ĐẠI HỌC ĐÀ NẴNG
TRƯỜNG ĐẠI HỌC CÔNG NGHỆ THÔNG TIN VÀ TRUYỀN THÔNG VIỆT - HÀN
Vietnam - Korea University of Information and Communication Technology

Image Filter

Lecturer: LeNga

Image filter

Three views of filtering:

- **Image filters in the spatial domain**
  - Filter is a **mathematical operation of a grid of numbers**S
  - moothing, sharpening, measuring texture
- **Image filters in the frequency domain**
  - Filtering is a **way to modify the frequencies of images**
  - Denoising, sampling, image compression
- **Templates and Image Pyramids**
  - Filtering is a **way to match a template to the image**
  - Detection, coarse-to-fine registration

Templates & Image Pyramids

- Image downsampling
- Anti-aliasing
- Gaussian image pyramid
- Laplacian image pyramid

Templates & Image Pyramids

- **Image downsampling**
  - Anti-aliasing
  - Gaussian image pyramid
  - Laplacian image pyramid

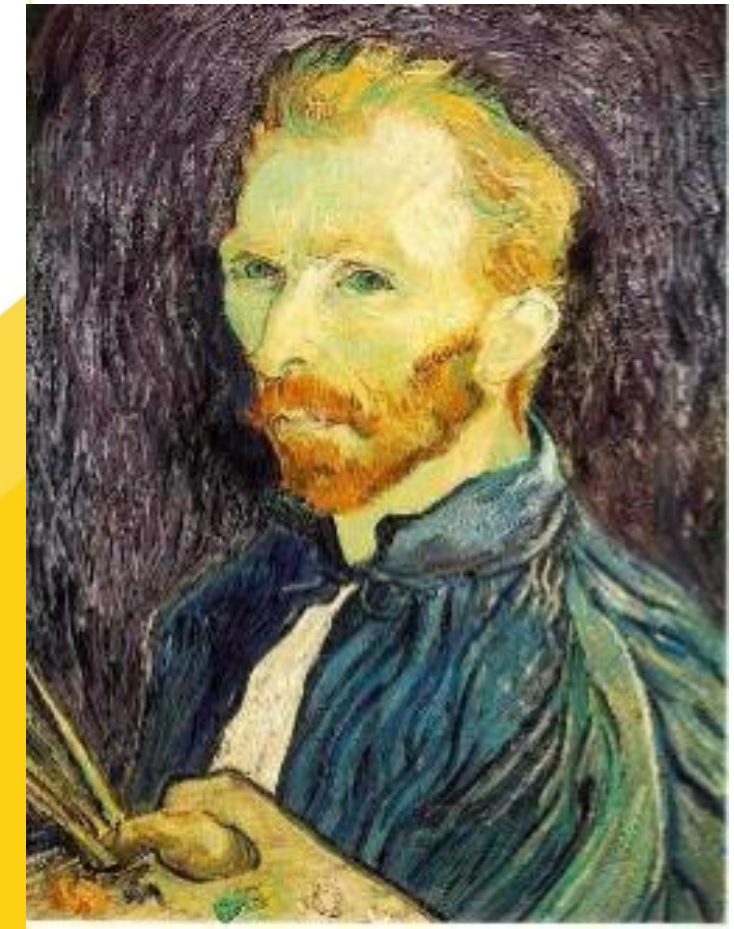
Image downsampling

- Why does a lower resolution image still make sense to us? What do we lose?

This image is too big to fit on the screen.
How would you reduce it to half its size?

Naïve image downsampling

Throw away half the rows and columns



1/2

delete even rows
delete even columns

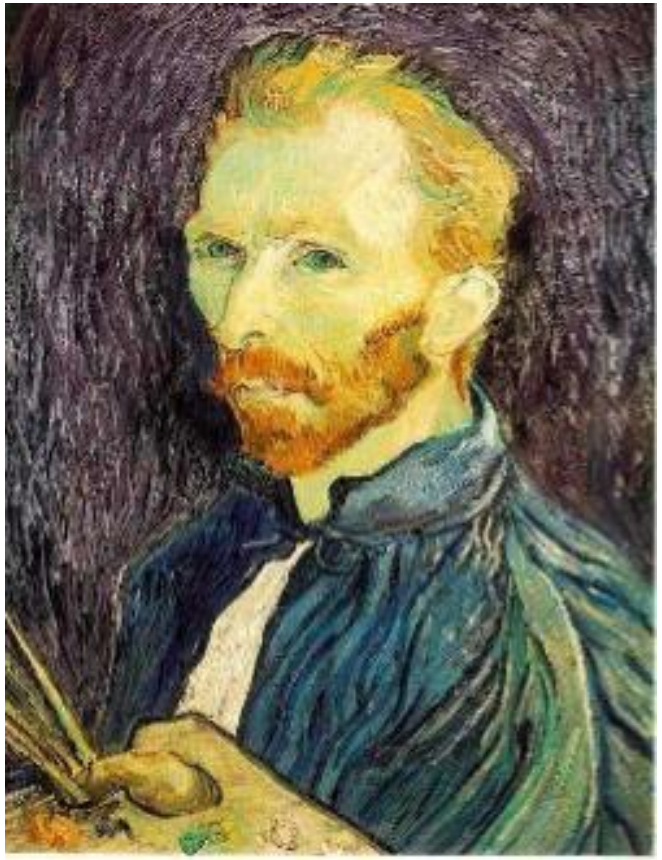
1/4

delete even rows
delete even columns

1/8

What is the problem with this approach?

Naïve image downsampling



1/2

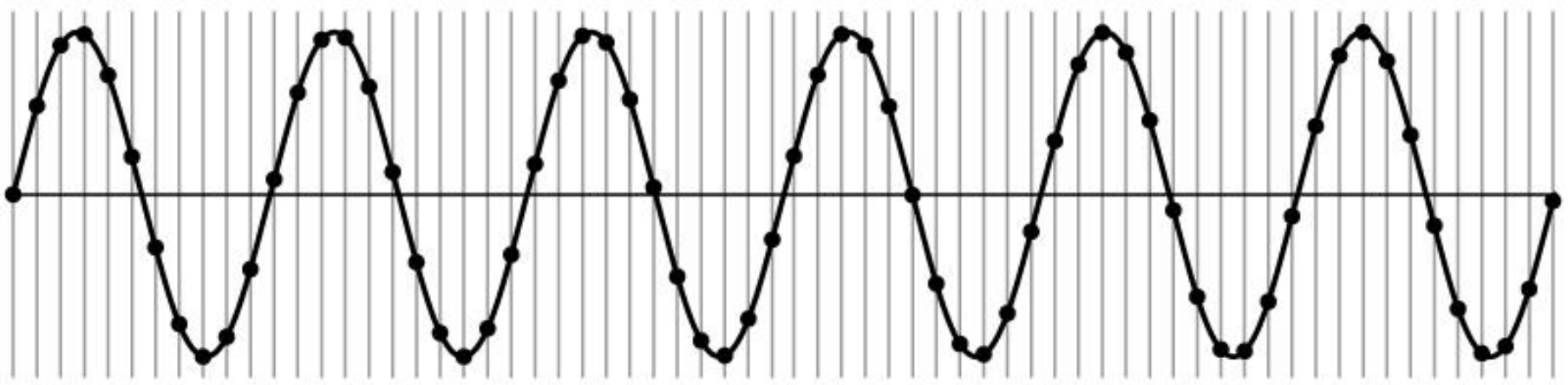
1/4 (2x zoom)

1/8 (4x zoom)

What is the 1/8 image so pixelated (and do you know what this effect is called)?

