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TOWARDS A MEASURING UNIT FOR SOUNDSCAPE BASED ON WHITE NOISE

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ABSTRACT

Focusing on the sound signal, acoustics can describe, calculate and simulate the behavior of sounds with a very high precision as well as psychoacoustics focuses on the psychological and physiological principles of sound perception. However, in complex situations like urban sound ambiances, it is still difficult to measure and separate the sounds of that surrounding soundscape. The aim of this paper is to present a new measure and unit that allow the assessment of the sounds imbedded in a soundscape, ranging from the louder to the unheard or masked one, by gradually introducing white noise in the soundscape.

1 INTRODUCTION

The soundscape is a transdisciplinary sound phenomenon based on measurable physical data, on perceptive observable data and on representational ones, which are verbalized. As the authors have already shown in previous papers, one must always articulate the language, the perception and the signal at the same time in order to remain in a transdisciplinary approach. This is why it is important to introduce:

- The signal as a physical quantity which yields the measurement by comparison,
- The perception as semantic filter which isolates the figure from the background,
- The language which defines the object of the measurement or of the perception.

These are the three indispensable conditions to describe the soundscape. The passive acoustic measurement can neither filter a complex sound *conglomerate* nor draw its figures, the perception/action in contact with the sound source cannot evaluate its physical amount isolated or immersed in soundscape, and the language cannot quickly restore the soundscape composition, plane by plane, figure and background with the exact contours where some mask others. This paper points out the method and the instrument developed in previous work and proposes a way to define a measurement for Soundscape.

2 THE METHOD

It is important to notice that soundscape is a representation in the sense of an aesthetic construction, a composition of which it is necessary to remove the parts of the whole.

The challenge being to visually represent Soundscape, it is thus on the level of its representation that measurement is considered in this paper.

2.1 WHITE NOISE AS A TOOL FOR SOUNDSCAPE MEASUREMENT

The method consists on introducing listening of a “measuring subject” to use the separating power of the ear, which then acts as a semantic filter in the multi-layer sound situation. To make this separation obvious, the language has a great importance and a double role in this protocol. The first role is to indicate the sound or group of sounds to be measured and which are significant for the subject. Then the language acts like a descriptor of sound shapes. The second role of the language is to indicate an objective value of the sound to be measured: either by comparison with a sound of reference, as it is the case of the measurement of sone, or by seeking to reach a qualitative rupture of the sound form, described by the language, as for example the limit of audibility such as it is performed in the audiometric tests. The authors have chosen to test this limit because it is more precise than the comparison between two sounds. However, since listening and language can not give a physical value, the latter is given by the difference to the limit of audibility. The measured result is a limiting curve of in situ audibility, where the background noise and the configuration of built space intervene actively in the determination of the limiting points of audibility. These points take part in the description of the sound situation.

For feasibility reasons, a masking white noise was introduced in order to reach the limits of audibility in the closed spaces without having to traverse long distances to the point to transship completely the place of the situation. In this way, in addition to the limit of audibility curves, the level of the white noise that intervenes in the mask effect was obtained. For the same level of white noise of reference the comparability of the results in various situations becomes possible.

An experimental programme was carried out at CAPS-IST, Technical University of Lisbon. The main assumption of this experimentation was based on the Zwicker and Scharf[i] experiments of masking when two tones were compared. The first tone (masker) is set to some fixed frequency and intensity. The second tone (test) is varied in frequency and intensity until it is masked by the first one. Therefore, the hypothesis is to consider a white noise, covering all frequencies as the masker of any sound having the same intensity of the loudest spectral component. If this is true, **the white noise level becomes the measure** of the highest frequency of any sound in the soundscape. The following question is now pertinent: is the experience of the two tones transposable to a complex sound coupled with white noise?

The tests were performed by using professional headphones and a computer in a quite room. Music composition software was used for mixing and the masking white noise was computer generated.

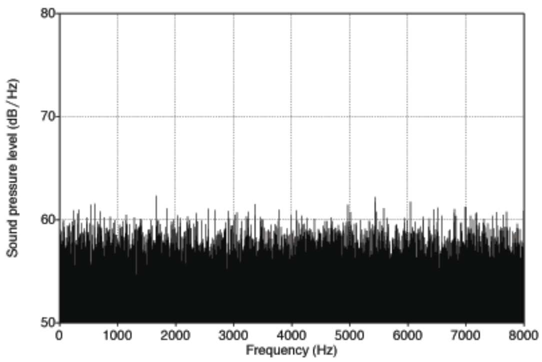


Figure 1 - Masking white noise measured at 60 dB L_{Aeq}

Various sounds were tested in a mono format presented binaurally:
• Recorded human voice reading text in a quiet room
• Synthetic orchestral strings playing A4 (440Hz) with reverberation
• Synthetic cathedral organ playing A4 with added reverberation.

