Exercise 9 TTK4165
Medical Signal Processing

Table of Contents

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Documentation

Purpose: Script answering tasks given in exercise 9 in the course TTK4165 Medical Signal Processing

Related files: imagelog.m: Image a matrix of ultrasound power in log scale

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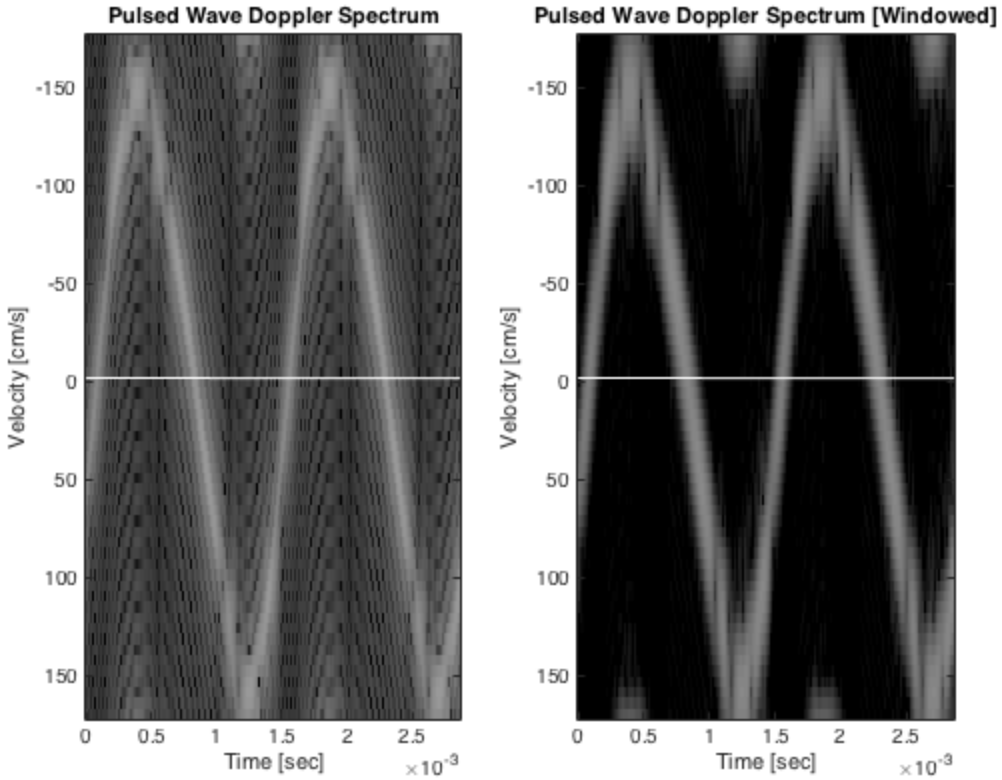
Last changes: 2016-03-25 EF: First attempt on part 2,3 and 4

Status: In production

Part 2 Pulsed Wave Doppler w/ analytic velocity

```
load slowmotion

% Find middle beam
middleBeamIq = squeeze(iq(:,4,:));

frameRate = s.Framerate_fps; % nFrames/seconds

nFrames = size(middleBeamIq,2); %nFrames

nSamples = size(middleBeamIq,1);

nSeconds = nFrames/frameRate;   %seconds = (nFrames/(nFrames/seconds))

time = 0:nSeconds/(nFrames-1):nSeconds;

distanceLength = s.iq.DepthIncrementIQ_m;

distance = 0:distanceLength/(nSamples-1):distanceLength;

% Find analytic velocity
rotationPeriod=0.908;
t0=0.0708;
```