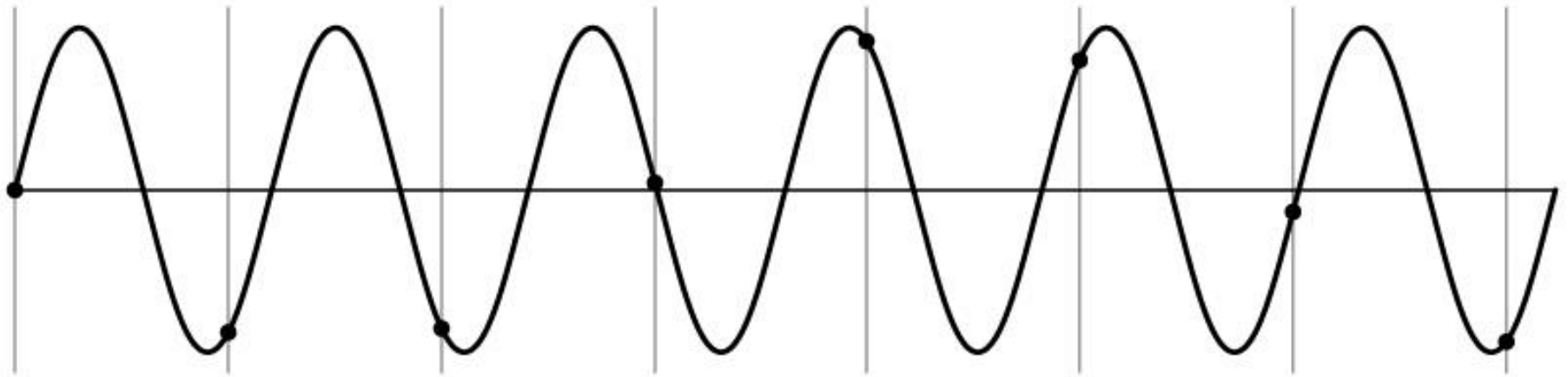
Sampling

Very simple example: a sine wave



Undersampling

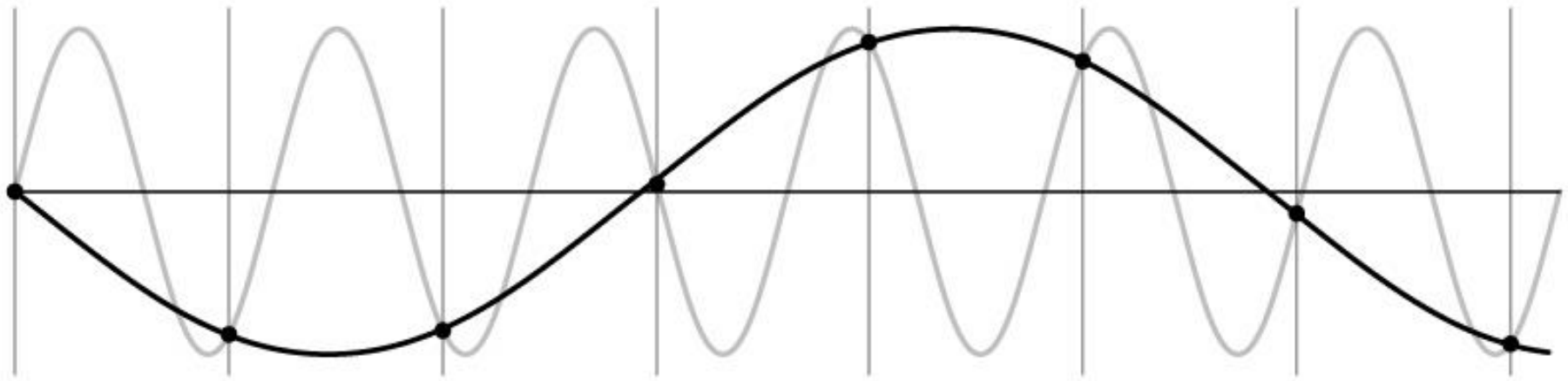
Very simple example: a sine wave



Unsurprising effect: information is lost.

Undersampling

Very simple example: a sine wave

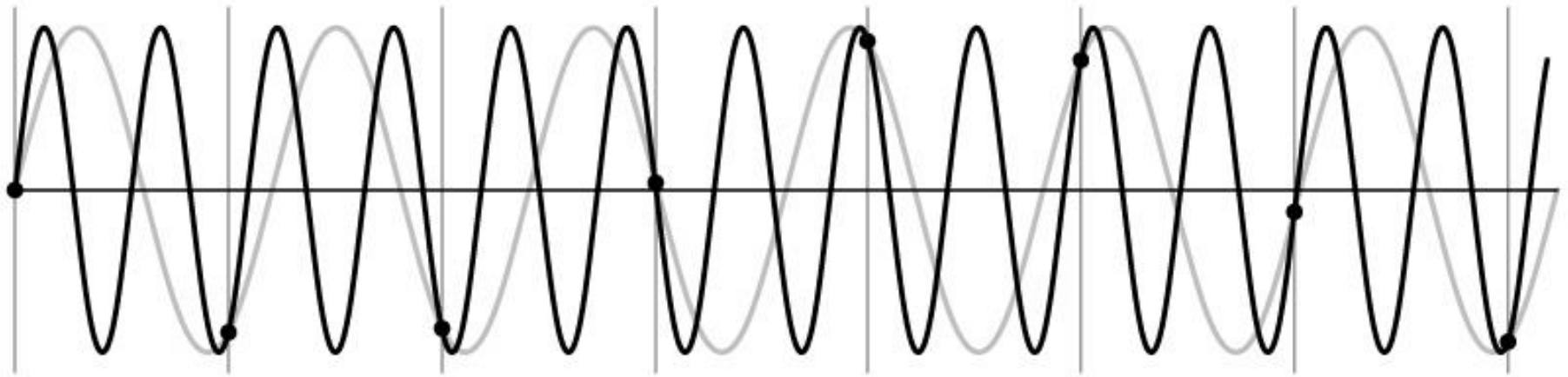


Unsurprising effect: information is lost.

Surprising effect: can confuse the signal with one of *lower* frequency.

Undersampling

Very simple example: a sine wave



Unsurprising effect: information is lost.

Surprising effect: can confuse the signal with one of *lower* frequency.

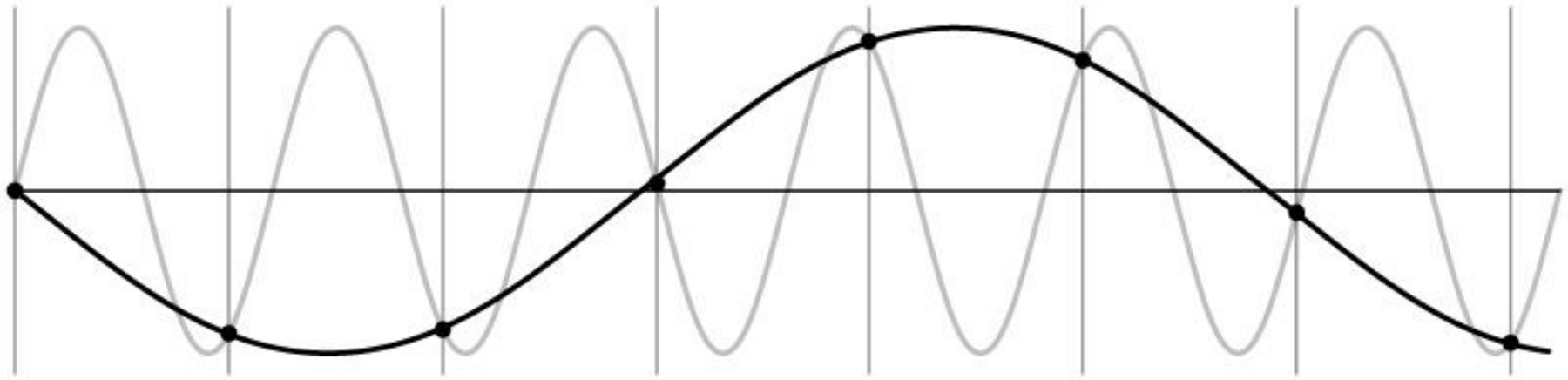
Note: we could always confuse the signal with one of *higher* frequency.

Templates & Image Pyramids

- Image downsampling
- **Anti-aliasing**
- Gaussian image pyramid
- Laplacian image pyramid

Aliasing

Fancy term for: *Undersampling can disguise a signal as one of a lower frequency*

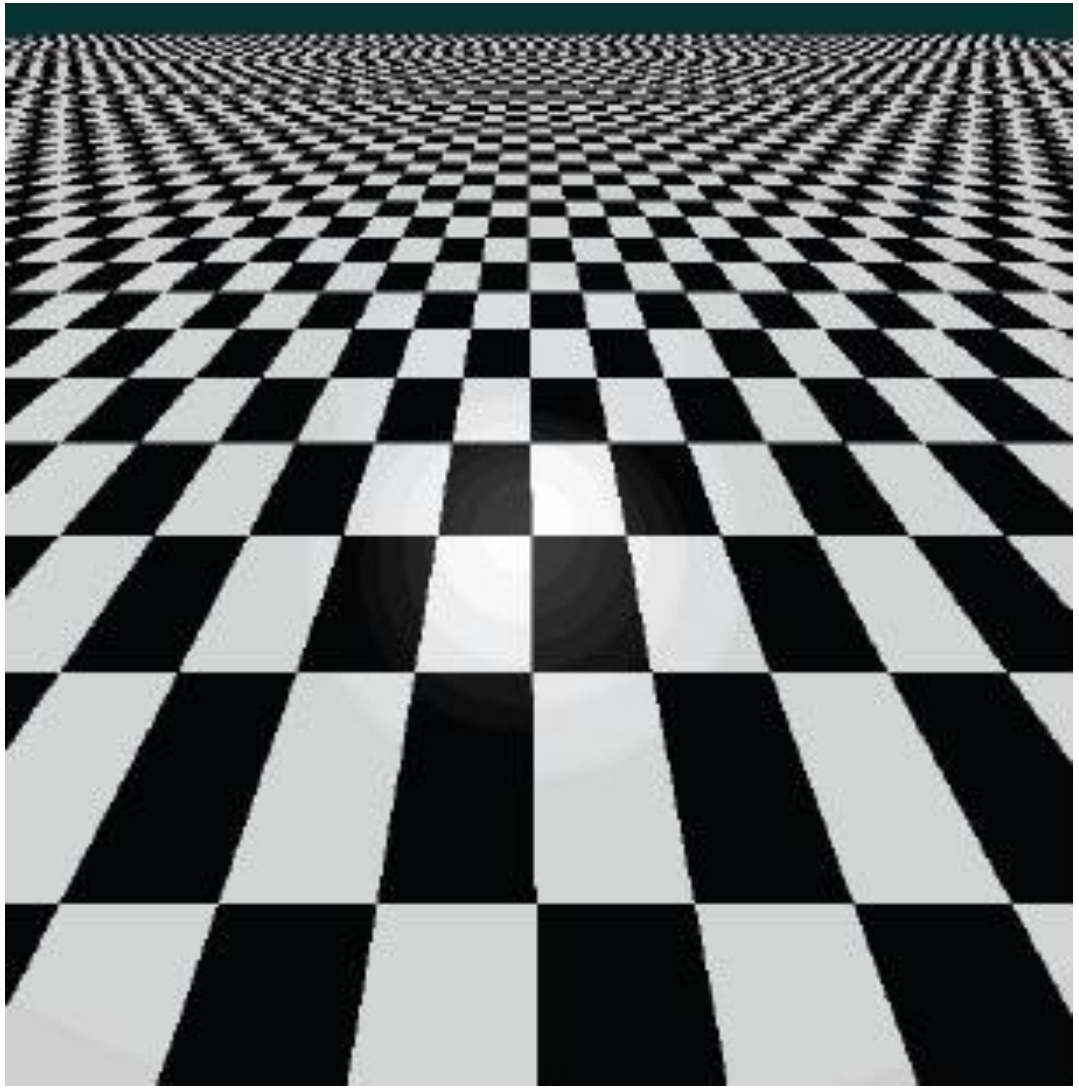


Unsurprising effect: information is lost.

