pixel: \([E_i, i+1] \times [E_j, j+1]\)

original: for each pixel \((i, j)\) do
\[c_{ij} = \text{random color} \left(i + 0.5, j + 0.5\right)\]

regular subsampling:
for each pixel \((i, j)\) do
\[c = 0\]
for \(p = 0\) to \(n - 1\) do
\[c = c + \text{random color} \left(i + \left(p + 0.5\right)n, j + \left(q + 0.5\right)r\right)\]
\[c_{ij} = \frac{c}{n^2}\]

equivalent to rendering

\(n \times n\) image + average blocks of \(n \times n \times n\) to get \(n \times n \times n\) image
Random samples

for each pixel \((ij)\) do

\(c = 0\)

for \(p = 0\) to \(n^2\) do

\(c = c + \text{ray-color}(i + \epsilon, j + \epsilon)\)

\(c_{ij} = c / n^2\)

\(\epsilon\) is a uniform random number in the range \([0,1)\).

Noise will likely be noticeable if individual pixel samples are jittered.

Random perturbation of a regular grid:

for each pixel \((ij)\) do

\(c = 0\)

for \(i = 0\) to \(n-1\) do

for \(p = 0\) to \(n-1\) do

\(c = c + \text{ray-color}(i + \epsilon, j + \epsilon, n, q + 3, \ell)\)

\(c_{ij} = c / n^2\)
Soft shadows

N light sources each with the intensity \( \|
\text{light source} \| \) in the light equivalent to regular shadows in and diversity
\( \Rightarrow \) many small lights required to get smooth

\[
a = 0.5 x + 0.5 y + \text{random} \quad \text{on surface of light}
\]

jitter both pixel samples + light samples:

for each pixel \((i, j)\) do

\[
c = c + \text{random-color}(i + r \cdot [p], x, 0), j + r \cdot [p], v, 0), s(p))
\]

\[
c_{ij} = c / N
\]

shuffle

for \(i = N-1\) down to 1 do

choose random integer between 0 and \(i\) inclusive.

swap array elements \(i\) and \(j\).
to fit $r$ and $r'$ sample a rainbow $\Delta$ with a
a constant degree of blur

with $\omega = \theta^2 (+ \theta, \theta)$

$u = -\frac{a}{2} + \theta a$
$\nu = -\frac{a}{2} + \theta \nu$

$r' = r + u\hat{r} + \nu \hat{\nu}$

$r'$ might be below the surface $\rightarrow$
set color contribution to zero