Fundamentals of Signal Processing and Data Analysis Homework 7

12311405 纪浩正

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1 Filtering to Obtain the High-Frequency Explosive Signal

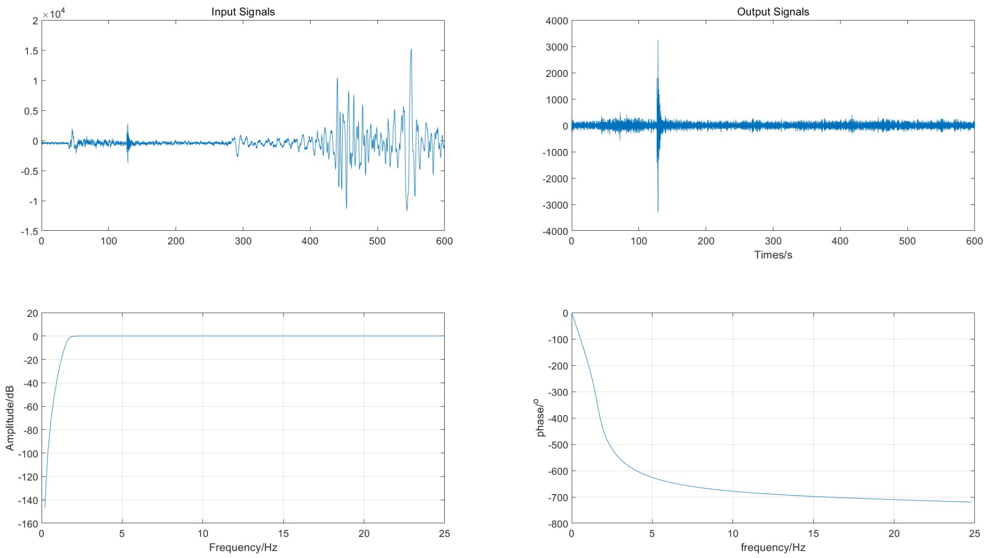

Figure 1: High-pass filter processing result

```
clc; clear; load kerl030916ud.txt
Fs = 50; dt = 1/Fs;
wp = 1.5*2/Fs; ws = 2.5*2/Fs;
Rp = 1; Rs = 30; Nn = 128;
[N,Wn] = buttord(wp, ws, Rp, Rs);
[b,a] = butter(N, Wn, 'High');
[H,f] = freqz(b,a,Nn,Fs);

figure;
subplot(2,2,3); plot(f, 20*log10(abs(H)));
xlabel('Frequency/Hz'); ylabel('Amplitude/dB');
grid on; set(gca, 'FontSize', 16);
```

```
subplot(2,2,4); plot(f, 180/pi*unwrap(angle(H)));
xlabel('Frequency/Hz'); ylabel('Phase/(degree)');
grid on; set(gca, 'FontSize', 16);

x = ker1030916ud';
y = filter(b, a, x);
t = (0:(length(x)-1)) * dt;

subplot(2,2,1); plot(t, x); title('Input Signals');
set(gca, 'FontSize', 16);

subplot(2,2,2); plot(t, y); title('Output Signals');
xlabel('Time/s'); set(gca, 'FontSize', 16);
```

