Music 420

Winter 2005-2006

Homework #1

Delay Lines

125 points

Due in one week (01/19/2006)

Theory Problems

1. (5 pts) [Delay Line Length] Assuming sound propagates at $c = 350$ meters per second (reasonable for air at standard pressure and 32 degrees Celsius), find the delay-line length M which can be used to simulate sound propagation delay over a distance of approximately 7 meters, where the simulation audio sampling rate is 50 kHz.

2. (5 pts) Suppose that pressure-wave amplitude was observed to decay by a factor of 2 in the geometry of the previous problem. In other words, sound propagation over a distance of 7 meters is associated with 6.02 dB of loss at all frequencies. What is the loss associated with propagation over one spatial sample?

3. Suppose the high E string of an electric guitar vibrates at 330 Hz and is measured to be 26 inches long from nut to bridge,
   (a) (5 pts) Find the speed of sound for transverse traveling-waves on the string
   (b) (5 pts) Find the spatial sampling interval at 44.1 kHz.

4. Sketch a delay-line simulation of an acoustic point-source at $\mathbf{x} = (1, 1, 0)$ meters, a listener at $\mathbf{x} = (2, 0, 0)$, a reflecting wall at $\mathbf{x} = (x, 2, z)$, and a second reflecting wall at $\mathbf{x} = (0, y, z)$. Assume the wall reflection coefficient is 1, and that air absorption is 0.1 dB per meter at all frequencies.
   (a) (10 pts) Find all acoustic path lengths.
   (b) (5 pts) Find all acoustic path gains.
   (c) (5 pts) Assuming sound speed is $c = 343$ meters per second, and the sampling rate is 44.1 kHz, find all delay-line lengths.
   (d) (10 pts) Find the transfer function from source to listener.
   (e) (10 pts) Using Matlab, plot the echogram (impulse response) and amplitude response (magnitude frequency response).

5. Sketch a delay-line simulation of an acoustic *plane-wave source* at $\mathbf{x} = (x, 1, z)$ meters, a listener in the source plane at $\mathbf{x} = (0, 1, 0)$, a reflecting wall at $\mathbf{x} = (x, 2, z)$, and a second reflecting wall at $\mathbf{x} = (x, 0, z)$. Assume air absorption is 0.01 dB per meter and the wall reflection coefficient is 0.9.

(a) (10 pts) Find all acoustic path lengths.

(b) (5 pts) Find all acoustic path gains.

(c) (5 pts) Assuming sound speed is $c = 343$ meters per second, and the sampling rate is 44.1 kHz, find all delay-line lengths.

(d) (10 pts) Find the transfer function from source to listener.

(e) (10 pts) Using Matlab, plot the echogram and amplitude response.

Lab Assignments

Lab assignments are due one day after the theory portion of the homework (typically Friday afternoon at 5pm). Lab assignments are to be submitted electronically at http://coursework.stanford.edu. For each assignment, submit a single archive (`zip` or `tar.gz`) file containing all code/figures/output for the assignment. For each problem in the assignment, create a sub-directory in the archive named `hwX_pY`, where `X` is the homework number, and `Y` is the problem number, and place all code/figures/output for that problem in that sub-directory.

1. Follow the instructions in "Introduction to the Synthesis Tool Kit (STK)" at `http://ccrma.stanford.edu/~jos/stkintro/`
   (a slight revision of Appendices A and B of the text for this course).

   There it is described how to download and install the latest STK from `http://ccrma.stanford.edu/CCRMA/Software/STK/`,
   followed by the installation of an overlay of additional files for this course.

2. Read the STK documentation at `http://ccrma.stanford.edu/software/stk/`.

3. Look over the library modules, especially anything named `Delay*`.

4. Run the STK example `projects/examples/sineosc` to verify that you have basic sound working in the STK and your operating system.

5. Familiarize yourself with the STK to the extent you have time.

6. Find the project directory `myproj/delay/` and read the file `README`. Compile and test this project by typing `make` in that directory. Make sure you understand what is going on.

7. Find the project directory `myproj/echo/`. Compile and test this project by typing `make` in that directory. Again, make sure you understand what is going on.

8. Modify the code `echo.cpp` and its `Makefile` so that it takes two delay inputs (in seconds) and gives a sound output which is the sum of the original input and the two delayed copies of itself. Save the modified codes to a new file called `twoechoes.cpp`.

9. Turn in your commented program listing of `twoechoes.cpp`.

10. **Optional Things to Try:**

    (a) If an input microphone is available (and works), set the delay to various values and try it out with a microphone. It is said that it is "impossible" to speak when there is a loud echo at roughly a one-syllable delay. Can you find such a delay? Try starting at 25 ms and doubling it each experiment.

    (b) Make the echo delay zero, hold the microphone near the speaker, and tap gently on the microphone. From what you hear, can you estimate the system delay? (Aside from real acoustic delays, most unwanted delays are due to buffering within the computer.)

    (c) Modify your program to emit a test impulse and record the resulting signal for one second. Hold the microphone at a typical listening position and run the program to record the impulse response of the speakers, listening environment, and microphone. Plot the dB magnitude of the FFT of the resulting signal. Is it flat? If not, what do you believe to be the main sources of error? Can they be equalized? Consider a final project based on this problem.