Principles of Biomedical Ultrasound and Photoacoustics
hw01: Displacement and Strain

Due on Thursday, Nov 2, 2017

106061531 Fu-En Wang

1 Introduction

For **Focused Ultrasound Thermal Therapy**, an important technique is to estimate the temperature change before and after applying it. The estimation can be derived by the echo-time shift before and after heating. Moreover, the temperature change can be formula as:

$$\Delta T(z) = \frac{C_0}{2} \cdot K \cdot \frac{\partial \Delta t(z)}{\partial z} \tag{1}$$

where $\Delta T(z)$ is the temperature change, C_0 is the speed of sound, K is a constant, $\frac{\partial \Delta t(z)}{\partial z}$ is the **thermal strain**.
In this homework, we need to finish the following requirements:

1. Estimate echo time shift in μs as a function of depth
2. Estimate thermal strain in % as a function of depth

2 Source Code

In this zip archive, there are two matlab source code files:

1. **EE6265_HW1_106061531.m**
2. **Windows.m**

"EE6265_HW1_106061531.m" is the main flow of this homework. It will use the class **Windows** in "Windows.m" to create an object, which can manage each window and makes our code more elegant, and plot figures with our given parameters.

3 Problems

In Equation 1, the term $\Delta t(z)$ is the echo-time shift before and after ultrasound heating. Because $\Delta t(z)$ is a function of z, which means $\Delta t(z)$ will vary at different depth. As a result, we can divide the pre-signal and post-signal into several frames with certain window size and apply cross-correlation for each pre/post window pair. By this way, we can estimate the time shift for each window. For more accurate result, we can upsample the origin signal to get more sample points and higher sample rate. In this homework, I upsample the signal to triple origin sample rate ($3 \times f_s$) and use a moving average filter with size 5 to denoise the echo-time shift.
In the following section, I will show and explain several results.

3.1 Echo-Time Shift

In this part, I run experiments with different paramters. Windows size is 2, 6, 10 wavelength, and each combines with different overlap ratio (0, 0.5, 0.75). Figure [1, 2, 3] show the Echo-Time Shift as a function of z for M = 2, 6 and 10, respectively.
In Figure 1, we can find that the echo-time shift is very unstable. Because the window size is only 2 wavelength, the small window will be very sensitive to noise. However, it will also preserve more detailed information of our signal. Also, same for the overlap ratio. When the ratio is small, the detailed information of signal will be harder to captured, while larger ratio can extract the variation of signal, so the change of echo-time shift will be more obvious.

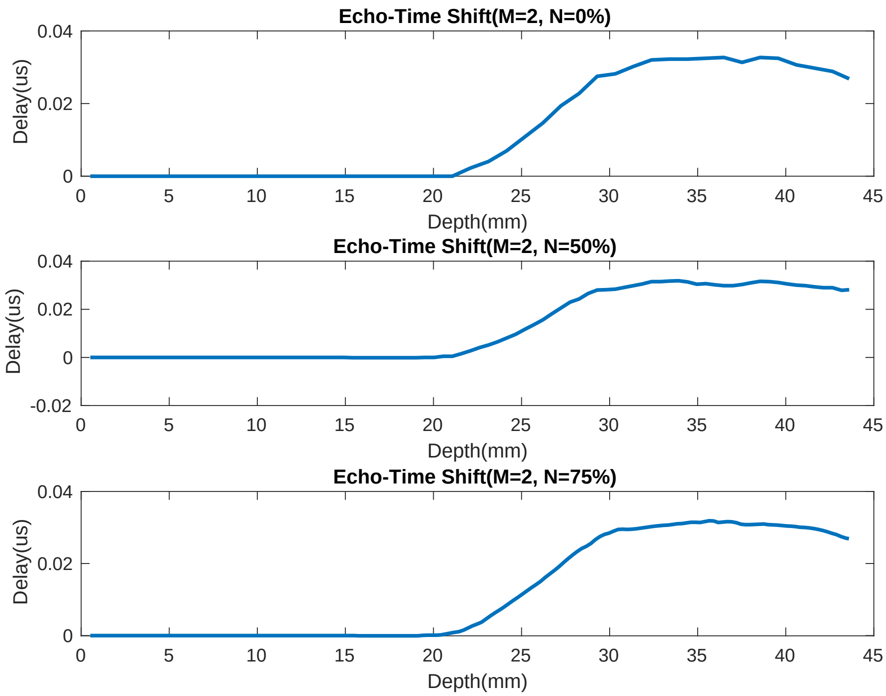

Figure 1: Echo-Time Shift (M=2)