2 Problem 2 & 3: Linear Phase Conditions

$$
\begin{aligned}
2\sum_{n=0}^{N-1} h\left(n\right) e^{-j\omega n} &= \sum_{n=0}^{N-1} h\left(n\right) e^{-j\omega n} + \sum_{n=N-1}^{0} h\left(n\right) e^{-j\omega n} \\
&= \sum_{n=0}^{N-1} h\left(n\right) e^{-j\omega n} + \sum_{n=0}^{N-1} h\left(N-1-n\right) e^{-j\omega\left(N-1-n\right)} \\
&= \sum_{n=0}^{N-1} e^{-j\omega\left(\frac{N-1}{2}\right)} \left(h\left(n\right) e^{-j\omega\left(n-\frac{N-1}{2}\right)} + h\left(N-1-n\right) e^{-j\omega\left(\frac{N-1}{2}-n\right)} \right) \\
&= e^{-j\omega\left(\frac{N-1}{2}\right)} \sum_{n=0}^{N-1} \left(h\left(n\right) e^{j\omega\left(\frac{N-1}{2}-n\right)} + \left(-1\right)^{p-1} h\left(n\right) e^{-j\omega\left(\frac{N-1}{2}-n\right)} \right) \\
&= e^{-j\omega\left(\frac{N-1}{2}\right)} \sum_{n=0}^{N-1} h\left(n\right) \Bigg(\left(1+\left(-1\right)^{p-1}\right) \cos\left(\left(\tfrac{N-1}{2}-n\right)\omega\right) \\
&\qquad + j\left(1+\left(-1\right)^{p}\right) \sin\left(\left(\tfrac{N-1}{2}-n\right)\omega\right) \Bigg)
\end{aligned} \tag{1}
$$

2.1 Problem 2: Type I Linear Phase

For even-symmetric impulse response ($h(n) = h(N-1-n)$), $p = 1$:

$$\sum_{n=0}^{N-1} h(n)e^{-j\omega n} = e^{-j\omega\frac{N-1}{2}} \sum_{n=0}^{N-1} h(n)\cos\left(\left(\tfrac{N-1}{2}-n\right)\omega\right)$$

2.2 Problem 3: Type II Linear Phase

For odd-symmetric impulse response ($h(n) = -h(N-1-n)$), $p = 2$:

$$\sum_{n=0}^{N-1} h(n)e^{-j\omega n} = e^{-j\omega\frac{N-1}{2}+\frac{\pi}{2}} \sum_{n=0}^{N-1} h(n)\sin\left(\left(\tfrac{N-1}{2}-n\right)\omega\right)$$

