ECE431 Homework 12
FIR and IIR Filters

Due via electronic submission, Friday 12/14 at 3pm.

You have started a new job at the engineering firm Mobile Monitoring in Heartland, Nebraska, to work on mobile patient monitoring devices for ambulance, helicopter, and other types of rescue units. You are charged with developing a new ECG monitor that measures the electrical heart signal of the patient. The difficult problem in doing so is that the ECG is contaminated by high levels of noise, primarily due to electronics in the mobile unit and patient motion/vibration. Your boss asks you to design a digital filter that reduces these undesirable noises, while preserving the ECG. She gives you a sample of a clean ECG signal and the same ECG signal with noise added. Both signals are sampled at 200Hz and are available on the course webpage in in the .mat file HW12Signals.mat. Given these signals, you must design a digital filter that will reduce noise in similar heart monitoring situations.

You are assigned the following tasks:

12.1 What is the approximate heartrate in beats per minute?

12.2 Plot the magnitude DFT of the clean and noisy signals, and use these plots to determine an effective noise filtering strategy. Remember the goal is to remove noise, but preserve the signal as much as possible. Give the specifications for your filter.

12.3 Design an IIR filter based on a continuous-time Butterworth filter and the bilinear transform (you may use MATLAB). Show that your filter satisfies the specifications.

12.4 Design an FIR filter using the Parks-McClellan filter design method (use firpm in MATLAB). Give a brief description of how you designed this filter (less than one page) and show that your filter satisfies the specifications.

12.5 Compare the impulse responses of the two filters (use filter on imp = [1 zeros(1,199)]) to the impulse response of an ideal lowpass filter (unit gain in the passband, zero gain outside the passband and zero phase). Can you see the effect of the IIR filter's nonlinear phase?

12.6 Compare the performance of the two filters by comparing the effect of the filtering on both the clean and noisy signals. Contrast the outputs of each filter for both signals and discuss the results.

12.7 In the previous homework assignment you designed IIR bandpass filters with passband 1 Hz to 7 Hz and stopbands 0 to 0.5 Hz and greater than 9 Hz, assuming a 30 Hz sampling frequency. Now design a linear phase FIR filter using firpm that satisfies comparable specifications. The passband gain of FIR filters is centered on 1, so in this case we require the passband gain to lie between 0.95 and 1.05. The stopband gain must be less than 0.1. Note that you will need to iterate on the filter order until you find a filter

that satisfies the specifications.
Use MATLAB to find the coefficients of the difference equation, plot the poles and zeros, the frequency response magnitude and phase, and the group delay. Verify that your filter satisfies the specifications.