Lecture 2.2 – Image Processing
Image Pyramids

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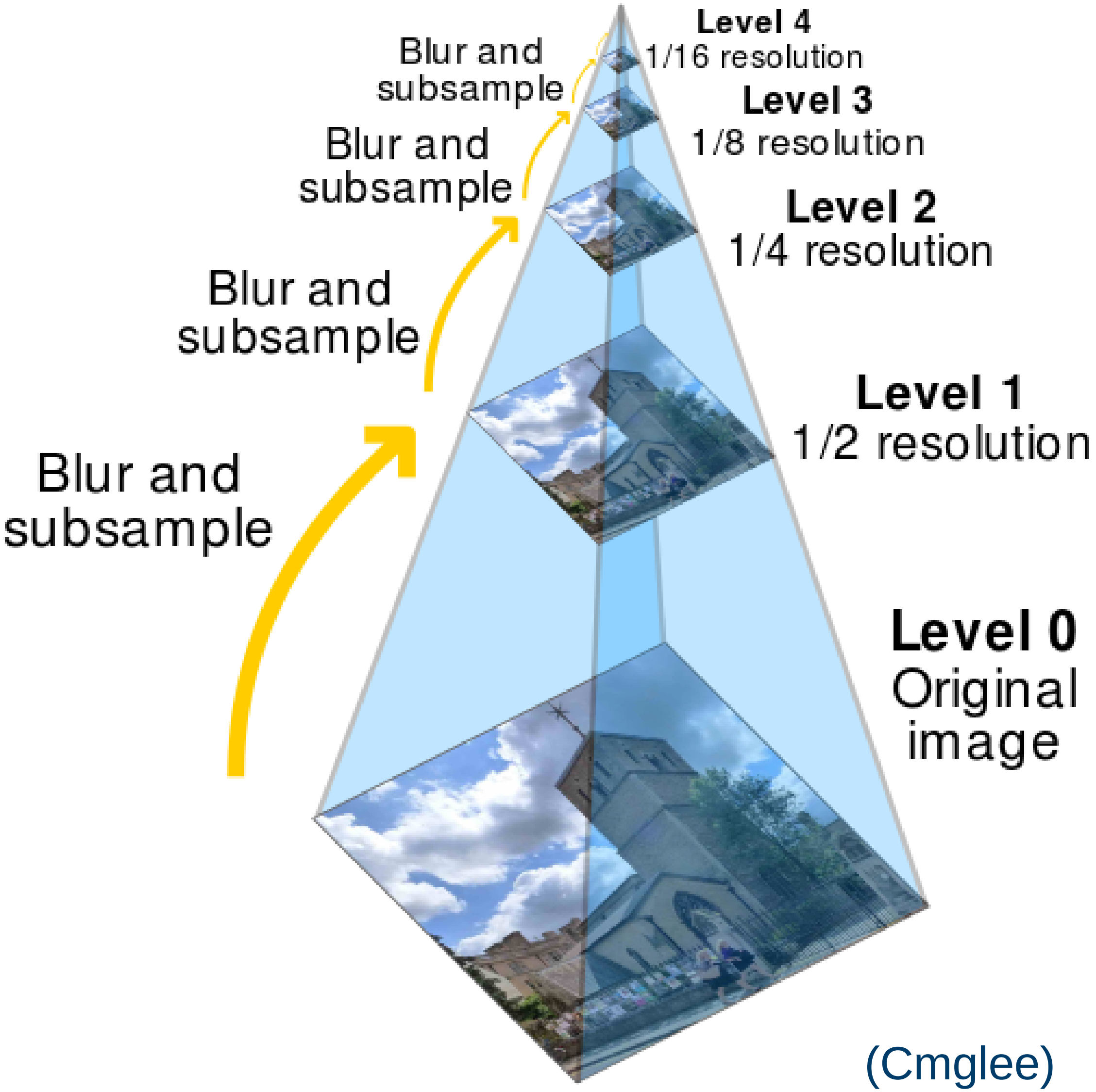
Pyramids

