CPSC 4040/6040 Computer Graphics Images

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Lecture 20
Removing Warp Artifacts

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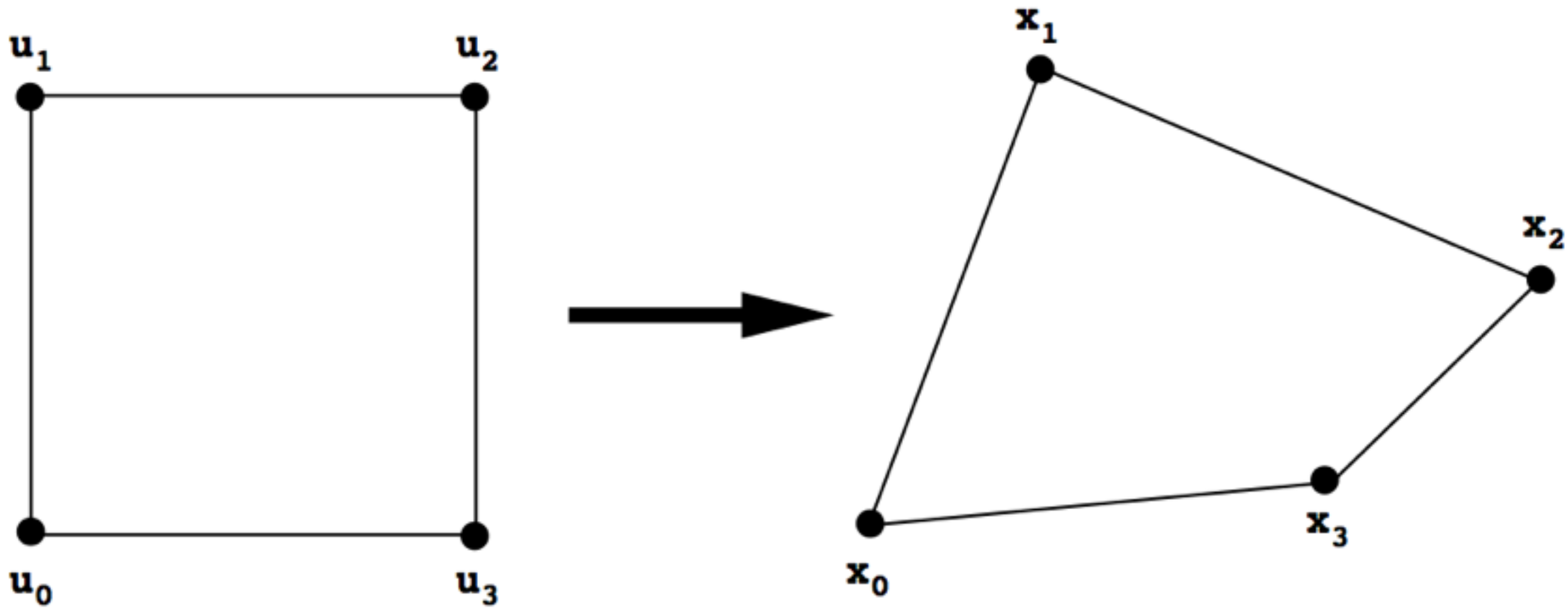
Slide Credits:
Szymon Rusinkiewicz

Agenda

Refresher from Lec19

Projective Warps

- What is the matrix?
- What the knowns? Unknowns? How many?



Algebra

- A general 3x3 matrix can express this entire class of warps (9 unknowns)
  - a_{33} acts as a global scale parameter, so we can always set it to 1 without losing generality
- The remaining 8 unknowns can be solved by 4 pairs of equations using the 8 known x_i, y_i values and the 8 known u_i, v_i values
- Solving these 8 equations gives the 8 remaining a_{ij} unknowns

$$x_i = \frac{a_{11}u_i + a_{12}v_i + a_{13}}{a_{31}u_i + a_{32}v_i + 1}$$

$$y_i = \frac{a_{21}u_i + a_{22}v_i + a_{23}}{a_{31}u_i + a_{32}v_i + 1}$$

Bilinear Warping

- Key Idea: Instead of using bilinear interpolation for pixel color values, we can use it to interpolate the positions in the warped image

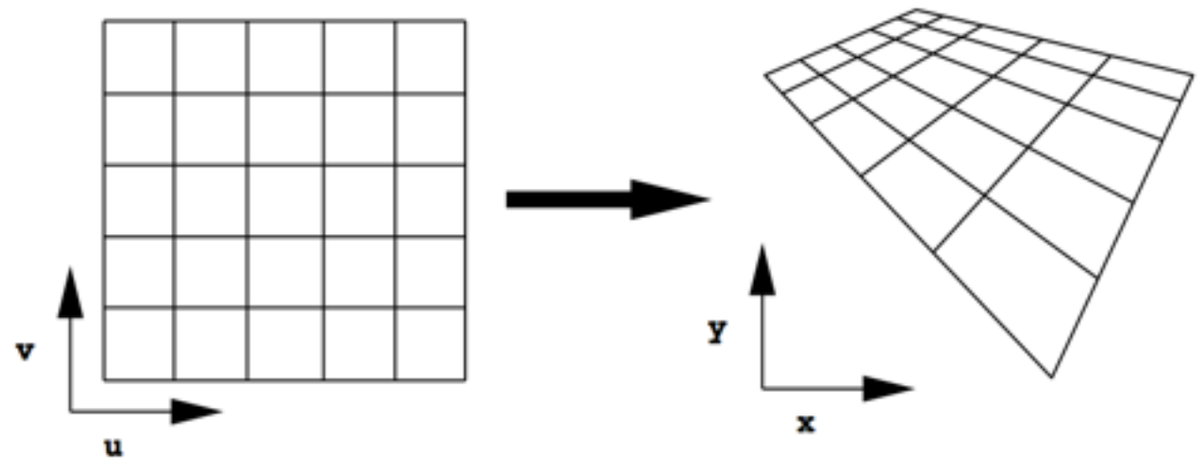


Figure 10.3: Foreshortening due to Perspective

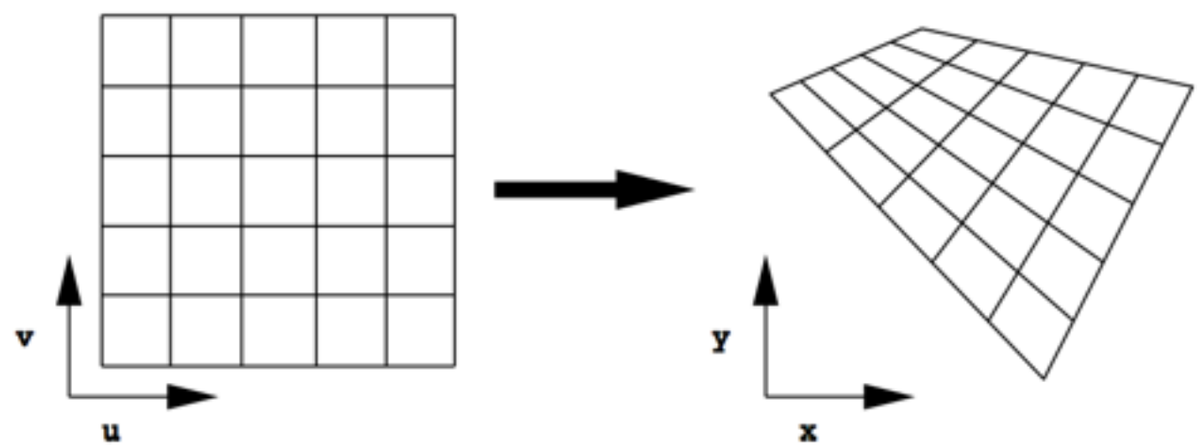
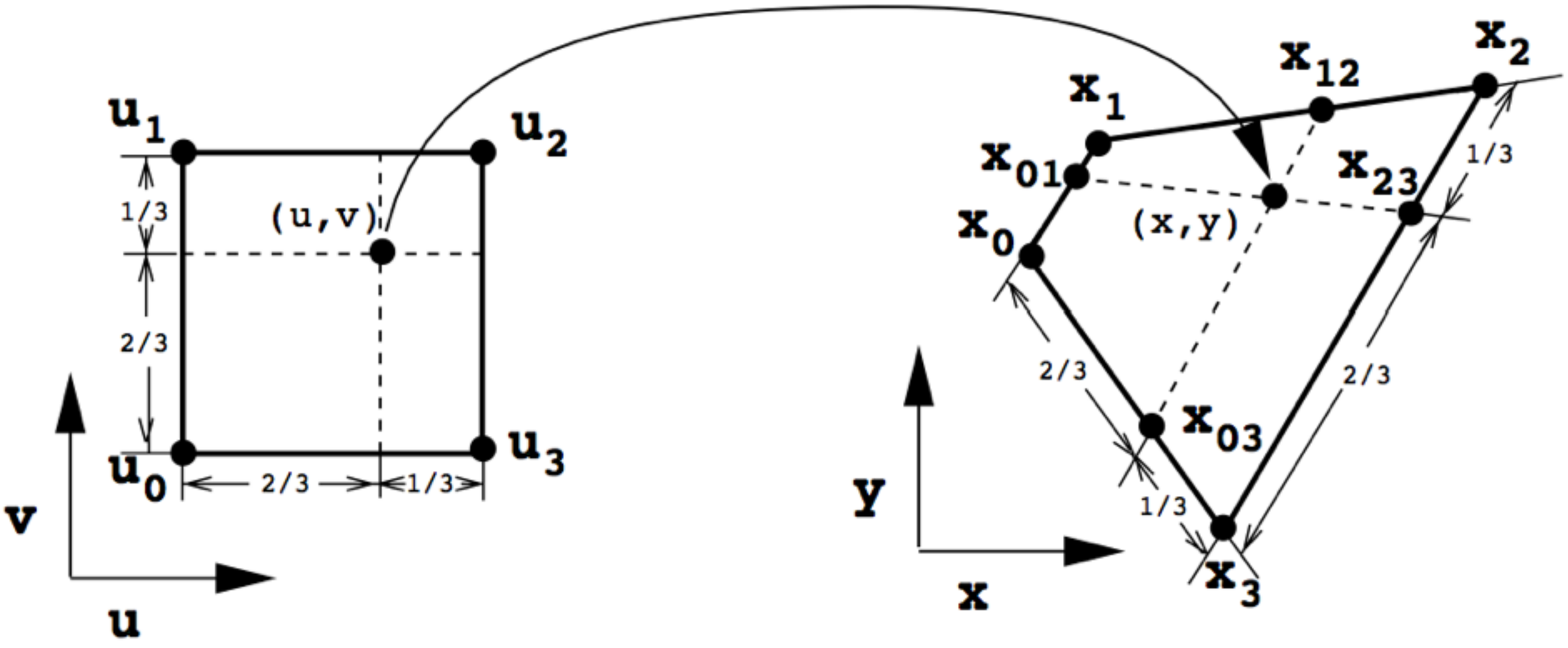


