UNIVERSITÄT HAMBURG, DEPARTMENT OF INFORMATICS, SIGNAL PROCESSING GROUP

Digital Media Signal Processing - Assignment II

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April 24, 2017

INTRODUCTION

Signals appear in different forms in the digital domain. They can be real-valued, complex-valued, one dimensional or multi-dimensional. We need to describe signals mathematically, to be able to define our problem, target and/or source. Systems on the other hand typically manipulate signals (e.g. measurements).
If we, e.g., have an EKG signal which contains a patients heart rate and a lot of noise, we need to be able to describe the signal and the noise. We can then design a system that separates the two, to ultimately make sense of the signal.

1 CONTINUOUS SIGNALS AND SAMPLING

Consider the following continuous, i.e., analogue, sinusoidal signal.

$$x_a(t) = \sin(2\pi \cdot 240\text{ Hz} \cdot t) + 3\sin(2\pi \cdot 360\text{ Hz} \cdot t)$$

Assume the signal is sampled at $F_s = 600$ Hz.

1. What is the Nyquist rate for $x_a(t)$?
2. What is the folding frequency given by F_s? (The folding frequency is the maximum frequency below which no aliasing will occur.)
3. What are the normalized frequencies f in the discrete time signal $x(n)$ after sampling with F_s?
4. If $x(n)$ is passed through an ideal D/A converter, what is the reconstructed signal $y_a(t)$?

2 Discrete Signals and Sampling

Consider the following discrete sinusoidal signals.

1. $x(n) = \cos\left(\frac{30}{105}\pi n\right)$
2. $x(n) = \cos(2n)$

For each signals, answer the following questions.

- What is the normalized frequency f?
- Is the signal periodic in n? If yes, what is the period length N?
- What is the corresponding frequency F if you assume a sampling rate of $F_s = 8000$ Hz?

3 Systems

For each of the following systems, determine if the system is *stable*, *causal*, *linear*, *time invariant*, and *memoryless*.

1. $y(n) = mx(n)$
2. $y(n) = 20\log_{10}(|x(n)|)$
3. $y(n+2) = 3x(n) - 2x(n+1) + 3.5x(n-2) + b$
4. $y(n) = tx(n) - b$, t being the temperature in degrees celsius
5. $y(n) = \sum_{k=-N}^{n+1} x(k)$ with $N \in \mathbb{N}$

4 Python

1. Write a function, which generates the signal
$$x(n) = 1/3\sin(2\pi F_0/F_s n + \theta_1) + 1/3\sin(4\pi F_0/F_s n + \theta_2) + 1/3\sin(8\pi F_0/F_s n + \theta_3),$$
with $F_0 = 440$ Hz and $F_s = 44.1$ kHz where θ_1, θ_2, and θ_3 can be arbitrarily chosen.
   a) Set $\theta_1 = \theta_2 = \theta_3 = 0$. Plot the signal and listen to it.
   b) Set $\theta_1 = 0.1$, $\theta_2 = -\pi/4$ and $\theta_3 = -\pi/12$. Again, plot the signal and listen to it.
   c) Compare the results using your plots and by listening to the signals. Can you hear a difference?
2. Generate a signal $y(n) = \tanh(10x(n))$. For $x(n)$ use the signal generated in 1 a). Plot and listen to the signal. Describe in words what you hear.
3. Generate the signal $x(n) = \sin(2\pi F_0/F_s n)$ with $F_0 = 10$ kHz and $F_s = 8$ kHz. Plot two periods of the signal and determine its frequency.