580.422 System Bioengineering II: Neurosciences (Spring 2015)

Homework #1: Psychometric Function and Signal Detection Theory Analysis

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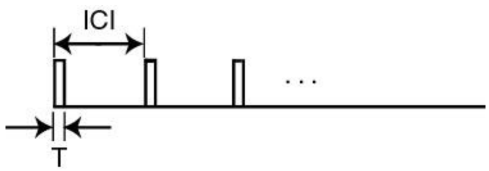
Due on Friday, February 6, 2015 at 1:00pm

NOTE: You will submit this assignment on BlackBoard. The assignment is listed under "Student Assessment" as "HW 1 Submission: Dr. Wang". Please be aware that there are four (4) submissions needed for this assignment. One submission for the results of each of the three experiments listed in this document (each document should be **converted to a PDF document**) and one submission form for your code used to run the experiments. Please contact SBE2.2015.TAS@gmail.com if you are confused with this submission process.

Background

When we listen to a periodic sequence of brief sounds, we may perceive it as being continuous or discrete depending on the interval between the sounds. For example, for a periodic sequence of clicks, we perceive it as being discrete if the *inter-click interval* (ICI) is 100 ms or continuous if the ICI is 10 ms. Acoustically, the click sequences are discrete in both cases. In this homework, you will practice on how to derive the *psychometric function* for the perception of a periodic click sequence as being continuous or discrete and for detecting jitters in a sequence of clicks. You will also exercise on using the signal detection theory to analyze your performance in discriminating two click trains.



A periodic click sequence is illustrated by the above graph, where *T* is the width of a click and *ICI* is the inter-click interval. The *repetition rate* (f_0) of this click train is $f_0 = 1/ICI$. You can write a Matlab program to digitally generate such click trains and then play them as sounds directly from the Matlab window using SOUNDSC or SOUND function and listen to them through a headphone or speaker via a computer's audio output port. Use these parameters: T = 0.1 ms, duration of each sequence = 1 sec, sampling rate = 40 kHz.

SOUNDSC: Autoscale and play vector as sound, same as SOUND except the data is scaled. [Note: Play the sounds at a comfortable sound level, but not too loud.]

Experiment-1:

Write a Matlab program to digitally generate 11 periodic sequences of clicks, each with a different *repetition rate* (Chose 11 f_0 values between 15 and 80 Hz in 10 logarithmic steps, i.e., the first and last f_0 values being 15 and 80 Hz, respectively). Play each click sequence 10 times (for a total of 110 click sequences) in *random order*. Listen to each click sequence and score "1" if it sounds "discrete" or "0" if it sounds "continuous". Record your scores as you go through all click sequences. You should not know which particular click sequence is being played while listening to it, but your computer program should keep track of it.

a) After listening to all click sequences, calculate the probability that you hear a click sequence of a particular f_0 as being *discrete* (i.e., the number of "1" you score divided by 10).
b) Plot this probability as a function of f_0, which is the "psychometric function" of the perceptual task you perform.

c) Determine the discreteness-to-continuousness boundary from the psychometric function by calculating f_0 corresponding to the probability of 0.5 (use interpolation). This is the "boundary f_0" value.

Experiment-2:

The stimuli used in Experiment-1 are "regular" click sequences, i.e., they are perfectly periodic. In this experiment, you will examine the perception of periodicity using click sequences that are not perfectly periodic, called "irregular click sequences". An irregular click sequence is produced by using ICIs drawn from a uniform distribution centered at a mean ICI (use RAND function in Matlab). For example, for an irregular click sequence with a mean ICI of 20 ms and 10% jitter, ICIs are chosen from a uniform distribution between [18, 22] ms. Your behavioral task in this experiment is to determine if a click sequence sounds "aperiodic" (score "1") or "periodic" (score "0"). Obtain psychometric functions for the following conditions (i.e., plot the probability of scoring "1" against J - the jitter amount).

a) Mean ICI = 10 ms, J = 5, 10, 15, 20, 25 %
b) Mean ICI = 30 ms, J = 5, 10, 15, 20, 25 %
c) Mean ICI = 80 ms, J = 5, 10, 15, 20, 25 %

For each mean ICI condition, determine the periodic-to-aperiodic boundary from the psychometric function by calculating J corresponding to the probability of 0.5 (use interpolation). This is the "boundary jitter (J)" value.

Experiment-3:

In this experiment, you will practice on using the signal detection theory to analyze the discrimination performance between two aperiodic click trains.

Note: This experiment is asking you to run a simulation and perform analysis on the results, not an experiment you will be performing on yourself. In this specific example, you cannot deterministically change your detection criterion (β).

1) The ICI distribution of "Click train A" has a mean of 10 ms and jitter of $\pm$2.5 ms uniformly distributed around the mean (i.e., ICIs are from a uniform distribution between [7.5, 12.5] ms). The "Click train B" has a uniform distribution of its ICIs between [10, 14] ms. The task of an ideal observer is to determine whether an aperiodic click train belongs to "Click train B" when a click train sample is randomly chosen from one of these two distributions. Compute the probabilities of *hit* (P_D) (i.e., when the observer hears "Click train B" when a sample from "Click train B" is presented) and *false alarm* (P_{FA}) (i.e., when the observer hears "Click train B" when a sample from "Click train A" is presented) for *detection criterion* (β) of 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 ms, respectively. Plot an ROC curve from these results.
2) Change "Click train B" to a uniform distribution of its ICIs between [11, 15] ms and repeat the above analyses. Plot an ROC curve from the results.