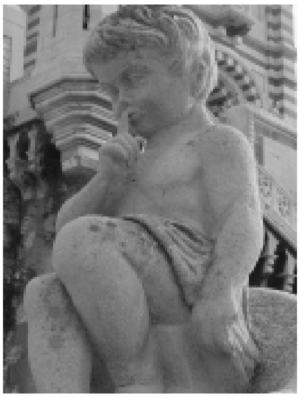

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Objective Representation of Urban Soundscape: Application to a Parisian Neighbourhood

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ABSTRACT

The European Directive 2002/49/CE proposes the L_{den} and/or the L_{night} criteria to assess noise impact on populations. These indicators are based on an average of the noise levels over long periods. When an infrastructure is not subjected to an important and regular flow of vehicles but rather with specific events that emerge from the background noise, the major influence on inhabitant's feelings is the nature of the sound sources identified. Moreover, although mechanical sounds are perceived negatively, some urban locations are perceived as pleasant (for instance a park or a market) due to the presence of birds or voices. The goal of O.R.U.S. project is to create a general system that provides an efficient representation of the acoustic environment i.e. in respect to what citizens perceive and describe. Monitoring systems located in strategic areas compute in real time an indicator that relates the unpleasantness and which is based on the identification of six categories of sound sources. Strategic maps providing spatial and temporal representations of sound sources identification and unpleasantness indicator are produced. An experiment is conducted in a Parisian neighbourhood.

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1. INTRODUCTION

Western societies have become more and more sensitive to their living environment. Reasons are: the process of rural migration that started several decades ago, the thickening and expansion of urban spaces, and the increasing presence of mechanical sounds, to name but a few. Recent studies on large panels of French populations have shown that urban noise pollution is seen as a problem of quality of life[1]. Indeed, it is urban citizen's first concern.

The European Directive 2002/49/EC of 25th June 2002 - related to the assessment and management of environmental noise - lays down a general framework to produce maps for city noise management[2]. Available to the public and intended to urban planners, these maps are strategic tools to prepare and implement action plans to prevent and reduce environmental noise where necessary and preserve environmental noise quality where it's good. As a common indicator, the directive recommends the use of the L_{den} (or L_{night}). This so-called *energetic indicator* is the equivalent sound pressure level calculated on 24 hours with penalty weights for evening and night periods, when noise is less tolerated. In other words, it is an average of the levels for a 24 hours period. This indicator provides a good representation of noise annoyance in the context of large and noisy transportation infrastructures. Moreover, this indicator can easily be measured with a classical sound level meters and can be predicted by many existing commercial softwares. The reduction of noise annoyance can be performed by the localisation of "overdosed" areas and then by the diminution of the L_{den} to more "acceptable" level (e.g. by building acoustic walls or reducing speed limitation)

Nevertheless, the majority of urban arteries are not subjected to large flows of vehicles. Thus, the average day levels are quite acceptable, even for area perceived as noisy. If you ask a passer-by about the sonic environment, he will describe it in terms of *sound sources* (mopeds, motorcycles etc. and also voices or birds twittering) and the moments when he perceives these sound events (merchandise delivery truck in the morning, horn or emergency sirens in the afternoon, motorcycle in the evening, voices of people shopping on the week-end…)[3]. A single yet striking example of this tendency is the Parisian planning of "Zone 30", where the speed of vehicles is limited to 30km/h. In these so-called *quiet areas*, sound levels measured and averaged during the whole day haven't decreased significantly although the environment is now perceived as more pleasant. Indeed, the noise coming from the vehicles has been replaced by voices or more traditional (non-mechanical) human activity sounds which are usually well accepted[4]. This example emphasizes the limitation of the energetic indicator to fit citizen perception of their sonic environment.

The ORUS (Objective Representation of Urban Soundscape) project is targeted to (1) help the planners manage urban development by taking into account the sonic environment and (2) provide a communication and information tool intended to urban residents. The system is seen as a complement to the maps built on the L_{den} indicator and is used to collect statistical data of sonic events. This system is built around a software suite called FDAI (From Descriptor to Automatic Identification).

Our aim is to design and use a perceptive indicator that accounts for urban resident's perception of sound. ORUS focuses on two aspects: on the one hand, we design a perceptive indicator which takes into account various urban sound sources; on the other hand, we build a monitoring system to assess the sound quality of urban areas, to identify sources of unpleasantness precisely.

In the first part of this paper, we set the theoretical concepts underlying the system. The second part focuses on the description of the technical system i.e. from the monitoring systems to the maps. We illustrate our matter with a concrete experimentation that was carried out in a Parisian neighbourhood.

The synopsis of the ORUS project is shown below:

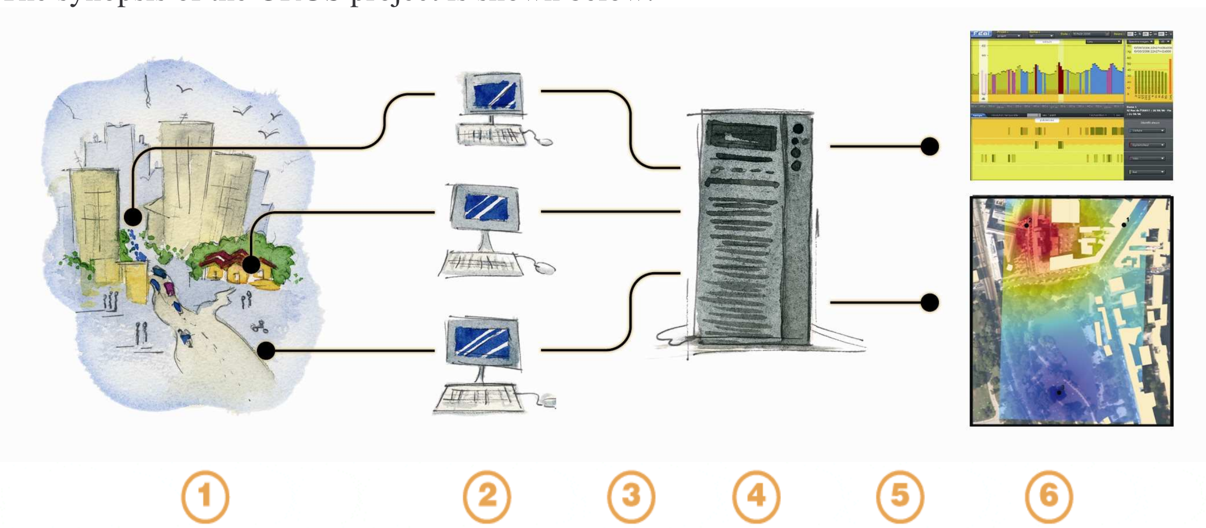

Figure 1 : general synopsis of the ORUS project

1. Urban soundscape
2. Long-time monitoring systems located on the area. Measurements data: L_{Aeq}, Octave Band, sound source identification (car, bus, mopeds, motorcycle, etc)
3. Data transmissions (IP) to server
4. Conditioning of the data (databases, calculation of unpleasantness, etc)
5. Data transmissions (IP) to client
6. Temporal and spatial representations (maps) of the data on a web site and on the Geographic Information System (GIS) ArcView.

2. THEORETICAL CONCEPTS

2.1. Noise annoyance and unpleasantness of sound

It is important to make a distinction between the concepts of *unpleasantness of sound* and *noise annoyance*.

Noise annoyance, seen as a negative evaluation of the environmental conditions, is a multifaceted concept covering mainly (1) immediate behavioural noise effects aspects like disturbance and interference with intended activities, and (2) evaluative aspects like nuisance, and "getting on one's nerves"[5]. About one third of the variance of annoyance can be "explained" by the variance of acoustical factors (e.g. energy, peaks, number of loud events, information about the sound sources, etc), the rest by the variance of personal and social factors (e.g. sensitivity to noise, noise coping capacity, expectations, etc)[6].

Unpleasantness of sound deals with sound quality. It focuses on sound (sound can be pleasant or unpleasant). It depends also on the sound meaning and on the location where it is heard.

ORUS provides the representation of the urban soundscape quality thought an *unpleasantness of sound* indicator.

2.2. Sound sources

Schafer define the concept of Soundscape when he designated sonic environment as musical composition, where the musical instruments are the sound sources[7]. Indeed, sound sources are spontaneously mentioned by urban citizens when ask to describe their everyday sonic environment. They naturally arrange the sources into categories such as *car*, *moped, bus*, *motorcycle*, *voice* and *bird*.

