Resampling (10, uniform)

for reconstruction: \( r \) = width between source samples
for pre-filtering: \( r \) = width between dest samples
hint: just pick the bigger one

\[
\begin{array}{ccccccc}
1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 \\
\end{array}
\]

\[
\begin{array}{cccc}
\downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow \\
\text{reconstruct} & \text{prefilter} & \text{prefilter} & \text{prefilter} & \text{prefilter} & \text{prefilter} & \text{prefilter} & \text{prefilter} & \text{prefilter} & \text{prefilter} \\
\text{x} & \text{x} & \text{x} & \text{x} & \text{x} & \text{x} & \text{x} & \text{x} & \text{x} & \text{x} \\
\end{array}
\]

\( \frac{3}{2} \) resampling

Note: we only reconstruct (and evaluate pre-filter) at the samples

Alternate:

Upsample (reconstruct)
Filter (convolve w/ pre-filter)
Sample

Show w/ box
What do filters do to images

1. Per-pixel operations:
   - brightness/contrast
   - color shift \((r, g, b) = F(r, g, b)\)
   - non-linear (threshold, quantize, ...)

2. Linear filters - convolution

\[ \text{Blur} = \text{LPF} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \approx \frac{1}{9} \begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix} \]

- Sensor
- Focus - discuss later in course
- Motion

Unsharp Mask

Image - Blurred version = blurry part
- So remove it

"High Pass Filter"

\[ 1 - \text{LPF} \begin{bmatrix} 0 & 1 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 0 \end{bmatrix} = \begin{bmatrix} -\frac{1}{4} & \frac{1}{2} & -\frac{1}{4} \\ \frac{1}{2} & \frac{1}{4} \end{bmatrix} \]

- Often flipped \[ \begin{bmatrix} \frac{1}{4} & \frac{1}{2} & \frac{1}{4} \\ \frac{1}{2} & \frac{1}{4} \end{bmatrix} \]
- Or even \[ \begin{bmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \end{bmatrix} \]

Different 2D versions

\[ \begin{bmatrix} 1 & -1 & 1 \\ 1 & 1 & 1 \\ -1 & 1 & 1 \end{bmatrix} \]
Does HPF "Sharpen" \[ 1 + \alpha \text{HPF} \]
No!
Adds in high frequencies \( \leftarrow \) perceived as sharpness

How to Sharpen
De Convolution - hard (if kernel is LPF)
\[
\hat{f} * g = h
\]
\( \hat{f} \) image \( \hat{g} \) blurred image

Problem 1 - deconvolution is hard (singular, sensitive)
2 - usually don't know \( g \) = BLIND deconvolution

Blending
image = \((1 - \alpha) I_1 + \alpha I_2\)
Accumulation (paint strokes) \( \leftarrow \) note how last has more emphasis
Feathering (makes transition less obvious)
Airbrush
Clone Tool

Compositing
each pixel stores how "opaque" it is \((\alpha)\)
0 = empty / clear \( i = \text{full (opaque)} \) or 255
Matte = image of \( \times \text{channels} \)
Over operator \( \Rightarrow \) blending