Surprising effect: can confuse the signal with one of *lower* frequency.

Note: we could always confuse the signal with one of *higher* frequency.

Aliasing in textures



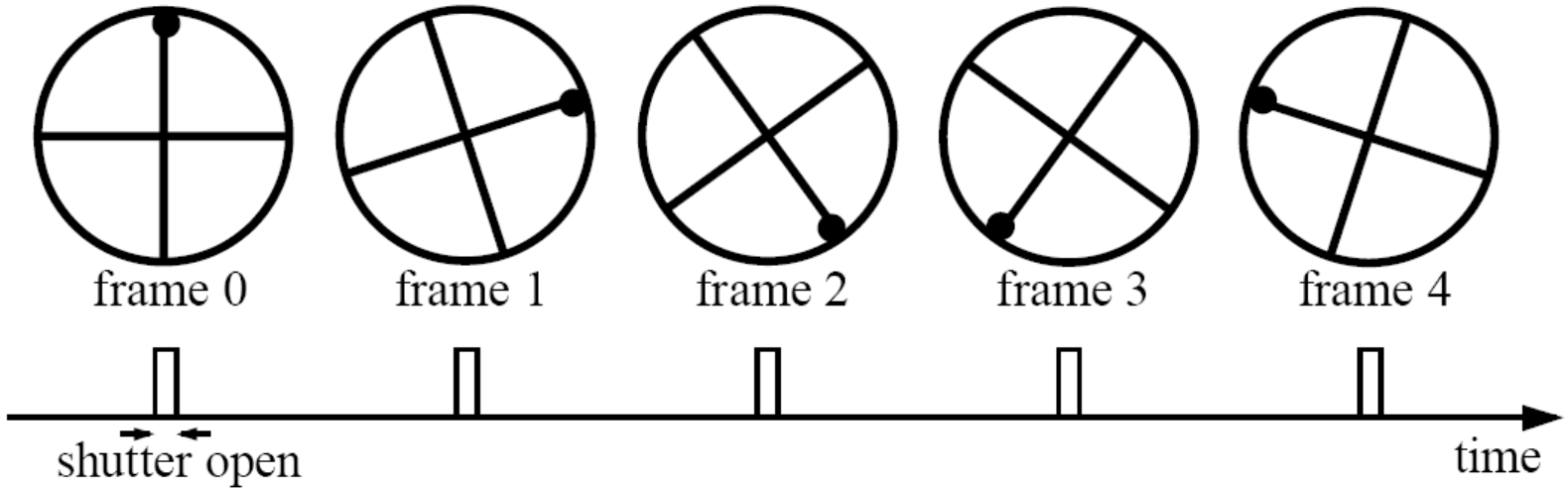
Aliasing in photographs

This is also known as “moire”

Temporal aliasing

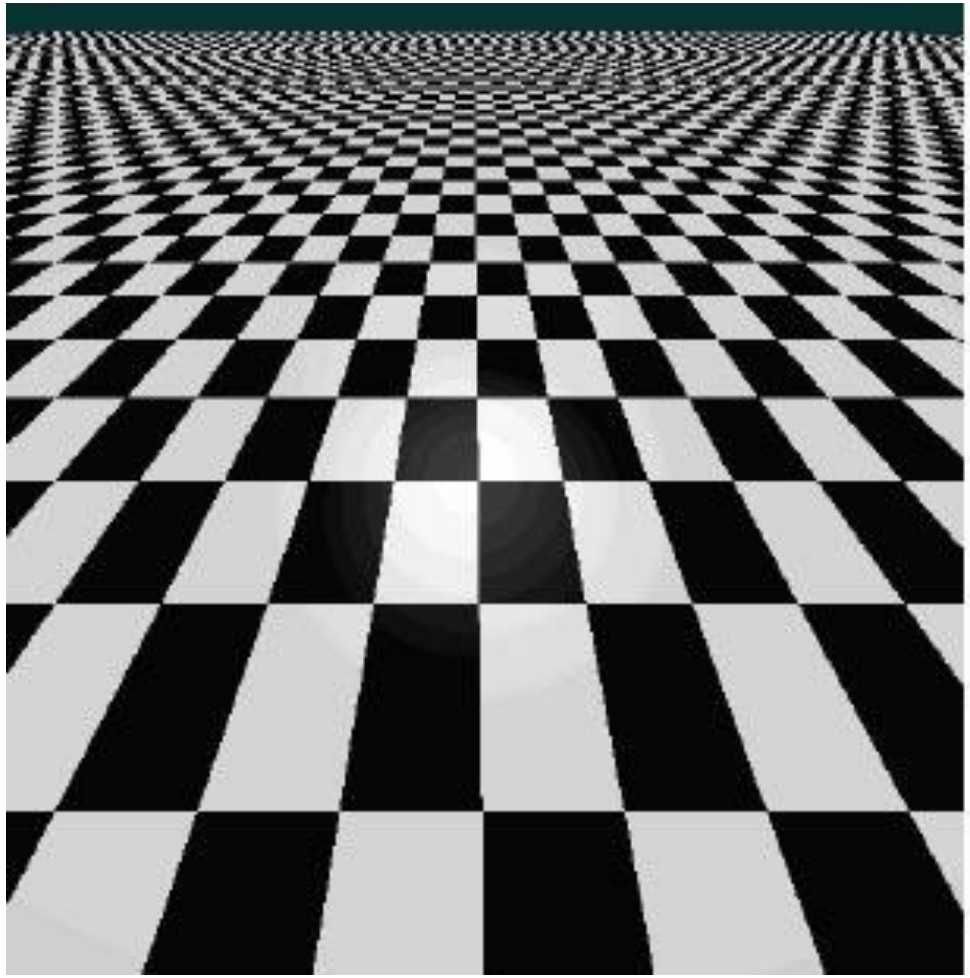
Imagine a spoked wheel moving to the right (rotating clockwise). Mark wheel with dot so we can see what's happening.

If camera shutter is only open for a fraction of a frame time (frame time = 1/30 sec. for video, 1/24 sec. for film):

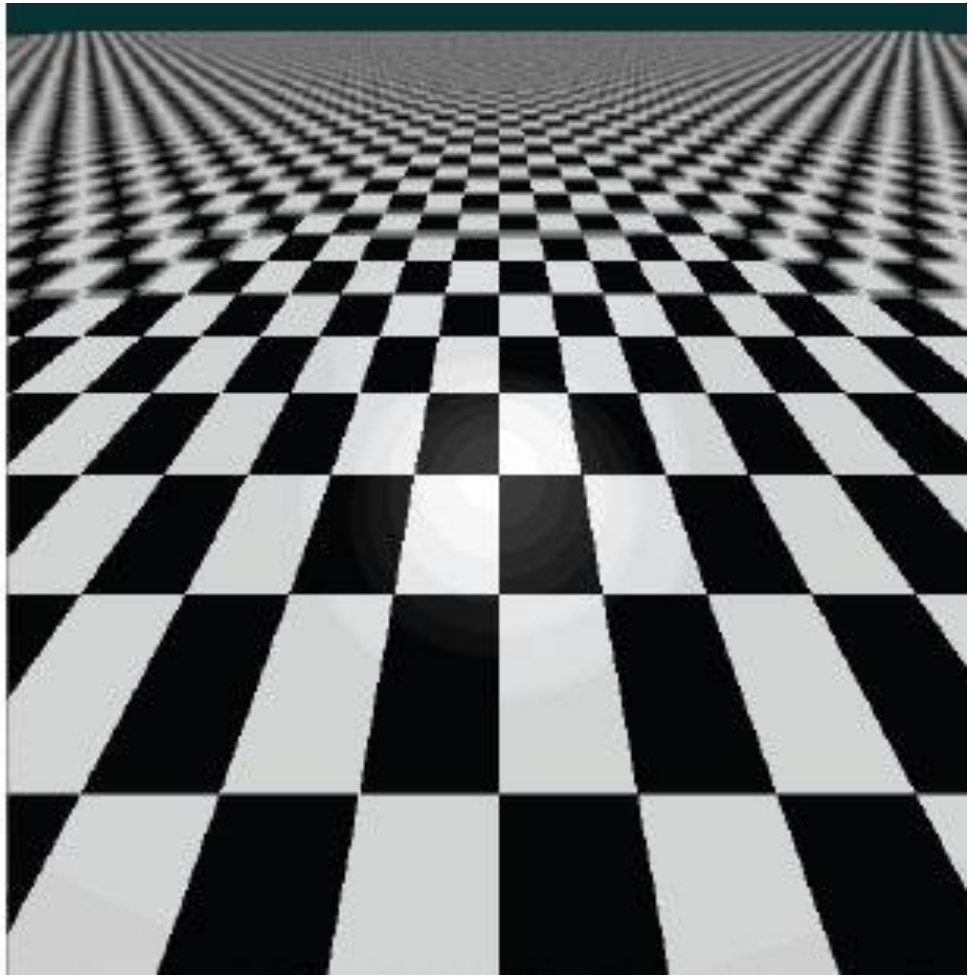


Without dot, wheel appears to be rotating slowly backwards! (counterclockwise)

Anti-aliasing in textures



aliasing artifacts



anti-aliasing by oversampling

…Anti-aliasing

Question 1: How much smoothing do I need to do to avoid aliasing?

