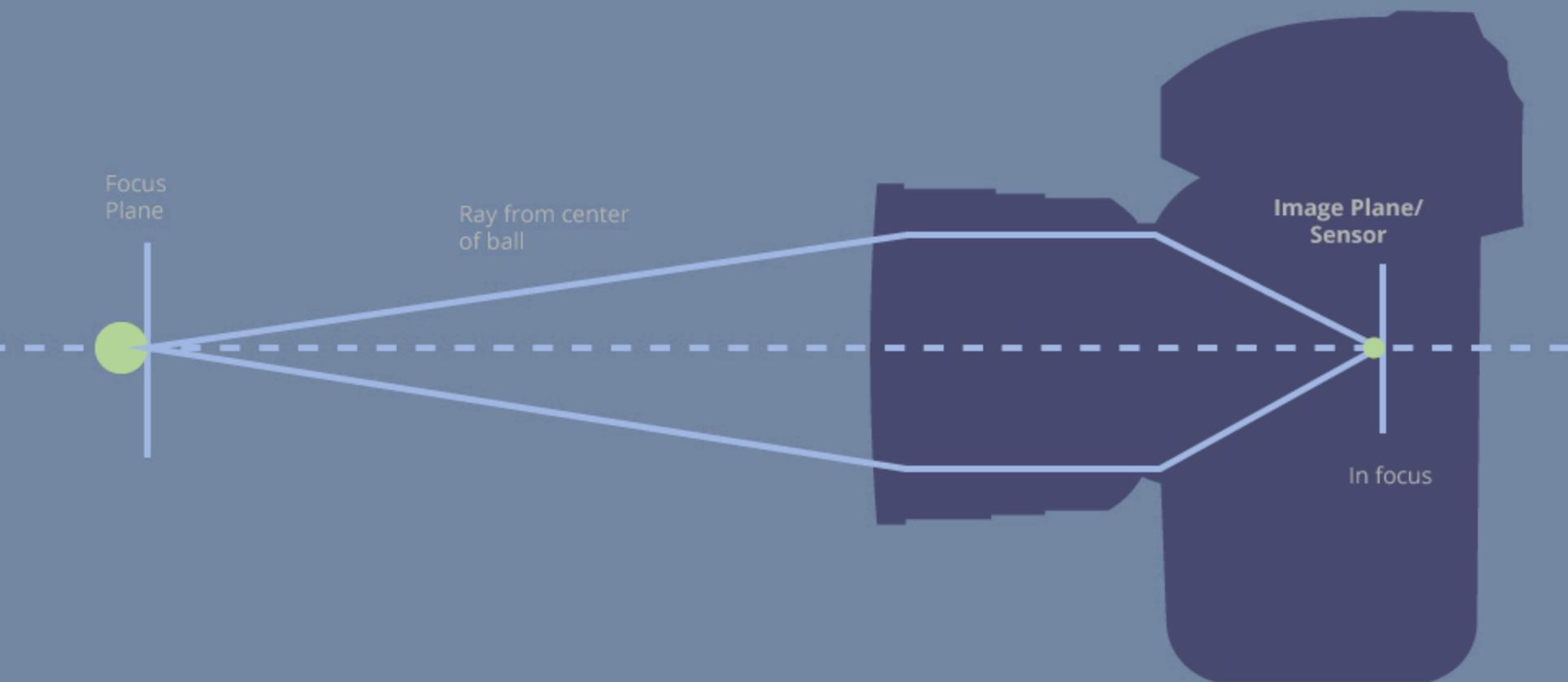


图像去模糊

章国锋/周晓巍

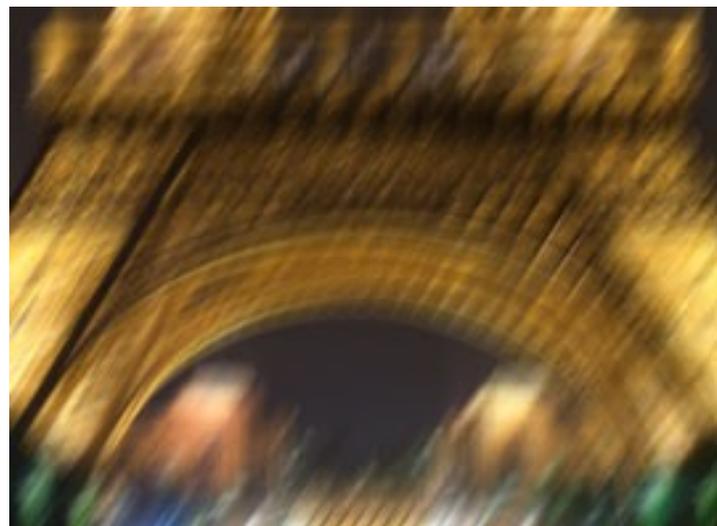
图像模糊的原因



图像模糊的原因

- 相机抖动

- 拍摄时相机不稳
- 全部画面被模糊



图像模糊的原因

■ 相机抖动

- 拍摄时相机不稳
- 全部画面被模糊

■ 物体的运动

- 部分物体运动
- 不同区域模糊不同



图像去模糊

- 利用硬件来去模糊
 - 三脚架
 - 不便携



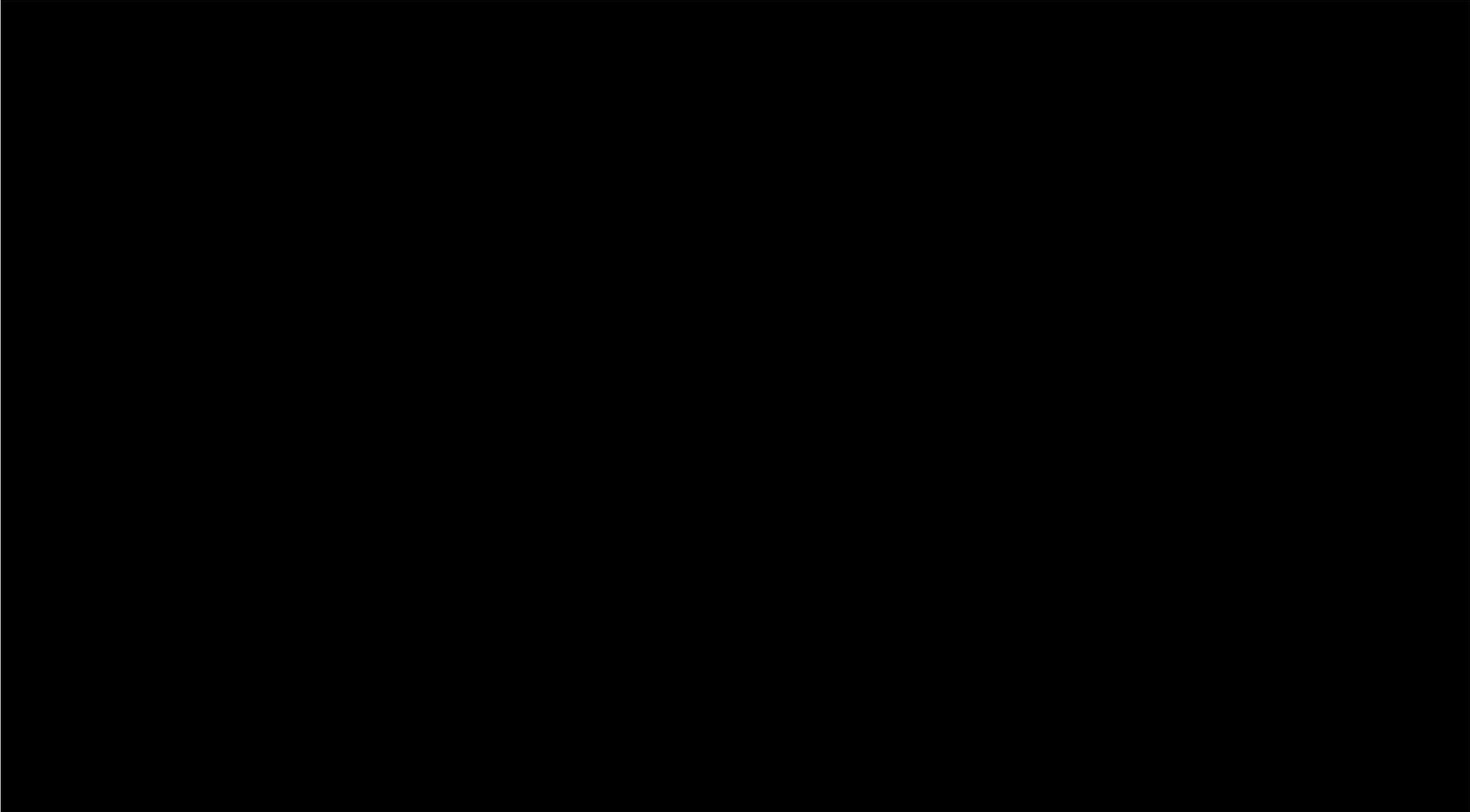
图像去模糊

■ 利用硬件来去模糊

- 光学防抖
- 结合IMU等传感器信息
- 专业稳定设备
- 总而言之：贵！



Steadycam



图像去模糊

- 不修改硬件？
 - 设计算法去模糊
 - 计算摄影学所关心的



Steadycam

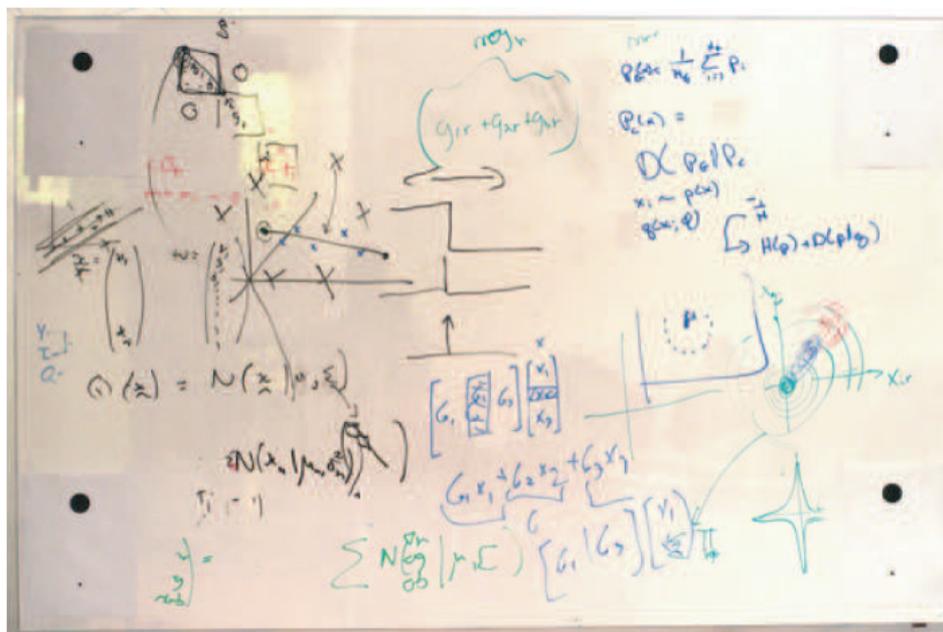


如何用数学模型描述？





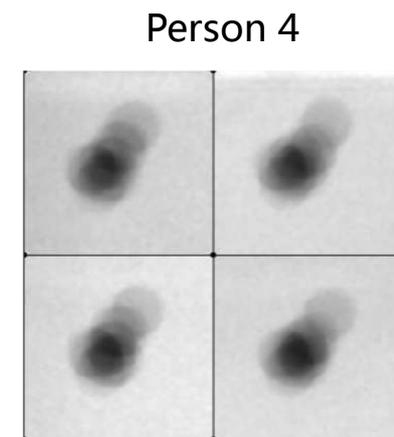
