



# Image Sampling

CSE 576

Ali Farhadi

# Image Sampling

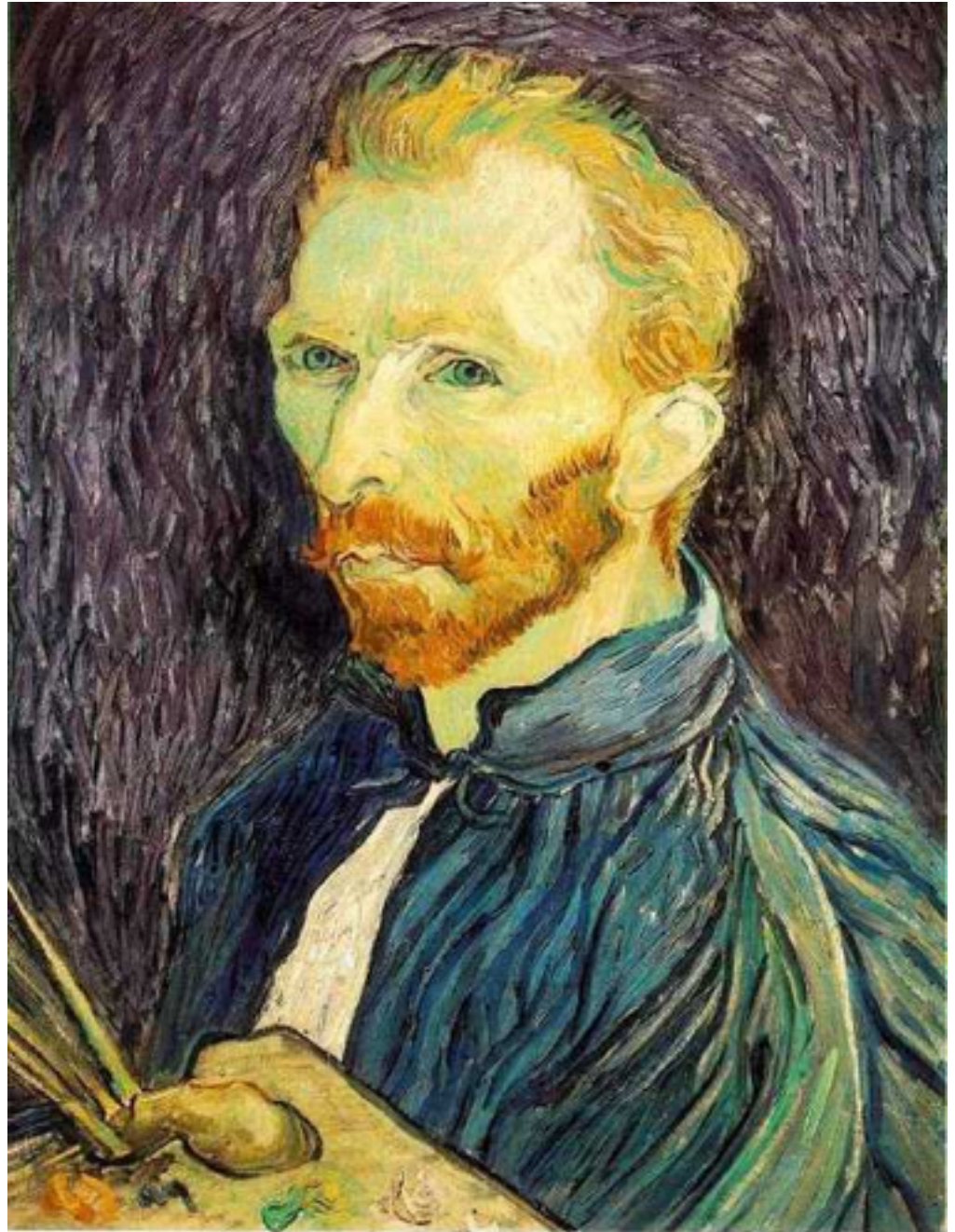
$$F(\text{img}) = \text{img}$$


$$F(\text{img}) = \text{img}$$


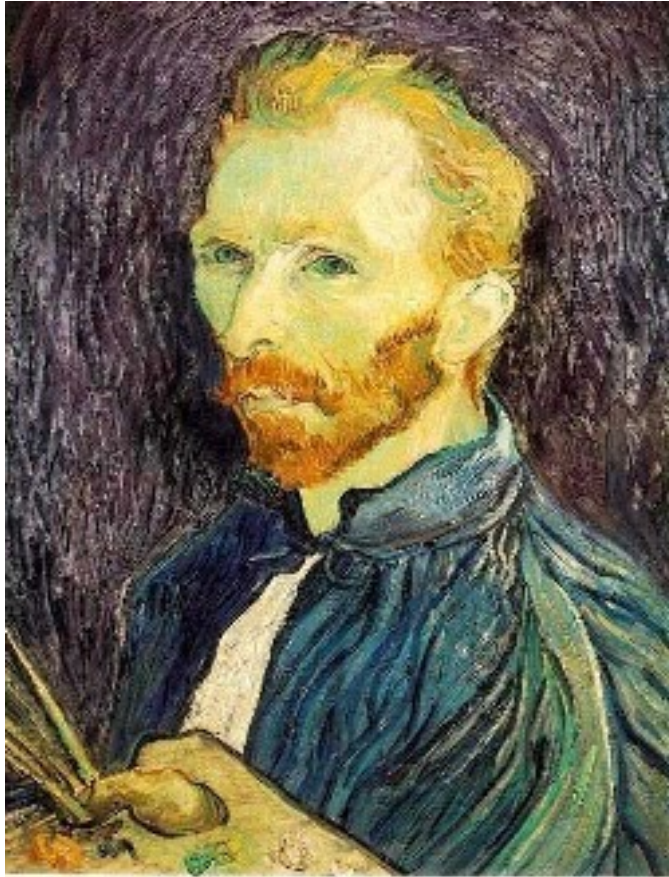
# Image Scaling

This image is too big to fit on the screen. How can we reduce it?

