

TOMMASO ROSATI
ELECTRONIC MUSIC



T H E
BOOK IS
NOW
AVAILABLE!

SPATIALIZATION

PLAY WITH SOUND

MANUAL FOR ELECTRONIC
MUSICIANS AND OTHER SOUND
EXPLORERS

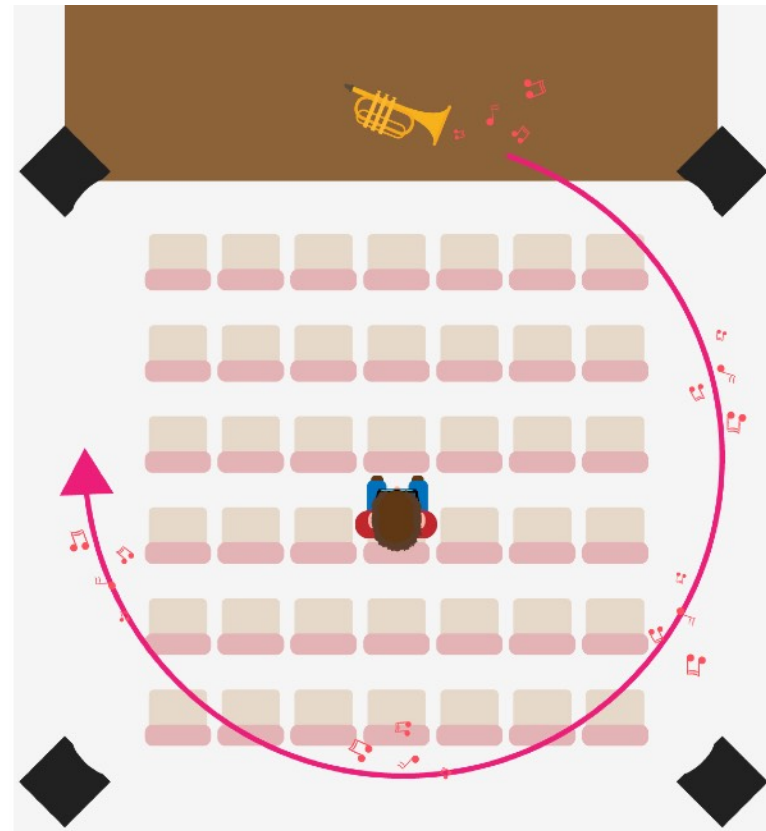
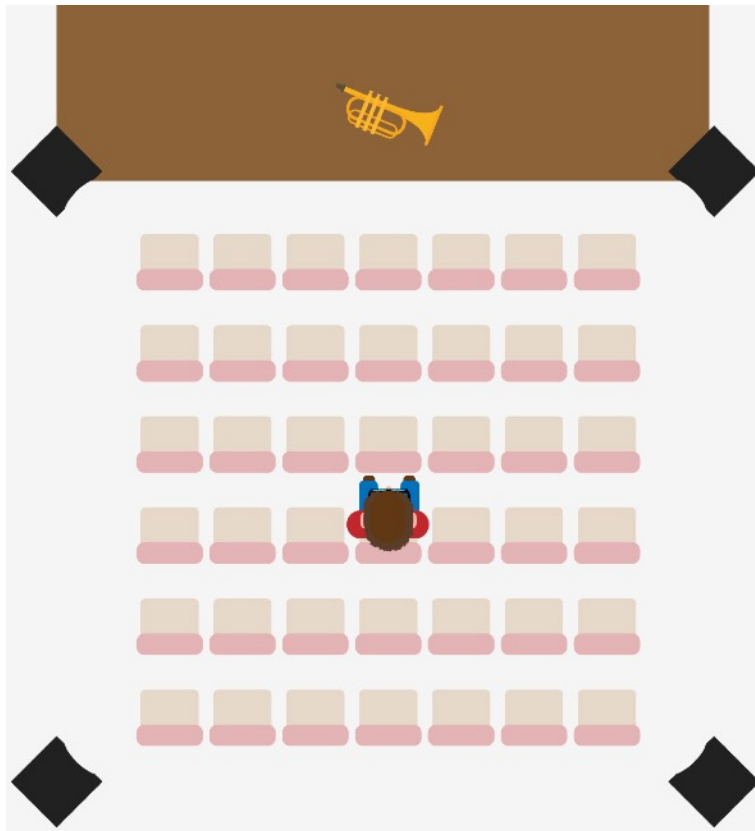