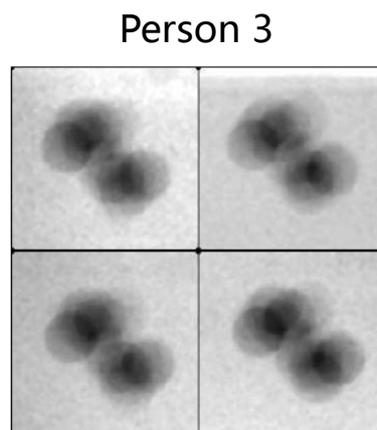
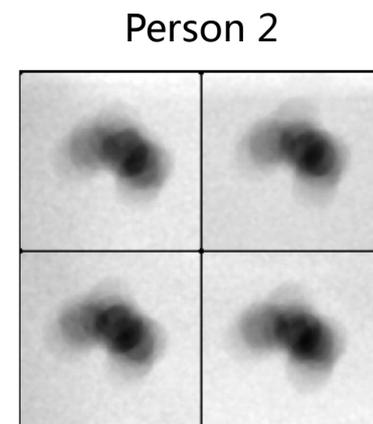
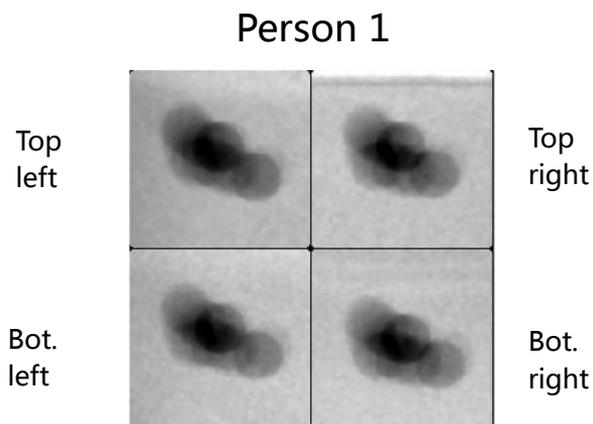
模糊的卷积模型



手持相机拍摄带有四个点标志的白板，曝光时间1秒钟

模糊的卷积模型

四个角模糊
基本相同



模糊的卷积模型

What is the result of filtering the impulse signal (image) F with the arbitrary kernel H ?

0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	1	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

$F[x, y]$



a	b	c
d	e	f
g	h	i

$H[u, v]$

$G[x, y]$

模糊的卷积模型

What is the result of filtering the impulse signal (image) F with the arbitrary kernel H ?