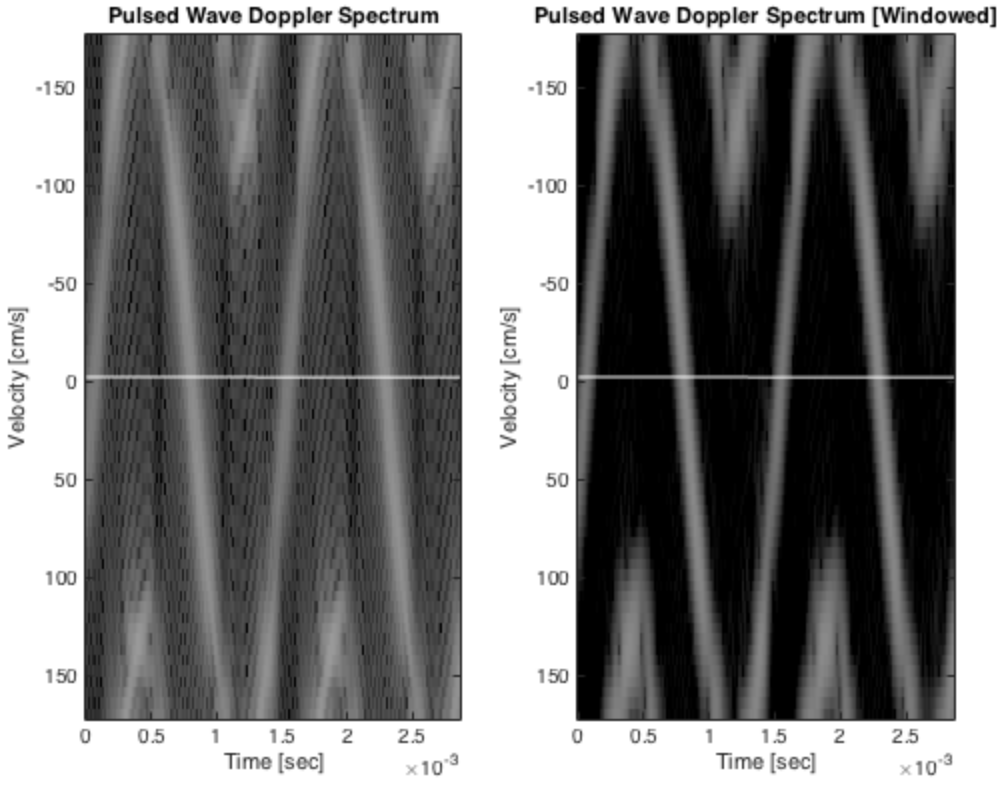
```
excenterDistance=0.67;

pistonAngularFrequency = (2*pi*(time-t0))/rotationPeriod;
pistonVelocityAmplitude = -(2*pi*excenterDistance)/rotationPeriod;

pistonVelocity = pistonVelocityAmplitude*sin(pistonAngularFrequency);
pointVelocity = -pistonVelocity;



% Make Pulsed Wave Doppler Spectrum
Nfft=64; %Zeropadding to length 64
crop=16;
depthindex = round(size(middleBeamIq,1)/2);
PHamming=zeros(Nfft, nFrames-crop+1);
P=zeros(Nfft, nFrames-crop+1);
for n=1:nFrames-crop+1,
    middleBeamIqFrames=middleBeamIq(depthindex,n+[0:crop-1])';
    P(:,n) = mean(abs(fftshift(fft(middleBeamIqFrames,Nfft))),2);

 middleBeamIqFrames=middleBeamIqFrames.*(hamming(crop)*ones(1,length(depthindex)))
    PHamming(:,n)=mean(abs(fftshift(fft(middleBeamIqFrames,Nfft))),2);
end;
%Frequency axis
frequencyAxis=(([0:Nfft-1]/Nfft)-0.5)*frameRate;

%Greyscale image of frequency specter in dB
gain = -25;
dynamicRange = 40;

timeAxis = 0:(1/frameRate)/(size(PHamming,2)-1):(1/frameRate);
PHamming=imagelog(PHamming,gain,dynamicRange);
P = imagelog(P,gain,dynamicRange);
figure(1);
% Plot image without windowing
subplot(1,2,1),image(timeAxis,frequencyAxis,P),colormap(gray(64));
hold on
subplot(1,2,1),plot(time,pointVelocity,'w'),title('Pulsed Wave Doppler
 Spectrum'),xlabel('Time [sec]'),...
    ylabel('Velocity [cm/s]');
% Plot image with hamming windowing
subplot(1,2,2),image(timeAxis,frequencyAxis,PHamming),colormap(gray(64));
hold on
subplot(1,2,2),plot(time,pointVelocity,'w'),title('Pulsed Wave Doppler
 Spectrum [Windowed]'),xlabel('Time [sec]'),...
    ylabel('Velocity [cm/s]');
```