How to generate a half-sized version?



# Image sub-sampling



1/4

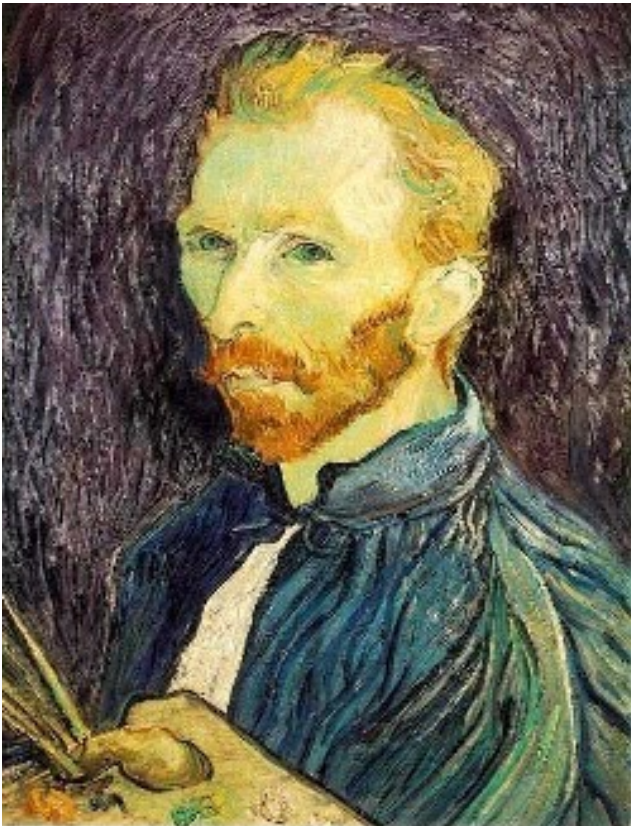


1/8

Throw away every other row and column to create a 1/2 size image  
- called *image sub-sampling*



# Image sub-sampling



1/2



1/4 (2x zoom)

