Assignment 7 Report

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Question 1 - Sinc pulses:

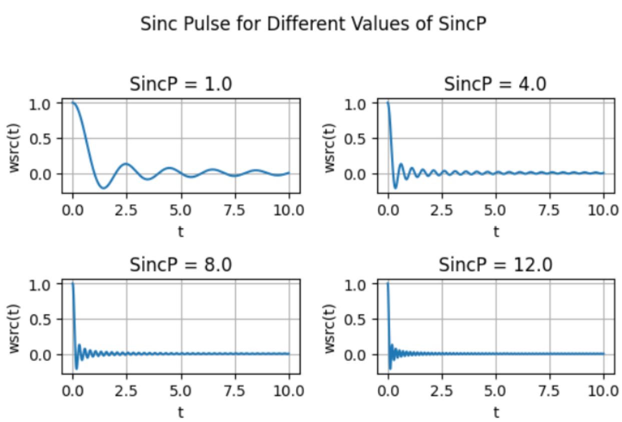
To generate the pulses that look like the ones given, first, a list of independent t values (various time/position instants) is created (5000 samples are chosen in the range 0 to 10, so that the curve is smooth). Then a parameter (`SincP`) that decides the width of the sinc pulse and the frequency of oscillations is defined. Using `np.sinc(SincP * t)`, we get the pulse plotted.

Higher values of `SincP` make the sinc function oscillate more frequently (closer together) and narrow the central peak, as the argument to `np.sinc` increases faster.

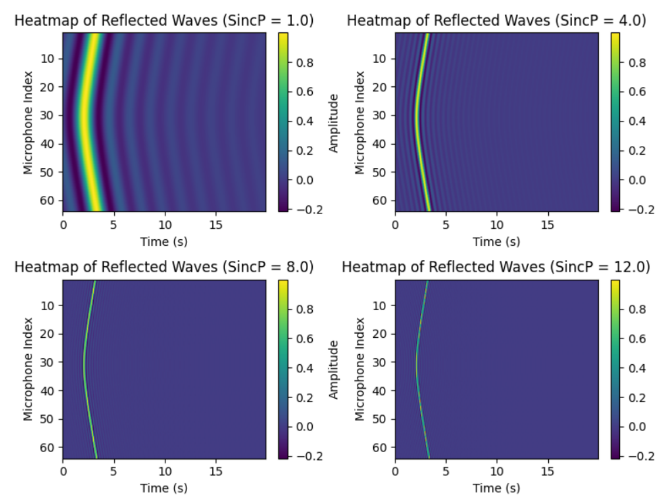
Lower values of `SincP` result in a wider sinc function, with oscillations spread farther apart and a broader central peak.

If this parameter is large, then the peak is very sharp with lesser spread, so it becomes more like an impulse signal. This means the final image with all the shifted signals received by the mics will be sharper, i.e., the maxima appears like a line if `SincP` is large. If it is small, the line spreads.

The images below illustrate these effects:



(a) Effect of `SincP` on Sinc Pulse Shape



(b) Heatmap Representation

Figure 1: Comparison of Sinc Pulse and Heatmap

Question 2 - DAS Algorithm

In the DAS reconstruction process, the x-axis represents spatial coordinates, specifically the distance from the microphones to an obstacle.

Nsamp indicates the total number of readings taken from the microphones at different time intervals. Since the same sound pulse propagates from the source to each microphone, the time delay experienced by the pulse provides information about how the sound wave spreads and travels across different positions relative to the microphones.

So yes it makes sense to correlate Nsamp with the x-axis in the reconstruction plot. By analyzing the data across the number of samples, we can visualize how the sound wave interacts with the environment over time, allowing us to infer the position of obstacles based on the amplitude and time delay of the received signals.

The choice of x-axis limit should be based on the maximum range of interest instead of taking all nsamp, we can take the maximum distance the wave can travel in the total duration of the sampling period.

Approach to implement DAS for the files given

Analysis of the plot of outputs of microphones after reflection

For the sample input we gave for one point obstacle, for each mic, there is only one maxima (smaller once are ignored), this means for the pulse sent it is reflected and reaching the mic only once so there is only 1 obstacle.