0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	1	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

$F[x, y]$



a	b	c
d	e	f
g	h	i

$H[u, v]$

		a	b	c		
		d	e	f		
		g	h	i		

$G[x, y]$

模糊的卷积模型

0	0	0	0	0	0	0
0	1	0	0	0	1	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	1	0	0	0	1	0
0	0	0	0	0	0	0

$F[x, y]$



a	b	c
d	e	f
g	h	i

$H[u, v]$

$G[x, y]$

模糊的卷积模型

0	0	0	0	0	0	0
0	1	0	0	0	1	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	1	0	0	0	1	0
0	0	0	0	0	0	0

$F[x, y]$



a	b	c
d	e	f
g	h	i

$H[u, v]$

a	b	c		a	b	c
d	e	f		d	e	f
g	h	i		g	h	i
a	b	c		a	b	c
d	e	f		d	e	f
g	h	i		g	h	i

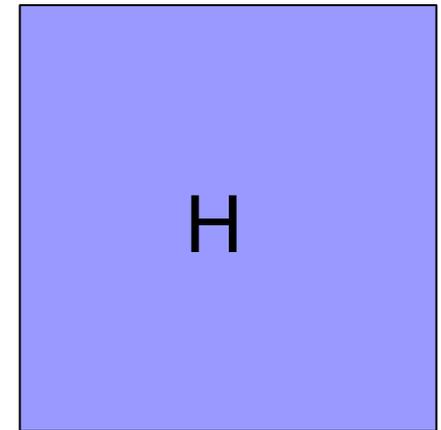
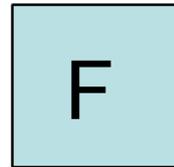
$G[x, y]$

模糊的卷积模型

$$G[i, j] = \sum_{u=-k}^k \sum_{v=-k}^k H[u, v] F[i - u, j - v]$$

$$G = H \star F$$

卷积操作



模糊的卷积模型

- 假设场景是静态的，并进行针孔成像
 - 没有物体运动，没有失焦，只有抖动



模糊图像
(拍摄的)

=



清晰图像
(要求解的)

⊗



模糊核

卷积算子

解卷积——盲与非盲

- 非盲去卷积
(Non-blind, NBID)



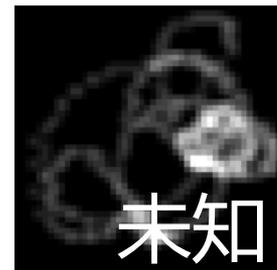
⊗



- 盲去卷积
(Blind, BID)



⊗



NBID

■ 是一个经典的问题

- Trott, T., “**The Effect of Motion of Resolution**”, *Photogrammetric Engineering*, Vol. 26, pp. 819-827, 1960.
- Slepian, D., “**Restoration of Photographs Blurred by Image Motion**”, *Bell System Tech.*, Vol. 46, No. 10, pp. 2353-2362, 1967.

The screenshot shows a Google Scholar search interface. The search bar contains the text "camera shake" and a "Search" button. To the right of the search bar are links for "Advanced Scholar Search", "Scholar Preferences", and "Scholar Help". Below the search bar, a green navigation bar displays "Scholar" and "All articles", with "Recent articles" highlighted. On the right side of this bar, it shows "Results 1 - 10 of about 11,600 for camera shake. (0.07 seconds)". A red circle highlights the number "11,600". To the right of the search results is a button labeled "Look up definition of st".

Google Scholar BETA

camera shake Search

Advanced Scholar Search
Scholar Preferences
Scholar Help

Scholar All articles Recent articles Results 1 - 10 of about 11,600 for camera shake. (0.07 seconds)

Look up definition of st

All Results

[T Teramoto](#)
[S Enomoto](#)
[D Gray](#)
[M Hamada](#)
[A Katayama](#)

[Camera capable of correcting camera-shake - group of 2 »](#)
H Ootsuka, T Okada, H Masumoto, M Hamada - US Patent 5,561,485, 1996 - patentstorm.us
Camera capable of correcting camera-shake - US Patent 5561485 from Patent Storm.
A camera comprises an angular velocity sensor for detecting camera-shake. ...
[Cited by 26](#) - [Related Articles](#) - [Cached](#) - [Web Search](#)

[Camera-shake preventing device - group of 2 »](#)
K Imafuji, N Terui - US Patent 5,337,098, 1994 - Google Patents
... when it is detected that said bat -tery has been consumed beyond a predetermined amount, said control means starts compensation of the camera shake in response ...
[Cited by 22](#) - [Related Articles](#) - [Web Search](#)

[Camera shake correction system - group of 4 »](#)
A Misawa, K Ikari, S Ueda... - US Patent 5,041,852, 1991 - Google Patents
... Misawa et al. [il] Patent Number: [45] Date of Patent: [54] CAMERA SHAKE CORRECTION ...
FIG. 27 PRIOR ART 7B Page 23. 5,041,852 CAMERA SHAKE CORRECTION SYSTEM ...

NBID

■ 是一个经典的问题

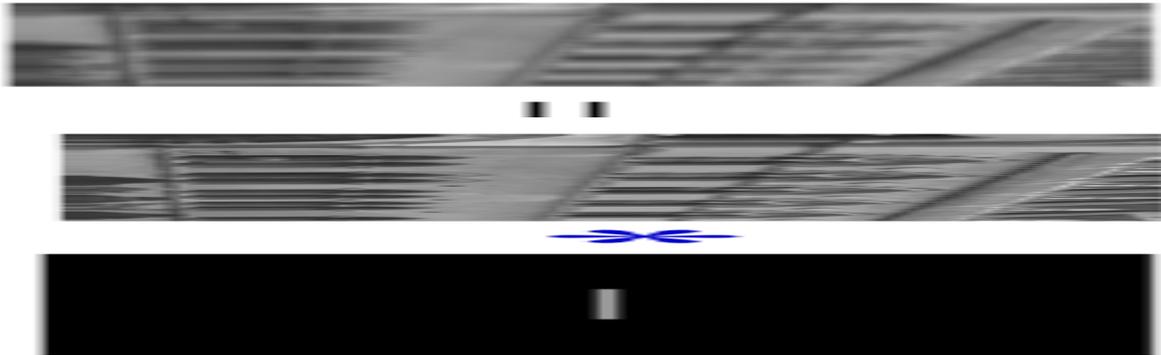
- Trott, T., “**The Effect of Motion of Resolution**”, *Photogrammetric Engineering*, Vol. 26, pp. 819-827, 1960.
- Slepian, D., “**Restoration of Photographs Blurred by Image Motion**”, *Bell System Tech.*, Vol. 46, No. 10, pp. 2353-2362, 1967.

■ 多数基于简单的模型

- 频域解卷积
- 贝叶斯模型 (Richard, 1972. Lucy, 1974.)
- 对卷积核要求高

NBID基本模型

- J: 拍摄到的图像
- I: 需要求解的图像
- K: 卷积核



频域解卷积

- 空域的卷积 = 频域的乘积
- 空域解卷积 = 频域的除法

Richardson-Lucy

- 一种常用的空域迭代去卷积方法

example, W_i indicates either the i th location in the array W or the value associated with the i th location. The unsubscripted letter refers to the entire array or the value associated with the array as in $W = \sum_i W_i$. The double-subscripted $W_{i,j}$ in two dimensions is interpreted similarly to W_i in one dimension. In the approximation formulas, a subscript r appears, which is the number of the iteration.

DISCUSSION

Given the degraded image H , the point spread function S , and the requirement to find the original image W Bayes's theorem comes readily to mind. In the nota-

This results in an iterative procedure where the initial $P_0(W_i)$ is estimated. An estimation often used is Bayes's postulate (also known as the equidistribution of ignorance), which assumes a uniform distribution so that $P_0(W_i) = 1/I$ or $W_{i,0} = W/I$.