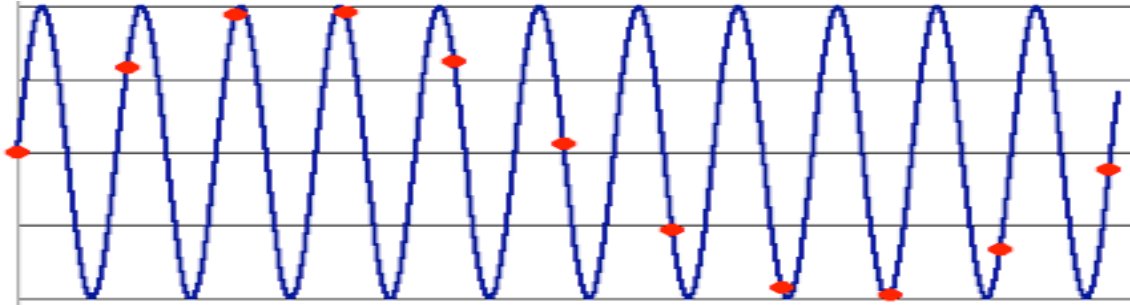


1/8 (4x zoom)

Why does this look so cruffy?

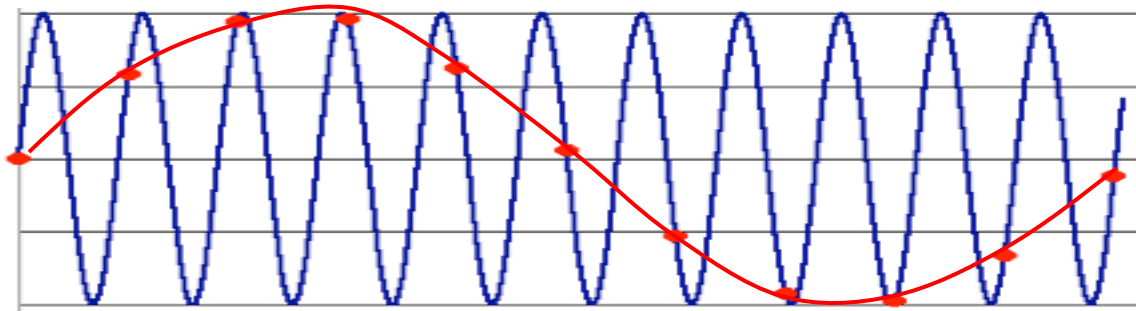
# Down-sampling

---



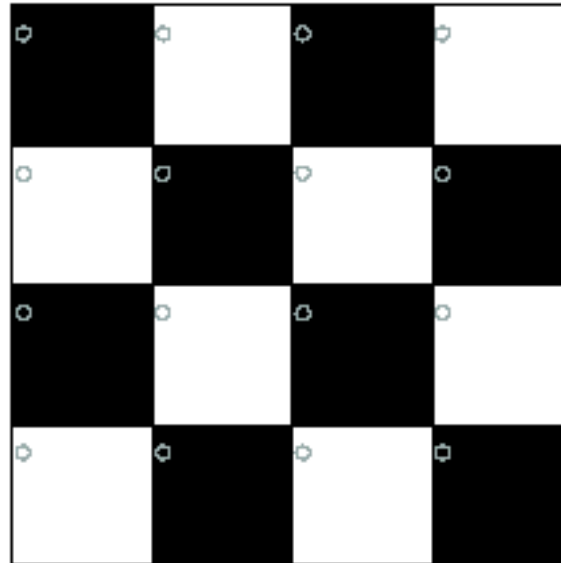
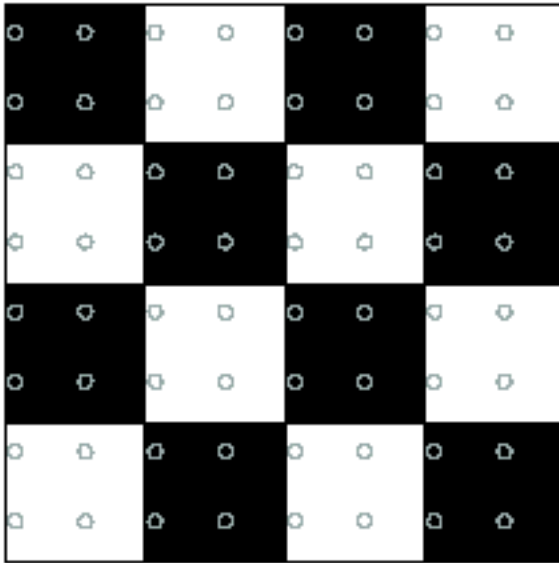
- **Aliasing** can arise when you sample a continuous signal or image
  - occurs when your sampling rate is not high enough to capture the amount of detail in your image
  - Can give you the wrong signal/image—an *alias*
  - formally, the image contains structure at different scales
    - called “frequencies” in the Fourier domain
  - the sampling rate must be high enough to capture the highest frequency in the image