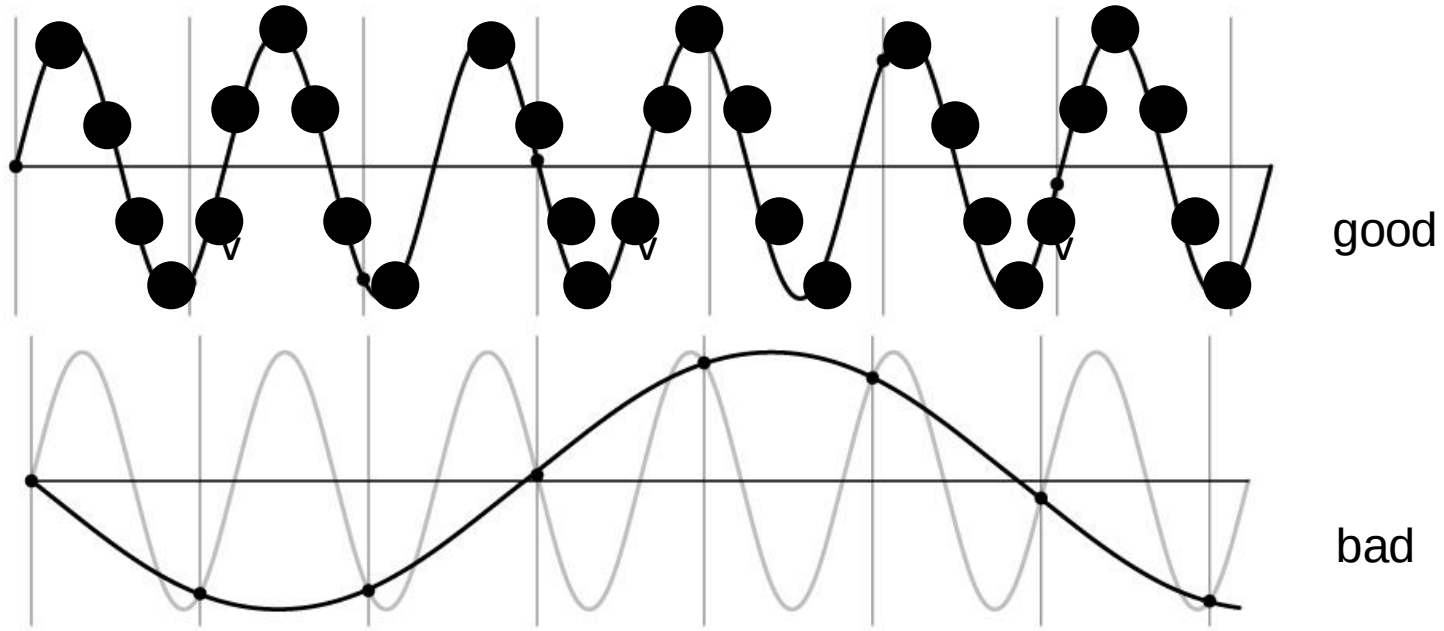
Question 2: How many samples do I need to take to avoid aliasing?

⇨ Answer to both: Enough to reach the Nyquist limit.

We'll see what this means soon.

Nyquist-Shannon Sampling Theorem

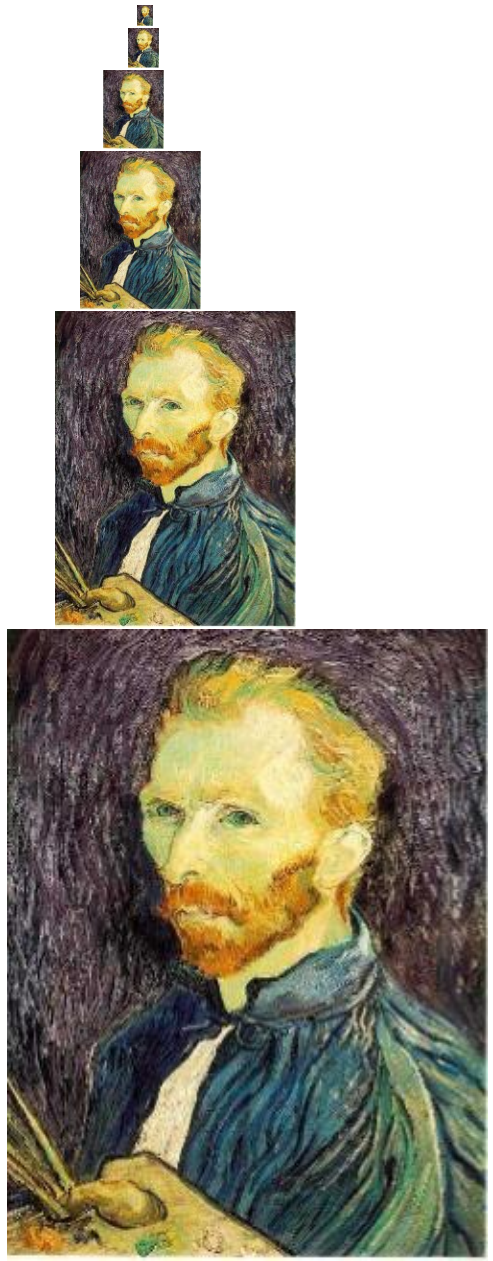
- When sampling a signal at discrete intervals, the sampling frequency must be $\geq 2 \times f_{max}$
- f_{max} = max frequency of the input signal
- This will allows to reconstruct the original perfectly from the sampled version



Templates & Image Pyramids

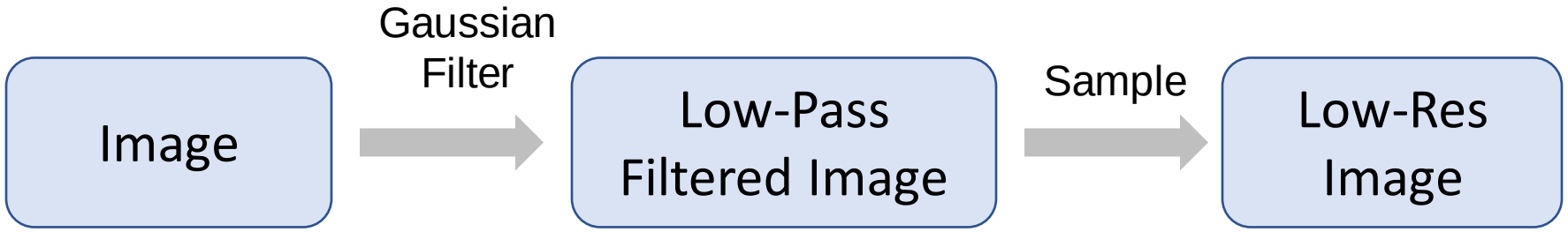
- Image downsampling
- Anti-aliasing
- **Gaussian image pyramid**
- Laplacian image pyramid

Gaussian image pyramid



The name of this sequence of subsampled images

…Gaussian image pyramid



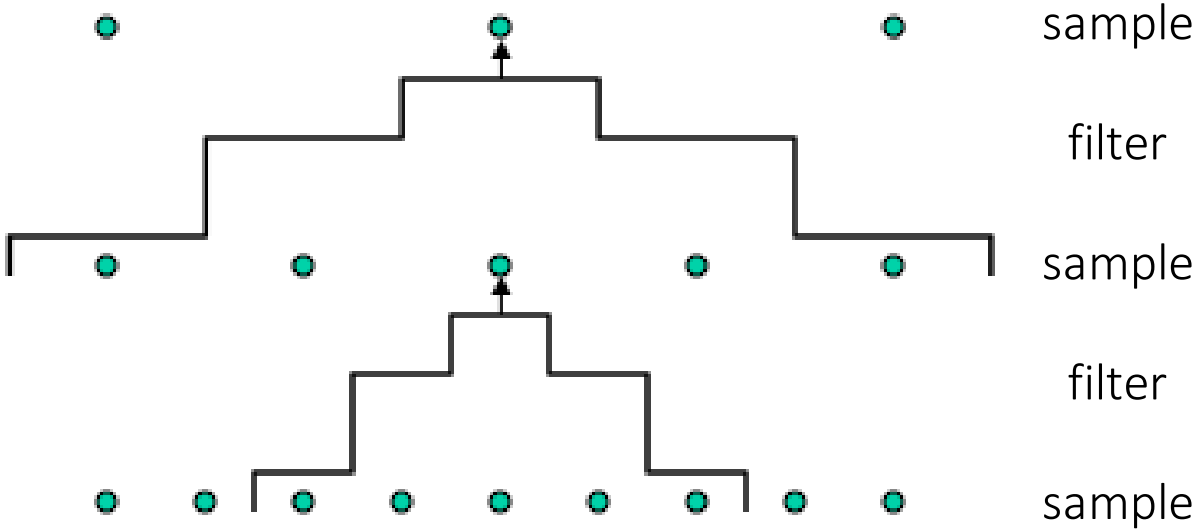
Algorithm

repeat:

filter

subsample

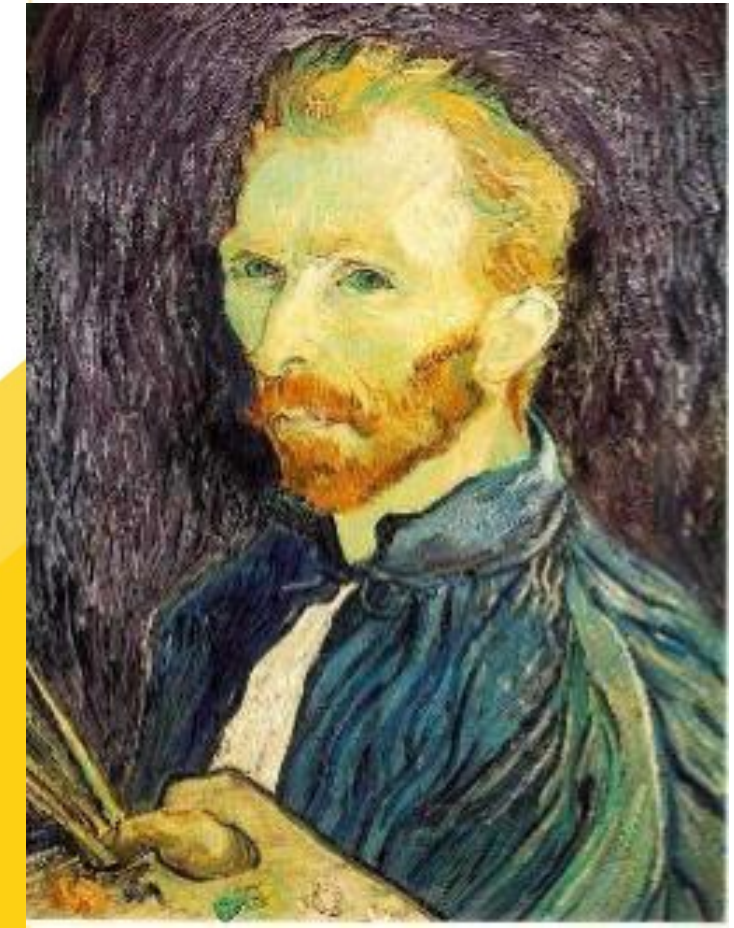
until min resolution reached



Question: How much bigger than the original image is the whole pyramid?

Answer: Just 4/3 times the size of the original image!

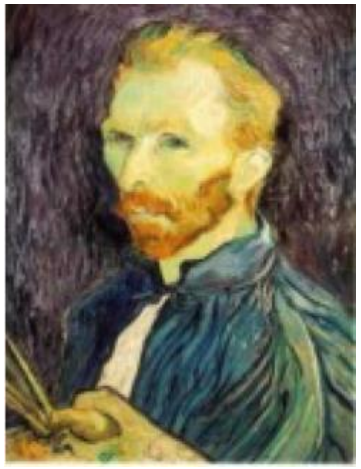
…Gaussian image pyramid



1/2

Apply a smoothing filter first, then throw away half the rows and columns

Gaussian filter
delete even rows
delete even columns



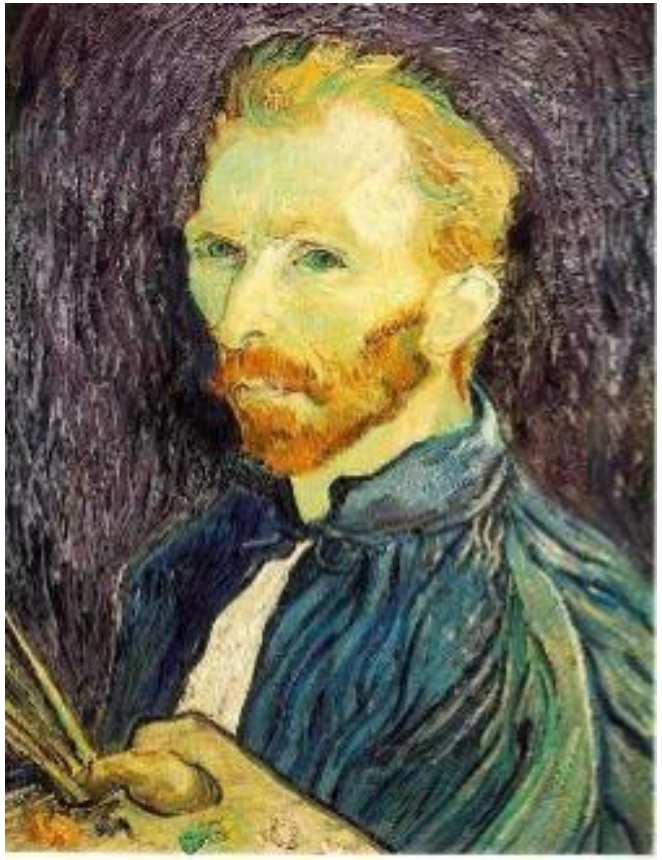
1/4

Gaussian filter
delete even rows
delete even columns

1/8

Better image downsampling

…Gaussian image pyramid



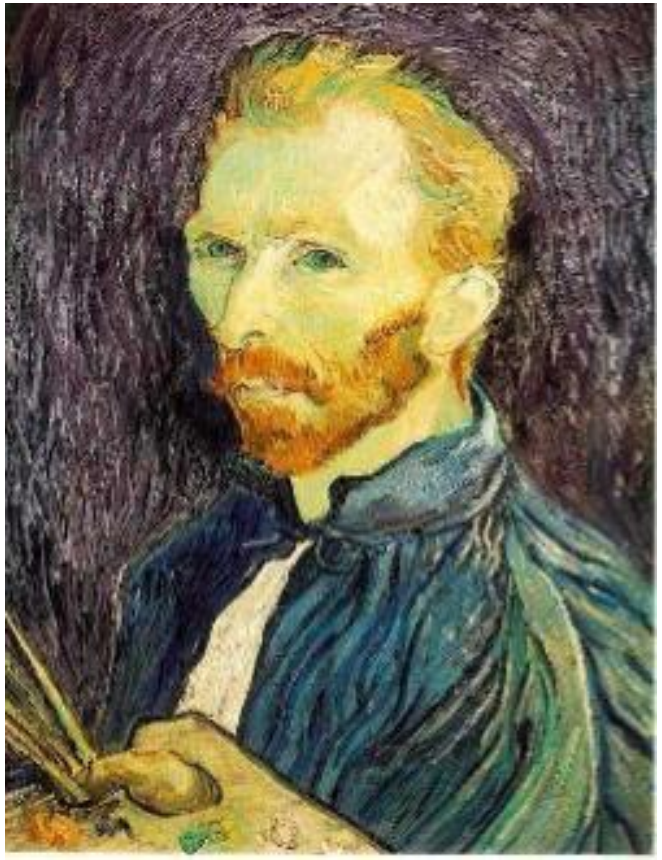
1/2

1/4 (2x zoom)

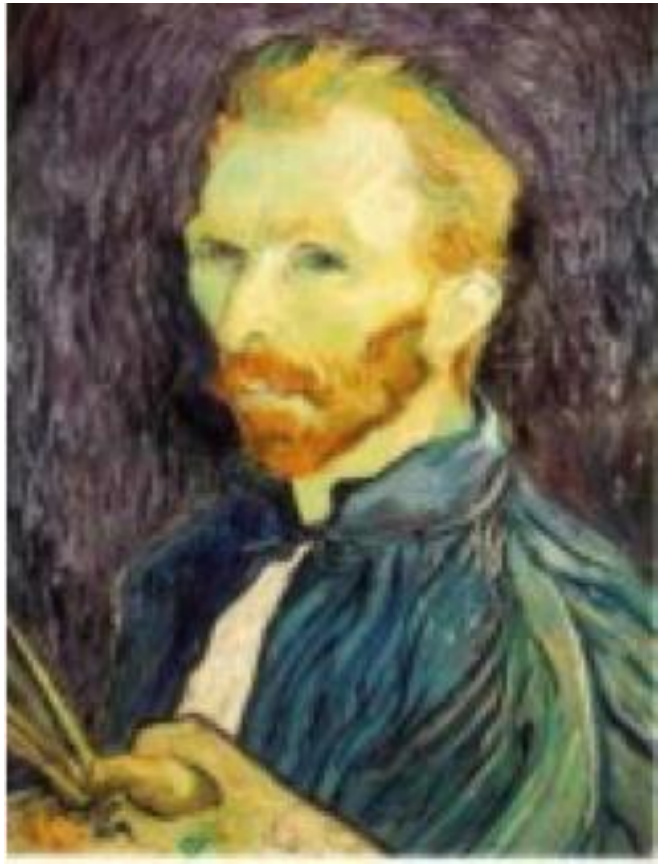
1/8 (4x zoom)

