Announcements

- Lab 2 – due today
- HW 5 – due next Wednesday March 7.
- Questions?
Why do we care sampling
Why do we care about sampling?
Why do we care sampling
Why do we care sampling
Why do we care sampling

Normal

Raw data

Recon

10 µm
Why do we care sampling

Normal

Using Moire effect

Review of sampling

Continuous time signal

\[ x_c(t) \leftrightarrow X_c(j\Omega) = \int x_c(t) e^{-j\Omega t} \, dt \]

Continuous time sampling

\[ x_s(t) = x_c(t) \sum_{k=-\infty}^{\infty} \delta(t - kT) \]

\[ X_s(j\Omega) = \frac{1}{T} \sum_{k=-\infty}^{\infty} X_c(j(\Omega - k\Omega_s)), \quad \Omega_s = \frac{2\pi}{T} \]

\[ = \sum_{k=-\infty}^{\infty} x_c(nT) e^{-j\Omega T n} \]

Discrete time spectrum

\[ X(e^{j\omega}) = X_s \left( j \left( \frac{\omega}{T} \right) \right) \]
4. An analog signal, whose spectrum is shown below, is to be processed with a digital filter using ideal C/D and D/C converters (with no analog anti-aliasing filters).

   a) (8 points) What is the minimum sufficient sampling rate to extract portion A of the signal? Sketch the magnitude of the digital filter that would be used at this sampling rate.
Sampling solution 1a

\[
\begin{align*}
\text{Low pass filter} \quad 20 \text{ kHz}
\end{align*}
\]
4. An analog signal, whose spectrum is shown below, is to be processed with a digital filter using ideal C/D and D/C converters (with no analog anti-aliasing filters).

   a) (8 points) What is the minimum sufficient sampling rate to extract portion A of the signal? Sketch the magnitude of the digital filter that would be used at this sampling rate.

   b) (7 points) Repeat for portion B of the signal.

\[ X(\Omega) \]

<table>
<thead>
<tr>
<th>-14</th>
<th>-10</th>
<th>-6</th>
<th>6</th>
<th>10</th>
<th>14</th>
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</thead>
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Sampling solution 1b

![Diagram showing a high pass filter with 20 kHz bandwidth and frequency labels -π, -3π/5, 3π/5, π.](image)
Sampling solution 1

a) \( f_s = 20 \text{ kHz} \)

b) \( f_s = 20 \text{ kHz} \)
The imaging process of an microscopy can be described below.

Assuming camera pixel size is $\Delta x$

The kernel is bandlimited with bandwidth of $B_x$

The magnification of the microscope is $M$

(a) Find the condition of $M$ in terms of $B_x$ and $\Delta x$ such that there is no aliasing in the pictures taken by the camera.
This is how we design optical system to have good enough sampling rate on the camera.

Nyquist sampling:

\[
\frac{1}{\Delta x} \geq \frac{B_x}{M} \implies M \geq B_x \Delta x
\]
Sampling question 2 (Optics!!)

The imaging process of a microscopy can be described below. Assuming camera pixel size is $\Delta x$

- The kernel is bandlimited with bandwidth of $B_x$
- The magnification of the microscope is $M$

(a) Find the condition of $M$ in terms of $B_x$ and $\Delta x$ such that there is no aliasing in the pictures taken by the camera.

(b) What if our kernel now is $\left[h(x)\right]^2$? What about $\left[h(x)\right]^3$?

Image $I(x) = o(x) \otimes h(x)$

Magnify
Sampling solution 2b (Optics!!)

After magnification

Kernel square

Kernel cube