2.3. Perceptive indicator

We propose an indicator based on the level and on the identification of sound sources for the assessment of *unpleasantness of sound*[8,9](Eq.1).

$$\text{Unpleasantness}_{1-10} = \alpha.\text{Level} + \beta.\%\text{T}_{\text{moped}} + \chi.\%\text{T}_{\text{cars}} + \ldots + \varphi.\%\text{T}_{\text{sources}} \qquad (1)$$

It is a linear regression whose variables are the global level (*Level*) and the relative time of appearance (*%T*) of the 6 afore-mentioned categories of sound sources. The value of the coefficients of the regression (*α, β*, etc) is specific to the type of soundscape perceived (e.g. park, market, district road). This indicator ranges from 1 ("very pleasant") to 10 ("very unpleasant") and is performed on 1-minute-sequences. It was extracted through 2 series of perceptive tests with a total amount of 80 listeners[10]. This indicator emphasizes the fact that the identity of the sound sources is very important for the listeners.

2.4. Current uses

ORUS aims to be a tool for urban planers and an information system for urban citizens.

Urban planers need a tool to simulate the soundscape quality in order to test potential modifications. The system computes the unpleasantness indicator for different configurations of sound sources and for different type of soundscape. Consequently they can take into account the sonic environment when they manage urban development.

Citizens need information that fit what they perceive when they complain to authorities. The system provides internet maps where sound sources are represented. Temporal and spatial maps are available with statistical data. Consequently, citizens can take part to the improvement of soundscape quality.

3. FDAI SYSTEM DESCRIPTION

Technically, the system can be decomposed into three main blocs (Fig.1). The software suite is called FDAI (From Descriptor to Automatic Identification).