Figure 10.4: Even Spacing under Bilinear Warp

Step 2: Forward Warp with u,v offsets



Inverse Bilinear Warp Can Be Computed from the Forward Warp

- Forward warp for a pixel (s, t) is equivalent to the following equations:

$$\overline{x} = (\overline{x_{12}} - \overline{x_{03}})v + \overline{x_{03}}$$

$$\overline{x_{03}} = (\overline{x_3} - \overline{x_0})u + \overline{x_0}$$

$$\overline{x_{12}} = (\overline{x_2} - \overline{x_1})u + \overline{x_1}$$

- where (s_0, t_0) is the lower left of the image, (s_1, t_1) is the upper right of the image, and (effectively normalizing)

$$u = \frac{s - s_0}{s_1 - s_0} \qquad v = \frac{t - t_0}{t_1 - t_0}$$

Inverse Bilinear Warp Can Be Computed from the Forward Warp

- Taking the inverse of

$$x = a_0 + a_1 u + a_2 v + a_3 uv$$

$$y = b_0 + b_1 u + b_2 v + b_3 uv,$$

- Leads to

$$v = \frac{-c_1}{2c_2} \pm \frac{1}{2c_2}\sqrt{{c_1}^2 - 4c_2 c_0}$$

$$u = \frac{x - a_0 - a_2 v}{a_1 + a_3 v},$$

- Where 0<u<1, 0<v<1, and

$$c_0 = a_1(b_0 - y) + b_1(x - a_0),$$

$$c_1 = a_3(b_0 - y) + b_3(x - a_0) + a_1 b_2 - a_2 b_1,$$

$$c_2 = a_3 b_2 - a_2 b_3.$$

Recall: Converting Between Image Domains

- When an image is acquired, an image is taken from some continuous domain to a discrete domain.
- **Reconstruction** converts digital back to continuous through interpolation.
- The reconstructed image can then be **resampled** and **quantized** back to the discrete domain.

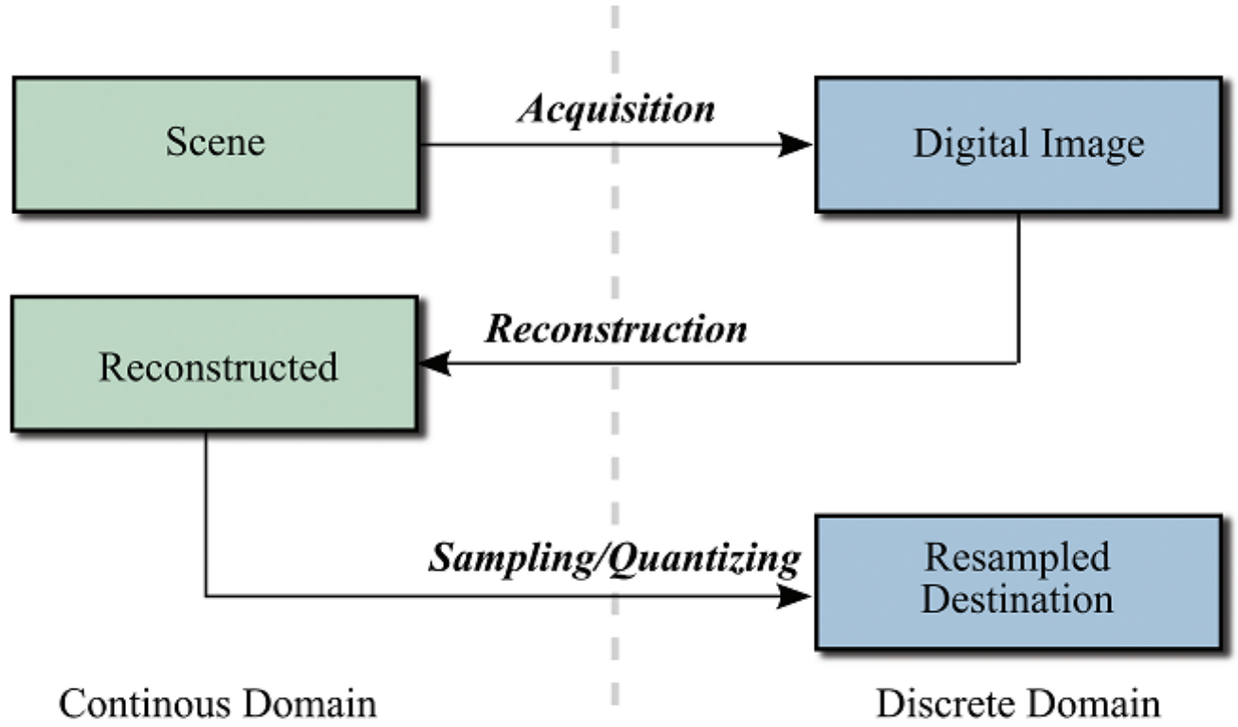


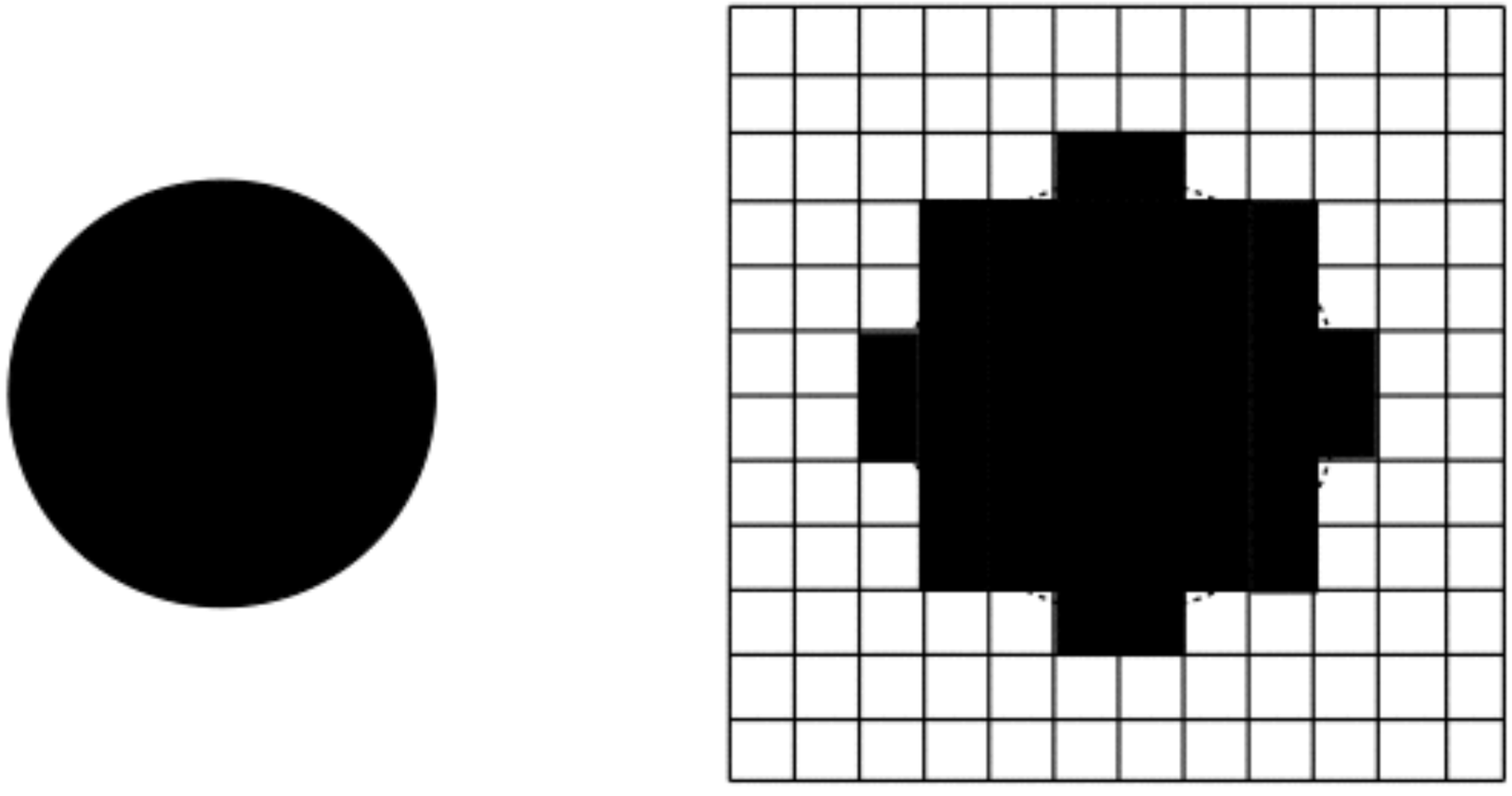
Figure 7.7. Resampling.