- Downsampling (decimation)
- Upsampling (interpolation)
- Pyramids
  - Gaussan Pyramids
  - Laplacian Pyramids (Lecture 2.3)
- Applications
  - Template matching (object detection)
  - Detecting stable points of interest
  - Image Registration
  - Compression
  - Image Blending
  - …



(Cmglee)

Image Scaling

- Assume that the image is too big for practical use:
  - Requires too much memory
  - Time consuming to process
  - Too big for the screen
  - …

- A smaller image can be obtained by image sub-sampling

Image Downsampling

1/2

1/4

1/8

Throw away every other row and column → image reduced to ½ size along each dimension.

Image Downsampling

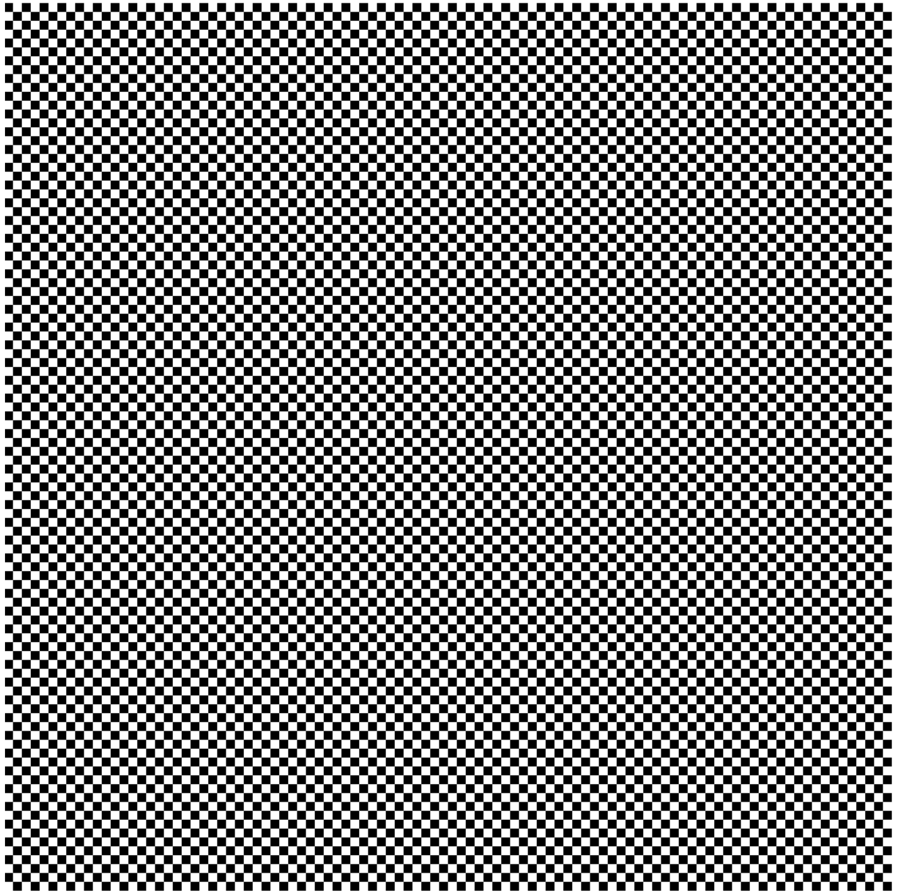
1/2

1/4 (2x zoom)

1/8 (4x zoom)

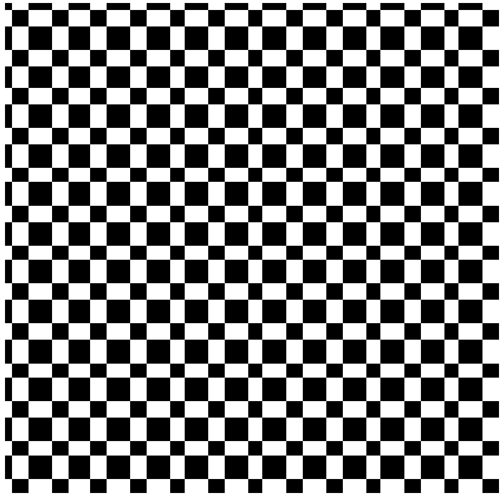
The subsampled images are of low quality. Why?

