Simulation of acoustic wave propagation and absorption

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November 2022

Introduction

The subject of acoustics is a field in mechanical engineering that I find particularly interesting. I decided to take interest in the simulation of acoustic wave propagation in a room. In this study, we are interested on how much sound is absorbed when hitting a wall. We know that a wall softens differently the frequencies that make up a sound depending on the material, which we call the absorption coefficient. By using a Fourier Transform, we are able to extract the frequency response of the sound. By following the works of Philip Morse[1], seen on the right-hand side, we are able to get the different values of this absorption coefficient for 4 different materials. Obtaining the total absorbed sound is done by using Parseval's identity, where we will represent our results in Sound Pressure Levels.

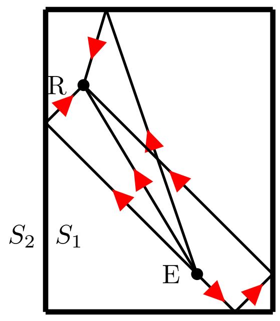

Figure 1: Schematic of the problem

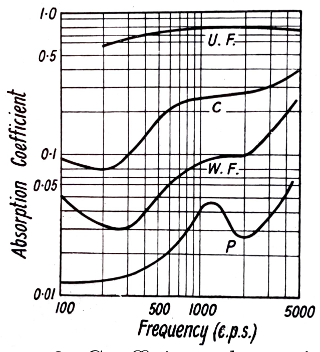

Figure 2: Coefficient absorption for different materials[1]

Experimental measurements and results

By using the information about how the absorption coefficient evolves depending on the frequency, we can simulate how the composition of different walls play a key role in our study. On that note, the following schematics show how sound is soften when the walls are made out of plaster, wooden furniture, carpet and upholstered furniture. In the figures, the blue circle represents the transmitter, whilst the black circle represents the receptor. We show here the effective travel paths that have the most influence on the sound perception.

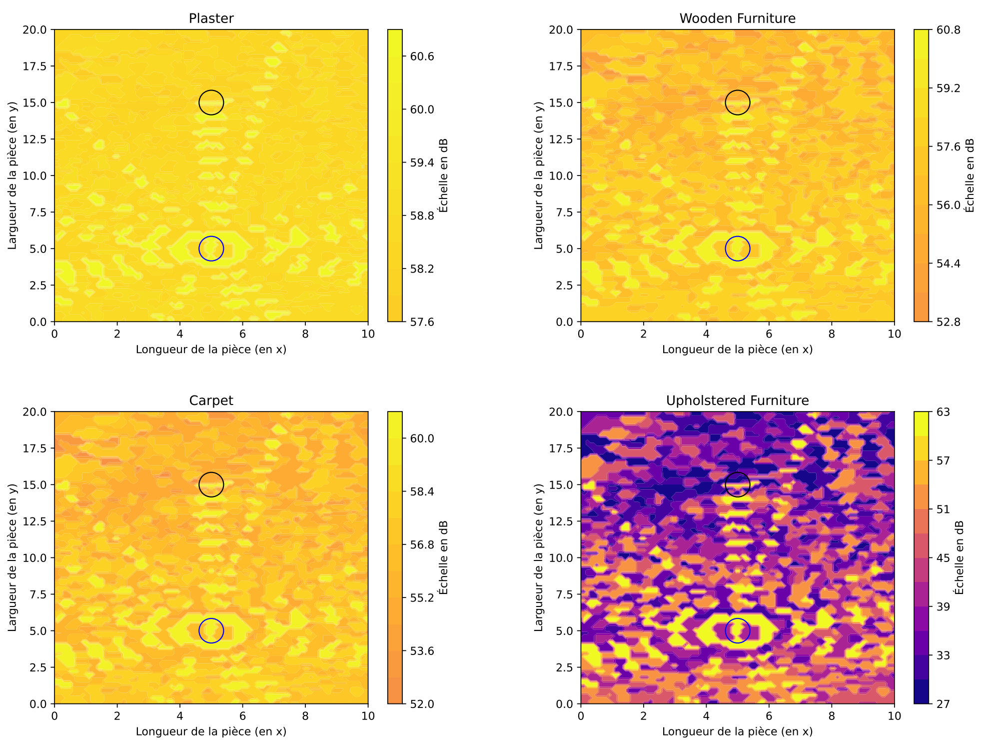

Figure 3: Comparing the material of the walls

We can observe that more the composition of the walls are thickened and dense, more the sound is absorbed. Yet being obvious, this coherence will help us solve some specific problems later on. Now, by taking interest on the position of the receptor, we get an interesting result. We realize that we have almost the same trajectory of sound for each case. This result repeats its self for any combination in this specific room. The result is interesting because we can play on where the most trajectories hit walls and place specific objects to soften the least possible our sound.

