EE2703 Assignment 7: Sound Localization

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Abstract

In this assignment, we were asked to reconstruct an image using the Delay-and-Sum (DAS) algorithm that is commonly used in Ultrasound image reconstruction

1 Usage

Simply run all the cells in `ee23b135.ipynb`. The notebook also contains the answers the questions given in the assignment. Place the files on which the DAS algorithm algorithm must be run on (like rx2.txt etc) in the same directory as the notebook :).

2 Part 1: Generating the sample readings

The function `generate_waveform_data` creates the data (as asked in the assignment).

NOTE: While plotting all the graphs in this assignment I follow the convention that the problem setter seemed to follow (With the data corresponding to the bottom most mic being shown on the topmost row. i.e The orgin is the topleft)

To generate the waveformes I simply followed the steps stated in the assignment. Since the obstacle reflects sound perfectly, we can treat it as a a delayed source. The delay can be found by $\frac{dist\_travelled}{dist\_per\_sample}$. (The graph below also contains the superposition of the readings directly from the source, but for the rest of the assignment, only the reflected waveform is used)

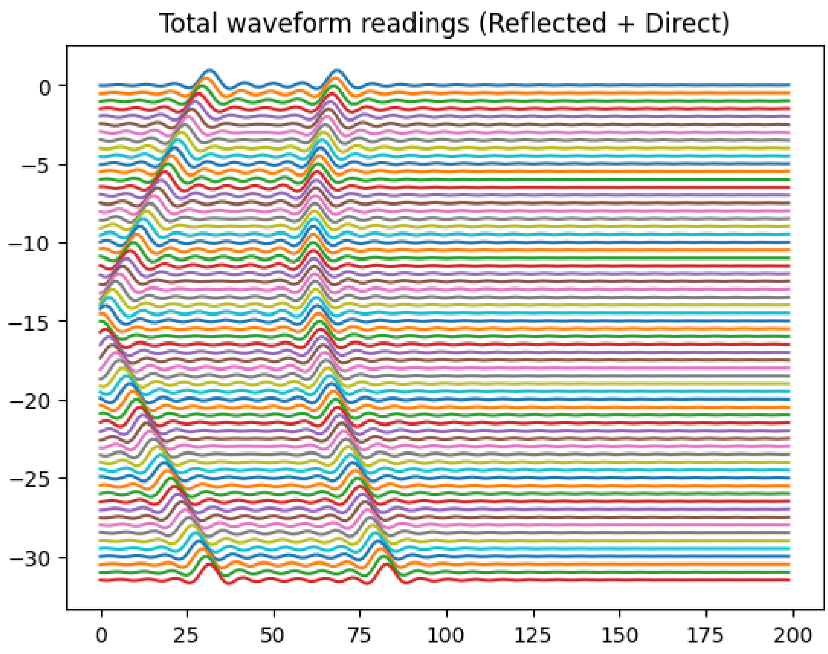

Figure 1: Data received by the mics (directly from source + with reflection)

3 Part 2: Delay and Sum Algorithm

The idea behind the algorithm is simple, we assume the obstacle to be at some given position, then we find which sample from the sample data would have corresponded to the first reflected wave (if the obstacle was actually present) and add this value up for every microphone in order to generate an image. It is easy to see that the amplitude will be highest at the position the obstacle is actually present at.

Ideally one would iterate over the whole 2D plane assuming the object to be at each coordinate, but realistically this is impossible. One can notice that it is actually enough to check the rectangle spanning from 0 to Nsamp * dist_per_sample in the x direction and $\frac{-(Nsamp*dist\_per\_sample+\frac{(Nmics-1)*pitch}{2})}{2}$ to $\frac{(Nsamp*dist\_per\_sample+\frac{(Nmics-1)*pitch}{2})}{2}$ in the y direction. (The reasoning for this is given in the answer to Question 5).

One more factor to take into account is the density of points checked in this region, I have provided a parameter called **resolution** that does this. The higher the resolution, the more points that are checked in the region :).