When the white noise was mixed with these sounds separately, the level of each sound was lowered until totally masked by the white noise. The white noise and the tested sounds levels were set and recorded to disc with the obtained level into digital audio format. Spectral analysis was applied to each sample.

The listening level did not need to be set constant. It was increased in the beginning of the test until a comfortable level of listening was reached. However, it was important to focus on the difference between the masker and masked sound levels.

The results correspond to one listener with a normal hearing. Other listeners have obtained the same results with only 3dB of difference. As the aim of this method is to measure objectively, but using the perception ability of only one subject as the measuring apparatus, therefore, it was not considered necessary to perform tests on a large panel of subjects. The results from one subject were seen to be sufficient. In fact, a better or a worst human quality of listening applied in this method of assessment corresponds to a high or low quality sound level meter used in standard acoustical measurements. Human sensitivity and perception are used instead of microphone sensitivity and high precision of signal processing of sound level meter.

The results conformed to the original expectations. The level of the loudest spectral component for of each sound was nearly equal to the level of the white noise (measured at 60 dB).

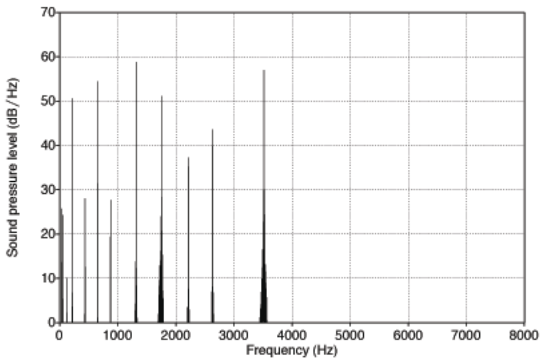


Figure 2 - Cathedral Organ (A4)

In the case of the cathedral organ, the louder frequency reaches 59dB at 1320 Hz.

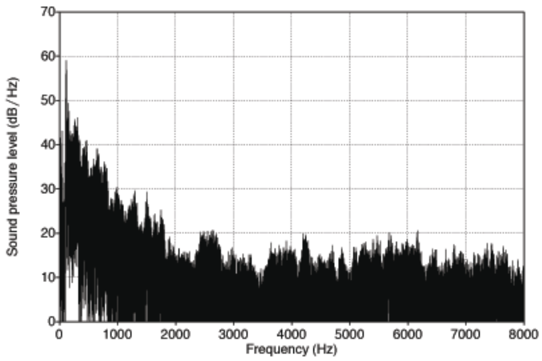


Figure 3 – Human voice reading a text

The louder frequency of the human voice reaches 59dB.

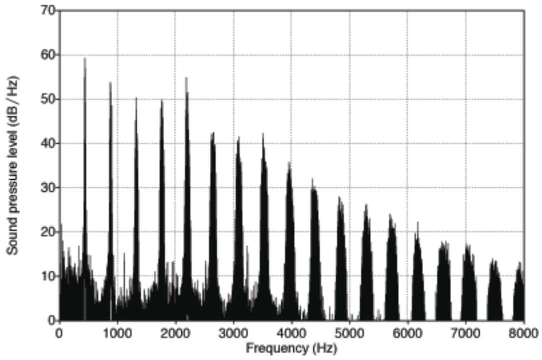


Figure 4 – Orchestral strings (A4)

The louder frequency of orchestral strings was measured at 60dB.

2.2 HUMAN PERCEPTION AS AN INSTRUMENT

The introduction of human perception during the process of analysis and signal processing makes it possible to target measurements on one or more noise sources selected separately from their background noise. Contrary to conventional measurements, which yield overall values of L_{Aeq}, without distinguishing sources, the method presented here allows a space description of a soundscape by standing out each sound form from its context. It can measure the range of a noisy source in a given place or test the range or the masking of an urban device (fountain, for example).

A question that can one ask in this approach is how "can a sound be perceived if it is partially masked?". Recent theories of perception[ii] agree that a part is sufficient for a whole recognition. That is what Augoyard[iii] compares to the asyndeton and synecdoche rhetorical figures: so even if a source is partially masked and if the rest of the perceived signal could make sense to the listener, then the recognition of the whole source is guaranteed.