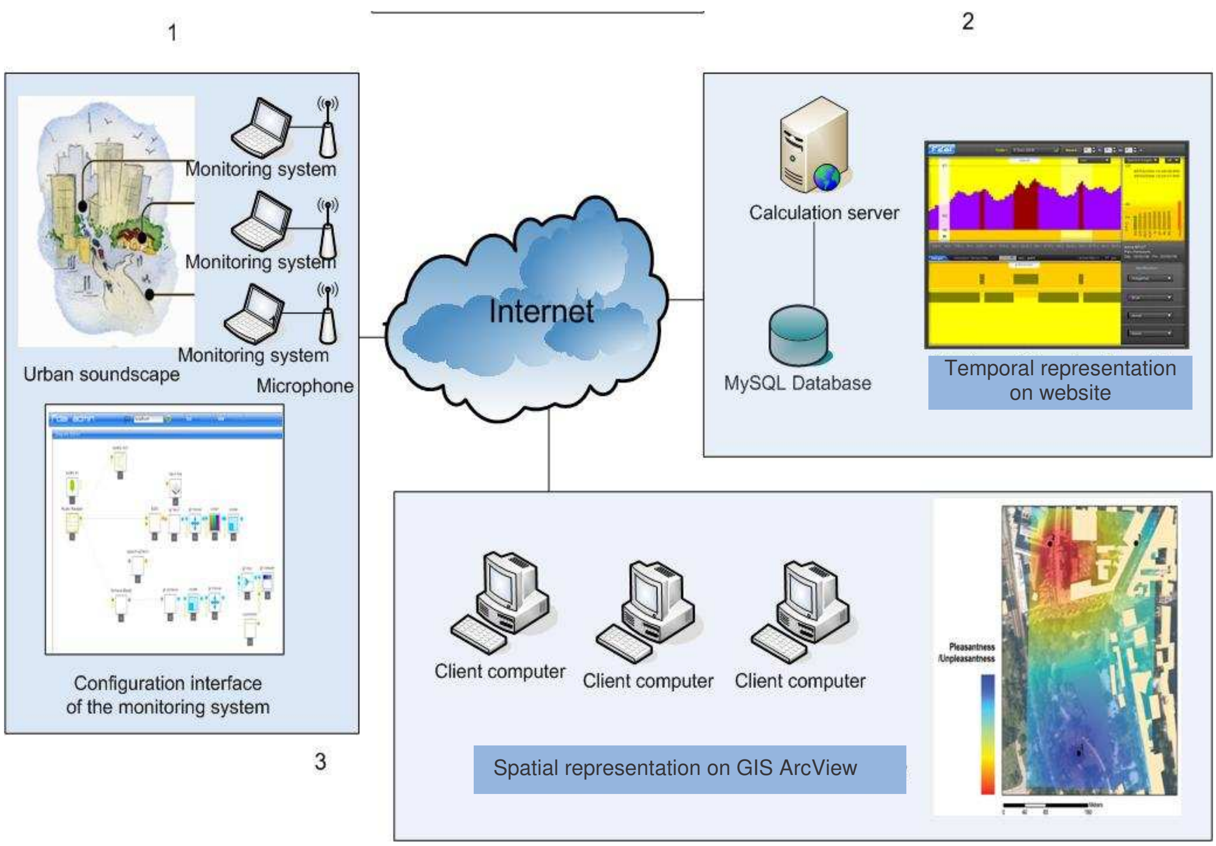

Figure 2 : synopsis of FDAI system. It consists of three main modules interconnected trough IP. Module 1 set up the monitoring systems, module 2 deals with the conditioning of the data measured on a server and provides temporal representation through web site; module 3 provides spatial representation thought animated maps on GIS (Geographic Information System).

The first step is to set up the measurements. Monitoring systems (that consist of a microphone connected to a notebook computer) are located in strategic areas (street, park, market…), FDAI compute normative criteria (e.g. L_{Aeq}, and energy of every octave band) and detects the type of sound sources considered. Depending of course on the resources of the computer and the complexity of the classifiers used, ideally seven types of sound sources can be identified simultaneously. Algorithms for automatic recognition of sound sources, based on an innovative signal extraction system[11], have been presented in 120th AES Convention[12]. Tested on large databases, the system achieves from 90% to 96% of correct detections according to the type of sound source considered. The system also performs the recognition of superposed sources. Since the system is always under development and training, the accuracy of detection is always increasing. Every minute the data calculated are stored in a text file. This text file is automatically sent via Internet to a calculation server.

The server receives raw data from every monitoring system and insert progressively into MySQL databases. With this stage, data measured on every system can be observed on an internet URL (presence of the sound sources identified, L_{Aeq} and energy in octave bands). Secondly the server performs the calculation of the perceptive indicator (cf. 2.3). The indicator is calculated every minute for each monitoring system.

Finally, the MySQL databases created at the server level are transmitted by IP to a client computer. Strategic maps are then produced on GIS's ArcView 9. The user can select different visual coats such as sound sources identification or the positive or negative appreciation of the soundscape quality. The system is built to provide actualised maps every minute. If the monitoring systems are performing on a long period, basic statistics can be computed on a selected part of the data (for example the ratio time of appearance of mopeds from one week to the other). The system also enables to predict pleasantness/unpleasantness of a one-minute sequence by fixing the level and the time of apparition of the sound sources.

4. APPLICATION TO A PARISIAN NEIGHBOURHOOD

The city of Paris covers an area of 105 km squared. The city has six thousand arteries equivalent to 1 700 km of streets, avenues, thorough fares…French regulation law[13] provides a 5-categorie acoustic classification for the arteries that receive more than 5000 vehicles a day and 48 % of the arteries of Paris are included in this classification. For these streets, the city of Paris have 2 and 3-D maps that correctly assess unpleasantness of noise with an energetic criteria averaged on 24 hours.

We focus on the 52% streets of in Paris that do not fit in this classification. In these streets, not subjected to large flows of vehicles and strongly characterized by alternations between sound events and background noise, the unpleasantness indicator describes in 2.3. is more adapted than just the level.

Parisians complain about sound sources that they clearly identify. On one hand they can accept continuous car traffic because it is part of economics they are most of the time involved in. On the other hand they cannot stand motorcycles because they don't own one. Moreover, they dislike public buses because of their crowding, they denounce easy "horn Latin behaviour" and police siren negligence. The ORUS project expresses Parisians' feeling about their sonic environment in their neighgborhood.

The application of the FDAI system to Parisian neighbourhoods has been experimented on 24-hours measurements performed in three different locations[1]. Measurement systems have been placed 2 meters away from balconies, 4 meters high from the street (Figure 3).

[1] The area selected is near Parc Montsouris in the 14th arrondissement of Paris.

Figure 3 : microphone placed 2 meters away from balconies and 4 meters high from the street. The microphone is connected to a computer that calculates in real time features such as L_{Aeq}, octave bands and sound source identification.

All features are calculated (L_{Aeq}, sound source identification, third octave bands) every second. As a first result, temporal evolution of these features can be seen on the web. Figure 4 shows Web interface.