Naïve image downsampling

…Gaussian image pyramid



1/2



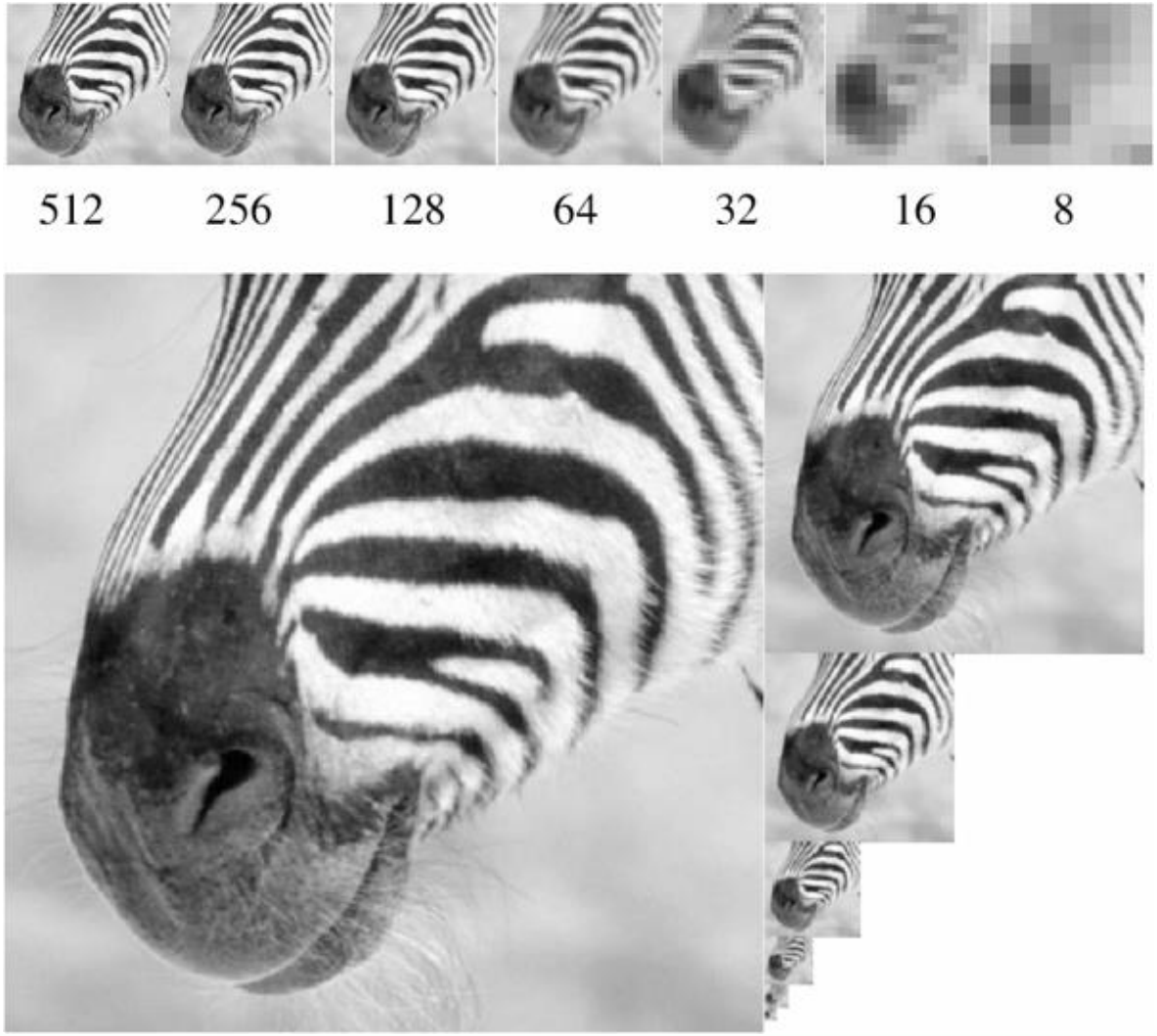
1/4 (2x zoom)

1/8 (4x zoom)

Better image downsampling with Gaussian pre-filtering

…Gaussian image pyramid

Some properties of the Gaussian pyramid



What happens to the details of the image?

- They get smoothed out as we move to higher levels.

What is preserved at the higher levels?

- Mostly large uniform regions in the original image.

How would you reconstruct the original image from the image at the upper level?

- That's not possible.

Templates & Image Pyramids

- Image downsampling
- Anti-aliasing
- Gaussian image pyramid
- **Laplacian image pyramid**

Laplacian image pyramid

Blurring is lossy

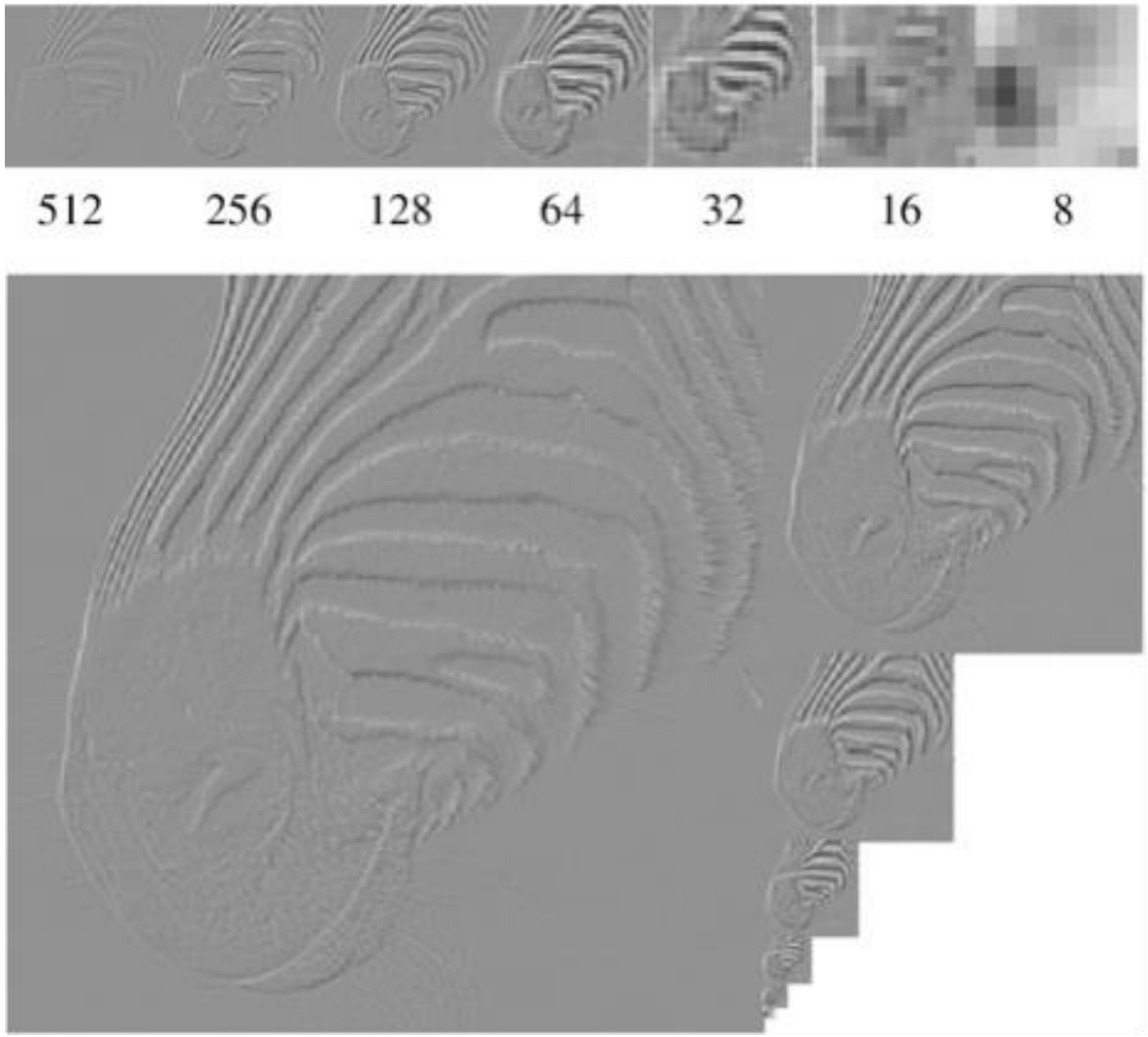
level 0

level 1 (before downsampling)

residual

Can we make a pyramid that is lossless?

…Laplacian image pyramid



At each level, retain the residuals instead of the blurred images themselves.

Can we reconstruct the original image using the pyramid?

- Yes we can!

What do we need to store to be able to reconstruct the original image?

…Laplacian image pyramid

level 0

=

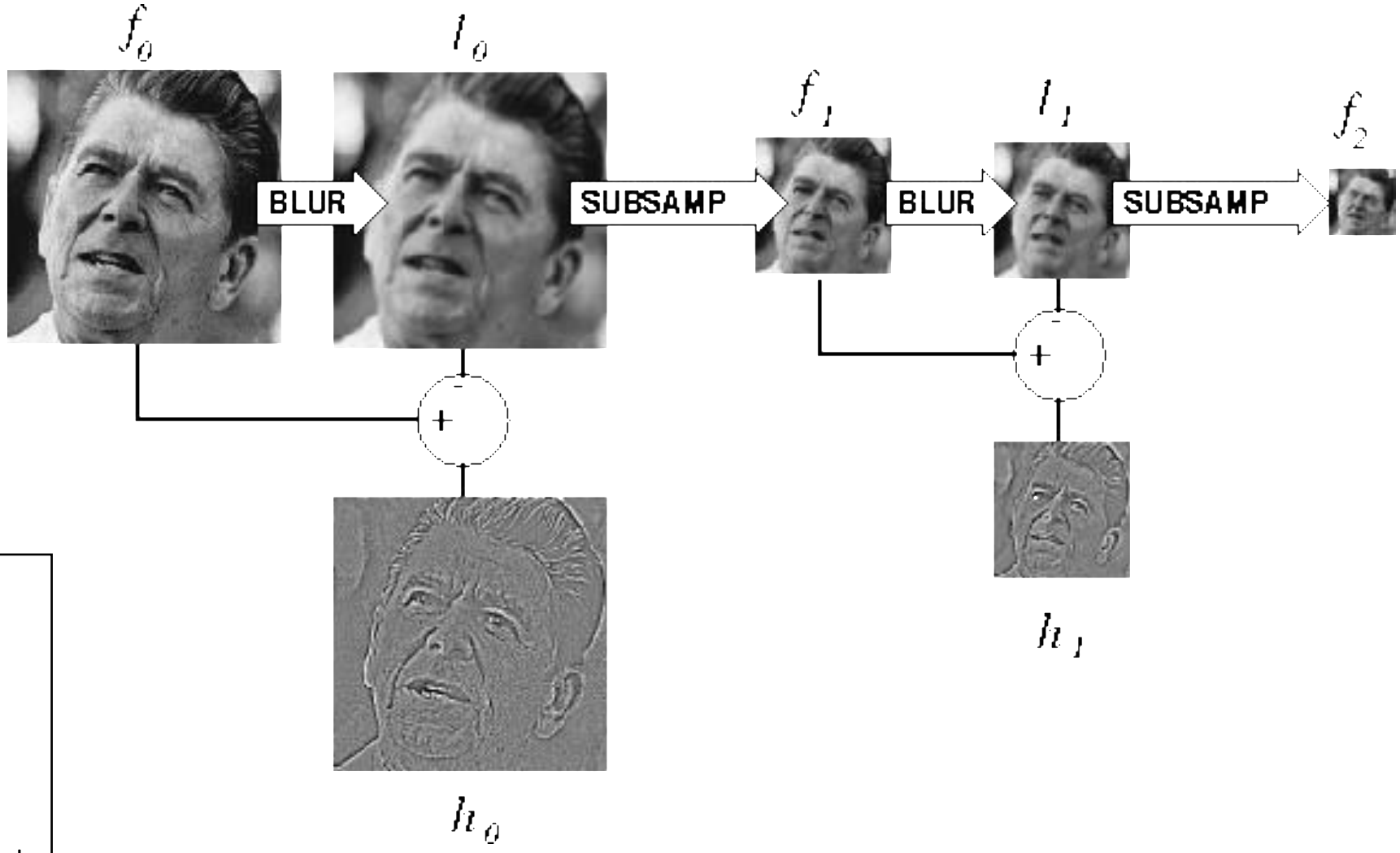
level 1 (upsampled)