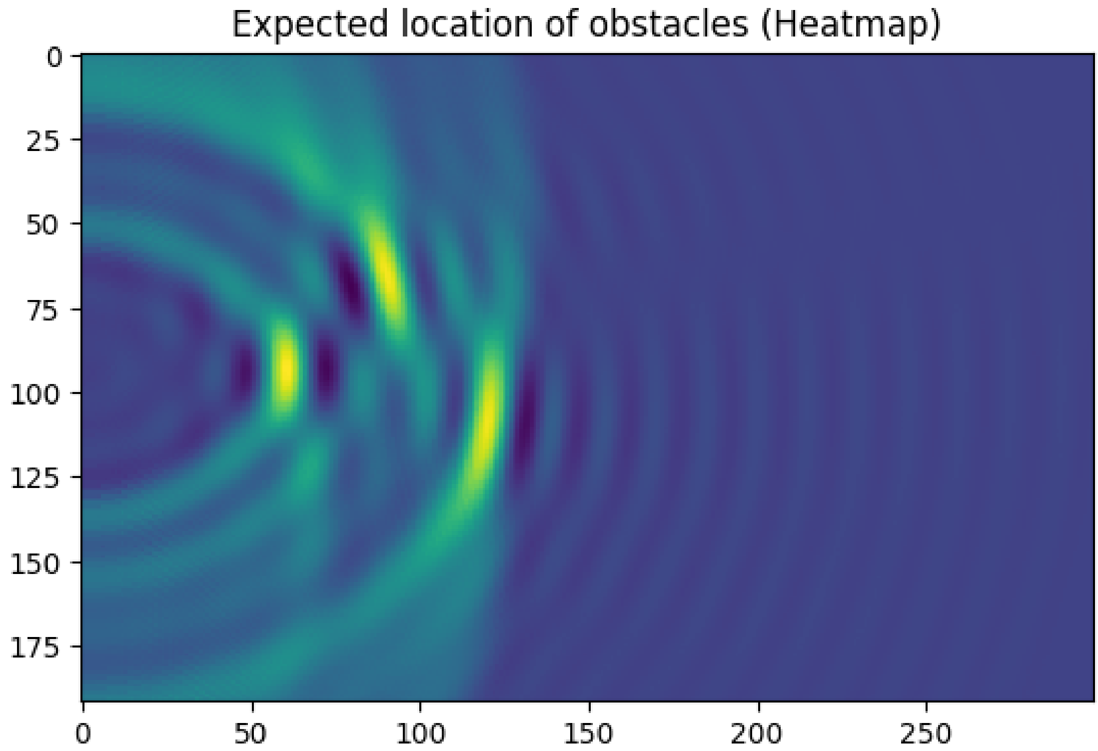

Figure 2: Reconstructed image for rx3.txt (With resolution set to 3, 3)

4 Answers to the Questions

4.1 Question 1: Sinc generation

In order to generate the different sinc pulses (shown in the assignment), on can play around with the SincP constant change the width(periodicity) of the sinc signal :) Increasing SincP makes the output signal seem narrower (Hence the generated heatmap images for said samples will have thinner bands), while decreasing SincP makes the output signal wider (Hence the bands will be wider)

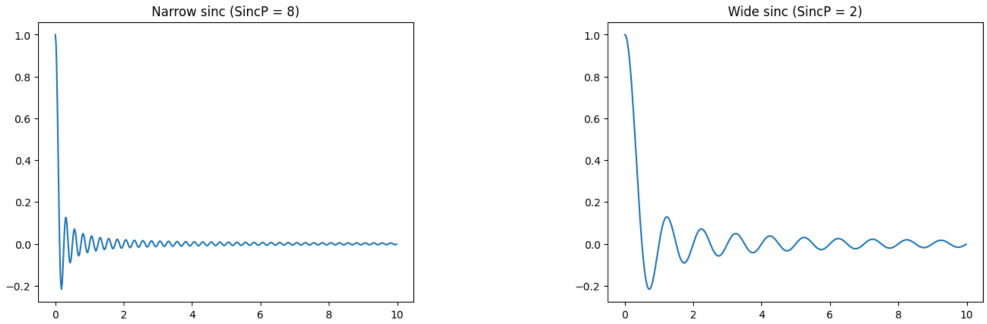

Figure 3: Diferrent sinc waves generated for with different SincP values

Figure 4: Mic readings generated with different SincP values

4.2 Question 2: Reasonable limits for image reconstruction

A slightly better limit to use is 'Nsamp / 2'.