Lesson 1: To reduce magnification artifacts we need to do a better job of reconstruction.

Fixing Jaggies / Magnification Artifacts

Reconstruction Artifacts

- Leads to staircasing or “jaggies”



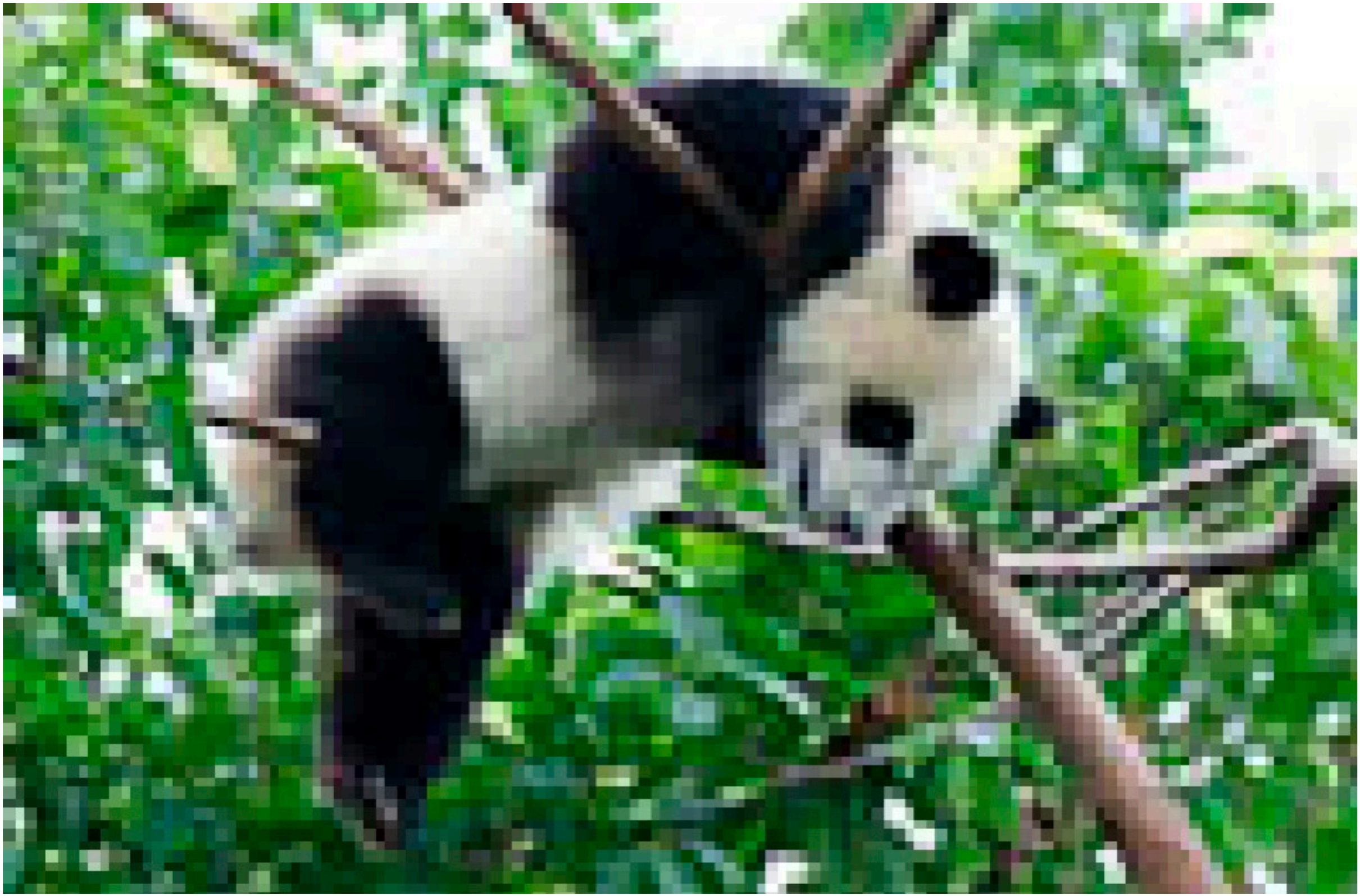
b) reconstruction artifacts

Do a Better Reconstruction?

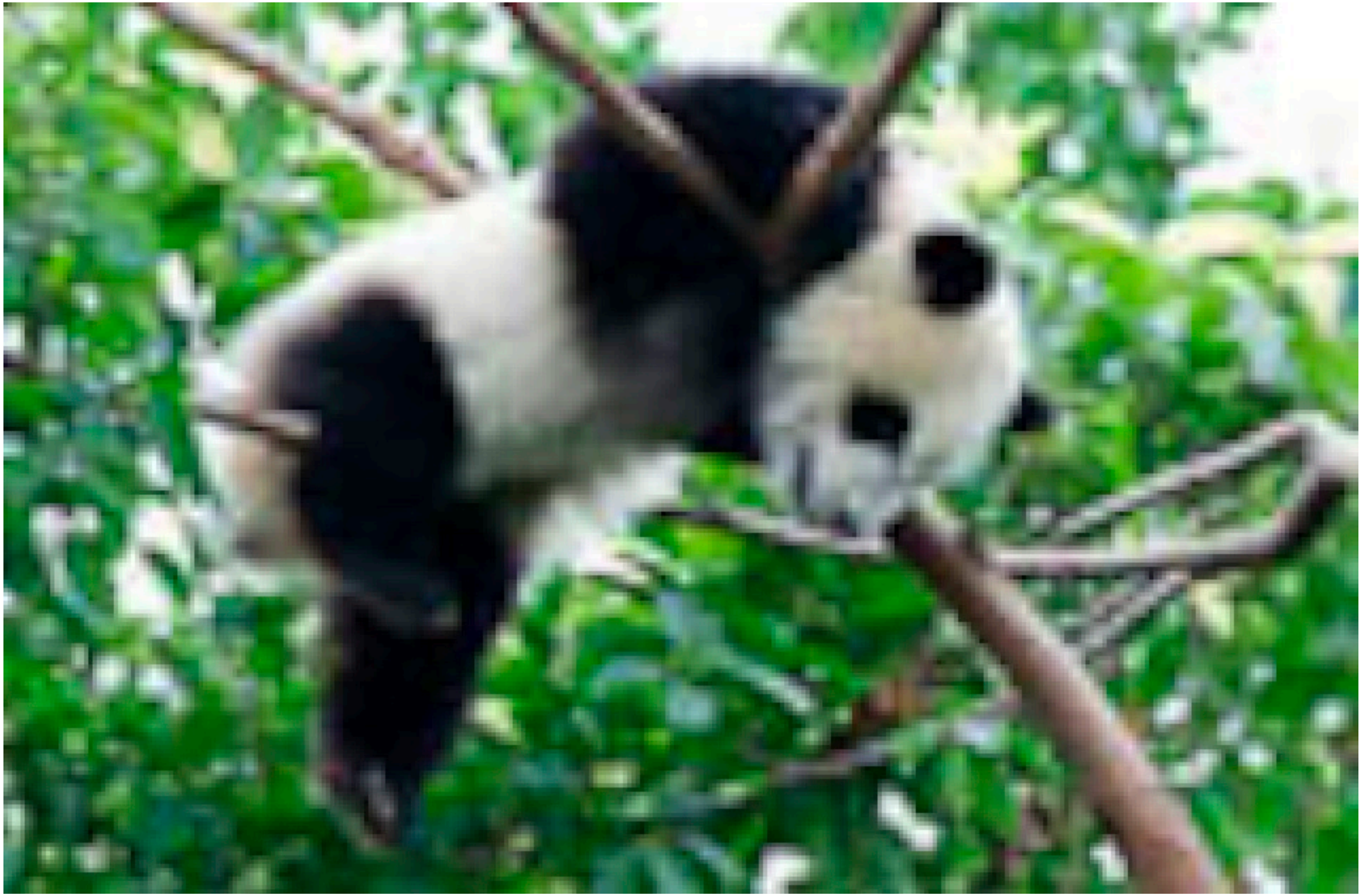
- Basic Idea: If we interpolate the data samples better we will have a superior reconstruction

- How? Bilinear Interpolation, Bicubic, etc.

