TBAG Exercise 2 Task 4

November 12, 2018

1 Task 2.4

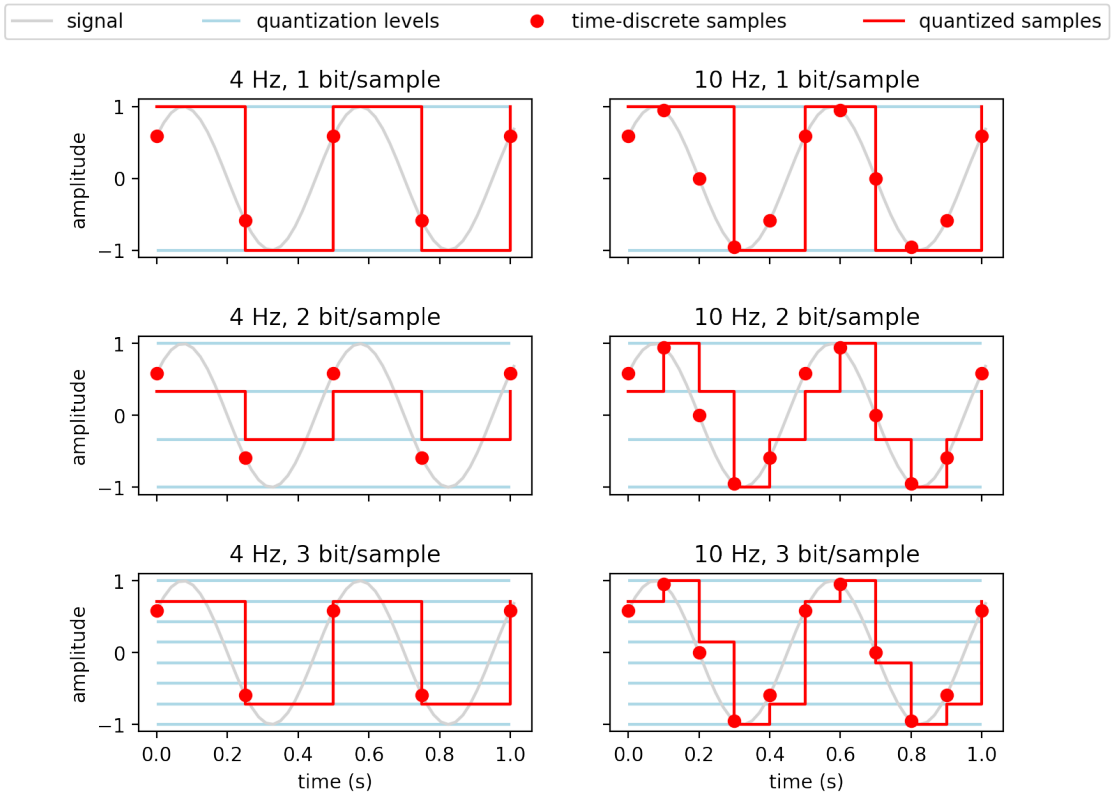
Recap the process of sampling & quantization by hand. Take a pen & paper and draw a sine wave that is made up of two cycles. Now you are supposed to draw the sample points for sampling rates of 4Hz & 10Hz as well as quantization points for sample sizes of 1bit, 2bit, and 3bit. How do the resulting sampled sine waves look like?

```
In [7]: import numpy as np
        import matplotlib as mpl, matplotlib.pyplot as plt

        mpl.rcParams['figure.dpi'] = 200
        mpl.rcParams['figure.figsize'] = (8, 6)
```

```
In [8]: def sample(signal, samplerate, start, end):
            times = np.arange(start, end, step=1/samplerate)
            samples = signal(times)
            return times, samples

        def quantization_levels(bitdepth, lowest, highest):
            return np.linspace(lowest, highest, 2**bitdepth)

        def quantize(values, levels):
            limits = np.mean([levels[:-1], levels[1:]], axis=0)
            return np.array([levels[level] for level in np.digitize(samples, limits)])
```

```
In [11]: # signal function
         # works with single values and numpy arrays as input
         def sinewave(t):
             return np.sin((t + 0.05) * 4 * np.pi)

         # sampling interval
         # add a slight overhead to the end to include one sample at the exact end of the inte
         start, end = 0, 1.01

         # quantization range
         lowest, highest = -1, 1
```

```
# sampling parameters
samplerates = [4, 10]
bitdepths = [1,2,3]

fig, axes = plt.subplots(len(bitdepths), len(samplerates), sharex='col', sharey='row'

for si, samplerate in enumerate(samplerates):
    times, samples = sample(sinewave, samplerate, start, end)

    for di, bitdepth in enumerate(bitdepths):
        levels = quantization_levels(bitdepth, lowest, highest)
        quantized_samples = quantize(samples, levels)

        ax = axes[di, si]

        ax.set(title=f'{samplerate} Hz, {bitdepth} bit/sample', xlabel='time (s)', yla

        p_levels = ax.hlines(levels, 0, 1, color="lightblue")
        p_signal, = ax.plot(np.linspace(start, end), sinewave(np.linspace(start, end))
        p_samples, = ax.plot(times, samples, 'o', color='red')
        p_quantized, = ax.step(times, quantized_samples, where='post', color='red')

# only show axis labels in outer axes
for ax in axes.flat:
    ax.label_outer()

fig.legend(
        (p_signal, p_levels, p_samples, p_quantized),
        ('signal', 'quantization levels', 'time-discrete samples', 'quantized samples
        loc='upper center',
        mode='expand',
        ncol=4)

fig.subplots_adjust(hspace=0.5)
```


signal
quantization levels
time-discrete samples
quantized samples
4 Hz, 1 bit/sample
10 Hz, 1 bit/sample
4 Hz, 2 bit/sample
10 Hz, 2 bit/sample
4 Hz, 3 bit/sample
10 Hz, 3 bit/sample
amplitude
time (s)
1
0
−1
0.0
0.2
0.4
0.6
0.8
1.0

In [ ]:

In [ ]: