Physical and perceptual point of view on soundscapes: comparing physics, perception and signal processing

Vincent Gibiat[1], Abril Padilla[2]

[1] LAMI-Université Paul Sabatier, 118 route de Narbonne F-31062 Toulouse, France, Email: gibiat@cict.fr
[2] 106 rue du réveil matin 78800 Houilles

Introduction

During the late seventies R. Muray Schafer [1] in a book entitled "The tuning of the world" defined the neologism soundscape and claimed for an urgently needed cooperation between musicians, acousticians, psychologists, sociologists and many others for studying, altogether, the soundscape to try to make it better. Today it is worth to point out that this cooperation is always waiting for only its beginning. When physicists are studying wave propagation in acoustic they ignore psychology or music, when musicians need for acoustics they ignore physics and so on. This work is not the whole cooperation asked for by R. Murray Schafer. It concerns only the peliminary work heard by a physicist and a musician. Among the whole problems of sound production propagation and analysis, we limited our common work to sound analysis. A very common soundscape has been, not explored, but sampled. We recorded signal in the suburban parisian network, RER and metro. Along all these recorded signals we have chosen another small sample. This sample has been used by one of us as the base material for a short musical example. This sample has been also analysed with both classical and different tools, spectrograms and phase spectrograms in a time frequency plane. To conclude, an excerpt of an electroacoustic piece composed by A. Padilla with the sounds of Zaragossa (Spain), is the base of the comments of the musician.

Physics, Phase and Perception

Soundscapes are nothing more than acoustic waves propagating in an environemental medium where people are living with building landscapes of different kind, animals, factories etc. All the human activities, all the natural behaviours, snow, rain, wind, produce sound at different levels. Sometimes wind does not respect the normatives. Sometimes sounds that have never annoy anybody become unacceptable. Sounds propagating are building a soundscape that should be described using human tools. The first of these tools are the basic laws of physics. Acoustic is working with waves that may be travelling, stationnary or even evanescent ones. Waves are propagating with very simple rules in a laboratory as well as in a natural environement. Describing wave propagation through the Sound Power Level in deciBels is a drastic simplification. It assumes that the acoustic propagation is that of a scalar which is not true. More it assumes too often that the sources are not correlated, that the field is a diffuse one etc. An acoustic source produce a wave, this wave travels around obstacles, in ducts, is refracted, scattered and the initial wave is breaking during propagation, producing as well stationary fields, diffused ones. All operations that affect not only the amplitude (and so the Sound Level) but also the phase of the wave trough various time delays. Neglecting this point is equivalent to say that the waves does not propagate, or that interference fields do not exist. The geometry of the propagation field is a very important point that may lead to trapped waves, localisation phenomena [2] etc. all only understable with phase information. It is the same than saying that a Dirac function is the same than a white noise. During the last decades, the role of the phase in perception has beginning to arise, instead of the old statement saying that phase is not perceptible. At least one major psychoacoustic effect is connected with phase in soundscapes, the precedence or Haas effect. Related with space localisation the main parameter in it is the time delay between to identical signals perceived by a listener. A time delay, a time difference, between correlated sounds implicates to be described the use of the phase in the signals.

Analysing Sound

Sound level

The classical analysis of soundscapes by means of the two dimensional maps of noise obtained through sound level measurements does not make any use of frequency information, time information and of course phase information. It leads to a high simplification of the acoustic field. Improvements such as description with octave bands or third octave bands provide a better information but even in that case coherent signals are not processed with their whole characteristics and their annoyance is underestimated or ignored. The main utility of such a description is noise maps, where indications of high sound level, or low-fi soundscapes are easily detected. On the other hand it ignores the zones of high fi soundscapes, and in low level noise zones it may exists highly annoying soundscapes.

Spectrograms

Soundscapes related with normatives need to be represented all along the map of a landscape, but as any landscape, a soundscape needs a listener, resting or moving in the sound scape. If at rest, the listener is embedded in the sound, the sound is wrapping him and sometimes is going through him. At this point a good representation is a point space representation, and should not be limited to a scalar value, to a sound level. The spectrogram gives a time frequency information, where the levels may be presented with any ponderation. The main problem of this representation is that short time events are represented as frequency variation as it is the case for any signal processing technic based on Fourier

Transform, when only the amplitude (or energy) is taken into account. As an exemple we present an excerpt of a signal recorded from the stage of RER parisian station "Charles de Gaulle". A train is arriving inside the station and stops. It brakes and a high frequency sound is cearly audible. This sound has been extracted, filtering the whole signal. Its spectrogram is presented on Figure 1. It appears as a limited band noise between 3500 Hz and 6000 Hz. Heared, it correspond to a very unpleasant sound of moderate (60 dB lin) level, where main frequencies are slightly visible. Nothing more can be said, the level in dBA is less than in linear, and the sound is only understandable as annoying and the "pure" frequencies difficult to see, even if well perceived. The amount of information is very important and it is not possible to easily reduce it.