Recall: Nearest Neighbor



Recall Bilinear Example



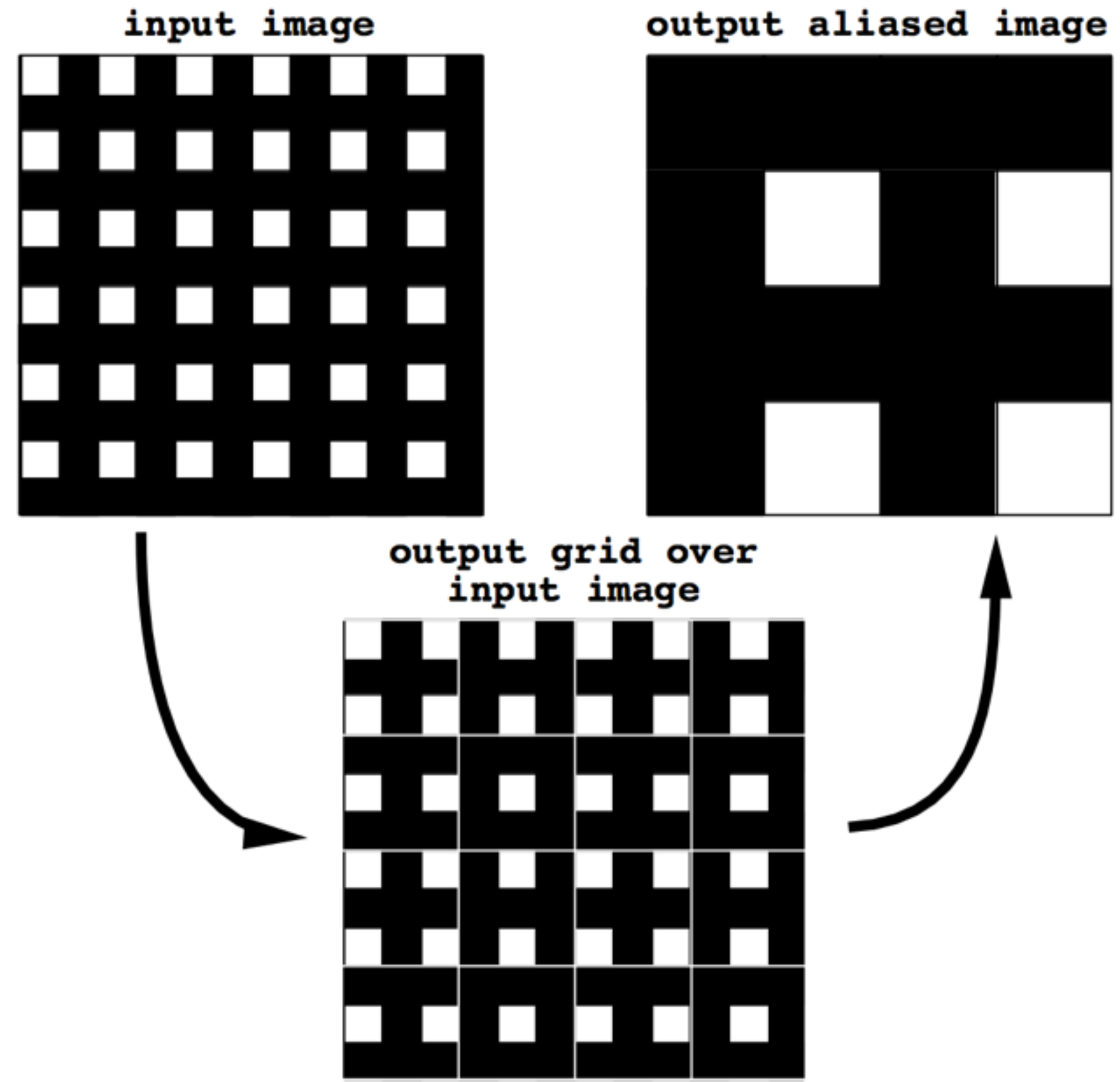
Recall Bicubic (from Photoshop)

Lesson 2: To reduce minification artifacts we must either 1) sample more finely than once for each output pixel, or 2) smooth the reconstructed input before sampling.

Fixing Aliasing / Minification Artifacts:

- Aliasing leads to missing and/ or unwanted features

- Example: 12x12 images scaled to a 4x4 image.



a) aliasing artifacts

Aliasing

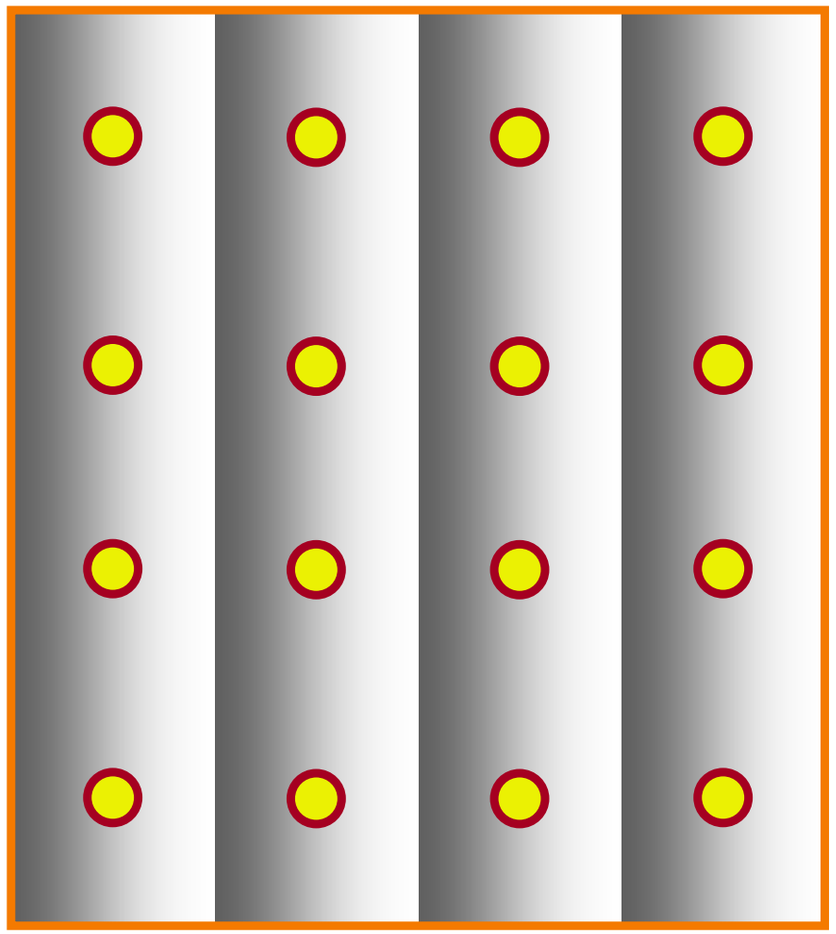
- When we minify, we use only a few samples to represent lots of data
- High frequencies “masquerade” as low ones
- Images look “ropey”. This is not jaggies!