TOMMASO ROSATI
TIMOTHY HSU

A Focal Press Book

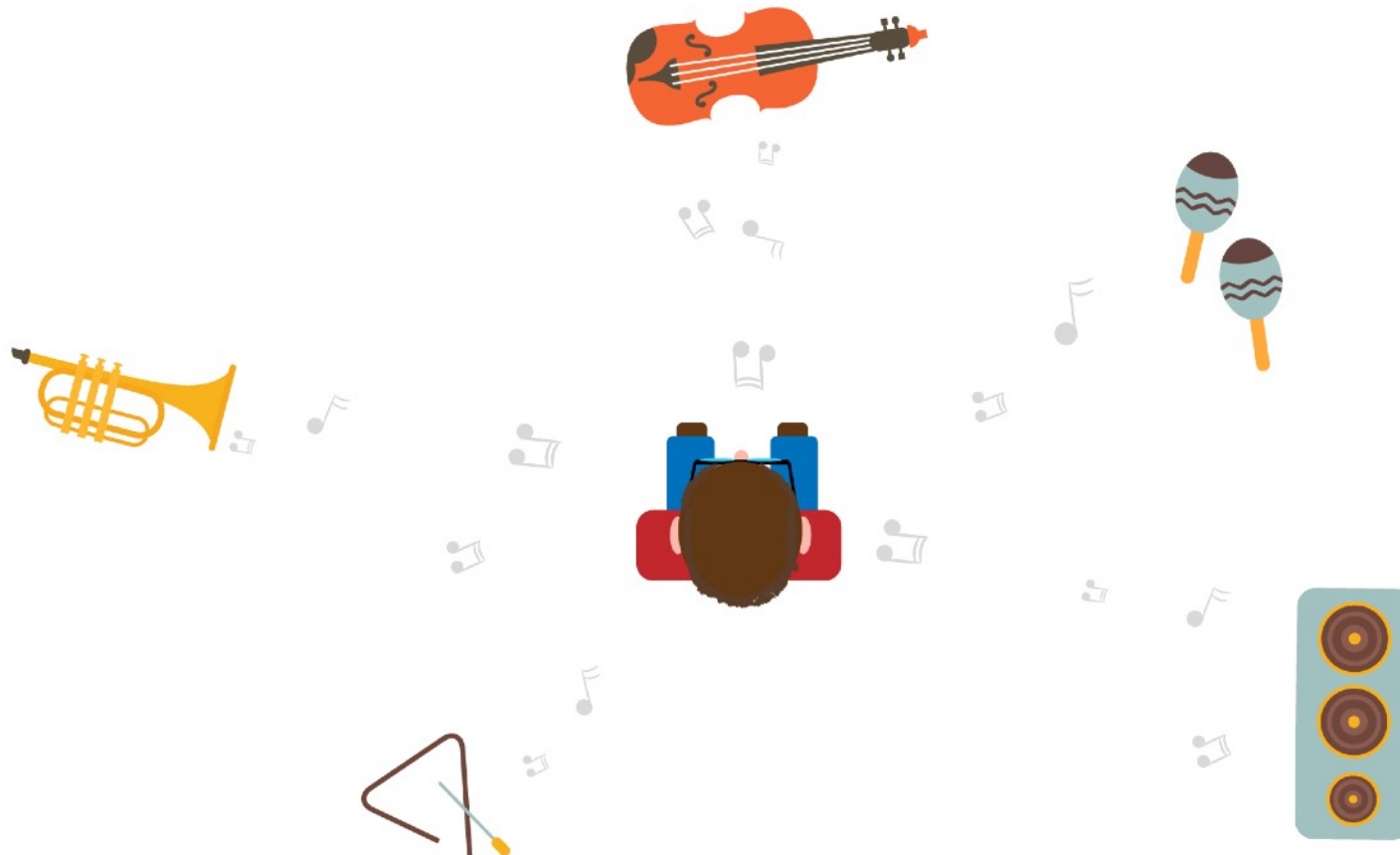


Spatialization is the compositional parameter allowing composers and producers to place and present sounds from positions surrounding the listener. Spatialization allows us to position these sounds statically, or even dynamically, relative to the listener.



How do we perceive the space?

We can localize sound, or perceive where sounds are coming from. Our auditory system can decipher whether a sound is coming from above or below, from in front or behind, or from the right or left with fairly high accuracy.



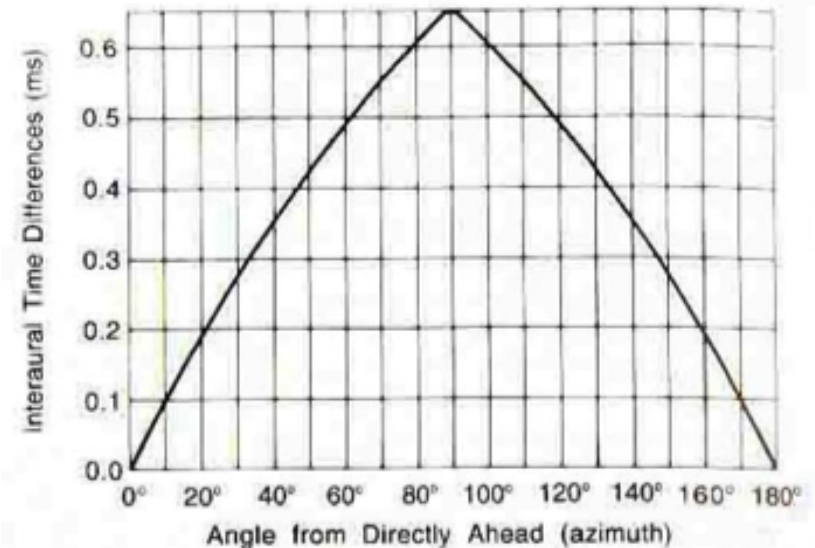
How do we perceive the space?

There are 3 basic parameters that allow us to perceive the space position of a sound:

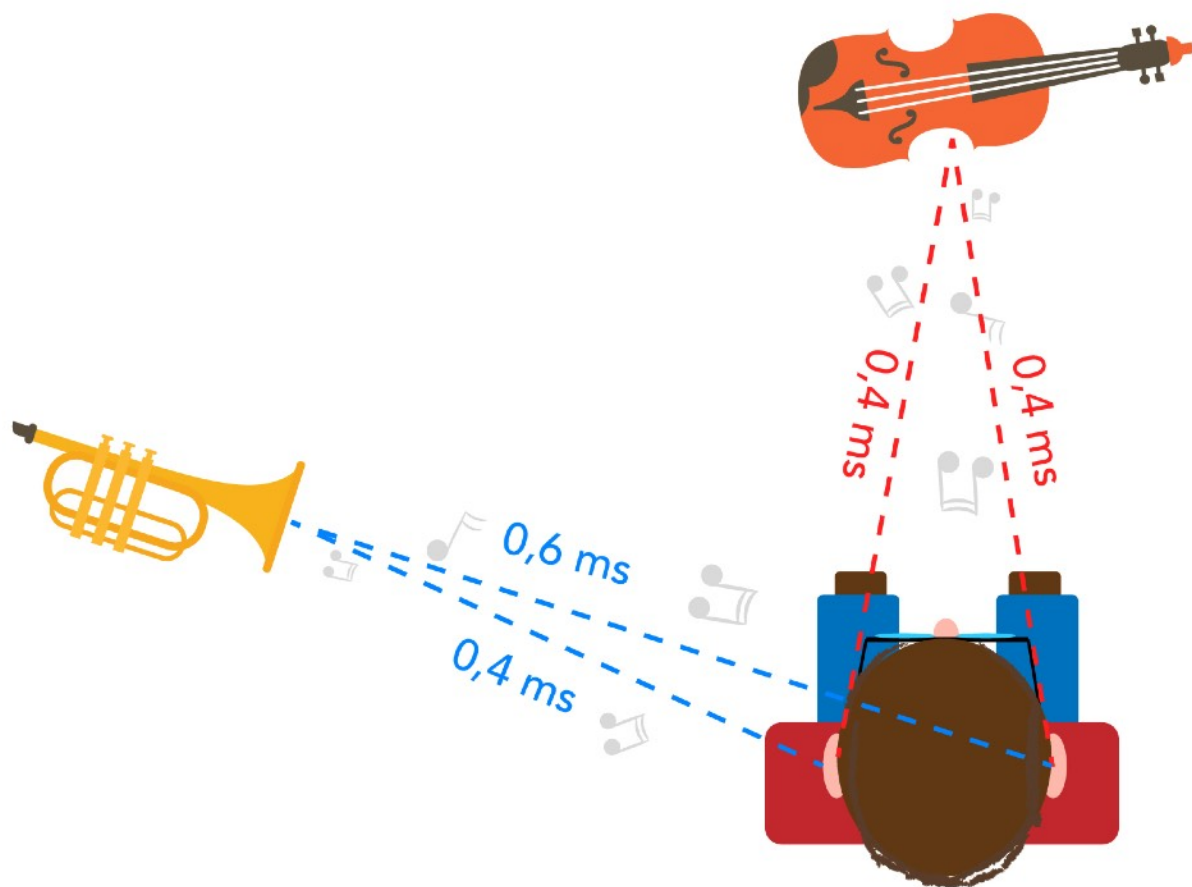
1) Interaural Time Difference (ITD)

This parameter is defined as the difference in arrival time for a sound to reach our left and right ears.

For example, a sound coming to you from your left side will reach your left ear before reaching your right ear, since the sound has to travel around your head to reach your right ear.



How do we perceive the space?