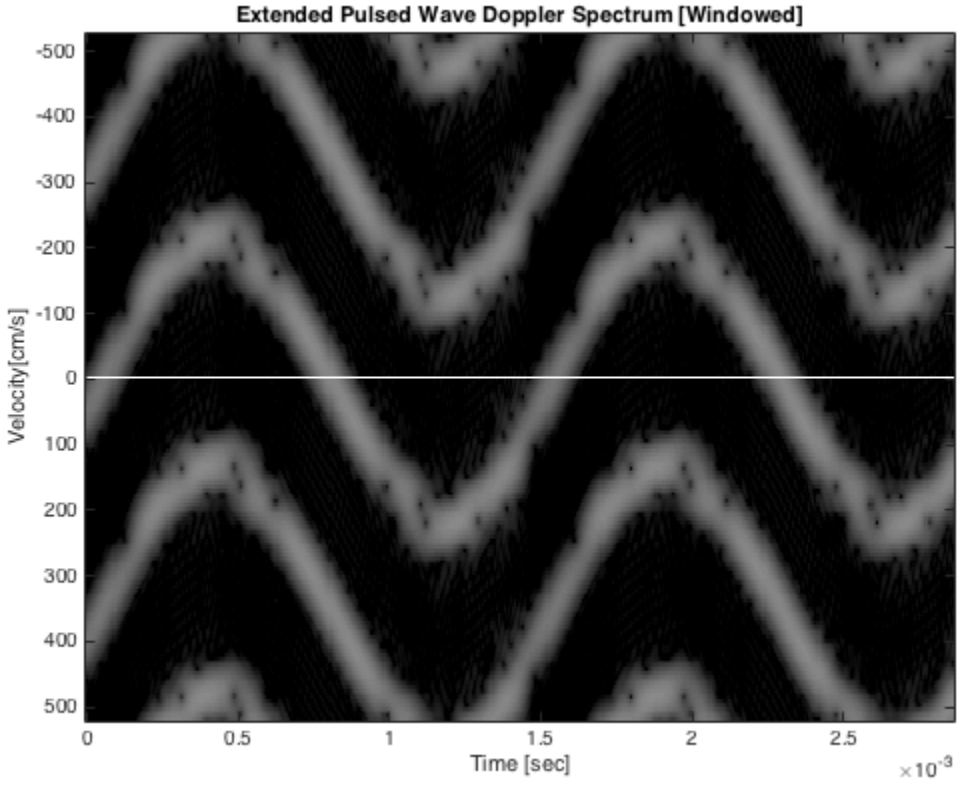
Part 3 - Doppler shift and aliasing

```
load fastmotion.mat

% Find middle beam iq
middleBeamIq = squeeze(iq(:,4,:));

nFrames = size(middleBeamIq,2); %nFrames

nSamples = size(middleBeamIq,1);

nSeconds = nFrames/frameRate;   %seconds = (nFrames/(nFrames/seconds))

time = 0:nSeconds/(nFrames-1):nSeconds;

distanceLength = s.iq.DepthIncrementIQ_m;

distance = 0:distanceLength/(nSamples-1):distanceLength;

% From suggested solution exercise 8
x=[0.0419;0.356;0.675];y=[2.75;4.12;2.78];
excenterDistance=(y(2)-y(1))/2;
rotationPeriod=x(3)-x(1);
t0=x(1);%R in cm, T and t0 in seconds
```

```
pistonAngularFrequency = (2*pi*(time-t0))/rotationPeriod;
pistonVelocityAmplitude = -(2*pi*excenterDistance)/rotationPeriod;

pistonVelocity = pistonVelocityAmplitude*sin(pistonAngularFrequency);
pointVelocity = -pistonVelocity;

% Make Pulsed Wave Doppler Spectrum
Nfft=64; %Zeropadding to length 64
crop=16;
depthindex = round(size(middleBeamIq,1)/2);
PHamming=zeros(Nfft, nFrames-crop+1);
P=zeros(Nfft, nFrames-crop+1);
for n=1:nFrames-crop+1,
    middleBeamIqFrames=middleBeamIq(depthindex,n+[0:crop-1])';
    P(:,n) = mean(abs(fftshift(fft(middleBeamIqFrames,Nfft))),2);

 middleBeamIqFrames=middleBeamIqFrames.*(hamming(crop)*ones(1,length(depthindex)))
    PHamming(:,n)=mean(abs(fftshift(fft(middleBeamIqFrames,Nfft))),2);
end;
%Frequency axis
frequencyAxis=(([0:Nfft-1]/Nfft)-0.5)*frameRate;

%Greyscale image of frequency specter in dB
gain = -25;
dynamicRange = 40;

timeAxis = 0:(1/frameRate)/(size(PHamming,2)-1):(1/frameRate);
PHamming=imagelog(PHamming,gain,dynamicRange);
P = imagelog(P,gain,dynamicRange);
figure(2);
% Plot image without windowing
subplot(1,2,1),image(timeAxis,frequencyAxis,P),colormap(gray(64));
hold on
subplot(1,2,1),plot(time,pointVelocity,'w'),title('Pulsed Wave Doppler
 Spectrum'),xlabel('Time [sec]'),...
    ylabel('Velocity [cm/s]');
% Plot image with hamming windowing
subplot(1,2,2),image(timeAxis,frequencyAxis,PHamming),colormap(gray(64));
hold on
subplot(1,2,2),plot(time,pointVelocity,'w'),title('Pulsed Wave Doppler
 Spectrum [Windowed]'),xlabel('Time [sec]'),...
    ylabel('Velocity [cm/s]');


PExtended = [PHamming;PHamming;PHamming];
frequencyAxis=([0:Nfft-1]/Nfft)-0.5;
frequencyAxis=[frequencyAxis-1, frequencyAxis, frequencyAxis
+1]*frameRate;
figure(3);
image(timeAxis,frequencyAxis,PExtended),colormap(gray(64));
hold on
plot(time,pointVelocity,'w'),title('Extended Pulsed Wave Doppler
 Spectrum [Windowed]'),xlabel('Time [sec]'),...
    ylabel('Velocity[cm/s]');
```