Plots of rx2 and rx3 data have 2 and 3 maximas, so this might mean there will be two and 3 obstacles in these situations.

DAS Algorithm Implementation

How DAS Works:

For each point in the grid and for each microphone, the distance between the source to the point and the microphone to the point is calculated. For this distance, we determine how much time it will take for the signal to travel, which gives us the time delay.

Next, we find the sample index by dividing the time delay by `dist_per_samp`. This translates the time delay into the equivalent number of samples that need to be skipped to reach the correct sample corresponding to this delay. If this index is within the total number of samples, it means the sample was actually taken and exists within our bounds on the X-axis.

We then accumulate the value of the signal at that point, repeating this for all microphones. Finally, we collect the signal values for every point in the grid and return the grid.

Application of DAS to the input files

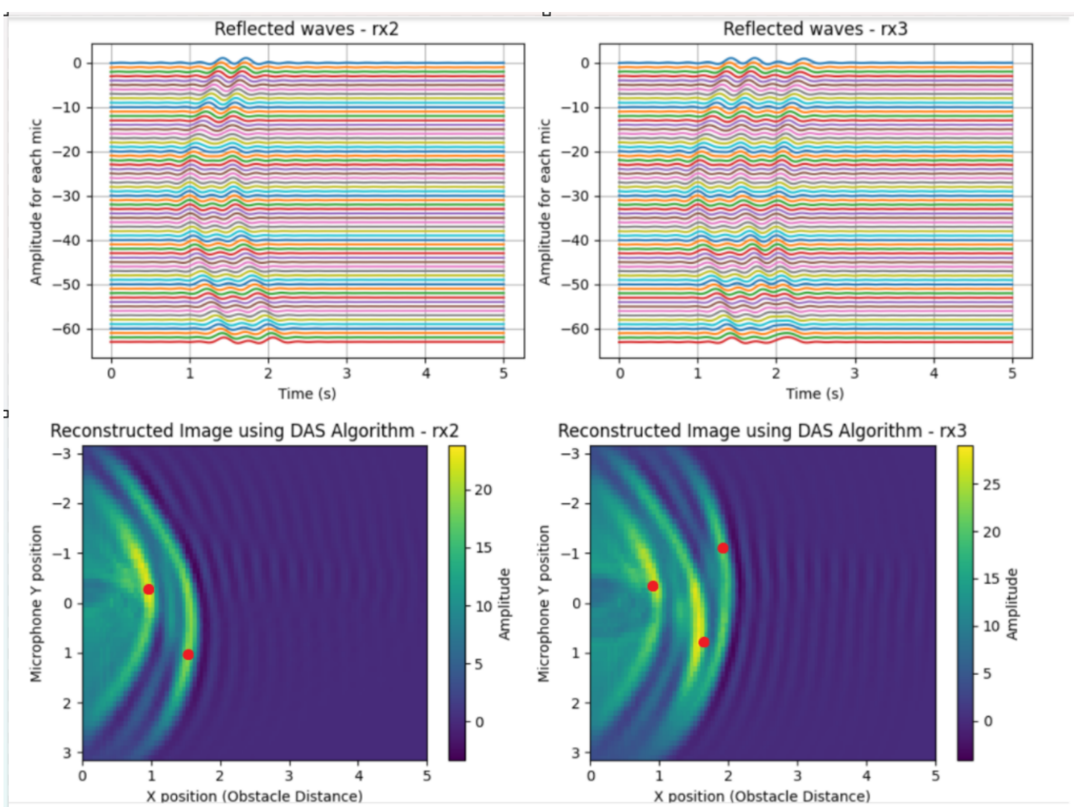
The function created above for reconstruction of grid is applied to both the input files and output is inferred.

Inference

The plot of reflected pulses sensed by mics have 2 and 3 major maximas respectively, so this means there might be two and three obstacles respectively.

The heatmap obtained after reconstruction for rx2 has two bands and one maxima in each band. This might be the location of the obstacle.

And similarly for rx3, there are 3 bands and each band again has a maxima which might be the location of the obstacle.



The red marks on each band might be the possible location of the obstacle.