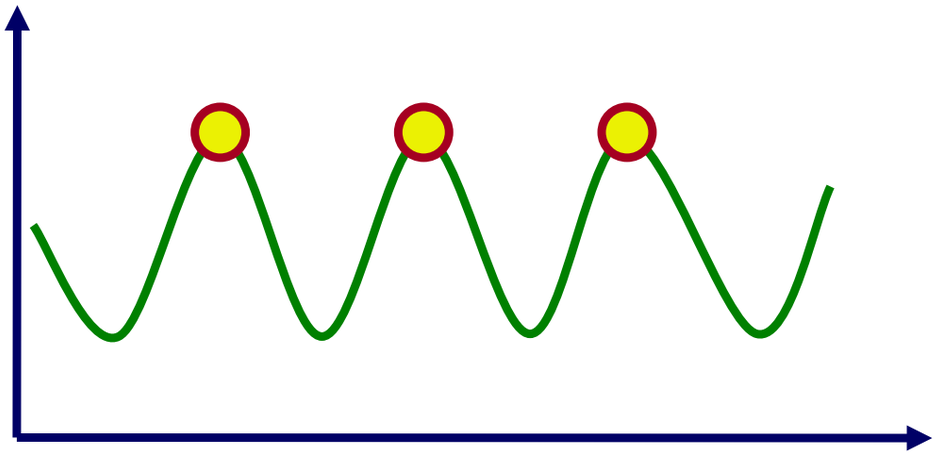
(Barely) adequate sampling

Inadequate sampling

Aliasing Described by Sampling Theory

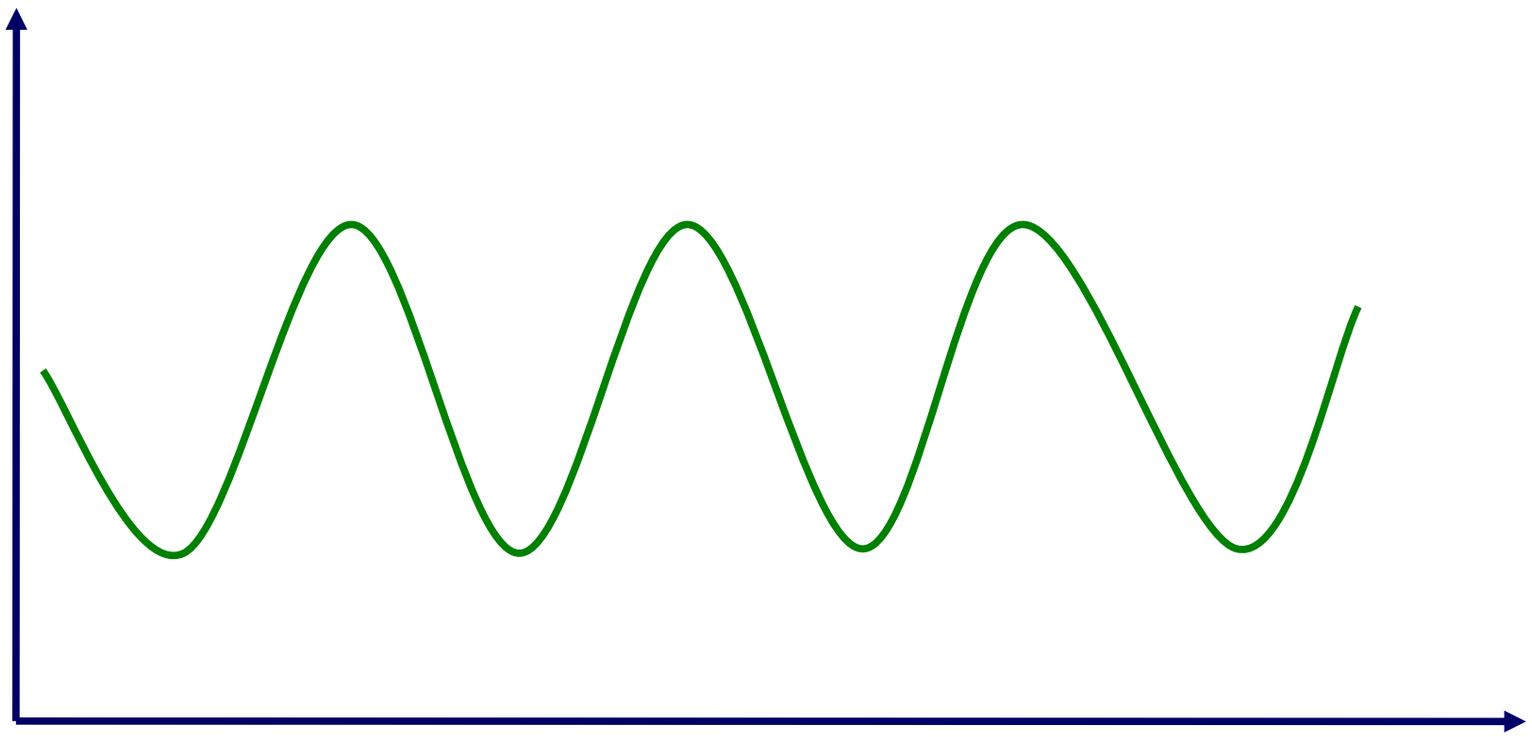
- What happens if we use too few samples?
- Aliasing: when high frequencies masquerade as low ones





How many samples are enough to avoid aliasing?

- How many samples are required to represent a given signal without loss of information?
- What signals can be reconstructed without loss for a given sampling rate?



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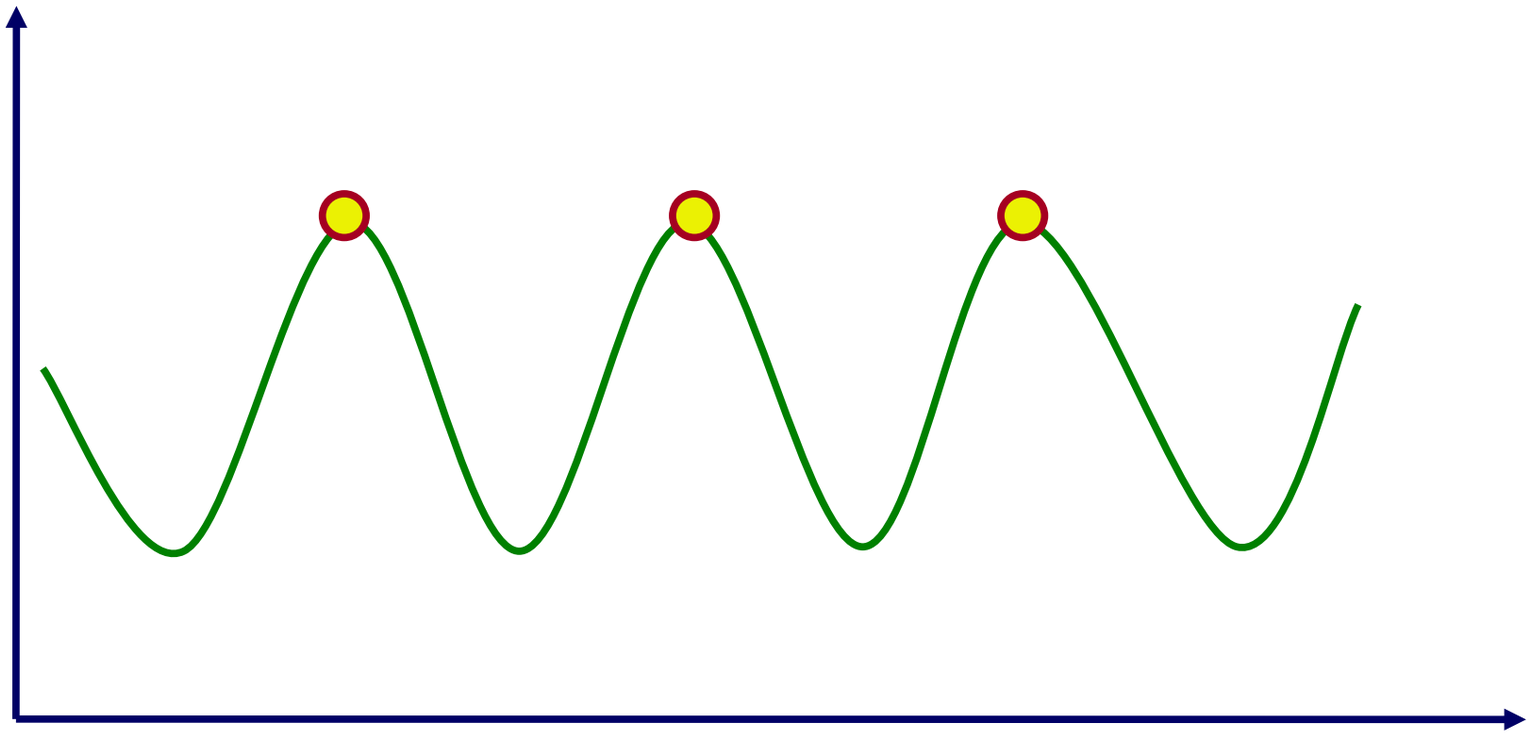

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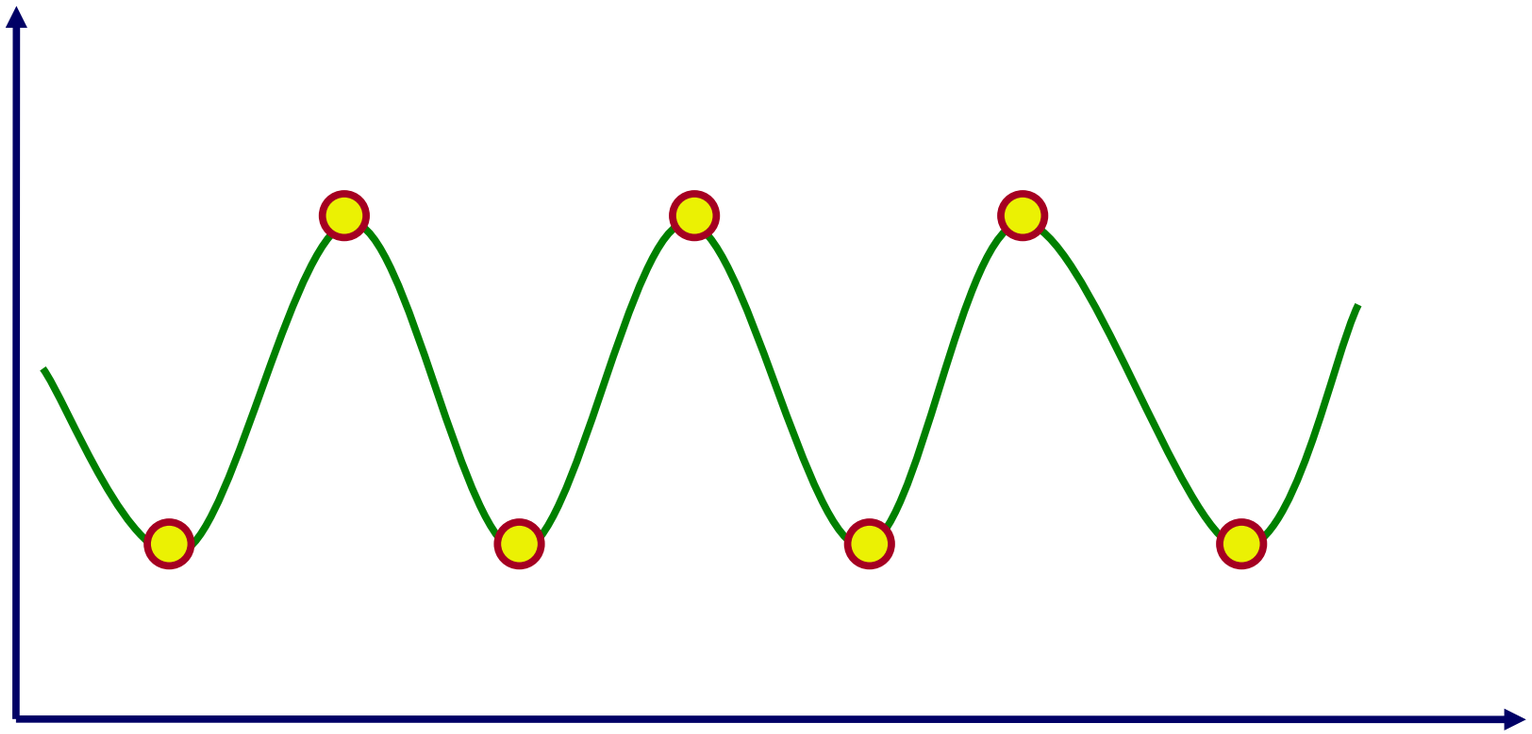