Equation (4) can be reduced to a more easily workable form by $P(W_i) = W_i/W$ and $P(H_k) = H_k/H = H_k/W$, since the restoration is a conservative process and $W = H$, and also $P(H_k|W_i) = P(S_{i,k}) = S_{i,k}/S$,

$$S = \sum_j S_j, \quad j = \{1, J\}.$$

Then Eq. (4) becomes

Richardson-Lucy

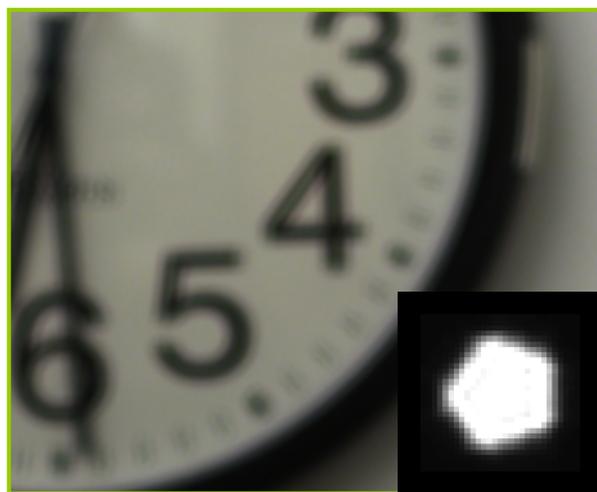
- 迭代算法:

- 直观解释

- 用当前估计的清晰图像进行卷积
- 与模糊图像比较得到差异 → 当前估计的误差
- 将误差补偿到估计图像

Richardson-Lucy

- 一种常用的空域迭代去卷积方法
 - 基于贝叶斯模型进行的最大似然估计
 - 缺点：噪音、Ringing Artifacts



Input



Richardson-Lucy

NBID是个病态问题

- 解并不唯一

Solution 1:



Solution 2:



NBID是个病态问题

- 解并不唯一
- 好的解要“自然”

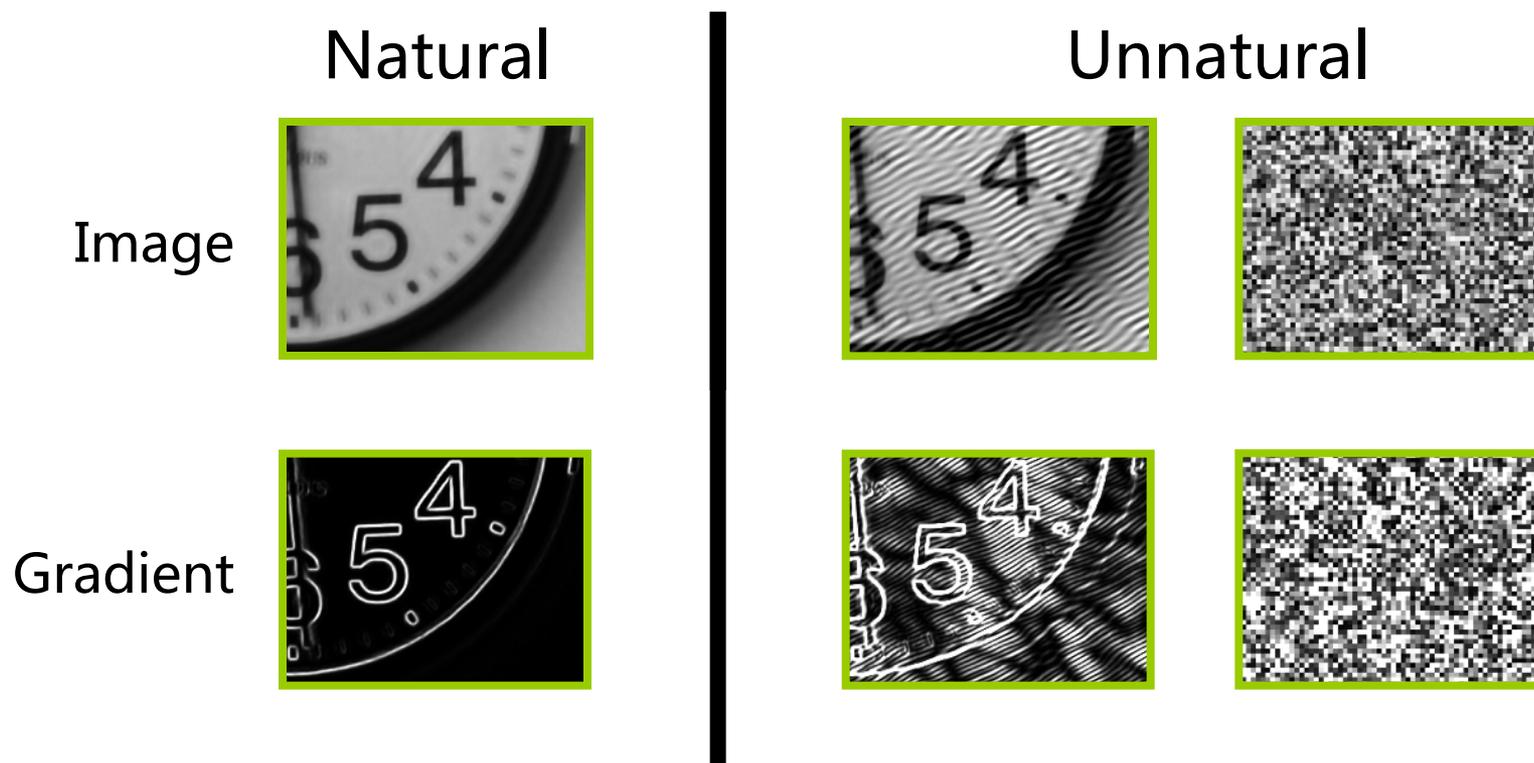
Solution 1:



Solution 2:



自然图片有什么特点？

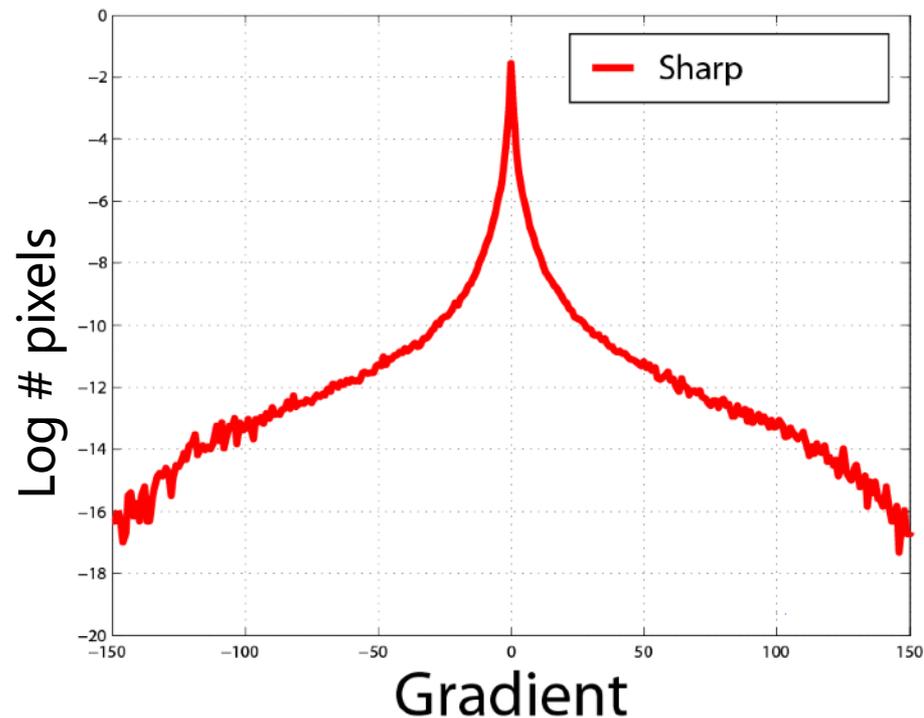


Natural images have sparse gradients

➡ put a penalty on gradients

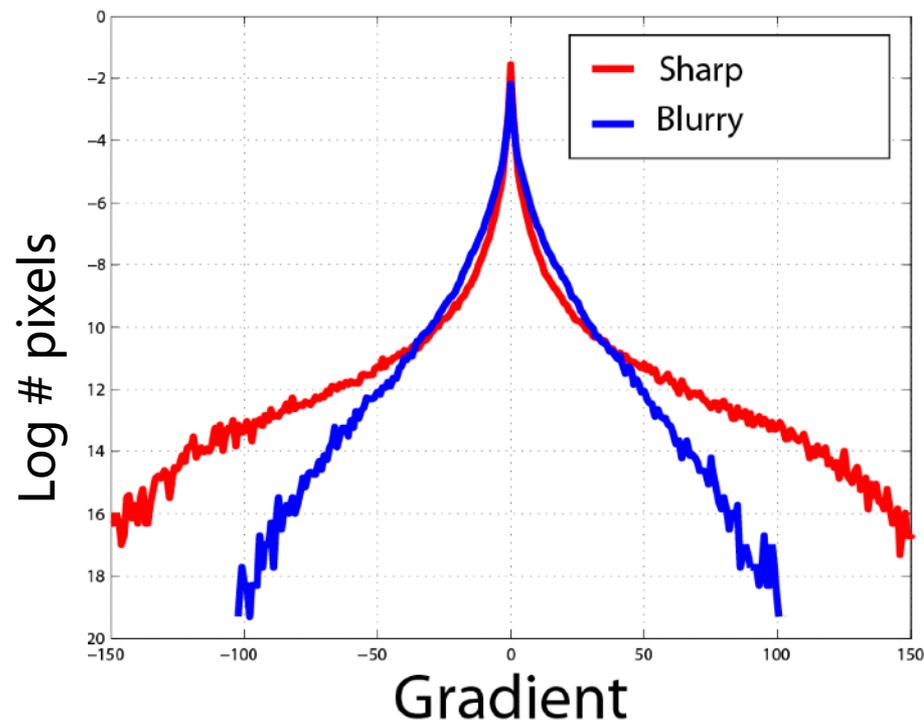
自然图像的统计特性

- 图像梯度的直方图具有明显的重尾分布 (Heavy-tail distribution)



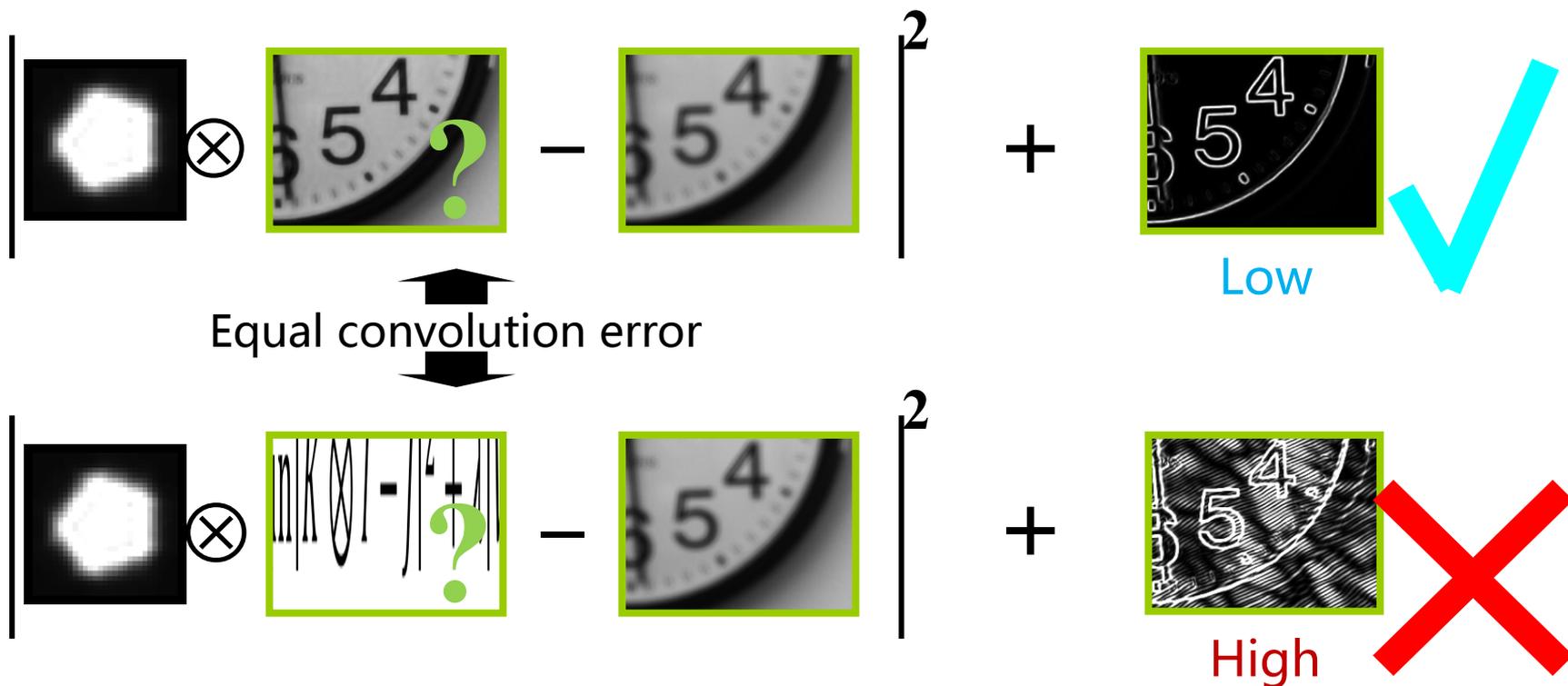
模糊图像呢？

- 并不会出现重尾分布



帶先验非盲去卷积

$$\min_I |K \otimes I - J|^2 + \lambda |\nabla I|^k$$



R-L vs. Prior

$$\min_I \left| K \otimes I - J \right|^2 + \lambda \left| \nabla I \right|^k$$

k=2

"spread" gradients



Richardson-Lucy



Gaussian prior

k=1

"localizes" gradients



Sparse prior

NBID的应用

■ 哈勃太空望远镜

- 升空时反射镜存在缺陷
- 最初使用去卷积方法消除问题



Image of star



NBID的应用

■ 哈勃太空望远镜

- 升空时反射镜存在缺陷
- 最初使用去卷积方法消除问题

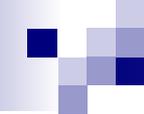
Before and after corrective optics



Blind Image Deconvolution (BID)

- 卷积核也未知
- 显然更加困难
 - 需要更多先验知识!