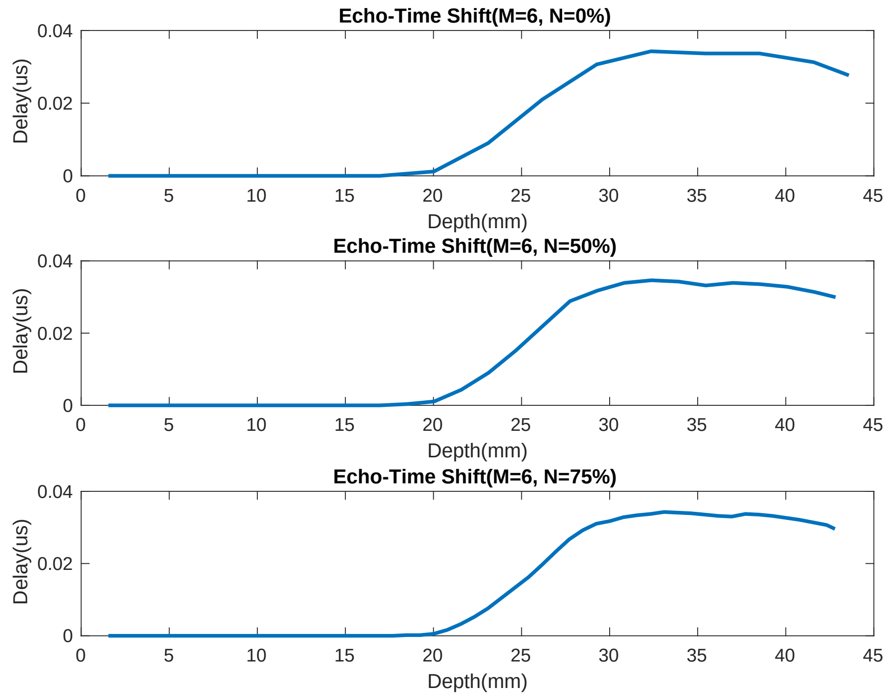

Figure 2: Echo-Time Shift (M=6)

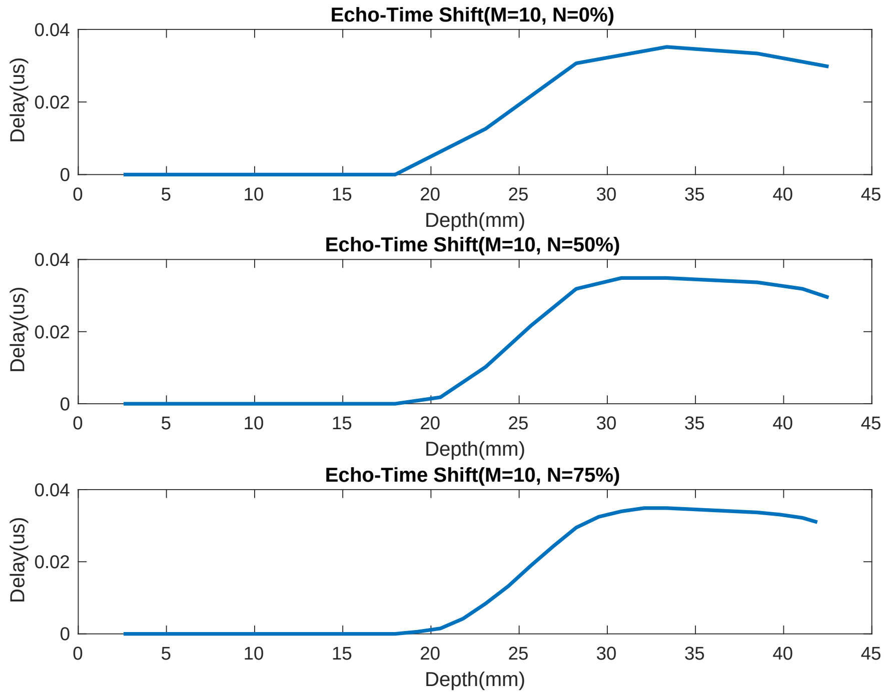

Figure 3: Echo-Time Shift (M=10)