# Sampling and the Nyquist rate

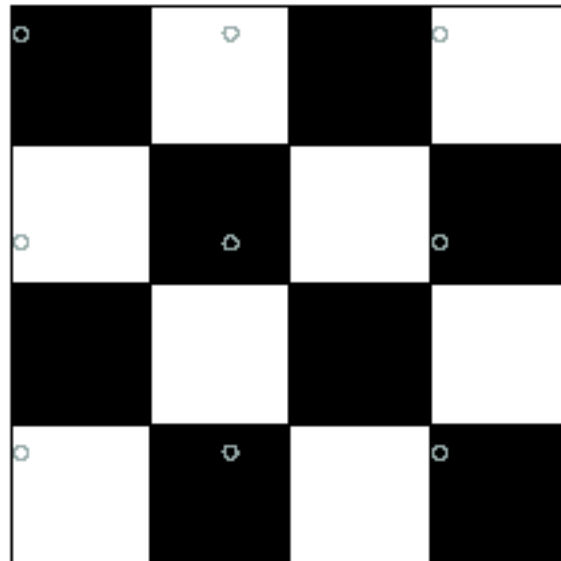
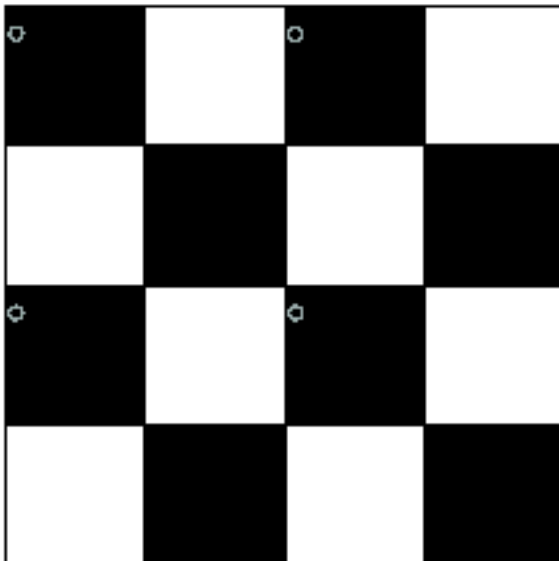


- **Aliasing** can arise when you sample a continuous signal or image
  - occurs when your sampling rate is not high enough to capture the amount of detail in your image
  - Can give you the wrong signal/image—an *alias*
  - formally, the image contains structure at different scales
    - called “frequencies” in the Fourier domain
  - the sampling rate must be high enough to capture the highest frequency in the image
- To avoid aliasing:
  - **sampling rate  $\geq 2 * \text{max frequency}$**  in the image
    - said another way:  $\geq$  **two samples per cycle**
  - This minimum sampling rate is called the **Nyquist rate**