ITD

Interaural Time Difference



= 0 ms



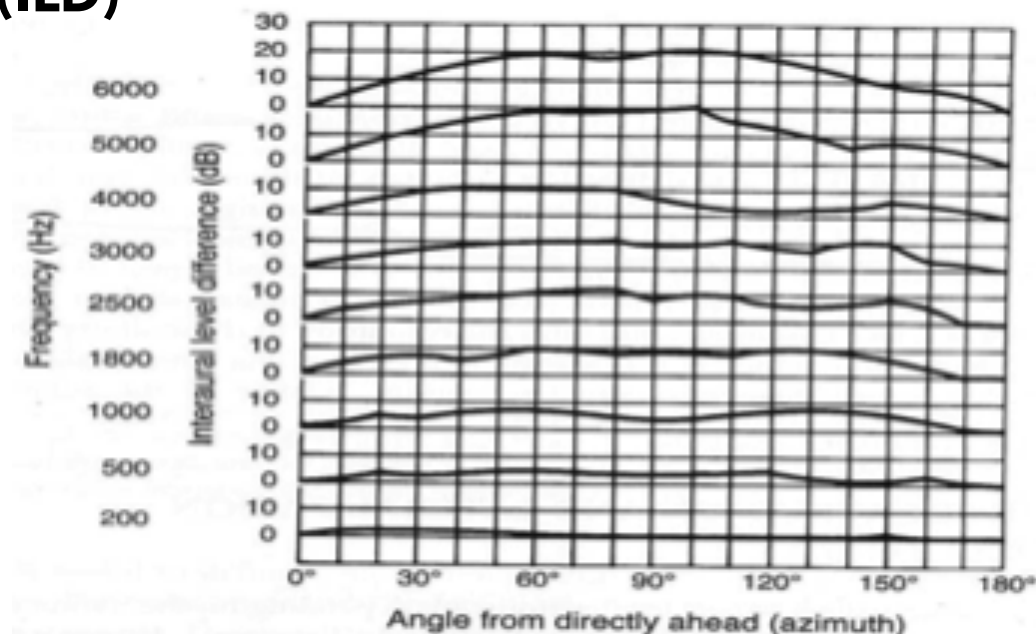
= 0,2 ms

How do we perceive the space?

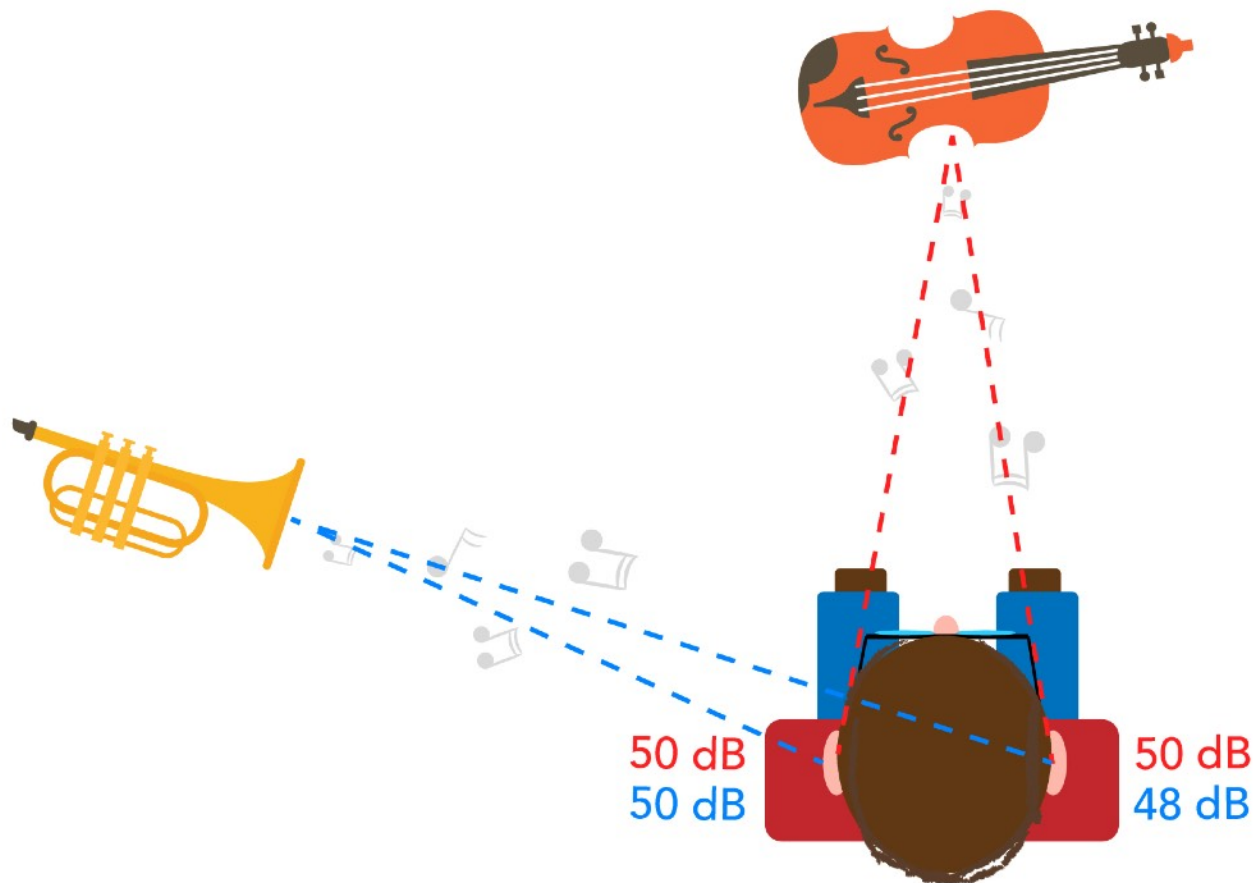
2) Interaural Level Difference (ILD)

ILD is the phenomenon where the amplitude that each ear receives can be different due to the spatial positioning of the sound source.

For example, a sound coming from the left will reach the left ear with greater sound intensity than the right ear because of our head's acoustic shadow.



How do we perceive the space?



ILD

Interaural Loudness Difference

 = 0 dB

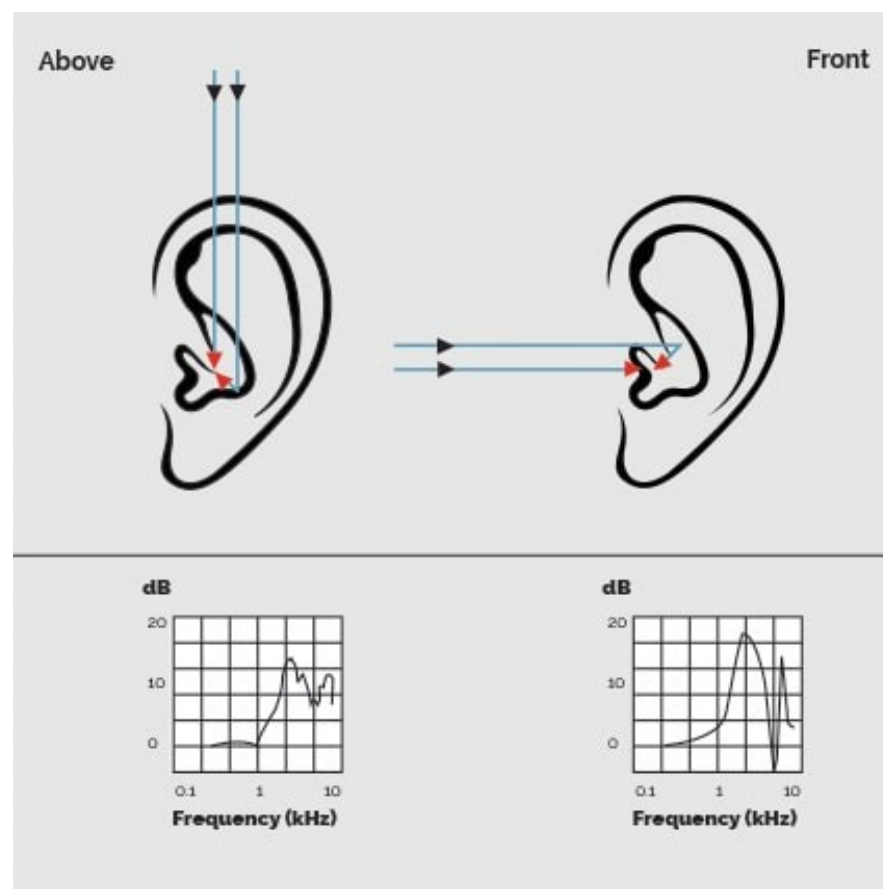
 = 2 dB

How do we perceive the space?