Even if the source is not masked at all, as in an anechoic room experiment, one knows that the listener is spatially in contact with only a small part of the whole signal. This sound contact reveals what we called a "sound topology"[iv]. One can easily understand that located measures allowed in this method do not reflect the whole source energy but the part of it that is still recognizable by the listener.

The signals that do not make sufficient sense to the listener are not measured. They are understood to fill the background.

2.3 LANGUAGE AS CONTROL PANEL

Usually, one takes into account the inhabitant perception of noise and the way he qualifies the surrounding sounds. The majority of these approaches starts first by measurement or computation, and then validate those objective results with some user's perceptions. The language is said to be an access to the human field of perception and collective representations. The reactions of these users are given as qualitative results that identify the components in a complex phenomenon. But the complexity here only concerns the field of perceptions and representations expressed by the language. The process is:

Signal $\rightarrow$ Perception $\rightarrow$ Language

If the aim of the qualitative representation is a spatial projection of the sound shapes, then an inverse process can be followed. Meaningful sounds of the environment that can be defined by the language are identified and selected beforehand. In this work, traffic noise, water sounds and ambient music were selected. They were the major sources in the urban area under analysis. Then, by an active perception procedure (cocktail effect) one can explore the environmental area in situ, or by listening to the recorded samples, and look for the signal corresponding to the defined sound. This is possible by an inversion of the classical process described below:

Language → Perception → Signal

By this method one confirm, contrary to the generally accepted ideas, that the language is not a specificity of social sciences, but it can objectively and actively participate in the process of perception and measurement. Let one notice that the language allows one in this method to target sound sources that are merged in the overall noise. And in this way, it brings more precision to the measurements.

3 A PERSPECTOGRAPH FOR SOUNDSCAPE

A patent was deposited[v]. The instrument is in fact an analogy of the Leonardo Da Vinci perspectograph, but applied to the sound space. It does not mean that the soundscape has a perspective in the sense of the Euclidian space but the method allows a description of the ratio between the components of the soundscape and the drawing of its representation in the same way that a perspectograph does for a landscape.

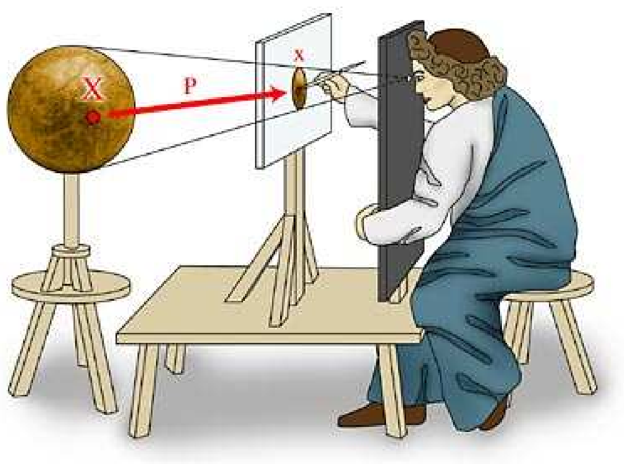


Figure 5 - Illustration of Leonardo's perspectograph. A point X on the globe is projected to a point x on the image plane via a straight ray from X to Leonardo's eye[vi].

3.1 THE PATENT

The invention in question, based on the experiments described earlier, relates to a portable device of measurement of the isophony curves, audibility limits, of one or several sources of noise by the effect of mask acoustic, to locate in the space the boundary points of audibility p (p0, p1, p2.) around a source of noise in order to draw the limits describing their sound morphologies by topographic sound curves.

Figure 6 - Praça do Rossio (Dom Pedro IV), where the first tests were carried out