3 Comparison of FIR and IIR Filtering on Seismic Waves (Changchun Station)

3.1 FIR Filter

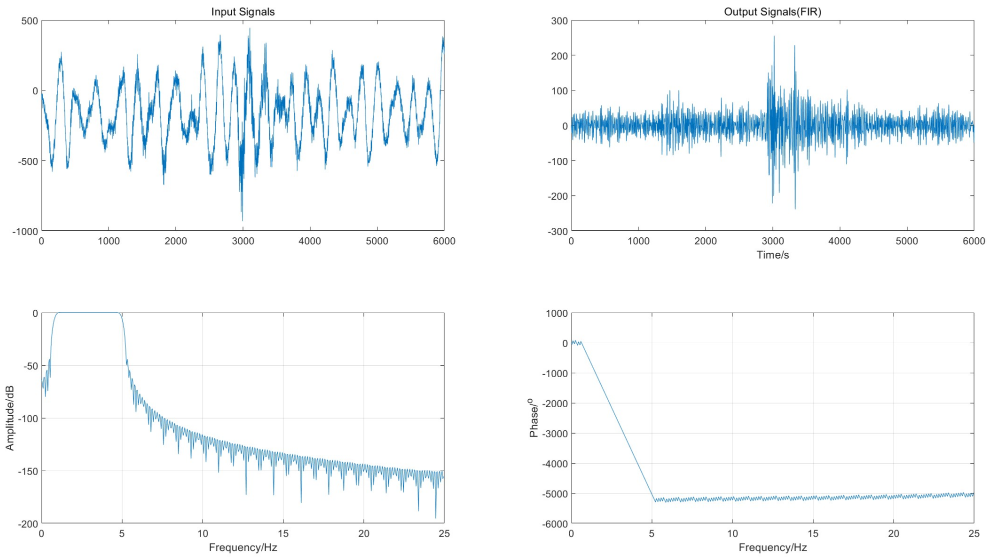

Figure 2: FIR Filter Result

```
clc; clear;
wp = [0.032 0.2]; N = 320; dt = 0.02;
b = fir1(N, wp, hanning(N+1));
[H,f] = freqz(b,1,512,1/dt);

figure;
subplot(2,2,3); plot(f, 20*log10(abs(H)));
xlabel('Frequency/Hz'); ylabel('Amplitude/dB');
grid on; set(gca, 'FontSize', 16);

subplot(2,2,4); plot(f, 180/pi*unwrap(angle(H)));
xlabel('Frequency/Hz'); ylabel('Phase/(degree)');
grid on; set(gca, 'FontSize', 16);

load ChangChun.txt
y = filtfilt(b, 1, ChangChun);
t = 0:length(ChangChun)-1;

subplot(2,2,1); plot(t, ChangChun);
title('Input Signals'); set(gca, 'FontSize', 16);

subplot(2,2,2); plot(t, y);
title('Output Signals (FIR)'); xlabel('Time/s');
set(gca, 'FontSize', 16);
```

3.2 IIR Filter

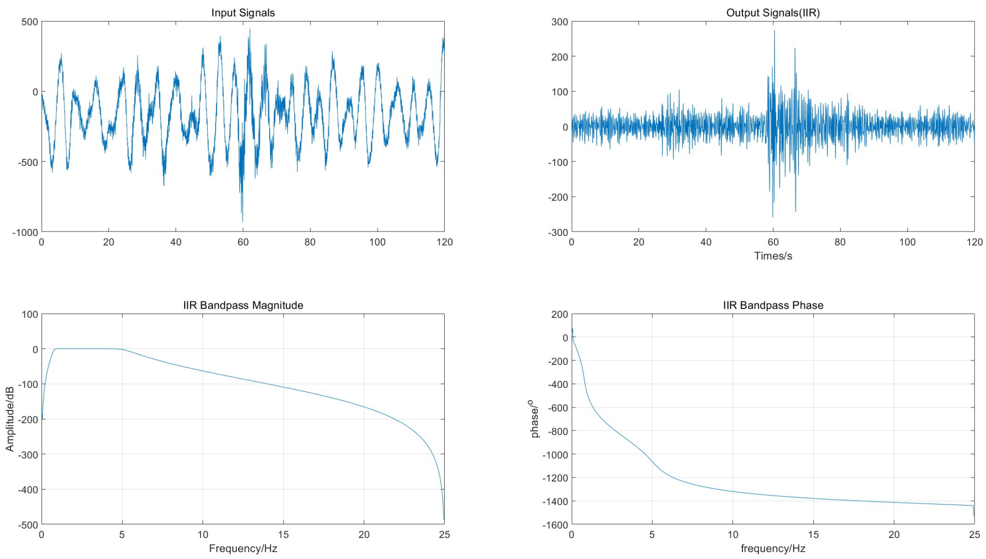

Figure 3: IIR Filter Result

```
clc; clear; load ChangChun.txt
Fs = 50; dt = 1/Fs;
wp = [0.8 5] * 2 / Fs;
ws = [0.5 7] * 2 / Fs;
Rp = 3; Rs = 30;

[N, Wn] = buttord(wp, ws, Rp, Rs);
[b, a] = butter(N, Wn, 'bandpass');
[H, f] = freqz(b, a, 512, Fs);

figure;
subplot(2,2,3); plot(f, 20*log10(abs(H)));
xlabel('Frequency/Hz'); ylabel('Amplitude/dB');
title('IIR Bandpass Magnitude');
grid on; set(gca, 'FontSize', 16);

subplot(2,2,4); plot(f, 180/pi*unwrap(angle(H)));
xlabel('Frequency/Hz'); ylabel('Phase/(degree)');
title('IIR Bandpass Phase');
grid on; set(gca, 'FontSize', 16);

t = (0:(length(ChangChun)-1)) * dt;
subplot(2,2,1); plot(t, ChangChun);
title('Input Signals'); set(gca, 'FontSize', 16);

y = filtfilt(b, a, ChangChun);
subplot(2,2,2); plot(t, y);
title('Output Signals (IIR)'); xlabel('Time/s');
set(gca, 'FontSize', 16);
```