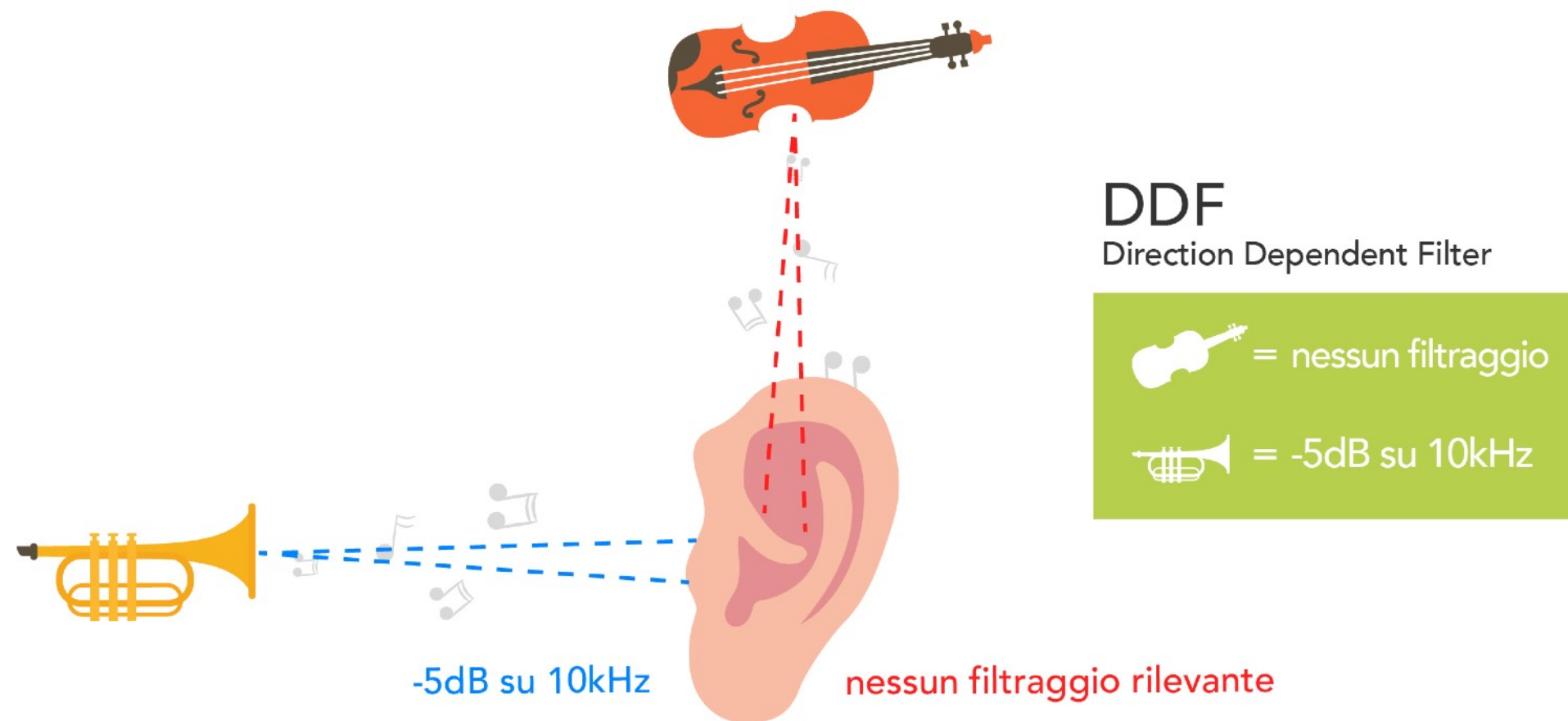
3) Head-related transfer function (HRTF)

As sound reaches a listener, the human body itself creates a set of acoustic interactions that results in essentially a frequency filter. The irregular shape of the pinna creates a direction dependent filter, or transfer function, that modifies the sound. These modifications are then passed to the brain, which interprets the content in a spatial sense.

For example, if a sound reaches the right ear first, is attenuated by 10 dB at the left ear, and has a 5 dB cut at 6 kHz, due to the head-related transfer function, our brain will perceive that sound source to come from the upper right of the listener.



How do we perceive the space?

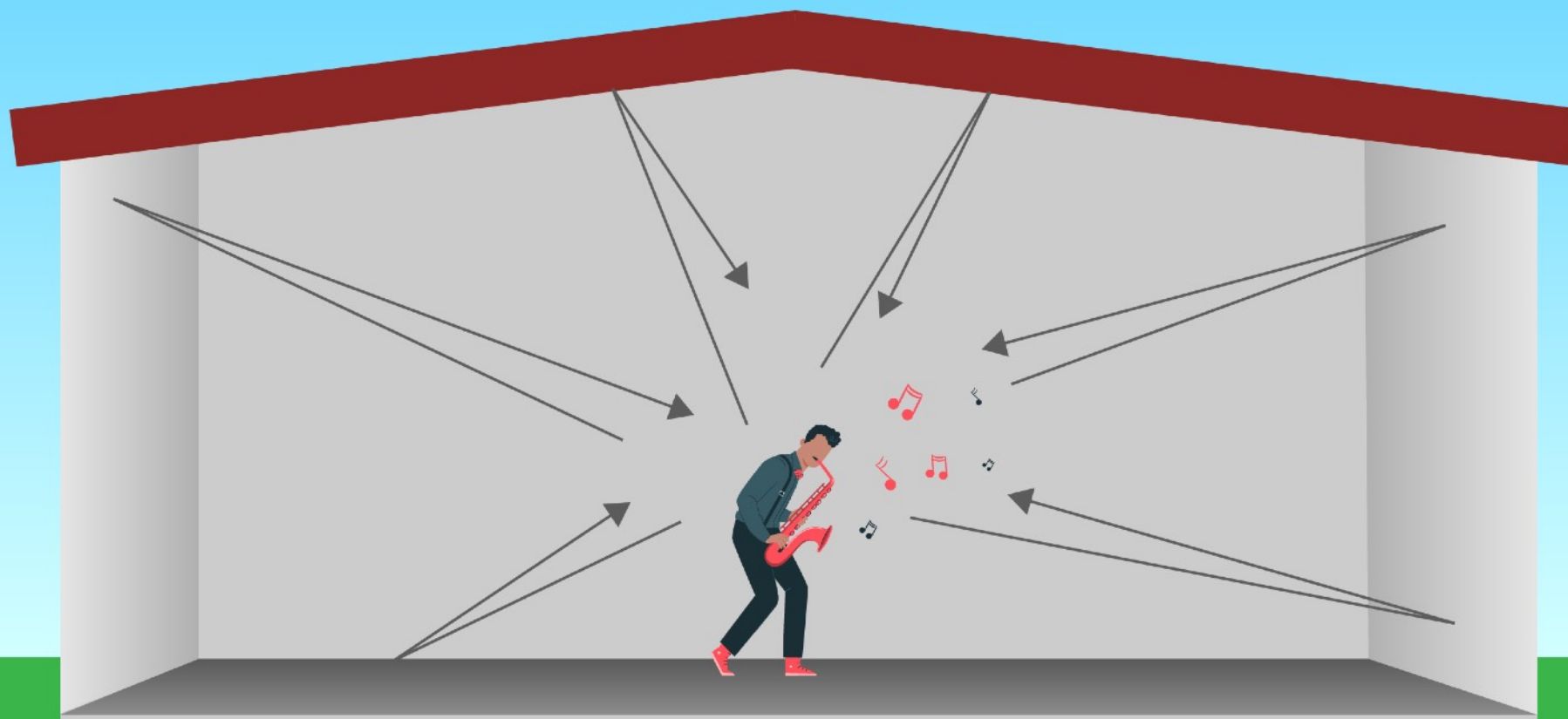


How do we perceive the space?