# 2D example



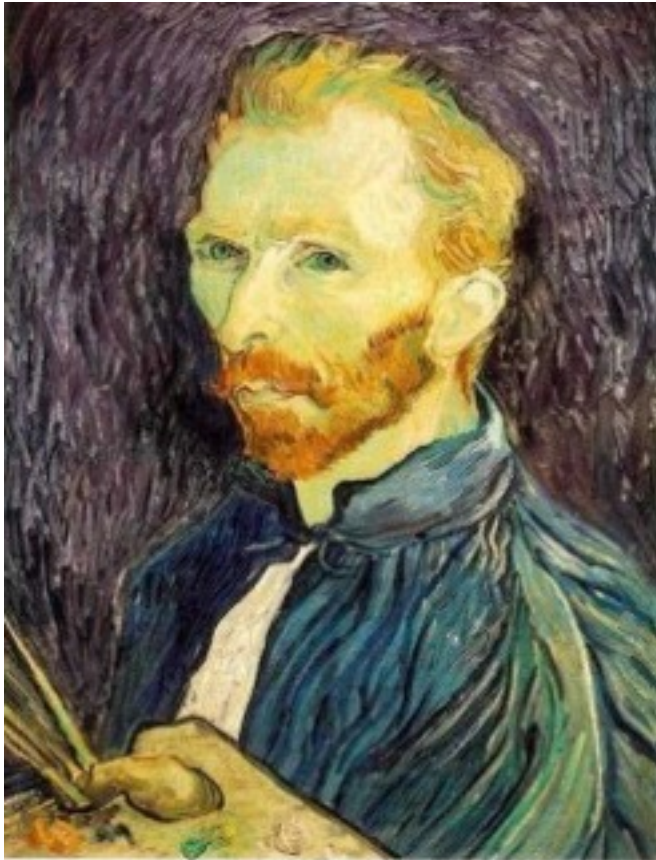
Good sampling



Bad sampling



# Subsampling with Gaussian pre-filtering



Gaussian 1/2



G 1/4

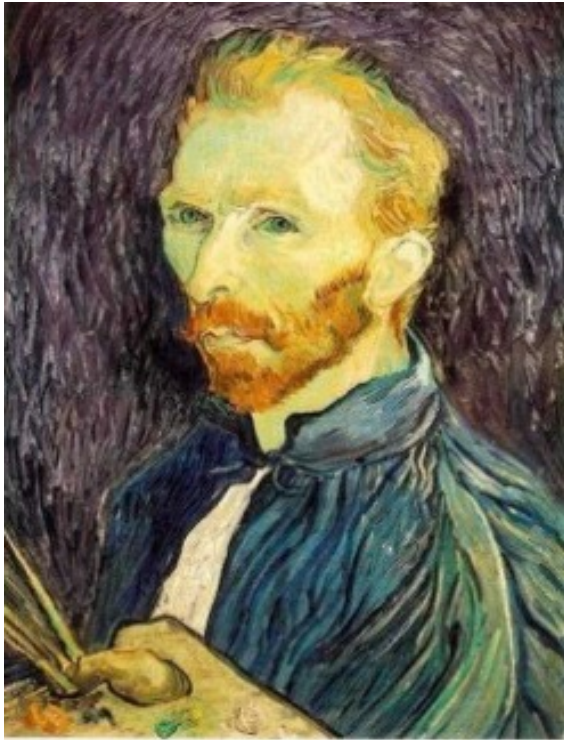


G 1/8

Solution: filter the image, *then* subsample

- Filter size should double for each  $\frac{1}{2}$  size reduction. Why?

# Subsampling with Gaussian pre-filtering



Gaussian  $1/2$



G  $1/4$



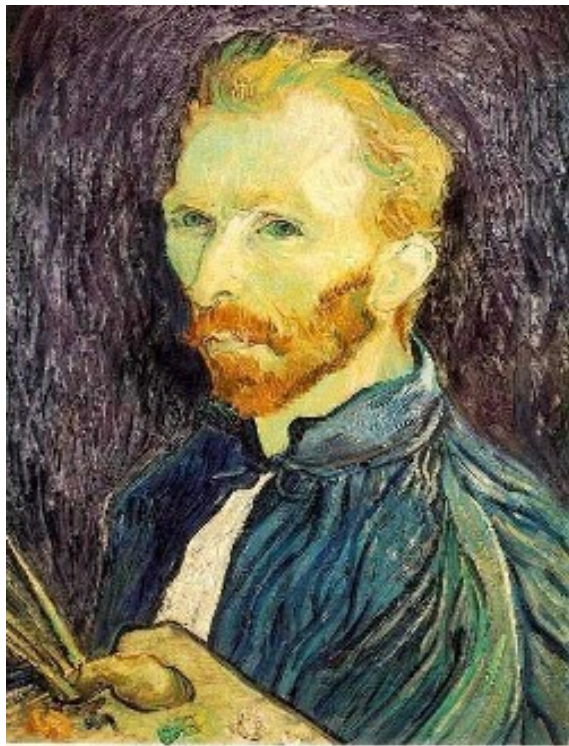
G  $1/8$

Solution: filter the image, *then* subsample

- Filter size should double for each  $1/2$  size reduction. Why?
- How can we speed this up?



# Compare with...



$1/2$



$1/4$  (2x zoom)



$1/8$  (4x zoom)



Moiré patterns in real-world images. Here are comparison images by Dave Etchells of [Imaging Resource](#) using the Canon D60 (with an antialias filter) and the Sigma SD-9 (which has no antialias filter). The bands below the fur in the image at right are the kinds of artifacts that appear in images when no antialias filter is used. Sigma chose to eliminate the filter to get more sharpness, but the resulting apparent detail may or may not reflect features in the image.