Spatial undersampling

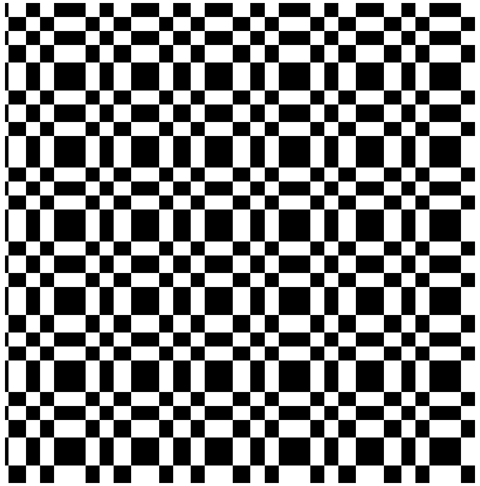


Checkerboard with 10 x 10 pixel squares

Downsampled images



1/10



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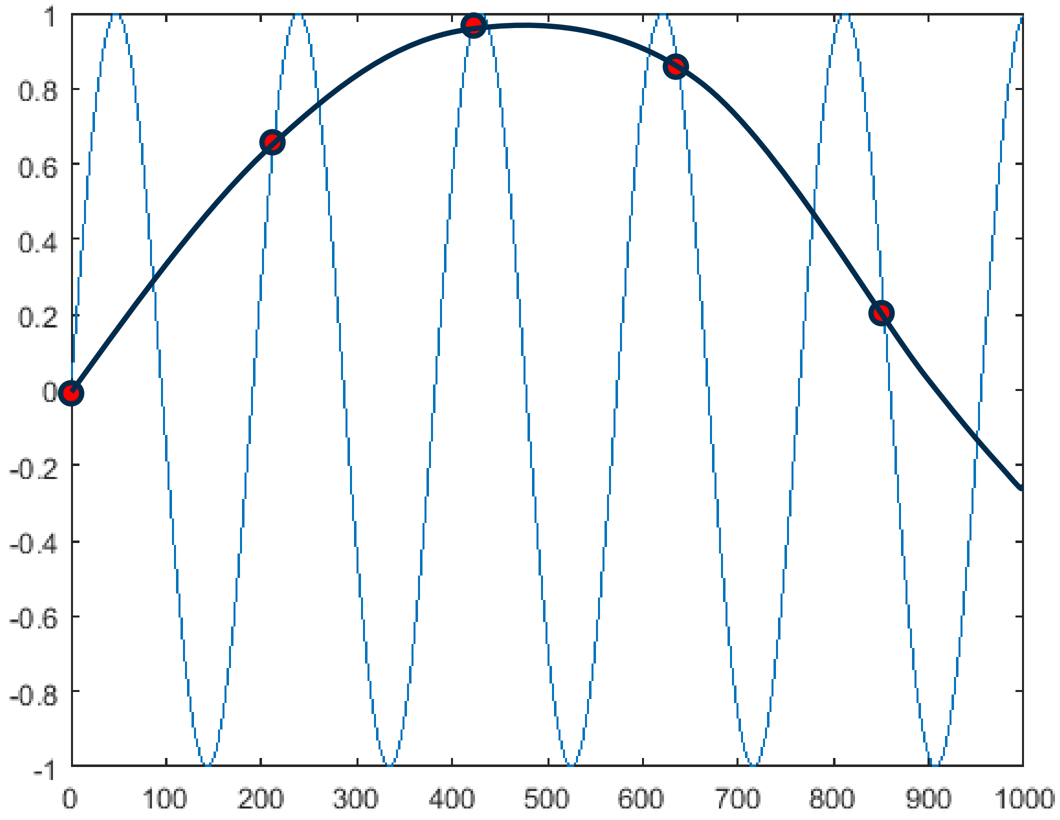
Aliasing