Removing Camera Shake from a Single Photograph

Rob Fergus, Barun Singh, Aaron Hertzmann,
Sam T. Roweis and William T. Freeman

SIGGRAPH 2006

Massachusetts Institute of Technology
and
University of Toronto

哪些信息是已知的？

- 图像的卷积模糊模型



=

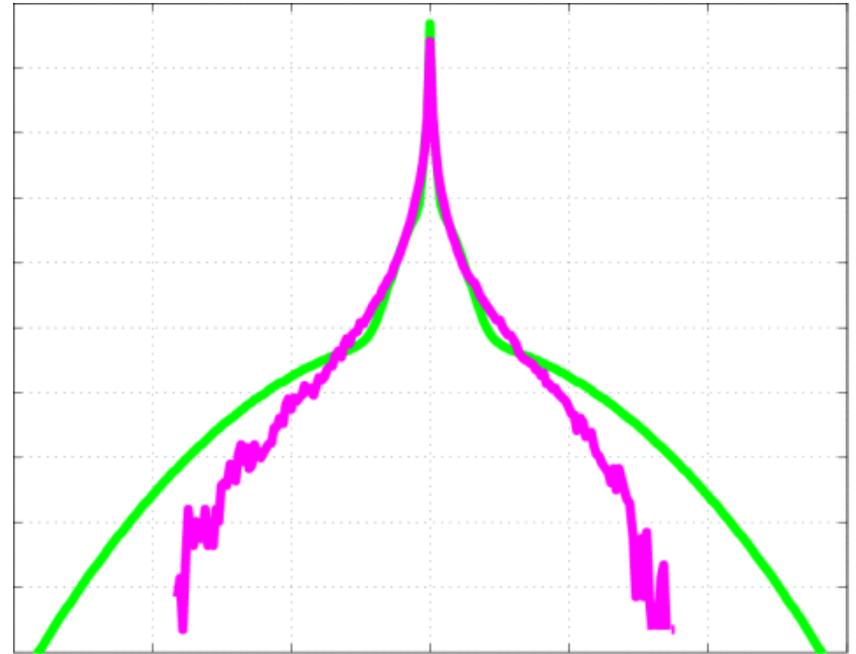


⊗



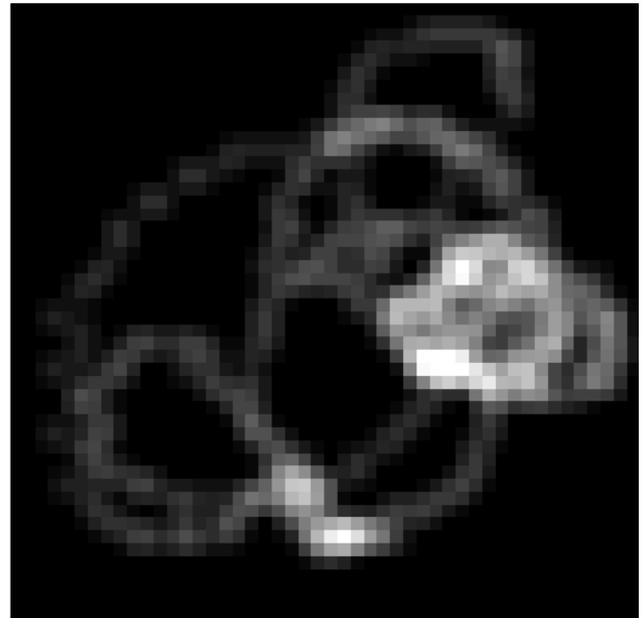
哪些信息是已知的？

- 图像的卷积模糊模型
- 图像梯度的先验信息
 - 重尾分布



哪些信息是已知的？

- 图像的卷积模糊模型
- 图像梯度的先验信息
 - 重尾分布
- 模糊核的先验信息
 - 非负且稀疏



人造数据的结果

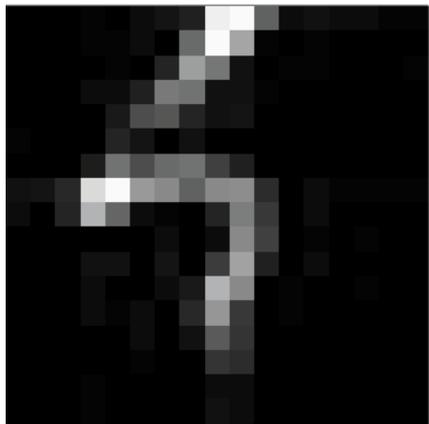
原始图片



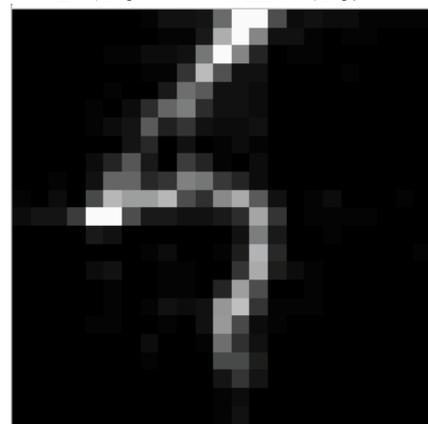
求解得到的图片



Ground-Truth 模糊核



求解出的模糊核



Blurry image



Matlab deconvblind



Blurry image

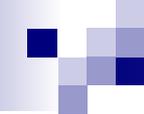


Deblurring output



True sharp image





真实数据结果

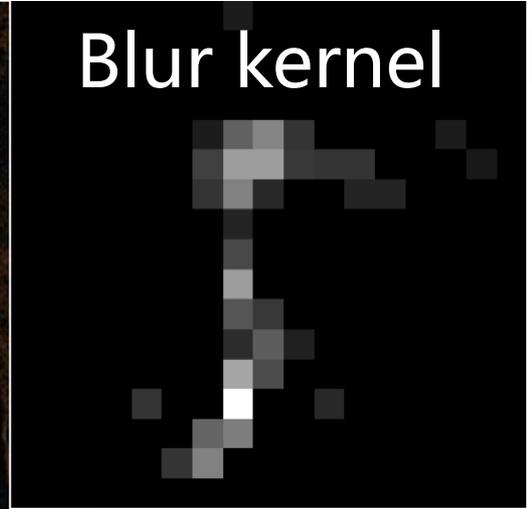
Original photograph



Output



Blur kernel



Original photograph



Output



Blur kernel

真实数据结果

- 结果并不完美
 - 相机类型等等并不知道，无法修正Gamma
 - 噪音模型很单纯
 - 最后的去卷积使用了简单的R-L
 -
- 启发了其后续一大批的工作

小结

- 相机抖动模糊的模型是什么？
 - 图像卷积
- **BID**和**NBID**的区别是什么？
 - 卷积核是否已知
- 解卷积这种病态问题要如何处理？
 - 需要发现先验知识来约束解