The environment

The reverberant field of a space can play an important role in how we localize sound.

For example, a sound with a lot of reverberation can be perceived as distant because the ratio between the energy of the direct sound and all the sound that bounces off the walls before reaching the listener is small.



Spatialization systems

A spatialization system allows a user to **virtually move a sound source through space**.

The more realistic spatialization systems consider all the parameters described in the previous slides: ITD, ILD, HRTF, and environment. With all of these parameters, the tradeoff is that for more accurate spatialization, there will be more calculations that the computer has to make.

channel	1	2	3	4	5	6	7	8	9	10	11	12
azimuth	40.61	34.25	-16.54	23.24	23.12	-1.83	56.58	53.76	82.02	46.24	112.91	114.11
elevation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-55.65	-23.82
radius	0.66	0.87	0.57	0.48	0.79	0.65	1.00	0.85	1.00	0.99	0.96	0.55

external Input

channel input off

ambi input off

spatial effects

granular off

granular settings

spectral off

spectral settings

ambi file record · play

choose record file

no file to record

choose play file

file play

stereo

ambi

at

decod

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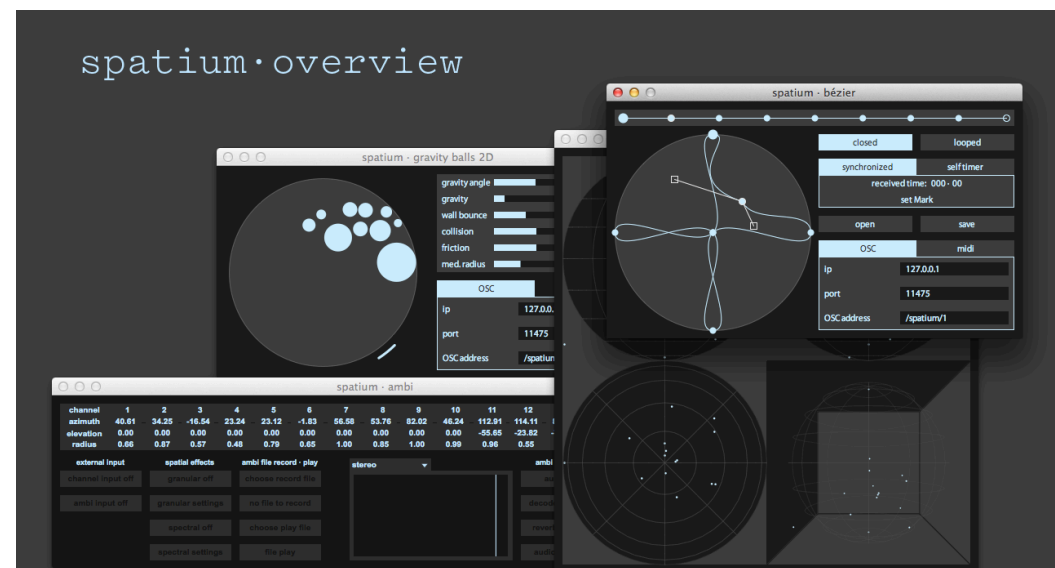
audi

Spatialization systems

hardware: dedicated machines that are more expensive and less common



software: computer software that performs algorithms that result in spatialization



Spatialization systems

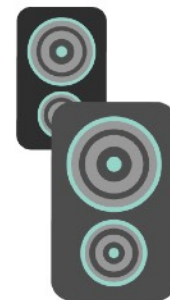
Binaural spatialization

When we spatialize sound directly with headphones into our ears, also known as binaural spatialization, we essentially trick our auditory system using only two channels of audio to create the illusion of three-dimensional audio. This method is used prevalently with 3D virtual reality systems, and especially in gaming.



Spatialization with speakers groups

In a studio or concert, it is possible to surround the audience with several speakers to achieve audio spatialization. While technically it only takes two speakers to create the effect of localization or spatialization, using four speakers (quad) or more will create more rich spatial sound fields.



Spatialization systems

Usually in quadraphonic systems, speakers are positioned in this way:

4 speaker

FL
FrontLeft

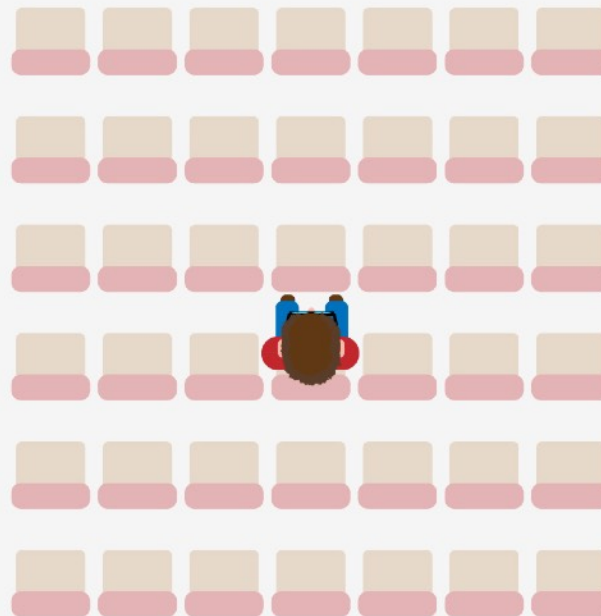


1



2

FR
FrontRight



RL
RearLeft



4

3

RR
RearRight



Spatialization systems

8 speaker

FL
FrontLeft



2 FC
FrontCenter



FR
FrontRight

ML
MiddleLeft



MR
MiddleRight

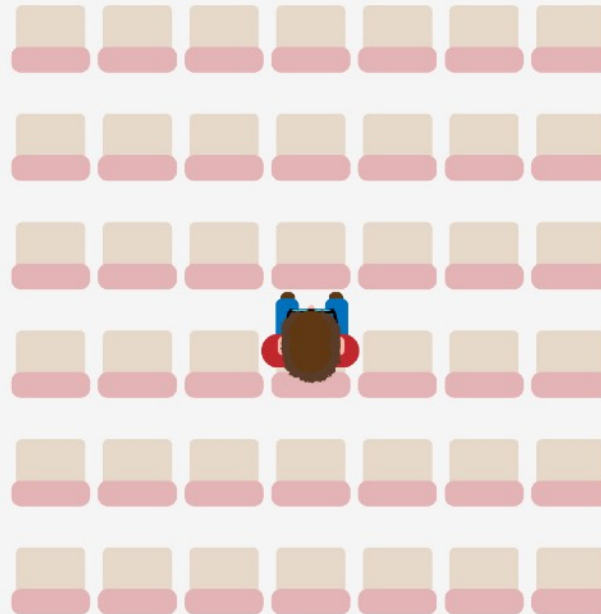
RL
RearLeft



6 RC
RearCenter



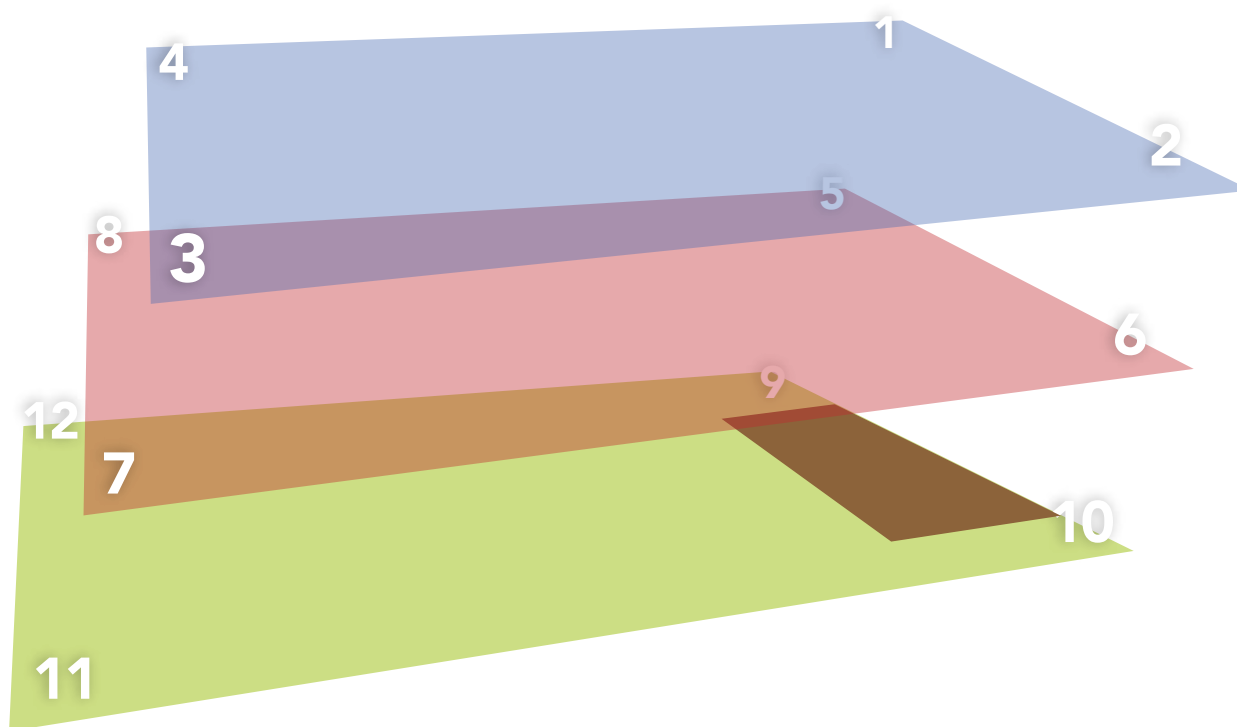
RR
RearRight



Spatialization systems

When you arrange speakers along multiple heights or orders, you can not only explore the vertical plane in sound, but you can also emphasize the perception of vertical shifts of sounds.

12 speakers
3 orders



Spatialization systems

Low frequency sounds

The low frequencies of the timbres we want to spatialize deserve a separate discussion.

The limitation of spatializing low frequencies is that it is difficult for humans to localize low (20-100 Hz) frequencies. Because of this, it is usually sufficient to use a single speaker called a subwoofer that can be placed anywhere in the room.

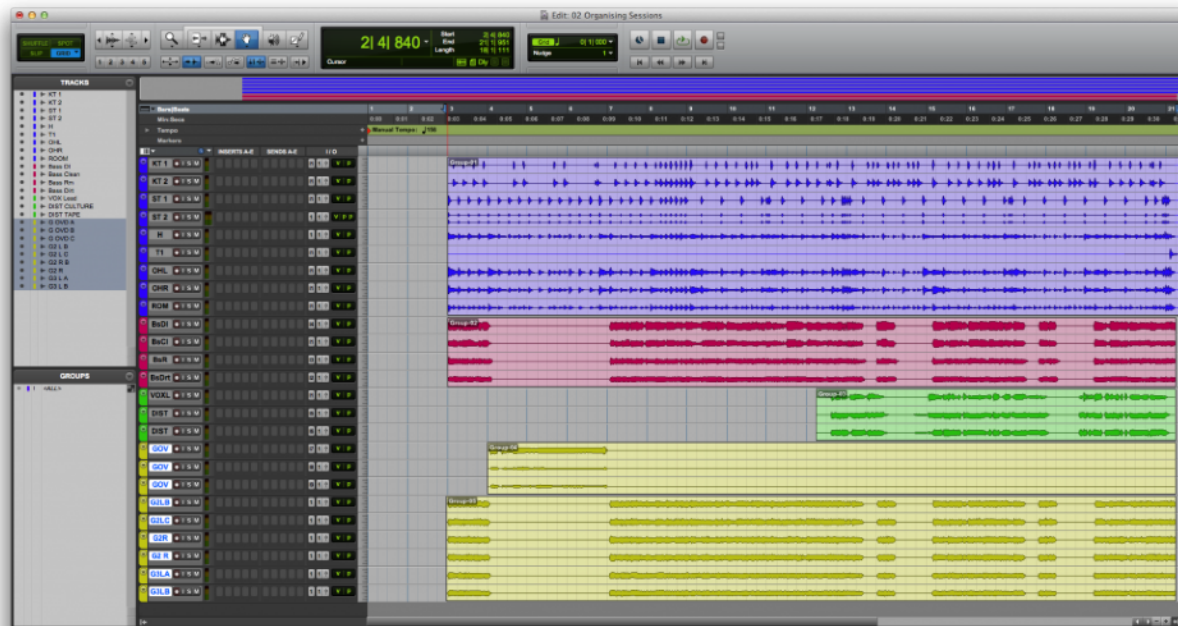


Control spatialization

There are two main ways to control spatialization:

Non-real time

You produce your work ahead of time in a DAW by creating separate tracks for each speaker or using a spatialization plugin that manages the various output channels. During concert performances, a multichannel playback device then distributes the audio to their respective speakers. This track player can be either a standalone hardware device or incorporated into computer software.



Control spatialization

Real time spatialization gives the creator and performer to opportunity to move sounds through space virtually in the present moment. This technique makes use of a mixer or more sophisticated control surfaces such as multi-touch surfaces (tablets, smartphones), joysticks, or even sensors.



Ipad with LEMUR app communicating OSC



Wii Remote controller connected with bluetooth

Panning

Panning is the angular placement of a sound in the stereo space of a playback system.

Panning is achieved by controlling the ratio of amplitudes that a sound is sent to each speaker in a stereo system.

By controlling the ratio of amplitudes, it essentially exploits only one of our perceptual parameters of sound localization: the ILD.

Panning is adjusted by a potentiometer (a pan pot) found on all mixers, or with a virtual knob in DAWs.