- Occurs when the (spatial) sampling rate is not high enough to capture the details in the image
- High frequencies are transformed to lower frequencies (i.e. aliases)
- To avoid aliasing the sampling rate must be at least two times the maximum frequency in the image (at least two samples per cycle)
- This minimum sampling rate is called the **Nyquist rate**.



Aliasing can be avoided by low-pass filtering the image before downsampling

Gaussian pre-filtering (low pass)

Gaussian 1/2

Gaussian 1/4

Gaussian 1/8

Gaussian pre-filtering (low pass)

Gaussian 1/2

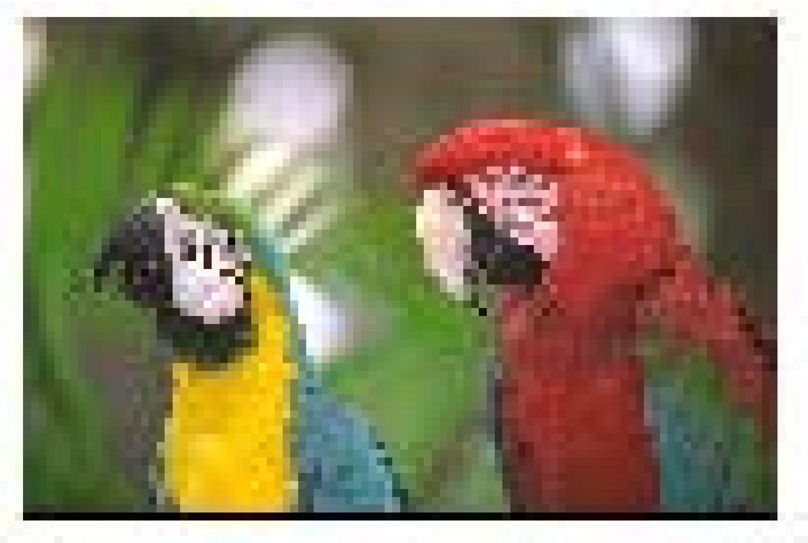
Gaussian 1/4

Gaussian 1/8

Compared to downsampling without low-pass filtering…

1/2

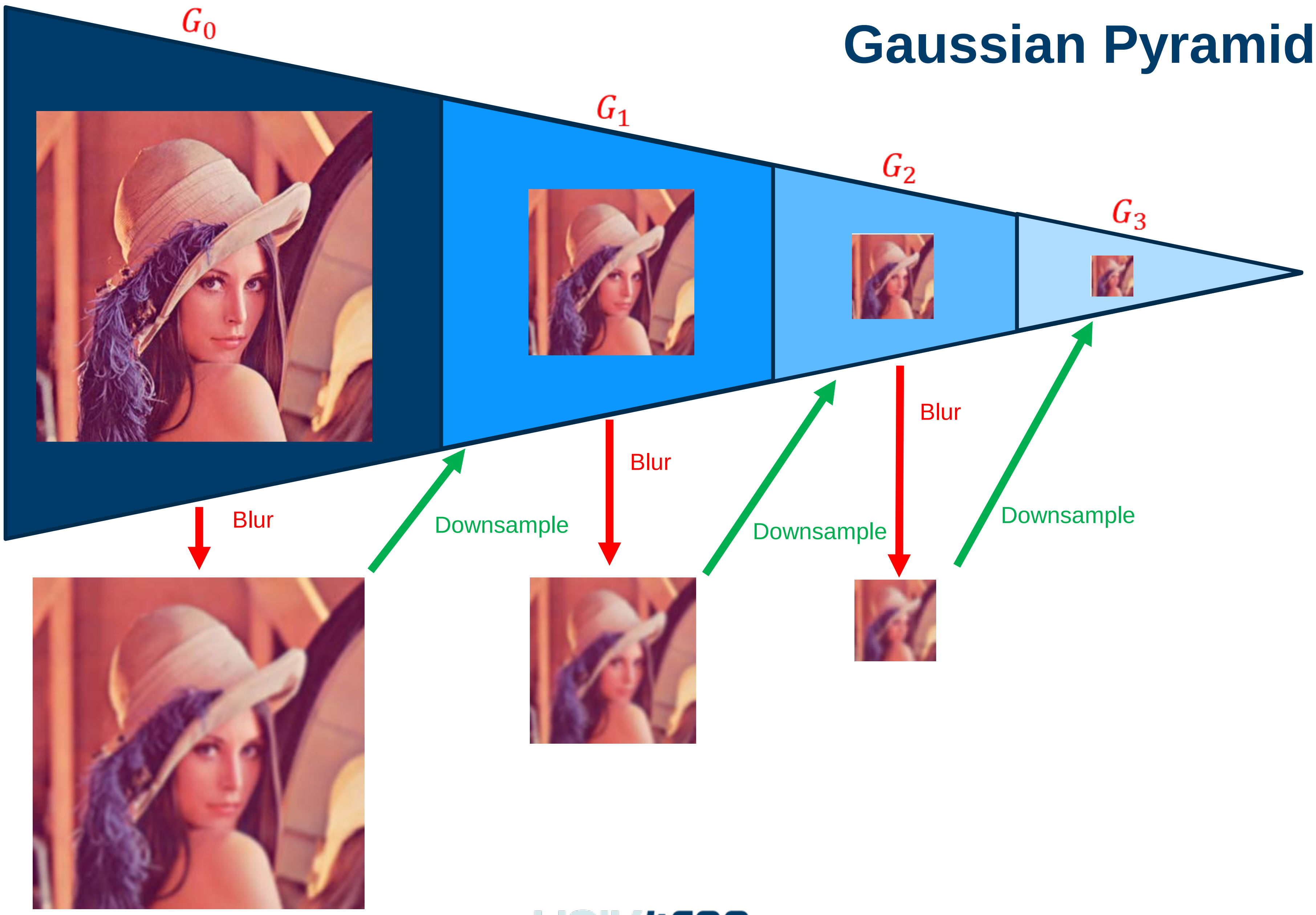
1/4



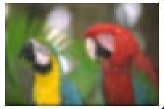
1/8

Conclusion: Low-pass filtering (i.e. smoothing with a Gaussian kernel) before subsampling the image!

Gaussian Pyramid



Upsampling



Nearest neighbor interpolation:

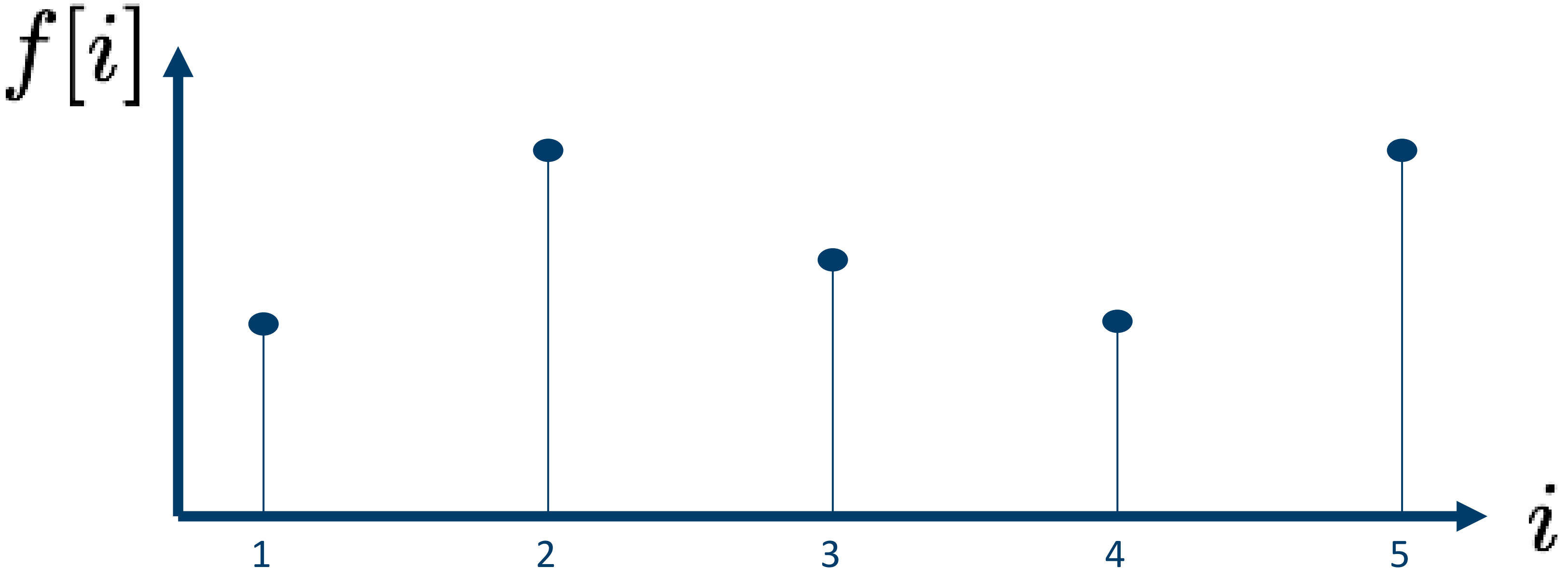
- Repeat each row and column 10 times
- Fast and simple approach.

10 x magnification

Image interpolation

A digital image is a discrete point-sampling of a continuous function:

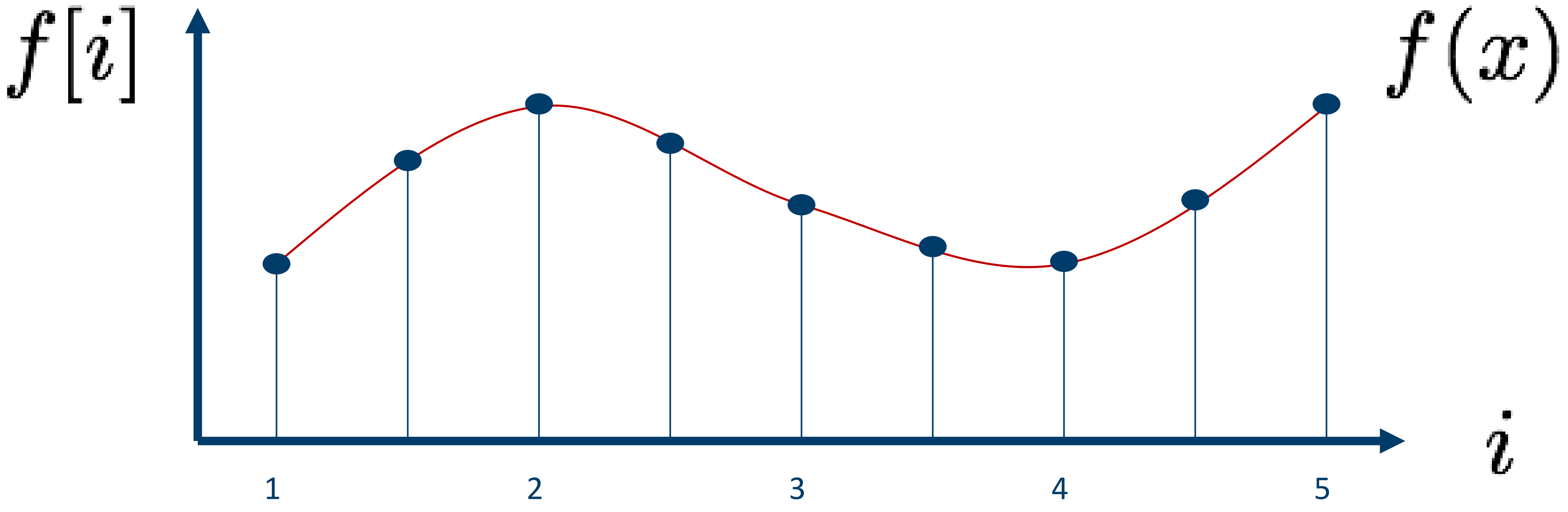
$$f[i,j] = quantize\{f(i\Delta x, j\Delta y)\} \quad \text{where} \quad x = i\Delta x \quad \text{and} \quad y = i\Delta y$$