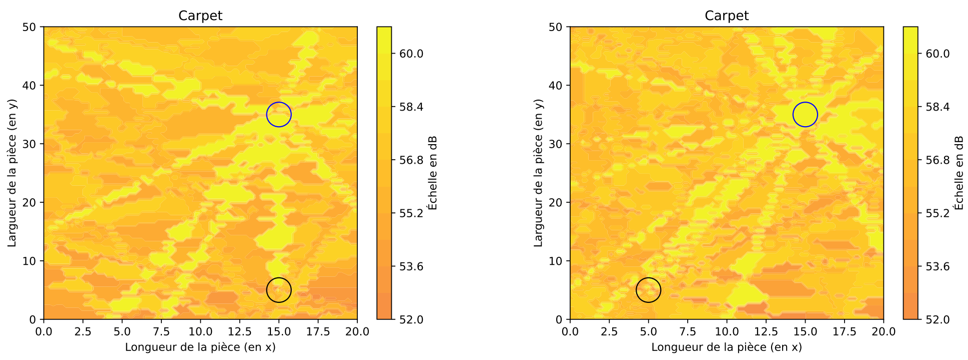

Figure 4: Comparing the position of the receptor

Finally, by fixing both positions of the transmitter and receptor but enlarging the room, we observe new trajectories that go to the right of the room. These trajectories will have late arrival times compared to those arriving directly on the left: this will cause echo and reverb. But, by analyzing our previous results, we can solve this issue. A first solution would to change the composition of the right wall to one made out of upholstered furniture, so that the sound would hardly be softened. Or, a second solution is to place a beam in the middle of the room to reflect the trajectory directly on the receptor.

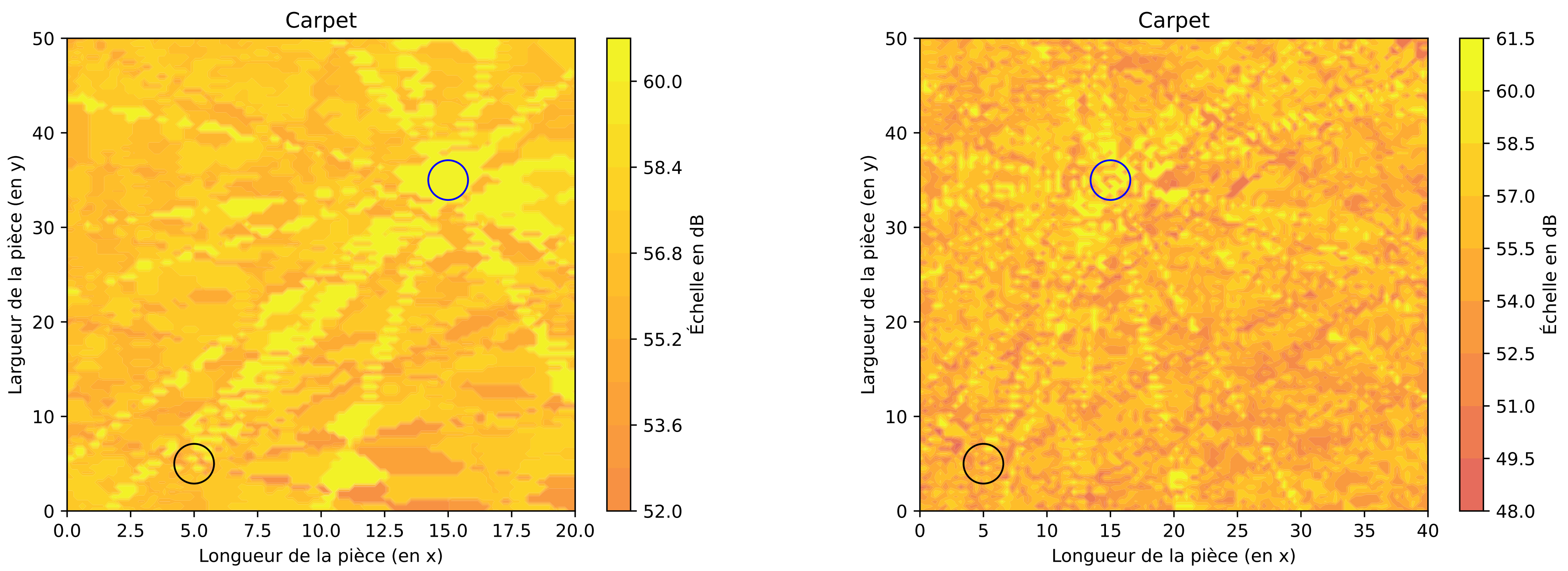

Figure 5: Comparing the dimension of the room

The simulation shows that using the perfect material and choosing the right dimensions can help overcome these phenomenons: both solutions mentioned above are highly used in many places. Its very intuitive yet rooms or halls still suffer from echo and reverb. In depth, my code is far from being perfect: if we look closely on the images, we see our straight trajectories being superposed by late arriving ones. Also, I have not yet managed to place a certain object in the room, nor to change the composition of a single wall.

References

[1] Morse Philip McCord. *Vibration and sound / By Philip M. Morse,...* eng. 2nd edition. International series in pure and applied physics. New York Toronto London: McGraw-Hill, 1948, cop. 1948.