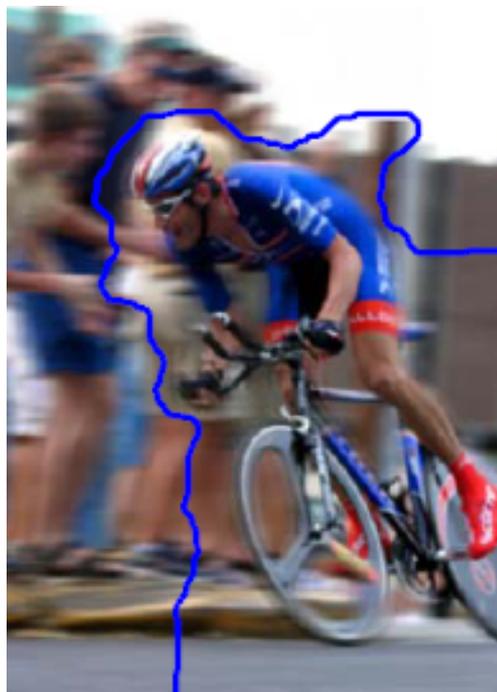
运动模糊 vs. 相机抖动

- 相机抖动
 - 全局一致的模糊

运动模糊 vs. 相机抖动

- 相机抖动
 - 全局一致的模糊
- 运动模糊
 - 不同物体模糊模式不同
 - 分层处理，假定层内模糊一致 (A. Levin, 2006)

Input & Segmentation

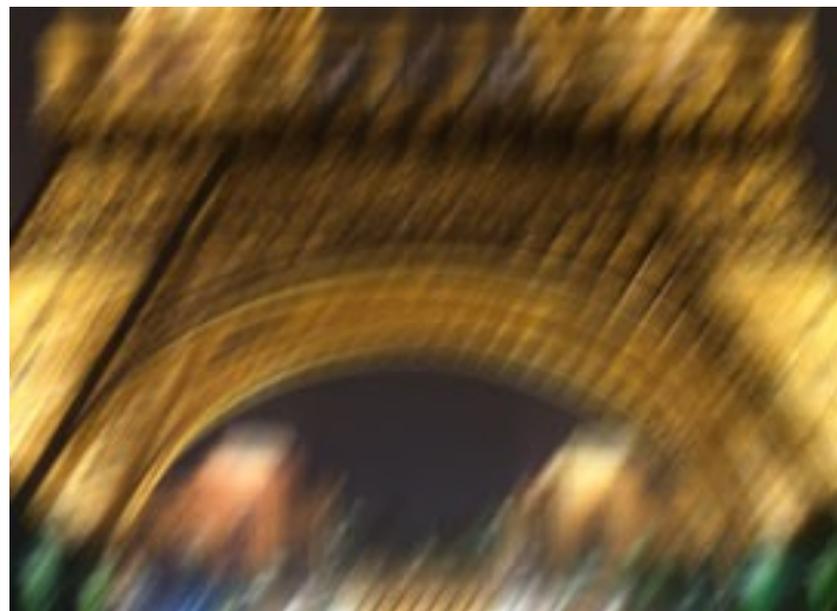


Deblurred image



运动模糊 vs. 相机抖动

- 相机抖动
 - 通常是由于不良的拍摄条件导致



运动模糊 vs. 相机抖动

- 相机抖动
 - 通常是由于不良的拍摄条件导致
 - 希望消除



运动模糊 vs. 相机抖动

- 相机抖动
 - 通常是由于不良的拍摄条件导致
 - 希望消除
- 运动模糊
 - 有时是为了画面效果



运动模糊 vs. 相机抖动

- 相机抖动
 - 通常是由于不良的拍摄条件导致
 - 希望消除
- 运动模糊
 - 有时是为了画面效果
 - 不一定需要消除





Light Painting

图像模糊的原因

■ 相机抖动

- 拍摄时相机不稳
- 全部画面被模糊

■ 物体的运动

- 部分物体运动
- 不同区域模糊不同

■ 镜头失焦

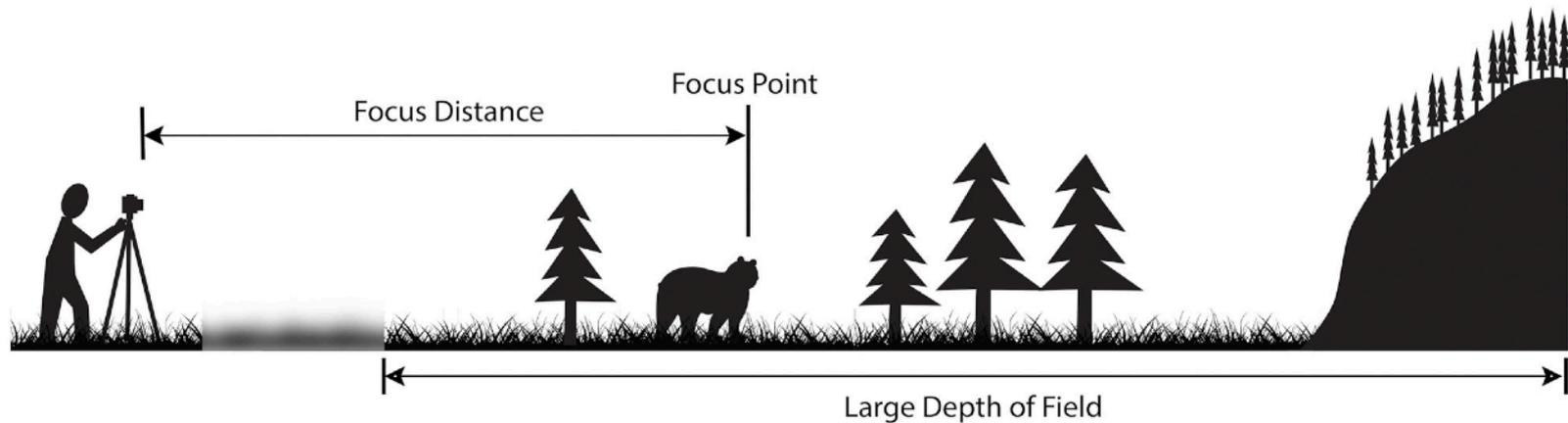
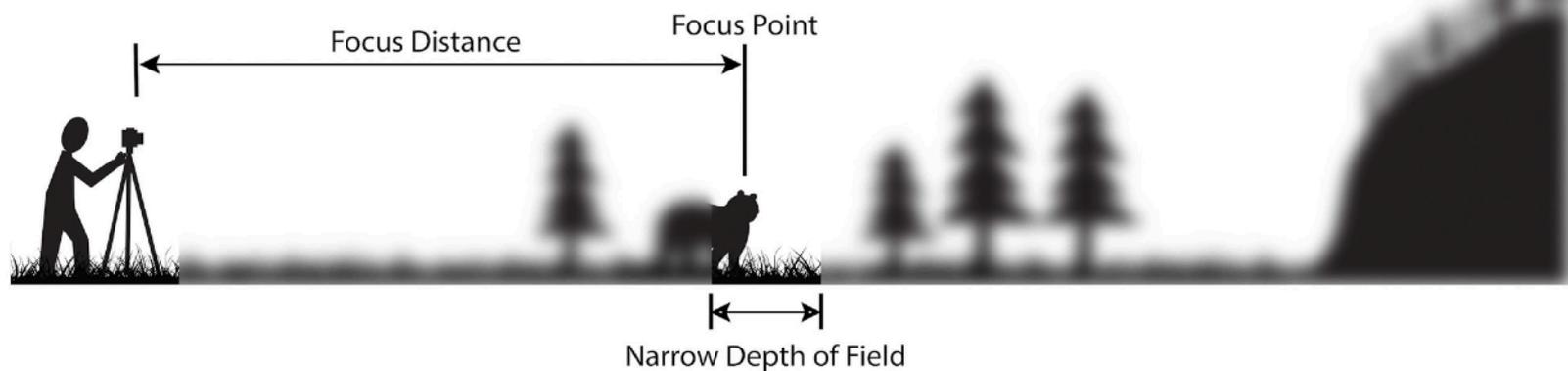
- 大光圈小景深时的效果
- 深度不同模糊程度不同

