生醫影像導論

Introduction to Biomedical Imaging

(11020EE 441000)

Homework #1 Part 1: Make Your Own First Ultrasound Image and Decipher the Imaging System –

Envelope Detection, and PSF Evaluation

Due: 24:00, 04/10/2022

After mechanical scanning 5 point targets with a single element transducer, we obtained the ultrasound raw/rf data set: “points_rf_data”. The experimental parameters are listed in the following:

- Depth of the 5 point targets: 6 mm, 9 mm, 12 mm, 15 mm, and 18 mm with respect to the depth of the transducer surface (the depth of the transducer surface: 0 mm)
- Time offset (i.e., the data acquisition time of the first data point): 6.48 μsec.
- Sampling rate: 50 MHz samples/sec.
- Distance between two successive scanning positions (i.e., dx in the provided sample codes): 50 μm

(a) Ultrasound image formation: follow the procedure of ultrasound image formation in the lecture notes to form an ultrasound image of the 5 point targets with 45 dB dynamic range and correct image axes (correct depth and lateral position). (procedure: envelope detection with Hilbert transform, log conversion, and then determine the image dynamic range)

(b) Find the focal length (i.e., depth) of the transducer according to the image you make in (a). One of the point targets is located at the focal point. Please explain how you find it out.

(c) Please tell the speed of sound of the imaged material. Once you know the speed of sound, go back to (a) and give the correct depth label of the B-mode image.

(d) Point spread function assessment: determine the lateral and axial resolution at the depths of the 5 point targets based on the fundamental definition of the spatial resolution and your eye examination. Does the imaging system own the best lateral and axial resolution at the focal point?

(e) Point spread function assessment: determine the -6 dB and -20 dB lateral and axial resolution at the depths of the 5 point targets using projection along the corresponding direction, and compare with the results in (d). Please comment your findings.

(f) Assume the -6 dB lateral resolution you estimated in (e) well matches the the theoretic value (i.e., -6 dB mainlobe width) at the focal point. Please tell the aperture size (i.e., the diameter) in mm of the used ultrasound transducer. Hint: you have to figure out the center frequency of the transmitted signals from the transducer. Remember to show how you figure out the center frequency.

(g) According to your results in (d) and (e), is the resolution "position dependent resolution"? Please discuss with axial and lateral resolution, respectively. It would be better that you can provide the plots of axial or lateral resolution as a function of depth, and discuss according to the plots.

(h) Can you decide that the point being imaged is located in front of, right at, or behind the focal point via its PSF shape? Please elaborate how you decide?

(i) Ultrasound image simulation of an anechoic cyst phantom: please simulate two ultrasound images of an anechoic cyst phantom at the focal zone and in the region centered at the depth of 18 mm, respectively, based on the principle of the linear space invariant system and the provided point spread functions. The 2D phantom size is 4 cm by 4 cm and the diameter of the anechoic cyst is 1 cm. The scatterer is distributed randomly in the phantom and is with the same back-scattering coefficient (or reflection coefficient). Note that for the number of the total scatterers required in your simulation, you have to guarantee that there are at least 10 scatterers with the sample volume (i.e., -6 dB sample volume) at the focal zone, and use the same number of the total scatterers for the two image simulation. Compare the contrast of the two images, elaborate and explain your findings. For the contrast estimation, please estimate the contrast (in dB) between the anechoic cyst and the background according to the equation provided in our lecture slide.

(j) (Bonus) Note that if you use "baseband demodulation" for the envelope detection correctly, you will get 5% bonus. You may call Matlab routine "fir1()" for your filter design.

(Hint:

(1) Envelope detection with Hilbert transform
Matlab function: "hilbert()"

(2) Matlab codes to show an image with 40 dB dynamic range:

```
envelope_dB = 20*log10(envelope/max(max(envelope))+eps);
image(envelope_dB+40);
colormap(gray(40));
colorbar;
```

(or see the MATLAB course demo of B-mode image formation)

(3) You can load all the provided data directly in Matlab by using

"load filename"

(4) For (d) and (e), you may need to interpolate the data, which can be done by using the MATLAB functions: imresize(), interp1() or resample().

(5) For (d) and (i), you may need to "convolve" the data with the provided point spread functions, which can be done by using the MATLAB functions: conv() or conv2().

(6) For (i), the random locations of the scatterers should be "uniform distribution", which can be done with the MATLAB function "rand()"

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Notice:

1. Please hand in your solution files to the LMS elearning system, including your word file of the detailed solutions, the associated Matlab codes, and all the related materials. It would be nice that you can put your codes with comments side by side along with your answer in the word file when necessary.
2. Name your solution files "EE4410_HW1_Part1_StudentID.doc" or "EE4410_HW1_Part1_StudentID.pdf" and "EE4410_HW1_Part1_StudentID.m", and archive them as a single zip file: EE4410_HW1_Part1_StudentID.zip.
3. The first line of your word or Matlab file should contain your name and some brief description, e.g., % EE 441000 王小明 u9612345 HW1 Part1 03/31/2022