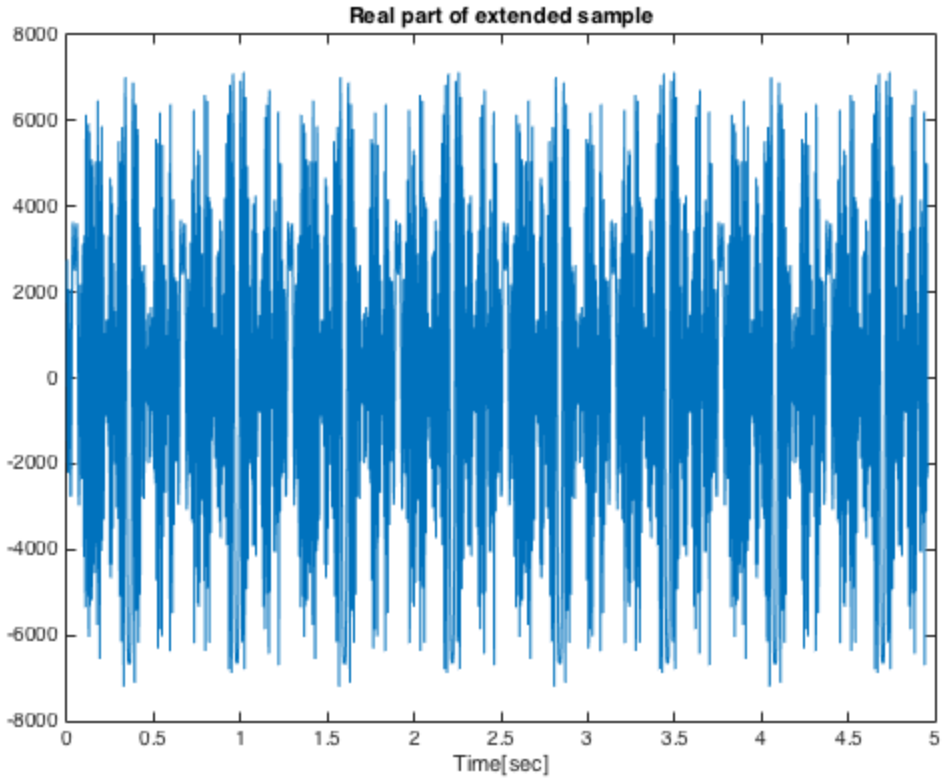

Pulsed Wave Doppler Spectrum
Velocity [cm/s]
-150
-100
-50
0
50
100
150
0
0.5
1
1.5
2
2.5
Time [sec]
×10^-3