1D example

A new image could be generated, at any resolution and scale, if the original function could be reconstructed.

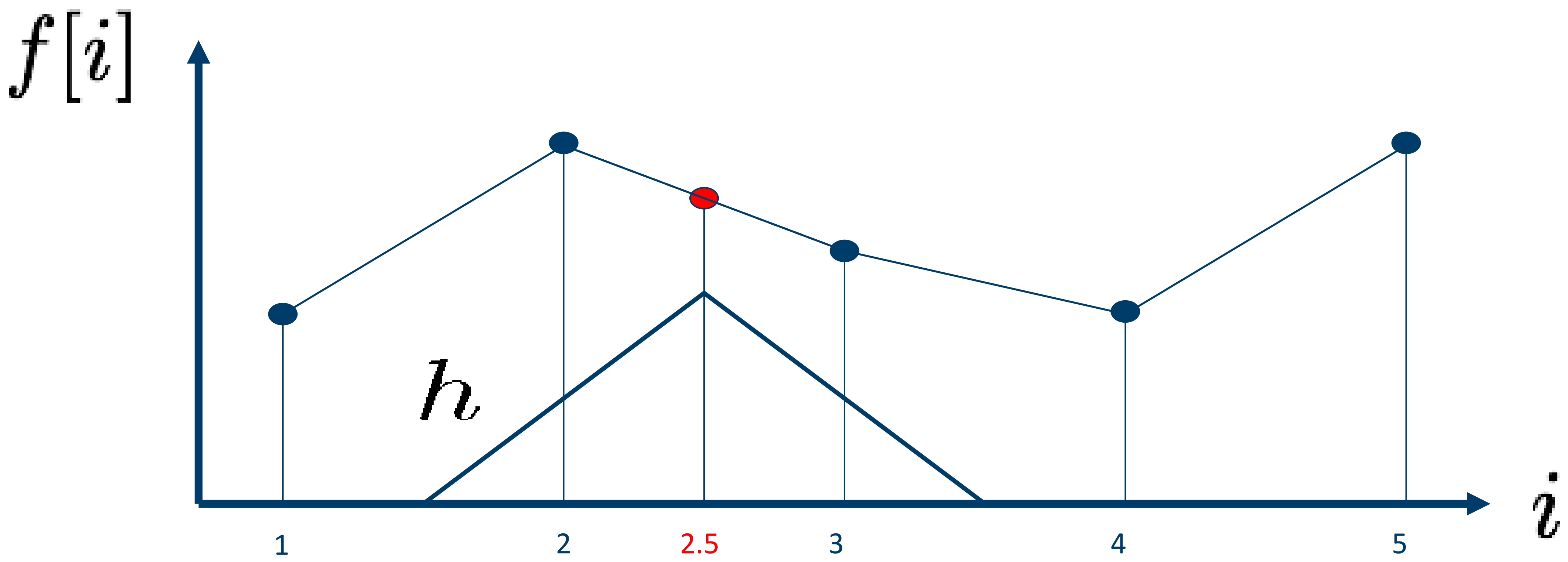
Interpolation by convolution



$$g[i,j] = \sum_{u=-k}^{k} \sum_{v=-k}^{k} h[u,v] f[i - ru, j - rv]$$

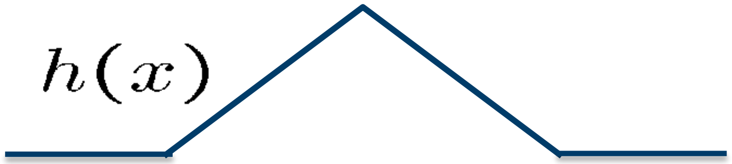
r = scale factor

Linear interpolation (bilinear for images)

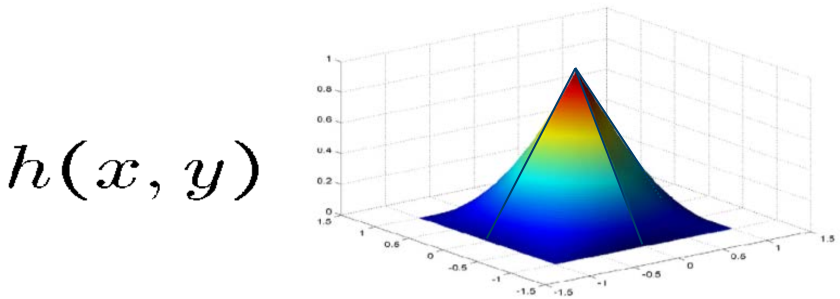


Some kernels for signal and image interpolation

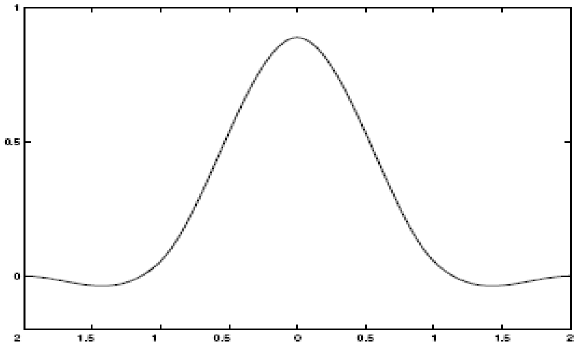
Linear:



Bilinear:



Bicubic (better choice for images):



Nearest neighbor:

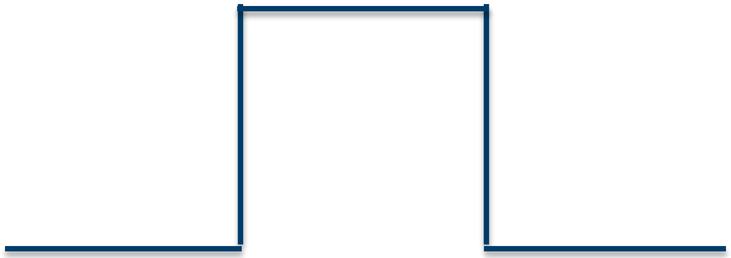
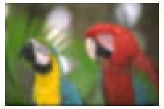


Image interpolation - examples



Nearest neighbor

Bilinear

Bicubic

Application: Template Matching with Image Pyramids

Input: Image, Template

1. Match template at current scale

2. Downsample image

3. Repeat 1-2 until image is very small

4. Take responses above some threshold, perhaps with non-maxima suppression.

Summary

Image Pyramids:

- Downsampling
- Upsampling
- Gaussian Pyramids

Read also: Szeliski 3.5