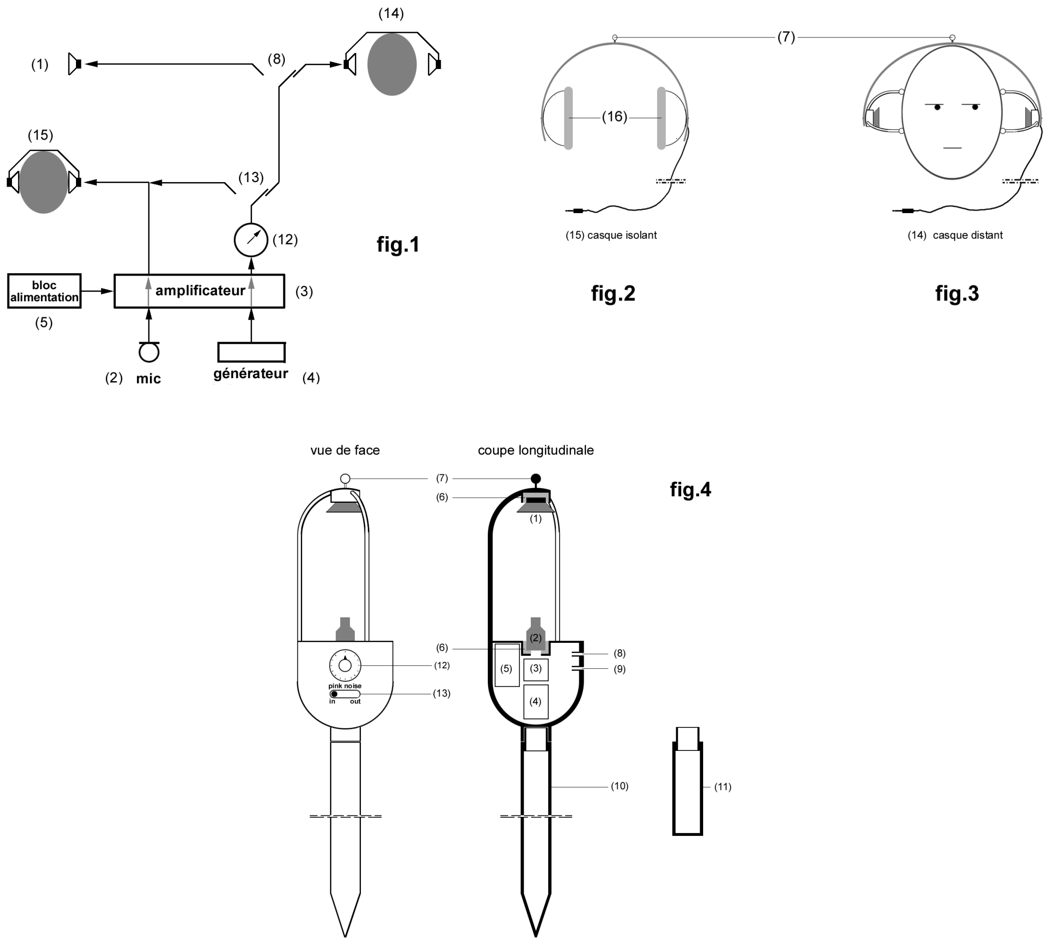


Figure 7 - Figures 1, 2, 3 and 4 in the patent

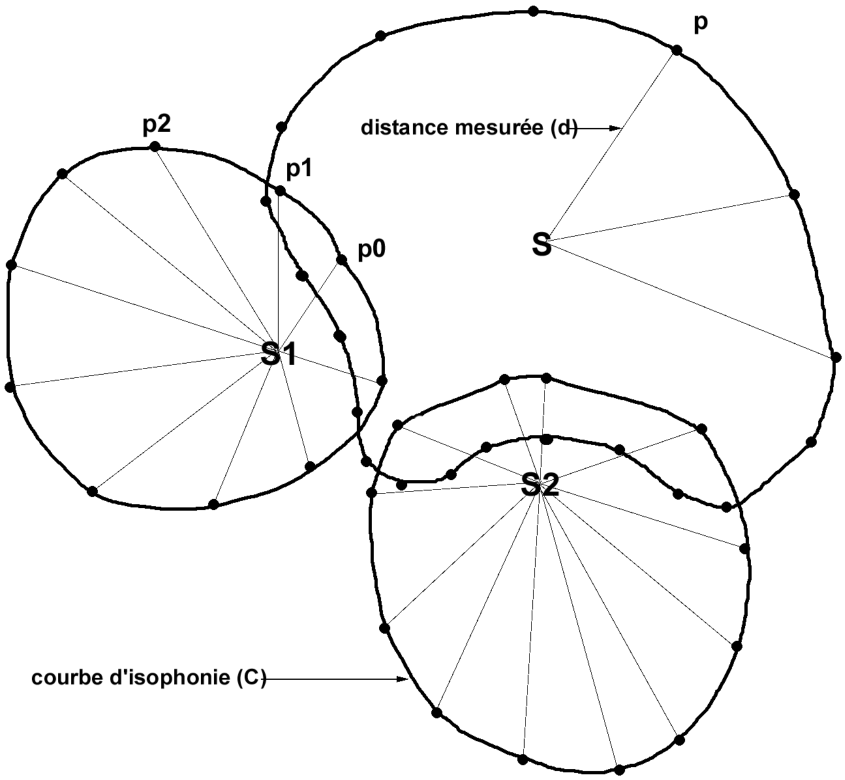
Figure 7 shows Figures 1, 2, 3 and 4 that illustrate the invention..

