UNIVERSITY OF ILLINOIS
Department of Electrical and Computer Engineering
ECE 417 Multimedia Signal Processing

Lecture 6 Sample Problems

Problem 6.1

Suppose that all of the low frequencies ($k < \frac{L}{2} - b$ and $k > \frac{L}{2} + b$, for some cutoff frequency $\omega = \pi - \frac{2\pi b}{L}$) are voiced, and all of the high frequencies ($\frac{L}{2} - b \leq k \leq \frac{L}{2} + b$) are unvoiced. In particular, suppose that $U_f[k]$ are independent zero-mean Gaussian random variables with

$$E\left\{U_f[k]U_f^*[k]\right\} = \begin{cases} \sigma^2 & \frac{L}{2} - b \leq k \leq \frac{L}{2} + b \\ 0 & \text{else} \end{cases}$$

Express the statistical autocorrelation $R_{uu}[n] = E\left\{u_f[m]u_f[m-n]\right\}$ in terms of the dsinc function $\text{dsinc}(\theta, L) = \frac{\sin(\theta L/2)}{L\sin(\theta/2)}$. Be careful, here: $E\left\{|U_f[k]|^2\right\}$ is not the DFT of the statistical autocorrelation, so you'll need to take the inverse DFT of $U_f[k]$ and $U_f^*[k]$ separately, to find $u_f[m]$ and $u_f[-(n-m)]$ separately, and then compute its expected value. Hint: make use of the identity $e^{-j\frac{2\pi n}{L}\left(\frac{L}{2}+\ell\right)} = (-1)^n e^{-j\frac{2\pi \ell n}{L}}$.

Problem 6.2

Overlap-add synthesis can be defined, in general, as

$$u[n] = \sum_{f=-\infty}^{\infty} u_f[n - fK]w[n - fK] \tag{6.2-1}$$

Find a window, $w[n]$, such that Eq. (6.2-1) gives the same result as the following linear interpolation formula, for $g = \lfloor \frac{n}{K} \rfloor$:

$$u[n] = \left(\frac{n}{K} - g\right) u_g\left[n - gK\right] + \left(1 + g - \frac{n}{K}\right) u_{g-1}\left[n - (g-1)K\right]$$

Problem 6.3

Consider the problem of synthesizing voiced speech in continuous time, using the formula

$$v(t) = \sum_m A_m(t)\cos\left(\theta_m(t)\right),$$

where $\theta_m(t)$ is defined as

$$\theta_m(t) = \int_0^t m\Omega_0(\tau)d\tau$$

and where the amplitude and fundamental frequency change linearly from one frame to the next, as

$$\begin{aligned} A_m(t) &= a_m + tb_m \\ \Omega_0(t) &= \alpha + t\beta \end{aligned}$$

Simplify the formula for $v(t)$ so it is a function of only the constant parameters a_m, b_m, α and β.