# More examples



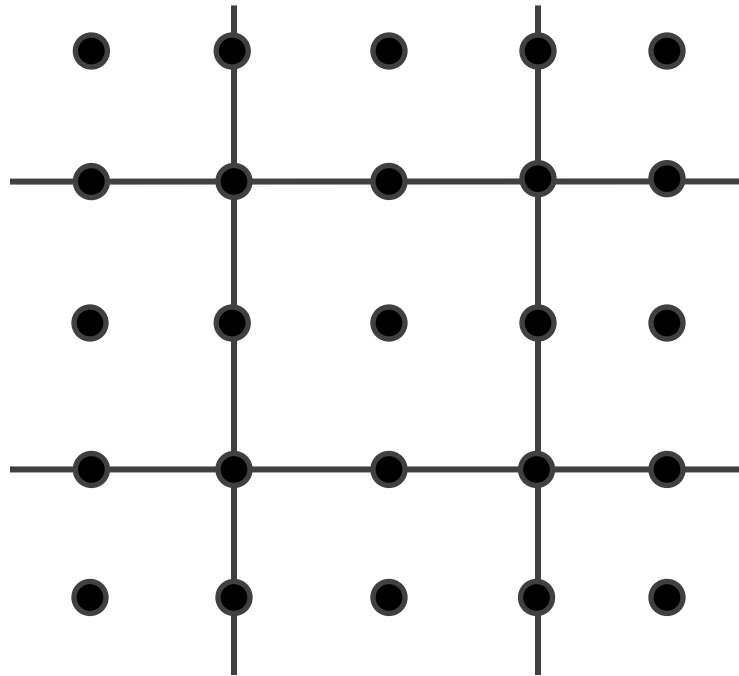
Check out Moire patterns on the web.



# Up-sampling

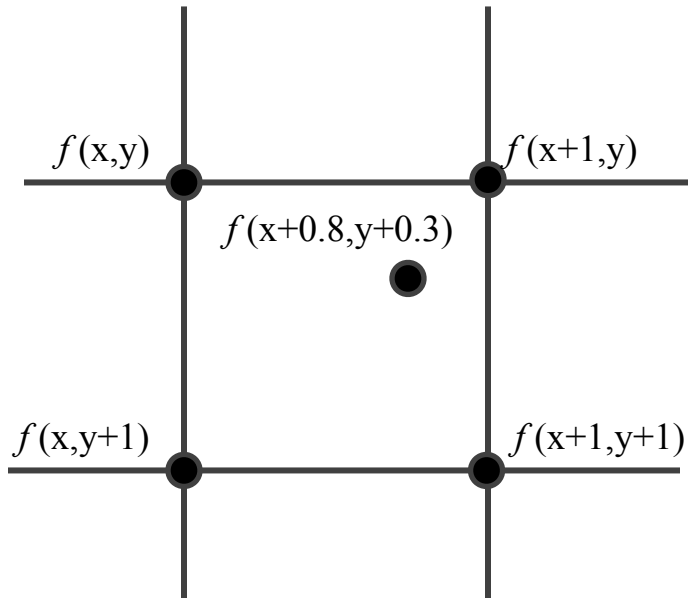
---

How do we compute the values of pixels at fractional positions?



# Up-sampling

How do we compute the values of pixels at fractional positions?