Figure 7.1 represents the diagram of the general principle of the device. It gathers the various possible uses according to whether the white vibration is connected to the distant headphone (14) (cf. figure 7.3), or with the loudspeaker (1).

Figure 7.2 represents a headphone closed to the ears and provided with soundproofing foam so that only the noises diffused by the loudspeakers are audible. Figure 7.3 represents a distant headphone, which consists of an aired headphone around the ears so that the noises emitted by the loudspeakers mix with the ambient noise.

Figure 7.4 represents the portable device with its foot or its handle. It gathers on the same vertical axis the point of test card (7), the loudspeaker (1), the microphone (2) and the foot of the test card (10) or its handle (11). The space between the loudspeaker (1) and the microphone (2) is ventilated to allow the mixture of the white noise emitted with the ambient noise when the loudspeaker (1) is connected.

Figures 8 and 9 illustrate the types of isophony curves obtained.



Legend:
S1, S2 and S3 = sources of noise
P0, p1, p2…pn = points measured with the same level of masking noise

Figure 8 – measured isophony curves

Figure 8 represents the isophony curves obtained by the measurement of the physical distance (d) between the source (S) and the point (p) of audibility limit. In this case, the white noise emitted and regulated at first once is maintained during the measurement of the other distances to the points p0, p1, p2,… pn.

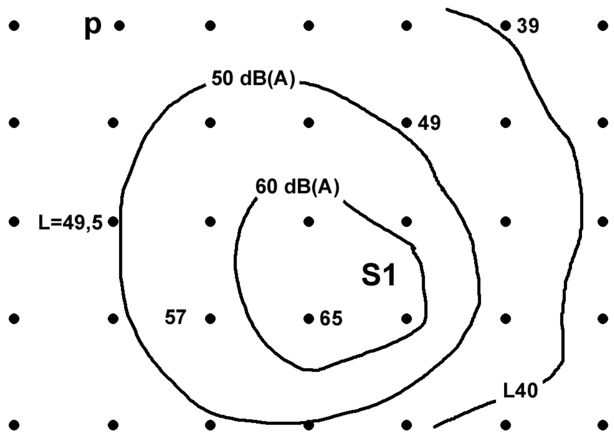


Figure 9 – calculated isophony curves

Figure 9 represents the isophony curves obtained by the measurement of the white noise level masking the S1 source on each preset points. The tracing of the curves is obtained by extrapolation or by intrapolation of the values obtained.

4 SPATIAL AND LINEAR REPRESENTATION

This measuring method, that takes into account the inter-masking of the sources, has been developed. It is based on the human perception as semantic filter and an introduced masking noise that brings the measure. The whole method is explained with details in other papers[vii].

The first tests in situ, were conducted at Praça do Rossio of Lisbon and analyzed at CAPS-IST acoustical laboratory. It was possible to measure separately the sound topologies and to distinguish them on a qualitative sound map (Figure10).

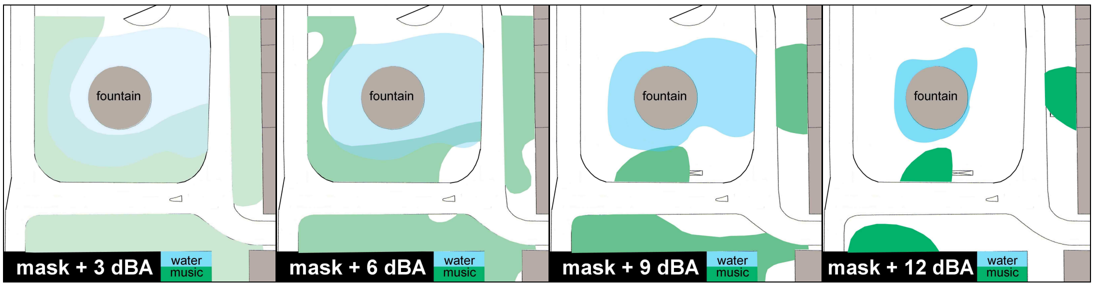


Figure 10 – Water and ambient music topologies in situ.

In order to obtain an outline of the fluctuations of sound topologies, one can gradually introduce a masking noise together with each sound fragment. The levels of the masking signal deferred on the map allow, by interpolation, to draw the curves of fluctuation of sound topology. That is equivalent to an increase in the background noise, which is a permanent natural mask.