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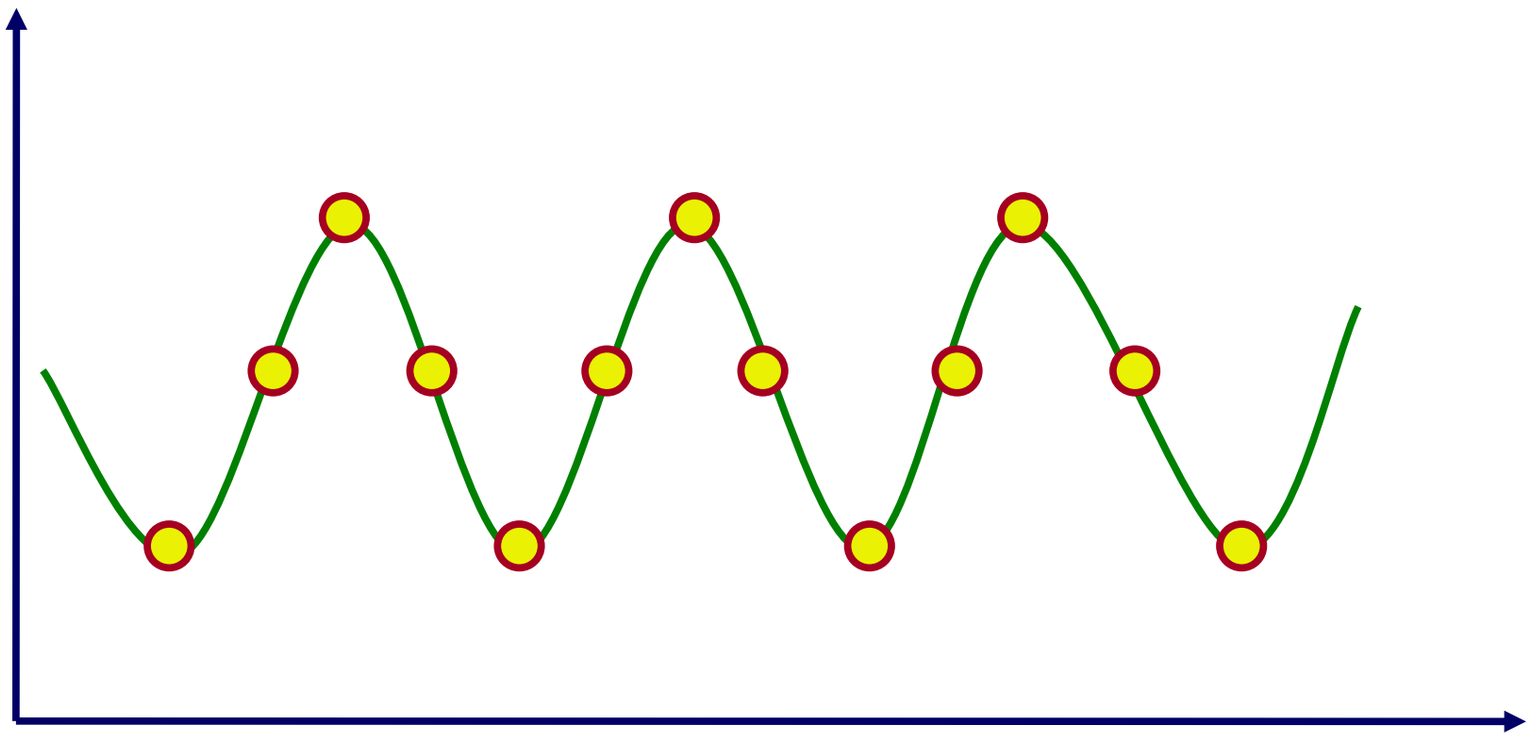

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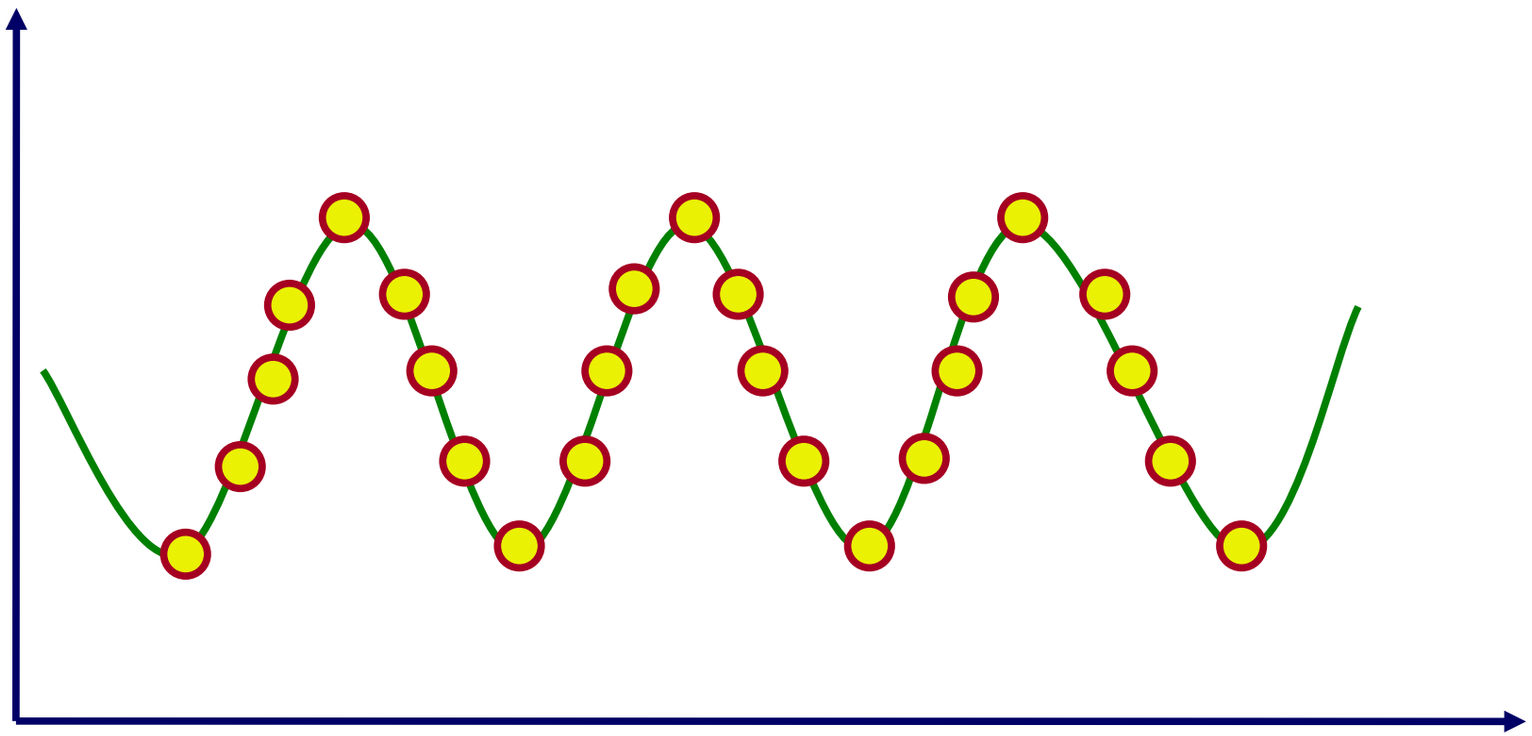


Antialiasing Filters

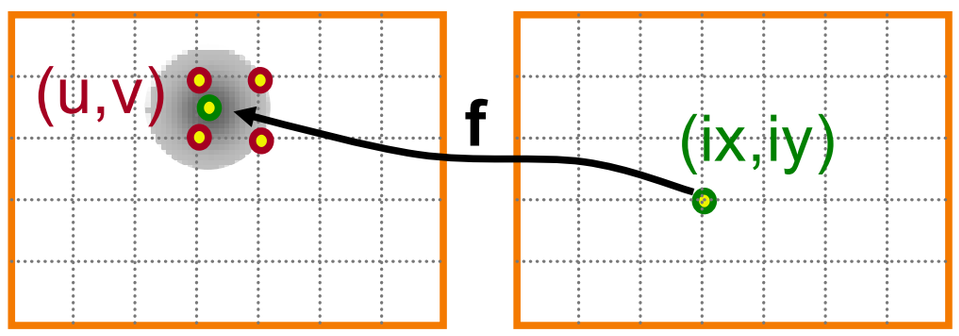
- Basic Idea: Smooth the image first to reduce the overall frequency

- How? Use filters!