+

residual

Does this mean we need to store both residuals and the blurred copies of the original?

…Laplacian image pyramid



Algorithm

repeat:

filter

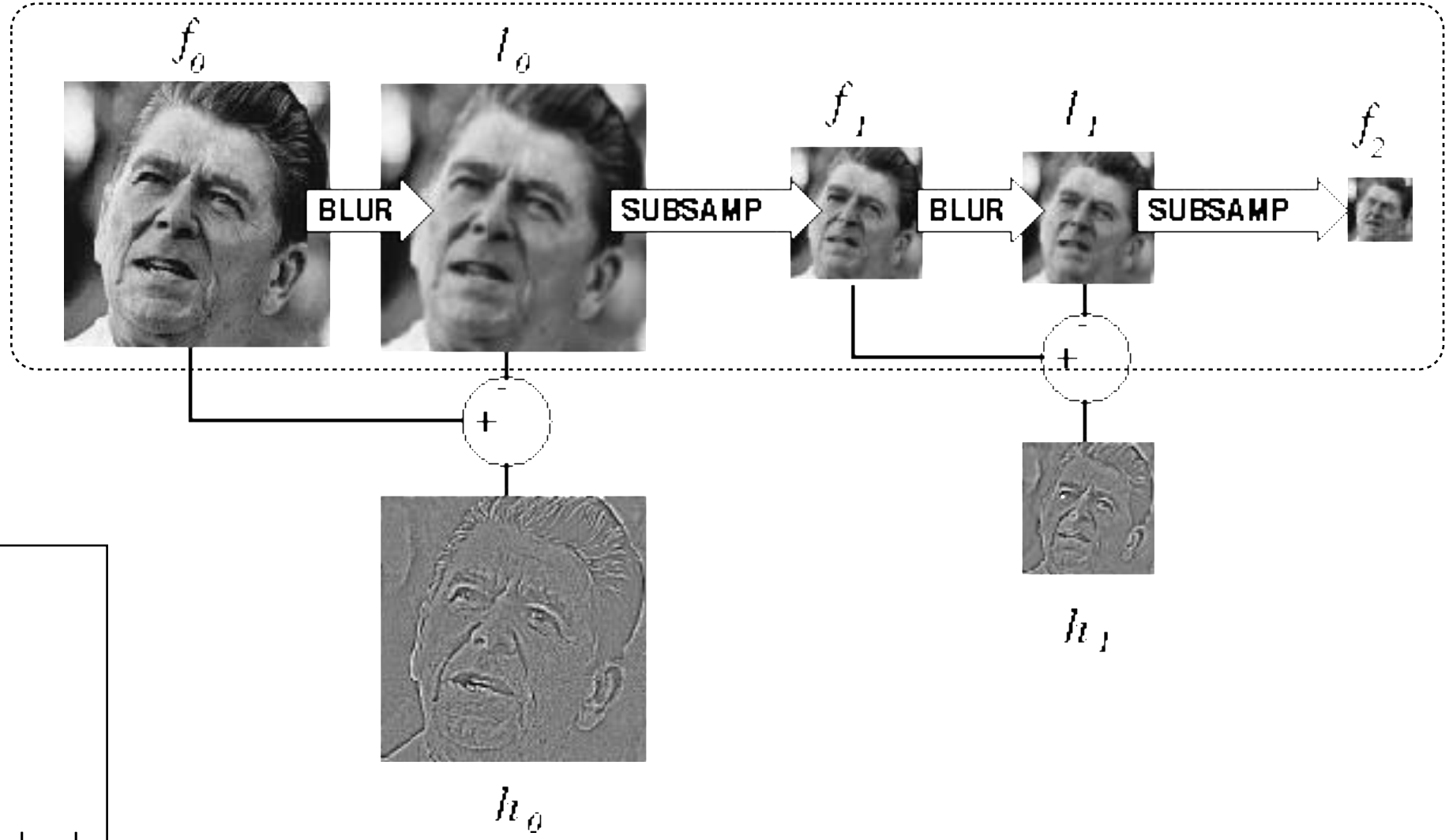
compute residual

subsample

until min resolution reached

…Laplacian image pyramid

It's a Gaussian pyramid.



Algorithm

repeat:

- filter
- compute residual
- subsample

until min resolution reached

…Laplacian image pyramid

What do we need to construct the original image?

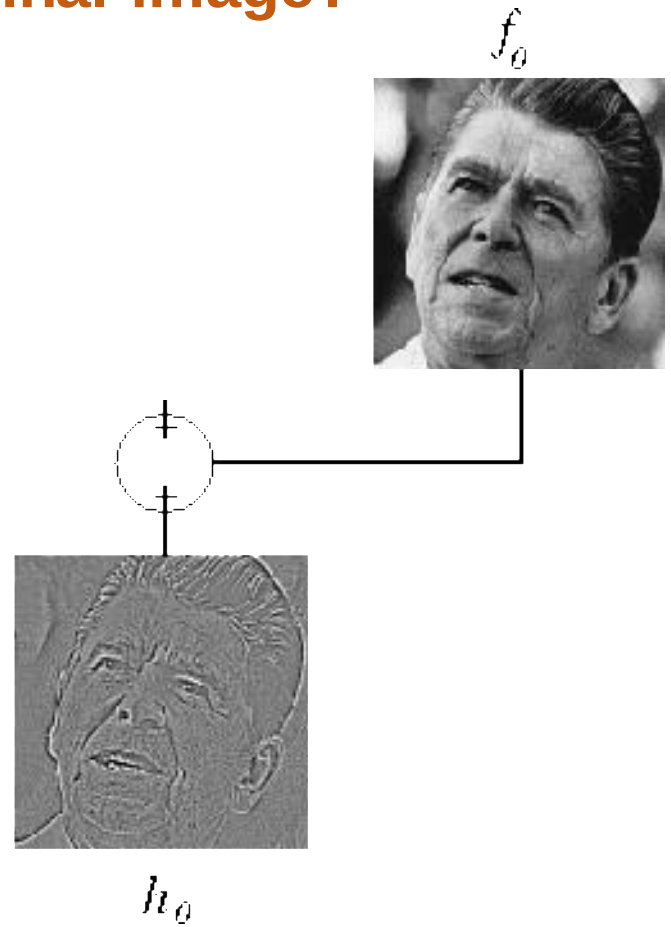
f_0

…Laplacian image pyramid

What do we need to construct the original image?