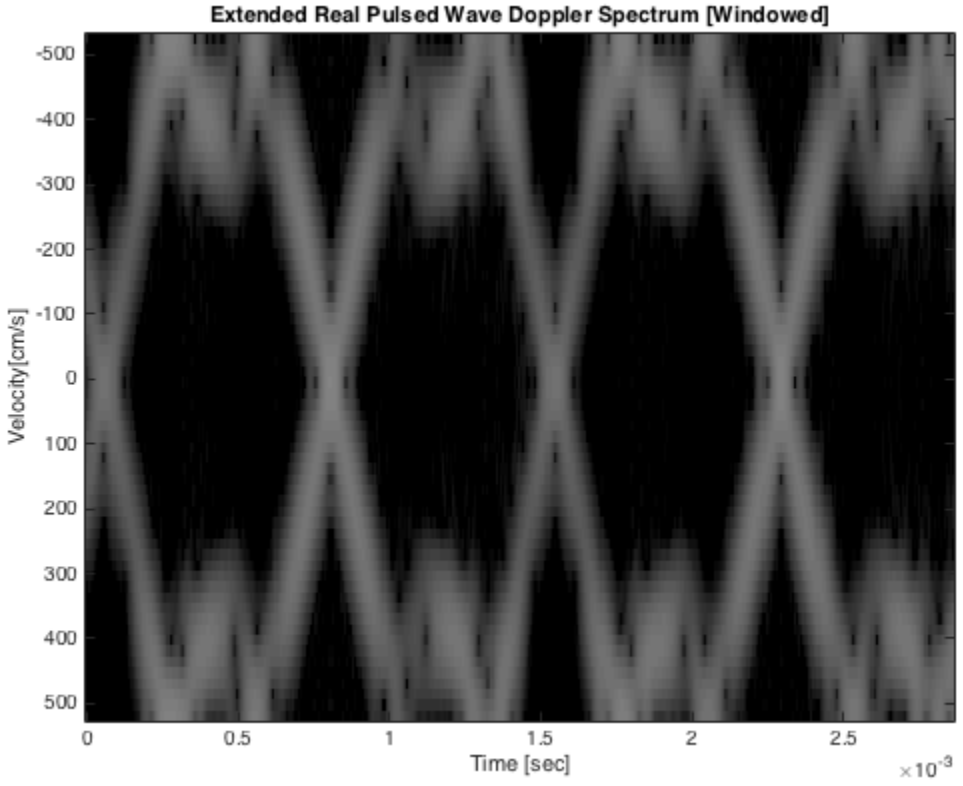
Pulsed Wave Doppler Spectrum [Windowed]
Velocity [cm/s]
-150
-100
-50
0
50
100
150
0
0.5
1
1.5
2
2.5
Time [sec]
×10^-3


Extended Pulsed Wave Doppler Spectrum [Windowed]
Velocity[cm/s]
-500
-400
-300
-200
-100
0
100
200
300
400
500
0
0.5
1
1.5
2
2.5
Time [sec]
×10^-3

Part 4 - Doppler sound

```
% Find middle sample
iqSample = middleBeamIq(round(size(middleBeamIq,1)/2),:);

% Extend sample, find real part, resample and rescale
iqSampleExtended = [iqSample,iqSample,iqSample,iqSample];
realSample = real(iqSampleExtended);
realSampleResampled = resample(realSample,8192,round(frameRate));
realSampleScaled = realSampleResampled/max(abs(realSampleResampled));

% Play hearable doppler frequency
soundsc(realSampleScaled,8192,8);

% Plot changes in time domain
timeExtended = 0:time(end)*4/(size(realSample,2)-1):time(end)*4;
figure(4);
plot(timeExtended,realSample),xlabel('Time[sec]'),...
    title('Real part of extended sample');

% Image FFT of real sample
PHamming=zeros(Nfft, nFrames-crop+1);
for n=1:nFrames-crop+1,
    middleBeamIqFrames=middleBeamIq(depthindex,n+[0:crop-1])';

 middleBeamIqFrames=middleBeamIqFrames.*(hamming(crop)*ones(1,length(depthindex)))

 PHamming(:,n)=mean(abs(fftshift(fft(real(middleBeamIqFrames),Nfft))),2);
end
timeAxis = 0:(1/frameRate)/(size(PHamming,2)-1):(1/frameRate);
PHamming=imagelog(PHamming,gain,dynamicRange);
figure(5),image(timeAxis,frequencyAxis,PHamming),colormap(gray(64));
title('Extended Real Pulsed Wave Doppler Spectrum
 [Windowed]'),xlabel('Time [sec]'),...
    ylabel('Velocity[cm/s]');
```


Real part of extended sample
8000
6000
4000
2000
0
-2000
-4000
-6000
-8000
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time[sec]


Extended Real Pulsed Wave Doppler Spectrum [Windowed]
Velocity[cm/s]
-500
-400
-300
-200
-100
0
100
200
300
400
500
0
0.5
1
1.5
2
2.5
Time [sec]
×10-3

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