Questions at the end

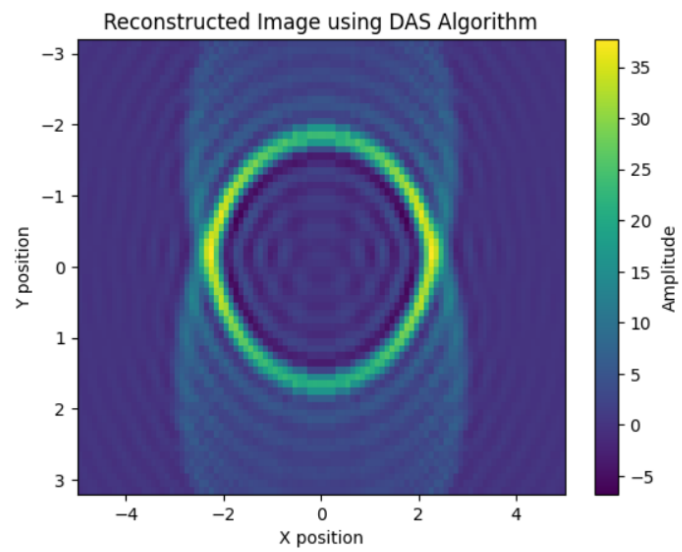
What happens if C is different - if C is decreased it looks like the image becomes sharper. Can you explain why intuitively?

The speed of sound C affects time delays and, consequently, the spacing between wavefronts in the DAS output. When C is decreased, time delays increase, causing signals to arrive at different microphones at slightly more separated intervals. This separation results in better phase alignment for coherent sources (such as reflections), thus increasing spatial resolution in the DAS output.

This can make the reconstructed image appear sharper since the lower C slows down wavefronts, allowing finer distinctions between regions. But, a higher C would compress the time delays, making reflected signals overlap more, which can blur the image.

The (x, y) coordinates corresponding to the maximum amplitude (yellow colour) is approximately (30, 22). Explain why this is the correct expected position for the given obstacle

I was getting an output that looked like this:



I considered the entire coordinate system and that mics are symmetrically placed above and below the origin and scaling of x and y axis is 0.1 (so that obstacle is around 3, -1)

This has maximas around (-2, 0.5) and (2, 0.5), So the obstacle might be located at these places.

They are obtained by getting the brightest pixels in the reconstructed heat map, since they use constructive interference, DAS detects the pixel with highest signal as the obstacle.

What is the maximum obstacle x- and y- coordinate that you can use and still have an image reconstructed?

For a meaningful reconstruction, the obstacle needs to fall within the area covered by the microphones. If the obstacle is placed too far beyond the microphone array's reach, there may not be enough distinct signal data points for accurate reconstruction.

The maximum x- coordinate should be less than the distance the pulse travels in the time we sample.

The maximum y-coordinate of the obstacle should be less than the number of microphones in the array. If the obstacle is positioned too far from the array (beyond the range that can be adequately sampled by the microphones), there will not be enough distinct signals from the microphones to reconstruct the image properly.

What happens if Nmics is increased or decreased? Do the experiments with Nmics = [8, 32, 64] and Nsamp = [50, 100, 200] (all combinations)

Obstacle is taken to be (3,-1) and all other parameters same as before.

Nmics (number of microphones): Increasing Nmics enhances spatial sampling along the microphone array, providing more information for the DAS algorithm. So reconstruction of reflected beams and maximas are better and we will be able to tell more exactly where the obstacle is located. Fewer mics, conversely, lead to less information, coarser reconstructions, and a blurrier image. It can be seen that as we increase the number of mics downwards, the maxima which was like a band before has now become more localized to points which tell the location of obstacle.

Nsamp (number of samples): Increasing Nsamp increases temporal sampling resolution, capturing wavefronts at finer intervals. A higher Nsamp thus produces a clearer image. Lower Nsamp will reduce temporal resolution, potentially leading to under-sampling of wavefronts. As it can be observed in the images, as the nsamp increases to the right, resolution of the images increase and more finer details are captured.

For Nmics = 64 and Nsamp = 200, it is almost accurately captured that obstacle is at (3, -1) and (3, 1).