Resampling with Filters

Output is weighted average of inputs:

```
float Resample(src, u, v, k, w)
{
  float dst = 0;
  float ksum = 0;
  int ulo = u - w; etc.
  for (int iu = ulo; iu < uhi; iu++) {
    for (int iv = vlo; iv < vhi; iv++) {
      dst += k(u,v,iu,iv,w) * src(u,v)
      ksum += k(u,v,iu,iv,w);
    }
  }
  return dst / ksum;
}
```

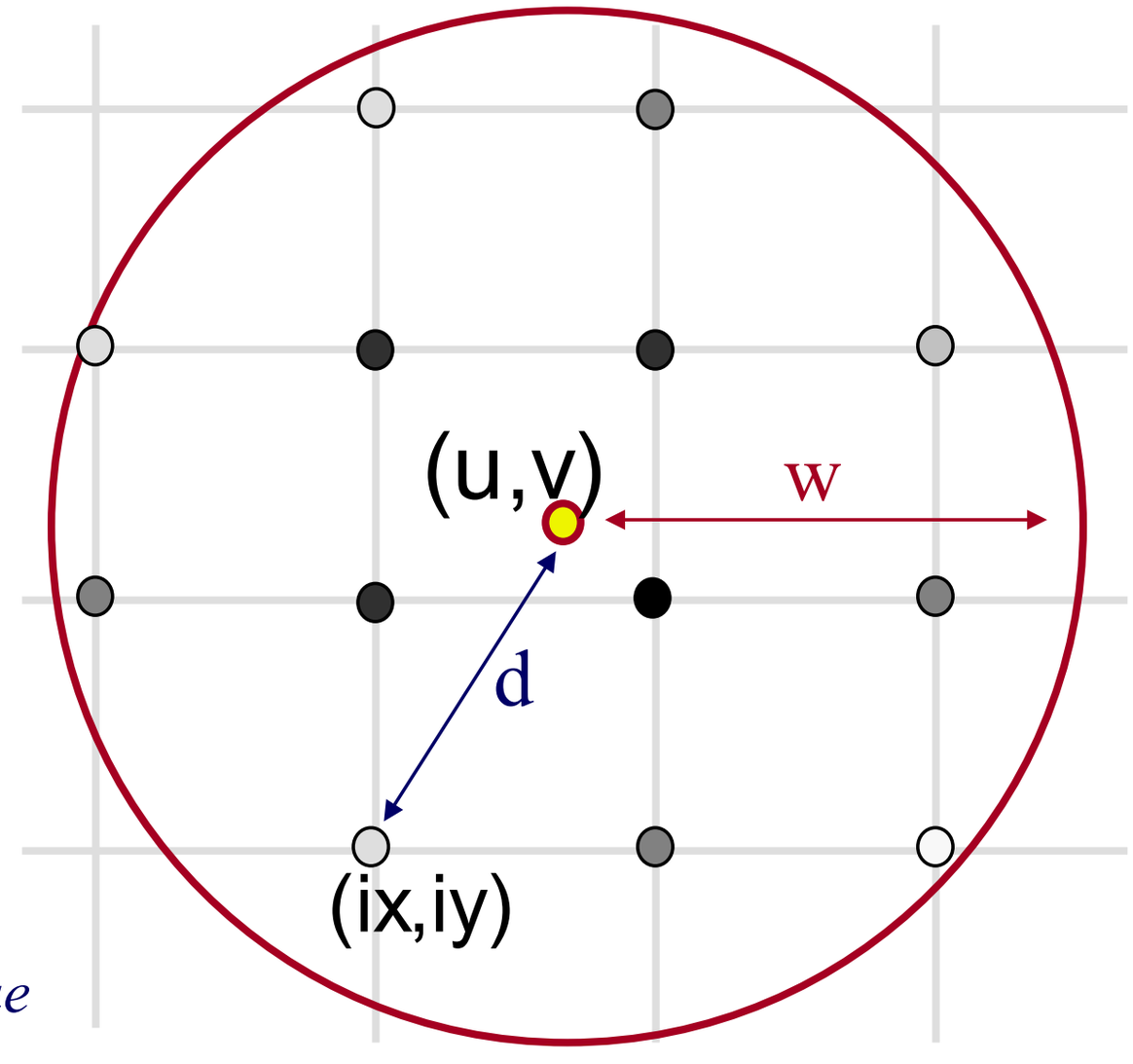


Local Convolution?

Compute weighted sum of pixel neighborhood

- Output is weighted average of input, where weights are normalized values of filter kernel (k)

```
dst(ix,iy) = 0;
for (ix = u-w; ix <= u+w; ix++)
  for (iy = v-w; iy <= v+w; iy++)
    d = dist (ix,iy)↔(u,v)
    dst(ix,iy) += k(ix,iy)*src(ix,iy);
```



k(ix,iy) represented by gray value

Smoothing an Image in This Way Limits the Frequency Bands

Point Sampled: Aliasing!