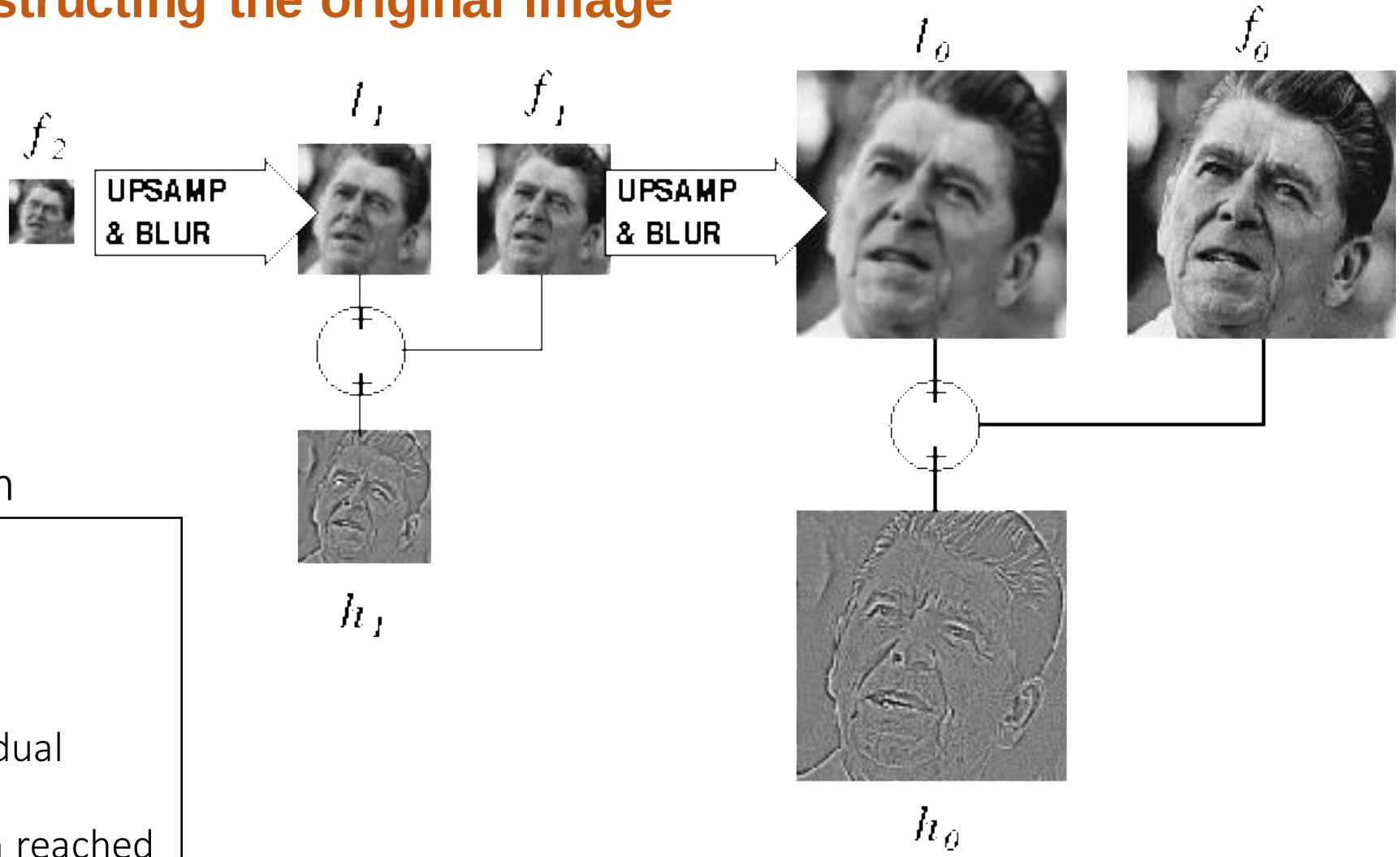
(2) smallest image

(1) residuals



…Laplacian image pyramid

Reconstructing the original image



Algorithm

repeat:

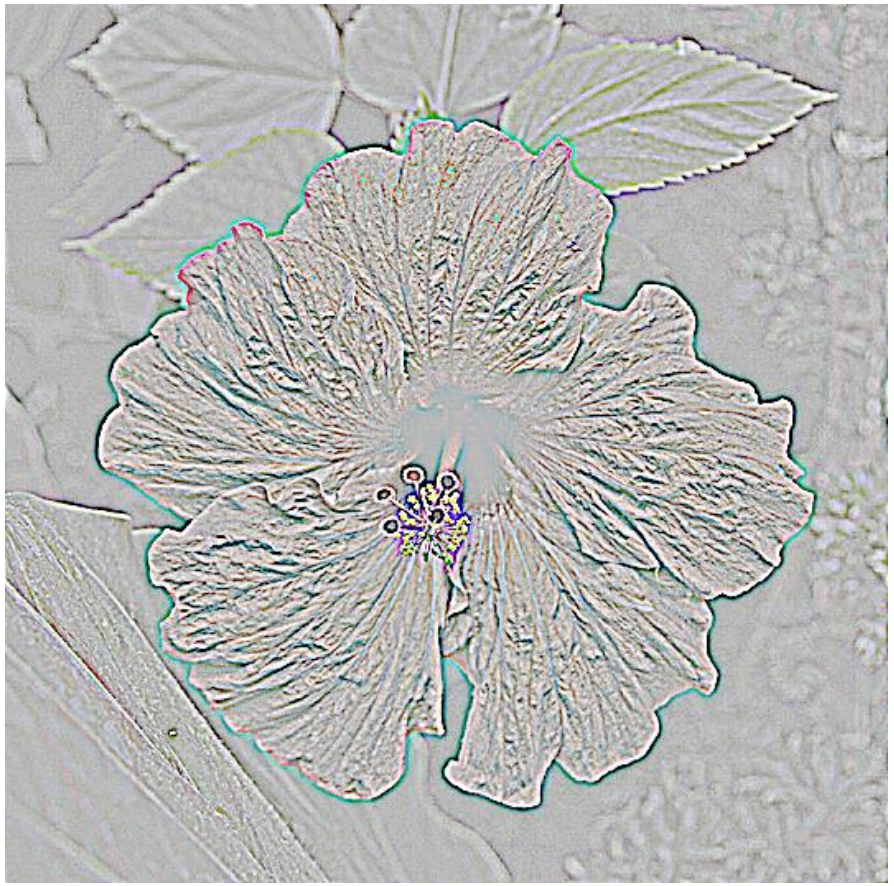
upsample

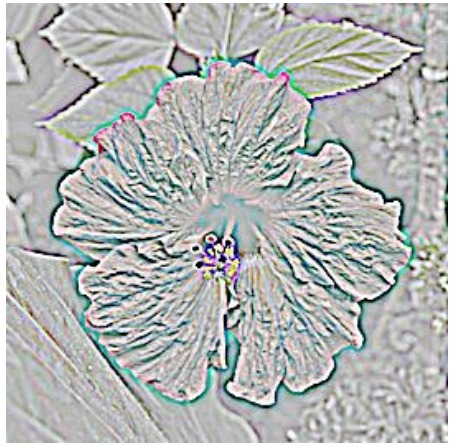
sum with residual

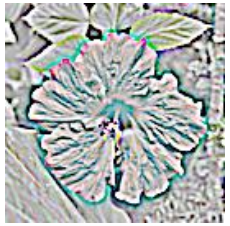
until orig resolution reached

Gaussian vs Laplacian Pyramid

Shown in opposite order for space.

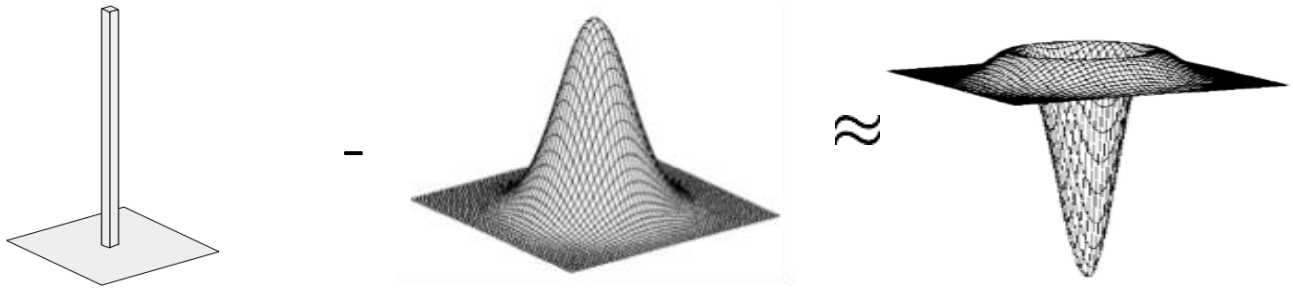






Which one takes more space to store?

Why is it called a Laplacian pyramid?



unit Gaussian Laplacian

Difference of Gaussians approximates the Laplacian

What are image pyramids used for?

image compression

multi-scale texture mapping

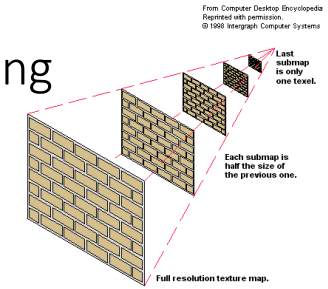
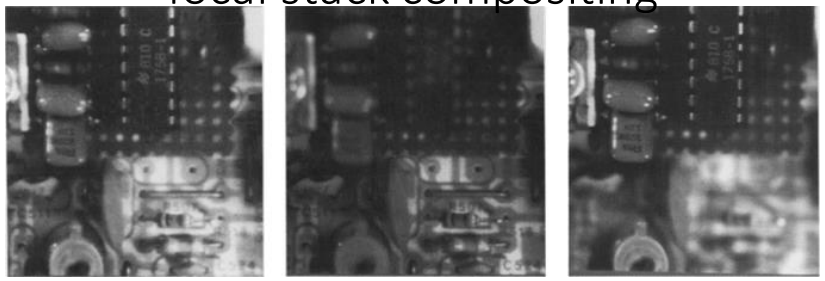
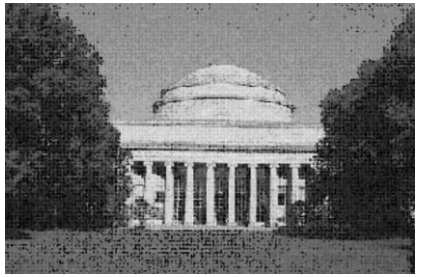


image blending

focal stack compositing



denoising



multi-scale detection

multi-scale registration

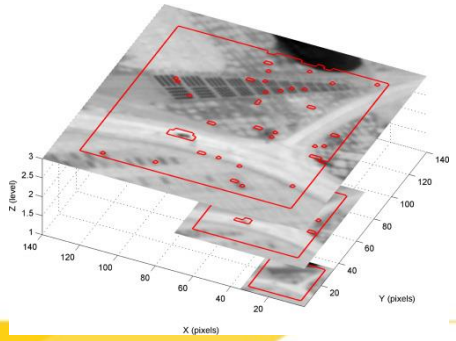


Image Filter

Thank You…!