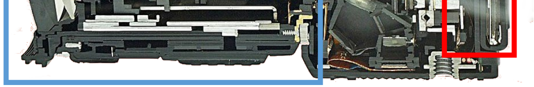


Blur, Sharpen

Scene motion

Blur, Sharpen

Sources: CMU 15-463, Dartmouth College CS89/189.

image from a perfect lens | imperfect lens PSF | image from imperfect lens

$$I \quad * \quad k \quad = \quad B$$

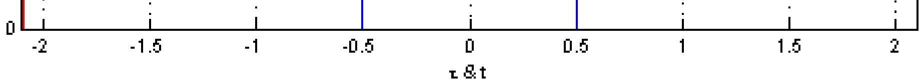
Source: Ioannis Gkioulekas

Source: Fredo Durand

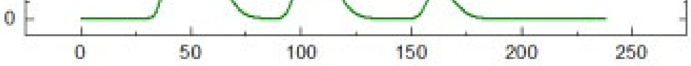
Source: Fredo Durand

Source: Ioannis Gkioulekas

Source: Ioannis Gkioulekas



Source: Ioannis Gkioulekas



Source: Ioannis Gkioulekas

$$f * (g + h) = (f * g) + (f * h)$$

Source: Ioannis Gkioulekas

Source: Fredo Durand

Source: Fredo Durand

1	1	0	0	0	0	0

f (original image) g (kernel) result

Source: Fredo Durand

Original

Blur (with a mean filter)

Source: Fredo Durand

(no change)

Source: Fredo Durand

Source: Fredo Durand

(applied in both dimensions)

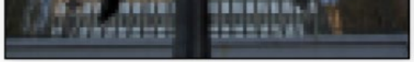
Source: Fredo Durand

(applied in both dimensions)

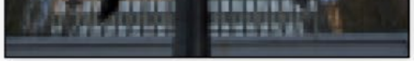
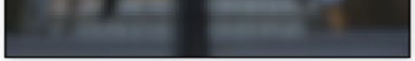
Far fi

Source: Fredo Durand

Source: Wojciech Jarosz



Source: Wojciech Jarosz

Source: Wojciech Jarosz

Horizontal gradient (absolute value)

Vertical gradient (absolute value)

Gradient magnitude

Source: Wojciech Jarosz

Source: Wojciech Jarosz

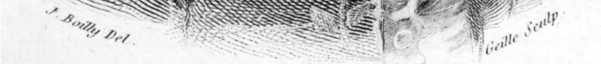
You can play with some filters here: https://setosa.io/ev/image-kernels/

Source: Fredo Durand

Source: Fredo Durand

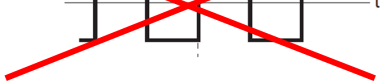
- But convolutions are expensive… **Fourier domain**!

Source: Fredo Durand



Jean Baptiste Joseph Fourier (1768-1830)

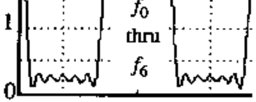
Source: James Tompkin



Source: James Tompkin

Source: James Tompkin

$$f(\text{target}) = f_1 + f_2 + f_3 \ldots + f_n + \ldots$$



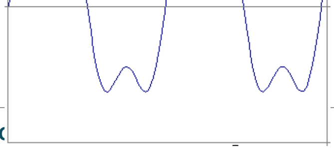
Source: James Tompkin

Source: James Tompkin

of *f(t)*

Source: James Tompkin

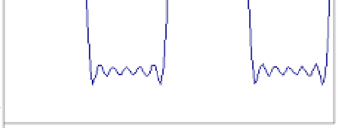
Source: James Tompkin



Source: James Tompkin

Source: James Tompkin

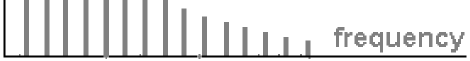
Source: James Tompkin



Source: James Tompkin

strong-contrast sharp edges)!

Source: James Tompkin



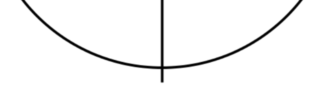
Source: James Tompkin

Amazing slide adapted from James Tompkin's

and **phases** (timing) of these sinusoidal components.

Amazing slide adapted from James Tompkin's

Amazing slide adapted from James Tompkin's



$$\varphi = \tan \quad \frac{\quad}{\mathrm{Re}(\varphi)}$$

Source: James Tompkin

Further explanations and intuitive interpretation: https://sites.northwestern.edu/elannesscohn/2019/07/30/developing-an-intuition-for-fourier-transforms/

Amazing slide adapted from James Tompkin's

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Amazing slide adapted from James Tompkin's

Source: James Tompkin

Source: James Tompkin

Source: James Tompkin

Source: James Tompkin

Source: James Tompkin

Source: James Tompkin

Source: James Tompkin

Source

Fourier transform **(amplitude)**

Fourier transform **(amplitude)**

Fourier transform **(amplitude)**

Source

Fourier transform **(amplitude)**

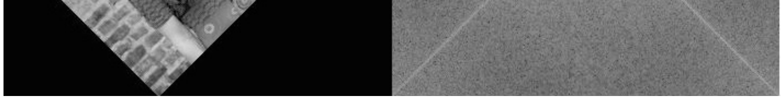
[Source]