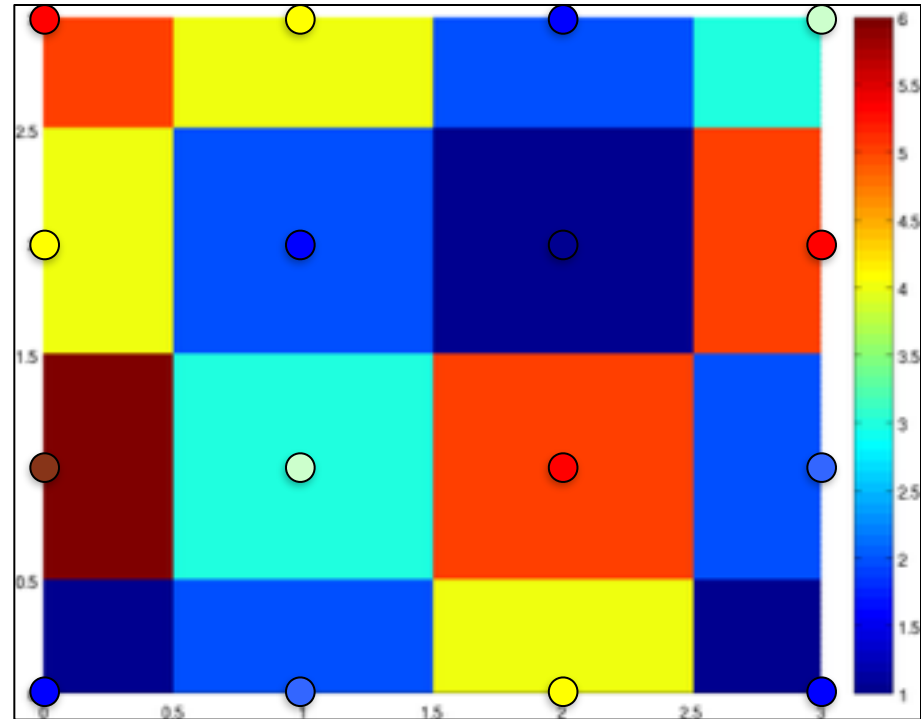


Bilinear sampling:

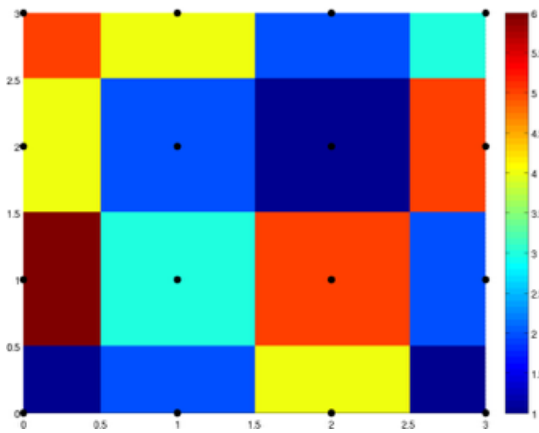
$$\begin{aligned} f(x + a, y + b) = & \\ & (1 - a)(1 - b)f(x, y) + \\ & a(1 - b)f(x + 1, y) + \\ & (1 - a)b f(x, y + 1) + \\ & ab f(x + 1, y + 1) \end{aligned}$$

Bicubic sampling fits a higher order function using a larger area of support.

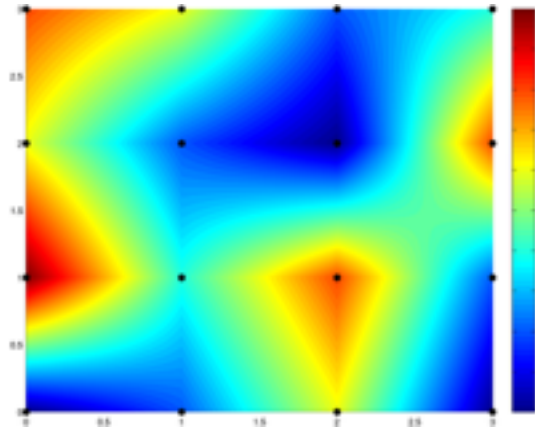
# Up-sampling Methods



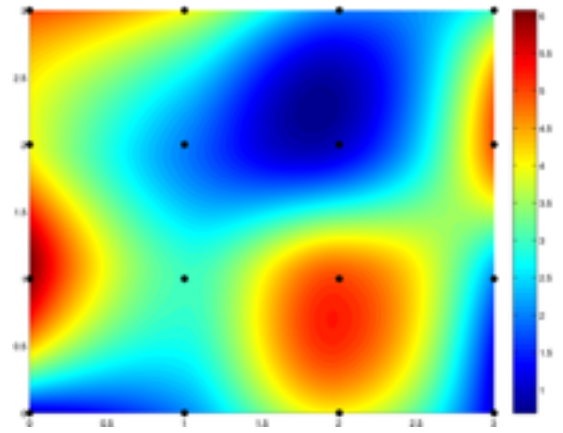
# Up-sampling



Nearest  
neighbor



Bilinear



Bicubic

# Up-sampling

---



Nearest  
neighbor



Bilinear



Bicubic