Correctly Bandlimited

Another Approach

- Instead of smoothing, we can also sample better and then aggregate the samples

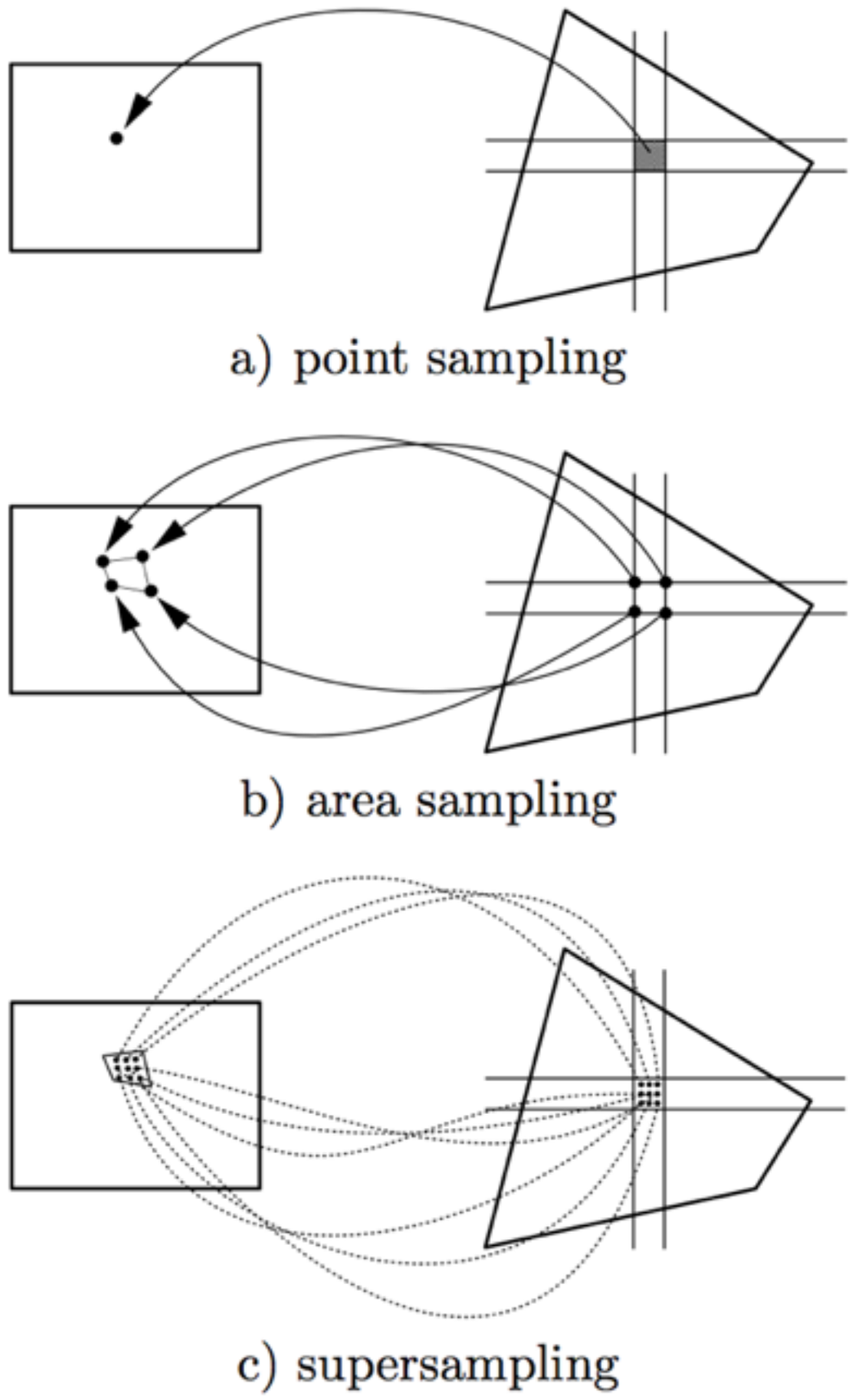


Figure 11.12: Sampling Techniques Under Inverse Mapping

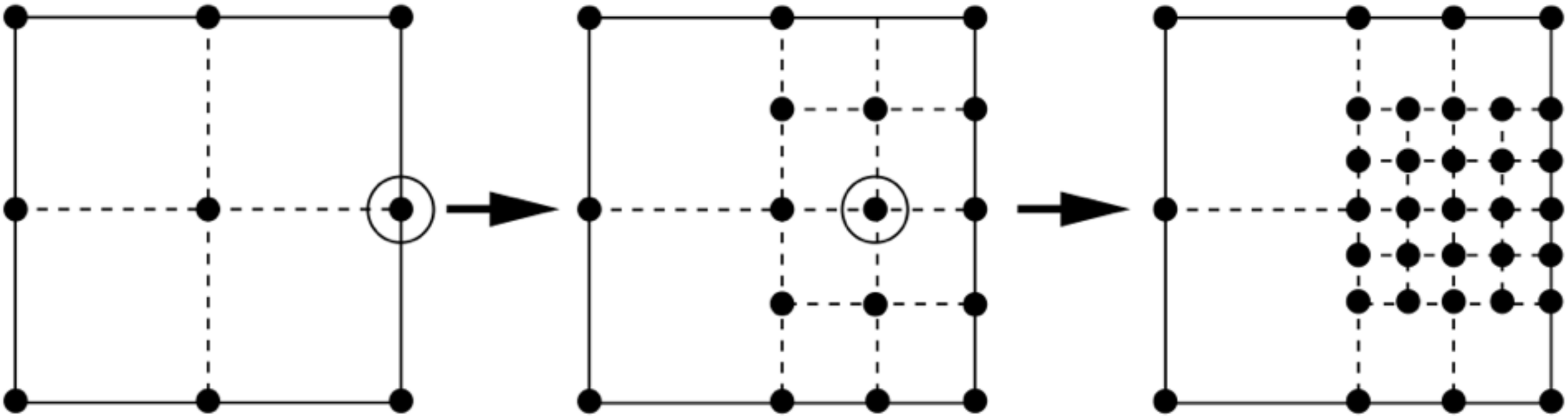


Figure 11.14: Adaptive Supersampling

Artifact “Free” Warping Pipeline

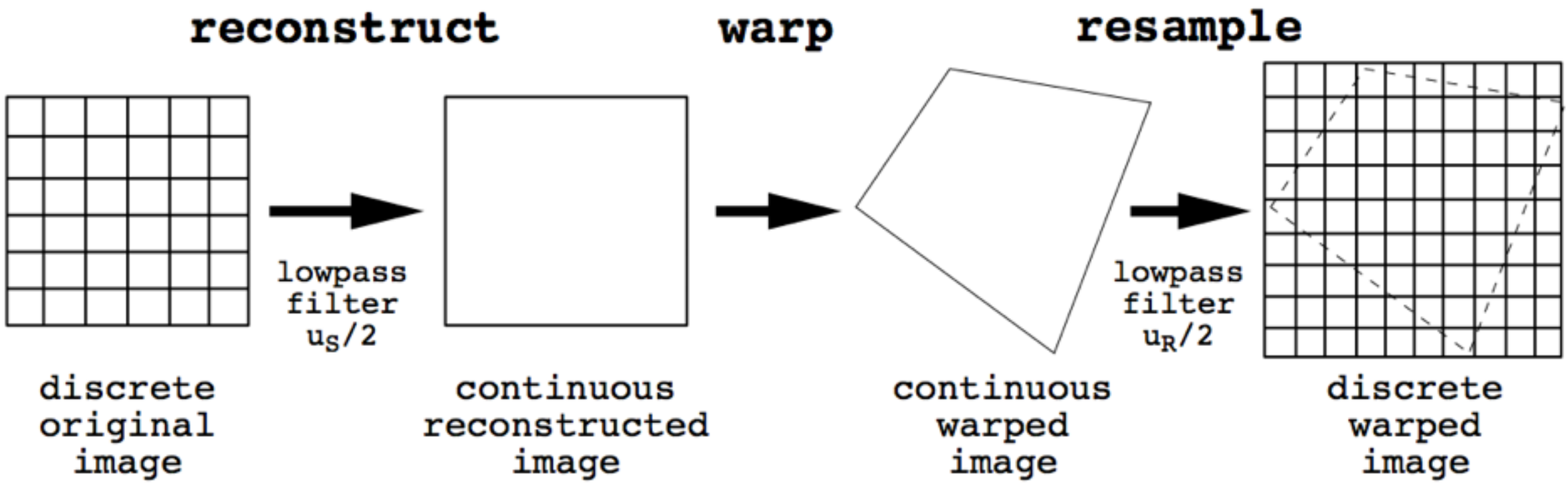
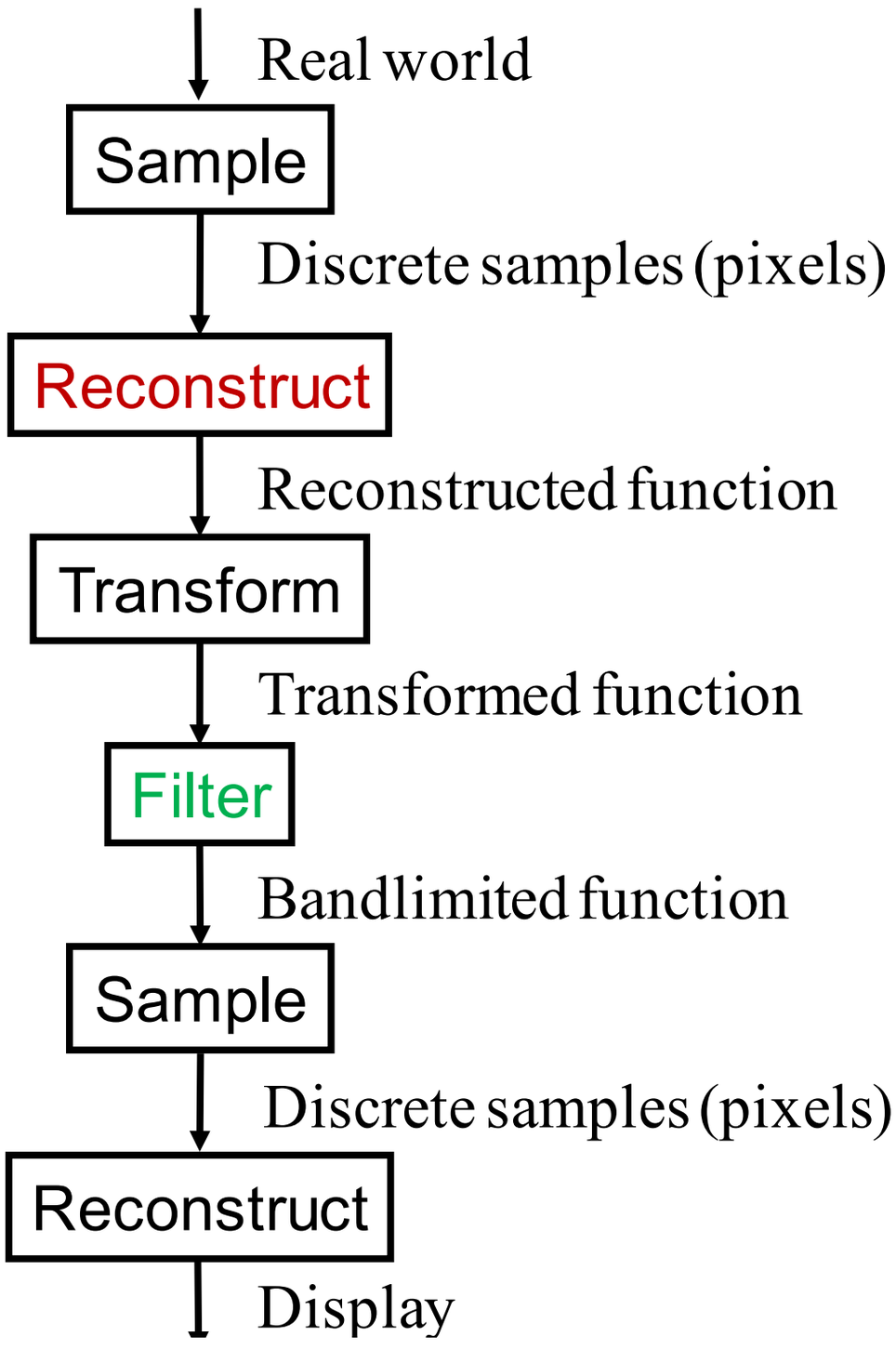


Figure 11.3: A Conceptual View of Digital Image Warping

Warping Pipeline

- Ideal resampling requires correct filtering to avoid artifacts
- Reconstruction filter especially important when magnifying
- Bandlimiting filter especially important when minifying



Lec21 Required Reading

- House, Ch. 13

Feature-Based Image Metamorphosis

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Shawn Neely

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1111 Karlstad Drive, Sunnyvale CA 94089

1 Abstract

A new technique is presented for the metamorphosis of one digital image into another. The approach gives the animator high-level control of the visual effect by providing natural feature-based specification and interaction. When used effectively, this technique can give the illusion that the photographed or computer generated subjects are transforming in a fluid, surrealistic, and often dramatic way. Comparisons with existing methods are drawn, and the advantages and disadvantages of each are examined. The new method is then extended to accommodate keyframed transformations between image sequences for motion image work. Several examples are illustrated with resulting images.

Keywords: Computer Animation, Interpolation, Image Processing, Shape Transformation.

tion-controlled variant called go-motion (in which the frame-by-frame subjects are photographed while moving) can provide the proper motion blur to create a more natural effect, but the complexity of the models, motion hardware, and required skills becomes even greater.

2.2 3D Computer Graphics Techniques

We can use technology in other ways to help build a metamorphosis tool. For example, we can use computer graphics to model and render images which transform over time.

One approach involves the representation of a pair of three-dimensional objects as a collection of polygons. The vertices of the first object are then displaced over time to coincide in position with corresponding vertices of the second object, with color and other attributes similarly interpolated. The chief problem with this technique is the difficulty in establishing a desirable vertex correspondence; this often imposes inconvenient constraints on the geometric representation of the objects, such as requiring the same number of