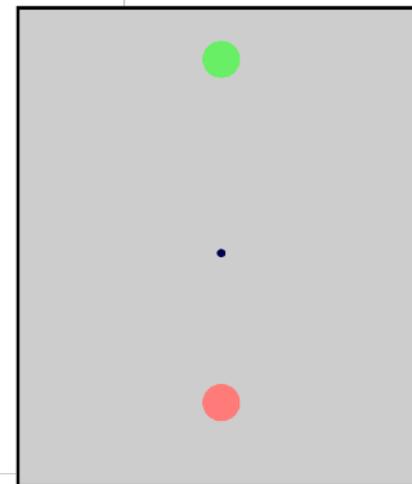
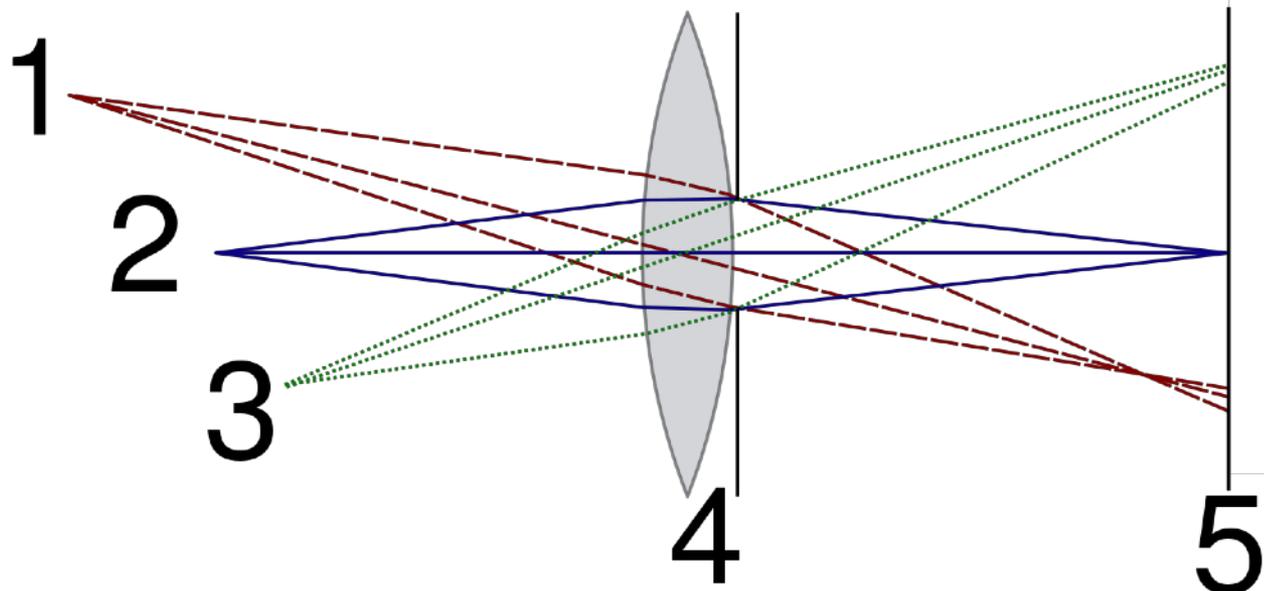
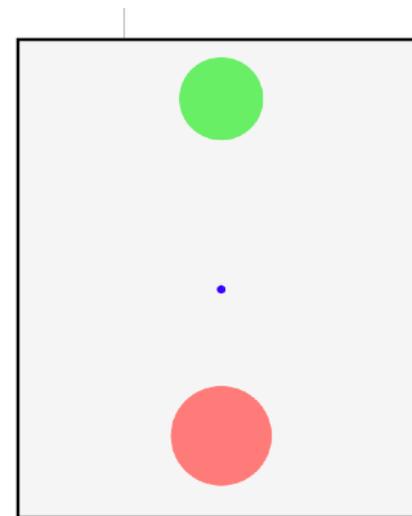
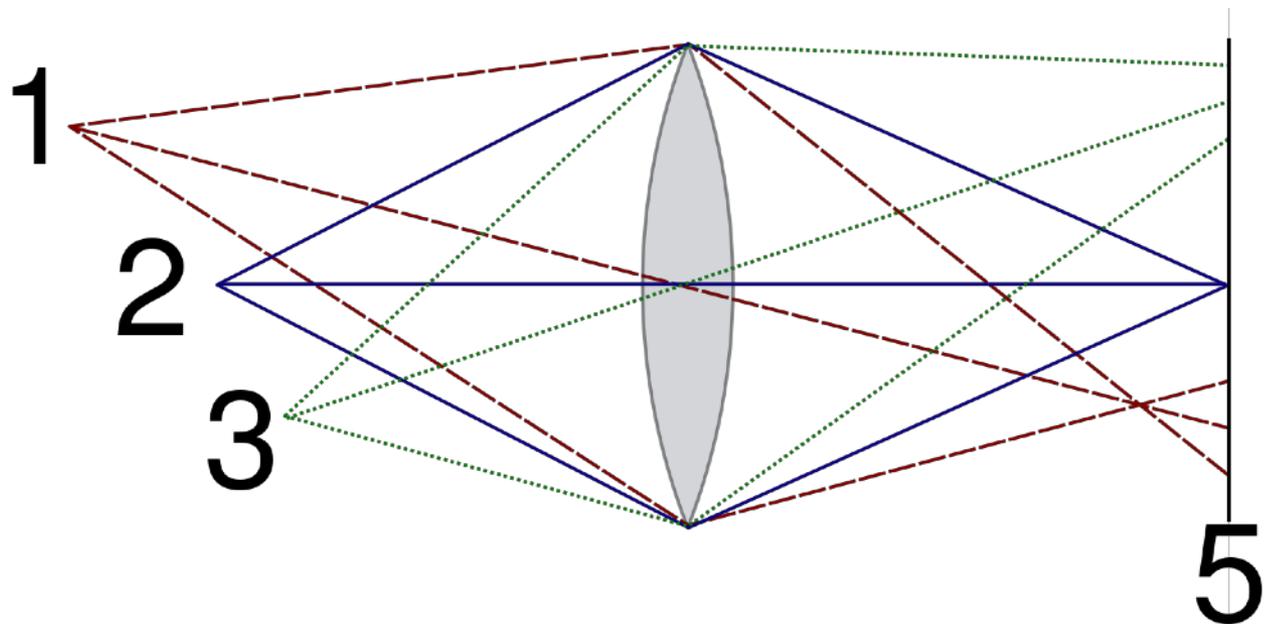


景深

... distance for that aperture. The scales on a lens barrel hyperfocal distance opposite you are using. If you then the depth of field will be to infinity. ◁ For a camera has a hyperfocal focus at 18 feet,

景深跟哪些因素有关





如何减小景深

- 大光圈
- 长焦距
- 距离近
- 背景远

The-Digital-Picture.com Reviews



镜头失焦

- 模糊核与深度有关



镜头失焦

- 模糊核与深度有关
 - 需要求解原始图像、深度、模糊核
 - 假定模糊核关于深度的模型已知?
 - Depth from focus/defocus
 - 另一个研究领域 (Depth from X)

手机人像模式如何实现的？