Panning

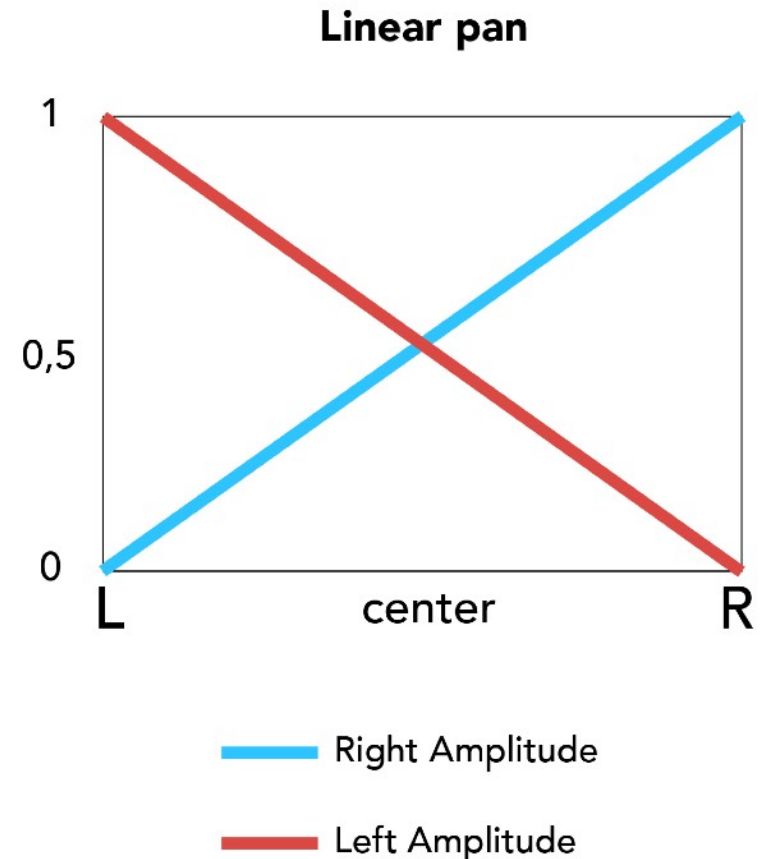
Panning algorithms

There are two main algorithms for panning:

Linear

This is the most simple mathematical way to achieve panning, even if it does not necessarily realistically match our auditory apparatus.

To achieve linear panning, we rescale the sound by multiplying it by values, corresponding to the potentiometer position, ranging from 0 to 1 on one speaker and the inverse (1 to 0) on the other.

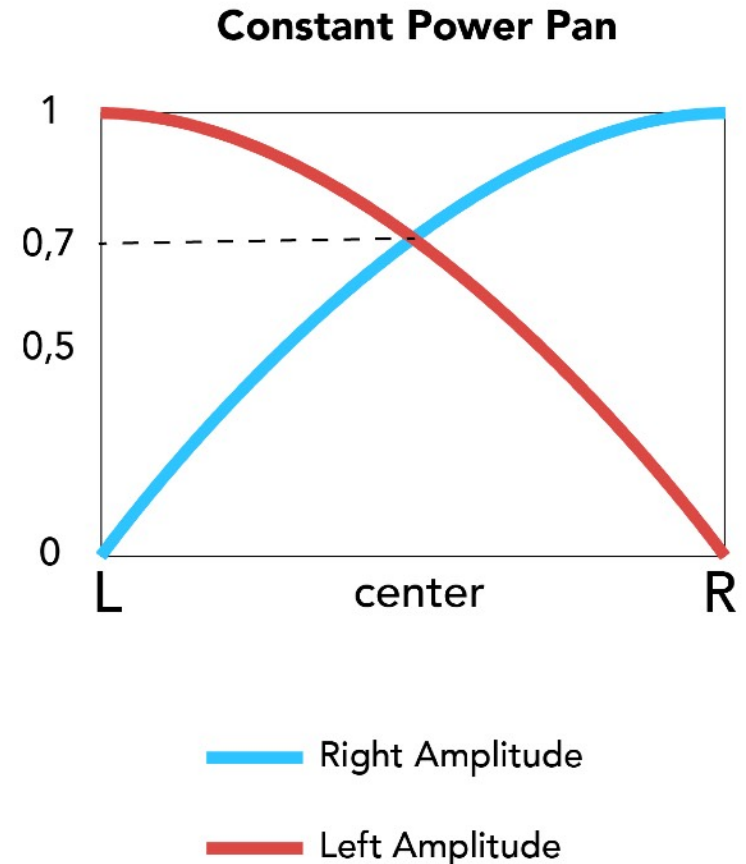


Panning

Constant Power Pan

This is an alternate panning algorithm that allows you to localize the sound to match our perceptions better. Instead of a linear relationship of position and amplitude, this technique follows a logarithmic curve instead.

To implement this method, instead of using the 0 to 1 scale from before, I will simply take the square root of those same values as my new multiplication factor.



Space as a compositional-performative parameter

We can consider space as a true and proper compositional parameter. The composer can choose the position of the instruments in the composition and also assign positions to the different notes of a single instrument, shaping the piece's evolution over time.

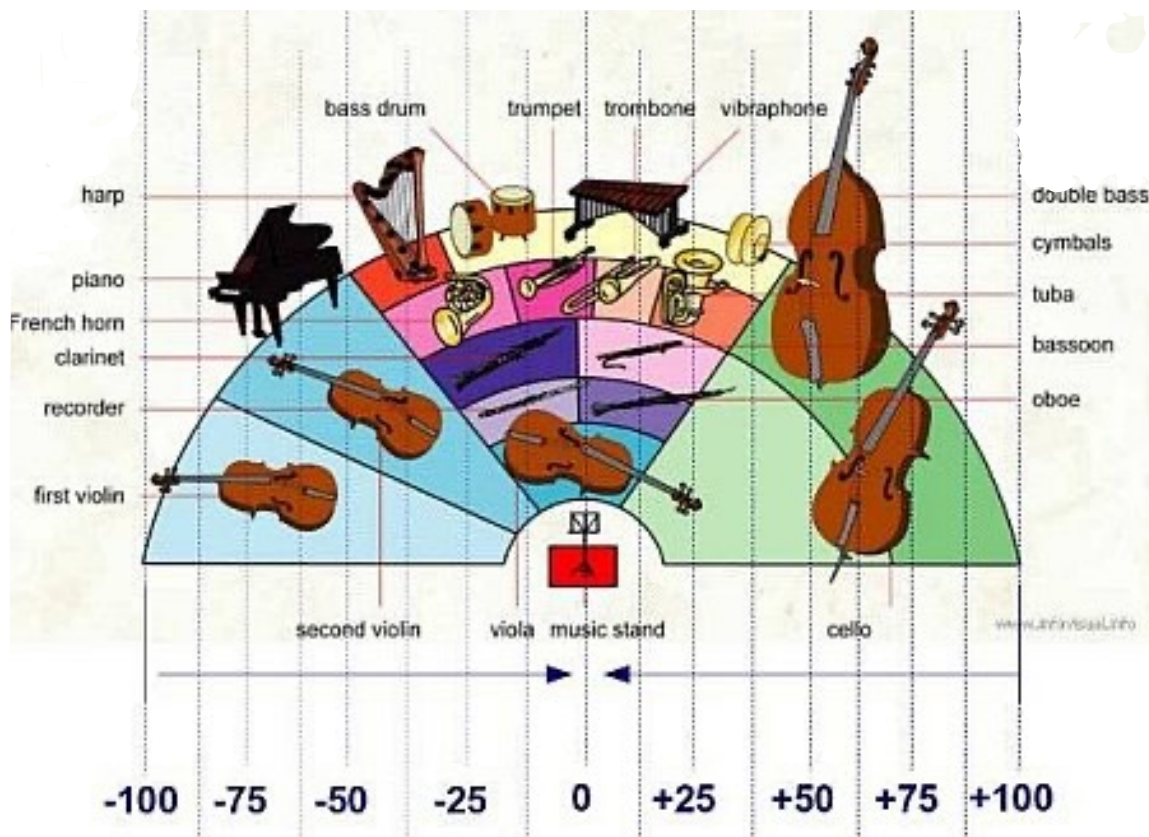
A producer utilizes panning to distribute the various instruments in a stereo space. This way, the listener will hear the track as if they were in the room where the musicians were playing.