Source

Source: James Tompkin

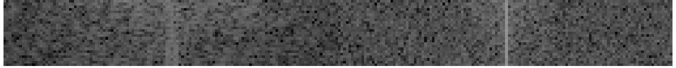
Source: James Tompkin

Source: James Tompkin

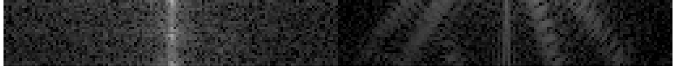


Source

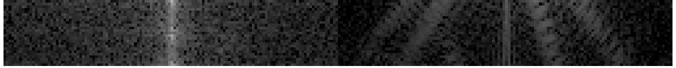
Source: James Tompkin



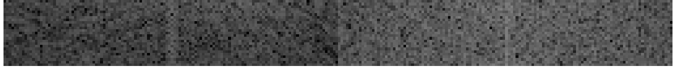
Source

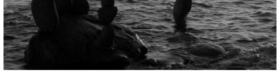


[Source]



Source





Source: James Tompkin

the low frequency (smooth) part of the signal can be seen.

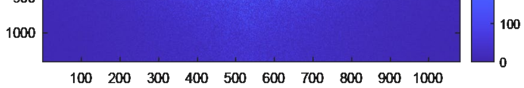
A. Oliva, A. Torralba, P.G. Schyns, “Hybrid Images,” SIGGRAPH 2006

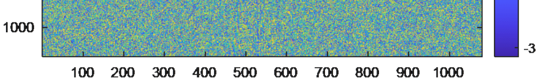
Source: James Tompkin

Source: Fredo Durand

Right?

Source: James Tompkin


1000
100
0
100 200 300 400 500 600 700 800 900 1000


1000
-3
100 200 300 400 500 600 700 800 900 1000

Original Image

Reconstruction from only the frequencies' amplitude

Source: James Tompkin

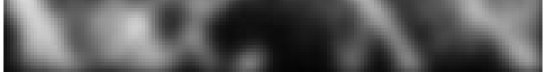
Source: James Tompkin

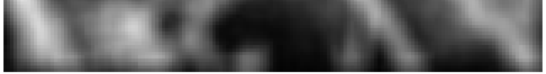
Source: James Tompkin


Source: James Tompkin

- Heavy in low frequencies, falling off in high frequencies

Source: James Tompkin





Source: James Tompkin

Box Filter

Gaussian Filter

Source: James Tompkin

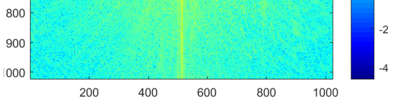
(applied in both dimensions)

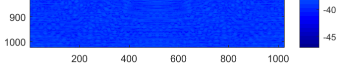
Far i

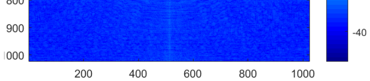
Source: Fredo Durand

Source: James Tompkin

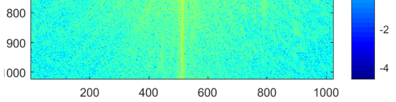
Source: James Tompkin

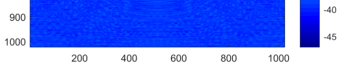


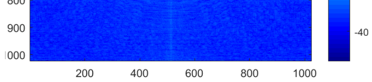




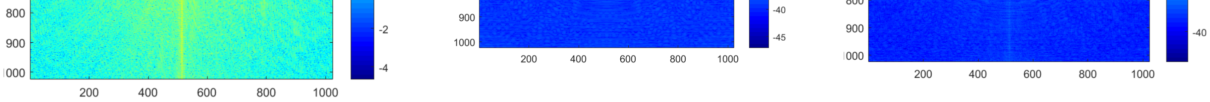
Source: James Tompkin



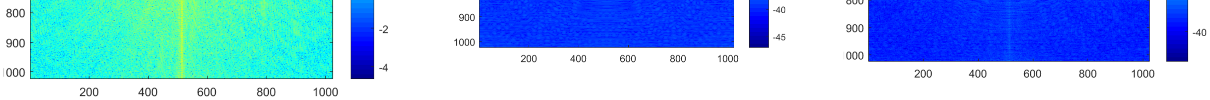




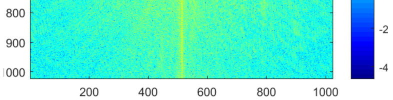
Source: James Tompkin

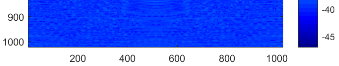


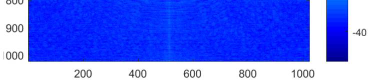
Source: James Tompkin



Source: James Tompkin







Source: James Tompkin

Source: Ioannis Gkioulekas

$$B \quad * \quad k^{-1} \quad = \quad I_{est}$$

Source: Ioannis Gkioulekas

$$\mathrm{SNR}(\omega) = \frac{\quad}{\text{noise variance at } \omega}$$

Source: Ioannis Gkioulekas

- When SNR is low (high noise), just set to zero.

Source: Ioannis Gkioulekas

naïve deconvolution

Wiener deconvolution

Source: Ioannis Gkioulekas

Source: James Tompkin

- Well… More or less…