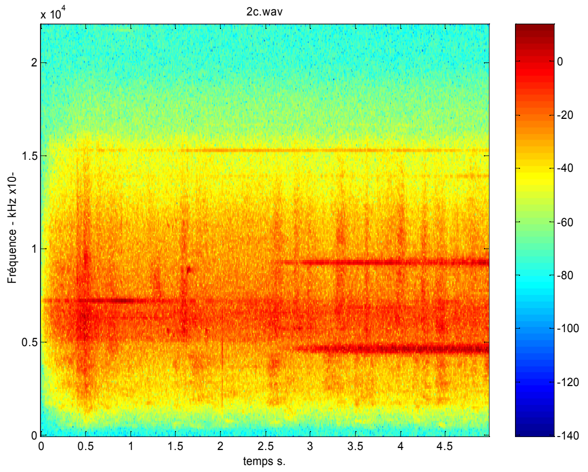

Figure 1: Amplitude Spectrogram of a band limited signal corresponding to an short part (5 s.) the braking phase of a train in a station. It appears as a noisy signal where some pure frequencies are slightly emerging.

Phase Spectrograms

A solution could be find in the ignored part of the Short Time Fourier Transform, that has lead to the spectrograms. A Fourier Transform of a signal, is a complex vector that can be represented both as a real and an imaginary part or as an amplitude and an argument. This argument is often called the phase of the Fourier Transform. Even if it has been often thought that the human ear does not use the phase information, it remains obvious that many psychoacoustic phenomena are directly related with time delayed informations processed by the ear. Precedence effect is one of them where more than using the amplitude the ear is working with time information. When a time signal is processed a common mistake is to say that the time information is lost. A Fourier Analysis transforms any time information in phase information.. From the analysis of phase one can recover time. The use of phase in each component of a Short Time Fourier Transform (STFT), leads to a new time frequency representation. It has been achieved in the eighties through different way. The most commonly used has been for speech signal the phase vocoder [3] Another possibility is the Differential Spectral Analysis [3]. Both are using the same basic tool, a STFT where the phase is first unwrapped by frequency bands then differentiated to obtain a time frequency information whose resolution is higher than for an amplitude spectrogram. The result for the example presented before is given on Figure 2. The information reduction is drastic. It reveals that what was appearing as frequencies emerging with difficulties from noise on figure 1 are in pure frequencies with strong time variations. The information is in such a way highly simplified, and very well correlated with the ear perception.

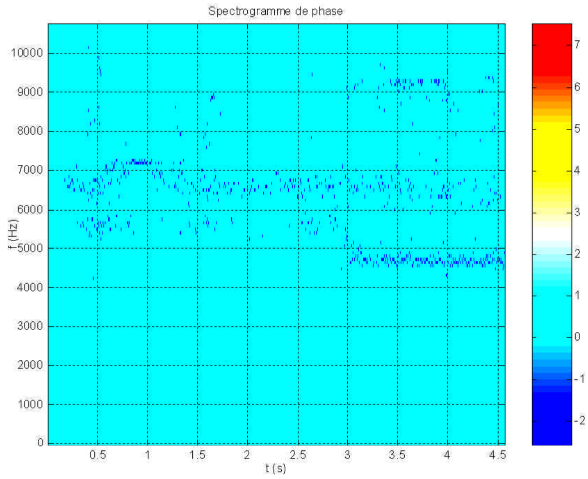

Figure 2: Phase spectrogram of the same signal than in Figure 1. The information has been highly reduced

Appropriation of Soundscape

The use of soundscapes as a material by music composers is not new, Schaeffer, Murray Schafer and many others has given birth to such electro-acoustic works. The piece "Lugar de antiguas vecindades" [4] is an example of how the sounds of a town can be recycled. It shows how, from an unknown town, discover more by hearing than by viewing, it is possible with unbelievable sonorities to valorize a sound richness, an expressive sounding existence, a valorisation of a soundscape by an artistic behaviour. Moreover in that work, in a crowd of power hammers, a tiny singing woman voice is clearly hearable. As the phase is the only way to give its coherence to that sound, its perception is clearly related with phase as a parameter that makes meaningful this voice.

References

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