In the illustration, you can see a very typical or classic positioning of instruments in a mix of a Pop, Rock, or Jazz song.



Space as a compositional-performative parameter

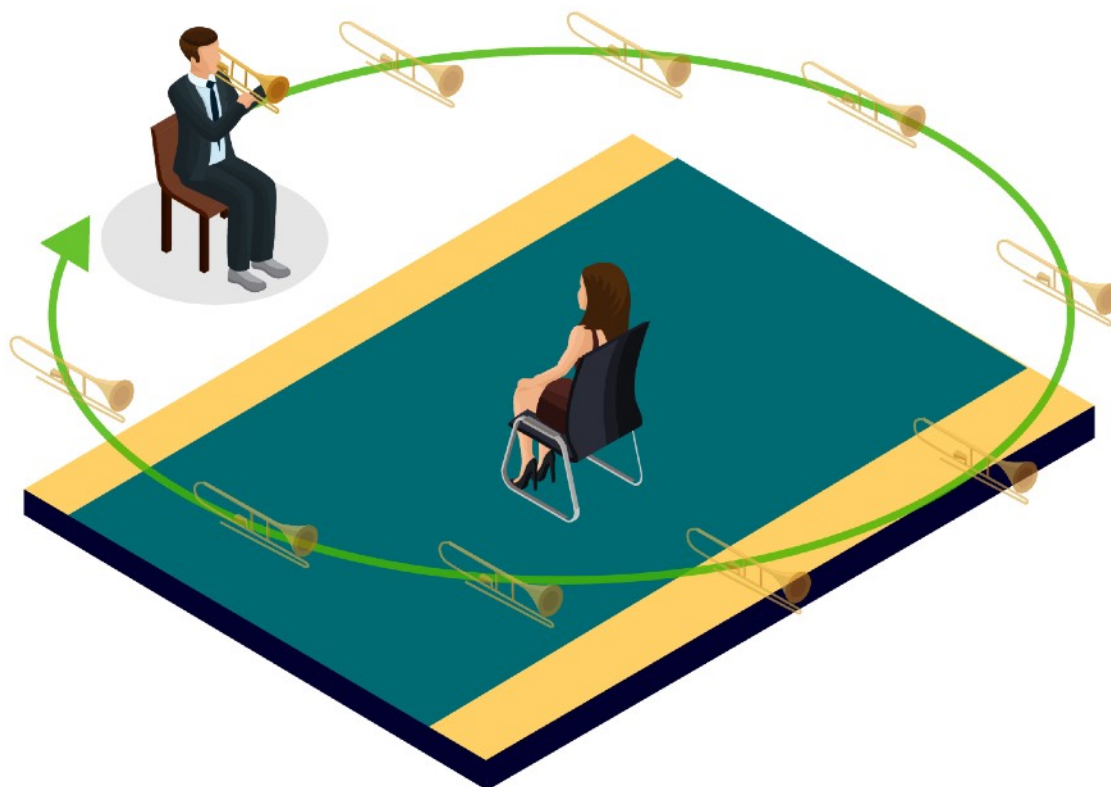
With classical music, we still must place the various instruments within a stereo field. Particularly with this style of music, we usually tend to preserve the physical arrangement of the musicians without seeking unusual or creative positions.



Space as a compositional-performative parameter

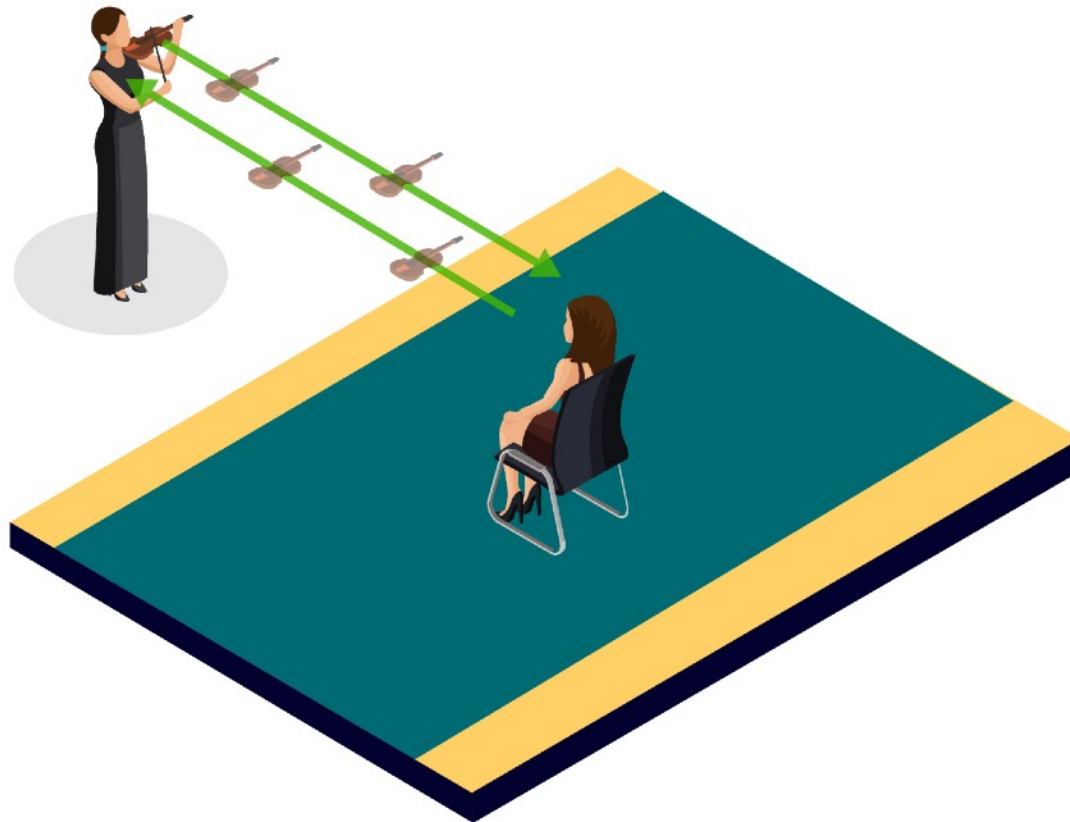
Spatialization is a **compositional parameter**, whether it is simple panning or a more complex spatialization system.

For example, I may choose to move the sound of a trombone so that it revolves around the listeners in certain sections.



Space as a compositional-performative parameter

Or have the sound of a violin move closer to or further away from the listener in the coda of my piece.



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