*Figure 4 : Temporal representation of soundscape features thought Web interface. This screenshot represents on top the evolution of the L_{Aeq} measured on one location. The colours are the projections of the most prominent identified sources mentioned on the bottom (*Voiture *means car,* Cyclomoteur *means moped,* Voix *means voice). On top right, octave-band energy of a selected part of the L_{Aeq} curve is calculated.*

Secondly, the maps, representing the three locations of measurements, are provided. Two kinds of representations are performed e.g. continuous or discrete. They are both presented in Figure 5.

Some observations can be suggested in order to improve the assessment of graphic representations of sound perception. The map will be more accurate with more monitoring systems available, especially for the continuous map. For an optimized map, we evaluate that a monitoring system is needed in every street of the neighbourhood. Indeed, every event detected could be reasonably extrapolated to the rest of the street. Additional work will enable to go further on the extrapolation of the features between measured locations

Moreover, vision influences the perception of sound quality[14],[15]. For instance at the border of a park and a street, the same sound environment could have different appraisal, depending if it is heard in the street side or in the park side. Thus, the extrapolation of the indicator has to take into account the boundaries of the different types of locations.

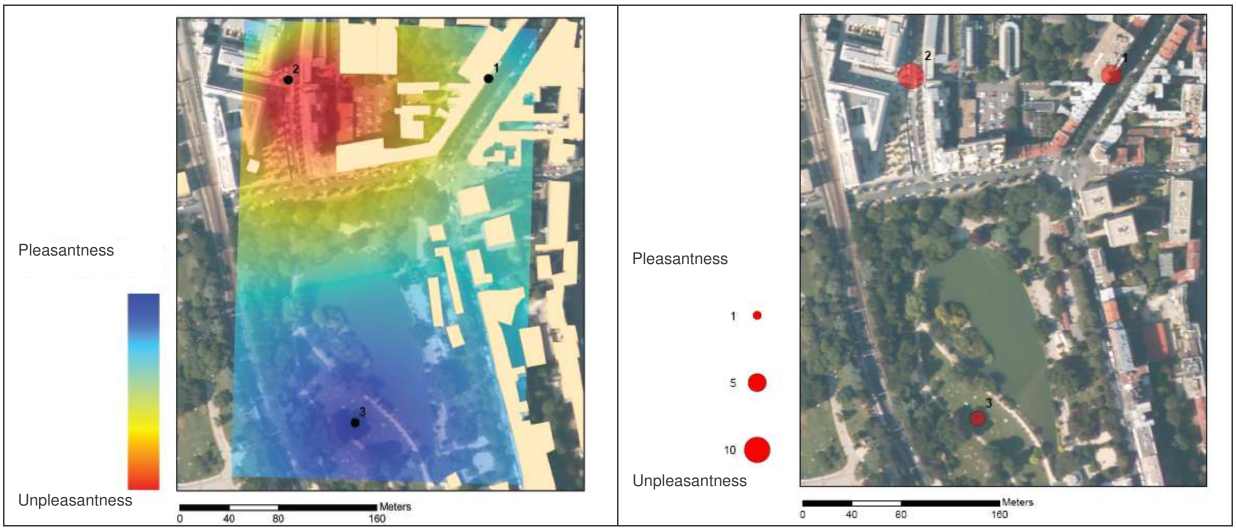

Figure 5 : Examples of spatial representations of soundscape quality provided on ArcView GIS. Three points are represented corresponding three monitoring systems located in a neighbourhood of the 14th arrondissement of Paris (Parc Montsouris). On the left hand side, an extrapolation (kriging method) is basically performed between the three points, on the right hand side; unpleasantness is represented by proportional circles. Each map is refreshed every minute. It is possible to choose other represented features such as L_{Aeq} or the time ratio of different identified sources

5. CONCLUSION

We have presented ORUS, a general system that provides an efficient representation of the acoustic environment i.e. in respect to what citizens perceive and describe. On one hand, this system is intended to planners to manage urban development by taking into account the sonic environment. One the other hand, the system is a communication and information tool to urban residents because it provides an adapted way to express their feeling about their sonic environment. Further studies will help to adapt the hedonic indicator to other types of locations such as school and commerce areas and to other types of sound sources (horns, trucks). Extrapolation methods can also be developed between measured locations.

Large scale experiments in Paris are currently undertaken; feedback coming from citizen and urban planners will be available soon.

ACKNOWLEDGEMENTS

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