In Figure 2, the result becomes much more smoothed than Figure 1. Because we have a larger window size, it will be more robust for noise but also loss more detailed information. Similar to Figure 1, the result gets more smoothed when applying larger overlap ratio.
In Figure 3, we get a more smoothed result than Figure 2 because the window size is larger too. However, I think 10 wavelength window size is not a suitable number for such task because the result is **too smoothed**, which losses too much information of signal and we cannot analyze it. As a result, I think 6 wavelength window size is the best choice for this task in homework.
From the result of Figure [1, 2, 3], we can find that larger window size and smaller overlap ratio will give a more smoothed result, while smaller window size and larger overlap ratio will preserve more detailed information but sensitive to noise.

3.2 Thermal Strain

In this section, we need to estimate thermal strain $\frac{\partial \Delta t(z)}{\partial z}$. First, we need to convert the echo-time shift into distance and then use difference approximation to calculate partial differential term as shown in Equation 2:

$$\frac{\partial \Delta t(z)}{\partial z} \approx \frac{diff(\Delta t(z) \cdot \frac{C_0}{2})}{diff(Depth)} \tag{2}$$

Figure [4, 5, 6] show the Thermal Strain (%) as a function of z for M = 2, 6 and 10, respectively.

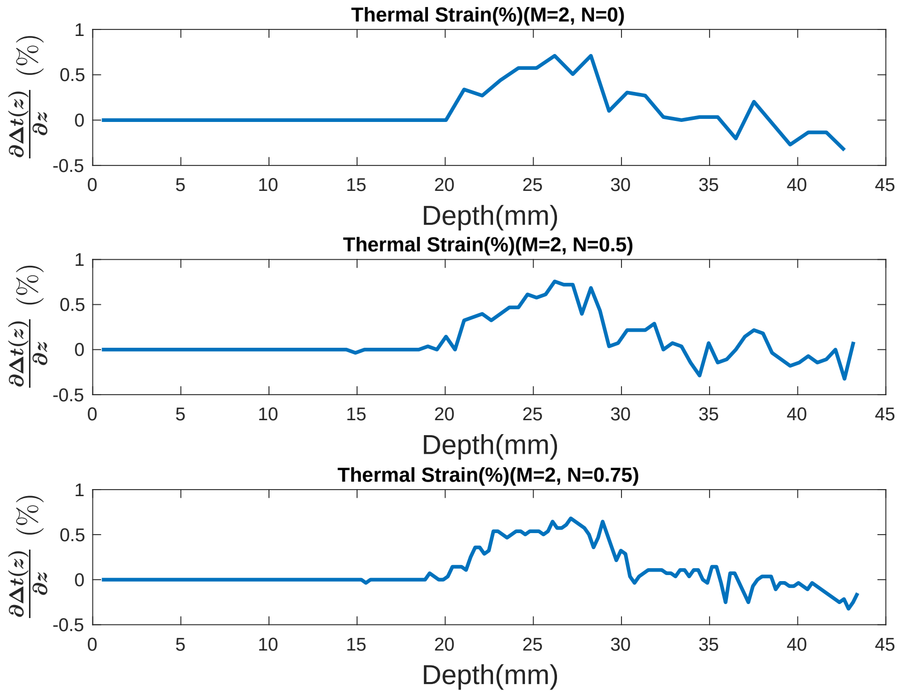

Figure 4: Thermal Strain (M=2)