This masking effect becomes obvious in the maps shown in Figure 10. One can observe the contractions of the sound topologies of the two sources (ambient electroacoustic music and fountain's water).

One can define exactly at which place each source becomes inaudible depending on the level of the masking background.

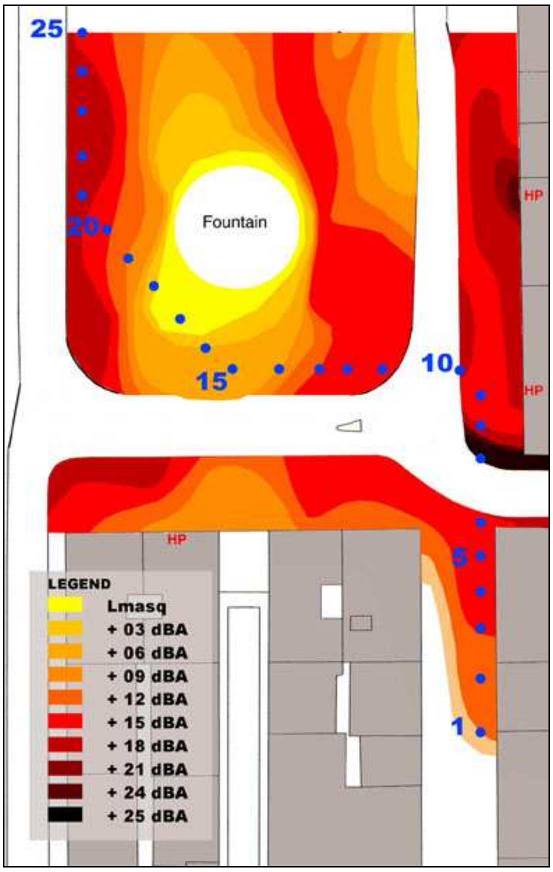


Figure 11 – Plan representation of soundscape in a potential course

Figure 11 shows the traffic sound topologies at Praça do Rossio, in Lisbon. Traffic noise acts as a mask for the other sources of the local soundscape. Its fluctuations make the other sources less heard or totally inaudible.

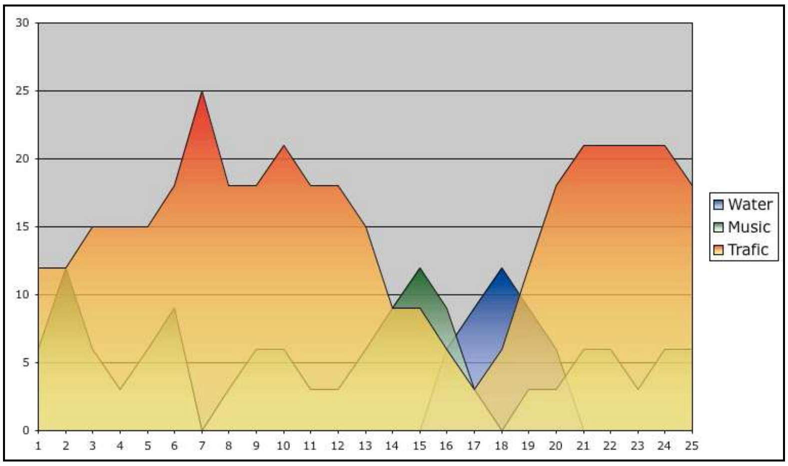


Figure 12 – linear representation of soundscape in a potential course

Starting from localized information, one can describe the composition of the soundscape that is potentially heard by some walkers, see Figure 11. In this way, one can observe with more acuity the critical points on the plan where annoying or dominant sources are actives (point 7.). And where this dominant noise becomes itself masked (point 17.)

5 A MEASURING UNIT FOR SOUNDSCAPE

The authors suggested that the introduced white noise measured in dB(A) becomes the tool of soundscape measure. One suggested in previous papers that a white noise of 60 dB(A) can be considered as the unit for such a measure and one called it a *bumblebee*.

This unit and its application will be developed and confirmed in forthcoming publications.

One hopes that more acuity in the visual representation of soundscape makes the action on the urban sound environment more precise both in terms of the results to be achieved and of the cost-benefit ratios of the possible solutions.

A new technique has been presented that lead to the production of qualitative sound maps. These can be powerful tools for the urban technicians and architects working with noise in the urban areas.

6 AKNOWLEDGEMENTS

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