In order to reconstruct the image at a given point, there must be atleast 1 mic that has a reading corresponding to reflectino of source waveform from said point. It is easy to see that if the source is at 0, the furthest an object can be will be of the form x, 0 and the corresponding 'latest sample' will be read by the mic present at 0, 0.

No we have the equation $2 * x <= Nsamp * dist\_per\_sample$ (The factor 2 exists since the wave has to reflect back) This gives us $x <= \frac{Nsamp*dist\_per\_sample}{2}$, i.e It is enough to go uptil the distance corresponding to Nsamp / 2 :)

4.3 Question 3: Intuition behind maximum amplitude being at (30, 22)

Since the obstacle was at 3, -1 we would expect the maxima to be at 3, -1 itself.

y coordinate 0 corresponds to the bottom most mic level, y coordinate 22 corresponds to the position of the 23rd mic from the bottom. The 23rd mic is at y coordinate -0.950000. x coordinate of 30 corresponds to a position of 30 / 10 = 3.

i.e The maxima corresponds to a coordinate of 3, -0.95 (which approximately matches the 3, -1 that we expected)

4.4 Question 4: Maximum x, y coordinate of obstacle that can still be reconstructed

For the image to be reconstructed one must be able to have atleast one reading of the reflected waveform by any of the mics. i.e $dist(obstacle, src) + dist(obstacle, mic) <= Nsamp * dist\_per\_samp$ for atleast 1 of the mics.

For point furthest away we get the locus to be one that follows:

$$dist(obstacle, src) + dist(obstacle, mic) == Nsamp * dist\_per\_samp$$

It is easy to see that these are just a bunch of ellipses, one may draw out said ellipses to find the exact locus of the furthest possible points the object can be to be reconstructed (It will be a non trivial shape)

An easier question to answer is the max(x coord) such that the obstacle can be reconstructed. Following similar logic to Question 2 we get $x <= \frac{Nsamp*dist\_per\_sample}{2}$. i.e The max x coord that can be reconstructed is Nsamp * dist_per_sample / 2.

Similarly to find the max(y coord) such that the obstacle can be reconstructed, we get $y + y - \frac{(Nmics-1)*pitch}{2} <= Nsamp * dist\_per\_sample$.

i.e The max y coord is $\frac{(Nsamp*dist\_per\_sample+\frac{(Nmics-1)*pitch}{2})}{2}$

4.5 Question 5: Effect of C on the image

Below I have generated waveforms for 2 different c. It is easy to see that for constant dist_per_samp and Nsamp, having a higher c means that the time values for which the microphones sample are much closer (higher C with const dist_per_samp implies higher sample rate)

A higher sampling rate means that more readings are taken with values of similar amplitude (i.e not much change per sample). This is why the higher C image looks wider (and less sharp due to the difference between consecutive samples being relatively lower). While the one with the lower C has a lower sample rate which makes nearby samples more different from eachother (**more visible contrast**) which makes it look sharper :).

Figure 5: Mic readings generated with different C values

4.6 Question 6: Testing out different values of Nmics and Nsamp

The more mics that are present, the more sure we can be of where the obstacle is in the reconstructed image (The region of high amplitude in the image is smaller). (This also makes sense intuitively as we basically have more information to work with).

Increasing Nsamp is only beneficical if the obstacle is placed further away, since I have tested for the obstacle being realtively close by (i.e It is able to be reconstructed for all the ranges of Nsamp), the use of Nsamp may not be evident.

It is important for Nsamp to be big enough to cover the location of the object, anything above this threshold value is not required.

(Images of these have been put on the page below).

5 Comments

Overall it was a rather simple assignment, the main problem I faced really was deciding whether to plot my graphs that aligns with the assignments convention or one that makes more sense intuitively (I decided to follow the assignment).