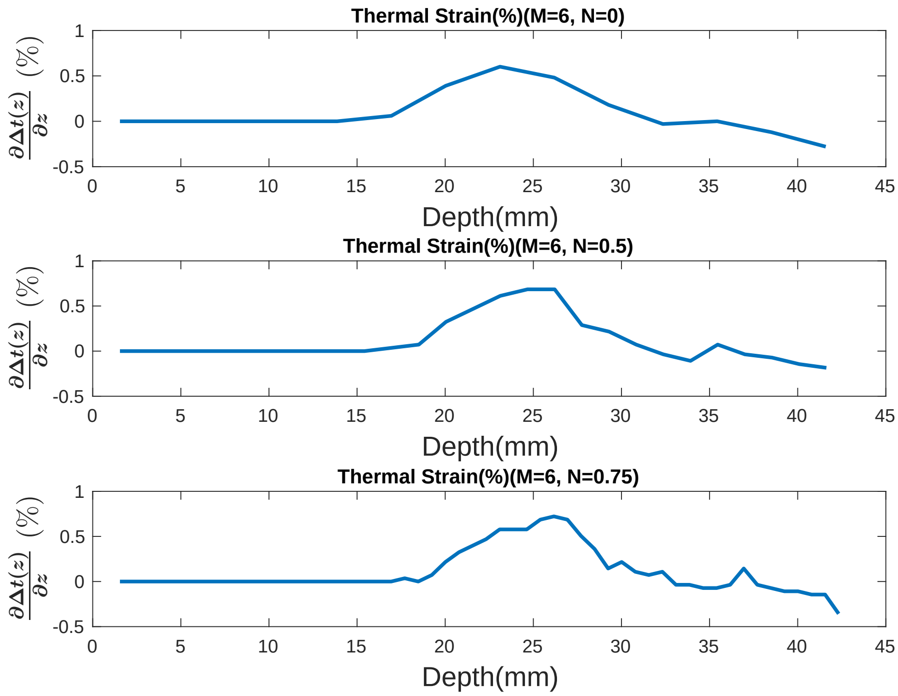

Figure 5: Thermal Strain (M=6)

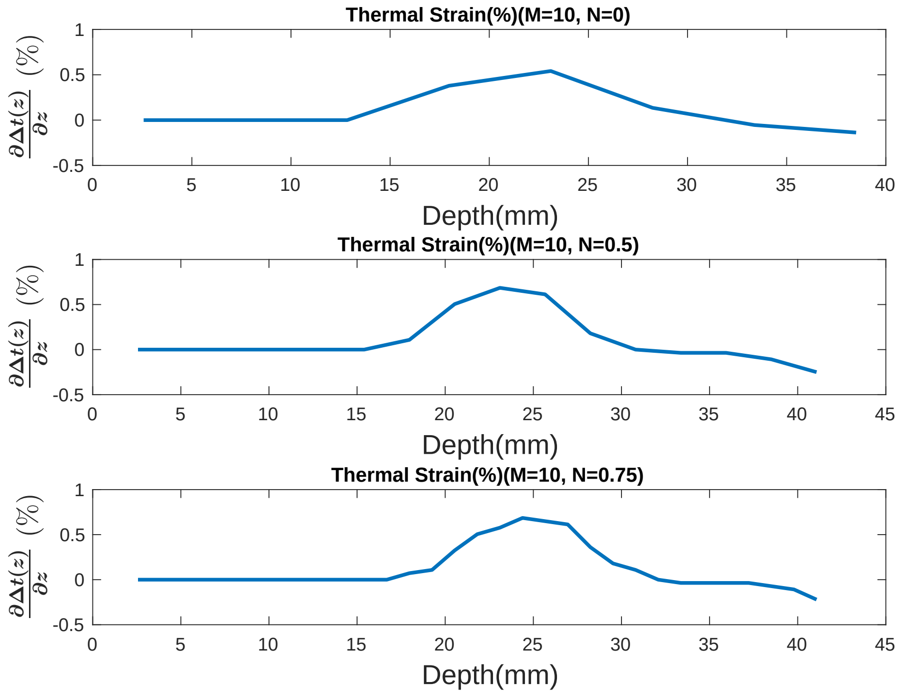

Figure 6: Thermal Strain (M=10)