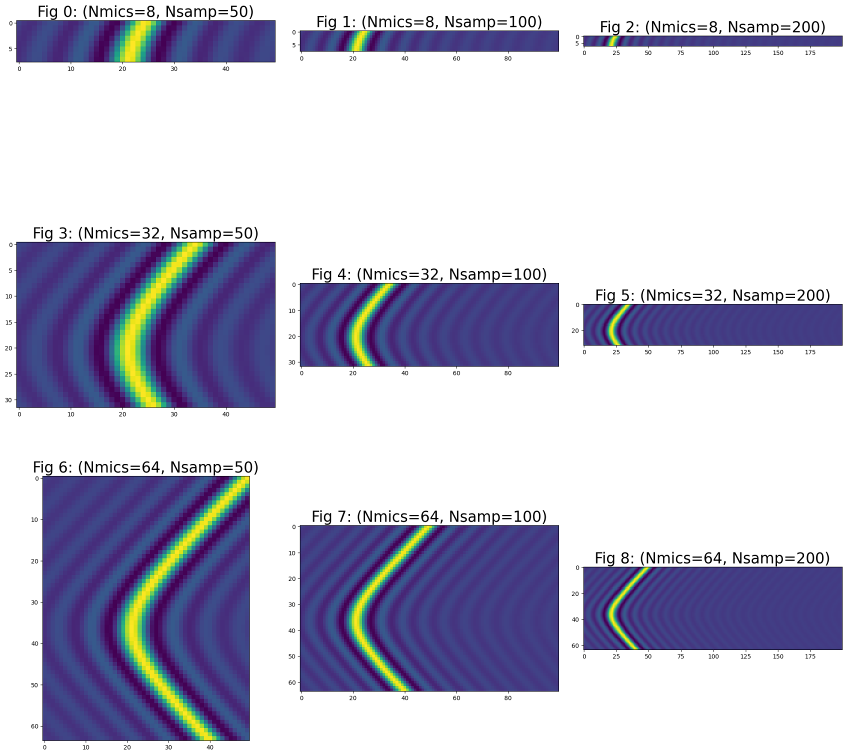

Figure 6: Generated sample data for object at (1, 0.5)

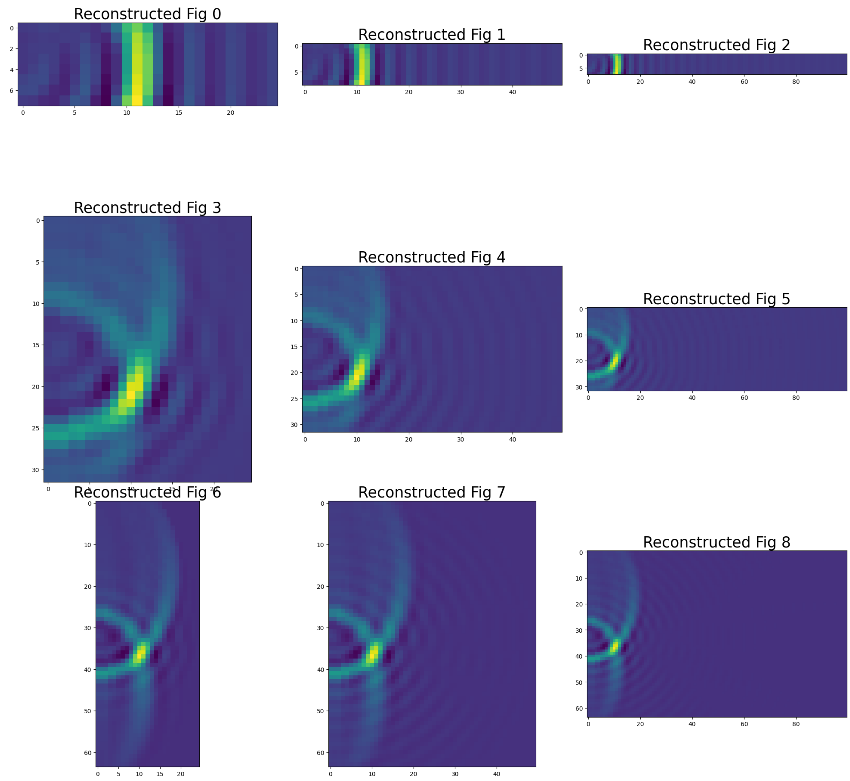

Figure 7: Reconstructed image for above generated waveforms